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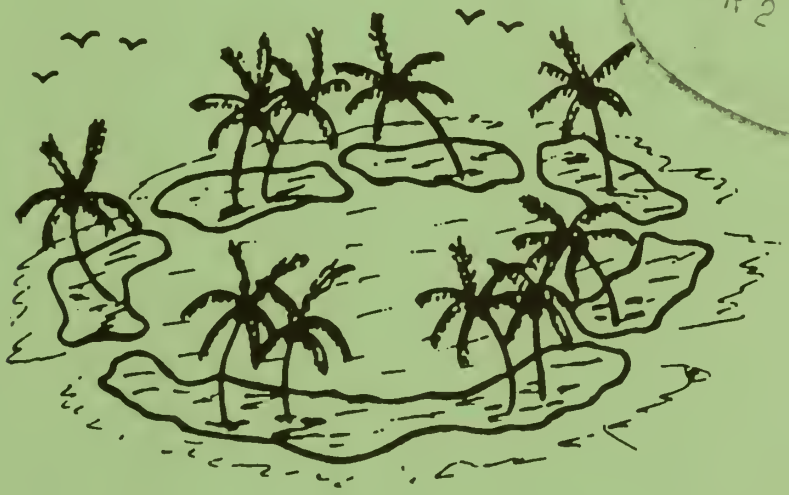

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PROCARP STRUCTURE IN SOME CARIBBEAN SPECIES OF *BOSTRYCHIA* MONTAGNE (RHODOPHYTA, RHODOMELACEAE): AN IMPORTANT SYSTEMATIC CHARACTER

BY

CELIA M. SMITH[1,2] AND JAMES N. NORRIS[1]

ABSTRACT

Newly elucidated features which can be used for taxonomic purposes are shown by the pre-fertilization procarp structure in species of the red alga *Bostrychia* Mont. Because female gametophytes are apparently rare in Caribbean field populations, having been seldom collected, these reproductive characteristics have not been evaluated previously, but may provide greater stability to the systematics of *Bostrychia* which is now based almost entirely on vegetative characteristics.

Four species of *Bostrychia*, as known from the Caribbean, *B. montagnei* Harv., *B. binderi* Harv., *B. tenella* (Lamour.) J. Ag., and *B. radicans* f. *moniliformis* Post, and one taxon of uncertain status, *B.* sp.?, were grown in culture and showed species specific features. Pre-fertilization structures that were quantified revealed differences in the length and width of trichogynes, the distribution and number of procarps present in fertile regions of the branchlets, and the number of cells of the fertile region. These differences show that reproductive structures are important taxonomic characters for species of *Bostrychia* and support the suggestion that *Bostrychia* is a primitive genus in the Rhodomelaceae.

INTRODUCTION

The red algal genus *Bostrychia* Montagne (1842, p.39) (Ceramiales, Rhodomelaceae) is widespread, occurring from tropical to cool-temperate regions, and usually associated with mangroves. The pre-fertilization arrangements of cells and development of the carpogonial branch for the nearly twenty known species of *Bostrychia* are for the most part unknown or undescribed. In the tropical and subtropical western Atlantic there are eight species recorded (Wynne 1986), and gametangial plants have been apparently rarely collected or reported.

Four tropical western Atlantic species, *B. montagnei* Harv., *B. binderi* Harv., *B. tenella* (Lamour.) J. Ag., and *B. radicans* f. *moniliformis* Post, represent members in 3 of the 8 groups presented in the artificial key of Post (1936). Based on characters of the vegetative morphology, one of these subgeneric groups includes the warm-water *B. montagnei* which is most closely related to, but does not overlap in distribution, with *B. arbuscula* Hook. et Harv. (an endemic to New Zealand), and a widely distributed, cool-water species, *B. scorpioides* (Huds.) Mont. ex Kütz. (Sluiman 1978; Prud'homme van Reine & Sluiman 1980). Another subgeneric group, *B. binderi*, *B. tenella*, and *B. calliptera* (Mont.) Mont. overlap in warm-water Pacific and Atlantic regions. Additionally, *B. binderi* and *B. tenella* have many morphological similarities, but have been separated on the nature of siphonous branchlets (e.g., Post 1936; Tseng 1943; Taylor 1960; Oliveira Filho 1977; Cordeiro-Marino 1978; Schnetter & Bula Meyer 1982; but see also Børgesen 1937; Tokida 1939; Puttock & King 1987; King et al. 1988). A third

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group, all ecorticate species, includes the world-wide *B. radicans* (Mont.) Mont., a new species from Japan, *B. pinnata* J. Tanaka et Chihara, and a south Pacific species, *B. kelanensis* Grun. ex Post, which have had gametangial phases illustrated (Möbius 1889; Cordeiro-Marino 1978; Tanaka & Chihara 1984a-b; King & Puttock 1986).

Because little emphasis has been placed on reproductive morphologies for species of *Bostrychia*, no previous comparisons have been made among species on the basis of procarpic morphologies. Here, we describe the construction and positioning of procarps in four species and one taxon of uncertain status, and based on vegetative morphology, compare their construction with morphologically related taxa. We also examine how differences in stages of procarpic development are taxonomically significant.

MATERIALS AND METHODS

Culture techniques

Isolates for culture were collected, from February 1986 to March 1987, growing primarily on the prop roots of red mangrove (*Rhizophora mangle* L.) or occasionally on rocky substrate from five sites in Florida: *B. montagnei* from the Marquesas Keys (Lat. 24^{O} 36' N, Long. 82^{O} 07' W); *B. binderi* from Clarence Higgs Memorial Beach Park, Key West (Lat. 24^{O} 32' N, Long. 81^{O} 47' W); *B. tenella* from the north side of Key West (Lat. 24^{O} 34' N, Long. 81^{O} 46' W); *B.* sp.?, a taxon of uncertain status, from the southeast side of Big Pine Key (Lat. 24^{O} 38' N, Long. 81^{O} 19' W); and *B. radicans* f. *moniliformis* from Little Jim Inlet, Indian River (vicinity of Ft. Pierce), east coast of central Florida (Lat. 27^{O} 40' N, Long. 80^{O} 26' W). An additional collection of fertile *B. montagnei* was made from the red mangroves at Twin Cays on the Belizean barrier reef, off central Belize (Lat. 16^{O} 48' N, Long. 88^{O} 05' W).

Whole female plants with prominent cystocarps were cleaned of contaminants and placed in 100 mls of 0.22 μm Millepore-filtered seawater, enriched to a concentration of 1% Provasoli Enriched Seawater (PES) (McLachlan 1973) under culture numbers of C. M. Smith, *#CMS* -10087 to -12038. Thalli were grown under a 14:10 light-dark regime at < 100 μmol quanta from fluorescent cool-white light bulbs at a temperature of 25 ^{O}C and salinity of 32 ^{O}/oo.

Media were changed approximately every two months. At the end of the first interval, nutrient levels were increased to 10 % PES; all other conditions were held constant.

After trichogynes were first observed, specimens were liquid preserved in 5% buffered Formalin/seawater, acidified in 2% HCl/distilled water, stained with aniline blue, and permanently mounted in serial dilutions of KARO clear syrup with phenol added as a preservative on microscope slides (Tsuda & Abbott 1985).

All our specimens from Florida and Belize were identified following Taylor (1960: 594-600), based on the taxonomic concepts of Post (1936). Voucher specimens, including microscope slides are deposited in the Algal Collection of the U.S. National Herbarium, National Museum of Natural History, Smithsonian Institution (US).

RESULTS

Procarps of Bostrychia montagnei

Fertile branches for *B. montagnei* from the Marquesas Keys, Florida were first observed from cultured plants eight months after collection, in culture *#CMS* -10104. Fertile branches of whole, dioecious thalli were somewhat inflated, markedly curved at the apex, and polysiphonous throughout (Fig. 1). Carpogonial branches for each axial cell began about 6 cells ± 1.68 (mean ± 1 S.D., n=13 branches) behind a branch apex, and extended to a mean of 13.3 cells ± 6.51 (mean ± 1 S.D., n=13 branches) and were also observed to the 25th axial cell.

Procarps were four-celled, carpogonial branches consisting of a carpogonium with an elongate trichogyne, borne above three cells which were connected via the supporting cell to the central axis (Fig. 2). The three carpogonial branch cells were separated from the supporting cell, and visually distinct from sterile cells. Carpogonial branch cells were discoid to ellipsoid in shape and non-granular in appearance, while the supporting cell was ±rectangular and granular. Usually one procarp per axial cell was present, although the location of the procarp appeared to be restricted in development to one of two fertile pericentral cells, both on the distal side of a fertile branch of mean length 19.1 cells ± 8.05 (mean ± 1 S.D., n=13 branches) (Fig. 1). A mean of 5.8 procarps ± 3.79 (mean ± 1 S.D., n=13 procarps) was observed over an average extent of fertile region composed of 8.3 cells ± 6.02 (mean ± 1 S.D., n=13 branches).

The mean length of mature trichogynes was 142.5 µm ± 22.01 (mean ± 1 S.D., n= 10 trichogynes). These long trichogynes had a marked sheath surrounding the protoplasmic strand, with a mean width of 8.5 µm ± 0.76 (mean ± 1 S.D., n=10 trichogynes). A basal collar of cell wall through which the trichogyne passed out of the cell wall of the fertile branchlet and a distinctive "cap" at the distal end of the tube sheath were marked features of these trichogynes (Figs. 2, 3).

Another notable feature of female *B. montagnei* in culture was the occurrence of sterile branches with monosiphonous tips. These thalli always had polysiphonous branches, but, in all long branches, there were monosiphonous portions which ranged up to 36 cells with a mean of 20.9 cells ± 6.88 (mean ± 1 S.D., n=12 branches) for branches which had a mean total length of 40.3 cells ± 8.18 (mean ± 1 S.D., n=12 branches). This monosiphonous branch tip in *B. montagnei* was also illustrated by Joly (1954, pl. III:fig. 3, as "*B. scorpioides* var. *montagnei*") in Brazilian material.

Similar results were found in procarps among individuals of *B. montagnei* cultured from the Twin Cays, Belize populations.

Procarps of B. binderi

Procarps of *B. binderi* were easily observed in fertile branches within the first month of culturing whole, fertile female thalli, collected from Clarence Higgs Memorial Beach Park, Key West, Florida, #*CMS*-12025.

Mature and immature procarps were found from cell four to cell eight behind the apex, with a mean distance of 5.6 cells ± 1.52 (mean ± 1 S.D., n=5 branches) for the first fertile cell behind the apical cell. These branches ranged in length from 11 to over 16 cells, with a mean of 13.6 cells ± 1.82 (mean ± 1 S.D., n=5 branches). In fertile branches, there was one procarp per fertile axial cell, and only one axial cell bore a procarp for each branch (n=6) (Fig. 4).

Mean length of mature trichogynes was 87.1 µm ± 14.36 (mean ± 1 S.D., n=4 trichogynes) with a width of 2.9 µm ± 1.50 (mean ± 1 S.D., n=4 trichogynes), and a slight bulbous tip (Fig. 5), but no pronounced collar at the base. From the apical 3 mm of this fertile thallus, all branchlets had polysiphonous bases, and had a mean of 12.7 monosiphonous cells ± 4.04 or 76.0 % of a total branch had monosiphonous cells (mean ± 1 S.D., n=18 branches) over a mean branch length of 17.1 ± 4.98 cells (mean ± 1 S. D., n=18 branches).

Procarps of B. tenella

Procarps of *B. tenella* were observed within the first year of collection, in cultured whole thalli from mangrove roots on the northeast side of Key West, Florida. This material, *CMS* #-10087 was not reproductive at the time of collection from the field site, but within 12 months produced procarps.

Procarps occurred from cell 4 to cell 11 behind the apical cells, with a mean of from cell 4.9 ± 0.92 (mean ± 1 S.D., n=14) to cell 10.8 ± 2.05 (mean ±1 S.D., n=14) (Fig. 15). A mean of four procarps were observed over that fertile cell range in branches which were on the average 15.8 cells long ± 3.29 (mean ± 1 S.D., n=14 branches) (Fig. 6).

This isolate had mature trichogynes with a mean length of 64.0 μm ± 17.27 (mean ± 1 S.D., n=10 trichogynes), and mean width of 8.1 μm ± 0.74 (mean ± 1 S.D., n=10 trichogynes). Trichogynes had lightly stained basal collars and inflated tips (Fig. 7).

Branches were nearly completely monosiphonous, with 11.7 cells ± 1.57 monosiphonous cells (mean ± 1 S.D., n=18 branches) , or 97.9 % ± 4.40 of the cells in branches which were 11.9 cells long ± 1.70 (mean ± 1 S.D., n=18 branches).

Procarps of B. sp.?, *a taxon of uncertain status*

Fertile branches of *B.* sp. ?, which has some vegetative features of both *B. binderi* and *B. tenella*, were observed in cultured whole, fertile female thalli, one month after collection. This field-collected specimen, *CMS#*-12037, was from the red mangroves in a salt flat on the Atlantic Ocean side of Big Pine Key, Florida Keys. Fertile branchlets were polysiphonous from the base to apex; the apical cells were small and difficult to distinguish.

Procarps were dense, compact arrangements of small cells located on inflated branchlets (Fig. 8), and were observed to start at the 2nd to the 23rd cell in a branch, with a mean from cell 3.2 ± 0.98 (mean ± 1 S.D., n=14) to cell 17.8 ± 5.00 (mean ± 1 S.D., n=14) (Fig. 15), in branches which had a mean length of 24.4 cells ± 6.03 (mean ± 1 S.D., n=14 branches). As many as 23 procarps were counted for 8 fertile axial cells indicating that multiple procarps were supported by a single axial cell, with a mean of 12.3 procarps ± 5.45 (mean ± 1 S.D., n=14 procarps) over fertile range of 14.3 axial cells ± 4.62 (mean ± 1 S.D., n=14 branches).

Mature trichogynes had a mean length of 183.0 μm ± 28.12 (mean ± 1 S.D., n=12 trichogynes), and mean width was 6.6 μm ± 0.94 (mean ± 1 S.D., n=12 trichogynes). There was no apparent collar at the base, but the tip of the trichogyne was slightly inflated (Figs. 9, 10).

Figures 1 to 3 (to right). Procarp features of *Bostrychia montagnei*. Fig. 1. An inflated, curved, fertile branchlet. Scale = 50 μm. Fig. 2. A carpogonial branch showing the basal collar at the cell wall. Scale = 5 μm. Fig. 3. Detail of the cap at the distal end of a trichogyne. Scale = 5 μm. (A C = axial cell; C 1, C 2, and C 3 = cells of the carpogonial branch; Carp = carpogonium; Supp c = supporting cell).

Figures 4 to 5 (to right). Procarp features of *Bostrychia binderi*. Fig. 4. A non-inflated, straight fertile branchlet. Scale = 50 μm. Fig. 5. Detail of slightly bulbous tip of a trichogyne. Scale = 5 μm. (For abbreviations, see legend for Figs. 1 to 3.)

Figures 6 to 7 (to right). Procarp features of *Bostrychia tenella*. Fig. 6. An inflated, curved, fertile branchlet. Scale = 50 μm. Fig. 7. A carpogonial branch showing the basal collar at the cell wall, and the inflated tip at the distal end of a trichogyne. Scale = 5 μm. (For abbreviations, see legend for Figs. 1 to 3.)

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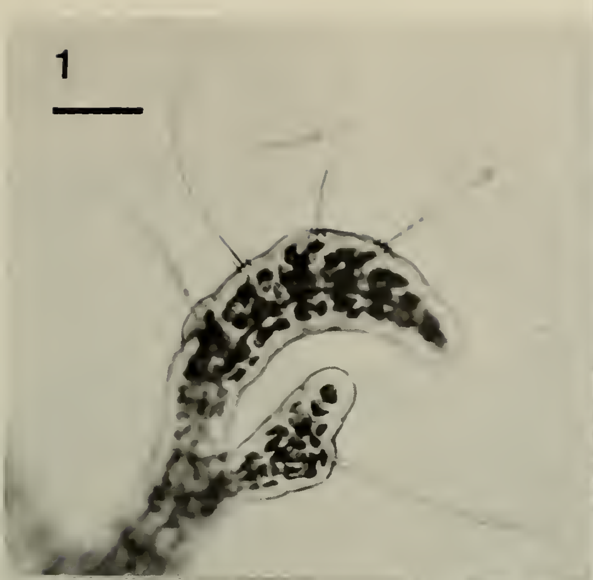

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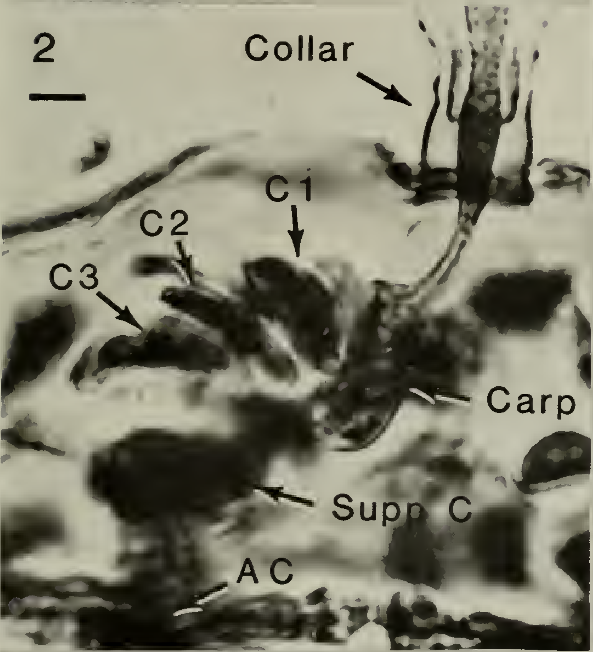
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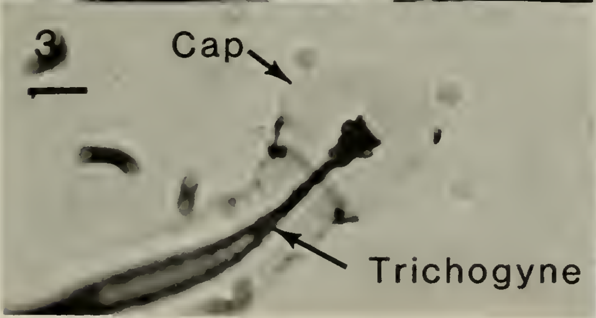
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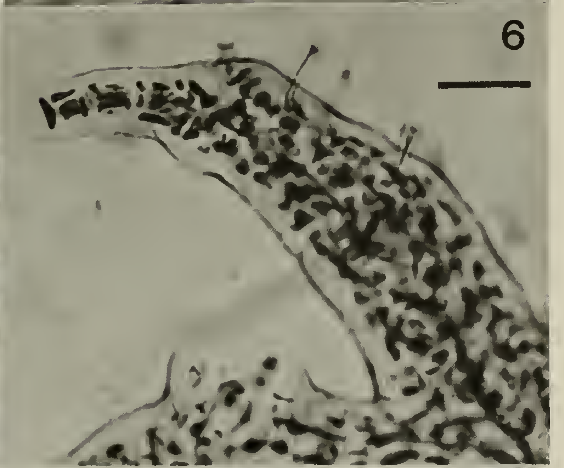

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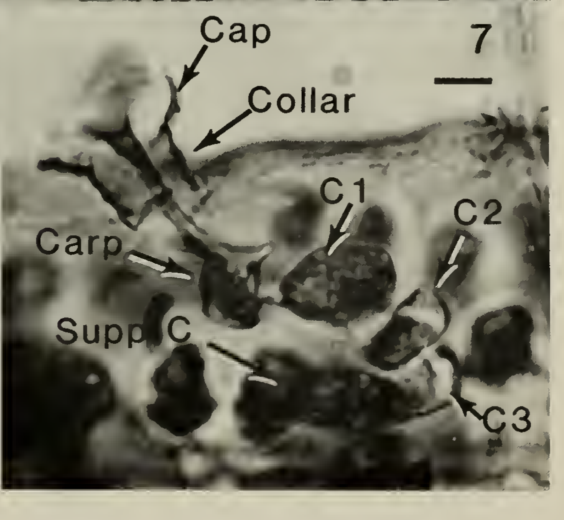
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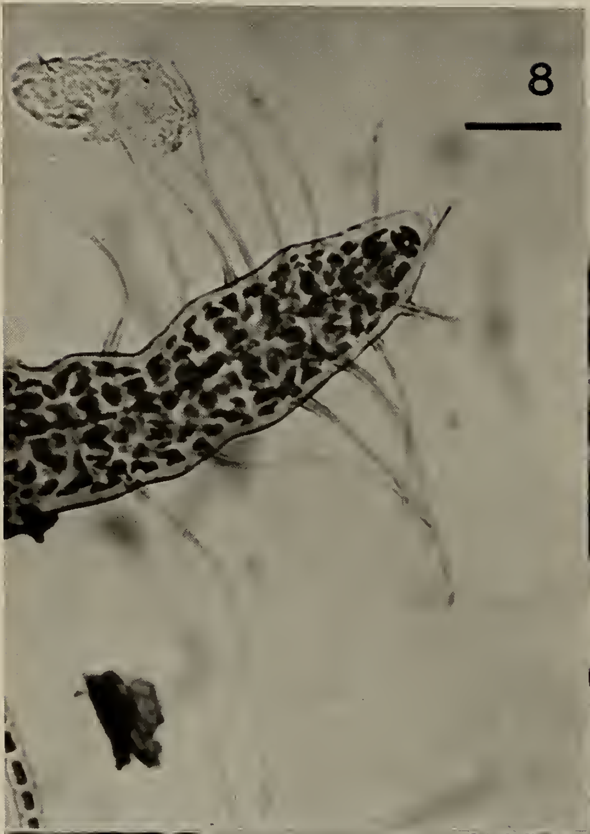

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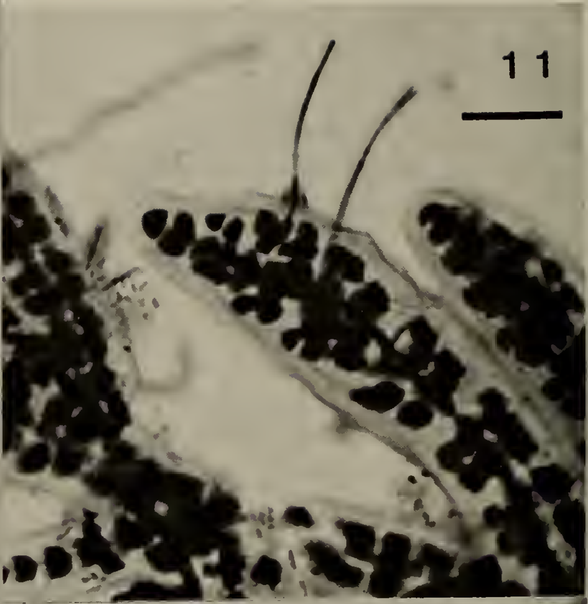

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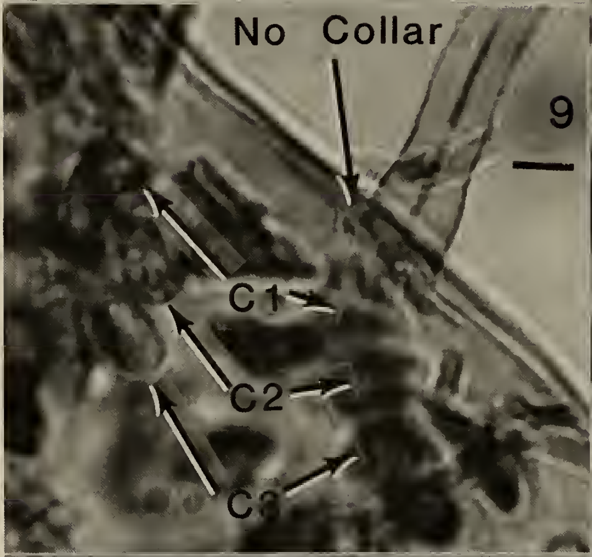

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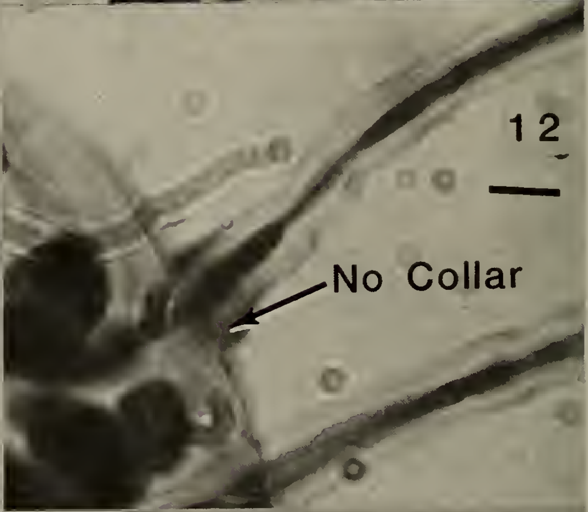

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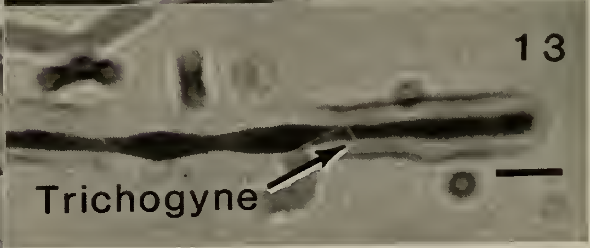

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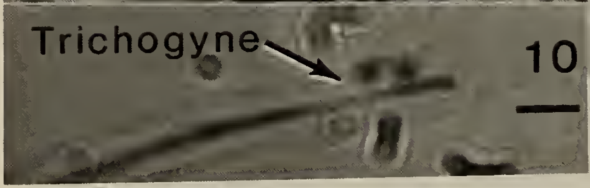

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Completely monosiphonous branchlets were not observed, although branches had monosiphonous portions of 34.7 cells long ± 10.34 (mean ± 1 S.D., n=18 branches), or 86.2 % ± 8.63 of branches which had mean length 43.0 cells ± 16.83 (mean ± 1 S.D., n=18).

Procarps of B. radicans *f.* moniliformis

Procarps of *B. radicans* f. *moniliformis* were easily observed in cultured whole, fertile female thalli, within the first month of collection, from Little Jim Islet, in the Indian River, vicinity of Fort Pierce, east (=Atlantic) coast of central Florida.

Procarps were found as early as the 2nd cell behind the apex, with a mean occurrence of 3.3 cells ± 0.75 (mean ± 1 S.D., n=12 branches) behind the apical cell (Fig. 15). Fertile regions extended to a mean of cell 5.8 ± 1.20 (mean ± 1 S.D., n=12 branches) on branches 9.25 cells long ± 2.8 (mean ± 1 S.D., n=12 branches). A mean of 2.7 procarps ± 0.78 (mean ± 1 S.D., n=12 procarps) was observed over fertile regions of 3.6 ±1.16 cells in length (mean ± 1 S.D., n=12 branches) (Fig. 11).

The mean length of mature trichogynes was 134.3 µm ± 17.60 (mean ± 1 S.D., n=12 trichogynes), with a mean width of 5.0 µm ± 0.99 (mean ± 1 S.D., n=12 trichogynes). Of the trichogynes studied, 11 of 12 lacked an aparent basal collar (Fig. 12). However, a stained collar at the base of a trichogyne was observed once. The tips of the trichogynes were not inflated nor did they have caps (Figs. 12, 13).

DISCUSSION

The goal of this research was to describe procarp structure and placement for four taxa, plus one taxon of uncertain status of *Bostrychia*, which on the grounds of vegetative morphology belong to three of the groups of Post (1936). As expected, construction of carpogonial branches of *B. montagnei*, *B. binderi*, *B. tenella*, *B. radicans* f. *moniliformis*, *B.* sp.?, and other more distantly related *Bostrychia* species are similar based on numbers of cells in a carpogonial branch (Table 1). The number of cells in a carpogonial branch , where known, was almost always four. However, Kumano (1988) reported mostly 3 celled carpogonial branches, and noted that a 4 celled carpogonial branch was observed only once in Japanese *B. flagellifera*.

Variability does exist among these species however, at the levels of organization for carpogonial branches. Differences among these taxa are seen in such features as: (1) size (lengths and widths) of the trichogynes (Fig. 14); (2) constructional details of trichogynes (e.g., presence or absence of distal caps and/or basal collars); (3) the numbers of procarps borne on an axial cell; and (4) the extent (i.e., numbers of cells) of fertile areas in a branchlet (Fig. 15).

The greatest trichogyne length, mean = 183 µm, was found for *B.* sp.?, the taxon of uncertain status. Size of this isolate's trichogyne did overlap with *B. montagnei* but was statistically distinct from

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Figures 8 to 10 (to left). Procarp features of *B.* sp. ?. Fig. 8. An inflated, curved, fertile branchlet. Scale = 50 µm. Fig. 9. A carpogonial branch showing the lack of a basal collar at the cell wall. Scale = 5 µm. Fig. 10. Detail of the slightly inflated tip at the distal end of a trichogyne. Scale = 5 µm. (For abbreviations, see legend for Figs. 1 to 3.)

Figures 11 to 13 (to left). Procarp features of *Bostrychia radicans* f. *moniliformis*. Fig. 11. An inflated, curved, fertile branchlet. Scale = 50 µm. Fig. 12. A carpogonial branch showing the lack of a basal collar at the cell wall. Scale = 5 µm. Fig. 13. Detail of the regular, non-inflated distal end of a trichogyne. Scale = 5 µm. (For abbreviations, see legend for Figs. 1 to 3.)

Table 1. Comparison of features for species of *Bostrychia* where procarps have been described.

Species	# cells/ cpbr	# cp/ax cell	fertile cell range	branch type	mean trichogyne length
B. arbuscula[3]	4	1 to 4	3 to 9th	NA	30*
B. binderi	4	only 1/ br	4 to 8th (but only 1 cell)	str	87.1
B. sp.?	4	1 to 2	2 to 23th	cur	183.0
B. kelanensis[5]	4	1 to 2	4 to 10th	str	80*
B. montagnei	4	1 to 2	6 to 25th	cur	142.6
B. pinnata[4]	4	1	4 to 10th	cur	60.5
B. radicans[1] f. *moniliformis* Brazil	4	1?	NA	NA	72.7
B. radicans f. *moniliformis* Florida	4	1	2 to 7th	cur	134.3
B. scorpioides[2]	4	1?	NA	NA	54*
B. tenella	4	1	4 to 11th	cur	64.0
B. flagellifera[6]	3(-4)	1	3 to 4th	NA	200.0

Key to terms: br= branch; cpbr= carpogonial branch; cur = curved; NA = not available; str = straight; * = mature trichogyne length may not have been illustrated.

References: [1] Cordeiro-Marino 1978; [2] Falkenberg 1901; [3] Hommersand 1963; [4] King & Puttock 1986; [5] Tanaka & Chihara 1984b; [6] Kumano 1988.

all other *Bostrychia* species by this length criterion. Trichogynes were shortest for *B. binderi* (mean = 87 μm) and *B. tenella* (mean = 64 μm); the differences were not statistically significant between these two species. These two, however, did differ statistically in the width of trichogynes. While the lenghts were clearly different, the trichogyne widths for *B. tenella* and *B.* sp.? did overlap (Fig. 14).

The presence or absence of trichogyne features, such as an inflated cap at the distal end of a trichogyne or a basal collar at the location where a trichogyne left the cell wall of a fertile region, varied among the species studied. *Bostrychia montagnei* had the most pronounced collars, which stained densely to reveal some constructional details, and had the most obvious inflated tips. *Bostrychia binderi* and *B. tenella* had inflated tips but neither had obvious or lightly stained collars. Trichogyne tips for *B.* sp.? appeared less inflated than other species while the basal collars were more prominent. *Bostrychia radicans* f. *moniliformis* showed neither of these features.

The numbers of procarps borne per axial cell also differed among these species. *Bostrychia* sp.? bore a mean of more than 12 mature procarps or withered trichogynes on a mean of 14 axial cells in a fertile range, while *B. binderi* was found to have only one procarp on an entire branch. *Bostrychia tenella*, in mean figures, had four procarps over about a six cell fertile region.

Differences in the extents of axial cells or parts of a branch which become fertile, occurred among these species of *Bostrychia* (Fig. 15). For *B.* sp. ? and *B. montagnei*, the range over which procarps and fertilized carpogonial branches extended past the 20th axial cell in fertile branches was (means) 14.3 and 8.3 cells, respectively. In contrast, for *B. radicans* f. *moniliformis* and *B. binderi*, they did not extend past the seventh cell, yielding substantially smaller fertile regions on branches (means = 3.6 and 6.5 cells, respectively). This difference may be attributable to generally shorter branches of these species.

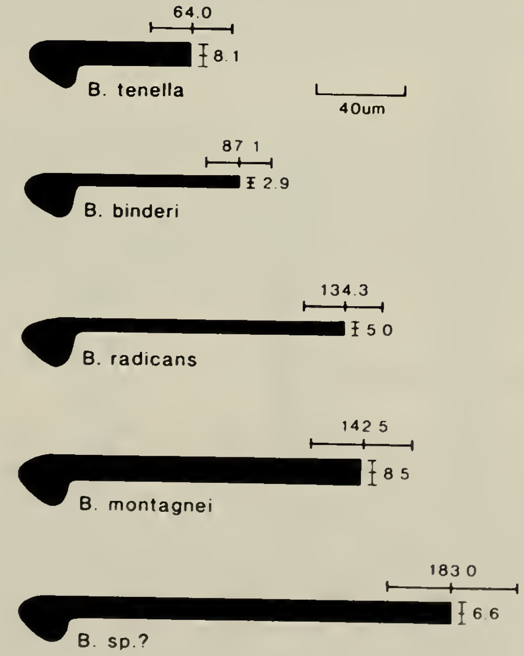

Figure 14. Diagrammatic comparison of trichogyne lengths and widths (X ± 1 S.D.) for five species of *Bostrychia* studied.

The extent of stability of these procarp features is unknown. For example, J. A. West (pers. comm.) found some variation in his culture isolates of other *Bostrychia* entities. Trichogyne length was longer for his isolates of *B. binderi* and *B. tenella* than those reported here, and there was some variation in numbers of procarps on a fertile branch. While it must be ascertained that these variations are not artifacts of culture conditions, comparisons between different populations in culture may reveal important biogeographic or temporal variations among populations of *Bostrychia*, or raise taxonomic questions. In another red alga, *Batrachospermum* Bory, trichogyne length was significant as a feature of the species, with the length of trichogynes correlated with branchlet length of the species (R. G. Sheath, pers. comm.).

The fate of multiple fertile procarps in a branch where fertile regions extend over multiple cells or, the fate of multiple procarps on the same axial cell appear to differ with the development of spermatangia or tetrasporangia. All our study material, and illustrations in published accounts, suggest that only one mature cystocarp develops per branch (e.g., Harvey 1853, Plate 14C, Fig. 2; Børgesen 1918, Fig. 303; Newton 1931, Fig. 206G; Joly 1965, Fig. 640; Cordeiro-Marino 1978, Fig. 351; Tanaka & Chihara 1984b, Fig.4-2; Prud'homme van Reine & Sluiman 1980, Fig. 11). Thus, in contrast to branches in which 10 or more axial cells bear spermatangia (Smith & Norris 1988) or tetrasporangia (Smith & Norris unpubl. data), the production of carposporangia appears to be developmentally regulated and restricted to one site for each branch, even though 20 or more procarps may be present on that branch.

Developmental restrictions may be necessary to eliminate all but one cystocarp because of the relatively large size of a mature cystocarp, and the way a cystocarp is devoloped on a branch, exteriorly rather than modifications produced when developed on branches, as generally occurs for spermatangia or being embedded in the stichidial branchlets as are the tetrasporangia in this genus. Possibly, the energetic costs of a developing cystocarp may stress nearby gametophytic cells so as to eliminate other cystocarps. Hommersand (1963, p. 255) suggests that limitations actually develop at the time of fertilization "... in a group of procarps the development of the first one to be fertilized causes the development of all the others to be suppressed at the stage at which the auxiliary cell is normally cut off."

Because a large fertile region has procarps at all developmental stages, it is likely that numerous procarps increase the probability of fertilization by extending the time when mature females are present. The large trichogynes most likely have increased the area of receptive surfaces available to bind spermatia. Although we lack data to test this hypothesis, this reasoning suggests that selection could favor red algal species which bear numerous, large-celled trichogynes on multiple branches of each thallus.

Procarps of B. montagnei *and close relatives*

Based upon construction of procarps of *B. arbuscula*, *B. scorpioides* and *B. montagnei*, the three species vary considerably: *B. arbuscula* and *B. scorpioides* have shorter trichogynes, 30 and 54 μm respectively, (Table 1) compared to the longer trichogynes of *B. montagnei*, (142.6 μm; Table 1, Fig. 14); *B. arbuscula* has 1 to 4 procarps per axial cell, while *B. montagnei* has 1 to 2; the fertile axial cells of *B. arbuscula* were from the 4th to the 6th axial cells, while in *B. montagnei* they extended from the 7th to 25th cells. In contrast for Caribbean *B. montagnei* there was little variation between Marquesas Keys (Florida) and Belize (Central America) populations studied. There was also little difference between the structure and occurrence of spermatangia in the isolates of *B. montagnei* from the Florida Keys and Belize (Smith & Norris 1988).

Procarps of B. binderi *and* B. tenella

The validity of separating *B. binderi* and *B. tenella* as distinct taxa has been controversial primarily because of the monosiphonous versus polysiphonous nature of branchlets which would seem to be a highly variable vegetative feature. For example, Post (1936) and Tseng (1943) considered them separate taxa, while Børgesen (1937), Tokida (1939), Puttock and King (1987), and King et al. (1988) considered them as one species.

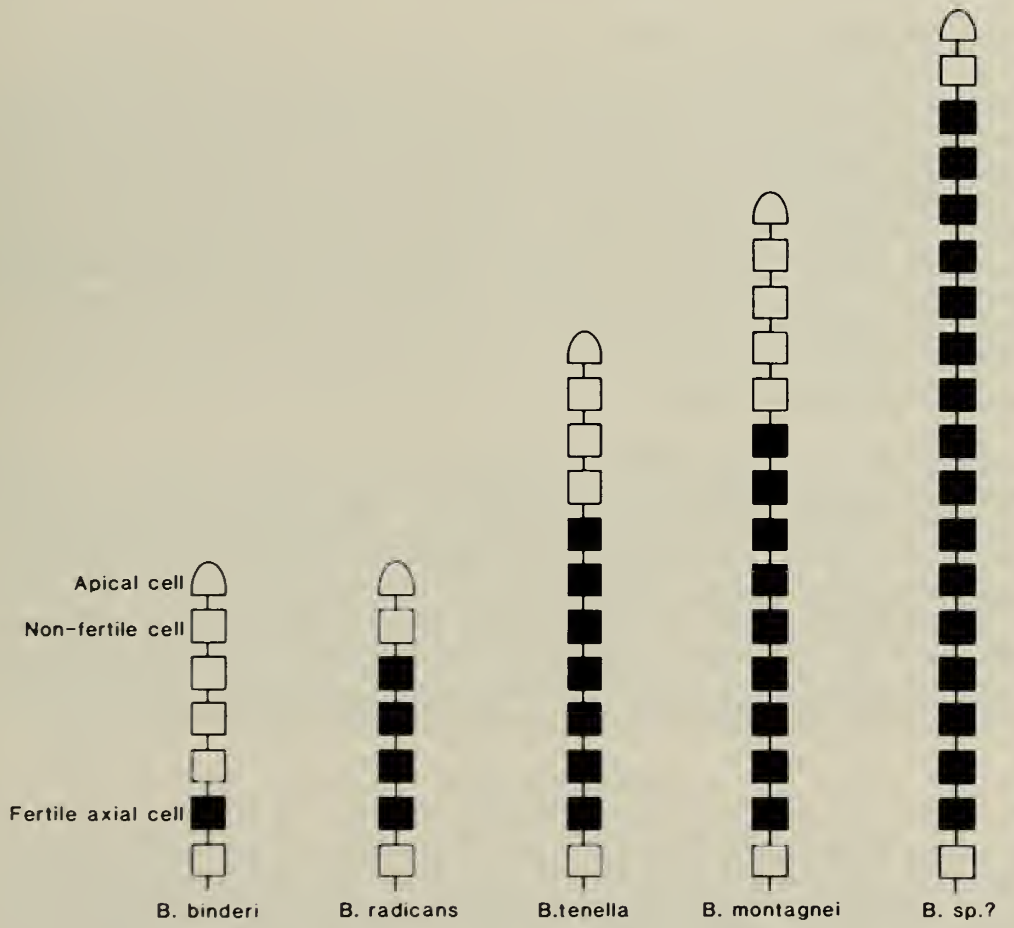

Figure 15. Diagrammatic comparison of the extent of axial cells in the fertile region of branchlets, which were seen to bear carpogonia distally from the branchlet apical cell (X of first and last cells seen fertile; based on multiple observations) in the five species studied.

The Caribbean isolates identified as *B. binderi* and *B. tenella* differed significantly in female reproductive structures when comparing the trichogynes, the number of procarps borne in the fertile axial cells of a single branch (only one in *B. binderi* vs. mean of 4 in *B. tenella*), and in the numbers of fertile axial cells per branch (Table 1; Figs. 14-15).

Differences in patterns of spermatangial production for these species also suggests that isolates of *B. binderi* from Puerto Rico (Caribbean Sea) and *B. tenella* from Tonga (southwest Pacific Ocean) are closely allied but not identical (Smith & Norris 1988). Comparative studies of the type specimen and type-locality material *B. tenella* from St. Croix, Virgin Islands (Post 1936) must be accomplished to confirm if spermatangial observations by Falkenberg (1901) of male *B. tenella* from Tonga are the same. Additionally, comparative reproductive and vegetative studies of the Puerto Rican, Tongan and specimens identified as *B. tenella* from other localities must be made with the type and type-locality specimens.

Reproductive comparisons with the other taxon in this group, *B. calliptera*, are limited by the lack of any description of its female or male reproductive structures.

Procarps of B. sp.?, *the taxon of uncertain status*

Based upon features of vegetative morphology, *B.* sp.?, with its polysiphonous/monosiphonous branchlets shows branchlet characteristics ascribed to *B. binderi* and *B. tenella*. Yet, while it has some vegetative morphological similarities, it also has distinct features of procarpic structure which statistically separate this entity from both Caribbean *B. binderi* and *B. tenella* (Table 1; Figs. 14-15). It is possible that the Florida Keys specimens represent: (1) a hybrid between *B. binderi* and *B. tenella*; (2) a polyploid of one of the species; or (3) a new species. Comparative studies of tetrasporangial and spermatangial specimens of *B.* sp.? with those of *B. binderi* and *B. tenella* are needed before its taxonomic status can be resolved.

Procarps of B. radicans *and close relatives*

Procarps of *B. radicans* f. *moniliformis* Post from southern Brazil (Cordeiro-Marino 1978) and *B. radicans* f. *moniliformis* from central Florida have similarly elongated trichogynes (Table 1; Fig. 14). What is not known for the Brazilian specimens is the extent of variation in placement of carpogonial branches and number per axial cell among populations, while for the Florida specimens there was 1 procarp per axial cell from the 2nd to 7th cell axial cells [for the Floridian isolate see Table 1; Figs. 14-15]. *Bostrychia kelanensis* has one to two procarps per axial cell from the fourth to the tenth axial cells (Tanaka & Chihara 1984b) , while the other ecorticate species, *B. pinnata* as known in Australia, is illustrated with three or four cells in a carpogonial branch (King & Puttock 1986). Female structures are unknown in the another ecorticate member of this group, *B. moritziana* (Sond. ex Kütz.) J. Ag.

CONCLUSIONS

The four species and one taxon of uncertain status of *Bostrychia* as known in the Caribbean exhibited distinctiveness in their procarpic structures, number and placement of procarps per axial cell, trichogyne size, and the occurrence of basal collars and/or distal caps on the trichogyne. Even though these characters are not readily evident to the naked eye on direct examination of field collections, our data suggest that these previously unused procarpic reproductive features are important in the systematics of *Bostrychia*. Based on use of these procarpic features, *B.* sp.? is distinct from both *B. binderi* and *B. tenella*, even though all three share some vegetative branch similarities. We suggest that *B.* sp. ? from the Florida Keys represents either a hybrid, a polyploid or a new species. Studies of the morphometrics of these entities and on their spermatangial and tetrasporangial thalli are needed to clarify their relationships.

Differences in placement and construction of female reproductive systems has been observed for another primitive red algal assemblage, the Nemaliales (see e.g., Abbott 1976). It is possible that the differences observed here in construction and placement of carpogonial branches among these Caribbean species may be attributable to the primitive state of *Bostrychia* within the family.

Since there is only one careful post-fertilization study of *Bostrychia* (i.e., *B. arbuscula* by Hommersand, 1963), comparisons of pre- and post-fertilization events for other species of *Bostrychia* should be investigated to test the validily of the procarp characters we proposed herein to be used in the systematics of the genus. Future studies should include investigating the range of both interspecific and intraspecific variation among field populations and culture conditions to test the stability of these characters over a range of conditions. And finally, while we observed differences in procarp structure among the Caribbean species we studied that correlate with the artificial groups suggested by Post (1936) in her key to the species, we recognize that these subgeneric groupings must be critically tested as well.

ACKNOWLEDGMENTS

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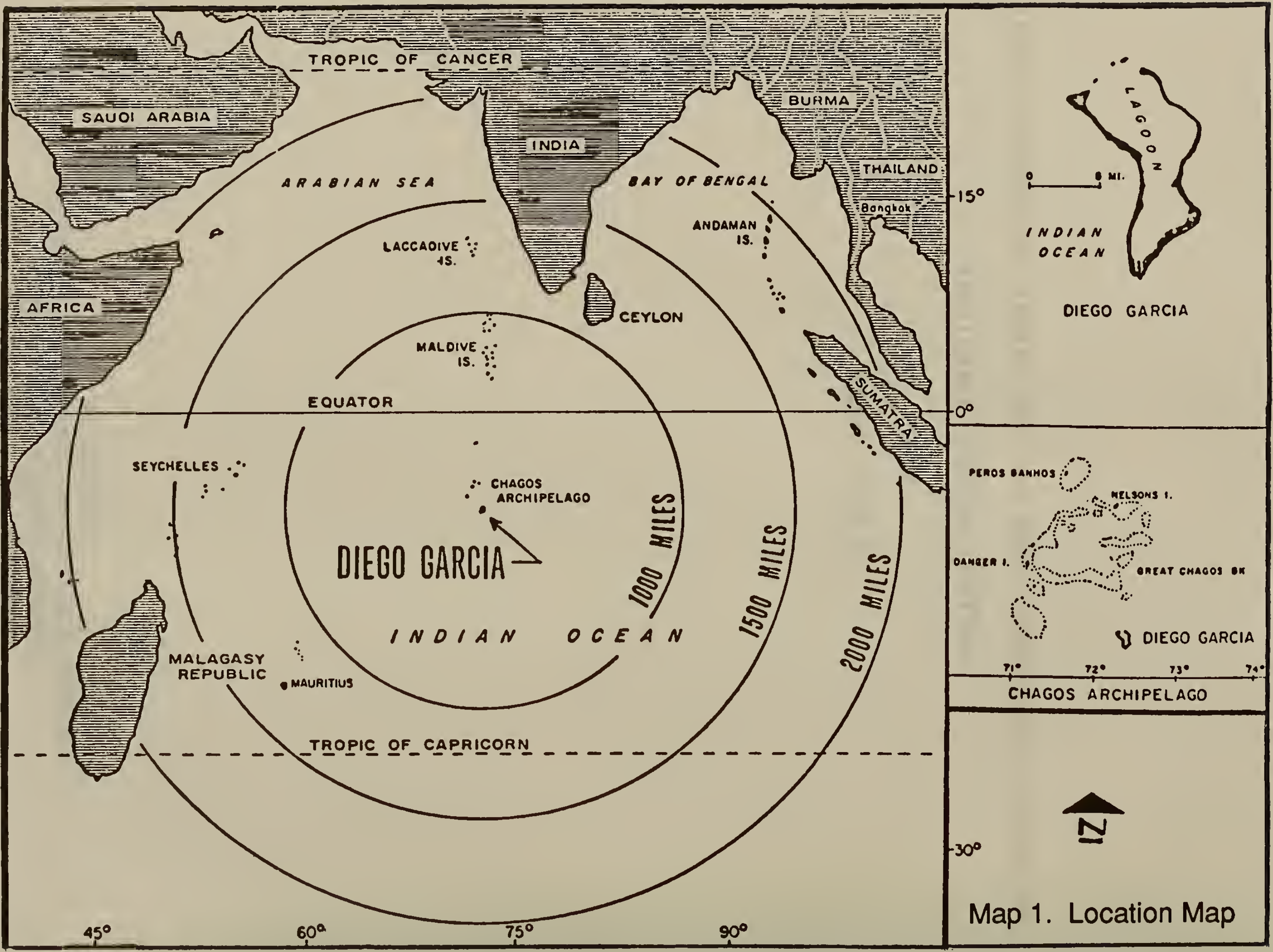
ATOLL RESEARCH BULLETIN
NO. 313

AN ANNOTATED CHECK LIST OF THE FLORA OF DIEGO GARCIA, BRITISH OCEAN TERRITORY

BY

J. M. W. TOPP

ISSUED BY
NATIONAL MUSEUM OF NATURAL HISTORY
SMITHSONIAN INSTITUTION
WASHINGTON,D.C.,U.S.A.
October 1988



Map 1. Location Map

AN ANNOTATED CHECK LIST OF THE FLORA OF DIEGO GARCIA BRITISH INDIAN OCEAN TERRITORY

by J. M. W. Topp*

ACKNOWLEDGEMENTS

It would clearly be impossible for a simple sailor and a very amateur botanist to have produced this annotated check list of the flora without the aid of professional experts. I am most grateful to the Royal Botanic Gardens, Kew for all the guidance and expertise they have most generously provided, and in particular Mr. Steve A. Renvoize and his colleagues. He and they have not only identified all the difficult species but have given me invaluable encouragement and support. Dr. A. Clive Jermy and his colleague Josephine Camus have identified the ferns. Dr. Tang and Mr. Ali Ibrahim of the Singapore Botanic Gardens have kindly helped. Dr. Charles R. C. Sheppard has provided me with lists of the flora found in the northern Chagos by D. A. Dutton and A. Field during the 1978/9 Joint Services expedition there and Commander A. J. Ryan RN generously sent me copies of the Joint Service Chagos reports for the expeditions of 1975 and 1978/9 A. M. (Tony) Hutson now of the Flora and Flora Preservation Society, gave me his 1971 botanical notes before I left London. Dr. Alan C. Leslie sent me some botanical descriptions I lacked. Use was made of the 1967 botanical survey by C. F. Rhyne of the Smithsonian and Dr. D. R. Stoddart of Cambridge University as reported in Atoll Research Bulletin No. 149 and I enjoyed reading Dr David Bellamy's book 'Half of Paradise'. It will be seen therefore that this check list is as much the product of others as myself. Nonetheless I accept full responsibility for all omissions and inaccuracies.

INTRODUCTION

DIEGO GARCIA - Physical Description

Diego Garcia is the largest and southernmost of the atolls, which with some 50 odd other islands, form the Chagos Archipelago. It lies approximately 7° 20' South 72° 27' East, (see Map 1) and has a continuous land rim of some 60 kilometres enclosing a lagoon 21 kilometres long and up to 11 kilometres wide. There are three small islands at the entrance to the lagoon. The land area is 30 sq kilometres. (6,720 acres or about 10.5 square miles). The average height is a little under 2 metres. (See Map 2). A detailed description of the island, its geomorphology and climate is given by D. R. Stoddart in Atoll Research Bulletin No. 149 of 27 August 1971. Annual rainfall averages just over 2600 mm. Humidity is high. Temperatures by day are generally about 30's C falling to the mid 20's by night.

DIEGO GARCIA - Botanical Description.

The island is heavily vegetated. Historically and botanically the significant events were discovery by the Portuguese in the early 16th century but little thereafter until the 18th century when the English and French made voyages of discovery to the Chagos. The first attempt to settle was by the English in

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1786 who brought six shiploads of soil from Bombay but later withdrew. The French started plantations in the late 1780's and these became well established in the mid 1790's. The islands were ceded to the English in 1814 and have remained British since but the plantations continued mainly under French cultural influence even when the English abolished slave labour in 1839. Experiments to use Diego Garcia as a coaling station were conducted in the 1880's and guano mining was carried out for a brief period but the prime activity until modern times continued to be production of coconut, and its derivatives. These various human activities and visitations from many lands added to the original native species and formed the flora as recorded by Rhyne and Stoddart in their 1967 survey.

Significant events occurred with the formation of the British Indian Ocean Territory, the 1966 Exchange of Notes between UK and USA (Cmnd. 3231) and 1976 Exchange of Notes between the UK and USA (Cmnd. 6413) which have allowed the United States to construct a number of facilities in the specific area of Diego Garcia. This has added further species. In 1971, when construction started, the coconut plantations were abandoned and in the specific area made way for building. Strenuous and effective measures are taken to protect the environment. The restricted area is now effectively a nature reserve and in the future it is likely that some of the original native flora will find additional room there.

It is still too early to rewrite the authoraitative and comprehensive report on the Land Vegetation of Diego Garcia by D.R. Stoddart, Chapter 11 of Atoll Research Bulletin No.149 but very minor amendments are already apparent. For example *Intsia bijuga* is present in the vicinity of Beacon No.2 (See Map 2) and spreading (this species is making an even more obvious comeback in I. Anglaise of the Salomon group to the north). The seaward beach-crest vegetation of the Southeast rim is abundant with *Suriana maritima* amongst which at least two large specimens of *Pemphis acidula* exist. *Premna serratifolia*, *Neisosperma oppositifolia* and several other species are much more common than indicated. The annotated check list which follows brings out some of these and other points. There are some 65 species recorded in this survey which were not reported in Atoll Research Bulletin No. 149. They are marked with an asterisk. They represent one third of the total number of species.

The water lenses and aquifers have been developed with about 100 wells to provide a continuous supply of 3,000 to 3,800 cubic metres a day (about 700,000 gallons) at present and possibly up to 4,700 cubic metres a day with daily peak demands of 8,500 cubic metres a day in the future except in periods of drought. This yield is sustained under a cleverly engineered and very carefully monitored scheme and where as only perhaps 30% of rainfall is recoverable, the discharge of ground water to the sea is likely to be reduced and perhaps a minor lowering of the water table will occur. Other agencies may also be at work. On 30 November 1983 there was an earthquake measuring 7.6 on the Richter scale and between that date and 1 August 1984 70 tremors of which 37 were 5.0 or more. This activity has now died down but it is possible that subtle changes of level have occurred thereby giving advantage to some species over others. These and other developments have produced a dynamic state of change over the last 15 years in Diego Garcia and the long term effect on the flora will be interesting to observe.

This current annotated check list was completed in April 1986. It is the product of 2 years occasional botanising while the BIOT Commissioners Representative. My official duties as Magistrate, Coroner, Civil Status Officer, Controller of Customs, Principal Immigration Officer, Commander British Forces Diego Garcia, Royal Navy Liason Officer and probably some other responsibilities have not allowed much time in this busy island to botanise though I kept an official watch on the fauna and flora in my capacity as de facto conservation officer. Thus, and given my own botanical limitations, the list is far from perfect - but it has been enormous fun producing it and I renew my thanks to all those professionals who have made it possible.

PSILOTACEAE

Psilotum nudum (L.) Beauv.
Common and widespread. Frequently grows at base of palm trees and old rotting tree stumps in damper places under shade and inland.

POLYPODIACEAE

Amphineuron opulentum (Kaulf.) Holttum.
Occasional and scattered, mainly on the east side of the island.

Asplenium longissimum Bl.
Frequent and widespread. Fronds can reach 5 feet. Often on rotting heaps of old coconut husks and rotten tree trunks on wetter, marshier, richer ground inland often in association with *Cylosorus interruptus*.

Asplenium macrophyllum Sw.
Occasional but widespread. Associates often with *A. nidus* on more stony, drier, less fertile ground nearer the ocean.

Asplenium nidus L.
Common and widespread. Profuse on the ground over wide areas especially under old woodland of *Hernandia sonora* and *Cocos*. Frequently grows as an epiphyte along the whole length of tree trunks and on branches. Fronds often reach height of 5 feet

Cyclosorus interruptus (Willd.) Ito
Common and profuse to the point of dominance in wet areas without shade and dryer areas with shade.

Pteris tripartita Sw.
Common and widespread. Fronds often reach 5 feet in shade or partial shade.

ARAUCARIACEAE

**Araucaria columnaris* (Forst.f.) Hook. ?
One tree in East Point Settlement garden reported (Stoddart) not found. Seed re-introduced by author in 1986 at the request of the Institute of Pacific Island Forestry, US Forest Service, USDA, Honolulu, who supplied the seed to investigate viability. Germination has been highly successful and seedlings will be planted out for landscaping when current construction in the specific area is complete.

PHYTOLACCACEAE

Rivina humilis L.
Common and widespread in woodland.

PORTULACACEAE

Portulaca oleracea L.
Common and widespread on sandy, poor soils. A constituent of the beach crest vegetation. A

pioneer plant on the fill of coralline material, dredged from the lagoon, used for construction foundations and surrounds.

Portulaca mauritiensis v. Poelln.
Not positively identified during this survey.

GUTTIFERAE

Calophyllum inophyllum L.
Frequent and widespread. Main concentrations are along the lagoon shore especially from Minni Minni and south but there are many magnificent specimens to 30 metres at inhabited or formerly inhabited sites and elsewhere throughout the island.

TILIACEAE

Triumfetta procumbens Forst.
Common and widespread. A component of the beach crest vegetation and occasionally further inland.

MALVACEAE

Abutilon indicum (L.) Sweet
Reported East Point, Wiehe in 1939. Not found in this survey.

Gossypium hirsutum L.
Occasional and scattered. Several specimens near Beacon No. 2 between Leconte Point and Cust Point. One specimen found SW of island near main road at 7° 25' South. Grown from seed to seed by author near BOQ 3 and now established as ornamental in town.

Hibiscus rosa-sinensis L
Frequent in town and widely cultivated for ornament.

Hibiscus tiliaceus L.
Frequent and widespread especially in th East Point area where it does great damage to abandoned buildings. Ocoasional elsewhere on the lagoon shore and inland.

Malvastrum coromandelianum (L.) Garcke
Reported East Point, Wiehe in 1939. Not found in this survey.

Sida acuta Burm. f.
Frequent in ruins of Point Marianne village and occasional at East Point plantation.

Sida pusilla Cav.
Common and widespread on open ground inland or beach crest. Grows in poor soil or even sand. A component of mown lawn areas. Usually prostrate, will grow in shade or where supported by taller grass to 30 cms. Leaf very variable depending on growing conditons.

BOMBACACEAE

Ceiba pentandra (L.) Gaertn.

A few mature trees behind the old Manager's House at East Point plantation.

STERCULIACEAE

Melochia pyramidata L.
Rare and only at East Point settlement.

**Waltheria indica* L.
One flourishing specimen found in well fields between 'R' and 'C' sites October 1984.

CRUCIFERAE

*Several *Brassica* and *Raphanus* species have been cultivated in the 1980s privately, on a very small scale and with varying degrees of success.

OXALIDACEAE

Averrhoa bilimbi L.
Frequent and scattered throughout the island but concentrated near former habitation sites and more common on the eastern side of the island.

RUTACEAE

**Citrus aurantium* L.
East Point area .

Citrus aurantiifolia (Christm.) Swingle.
East Point area and very occasionally elsewhere.

**Triphasia trifolia* (Burm.f.) P. Wils.
Occasional and scattered mainly on east side of the island at East Point and north but also between town and Splendidville.

SURIANACEAE

Suriana maritima L.
Common and widespread along ocean rim and on sandy lagoon inlets. Occasionally grown for ornament.

ANACARDIACEAE

Mangifera indica L.
Occasional, mainly at East Point behind the old Manager's house; also Point Marianne and modern habitation areas where the occasional young tree is growing.

LEGUMINOSAE

Albizia lebbeck (L.) Benth.
Several mature trees in East Point area where it has naturalized. One tree transplanted by author to town area.

Canavalia cathartica Thou.
Occasional and scattered in old woodland and along lagoon shore.

**Caesalpinia bonduc* (L.) Roxb.
Rare; only at East Point.

**Cassia occidentalis* L.
Common but localised to former habitation sites: frequent at East Point and occasional elsewhere..

**Delonix regia* (Boj. ex Hook.) Raf.
Occasional. One mature tree at East Point. Reintroduced (1984) by author with seed from Boddam, Salomons and raised for ornamental planting. Further seed introduced (1985) by author from Institute of Pacific Island Forestry, US Forest Service, USDA, Honolulu.

**Enterolobium cyclocarpum* Griseb.
Seed introduced by author at request of and from Institute of Pacific Island Forestry, US Forest Service, USDA in 1985 for ornamental planting, landscaping and to investigate viability.

**Erythrina variegata* var. *orientalis* (L.) Merr.
Seed introduced by author from Institute of Pacific Island Forestry, US Forest Service, USDA in 1985 for ornamental planting, landscaping and to investigate viability.

Intsia bijuga (Colebr.) 0. Ktze.
Occasional and localised to East Point and northwards and to area of Beacon No. 2.

Leucaena leucocephala (Lam.) de Wit
Common but localized to former habitation sites: profuse among Point Marianne village ruins where ground extensively disturbed in 1984 when it became dominant (1985). Occasional elsewhere and sometimes grown for ornament.

Mimosa pudica L.
Rare and found only at East Point on shore near pier.

**Pithecellobium saman* (Jacq.) Benth.
Seed introduced by author at request of and from Institute of Pacific Island Forestry, US Forest Service, USDA in 1985 for ornamental planting, landscaping and to investigate viability.

**Pithecellobium unguis-cati* (L.) Benth.
Several mature trees at East Point. Grown from seed by author for ornament in town.

**Sesbania grandiflora* Pers.
One mature tree 5 m high and two younger specimens at south end of camp just north of North Power Plant.

**Vigna marina* (Burm.) Merr.
Seed introduced from I. du Coin, Peros Banhos by author in 1985 and planted in town at BOQ 3 for ornament. This species has achieved complete dominance in the old plantation at I. du Coin. Planted BOQ 7 for ground cover.

*Note. Several legumes for private cultivation have been recently introduced.

CRASSULACEAE

Kalanchoe pinnata (Lam.) Pers.

Common and widespread in clearings or partial shade of woodlands.

COMBRETACEAE

Terminalia catappa L.

Occasional and widespread, more frequent in former habitation areas and grown also for ornament in town.

LECITHIDACEAE

Barringtonia asiatioa (L.) Kurz

Frequent and widespread but mainly in area between East Point and Minni Minni with a much smaller number on the opposite side of the lagoon between the SE end of the runway and for a mile south. Otherwise only very occasional. Grown in town for landscaping.

MYRTACEAE

Eugenia javanica Lam.

Rare, only a few specimens at East Point. Singapore Botanic Gardens identified fruit as *E. aquea*.

LYTHRACEAE

**Pemphis acidula* Forst.

Rare and only two specimens found: on ocean shore approximately 1.5 and 2.5 kilometres respectively SW of Horsburgh Point amongst an extensive shore line of *Suriana maritima*. This species is more common in the most northern islands of the Chagos, notably I. Anglaise in the Salomons and the northern isles of Peros Banhos.

TURNERACEAE

Turnera ulmifolia L.

Common and widespread especially in cultivated ground.

PASSIFLORACEAE

Passiflora suberosa L.

Common and widespread usually in wooded areas. Leaves very variable in shape.

CARIACACEAE

Carica papaya L.

Occasional and scattered, usually openground around where planted and increasingly in the specific area around modern habitation. Also on East Island.

UMBELLIFERAE

**Centella asiatica* (L.) Urb.

Found in early 1986 in ruins of Point Marianne village where ground was cleared to bare earth in mid 1984 and subsequently left to revegetate.

**Hydrocotyle bonariensis* Lam.

One patch 15 x 15 metres found between old Meteorological Station building at East Point in 1984. Subsequently grown in BOQ 3. In 1985 in response to a request for "a low growing plant that needs no maintenance and can tolerate very poor soil in full sunlight and provide uniform ground cover". It was planted behind BOQ 7 in town.

CUCURBITACEAE

Cucumis melo L.

Occasional and scattered on rough, dry, open ground.

Cucurbita mosohata (Duch. ex Lam.) Poir.

Very occasional on rough, dry, open ground. Other members of the gourd family have been introduced for private cultivation.

RUBIACEAE

**Dentella repens* J.R. & G. Forst.

Frequent but localised to a few areas starting from just south of the runway and working north. The main area is about 400 yards north of Splendidville. It forms mats up to a foot wide on flat, sandy open, ground which has been disturbed, levelled and flattened and where there is not much competition from other species.

Guettarda speciosa L.

Common and widespread. A main tree constituent of the beach crest vegetation usually just inland from ocean shore with *Scaevola sericea* and *Tournefortia argentea*. Also frequent inland. The dominant natural fragrance.

**Ixora* sp.

Planted in town area for ornament.

Morinda citrifolia L

Common and widespread on all terrains inland.

**Oldenlandia corymbosa* L.

Frequent in sandy soil on open ground and as a constituent of lawns in the town area.

**Spermacoce assurgens* R. & P.

Common and widespread on all sorts of open ground from hard and stony to mown lawn and cultivated land.

CAMPANULACAEAE

Hippobroma longiflora (L.) G.Don.

Frequent and widespread in the East Point area, with a few specimens at Foint Marianne and the town (BOQ 3) where planted for ornament.

COMPOSITAE

Ageratum conyzoides L.

Occasional and confined to former habitation areas such as Point Marianne and East Point.

**Bidens pilosa* L.

Frequent and widespread in specific areas especially at edges of woodland. During the last 2 years it has been reduced through "tidying" of the vegetation by the US Navy.

**Conyza canadensis* (L.) Cronquist

Common and widespread.

**Eclipta prostrata* (L.) L.

Common and widespread. An early coloniser.

Melanthera biflora (L.) Wild

Common and widespread on open rough ground especially in the specific area, often forming belts along roads and trails.

Mikania micrantha Kunth.

Profuse where it occurs but localised to former habitation areas at East Point and Point Marianne, SE and SW of the runway.

Synedrella nodiflora (L.) Gaertn.

Occasional on disturbed or cultivated ground mainly in the town area.

**Tagetes* sp.

Cultivated for ornament.

Tridax procumbens L.

Common and widespread on all sorts of open ground.

Vernonia cinerea (L.) Less.

Common and widespread on all sorts of open ground.

**Vernonia grandis* (DC.) J.Humb.

Occasional and usually at former habitation sites or where ground is disturbed; mainly in vicinity of runway and largely on the west side of the island. Increasing.

GOODENIACEAE

Scaevola sericea Vahl

Very common indeed throughout the island inland and on the shore where it forms almost impenetrable barriers up to 100 yds deep. Branches overhang the high water mark to make passage at high water impossible except by wading. An early pioneer of sandy shores. Known throughout the island as 'scavvy' which term is used by the layman to describe all the vegetation of Diego Garcia.

SAPOTACEAE

Mimusops coriacea (DC.) Miq.
Some 50 specimens in and around the East Point settlement area. Many specimens are young although some quite small trees have already borne fruit. May be *M. commersonii*.

APOCYNACEAE

Catharanthus roseus (L.) G. Don
Frequent; grown for ornament; naturalised in some places, notably in East Point area.

Cerbera odollam Gaertn.
Reported be Lambrecht, m.s. WHO Rept., 1969 but not found by author. However, one fruit (identified Kew) found on the shore line 1985. Lambrecht correctly reported *Mimusops*. It is possible *Persea americana* was taken for *Cerbera odollam*.

**Neisosperma oppositifolia* (Lam.) Fosb. & Sachet
Common and widespread

**Nerium oleander* L.
Introduced 1985 and 3 plants flourishing in camp just north of North power plant.

Plumeria sp.
One small tree discovered in flower at the old settlement in Boddam I., Salomons, possibly introduced by visiting yacht. Listed here as likely to be introduced to Diego Garcia for ornament.

ASCLEPIADACEAE

Asclepias curassavica L.
Frequent in the East Point area where it is naturalised. Grown by author for ornament in town area.

BORAGINACEAE

Cordia subcordata Lam.
Common and widespread inland and on lagoon shore. Planted for landscaping in town area.

**Heliotropium ovalifolium* Forsk.
12 specimens found in a small mown area in the corner of where the main road meets the 'C' site road. Several specimens successfully transplanted to BOQ 3. Also found ocean side of sewage lagoon 0.8 km north of runway northern over run.

Tournefortia argentea L. f.
Common and widespread inland and on ocean and lagoon shores where it is a main constituent of the beach crest vegetation. Also grown for landscaping in the town.

CONVOLVULACEAE

**Ipomoea aquatica* Forsk.
Rare. Well established in two permanently wet areas north and south ends of runway. Also occurs

behind Splendidville in a small cleared area of water.

Ipomoea batatas (L.) Lam.
Very occasionally cultivated.

Ipomoea macrantha Roem. & Schult.
Common and widespread in woodland from inland to shores of both lagoon and ocean. Climbs over shrubs and low trees. Somtimes spreads over low ground.

Ipomoea pes-caprae (L.) Sweet
Common and widespread especially on sandy shores where it will extend to the high water mark, and on open ground. A smaller leafed variety occurs in a wet peaty area of I. du Coin, Peros Banhos.

SOLANACEAE

**Capsicum annum* L.
Cultivated.

Capsicum frutescens L.
Cultivated.

**Lycopersicum esculentum* Mill.
Cultivated and occasionally naturalised.

Solanum nigrum L.
Rare and found only at East Point.

**Solanum melongena* L.
Cultivated.

**Solanum tuberosum* L.
Cultivated.

SCROPHULARIACEAE

Bacopa monnieri (L.) Wettst.
Common and widespread in permanently or semi-permanently wet places.

Striga asiatica (L.) Kuntze
Common and widespread parasitizing on various grasses including *Dactyloctenium ctenoides*, *Stenotaphrum dimidiatum* and increasing with great enthusiasm on the recently US introduced *Cynodon dactylon*; once seen on *Paspalum nutans*.

ACANTHACEAE

Hemigraphis alternata (Burm. f.) T. Anders.
Several well established patches at East Point behind the old managers house. Also grown for ornament in the town area.

PLANTAGINACEAE

**Plantago major* L.
Rare and confined to the town area. Found between BEQ 9 and BEQ 11 in 1985 and 1986. Possibly introduced with grass seed.

BIGNONIACEAE

**Tabebuia heterophyllum* (DC) Britton
Common and widespread in the East Point area and planted for landscaping in the town.

VERBENACEAE

Lippia nodiflora L.
Common and widespread especially on open ground, poor soil and the shore.

Premna serratifolia L.
Frequent and widespread especially in the north west of the island.

Stachytarpheta jamaicensis (L.) Vahl
Common and widespread on open ground.

**Stachytarpheta urticaefolia* Sims
Confined to East Point area.

NYCTAGINACEAE

Boerhavia repens L.
Common and widespread on open ground; a constituent of the beach crest vegetation. Only the white form is found in Diego Garcia; the pink form occurs more often in other islands of the Chagos.

**Bougainvillea* sp.
Grown for ornament in the town.

Pisonia grandis L.
Rare and scattered. This interesting tree is undoubtedly native. It has become rare in Diego Garcia. There is one specimen just north of the incinerator site and 5 specimens in the southernmost Barachois. Half a dozen exist just inland from Horsburgh Point and 3 on East Island. The main concentration of some dozen is along the main road between the Donkey Gate and the South Point of the island (power poles: 1 between power poles 166 and 168, 2 between 182 and 184, 6 between 184 and 122, 1 at 198 and 1 at 210 on the ocean side, and on the lagoon side 1 at 192, and one each, just north of the incinerator, at 83, 99 and 109.)

In 1985 a second power line was constructed on the west side of the road and several trees were lost or trimmed for this purpose. I issued a Public Notice under the Wildlife legislation of BIOT to reduce further depradation. In the specific area the trunks of the trees up to some six feet above the ground appear as if gnawed and the soft trunks are almost ringed. It is not clear what causes this effect. It may be rats, possible crabs and even possibly donkeys of which there are about 200; alternatively it may be a disease that rots the base of the trunks.

Where the tree exists in Diego Garcia the land is poor, often of broken coral rock and in all cases where the island is very narrow and close to both ocean and lagoon. Indeed it may not be fanciful to suggest that these sites were perhaps the original dividing points of the islands of Diego Garcia before the whole island became a continuous rim of nearly 80 kilometres; but this is speculation. However what is an observable fact is an appparent affinity, in the 55 odd islands of the Chagos Archipelego, namely that where there are no rats, there are birds breeding in profusion and also *Pisonia grandis*. This may of course be coincidental rather than causal. If causal it is reasonable to speculate that originally, before man and thus rat, birds bred far more profusely in Diego Garcia and *Pisonia grandis* was much more common; that since man and rat it has declined, is declining and ultimately will become extinct in Diego Garcia except on East Island which is free of rats and rarely visited by man. The fact that dispersal of *P. grandis* is by the adhesion of fruit to the plumage of birds may lend weight to the speculation.

AMARANTHACEAE

Achyranthes aspera var. *velutina* (Hook. and Arn.) C.C. Townsend
Occasional and scattered usually on borders of woodland or in partially shaded woodland, sometimes as beach crest vegetation. More common on East Island as it is in other 'bird' islands (see entry under *Pisonia grandis*).

Aerva lanata Juss.
Rare and found only on mown grassland at 'R' site.

Amaranthus viridis L.
Not found but reported by Stoddart as seen by Wiehe in 1939.

**Lagresia micrantha* (Bak.) Schinz.
Rare and found only at Simpson Point and near GEODSS site.

LAURACEAE

Cassytha filiformis L.
Common and widespread, parasitic on *Scaevola*.

**Persea americana* Mill.
One mature fruiting tree at East Point. Cultivation started in new habitation areas.

HERNANDIACEAE

Hernandia sonora L.
Common and widespread often dominant in woodland but otherwise well distributed in mixed woodland, sometimes on the lagoon shore. Outer translucent fruit case usually white but sometimes pink.

Gyrocarpus americanus Jacq.
Reported by Stoddart as seen by Wiehe in 1939 but not found during this survey.

EUPHORBIACEAE

Acalypha indica L.
Rare and found only in old habitation sites: Point Marianne and East Point.

Breynia disticha Forst.

Frequent but localised to the East Point area mainly near the cemetry.

Codiaeum variegatum (L.)Bl.
Cultivated for ornament in town area.

Euphorbia cyathophora Murr.
Frequent on borders of woodland and disturbed mounds of soil. Cultivated for ornament. Red patches on leaves sometimes replaced with white.

Euphorbia hirta L.
Common and widespread. A persistent weed in cultivated ground.

Euphorbia prostrata Ait.
Frequent and widespread especially on disturbed soil, paths and in the cracks of concrete.

**Euphorbia rubicunda* Steud.
Very occasional on sandy coral ground in town area and north of the runway.

**Pedilanthus tithymaloides* (L.) Poit.
Grown for ornament usually as a hedge. Never seems to flower.

Phyllanthus amarus Schum.
Common and widespread on open ground and a weed of cultivation.

Phyllanthus maderaspatensis L.
Common and widespread on open ground and a weed of cultivation.

Phyllanthus sp.
Occasional and confined to former habitation sites (East Point and Point Marianne) and BOQ 3.

**Ricinus communis* L.
Rare and confined to area half a mile south of runway.

URTICACEAE

Pilea microphylla (L.) Liebm.
Common and widespread in lightly wooded areas and on the borders of woodland.

Pipturus argenteus (Forst. f.) Wedd.
Common and widespread. Mainly in former plantation areas.

MORACEAE

Artocarpus altilis (Park.) Fosb.
Occasional and mainly at East Point where there are a dozen mature trees.

Ficus benghalensis L.
Frequent and scattered, usually near former habitation sites.

Ficus religiosa L.

7 trees in a row at the north end of East Point near the old Meteorological station accommodation.

CASUARINACEAE

Casuarina equisetifolia L.
Common and widespread. An early coloniser of disturbed ground and sandy shores.

CUPRESSACEAE

**Thuja orientalis* L.
Some thirty specimens in the town area and Beach House Park; imported 1980.

ORCHIDACEAE

**Vanilla planifolia* Andr.
Several acres a little south east of Minni Minni and a small area behind Splendidville. Occasionally grown for ornament in town.

*A number of cultivated orchid were brought in.

MUSACEAE

Musa sapientum L.
Occasional and scattered. Cultivated in modern habitation areas.

LILIACEAE

Allium sp.
Introduced recently for private cultivation.

**Crinum asiaticum* L.
Frequent; grown for ornament.

Crinum latifolium L.
Frequent; grown for ornament.

Haemanthus multiflorus Martyn.
Frequent; grown for ornament.

**Hippeastrum equestre* Herb.
Occasional in current or former habitation sites.

Hymenocallis littoralis (Jacq.) Salisb.
Reported by Stoddart but not found this survey.

**Sansevieria trifasciata* Hort. ex Prain
Planted for ornament.

Zephryanthes rosea (Spr.) Lindl.

Common and widespread; mainly in habitation or former habitation sites where it was originally planted for ornament, but widely naturalised.

ZINGIBERACEAE

**Zingiber spectabile* Grif.
Occasionally cultivated.

COMMELINACEAE

Commelina benghalensis L.
Frequent and widespread on open ground, in permanently or semipermanently wet areas and dry ground especially mounds of soil and rubbish tips. Distribution has been increased by developement in the specific area where vast quantities of soil have been moved around.

**Zebrina pendula* Schnizl.
Found in old graveyard half a mile east of former settlement at I. du Coin, Peros Banhos, whence cuttings taken by author in 1984 for propogation in town area of Diego Garcia where it flourishes as an ornamental plant.

PALMAE

Cocos nucifera L.
Common and widespread throughout the island, in plantations, naturally, and on both lagoon and ocean shores.

Hyphaene sp.
One fan palm tree grows behind the old Manager's house at East Point.

Phoenix sp.
One mature tree with 3 large trunks at East Point between old Manager's house and former hospital just to the south.

**Roystonea elata* (Bartr.) Harper (?).
3 young trees (imported 1980 ?) flourishing beside the town swimming pool; a further two just west between the pool and the gymnasium., and two more outside the gymnasium.

PANDANACEAE

Pandanus tectorius Park.
Two old trees at Point Marianne but also widely planted in the town for ornament.

POTAMOGETONACEAE.

Thalassodendron ciliatum (Forsk.) den Hart.
Abundant in the lagoon.

POACEAE (GRAMINEAE)

**Andropogon bicornis* L.

Occasional and largely confined to a small area (of artificially created land made up of dredged lagoon bottom and now compacted coral/shell/sand) just north of the Small Boat Basin.

Bambusa vulgaris Schrad. ex Wendl.
One large growth behind Manager's house East Point plantation.

**Bothriochloa bladhii* (Retz.) Blake.
Occasional in town area.

**Cenchrus echinata* L.
Rare; found in lawn between BEQs 9 and 11; possibly introduced with grass seed.

**Chloris inflata* Link
Frequent but largely localised to an area of several hundred acres of reclaimed land fill of coralline material dredged from the lagoon; dominant in silt but less successful on drier, higher dredged material.

**Cynodon dactylon* (L.) Pers.
3,665 pounds have been sown, mainly in the runway area and north. Common in mown areas and lawns. So far holding its own against longer established grasses. Already parasitized by *Striga asiatica*.

**Dactyloctenium ctenoides* (Steud.) Bosser
Common and widespread. An early pioneer of the shore and where coral silt and sand have been recently distributed or redistributed.

Digitaria horizontalis Willd.
Frequent and widespread usually on rougher, natural, sandy soil.

**Digitaria longiflora* (Retz.) Pers.
Frequent and widespread. An increasing component of mown areas. Dominant on Ball Field 2 in town. Makes a good lawn.

**Digitaria setigera* Roth
Frequent and widespread usually in more recently developed areas.

Eleusine indica (L.) Gaertn.
Common and widespread.

Eragrostis tenella (L.) P. Beauv. var *insularis* Hubb.
Common and widespread. Dominant in mown areas at 'R' site.

**Lolium perenne* L.
Large patch discovered March 1986 at west entrance to new gym; almost certainly introduced with grass seed.

**Leptochloa uninervia* (Presl) H.& C.
Frequent but largely confined to about a 100 acres of former lagoon sand and coral flat which has been cut off from the sea just north of POL pier; a few specimens on boundary vegetation NW of runway.

Lepturus repens (G. Forst.) R. Br.
Frequent and widespread usually on rougher, natural, sandy soil.

**Panicum maximum* Jacq.
Introduced from Boddam, Salomon Islands by author in 1985 and established at BOQ 3.

**Paspalum nutans* Lam.
Occasional and scattered. Prefers drier ground than *P. vaginatum*. Is increasing in town area.

Paspalum vaginatum Sw.
Common and widespread especially in semi-permanently wet places. The only grass in tidal inlets. Dominant in some places.

Pennisetum polystachion (L.) Schult.
Reported (Stoddart 1971) Northwest Foint and Foint Marianne but not found this survey possibly because of extensive development at the two reported sites.

Stenotaphrum dimidiatum (L.) Brong.
Common and widespread especially in richer ground. Makes a good lawn.

Stenotaphrum micranthum (Desv.) C.E. Hubb.
Frequent and widespread especially on sandy shores.

**Sorghum halepense* Pers.
Several specimens discovered April 1986 at incinerator site between Runway and South power plant

Zea mays L.
Cultivated with little success.

TYPHACEAE

**Typha domingensis* Pers.
A large patch near the North power plant may have been introduced from Louisiana USA in ca. 1979. Development threatens this site and the author has therefore re-established with seed in water run-off draining ditch just east of Airport Terminal building.

CYPERACEAE

**Cyperus* c.f. *aromaticus* (Ridl.) Mattf. et Kük.
Occasional and confined to a small area just south of where POL pier meets DOL road.

**Cyperus difformis* L.
Occasional and localised to town area just west of BEQ 13, and just NE of runwav.

Cyperus dubius Rottb.
Common and widespread. A frequent component of mown lawn areas.

**Cyperus iria* L.
Occasional and localised to just NE of runway.

Cyperus kyllingia Endl. [Kyllinga colorata (L.)Druce]
Occasional and localised mainly at Point Marianne where it is plentiful, East Point. just NE of runway and just west of BEQ 13 in the town area.

Cyperus ligularis L.
Common and widespread. Open ground. Component of beach crest vegetation. Often on poor soil in dry places.

**Cyperus polystachyos* Rottb.
Common and widespread especially in damp places.

Cyperus rotundus L.
Occasional and localised to main track of East Point Plantation.

Cyperus sphacelatus Rottb.
Occasional and localised. East Point, town area.

**Cyperus surinamensis* Rottb.
Occasional and localised. Several specimens found vicinity POL pier/DG 1 road and SW of runway where it is increasing, and NE of runway. Also in town area just West of BEQ 13.

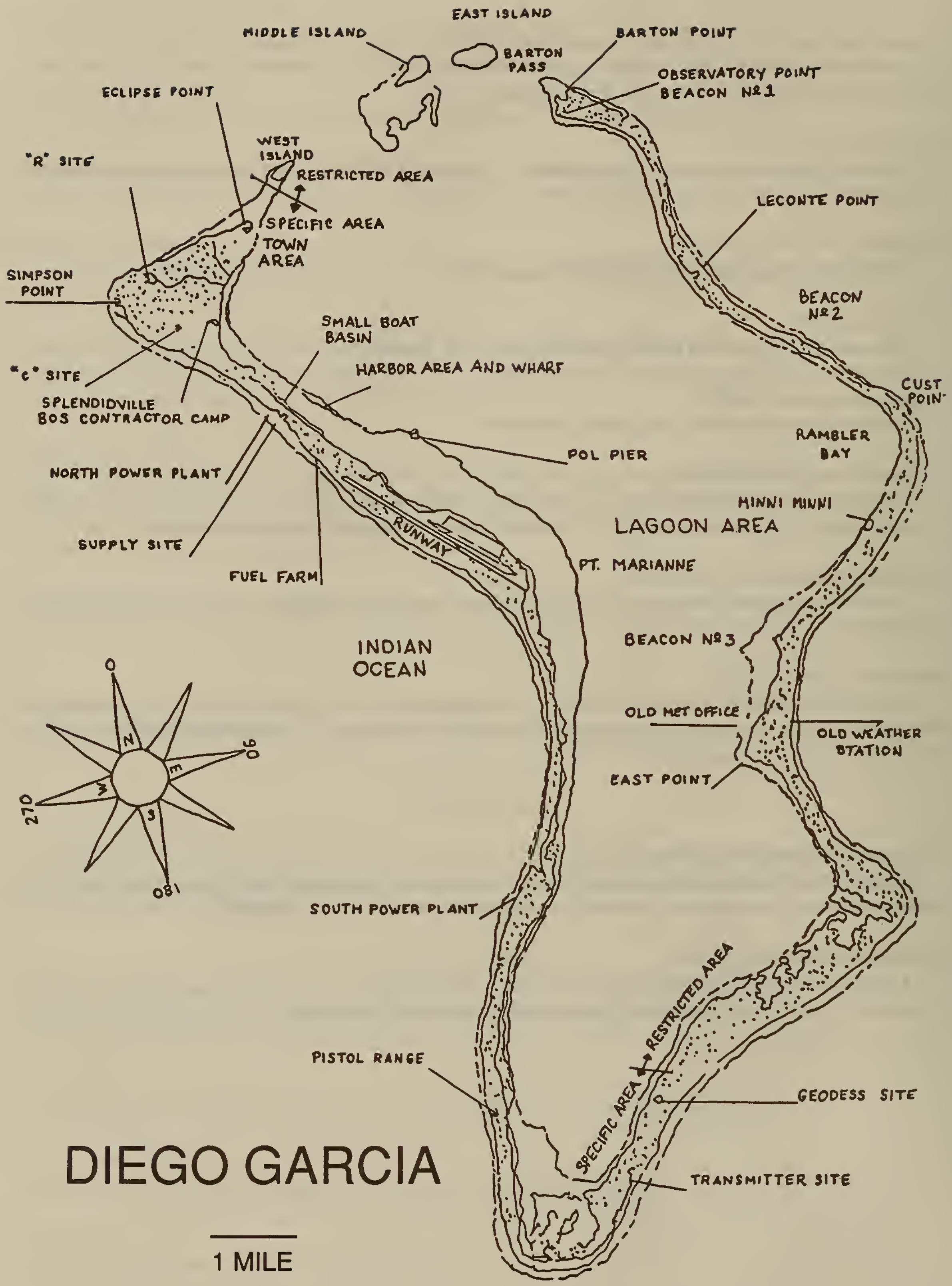
Eleocharis geniculata (L.) R. and S.
Common and often dominant on permanently or semi-permanently wet open ground throughout the island

Fimbristylis cymosa R.Br.
Common, widespread, on usually open ground varying from almost pure sand on the beach crest to wet places inland. A pioneer of naturally or humanly disturbed soil. Very variable in habit depending on soil and wetness of ground.

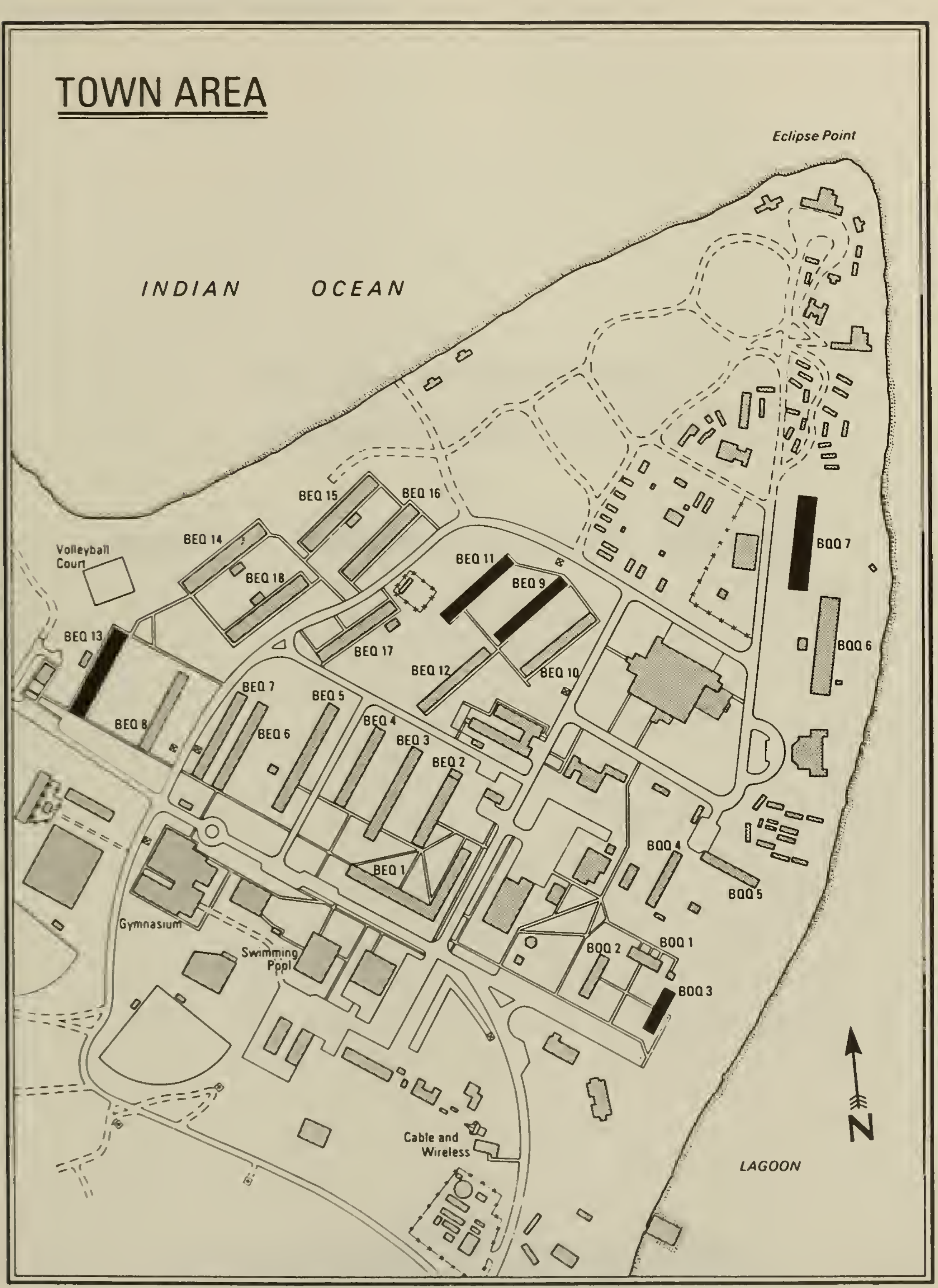
ARACEAE

Alocasia macrorrhiza (L.) Schott.
Frequent and widespread especially near former habitation sites at East Point, Minni Minni and Point Marianne. Also grown in modern habitation sites and in town for ornament.

Alocasia plumbea van Houtte.
Less common than *A. macrorrhiza* but with a similar distribution. Also in permanently wet area between 'C' site, 'R' site and behind Splendidville, and just NE of runway.



Map 2. Detail of the Atoll



Map 3. Detail of Town Area

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NO. 314

THE BIRDS OF BIKINI ATOLL, MARSHALL ISLANDS: MAY 1986

BY

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ABSTRACT

Field work conducted by the senior author at Bikini Atoll, Marshall Islands, in May 1986 yielded twenty-three species of birds; six of these were documented as nesting and an additional four species almost certainly nest as well. Six species were previously unrecorded for Bikini Atoll, and one of these, the Laughing Gull (*Larus atricilla*) was new to Micronesia. The recorded avifauna for Bikini Atoll now stands at twenty-six species. Major seabird colonies were located on Aomoen (and other northern islets), Nam, and Oroken/Jalete/Lukoj (and other southeastern islets). *Scaevola* and *Tournefortia* scrub and *Pisonia grandis* forests are the most frequently used habitats for nesting seabirds. Numerically, the most abundant breeding birds were the terns *Anous minutus*, *A. stolidus* and *Gygis alba* and the boobies *Sula leucogaster* and *S. sula*. Environmental rehabilitation options which minimize habitat alteration on the important nesting islets are recommended. Close monitoring and protection of seabird populations after Marshallese resettlement will guard against excessive disturbance and exploitation.

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INTRODUCTION

Bikini Atoll is located in the northwestern Marshall Islands in eastern Micronesia (latitude 11° 20' to 11° 44'N; longitude 165°10' to 165°44'E). It is a large coral atoll consisting of some twenty-two islets, the two largest of which are Bikini Islet (560 acres) and Eneu Islet (304 acres). These low islets (less than 4m maximum elevation) are partly to extensively wooded, although the vegetation of all islets has been disturbed through human agency. Soil and vegetation characteristics and plant species lists are given in Fosberg (1986). The breeding avifauna of Bikini Atoll consists of up to ten species of seabirds, most of which are widespread through the tropical Pacific Ocean, and one species of heron. Several additional non-breeding species, mostly shorebirds, are recorded.

Reviews of the avifauna of Micronesia (e.g. Baker 1951, Owen 1977, Pyle and Engbring 1985, Pratt *et al* 1987) have been general in scope or have concentrated on the higher, ecologically more diverse islands in the western part of the region. Considerably less attention has been paid to the lower atolls which make up the easternmost portion of Micronesia. The avifauna of the Marshall Islands was summarized by Amerson (1969); in that work seventeen species were listed for Bikini Atoll, five of which were proven to nest there. Published references to Bikini Atoll's avifauna, apart from the above-mentioned works, are few, but include Anderson (1981) and Fosberg (1966).

In this paper we discuss the results of field work conducted by the first author on Bikini Atoll in May 1986; during this visit seabird population sizes, nesting status, and habitat requirements were evaluated, and avifaunal lists were developed for most of the atoll's islets. We interpret the results in light of previous studies of Bikini Atoll and other coral atolls in the region. In particular, we (1) summarize what is currently known of the avifauna of Bikini Atoll, (2) discuss the probable impacts of three periods of human influence on Bikini Atoll (Marshallese settlement, United States atomic weapon testing, and environmental rehabilitation activities), and (3) suggest probable effects and possible mitigating measures related to proposed Marshallese resettlement on Bikini Atoll.

METHODS AND MATERIALS

Field work was conducted on Bikini Atoll 14-28 May 1986 by K. L. Garrett; additional observations were made at sea between Bikini Atoll and Kwajalein Atoll aboard the research vessel Egabrag II by K. L. Garrett on 28-29 May 1986. During field work on Bikini Atoll, visits were made to thirteen of the islets, representing all parts of the atoll. In Table 1 we list the dates each islet was visited, and in Figure 1 show their location.

Table 1. Field effort by islet or islet-group

ISLET	DATES OF COVERAGE [MAY 1986]														
	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
Eneu	X		X												X
Bikini		X	X	X	X	X	X	X	X		X	X			
Odrik/Lomilik							X								
Bokantuak								X	X		X				
Iomelan									X						
Aerokoj/Aerokojlol										X					
Enidrik										X					
Lukoj										X					
Jalete										X					
Aomoen											X		X		
Nam														X	
Oroken														X	

An attempt was made to cover all habitat types on each islet visited, although more thorough coverage was possible along the periphery of the islets and in more open habitats in islet interiors. Denser vegetation associations, such as low thickets of *Scaevola*, were penetrated where possible. For each islet, estimates were made of the number of adult birds present and all visible nests, egg sets and dependent young were counted. Population estimates were derived from direct counts of adult birds on most of the smaller islets. On certain islets, such as Nam, where coverage of interior habitats was impossible, population estimates were extrapolations of direct counts with available habitat area taken into account. It should be noted that most islets covered were of such small size that complete surveying was possible in a single visit.

At-sea transects from aboard the Egabrag II were conducted in the manner described by Ainley and Boekelheide (1983). The observer (Garrett) was stationed on the ship's bow, with observer eye level about 6m above the water surface. All birds within 300 m of the ship in a 90 degree quadrant bounded by lines extended straight ahead from the bow and straight abeam of the side providing the most advantageous lighting were recorded. As the ship's speed was a constant 8.5 knots, each fifteen minute transect covered an area of approximately 118 hectares. Densities were calculated as individuals per 100 ha by multiplying the number of individuals recorded during each transect by a factor of 0.85. In the region surveyed, adjustments for ship-following or ship-avoiding birds did not appear to be necessary.

A collection of twenty-seven specimens, housed in the Natural History Museum of Los Angeles County, provided voucher specimens and allowed for some analysis of molt, stomach contents, parasite infestations and breeding condition. Appendix A lists these specimens and associated pertinent data.

RESULTS

Twenty-three species of birds were found on Bikini Atoll and adjacent marine waters. In Table 2. we list these species and their general status in the region. Three additional species are listed for Bikini Atoll by Amerson (1969) and Anderson (1981), bringing the known list for the atoll to a minimum of twenty-six species. Of the twenty-three species observed during the present study, nesting was proven for six species, and strong evidence of nesting was obtained for an additional four species. Two additional observed species (Wedge-tailed Shearwater and Great Frigatebird) nest in the Marshall Islands and might possibly nest on Bikini, though no evidence was obtained during current field work. Of the remaining species, three were migrant shearwaters which nest in the Australasian region and spend the austral winter in the North Pacific Ocean, seven were arctic nesting shorebirds which occur in Micronesia as wintering birds or transients, and one was a North American gull of purely accidental occurrence.

Table 2. Bird species observed at Bikini Atoll, May 1986

Annotations:
N = nesting observed
N? = nesting suspected
nb = non-breeder; species nests in Micronesia
m = migrant; species does not nest in Micronesia
* = previously unrecorded at Bikini Atoll
** = previously unrecorded in the Marshall Islands

Family Procellariidae
1. *Puffinus pacificus* nb
Wedge-tailed Shearwater
2. *Puffinus bulleri* m*
Buller's (New Zealand) Shearwater
3. *Puffinus griseus* m*
Sooty Shearwater
4. *Puffinus tenuirostris* m*
Short-tailed Shearwater
Family Phaethontidae
5. *Phaethon rubricauda melanorhynchos* N?
Red-tailed Tropicbird
Family Fregatidae
6. *Fregata minor palmerstoni* nb
Great Frigatebird
Family Sulidae
7. *Sula sula rubripes* N
Red-footed Booby
8. *Sula leucogaster plotus* N
Brown Booby
Family Ardeidae
9. *Egretta sacra sacra* N?
Eastern Reef Heron
Family Charadriidae
10. *Pluvialis dominica fulva* m
Lesser Golden-Plover
Family Scolopacidae
11. *Heteroscelus incanus* m
Wandering Tattler
12. *Heteroscelus brevipes* m*
Gray-tailed Tattler
13. *Numenius phaeopus variegatus* m
Whimbrel
14. *Numenius tahitiensis* m
Bristle-thighed Curlew
15. *Arenaria interpres interpres* m
Ruddy Turnstone
16. *Calidris alba* m*
Sanderling
Family Laridae
17. *Larus atricilla* m**
Laughing Gull
18. *Sterna bergii cristatus* N?
Crested Tern
19. *Sterna sumatrana sumatrana* N
Black-naped Tern
20. *Sterna fuscata oahuensis* N?
Sooty Tern
21. *Anous stolidus pileatus* N
Brown Noddy
22. *Anous minutus marcusi* N
Black Noddy
23. *Gygis alba candida* N
White (Fairy) Tern

In Appendix B we list all species recorded and the islets on which they were observed. In the following text we present information about these species in two formats. First, we discuss each islet or islet-group, its habitats, and its bird populations. Second, we provide detailed accounts for each species, in phylogenetic order; included are accounts for species published as having occurred on Bikini Atoll, but not encountered during the present field work.

ISLET ACCOUNTS

The accounts for the islets or islet groups contain first a descriptive statement of habitats, disturbance factors and other factors which influence their avifauna. These descriptions are brief, and the reader is referred to Fosberg (1986) for a detailed discussion of habitats on each of the islets. A discussion of bird population sizes, nesting activity, foraging activity, and other aspects of avian biology follows. Islets are treated in a sequence beginning at Eneu Islet, in the southeastern part of the atoll, and continuing counter-clockwise through the eastern, northern, and southwestern islets.

A. ENEU

Eneu is the second largest islet of Bikini Atoll, with an area of approximately 304 acres. It is located on the east side of the main pass of the atoll, and is oriented approximately north-south. The dominant features of the islet are a grid of planted coconut palms (*Cocos nucifera*) and the airstrip. Eneu is the only islet other than Bikini Islet which presently has continuous human presence (one or two residents in the house and occasional activity at the storage/ machine building, airstrip and landing dock). Rats (*Rattus*, sp.) are reported to occur commonly on Eneu Islet.

Bird habitats on Eneu can be characterized as follows: (1) beaches, including sandy beaches, coral flats and beach rock; (2) sparse, short grass and herbs associated with cleared areas (e.g. the airstrip); (3) scrub, dominated by *Tournefortia* and *Scaevola*; (4) coconut plantations; and (5) *Cordia* and/or *Pisonia* forest. The last habitat type is poorly represented on Eneu.

No evidence of nesting seabirds was encountered during visits to Eneu, although small nesting populations of the White Tern in Tournefortia shrubbery or *Pisonia* trees might have been overlooked. The lack of breeding seabirds is most likely explained by continuous human presence, and by the presence of rats and cats.

The open habitats along the air strip were occupied by foraging Lesser Golden-Plovers and Ruddy Turnstones, with high counts of 18 and 10, respectively. Along the beaches and coral reef flats, the following species were encountered, with maximum counts given in parentheses: Eastern Reef Heron (4), Lesser Golden-Plover (8), Wandering Tattler (4), Ruddy Turnstone (4), Black-naped Tern (2), Crested Tern (6 on sandspit at north tip), and Black Noddy (4). Additional species flying low over the islet were: Great Frigatebird (5), Brown Booby (1), Sooty Tern (5), Brown Noddy (7), and White Tern (5).

Perhaps because the seaward fringing reef is quite narrow near the southern tip of Eneu Islet, deep-water foraging flocks of seabirds were noted relatively close to shore there. These flocks contained 500+ noddies (not identified to species), at least three Brown Boobies, and several shearwaters, apparently Wedge-tailed.

B. BOKANTUAK and IOMELAN

A series of five small islets lie between the major islets of Eneu and Bikini. The northernmost two of these, Bokantuak and Iomelan, may be reached on foot at low tide from the southeastern tip of Bikini Islet. The central islet is bare of vegetation. Observation from a small boat suggests that the avifauna of the southernmost two islets, Rojkora and Bokonjebi, is quite similar to that of Bokantuak and Iomelan.

Bokantuak and Iomelan are dominated by _Scaevola_ thickets with scattered _Tournefortia_ (the latter is most frequent along the lagoon side). The ocean side is fringed by a broad reef; above high tide line there is a broad stretch of crushed coral and beach rock. Open gravelly areas extend inward from the ocean side toward the center of each islet. Scattered _Guettarda_ grows on Iomelan but was not noted on Bokantuak.

Bokantuak and Iomelan, and presumably the other two vegetated islets in this chain, have small nesting colonies of Brown Noddies and White Terns, along with scattered nesting pairs of Black-naped Terns. Two nesting pairs of Black-naped Terns were found on Bokantuak Islet, the "nests" being shallow scrapes in the crushed coral two to three meters from the nearest _Scaevola_ thickets; each scrape contained a single egg. Two White Tern eggs and two additional chicks were located on Bokantuak; all were in _Tournefortia_ trees near the lagoon side. Only one Brown Noddy nest was located; it was in a _Scaevola_ shrub and contained a single egg. Aggressive behavior by all three species of terns suggests that many additional nesting pairs were present. Combined estimates for Bokantuak and Iomelan breeding populations were: Black-naped Tern, 15 pairs; Brown Noddy, 30 pairs; White Tern, 200 pairs. Inclusion of the southern two islets in this chain would probably at least double these numbers.

Other birds noted on Bokantuak and Iomelan Islets were: Eastern Reef Heron (2-3), Lesser Golden-Plover (2), Gray-tailed Tattler (1), Bristle-thighed Curlew (2), Whimbrel (1), Ruddy Turnstone (5), Crested Tern (4), and Laughing Gull (1). Black Noddies and one Brown Booby were noted on the adjacent coral flats and heads at low tide.

C. BIKINI

Because work on the atoll was headquartered on Bikini Islet, that islet received the most thorough coverage. The entire lagoon and seaward shores were covered several times, as was the interior. Avian habitats on Bikini Islet could be characterized as for Eneu Islet: (1) beaches, including sandy beaches, coral flats and beach rock; (2) open areas dominated by grasses, as along roadsides; (3) scrub, dominated by *Scaevola* and *Tournefortia*, but locally also by *Leucaena* or *Suriana*; (4) coconut plantations, which dominate the interior of the islet; and (5) patches of woodland dominated by *Cordia*, *Dodonea* or other small trees.

No seabirds were found nesting on Bikini Islet, a not unexpected result considering the human activity there and the presence of cats and rats throughout the islet. The continuous presence of one or two mildly aggressive pairs of White Terns in *Tournefortia* and *Suriana* scrub near the southeastern tip of the islet does suggest that this adaptable species might in fact nest on the islet.

Seventeen species of birds were recorded on or over Bikini Islet. This was the highest species list for any islet on the atoll, the result, no doubt, of saturated coverage. Notes on each of the species follow:

Red-tailed Tropicbird. One flying low over the northwest tip of the islet on 15 May.

Red-footed Booby. Occasionally seen over the lagoon just off the islet.

Brown Booby. Adults regularly seen over the lagoon and ocean waters just offshore, and perched on taller coral heads on the ocean reef.

Great Frigatebird. Small numbers occasionally seen high over the islet, with flocks of up to six birds.

Eastern Reef Heron. Up to half a dozen birds seen almost daily, primarily along shorelines and on reefs, but occasionally in cleared areas and roadsides in the interior. Possibly nests on the islet; other observers have commented on the tendency of this species to nest in concrete bunkers (such bunkers exist in Bikini Islet).

Lesser Golden-Plover. Up to 12 per day found along beaches and other open areas (e.g. roadsides).

Bristle-thighed Curlew. Occasionally seen along beaches and sandspits, especially at the southeastern tip of the islet. Maximum daily count: four.

Whimbrel. Occasionally seen along beaches or in grassy areas in the interior of the islet. Maximum daily count: six.

Wandering Tattler. Small numbers regularly seen along beaches, especially coral flats on the seaward shore. Maximum daily count: eight.

Ruddy Turnstone. Small numbers occasionally seen along beaches. Maximum daily count: seven.

Sanderling. One seen along seaward beach on 15 May.

Black-naped Tern. Small numbers regularly seen along the shorelines, especially on sandspits at the southeastern and northwestern tips of of the islet; regularly seen foraging over the lagoon just off the islet. Both adults and juveniles noted, but no signs of nesting found.

Sooty Tern. Small numbers of adults occasionally seen over the islet or adjacent waters.

Crested Tern. Up to ten per day regularly seen along beaches and, especially, sandspits. Foraging noted in shallow lagoon waters and, especially, over the seaward reef. Both adults and juveniles noted, but no signs of nesting.

Brown Noddy. Small flocks regularly seen in flight over the islet and adjacent waters; not seen perched.

Black Noddy. Small flocks frequently seen in flight over the islet and adjacent waters; also regularly found on beaches, but not seen perching in trees. Foraging flocks frequently seen over lagoon and ocean waters; small numbers also foraged along the seaward shore of the islet.

White Tern. Small numbers regularly observed over beaches and adjacent waters, and with foraging flocks of noddies over the lagoon. Aggressive birds perching in shrubs at the southeast tip of the islet suggested the possibility that one or two pairs may nest.

D. AOMOEN

Aomoen is the easternmost of a chain of narrow, scrubby islets interconnected by sandbars along the northern section of the atoll. The vegetation is simple, with *Scaevola* and *Tournefortia* being the dominant shrubs; shrub growth is densest around the slightly raised perimeter of the islet. There are extensive low flats of grasses and sparse shrubs throughout the interior of the islet. Habitats on the islet may thus be characterized as: (1) beaches, including sandy beaches, coral flats and beach rock; (2) open grassy areas with sparse shrub growth, dominating the islet's interior; and (3) mixed *Scaevola* and *Tournefortia* scrub, found through much of the islet, but especially around the raised perimeter.

The most striking ornithological feature of Aomoen Islet is the nesting colony of Brown Noddies. A minimum of 500 nesting pairs were estimated to be present; nest sites ranged from simple scrapes among the sparse grasses in the open interior portion of the islet to more elaborate stick and leaf lined structures located from one to three meters high in *Scaevola* (primarily) or *Tournefortia* shrubs. Eggs, downy young, and nearly-fledged juveniles were all commonly encountered, indicating an extended nesting season. The greatest concentration of nests was found on the ground in the central portions of the islet.

White Terns were also found nesting commonly on the islet. Over 250 pairs were estimated to be present, with eggs and downy young found exclusively on *Tournefortia* branches, especially around the perimeter of the islet.

Black-naped Terns were assumed to be nesting, based on repeated aggressive swoops by adult birds along the sandy or crushed coral seaward shore. It is likely, based on this behavior, that up to five pairs were nesting.

Other species of birds noted on Aomoen Islet were:
Brown Booby. Up to four birds present over seaward reef.
Great Frigatebird. One adult female seen on each visit.
Lesser Golden-Plover. Up to six seen on seaward beach.
Wandering Tattler. Two seen on seaward beach.
Bristle-thighed Curlew. Three seen on seaward beach.
Ruddy Turnstone. Ten seen on beaches.
Crested Tern. Six birds noted just offshore; flying juveniles noted, but no definite signs of nesting.
Sooty Tern. Up to fifteen adults noted over the islet, but no signs of nesting.

E. ODRIK/LOMILIK

These islets are joined by a vegetated sandbar and are, in fact, joined by sandbars to Aomoen Islet on the east and Bwikor Islet on the west. Field work was limited to the Lomilik (eastern) side of the Odrik/Lomilik chain. Bird habitats were generally similar to those described for Aomoen Islet, consisting of: (1) beaches; (2) open grassy areas with sparse *Scaevola* and *Tournefortia* growth; and (3) dense *Scaevola* and *Tournefortia* scrub. In addition, a small shallow pond constructed for milkfish production and bordered by *Suriana* growth is located in the center of the islet. Such ponds are utilized by shorebirds, and apparently are visited occasionally by migratory waterfowl in late fall and winter (none recorded during present field work). The western islet of Bwikor was not visited, but probably does not differ substantially from Odrik/Lomilik in its birdlife.

Nesting of both Brown Noddies and White Terns was observed. The Brown Noddy population on Odrik/Lomilik was estimated at 100+ pairs. At least ten nests were observed on inner branches of *Tournefortia* in one small section of the islet, and several downy young and feathered juveniles were noted on the ground. In addition, two dense flocks of Brown Noddies on the seaward beach totaling some 150 birds may have been composed largely of fledged juveniles (which are similar in outward appearance to adults). The Brown Noddy nesting population on Odrik/Lomilik appeared to be lower than that on Aomoen, perhaps because of the very restricted area of grass and sparse scrub compared to the latter islet.

White Terns nested on *Tournefortia* branches, as on other islets. Up to 100 pairs were probably present, and adults would hover low overhead and call, as if being vigilant around eggs or young, wherever *Tournefortia* growth was prevalent. No systematic counts of White Tern or Brown Noddy eggs and young were made since the islet was visited during mid-day when prolonged disturbance might have affected nesting success.

Sooty Terns are presumed to nest on the Bwikor/Odrik/Lomilik/Aomoen chain of islets, although no evidence was obtained during the present visit. Visitors working on Bikini Atoll in November 1985 described the presence of large numbers of terns from these islets which fit the description of Sooty Terns (BARC consultants, *pers. comm.*) . During our field study at least fifty adults were observed flying over Odrik/Lomilik, along with at least five juveniles. As juveniles are rarely seen around land other than natal islets, it is assumed that these young birds represented the end of a winter through early spring nesting season; nesting cycles of this species in the tropical Pacific Ocean are complex (see, for example, Ashmole 1965).

Other bird species noted at Odrik/Lomilik Islet were:
Red-tailed Tropicbird. One adult flying low over the islet; possibly nests under Scaevola scrub.
Brown Booby. At least five adults flying low over the islet and just offshore; no signs of nesting.
Great Frigatebird. One adult female overhead.
Eastern Reef Heron. Two birds along the seaward beach.
Lesser Golden-Plover. Six birds on the beaches.
Ruddy Turnstone. At least ten birds, on beaches and on the shore of the milkfish pond.
Crested Tern. At least eight over the islet and adjacent waters. No signs of nesting.
Black Noddy. Small flocks well offshore, but not seen in the immediate vicinity of the islets.

E. NAM

Nam is one of the larger islets on Bikini Atoll, located in the northwestern portion. Its western end was truncated by the Bravo test blast. Habitats include (1) beaches, primarily finely crushed coral on the lagoon side and a combination of this and raised coral and shelf-like beach rock on the seaward reef side; (2) dense Scaevola scrub with intermixed Tournefortia, Guettarda and other shrubs, covering most of the islet; and (3) limited Pisonia growth, such as at the western tip of the islet. There is very little area covered by grass and sparse scrub.

Brown Boobies were found nesting at the eastern tip of Nam Islet. At least twenty adults were flying around the eastern tip, or sitting at the edge of scrub. Five downy chicks were found at the edge of the Scaevola/Tournefortia scrub, and it is likely that more chicks were present a few meters back into the scrub. Ten to twenty nesting pairs were likely present.

Brown Noddies were nesting abundantly throughout the scrub areas of the islet. The number of nesting pairs was estimated to be at least 500, and young of all ages were observed. Nesting was observed in both Scaevola and Tournefortia, with no ground nesting noted.

Black Noddies were found nesting in a colony of about twenty-five pairs in Pisonia trees and taller

Tournefortia near the western tip of the islet. Up to fifty additional individuals were seen around the perimeter of the islet, and it is likely that many more pairs were nesting in taller vegetation in the interior of the islet.

White Terns were abundant throughout the islet, and both eggs and young were noted. Up to 350 nesting pairs were estimated to be present, based on the hovering behavior of adults around the Tournefortia shrubs.

Black-naped Terns were concentrated along the lagoon shore and, especially, the eastern tip of the islet. Several juveniles, capable of flight, were noted. Based on aggressive behavior by adults, it was estimated that at least ten pairs were nesting on Nam Islet. A concentration of twenty-five adult birds near the eastern tip of the islet suggests that the nesting population might well exceed this number, although these birds were perhaps packed too densely to represent breeding birds (which appear to be well-spaced in a linear edge habitat rather than clumped together).

Other bird species noted at Nam Islet were:
Buller's Shearwater. Six birds flying over the Bravo crater just west of the tip of the islet.
Red-tailed Tropicbird. One or two adults were flying low over the seaward shore of the islet; nesting under the Scaevola scrub here is likely.
Great Frigatebird. Some twenty-five birds were resting on vegetation near the eastern tip of the islet, including three or four adult males, at least fifteen adult females, and at least six juveniles. No nests or young were observed, and it is not known whether this species currently nests on the islet.
Eastern Reef Heron. Two birds noted on the seaward reef.
Lesser Golden-Plover. About thirty-five birds noted, primarily on the seaward shore.
Wandering Tattler. Eight birds noted around the shoreline.
Bristle-thighed Curlew. Two birds noted along the shoreline.
Whimbrel. One bird noted on the seaward shore.
Ruddy Turnstone. Thirty birds noted along the shoreline, primarily along the seaward shore; at least one flushed out of a Scaevola thicket.
Crested Tern. Twenty birds around the shoreline, including at least five flying juveniles; no definite signs of nesting here.
Sooty Tern. Five birds flying overhead; no signs of nesting here.

F. OROKEN

Oroken is part of a series of small islets in the southwestern portion of Bikini Atoll. From northwest to southeast, lie the islets of Bokdrolul, Bokaetoktok, Oroken, and Adrikan, each separated by a fairly deep pass through the fringing reef. Two islets located farther southeast, Jalete and Lukoj, are treated separately below. Bokdrolul and Bokaetoktok viewed from the lagoon, but only Oroken was covered on foot; Adrikan was observed only from a distance. These four islets are all similar in general vegetation structure, and the notes given below for Oroken likely apply to each of the islets. These islets, along with Nam, lie the greatest distance from the inhabited islets of Eneu and Bikini (more than fifteen miles), and might therefore be expected to suffer the least frequent disturbance by humans. Significant avian habitats on Oroken are: (1) beaches, primarily sandy; (2) *Tournefortia* and *Scaevola* scrub, dominated by the former; and (3) *Pisonia grandis* forest. As is typical of the last habitat, the forest is dense but lacks undergrowth.

The most prominent features of the birdlife of Oroken Islet are the presence of large numbers of nesting boobies of two species, and the presence of a very large nesting colony of Black Noddies in the *Pisonia* forest. Smaller numbers of White Terns also nest.

Brown Boobies nested abundantly around the perimeter of the islet; an estimated 200 chicks were seen, along with a few eggs. Extrapolating to include the portions of the islet's perimeter that were not covered, an estimated 300 pairs of Brown Boobies nest on Oroken. Nearly all chicks were found at the edge of the *Tournefortia* scrub, or in the first ten to twenty meters in toward the center of the islet from the scrub edge. A small number of chicks and sitting adults were noted well into the interior of the islet. The young varied in age from naked, newly hatched birds to fully feathered birds just capable of flight. As for many bird species in the region, this suggests a rather prolonged nesting period. Small numbers of Brown Boobies were also observed from a distance on Bokdrolul and Bokaetoktok Islets, and the species is assumed to be nesting there as well.

Red-footed Booby nests were confined to the taller shrubs and trees, as is typical of this species. Nests were located in *Pisonia* and, especially, *Tournefortia*. Nesting pairs were concentrated toward the perimeter of the wooded part of the islet. About forty chicks were seen, along with some 300 flying birds (mostly adults, but some juveniles). A minimum of 100 nesting pairs is assumed, and the figure is possibly twice that. Even from some distance, some thirty Red-footed Boobies were noted on Bokdrolul Islet, and the species is assumed to be nesting there and perhaps also on Bokaetoktok.

Black Noddies were easily the most abundant birds on Oroken Islet, with nests located in virtually every Pisonia tree checked. Highly colonial, these terns were encountered in densities of ten to twenty nests per Pisonia tree, even in the very center of the islet. Nests were located from four meters to treetop height. Most nests observed had an attending adult, but no large chicks were observed; several small chicks were seen. A conservative estimate of 2000 pairs was made. Only small numbers of Black Noddies were noted from a distance at Bokdrolul and Bokaetoktok Islets, and it is not known whether the species nests in Pisonia forests there.

White Terns had eggs in both Tournefortia and Pisonia, and adults hovering over presumed nests sites were found throughout the islet (though concentrated around Tournefortia growth around the islet's perimeter). A conservative estimate of 200 nesting pairs was made for the islet. Several dozen White Terns were noted over Bokdrolul and Bokaetoktok, and it is almost certain that the species nests on those islets as well.

Other species noted on Oroken Islet were:
Great Frigatebird. Fifty birds, representing a fairly even mix of adult males, adult females and juveniles, were perched along the outer edges of the wooded areas. No signs of nesting observed.
Lesser Golden-Plover. Three observed along the shoreline.
Bristle-thighed Curlew. One observed along the lagoon shore.
Ruddy Turnstone. Ten observed, primarily along the seaward shore; one flushed from the ground under the Pisonia forest.
Crested Tern. Two noted just off the northwest tip.
Sooty Tern. Eight noted in flight overhead; no signs of nesting.

The only bird species noted in this area of the atoll but not on Oroken Islet was a single Red-tailed Tropicbird over Bokaetoktok; this species may nest under scrub at the perimeter of these islets.

G. JALETE

This small islet is covered with scrub, dominated by Scaevola and Tournefortia; it lacks Pisonia forest. A few coconut palms are found in the center of the islet, and the islet has a good population of coconut crabs.

Brown Boobies were nesting along the southern and eastern shores of the islet, at and just inward from the edge of the scrub. At least thirty downy young and two weakly flying juveniles were noted, and a minimum estimate of fifty nesting pairs was made.

Brown Noddies were found nesting commonly throughout the islet, and young of all ages were observed. An estimated minimum of 200 nesting pairs were present. Nests were observed on the ground and, especially, in _Scaevola_ and _Tournefortia_ shrubs.

At least six pairs of Black-naped Terns were assumed to be nesting along the periphery of the scrub. Two downy young (siblings?) were found under a _Tournefortia_ shrub just inward from the high tide line. The minimum population estimate was based on defensive behavior and calling by adults. An additional three flying juveniles were observed.

Other birds observed were:
Lesser Golden-Plover. Five along the shoreline.
Bristle-thighed Curlew. Four along the shoreline.
Ruddy Turnstone. Six along the shoreline.
Sooty Tern. One adult flying overhead.
Crested Tern. Four observed along the shoreline.
Black Noddy. At least fifty birds were perched in _Tournefortia_ shrubs near the periphery of the islet, but no signs of nesting were observed.

No Red-tailed Tropicbirds were observed around Jalete Islet, although the species is said to nest under shrubs around the periphery of the islet. Somewhat surprisingly, no White Terns were noted at Jalete Islet.

H. LUKOJ

This small islet is located just southeast of Jalete Islet, and generally resembles that islet except for a fairly well-developed forest of _Pisonia_ in the interior and, especially, at the western end of the islet. Otherwise the islet consists of well-developed _Tournefortia_ and _Scaevola_ scrub, with an admixture of _Guettarda_, _Pemphis_ and other shrubs.

Red-footed Boobies were numerous around Lukoj Islet, especially in roosts at the eastern end of the islet, where an estimated 30 adults and 20 flying juveniles were seen. One downy chick was seen in a nest in _Pisonia_ at the western tip of the islet, and it is likely that many more nests were present. Nevertheless, the breeding population for this islet must be conservatively estimated at less than twenty pairs.

Black Noddies were nesting commonly in the *Pisonia* forest, with over three hundred nests counted near the western tip of the island, all high in *Pisonia* branches. Based on this density of nests, the extent of the *Pisonia* forest on Lukoj, and the number of adults noted flying around the islet, an estimate of 500 nesting pairs of Black Noddies was made. Several flying adults had small *Pisonia* twigs adhering to the plumage, caused by the dense hooks on the small *Pisonia* burrs. At least one adult was found unable to fly because of dense *Pisonia* burrs stuck to the wings and other parts of the plumage (LACM specimen # 103109).

The presence of several sitting Great Frigatebirds near the eastern tip of the islet suggests the possibility of nesting. Three adult males, ten adult females and twenty white-headed immatures were counted, but no signs of active nesting were observed.

Black-naped Terns were certainly nesting around the perimeter of the islet, based on aggressive diving behavior of adults and the presence on the beach of at least three flying juveniles. Fifteen adult birds were counted, and it is likely that the nesting population for Lukoj was at least six pairs.

No definite evidence of nesting was obtained for the Brown Noddy, although adults were commonly seen over the scrub around the perimeter of the islet, and nesting seems likely in the *Pemphis*, *Tournefortia*, or *Scaevola* growth. About fifty adults were noted.

White Terns were found over the entire islet, with a minimum of 100 adults estimated. Hovering and calling behavior around the edge of the scrub suggested that the species was nesting, but no eggs or young were found. It would appear likely that at least fifty pairs were nesting on Lukoj.

Other bird species noted were:
Lesser Golden-Plover. Eight along beaches.
Wandering Tattler. Two on beach rock of ocean shore.
Bristle-thighed Curlew. Three along beaches.
Ruddy Turnstone. Six along beaches.
Crested Tern. Five adults just offshore; no signs of nesting here.
Sooty Terns. Five adults overhead.

I. ENIDRIK

Enidrik was visited only briefly in the late morning of 23 May, so few conclusions could be drawn about the breeding avifauna of the islet. Only the western portion of the islet was visited, although the entire lagoon side was viewed from the small boat. Most of Enidrik consists of typical Tournefortia and Scaevola scrub, with a considerable admixture of tall Pemphis, Guettarda, and Cordia; Suriana growns commonly along the perimeter berms. High waves generated by Typhoon Lola the week prior to the visit had flattened some of the scrub on the western end of the islet.

Bird species observed at Enidrik Islet were:

Brown Booby. Two adults just offshore; no signs of nesting of this species or Red-footed Booby.

Eastern Reef Heron. Two birds seen along the shoreline.

Lesser Golden-Plover. Twelve observed along the shorelines.

Wandering Tattler. One observed along the ocean shoreline.

Bristle-thighed Curlew. One observed along the ocean shoreline.

Ruddy Turnstone. Four observed along the shoreline.

Black-naped Tern. Six adults observed, including a noisy and aggressive pair that undoubtedly had a nearby nest. Extrapolating to the entire perimeter of Enidrik, it is likely that at least ten pairs of Black-naped Terns nest on the islet.

Crested Tern. Eight adults observed; no signs of nesting.

Brown Noddy. At least ten adults observed, and at least three old nests seen in scrub.

Black Noddy. Twenty birds seen well offshore; no evidence of nesting on Enidrik Islet.

White Tern. At least thirty adults flying over Tournefortia and Pemphis scrub; undoubtedly nesting based on calling and hovering behavior. Assuming rather even densities around the islet's scrub perimeter, it is likely that at least fifty pairs of White Terns nest.

J. AEROKOJ/AEROKOJLOL

These two islets are broadly connected by a vegetated sandspit and thus simply appear as one islet. In turn they are connected on the west to three smaller islets (Bikdrin, Lele, Eneman) by a very shallow reef (and remnants of an old causeway, now appearing as a series of rusted metal pilings). An old air strip on

Aerokoj/ Aerokojlol is overgrown, but recognizable by the scattered distribution of the tall *Tournefortia* scrub and the even gravelly substrate. A few coconut palms grow toward the eastern end of the islet. Otherwise the islet is dominated by typical *Scaevola* and *Tournefortia* scrub, perhaps attaining a somewhat taller stature here than on many other islets. Scattered other shrubs occur, but no *Pisonia* is present.

Over one hundred adult Brown Noddies were observed, and at least five nests were found in *Tournefortia* shrubs. It is likely that the nesting population was between fifty and one hundred pairs.

White Terns were numerous, with over two hundred birds seen. No eggs or young were noted, but hovering and calling behavior of adults suggested that the species was nesting, with a population probably in excess of one hundred pairs.

Black-naped Terns were suspected to be nesting along the shoreline on the ocean side, with six adults observed and one especially aggressive pair strongly indicating active nesting.

Other bird species observed at Aerokoj/Aerokojlol were:

Brown Booby. Twenty-five adults perched along the eastern shore, but no signs of nesting observed.

Eastern Reef Heron. Three observed along the shoreline.

Lesser Golden-Plover. Thirty observed along the shoreline and shallow reefs.

Wandering Tattler. Two observed on the shallow reefs.

Bristle-thighed Curlew. One observed along the shoreline.

Ruddy Turnstone. Twenty-five observed along the shoreline and shallow reefs.

Crested Tern. Ten seen around the shorelines and just offshore; no signs of nesting noted.

Black Noddy. About fifty birds around the islets; while a few were perched in trees, there were no signs of nesting.

SPECIES ACCOUNTS: AN ANNOTATED LIST OF THE BIRDS OF BIKINI ATOLL

The following accounts treat each of the species recorded from Bikini Atoll, including three species not recorded during present field work. Information summarized in these accounts includes: (a) general world distribution and status, including conservation status (data from Harrrison 1983 and Hayman _et al_ 1986); (b) status and distribution on Bikini Atoll; (c) estimated population size on Bikini Atoll; (d) nest-site requirements (where applicable); (e) foraging habits and requirements (where known); (f) notes on additional aspects of behavior and ecology.

Figures 2 through 8 show the distribution of nesting colonies of the six species confirmed as breeders on Bikini Atoll, as well as roost sites (possibly also used for nesting) of the Great Frigatebird.

1. _Puffinus pacificus_ WEDGE-TAILED SHEARWATER

This tropical and sub-tropical shearwater of the Pacific and Indian Oceans nests over a broad longitudinal range which includes some of the Marshall Islands. It is closely related to the Buller's Shearwater, the latter breeding only in the cooler southwest Pacific Ocean. Most recent authors (e.g. Mayr and Cottrell 1979) consider _pacificus_ to be monotypic.

Amerson (1969) considered this species to be a possible breeder on Bikini Atoll, but firm nesting evidence was lacking. No nesting evidence was obtained during present field work; the species is probably best considered a regular visitor to offshore waters and, occasionally, the lagoon, throughout the year. Two birds were flying north through the wide pass between Eneu and Aerokoj Islets on 23 May. One bird was seen about 6 nautical miles south of Eneu Islet on 28 May, and eleven additional birds were seen on 29 May off the west side of Kwajalein Atoll. Wedge-tailed Shearwaters nest in burrows within vegetated portions of atoll islets; no certain nest burrows were noted during present field work. They feed well at sea, often joining mixed foraging flocks of terns and boobies (as observed on 29 May from the Egabrag II).

All Wedge-tailed Shearwaters noted during present field work were of the dark color morph; both dark and light color morphs are known from Micronesian populations; light morphs are said to predominate at breeding colonies (Amerson 1969).

2. _Puffinus bulleri_ BULLER'S SHEARWATER

Buller's Shearwaters nest on islets off North Island, New Zealand, then migrate northward across the western and central Pacific Ocean as far as Alaska; the species is strictly a migrant through Micronesia. The species was not recorded at Bikini Atoll prior to this study.

Six Buller's Shearwaters were observed flying across Bikini Lagoon at Bravo Crater just west of Nam Islet on 27 May. A single bird was seen the same day in the pass east of Aerokoj. Four birds were seen from six to fifteen nautical miles south of Eneu Islet on 28 May, and six additional birds were seen north and just west of Kwajalein Atoll on 29 May.

3. *Puffinus griseus* SOOTY SHEARWATER
4. *Puffinus tenuirostris* SHORT-TAILED SHEARWATER

These two monotypic species are considered together, as their seasonal roles in the Marshall Islands are roughly similar. Both breed on islands in the Australasian region, migrating broadly across the Pacific ocean as far as the Aleutian Islands (with Short-taileds even reaching the Bering Strait); both species are strictly migrants through Micronesia. Previous publications list neither of these species for Bikini Atoll, although migrants are frequently recorded in Marshall Islands waters.

Two Sooty Shearwaters were seen in Bikini Lagoon, northwest of Eneu Islet, on 16 May. Two Short-tailed Shearwaters were just off the ocean side of Aerokoj/Aerokojlol on 23 May. Several additional dark shearwaters seen in the lagoon or just offshore were not identified to species. An additional Short-tailed Shearwater was seen from the Egabrag II approximately 25 nautical miles SSE of Eneu Islet on 28 May. Large numbers of both of these species are to be occasionally expected in waters around Bikini Atoll, especially during their northward migration (roughly March through May).

5. *Phaethon rubricauda* RED-TAILED TROPICBIRD

The subspecies *melanorhynchos* nests widely over the tropical central, south, and west Pacific Ocean, primarily on low atolls. The smaller White-tailed Tropicbird, *Phaethon lepturus*, also occurs through these regions, nesting mainly on higher islands; it has not been recorded from Bikini Atoll.

Although Amerson (1969) did not specifically record Red-tailed Tropicbirds from Bikini Atoll, their presence at Bikini as recorded during the present study is hardly surprising. Single birds were noted at Bikini Islet, Odrik/Lomilik Islet, Nam Islet, and Bokaetoktok Islet. This species is said to nest on the northern islets and on Jalete Islet, but no evidence was obtained during the present study. Red-tailed Tropicbirds nest on the ground, usually under *Scaevola* or other growth (Clark *et* al 1983). It is likely that their nesting season at Bikini does not include late spring; if the species was in fact nesting during late spring, population size was certainly quite low.

6. Fregata minor GREAT FRIGATEBIRD

This species breeds widely through the world's tropical oceans, and is the most abundant and widespread frigatebird in the tropical Pacific Ocean. The subspecies palmerstoni is the form found in the Marshall Islands (and widely through the Pacific).

Amerson (1969) considered this species a possible breeder at Bikini Atoll. No confirmation of breeding was obtained during the present study, but the species is not uncommon around the atoll and utilizes several islets for roosting. Small numbers were occasionally noted over Bikini and Eneu Islets, and single adult females were seen over Aomen and Odrik/Lomilik Islets. Roosts or post-breeding aggregations of Great Frigatebirds were found on three islets: Nam (25), Oroken (50), and Lukoj (33) (Fig. 2). About 40% of these birds were white-headed juveniles. If frigatebirds were nesting, juveniles would be expected to be rather evenly spaced, on or near nests. Instead, flocks were rather tightly clumped and no nest structures were noted. Frigatebird nests are usually placed on the tops of low shrubs, and active nests should have been visible. We conclude that Great Frigatebirds probably do not nest on Bikini Atoll, although more study is needed.

7. Sula dactylatra MASKED (BLUE-FACED) BOOBY

Masked Boobies of the subspecies personata nest widely through the central, south and west Pacific Ocean; they have been recorded as nesting at Taongi and Bikar in the northern Marshalls.

A single individual recorded off the atoll by Anderson (1981) is the only record of this species for Bikini. The species was not found during present field work.

8. Sula sula RED-FOOTED BOOBY

Like the other boobies occurring at Bikini Atoll, Red-foots are widespread through the world's tropical oceans. The subspecies rubripes nests abundantly over much of the tropical Pacific and Indian Oceans.

On Bikini Atoll Red-footed Boobies were found nesting only on the southwestern islets (Fig. 3). An estimated twenty pairs were nesting on Lukoj Islet, 100 (to 200) pairs on Oroken Islet, and perhaps thirty pairs on Bokdrolul Islet. Series of specimens collected on Oroken and Bokdrolul Islets in April-July 1946 (Amerson 1969) suggest that these islets were important nesting colonies then as well. Small numbers of Red-footed Boobies were occasionally noted over the lagoon in other sections of the atoll. A minimum nesting population for the atoll of 150 pairs is suggested, although more thorough coverage of the southwestern islets would very likely reveal a total population of at least 300 pairs.

Red-footed Boobies build stick nests in tall shrubs and low trees, and breeding was restricted to islets containing *Pisonia* forest (although nests were not necessarily placed in *Pisonia*). Both downy young and flying juveniles were noted during the present study. Red-footed Boobies feed on fish and squid both well at sea and just offshore; they are frequently associated with large foraging flocks of noddies. Prey is obtained by shallow plunge-diving or by aerial pursuit just above the surface of the water (Schreiber and Clapp 1987). Fifteen birds were part of a feeding flock also containing Black and Brown Noddies off the ocean side of Aerokoj on 23 May. Large feeding flocks were also noted between Bikini and Kwajalein Atolls on 29 May.

Red-footed Boobies occur in a variety of color morphs. The predominant morph at Bikini Atoll was white bodied and white tailed, with dark remiges; a large number of these birds had some brown on the upper wing coverts, and many were completely brown mantled. A small percentage of birds were brown bodied and white tailed. No dark tailed adults were noted.

9. *Sula leucogaster* BROWN BOOBY

Brown Boobies are widespread through the world's tropical and subtropical oceans. The subspecies *plotus* nests through much of the tropical central, south and west Pacific and the Indian Ocean, and is the nesting subspecies on Bikini Atoll. This species is probably numerically less abundant than the Red-footed and Masked Boobies in the tropical Pacific Ocean.

Amerson (1969) considered this species a possible breeder at Bikini Atoll. During the present field work breeding colonies were found on Nam Islet and some of the southwestern islets (Fig. 4). Ten to twenty pairs were estimated from Nam, at least 300 pairs from Oroken, and fifty pairs from Jalete. It is quite possible that nesting also occurred on Bokdrolul and Bokaetoktok Islets. With more thorough coverage of the southwestern islets, it is likely that May 1986 breeding population of Brown Boobies at Bikini Atoll would have been found to exceed 400 pairs. All stages from eggs to flying juveniles were observed during the present field work. As in many Bikini Atoll seabird species, this suggests a prolonged, asynchronous breeding season; such asynchrony implies that population counts derived from a single visit are likely to be low. Brown Boobies nest strictly on the ground, under the cover of _Tournefortia_ and other shrubs, and, on Oroken, under _Pisonia_ trees.

Brown Boobies forage over the lagoon and well at sea (Red-footed Boobies, by contrast, forage well at sea but only infrequently over the lagoon).

10. _Egretta_ _sacra_ EASTERN REEF HERON

This medium-sized heron is resident from the coasts of southeast Asia east through much of the tropical southwest Pacific Ocean, including, for example, the Marshall, Gilbert, Phoenix and Line Islands, and French Polynesia (Hancock and Elliott 1978). The nominate subspecies occurs through most of this region, including the Marshall Islands.

Amerson (1969) considered the Eastern Reef Heron a possible breeder on Bikini Atoll. BARC consultants visiting Bikini Atoll have mentioned the tendency of this species to nest in bunkers. Hancock and Elliott (1978) note that this species may nest on the ground, in shrubs or small trees, on ledges, or in crevices. No evidence of nesting was found during present field work, but this relatively sedentary species was encountered frequently and almost certainly nests at Bikini Atoll. From two to six birds were encountered on most islets visited, except the small southwestern islets, where no reef herons were seen. The total population for the atoll is estimated at fifteen to twenty-five pairs. Birds were generally encountered along seaward reefs, but also along lagoon shorelines and, on Bikini and Eneu Islets, in clearings and along roads well into the interior of the islets. While Eastern Reef Herons probably feed primarily on crabs and fish at Bikini Atoll, their frequent presence in the interior of the larger islets suggests that their diet may also include prey such as lizards and grasshoppers; if this is the case, the reef heron is the only resident bird species on Bikini Atoll which derives some of its food from the terrestrial ecosystem.

As Eastern Reef Herons are polymorphic, various observers in Micronesia have commented on the relative frequency of dark, mottled and white plumage morphs. For example, Anderson (1981) found 18 dark, 14 mottled and 13 white morphs on atolls he visited, while Fosberg (1966) considered dark and white morphs about equally frequent and mottled birds relatively infrequent.

During present field work, morphs were encountered as follows: six dark, two mottled, and eleven white.

11. Poliolimnas cinereus WHITE-BROWED RAIL

A single individual of the Micronesian race micronesiae was collected on Bikini Islet on 3 January 1933 (Amerson 1969). This is the only record of a rail from the Marshall Islands.

12. Pluvialis dominica LESSER GOLDEN-PLOVER

Lesser Golden-Plovers occurring in the Marshall Islands belong to the race fulva (often referred to as the Pacific Golden-Plover). Fulva breeds in tundra regions from northern Siberia east to western Alaska and winters widely through the central, south, and southwest Pacific. It is a winter visitor and migrant in the Marshall Islands, although small numbers of non-breeding birds remain through the summer.

Lesser Golden-Plovers were recorded on all islets visited, with a conservative minimum total of 150. Flocks of up to twenty birds were seen, and the species was encountered in roughly equal abundance on large and small islets. It is likely that during migration peaks the Bikini Atoll population is considerably higher than 150 birds. Numbers would be expected to be lowest from late May through late July. Foraging birds were encountered on beaches, reefs (at low tide), and open terrestrial habitats (such as the Eneu airstrip and Bikini roadsides). Occasionally birds were even encountered in small clearings in wooded areas.

13. Heteroscelus incanus WANDERING TATTLER

As with the Lesser Golden-Plover and all other shorebirds recorded on Bikini Atoll, the Wandering Tattler nests in arctic regions and occurs in the Marshall Islands in a strictly non-breeding role. Specifically, Wandering Tattlers breed above tree line in Alaska and extreme eastern Siberia, and winter along the western coasts of the Americas and through all but the westernmost Pacific islands.

Wandering Tattlers were found on nearly all of the islets visited, with a maximum counts of ten on Bikini Islet and eight on Nam Islet. A total of about thirty birds was noted during field work, but this number would be expected to be higher during winter and, especially, peak spring and fall migration periods. Birds were encountered on shorelines and, especially, reefs.

14. *Heteroscelus brevipes* GRAY-TAILED TATTLER

The Gray-tailed Tattler is closely related and very similar in appearance to the Wandering Tattler. It breeds locally in eastern Siberia and winters in the southwestern Pacific and Australasian regions.

Amerson (1969) considered this species an uncommon migrant through the Marshall Islands, but listed records only for Eniwetok and Kwajalein Atolls. One bird was observed during present field work: at low tide on the reef adjacent to the northern end of Bokantuak Islet on 21 May; this apparently represents the first sighting for Bikini Atoll. This species must be distinguished carefully from the Wandering Tattler; Gray-tailed Tattlers are paler in all plumages, and their most frequent call note (an upslurred "chu-weet?") is very different from the calls of Wanderings. This species may occasionally be more numerous on Bikini Atoll, as suggested by the senior author's sighting of 20 birds at Majuro, Majuro Atoll, on 13 May 1986.

15. *Numenius phaeopus* WHIMBREL

Whimbrels breed across the Arctic tundra regions and winter widely through the temperate and tropical latitudes of the northern and southern hemispheres. The subspecies occurring on the Marshall Islands is *variegatus*, which breeds in eastern Siberia and winters in southeast Asia, the Australasian region, and islands of the southwest Pacific.

Amerson (1969) considers the Whimbrel a common migrant and winter visitor to the Marshall Islands, but does not list the species from Bikini Atoll. Anderson (1981) did not list Whimbrel from Bikini. During present field work the Whimbrel was recorded only on Bikini Islet (at least six birds), Bokantuak Islet (one), and Nam Islet (one). All could be clearly assigned to *variegatus* based on the barred whitish lower back and rump. Only on Bikini Islet did the Whimbrel outnumber the Bristle-thighed Curlew. Whimbrels were primarily seen along sandy shorelines.

16. *Numenius tahitiensis* BRISTLE-THIGHED CURLEW

This close relative of the Whimbrel breeds very locally in extreme western Alaska and, presumably, in eastern Siberia (few nests have ever been located). It winters on islands in the central and south Pacific; although widespread in winter in this region, it is nowhere abundant.

Amerson (1969) considered this species a common migrant and winter visitor in the Marshall Islands, and listed four March and April specimens taken on Bikini Atoll. During present field work Bristle-thighed Curlews were recorded in small numbers on nearly every islet visited; a conservative total for the atoll was twenty-five birds. Birds were found on reefs, beach rock, and sandy shorelines. Peak numbers occurring during winter and migration would likely considerably exceed the present estimate of twenty-five birds. Crabs and other intertidal invertebrates probably constitute the major portion of the diet of this species.

17. *Arenaria interpes* RUDDY TURNSTONE

This species breeds widely across the far northern latitudes and winters through most of the world's temperate and tropical coasts. Subspecies are poorly defined, but Micronesian birds are almost certainly of the nominate race.

The Ruddy Turnstone is considered a common migrant and winter visitor in the Marshall Islands by Amerson (1969), who lists five February, March and August specimens from Bikini Atoll. The species was found on all islets visited during present field work, in numbers ranging from four to thirty-one per islet. A conservative total estimate for the atoll is 130 birds, making this species second in numerical abundance to the Lesser Golden-Plover among Bikini Atoll shorebirds. All types of beaches and reefs were utilized, as well as open areas in the interior of the larger islets.

18. *Calidris alba* SANDERLING

This small sandpiper nests across the high arctic and winters over a very broad latitudinal range along most of the world's coasts.

While Amerson (1969) considers this species a common migrant and (presumably) winter visitor in the Marshall Islands, neither he nor Anderson (1981) list any records for Bikini Atoll. During present field work a single bird was seen on 15 May foraging along the southeast shore of Bikini Islet.

19. *Larus atricilla* LAUGHING GULL

Gulls are generally absent from oceanic islands of the tropical Pacific Ocean; the few records pertain to long distance wanderers. Prior to the present field work, the only gull recorded from the Marshall Islands was a single Franklin's Gull (*Larus pipixcan*) photographed at Majuro Atoll (Anderson 1981).

A single adult Laughing Gull in alternate plumage was observed on Bokantuak Islet, just south of Bikini Islet, on 21 May. On 22 May the same individual was seen and photographed on the next islet to the south, Iomelan. The Laughing Gull breeds on the Atlantic coast of the United States, along the Gulf of Mexico, and locally through the Caribbean Sea. Non-breeding birds are found more widely along the coasts of North, Middle and northern South America, and the species has been recorded with some regularity on the Hawaiian Islands. The present record is the first for Micronesia (Garrett, in press).

20. Sterna bergii CRESTED TERN

The Crested Tern breeds from the islands of the central, south and western tropical Pacific Ocean to the coasts of Australasia, southeast Asia and south Africa. The subspecies cristata is the form breeding from eastern Australasia east into the Pacific.

Amerson (1969) listed the Crested Tern as a breeding species on Bikini, citing a series of nestlings taken as specimens in August. During the present field work these terns were noted on every islet visited on Bikini Atoll, but positive evidence of nesting was not obtained. The number of flying juvenile birds, combined with the sedentary nature of this species, suggest that the species does currently nest at Bikini. A minimum of 85 birds was found on the various islets visited, of which about 25% were juveniles. It is likely that at least thirty to fifty pairs of Crested Terns nest at Bikini Atoll. The largest number of adult birds was found on Bikini and Nam Islets. Crested Terns nest in open sand or gravel areas on islets, sometimes loosely associated with Sooty Tern colonies. Nestlings are recorded for May on some atolls in the Marshall Islands (Amerson 1969), so breeding schedules for the region are probably complex. Many flying immature birds were judged to be relatively recently fledged, and a few were begging food from nearby adults; this behavior may occur well away from breeding grounds for up to four months, however (Feare 1975). No courtship activity was noted during the present field work, although such activities as preliminary to a summer nesting season might have been expected. Crested Terns are very rarely seen at sea, and the degree to which they disperse between atolls is unknown but likely to be small. Foraging Crested Terns were noted along beaches on both the lagoon and seaward sides of the islets, but particularly favored was the outer edge of the fringing reef at low tide.

21. Sterna sumatrana BLACK-NAPED TERN

The Black-naped Tern is less widespread through the tropical Pacific Ocean than the other seabird species which nest at Bikini Atoll. It breeds on islands in the Indian Ocean, the coasts of southeast Asia and northern Australia, east into the Pacific to the Phoenix Islands. The nominate race occurs on Bikini Atoll.

Black-naped Terns were listed by Amerson (1969) as possible breeders at Bikini Atoll. We obtained definite nesting evidence during present field work with the discovery of eggs on Bokantuak Islet and downy chicks on Jalete Islet; aggressive behavior and fish-carrying by adults on most of the islets visited suggest that nesting was actually widespread (Fig. 5). We conservatively estimate fifty-five nesting pairs for the atoll, but the number is possibly considerably higher. These terns were found to nest on open gravelly substrate from one to three meters away from the edge of the Scaevola/Tournefortia scrub zone. Such nests were sometimes just above the high tide line, but on Bokantuak Islet, at least two pairs were nesting well into the interior of the tiny islet where broad gravelly pans extended inland. Nesting pairs were generally separated by at least twenty meters. Downy young were found under the shade of the outermost shrubs. Most foraging appeared to take place over the lagoon; Black-naped Terns often mixed with small flocks of noddies, but frequently foraged alone as well.

Measurements of two eggs from separate nests on Bokantuak Islet were: 38.1 X 27.7 mm (15.0g) and 38.7 X 27.9 mm (13.5g).

22. Sterna fuscata SOOTY TERN

The Sooty Tern is one of the most abundant and widespread nesting birds of the world's tropical oceans. The subspecies oahuensis nests through most of the tropical Pacific Ocean and is the form occurring at Bikini Atoll. The overall population of this subspecies is perhaps in the tens of millions (three to four million pairs nested at Christmas Island, Republic of Kiribati, Line Islands, during peak years).

Amerson (1969) considers the Sooty Tern a possible breeder on Bikini Atoll. While the species was not recorded actually breeding during current field work, we believe that colonies did exist in late 1985/early 1986 on some of the northern islets. On the Odrik/Lomilik section of northern islets at least fifty adults were observed, along with at least five flying juveniles. As noted under the account for those islets, juveniles are rarely seen around land other than at their natal colonies. We thus believe these juveniles represented offspring from a recent nesting effort. Some adults on Odrik/ Lomilik were swooping low over areas of sparse shrubs and extensive grass cover (typical nest sites), but no eggs or young chicks were discovered. Small numbers of adult Sooty Terns were noted in flight over most of the other islets visited, again with no evidence of nesting. If Sooty Terns do nest on the atoll, their population size is probably quite low.

Sooty Terns usually nest in densely packed colonies in open grassy areas with sparse shrubs; such conditions do occur on several of the northern islets, from Bwikor east to Aomen. These terns feed well at sea, and are highly pelagic while not nesting.

23. Anous stolidus BROWN NODDY

The two species of noddies are common and widespread in the world's tropical and subtropical oceans, the Brown Noddy being the slightly more widespread of the two. Brown Noddies of the subspecies pileatus nest through much of the central, south, and western Pacific Ocean, as well as the Indian Ocean; this is the nesting form at Bikini Atoll.

Amerson (1969) listed egg and nestling specimens taken at Jalete Islet in March 1946, thus documenting breeding of this species. During the present field work the species nested commonly on several islets, with the largest colonies noted at Aomoen (500 pairs minimum), Odrik/Lomilik (100 pairs), Nam (500 pairs), Jalete (200 pairs), and Aerokoj/Aerokojlol (50 pairs minimum); see Fig. 6. On most of these islets eggs, downy chicks, and nearly fledged young were all observed. The total nesting population for the atoll is difficult to estimate, since the breeding season appears to be prolonged, but our conservative minimum estimate is 1500 pairs (the true figure likely well exceeds that number). Data from Anderson (1981) and Fosberg (1966) suggest this species breeds virtually throughout the year in the Marshall Islands.

Brown Noddies nest in moderately dense colonies; nests are located on the ground (among grasses in areas of sparse shrubs or at the edge of dense shrubbery) or in Scaevola, Tournefortia, or Pemphis shrubs (where the nests of dead leaves and sticks are often conspicuous). Even within a small area in a single colony this mixture of nest sites was evident.

In Table 3 we present mass and dimensions of five Brown Noddy eggs from Bokantuak and Aomoen Islets.

Larval chigger mites found on several nestling Brown Noddies were identified as _Eutrombicula wichmanni_, a widespread species in the Pacific region. These mite larvae infestations appeared as red patches, two to five mm in diameter, scattered through the apteria.

TABLE 3. Dimensions and mass of eggs of Brown Noddies from Bokantuak and Aomoen Islets.

Length (mm)	Width (mm)	Mass (gm)
52.6	35.3	36.0
52.8	36.2	38.0
49.6	36.4	37.2
55.6	33.9	36.0
51.8	36.0	37.2

Both noddy species forage by picking prey (usually small fish or squid) from the water surface; foraging flocks are often dense, containing up to several hundred individuals. The two noddy species will mix within foraging flocks, or form pure flocks. Both species were noted foraging over the lagoon and over the open ocean, with the Brown Noddy numerically less abundant in both areas.

24. _Anous minutus_ BLACK NODDY

Like its congener, the Black Noddy is widespread and geographically variable. The subspecies nesting at Bikini Atoll appears to be _marcusi_, which nests in the tropical western Pacific north of the Australasian region.

Amerson (1969) cited a nestling of this species taken at Oroken Islet in July, and Fosberg (1986) refers to nesting colonies in the _Pisonia_ forests of certain southwestern islets of the atoll. During present field work nesting colonies were found on Nam (twenty-five pairs minimum), Oroken (2000 pairs), and Lukoj (500 pairs) (Fig. 7). Nesting was also suspected on several other southwestern islets which were not visited (e.g. Bokdrolul and Bokaetoktok), although the species was not nesting on Jalete Islet (which lacks _Pisonia_ forest). Because of the difficulty of estimating the number of nesting pairs in a forested habitat and the likelihood that the breeding season is prolonged in this species, the estimates above may be very conservative. Anderson (1981) suggested an October through April nesting season for this species at Ujelang Atoll, but implied that some nesting took place throughout the year.

Certainly at least 3000 pairs of Black Noddies must nest at Bikini Atoll, making it numerically the most abundant bird species on the atoll.

Black Noddy nests were found exclusively in Pisonia trees, although other tall woody species may also be utilized. Colonies were rather dense, with ten to twenty nests noted in some trees. Nests were located inside the canopy, usually more than 5m above the ground. As Fosberg (1986) has noted, this species, perhaps along with other tern species and Sula, is an important agent in the formation of atoll phosphate rock. Stages of this process are evident on the southwestern islets of Bokaetoktok, Oroken and Lukoj. Because of the affinity of nesting Black Noddies for Pisonia trees, many individual birds are noted with small burrs of Pisonia adhering to their plumage. Occasionally entire fruit bearing twigs stick to the birds' feathers; when such burr clusters entwine the flight feathers, birds are sometimes rendered flightless. We do not know if this is a significant mortality factor in Black Noddies.

25. Gygis alba WHITE TERN

The White, or "Fairy", Tern is a widespread nester around the world's tropical oceans. The taxonomy of the Pacific Ocean forms of this species is complex and is best reviewed by Baker (1951). The form breeding in the Marshall Islands is candida, which also breeds north to the Bonin and Marianas Islands and east to the Line, Phoenix and Hawaiian Islands.

White Terns are among the most conspicuous birds of the Marshall Islands. Amerson (1969) lists the species as a resident breeder on Bikini Atoll, citing a nestling specimen taken in March. During the present field work White Terns were found on every islet visited except Jalete (Fig. 8). Significant populations occurred on most of these islets except Eneu (where only five birds were seen and no evidence of nesting was found) and Bikini (where the species was seen regularly in small numbers but nesting was probably limited to one or two pairs at the southeastern tip of the islet). The largest colonies were on the Bokantuak/Iomelan Islet chain (200 pairs minimum), Aomoen (250 pairs), Nam (350 pairs), and Oroken (200 pairs). We conservatively estimate a total of 1300 pairs. It appears (e.g. Baker 1951) that nesting of White Terns occurs through much of the year, so the total annual nesting population at Bikini probably far exceeds this number.

White Terns lay their single eggs on the larger branches of woody shrubs and trees, especially favoring Tournefortia on most islets. They utilized Pisonia as well as Tournefortia on Oroken. As no nest is constructed, counts of nesting pairs must often be based on the behavior of adult birds. On most islets nesting was concentrated in shrubs toward the islet perimeter, although some pairs nested nearer to the islet centers. Nesting colonies of White Terns and Brown Noddies were often in the same areas, although breeding White Terns were generally more sparsely distributed.

In Table 4 we present mass and dimension data for seven White Tern eggs. Larval chigger mites collected from downy White Terns were identified as Eutrombicula wichmanni.

TABLE 4. Dimensions and mass of seven eggs of White Terns from Bokantuak, Aomoen, and Odrik/Lomilik Islets.

Length (mm)	Width (mm)	Mass (gm)
41.2	28.6	17.5
41.9	30.0	21.5
41.7	30.8	21.2
40.6	30.0	20.0
39.9	30.5	21.0
41.0	29.7	20.5
38.0	30.0	18.5

White Terns forage over lagoon and ocean waters, frequently associating with large groups of noddies. Their diet consists of small fish and squid.

26. Eudynamis taitensis LONG-TAILED CUCKOO.

This species breeds in New Zealand and adjacent islands and spends the austral winter (roughly March through October) in the islands of the tropical Pacific (principally in Polynesia, but also in parts of Micronesia and Melanesia).

Amerson (1969) cites two specimens from Bikini Atoll: one from Oroken 1 May 1946 and one from Nam 6 August 1947. No cuckoos were observed during the present field work. This is the only bird species recorded from Bikini Atoll which is limited to terrestrial habitats.

AT-SEA TRANSECTS

In addition to the surveys of Bikini Atoll islets described above, Garrett conducted a series of transects on 28-29 May from aboard the Egabrag II. As the foraging range at sea of nesting species on Bikini Atoll is not documented, it is by no means asserted that all birds recorded during these transects were from Bikini populations. In fact, the ship's course brought it close to Wotho Atoll and close to the lee of Kwajalein Atoll for a considerable distance. Transect results are presented here to extend the limited knowledge of at-sea distribution and abundance of Marshall Islands birds. Transects were conducted on a straight-line course between Eneu Islet, Bikini Atoll, and the major pass on the southwest side of Kwajalein Atoll.

A total of thirteen transects were conducted, eleven of them on 29 May (Table 5). In addition, observations were made between transects; the total time of active observation was 10.5 hr. The lack of proportionality between transect densities and total counts is due to the random sampling nature of the transects (e.g. several large flocks of noddies and boobies were seen but did not fall within the transect time periods and/or the transect distance limits).

Table 5. Results of at-sea transects

SPECIES	DENSITY*	TOTAL**
Wedge-tailed Shearwater	0.07	13
Buller's Shearwater	0.07	10
Sooty Shearwater	0.13	2
Short-tailed Shearwater	0.20	3
dark shearwater, species?	-	3
Red-tailed Tropicbird	-	1
Brown Booby	0.39	41
Red-footed Booby	1.50	152
Pomarine Jaeger	-	1
Brown Noddy	18.00	723
Black Noddy	36.30	1847
noddy, species?	-	310
TOTAL	56.66	3106

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*DENSITY = number of individuals per 100 hectares; limited to those birds recorded during official transect periods (15 min./hr)

**TOTAL = total number of individuals observed during cruise (total observation time = 10.5 hr.)

DISCUSSION

Our data indicate that avifaunal diversity and abundance at Bikini Atoll is typical of low coral atolls in the region, with significant nesting populations of several species of seabirds. We recorded twenty-three species at Bikini, compared to seventeen species compiled from a variety of sources by Amerson (1969). The increase can be explained simply by more thorough coverage during the present field work; the species we added were, for the most part, migratory shearwaters and shorebirds present in low densities. Historical details of Bikini Atoll bird populations are lacking. We infer that current populations equal or exceed those known during field work in 1946 and 1947 (Amerson 1969). Data prior to the 1946 removal of the Marshallese people from Bikini are insufficient to draw a comparison of "inhabited" and "uninhabited" periods.

Data do not appear to be available to allow an analysis of the effects of atomic testing on Bikini Atoll seabird populations. It cannot be documented that any species have disappeared from the atoll due to bomb testing, although pre-testing surveys were few. It is likely that most or all current populations of Bikini Atoll seabirds represent recolonizations occurring after the conclusion of atomic bomb testing, but even this statement requires substantiating data not available to us. Mutations of rats from Enewetak Atoll after nuclear testing have been documented (Temme 1987), but no such studies of seabirds exist.

Analyses of the effects of proposed environmental rehabilitation scenarios and resettlement of Bikini Atoll by the Marshallese must be made within the framework of known factors which threaten seabird populations. A discussion of such factors is presented by the ICBP Seabird Specialist Group (Croxall, Evans and Schreiber, eds., 1984). Recurrent threats to seabird populations include alien species (such as cats and rats), habitat modification and destruction, and disturbance and exploitation by humans. Recommendations contained in the ICBP publication include: (1) surveys for, and censuses of, seabird colonies; (2) elimination of alien species; (3) establishment of, and improvements to, reserves; (4) prevention or reduction of habitat disturbance and destruction; (5) protection from exploitation; (6) education and publicity; (7) legal protection; and (8) research.

The alternative plans for the rehabilitation of Bikini Atoll fall into three major categories (BARC 1984): (1) delay of resettlement for about eighty years to allow the decay of radionuclides to acceptable levels;

(2) treatment of soil to reduce the uptake of cesium-137 by plants; and (3) removal of contaminated soil. These alternatives apply only to Bikini Islet, and Marshallese resettlement will be restricted to Bikini and Eneu Islets. Under alternative (3) contaminated soil would be disposed either in the lagoon (Bravo crater), on an unoccupied islet, on the seaward side of Bikini Islet, or between Bikini and Eneu Islets to help form a causeway. The probable effects of these various alternatives are discussed below. Additionally, we discuss the potential impacts of the return of Marshallese residency on Bikini Atoll.

Delay Of Resettlement

A delay of resettlement has the primary advantage of avoiding any adverse impacts necessitated by the implementation of soil treatment and (especially) soil removal alternatives. Potential harm to bird colonies through disturbance and exploitation by the Marshallese would continue to be a concern with this option, because the islet of Eneu would be inhabited even with a delay of the resettlement of Bikini Islet.

Treatment Of Soil

Various methods have been proposed for reducing harmful effects of cesium-137 without removing existing topsoil on Bikini Islet. These include leaching of the soil with sea water, cropping of vegetation, adding a layer of "clean", fertile soil over the contaminated soil, or the use of potassium fertilizer to block cesium uptake. The application of each of these methods would be necessary only on Bikini Islet. The soil treatment alternatives have the advantage, like the delay of resettlement, of avoiding the potential harmful impacts of soil removal and disposal. While Bikini Islet is the largest in the atoll, it is currently the least important (along with Eneu) for nesting seabirds. This is undoubtedly due to a history of intensive human occupation, continued disturbance through maintenance and rehabilitation work, and the introduction of cats and rats. Therefore, while soil treatment operations may have a temporary impact on the distribution and behavioral patterns of the shorebirds and non-breeding seabirds which visit Bikini islet, the impacts on nesting seabirds are expected to be negligible. Sea turtles nesting on the seaward shore of Bikini Islet should receive little harmful impact from soil treatment operations, as they are physically well removed from agricultural sites.

Soil Removal

The clearing of vegetation and removal of topsoil has been advanced as an effective method of diminishing soil contamination. A further version of this alternative entails the replacement of removed soil with sediment dredged from the lagoon. Soil removal and replacement manipulations would have a major temporary effect on the habitats of the treated islets, although vegetation would ultimately return or agricultural crops would be planted. Such manipulations on Bikini Islet would have little impact on nesting seabirds because of the islet's relatively unimportant status for breeding seabirds.

Potentially harmful effects of soil removal fall into two main categories. First, the removal of soil and vegetation from islets other than Eneu and Bikini would disrupt any seabird nesting that is underway and would temporarily create a habitat without significant tall vegetation growth (and therefore unsuitable for most Bikini Atoll seabird species). Several small islets identified as requiring excavation in order to meet cesium-137 standards for agriculture are very important for nesting seabirds (e.g. Aomoen, Lukoj, and Jalete). Removal of taller *Scaevola*, *Tournefortia*, and *Pisonia* (Lukoj) from these islets would impact the nesting of noddies, White Terns and Red-footed Boobies for a considerable period. Secondly, the various plans for the disposal of removed topsoil have potential negative impacts on wildlife. Disposal of spoil on any of the islets with important breeding colonies will have at least short-term effects on nesting success (through direct disturbance and through habitat alteration). Negative effects on seabirds would be essentially permanent if spoil disposed on islets were to be capped with concrete. Disposal of soil on the seaward side of Bikini Islet to extend the islet would have little effect on Bikini Atoll seabird populations, but could impact sea turtle nesting (although human disturbance factors on this islet would likely reduce or eliminate sea turtle nesting on Bikini whether soil disposal takes place there or not). Creation of a causeway between Eneu and Bikini using spoil would probably eliminate nesting populations of Brown Noddies, White Terns and Black-naped Terns on the small islets between Eneu and Bikini. Again, however, a large human population on Eneu and Bikini would probably impact tern colonies on these islets whether or not a causeway is built, since the reef between these islets can be walked at low tide.

Effects Of Marshallese Resettlement

As noted above, among the most insidious effects of humans on populations of seabirds are the exploitation of colonies for food (or other resources) and the introduction of predators (such as cats and rats). Both of these concerns must be addressed if and when the Marshallese resettle Bikini Atoll.

The direct impacts of Marshallese resettlement of Eneu and Bikini Islets are expected to be minimal, since neither islet contains seabird nesting colonies. Of greater concern is the potential for disturbance to and exploitation of seabird nesting colonies on outlying islets. Disturbance can be direct, through visitation of colonies, or indirect through habitat modification and the introduction of predators. Exploitation can likewise be direct, through harvesting of eggs, nestlings and adults at breeding colonies, or indirect through exploitation of critical marine food resources upon which seabirds depend.

While human/seabird coexistence on atolls is by no means impossible, there appears to be a general negative correlation between seabird populations and human populations on the atolls of the Marshall Islands. In Figure 9 we show the relationship between the number of confirmed breeding native bird species and the 1964 human population estimates for all of the Marshall Islands for which sufficient data exist (taken from Amerson 1969). A negative trend is evident from the graph. While this gives only a first order approximation of the relationship between human and bird populations, it suggests that resettlement of Bikini Atoll will likely result in a downward adjustment in the number of breeding bird species. It is important to point out that local extinctions of both seabirds and landbirds have probably occurred on oceanic islands such as the Marshalls since the earliest settlement by humans (Olson and James 1982). Thus, while no breeding landbirds are known historically from Bikini Atoll, there may well have been populations of species such as the Micronesian Pigeon, *Ducula oceanica*, in the distant past.

Cultural Or Subsistence Value of Bikini Seabirds

Birds have been of direct importance to the Marshallese as a food source. Seabird colonies are frequently exploited for eggs, nestlings and adults. The Micronesian Pigeon is another bird species which has been used for food by the Marshallese, but it does not occur on Bikini Atoll or neighboring atolls.

Indirectly, seabirds are valuable to Marshallese fishing operations; through much of the tropical Pacific Ocean fishermen have learned to locate concentrations of food fish by looking for foraging flocks of noddies, White Terns, boobies and other seabirds. Serious depletion of Bikini Atoll seabird populations would probably reduce seabird foraging in the waters immediately surrounding the atoll, perhaps affecting the efficiency of fishing operations.

Cultural and aesthetic values derived by the Marshallese from birds are difficult to estimate, but are certain to suffer in proportion to the loss of bird populations.

RECOMMENDATIONS

Recommendations derived from field and literature studies of Bikini Atoll's avifauna are presented below as follows: first, islets and islet groups are prioritized in terms of their importance as seabird nesting habitat; habitats within these islets are also prioritized. Second, the various options for rehabilitation and resettlement are ranked in terms of their potential impacts on birds. Finally, some recommendations for further study are offered.

Habitat Recommendations

Maintenance of the current diversity of Bikini Atoll seabirds will require the preservation of some or all of the islets on the northern and southwestern portions of the atoll. Islets dominated by relatively low growth of *Scaevola*, *Tournefortia* and other shrubs harbor large colonies of Brown Noddies and White Terns. The small southwestern islets which have well-developed *Pisonia* forests constitute the only important breeding sites of Black Noddies and Red-footed Boobies on the atoll. The most important *Pisonia* islets are Oroken, Lukoj and (presumably) Bokdrolul and Bokaetoktok. Islets dominated by lower shrubs which have large breeding colonies of noddies, White Terns, and Brown Boobies are Nam, Odrik/Lomilik/Aomoen (apparently lacking Brown Boobies) and Jalete (apparently lacking White Terns). Preservation and protection of all of the islets mentioned above should be a major priority if maintenance of Bikini Atoll seabird abundance and diversity is desired.

Islets of lesser preservation priority, but still documented as harboring significant seabird populations, are: the Bokantuak/Iomelan chain between Bikini and Eneu Islets, Aerokoj/ Aerokojlol Islets, and Enidrik Islet.

Fosberg (1986) documents the ecological and historical significance of phosphate rock formation which occurs in connection with dense seabird colonies in *Pisonia* forests. We concur with Fosberg that preservation of *Pisonia* forests and protection of their seabird faunas should be a major conservation priority at Bikini Atoll.

Resettlement Recommendations

For the maintenance of maximum seabird diversity and abundance, the ideal alternative for Bikini Atoll would clearly be a permanent ban on Marshallese resettlement. We recognize, however, that this option is not realistic and not desirable to the Bikinians.

Environmental cleanup options which minimize habitat destruction on islets demonstrated as important to breeding seabirds are desirable. For this reason, soil removal and disposal options are recommended against if they involve removal of soil/vegetation or dumping of spoil on islets given high preservation priority in the section above.

Soil treatment options which are limited to Bikini Islet would have no harmful impact on seabird populations.

The construction of a causeway between Eneu and Bikini Islets would slightly diminish atoll populations of Brown Noddies, White Terns and Black-naped Terns, but would not have a major overall impact.

It is recommended that Bikinian access to the important nesting islets on the north and southwest portions of the atoll be restricted. As some nesting appears to take place through the entire year, restrictions should be year-round. Excessive disturbance is known to cause abandonment of nests of many seabird species, to subject eggs and young to physiological stress, and to expose eggs and young to increased predation pressures. Consumptive exploitation of seabird eggs, young, and breeding adults can also have significant negative impacts on seabird populations. An ideal option would be the ban on visits to all islets extending counter-clockwise from Aomen through Lukoj. If such a ban is not practical, then close monitoring of visits and of bird population sizes and breeding success is certainly called for.

It is further recommended that a program to monitor the health and productivity of Bikini Atoll seabird populations be established in conjunction with Marshallese resettlement.

Recommendations For Further Study

Additional basic information on Bikini Atoll seabird populations is desirable. Specifically, population studies should be conducted in fall and early winter in order to gain a more complete understanding of seasonal variation in population sizes and annual nesting cycles. Such information might confirm nesting for several species currently only suspected of breeding at Bikini Atoll (e.g. Sooty Tern, Crested Tern, Red-tailed Tropicbird, Great Frigatebird, and Wedge-tailed Shearwater) and yield a better understanding of total annual population sizes.

Literature and field studies of other atolls in the Marshall Islands would be helpful in determining the factors which prevent or promote coexistence between human populations and seabird populations. Studies should compare atolls with large human populations (e.g. Kwajalein) and those which are uninhabited or nearly so.

Long-term population studies of terns and other seabirds in the Marshall Islands could help determine whether the harvesting of eggs and young for food might be managed in order to provide the Marshallese with a renewal food resource.

SUMMARY

The avifauna of Bikini Atoll consists of at least twenty-six species. During field work in May 1986 twenty-three species were recorded; six of these were documented as nesting, and an additional four species almost certainly nest as well. Major seabird colonies were located on Aomoen (and the other northern islets), Nam, and Oroken/Jalete/Lukoj (and the other southestern islets). *Scaevola* and *Tournefortia* scrub and *Pisonia grandis* forests are the most frequently used habitats for nesting seabirds. Environmental rehabilitation options which minimize habitat alteration on the above islets are recommended. Close monitoring and protection of seabird populations after Marshallese resettlement will guard against excessive disturbance and exploitation.

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Appendix A. Specimens collected at Bikini Atoll, May 1986.

Format:

Species name/ LACM Catalog Number/ Age/ Sex/ Gonads/ Weight
Date/ locality of collection.
Additional Notes/ [Nature of Specimen]

All specimens are housed at the Natural History Museum of Los Angeles County.

Sula leucogaster plotus #103104 Nestling/ male 7X2
15 May 1986 southwestern islets
Captured alive by Marshallese 4 May 1986 [study skin]

Sula sula rubripes #103129 adult/ male/ 898g
27 May 1986 Oroken Islet
Stomach contained about 40 squid beaks [flat skin and skeleton]

Sula sula rubripes #103130 Juvenile/ male/449g
27 May 1986 Oroken Islet
Found freshly dead [flat skin and skeleton]

Numenius tahitiensis #103118 adult/ female/ 10x6/ 465g
25 May 1986 Bikini Islet
Tail molt; largest ovum = 1mm [flat skin and skeleton]

Sterna bergii cristata #103119 adult/ female/ 275g
25 May 1986 Bikini Islet
Largest ovum = 3mm [study skin and partial skeleton]

Sterna bergii cristata #103120 adult/ male/ 11x6/ 79g
23 May 1986 Jalete Islet
Stomach contents = two fish, each 4cm [study skin]

Anous stolidus pileatus #103105 juvenile/ male/ 5x3/ 202g
20 May 1986 Odrik/Lomilik Islet
Heavy body, tail, wing molt [study skin]

Anous stolidus pileatus #103110 nestling/ sex?/ 175g
23 May 1986 Jalete Islet
All flight feathers in sheath [study skin]

Anous stolidus pileatus #103114 adult/ female/ 10x8/ 175g
24 May 1986 Aomoen Islet
Largest ovum = 4mm; stomach contents = fish remains [study skin and partial skeleton]

Anous stolidus pileatus #103125 nestling/ sex?/ 37.5g
26 May 1986 Aomoen Islet
Egg tooth prominent [alcoholic]

Anous stolidus pileatus #103126 nestling/ sex?/ 92g
26 May 1986 Aomoen Islet

[study skin]

Anous stolidus pileatus #103127 nestling/ sex?/ 109g
26 May 1986 Aomoen Islet
Stomach contents = 2 squid beaks, fish remains [study skin]

Anous minutus marcusi #103109 adult/ female/ 97g
23 May 1986 Lukoj Islet
Covered with *Pisonia* burrs; largest ovum = 3mm [flat skin and skeleton]

Anous minutus marcusi #103113 adult/ sex?
23 May 1986 Jalete Islet
mummufied [skeleton]

Anous minutus marcusi #103115 adult/ female/ 8x5/ 88.5g
25 May 1986 Bikini Islet
Largest ovum = 1.5mm; no brood patch [study skin and partial skeleton]

Anous minutus marcusi #103116 adult/ male/ 2x1/ 108g
25 May 1986 Bikini Islet
Inner primary molt [flat skin and skeleton]

Anous minutus marcusi #103117 adult/ male/ 3x2/ 102g
25 May 1986 Bikini Islet
Inner primary molt [study skin and partial skeleton]

Gygis alba candida #103106 adult/ male/ 8x4/ 114g
21 May 1986 Bokantuak Islet
Brood patch bare [study skin]

Gygis alba candida #103107 adult/ female/ 10x5/ 100g
22 May 1986 Iomelan Islet
Largest ovum = 3mm [study skin and partial skeleton]

Gygis alba candida #103108 adult/ male/ 3.5x1.5/ 103g
22 May 1986 Iomelan Islet
[flat skin and skeleton]

Gygis alba candida #103121 adult/ female/ 10x5/ 87g
26 May 1986 Aomoen Islet
Largest ovum = 2.5mm [study skin and partial skeleton]

Gygis alba candida #130122 adult/ male/ 8x4/ 110g
26 May 1986 Aomoen Islet
[flat skin and skeleton]

Gygis alba candida #103123 nestling/ sex?/ 23g
26 May 1986 Aomoen Islet
parasitic mites collected [alcoholic]

Gygis alba candida #103124 nestling/ female/ 3x2/ 86g
26 May 1986 Aomoen Islet
[study skin]

Gygis alba candida #103128 adult/ sex?/ 108g
27 May 1986 Nam Islet
Brood patch unfeathered [alcoholic]

Appendix B. Complete species list for each islet visited, Bikini Atoll, May 1986.

+ = species present
n = breeding probable
N = breeding confirmed (eggs and/or young found)

	Eneu	Bokonjebi	Rojkora	Iomelan	Bokantuak	Bikini	Aomoen	Lomilik	Odrik	Nam	Bokdrolul	Bokaetoktok	Oroken	Adrikan	Jalete	Lukoj	Enidrik	Eneman	Lele	Bikdrin	Aerokojlol	Aerokoj
Phaethon rubricauda						+		+		n		+										
Sula sula					+	+					+	+	N			N						
Sula leucogaster	+				+	+	+	+		N	+	+	N		N		+	+	+		+	+
Fregata minor	+					+	+	+		+	+	+	+			+						
Egretta sacra	+			+	+	+		+		+							+				+	+
Pluvialis dominica	+				+	+	+	+		+			+		+	+	+				+	+
Numenius phaeopus					+	+				+												
Numenius tahitiensis	+				+	+	+			+			+		+	+	+					+
Heteroscelus incanus	+				+	+	+			+						+	+				+	+
Heteroscelus brevipes					+																	
Arenaria interpres	+				+	+	+	+		+			+		+	+	+				+	+
Calidris alba						+																
Larus atricilla				+	+																	
Sterna bergii	+			+	+	+	+	+		+			+		+	+	+	+	+	+	+	+
Sterna sumatrana	+			n	N	+	N			n					N	N	n					
Sterna fuscata	+					+	+	+	+	+			+		+	+		+	+			
Anous stolidus	+			n	N	+	N	N	n	N					N	n	n	+	+	+	N	N
Anous minutus	+				+	+				N	+	+	N		+	N	+	+	+		+	+
Gygis alba	+	+	+	N	N	n	N	N	n	N	+	+	N	+		+	n	+	+	+	n	n

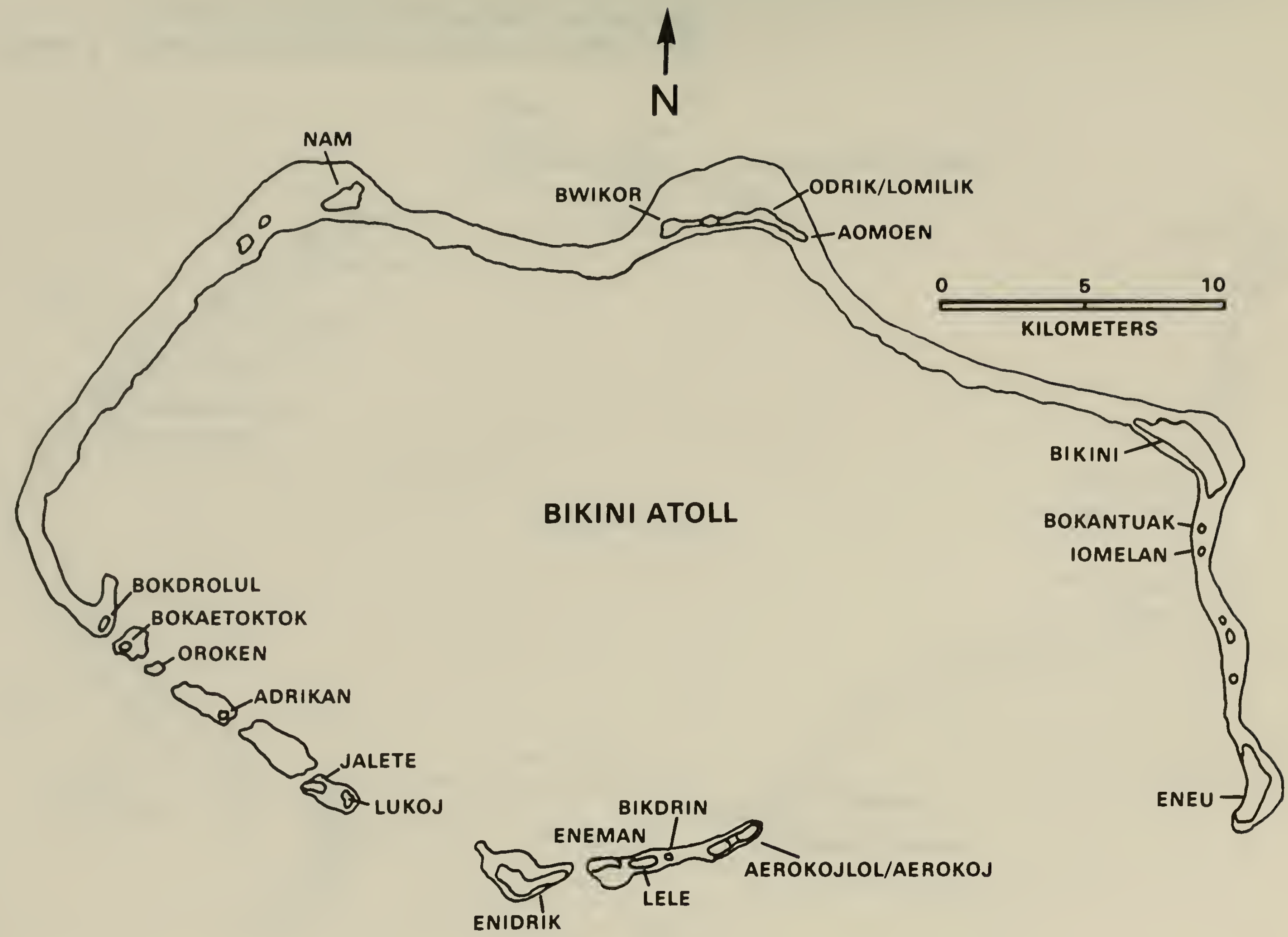

Figure 1. Location of islets of Bikini Atoll, Marshall Islands.

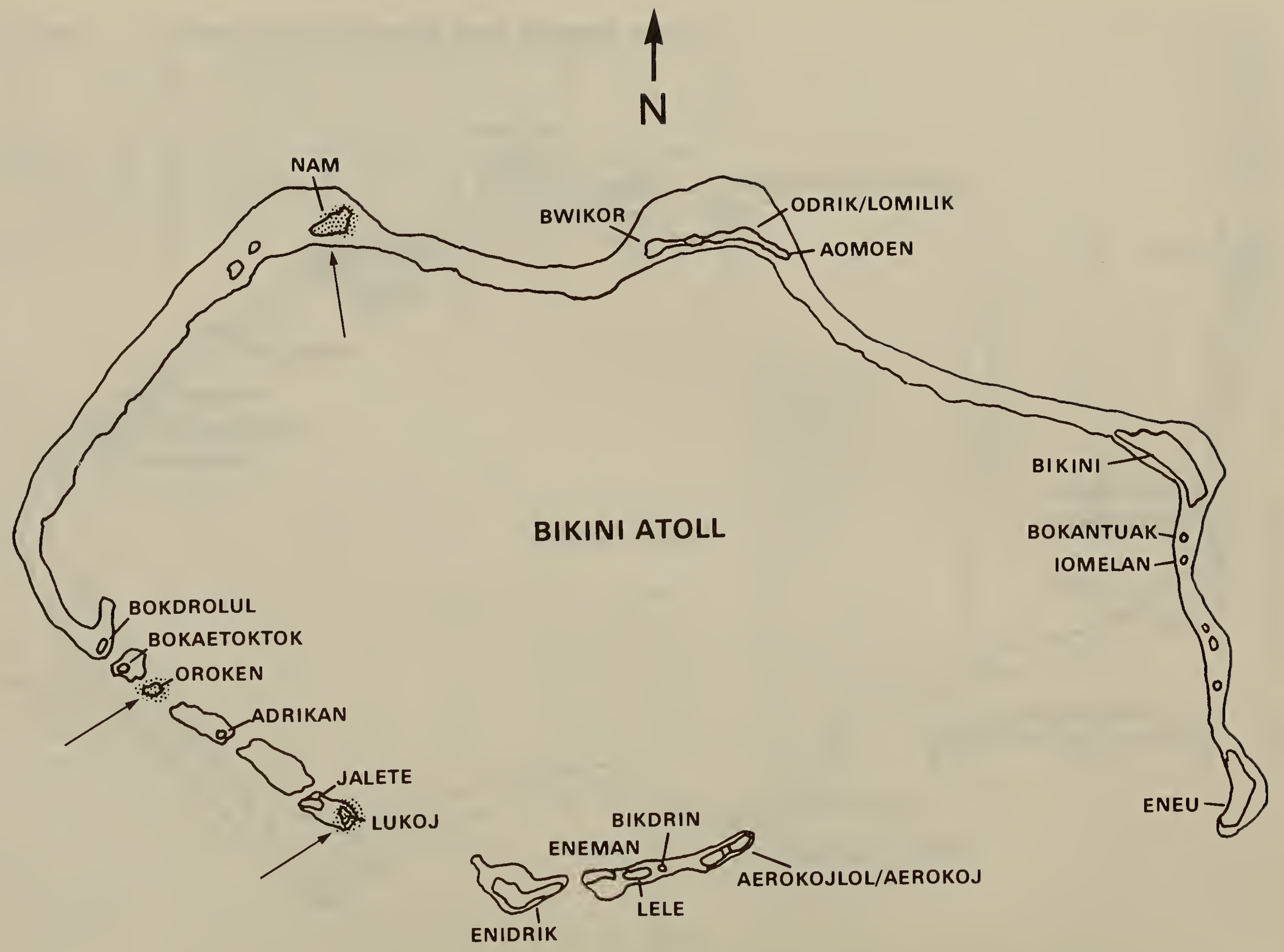

Figure 2. Roosting sites of Great Frigatebird, *Fregata minor*. Nesting is possible, but unproven, at these sites.

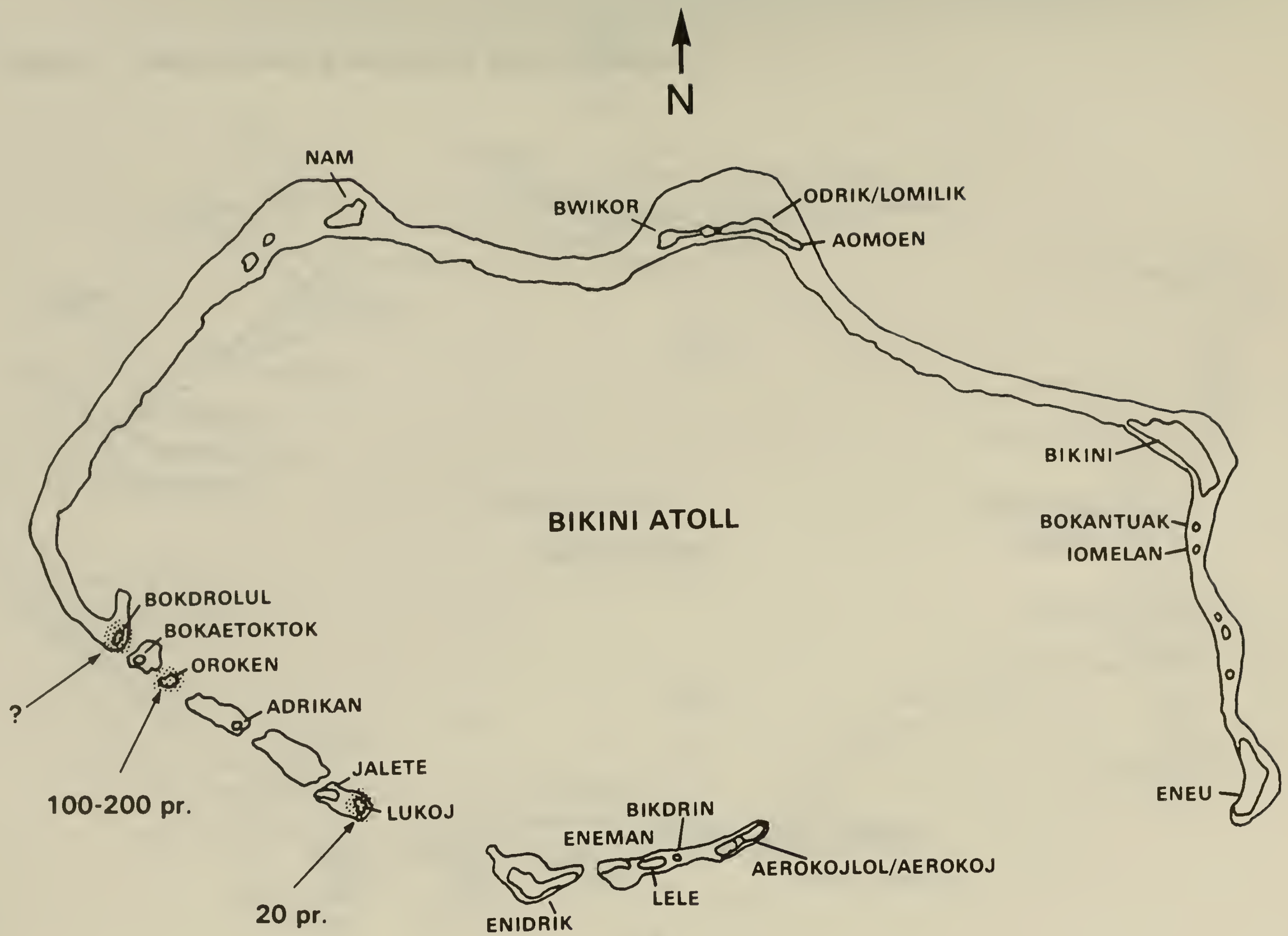

Figure 3. Nesting sites of Red-footed Booby, *Sula sula*.

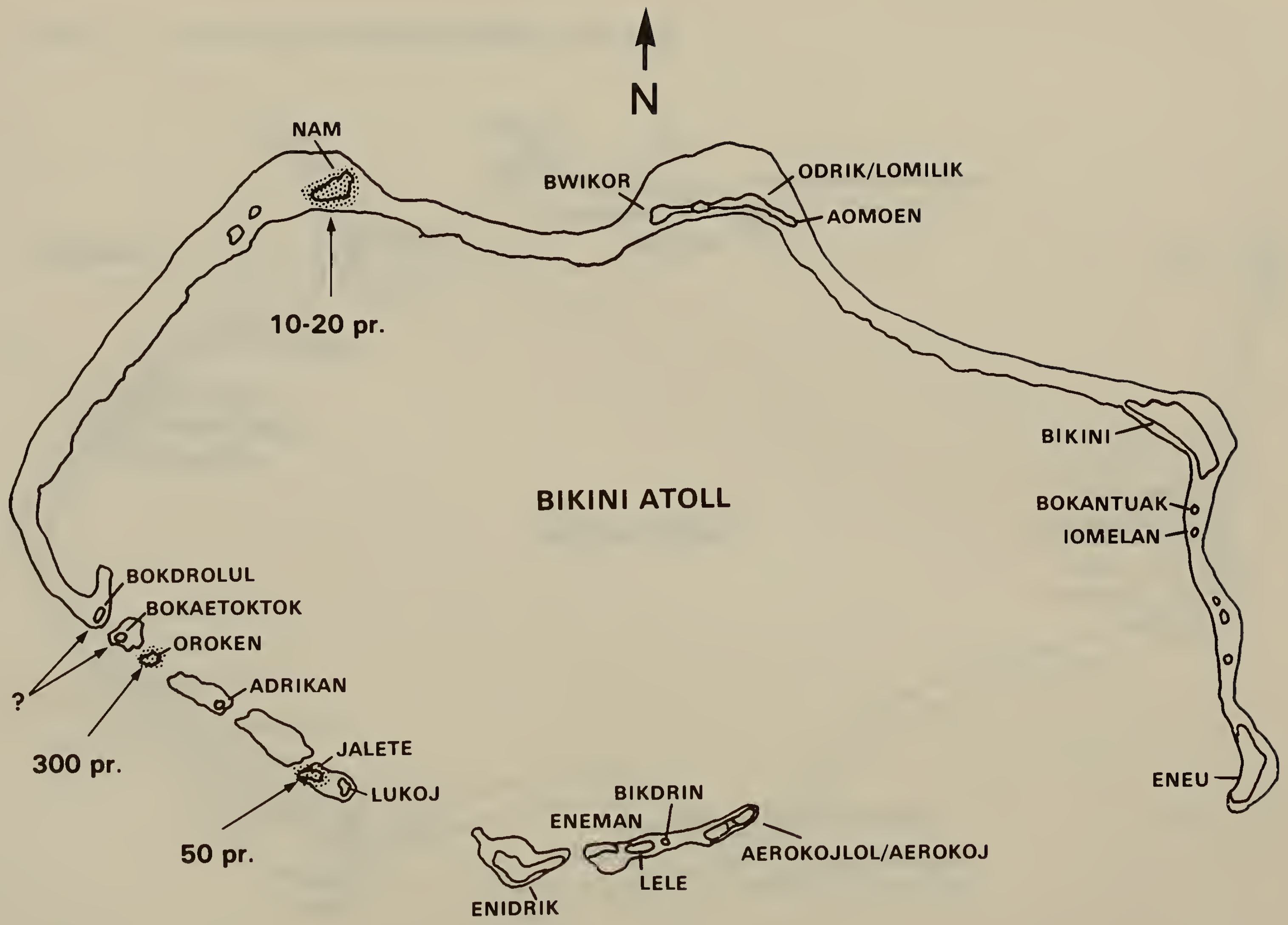

Figure 4. Nesting sites of Brown Booby, *Sula leucogaster*.

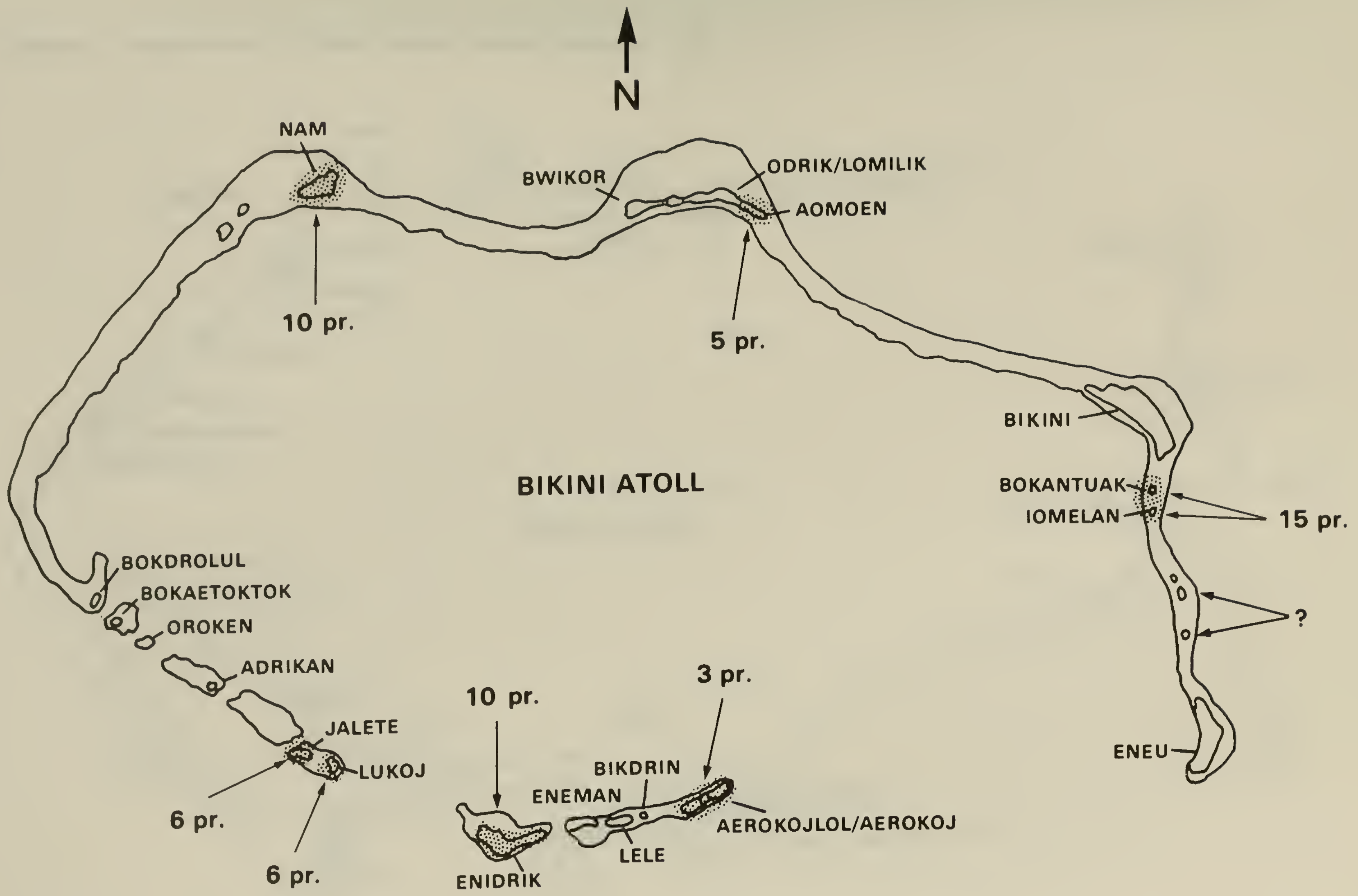

Figure 5. Nesting sites of Black-naped Tern, *Sterna sumatrana.*

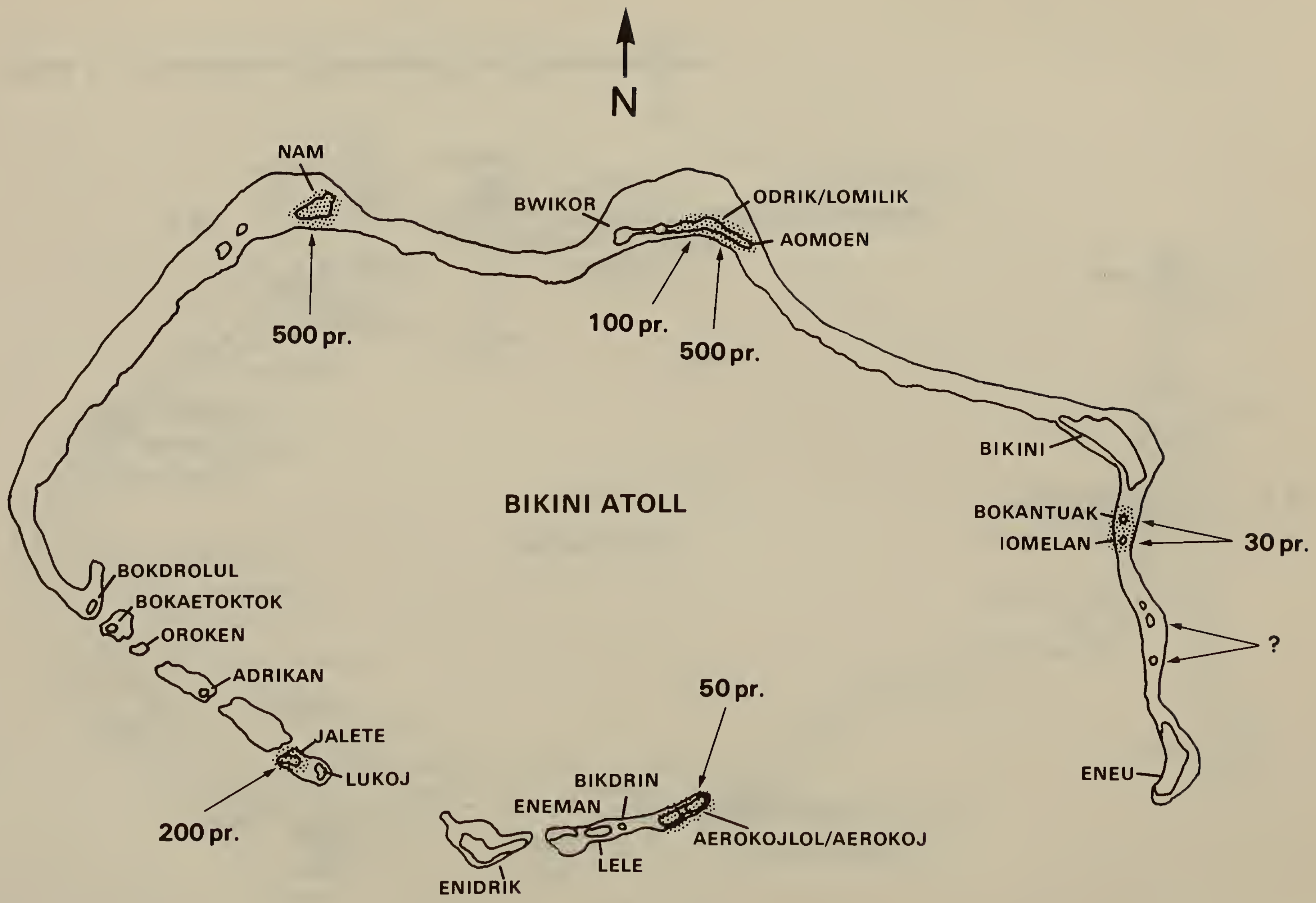

Figure 6. Nesting sites of Brown Noddy, *Anous stolidus*.

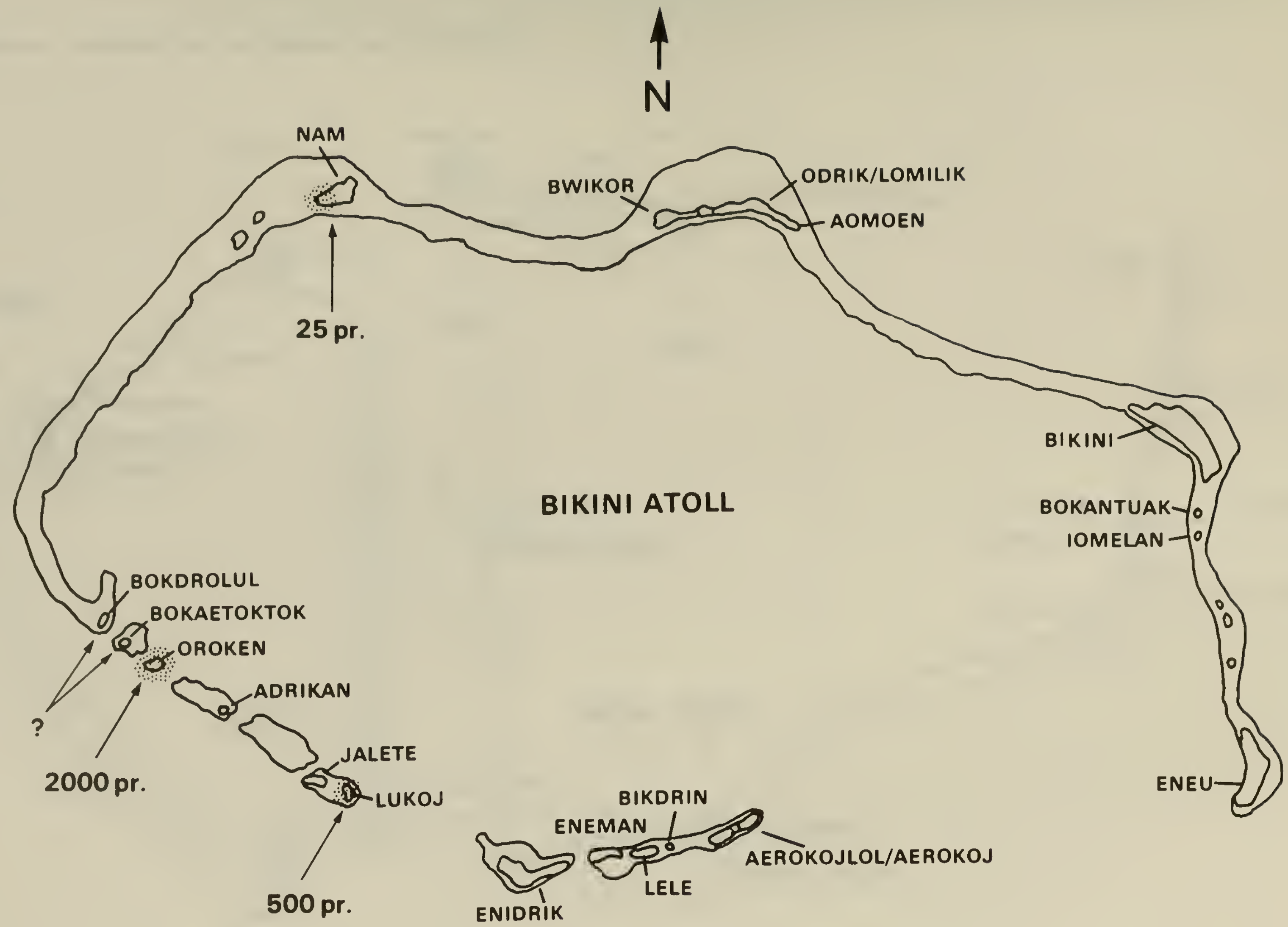

Figure 7. Nesting sites of Black Noddy, *Anous minutus*.

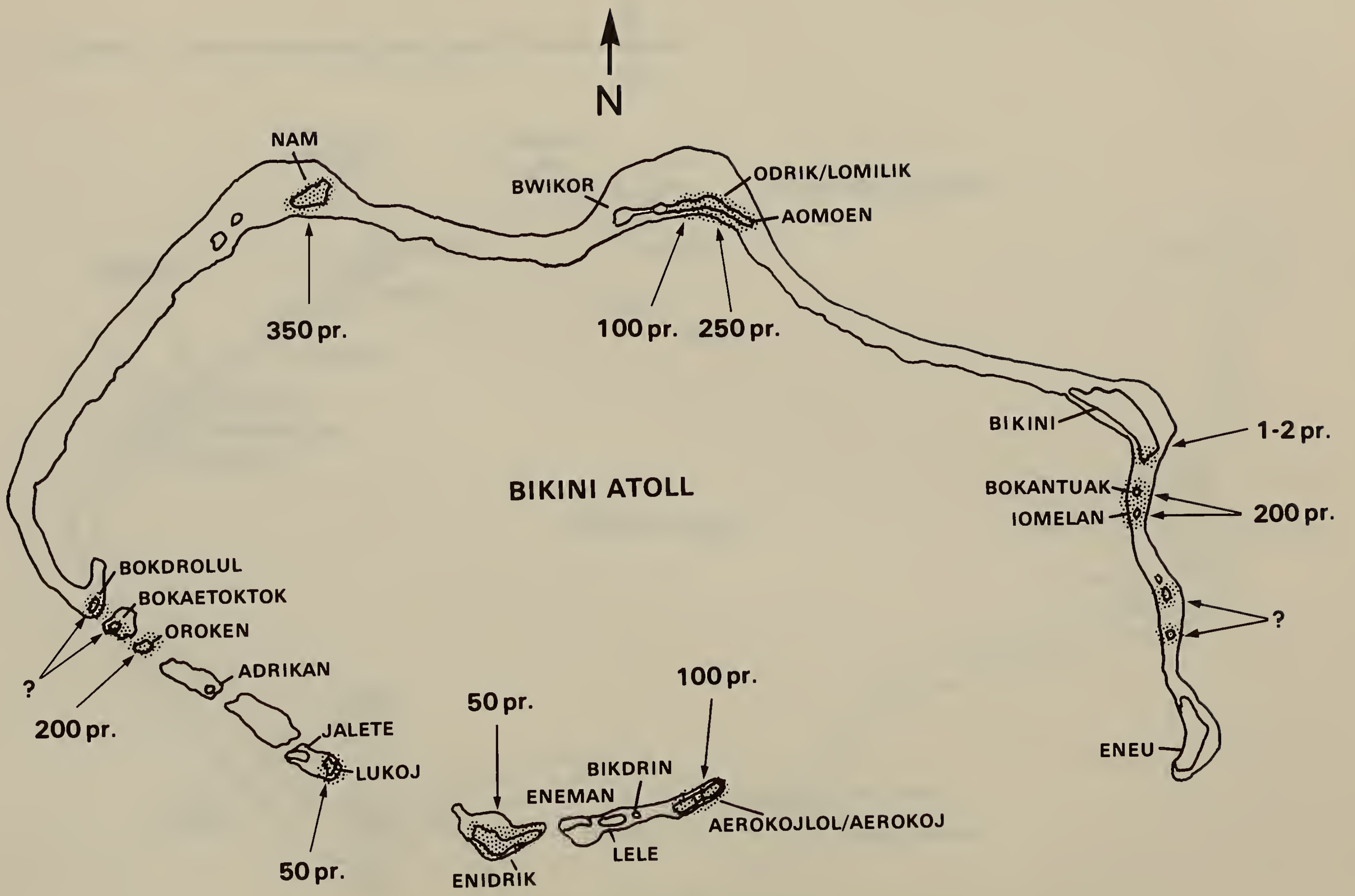

Figure 8. Nesting sites of White Tern, *Gygis alba.*

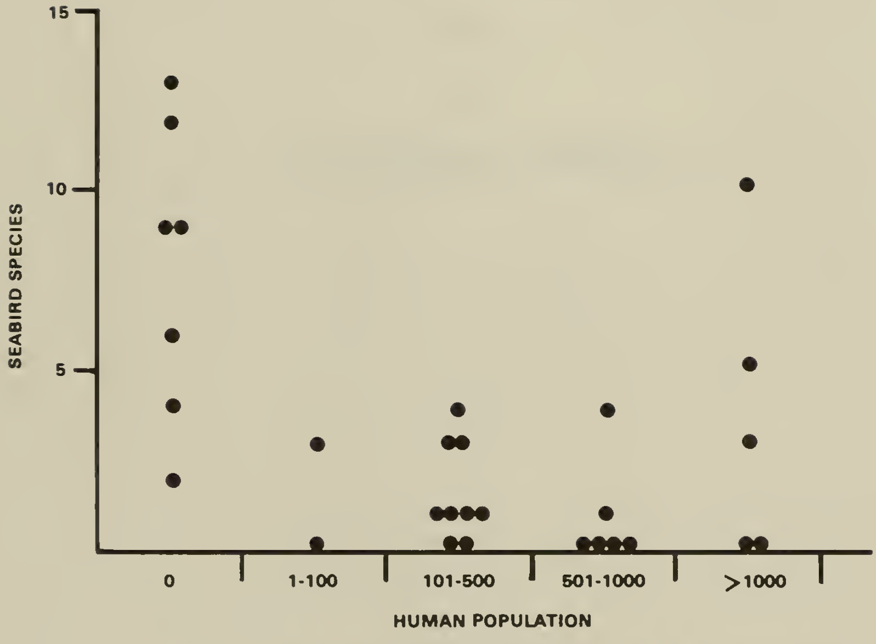

Figure 9. Number of confirmed breeding bird species plotted against 1964 human population size for twenty-nine different atolls in the Marshall Islands (data from Amerson 1969).

ATOLL RESEARCH BULLETIN
NO. 315

VEGETATION OF BIKINI ATOLL,

1985

BY

F. RAYMOND FOSBERG

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VEGETATION OF BIKINI ATOLL, 1985

BY

F. Raymond Fosberg*

PREFACE

This paper is presented in exactly the form submitted to the Bikini Rehabilitation Committee (BARC), sponsor of the survey which produced it. A summary of it, not included here, forms a chapter of the Survay Report, submitted in 1986. The present text was attached to that report as an appendix. This and the accompanying report on Bikini birds are published here with the permission of BARC. We thank the charman of BARC, Dr. Henry Kohn, of Berkeley, California, and his committee for the opportunity to study the vegetation and bird fauna of this devastated coral atoll.

ABSTRACT

Before 1946 Bikini Atoll, Northern Marshall Islands, was largely planted to coconuts, and supported a small Marshallese population. Small areas unsuitable for coconuts retained approximately indigenous vegetation, In 1946 the people were removed and the atoll was used for 12 years as the site for nuclear weapons-testing, resulting in the destruction or serious alteration of all vegetation. The survey report here, made in 1985, showed that, in addition to replanted coconut plantations, native forest and scrub vegetation had recovered to a surpising extent, though its composition, as to proportion of species, had changed. Some species were missing and some exotics had become established. Some species exhibited unusually large stature and luxuriance. Comments and recommendations are presented relative to the possible return of the Marshallese when the atoll is sufficiently decontaminated of its radionuclide content.

INTRODUCTION:

Bikini is a large coral atoll, one of the northwestern of the Marshall Archipelago, eastern Micronesia. It lies between 11°20' and 11°44'N latitude and between 165°10' and 165°36'E longitude.

On its roughly rectangular reef were originally 25 islets (motu in Polynesian) reduced to 22 since the atomic bomb tests in 1946-1958. The two largest islets are Bikini, 560 acres, and Eneu, 304 acres, on the eastern end of the reef. Other large islets are Nam, Enidrik and Aerokojlol.

All of the islets are low coral platforms reaching a maximum of about 10-15 feet elevation. They are made up of loose or consolidated calcium carbonate sediments, formed of the calcareous skeletons of marine plants and animals, which grew, over millions of years, on very slowly subsiding marine volcanoes.

Physiographically, atoll islets exhibit a central plain, with or without shallow depressions, surrounded, peripherally, by low beach ridges of coral sand or gravel. Occasional sections of beach ridge may be storm deposits composed of cobbles and/or boulders, usually rounded; these usually are single skeletons of massive corals (scleractinians), sometimes fragments of consolidated sediment. Here and there, especially on the seaward sides of the islets, shelf like ledges or extensive exposures of

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hard limestone conglomerate protrude from beneath the beach ridges. Also, outside the beach ridges are frequent elongate, sloping formations of beach-rock, consolidated, lithified beaches of sand or gravel. These commonly slope toward the ocean or lagoon, at the angle of the beach that was consolidated.

Through weathering and the action of vegetation, soils formed, ranging from unaltered carbonate sediments through varying additions of decomposed plant materials or humus to the upper layers. The extreme in this respect has an upper layer, or "A" horizon of pure humus, frequently underlain by a hardpan layer of calcium phosphate rock.

Nothing is known with certainty of the vegetation of Bikini prior to the coming of the Marshallese people. However, we can be reasonably sure that it was for the most part woody-forest or scrub, with grass on very poor or dry sites. Coconuts, and probably root-crops such as taro were brought in by the Marshallese, resulting in some alteration of the vegetation. Occupation by the Germans and later Japanese, brought an alteration of most of the suitable land to commercial coconut plantations, for production of copra. This meant the disappearance of most of the native vegetation, though all or most of the native plant species probably survived.

On the islets mapped in any detail for the present survey no unaltered natural vegetation has survived. Neither description nor interpretation in terms of natural vegetation types is attempted, as with the degree of alteration that the vegetation has undergone, such an attempt, at least on the basis of a short term reconnaissance study, would result in nothing but futility.

Formal, quantitative vegetation descriptions cannot be prepared with the data in hand, and would, in any event, be essentially meaningless. Instead, brief practical descriptions are offered of mappable facies as can be recognized. The degree of generalization is necessarily extreme. Otherwise it would require an excessive number of map units, which could not be recognized on the 1978 air photos available. Also, it is obvious that much change in the detail of the plant communities has taken place in the ensuing seven years.

The boundaries have essentially been sketched from the photos, except where it is obvious that changes have taken place. Areas differing on the photos have been visited where possible, to control the interpretation of the texture, colors and patterns.

The same scheme of units has been used for the principal islands, with differences in composition and physiognomy noted as necessary.

MATERIALS AND METHODS:

The method used in this reconnaissance was by examination of a set of excellent aerial color photos, made in 1978, followed by personal field studies. As much ground was covered by car and on foot as was practical in the time available. Ten islets were visited, including four of the five larger ones, Bikini, Eneu, Nam, and Aerokojlol. All different textures and colors seen on the photos were field-checked and notes made on the structure and physiognomy of the vegetation written down in very abbreviated style, but with species noted with anything of interest as to their occurrence. Species were listed for each islet visited, and at least one gathering was made of herbarium specimens of each species found on the survey (except of the coconut and the plants in the experimental gardens). These specimens were studied and carefully identified as they were prepared for preservation after being brought from the field. When they have been received in Washington, dried and labeled, the best set will be deposited in the U.S. National Herbarium, Smithsonian Institution, a second set sent to the B. P. Bishop Museum's Herbarium Pacificum in Honolulu. Further sets, as available, will be distributed to other important herbaria with tropical Pacific interests.

After work on an islet was concluded a description of its vegetation and the patterns of distribution of the different types discriminated was prepared and for the three largest, Bikini, Eneu, and Nam, maps were sketched, boundaries based on the air photos as modified by the field observations. A list of plants was added for each islet described, and a combined list for the atoll was prepared.

RESULTS

ENEU ISLET

Eneu, treated first as it was studied first, is the second largest islet on the Bikini reef, 4 miles in circumference, one and a half miles long, a maximum of one third of a mile wide, and with an area of just over 300 acres (304 acres). It lies at the southeast corner of the atoll, its larger, rounded end to the south, its pointed end north. Its principal geographic features are the 4,500-foot long airstrip, and the coconut plantation which covers most of the land surface exclusive of the airstrip and its asphalt parking area.

The coconut trees are planted on a precisely laid-out 30 foot square grid system. There has been no maintenance of this plantation since the Bikini people were removed in 1978.

The physionogmy of the plantation varies from luxuriant, with dense tall undergrowth and tall (to 10 m) coconut palms, to sparse, almost lacking undergrowth, and variously stunted palms. In the more open or sparse areas of coconuts, the ground is covered by tall grass, mostly Eustachys petraea. Lepturus repens is generally common to abundant, often in shadier places than Eustachys.

A superficial study of the vegetation of Eneu enables one to distinguish ten physiognomic types. These are listed below, with brief practical descriptions and indicated on the map in correspondingly numbered units, which are used in mapping both the islets.

1. Tall luxuriant coconut plantation, trees to about 10 m, tall, undergrowth varying in height and composition, but closed, comprising Tournefortia, Scaevola, Dodonaea, Guettarda, Pandanus, Cordia, Pisonia, Clerodendrum and coconut (Cocos) seedlings. The coconut seedlings are clustered around the bases of coconut trees where the nuts have fallen, unharvested. The different trees and shrubs vary in abundance.

Dodonaea is prominent in most places and forms a significant proportion of the total vegetation. A grass ground cover, mostly Lepturus, is found where the shade is not too dense. A soil with blackish or dark gray A horizon 10-20 cm thick is often found in this vegetation. Cassytha forms a parasitic veil over many bushes and small trees, killing some, and incidentally starving itself to death.

2. Coconut plantation but with trees usually smaller, less luxuriant, often yellowish, undergrowth thin, often sparse or lacking, seldom very tall, or of closed grass, usually Eustachys and Lepturus, which forms a thick ground cover. In places where bare ground is exposed several broad-leafed weedy herbs may be common.

3. Very poor coconuts, small, usually yellowish, undergrowth practically lacking. Locally scattered Suriana bushes, grass ground cover sparse mostly Lepturus and Fimbristylis.

4. Sparse stand of tall coconut palms with dense tall second story of Tournefortia and Guettarda, shade very dense, openings with dense ground-cover of Tridax and other weeds, Lepturus, and in more open spots, Eustachys. No Dodonaea was observed here. This type was only seen at the south end of Eneu islet.

5. Small areas of dense forest of Pisonia and Cordia were seen near the middle of the islet. This may be something like the original vegetation of the island, but is probably not a persisting remnant of this original cover.

6. Along the parts of the seaward coast are sandy areas, partly bare and probably shifting with the wind. Patches of Lepturus tend to stabilize this sand, scrub of Suriana and Scaevola forms a mosaic with the Lepturus and Boerhavia and open sand. The Lepturus is very low and thin, the patches enlarging by creeping spreading stolons, the Boerhavia also forming spreading mats. There are practically no living coconuts in these sandy areas. A few fallen dead ones are seen.

7. At the extreme northern end of the islet is an area of an irregular mixture of Tournefortia, Scaevola, with some Suriana. the latter mostly at the extreme point. The ground cover is Lepturus with some Triumfetta. Cassytha is common, parasitizing most of the plants. The whole varies from scrub to scrub-forest stature and appears very irregular, with a few openings showing bare sand, and mostly supporting a mixture of grasses, Fimbristylis and some weedy broadleaf herbs.

8. Along the two sides of the airstrip are narrow bands of tall grass and weeds, with a few young invading tree and shrub seedlings. This weedy vegetation appears to have been cut back at intervals. Cassytha is very abundant here, locally forming a tangle that is tiresome to walk through. At the lagoon end of the runway is a broader area of this herbaceous cover, bordering the beach.

9. The runway surface is a very short, open area of small bunch-grass of Lepturus, Eustachys and Fimbristylis. This appears to have been mowed at intervals to keep it so short. The ground seems hard and compact.

10. Along almost the entire periphery of the island, between the road and the beach where there is a road, is a sand or gravel beach ridge. This is generally covered by a narrow strip of scrub or scrub-forest varying in composition from place to place, but made up of Tournefortia. Scaevola, Cordia and Suriana. Cassytha covers many bushes and trees, some of them dead. This vegetation serves somewhat as a windbreak, protecting the plantation, but the coconut trees are planted too close to the beach to allow the formation of an effective natural windbreak such as found in many places in the Marshalls.

Plants observed in 1985 were:

Pandanus tectorius
Cenchrus echinatus
Dactyloctenium aegyptium
Lepturus repens
Fimbristylis cymosa
Cocos nucifera
Boerhavia tetrandra
Pisonia grandis
Portulaca australis
Portulaca lutea
Cassytha filiformis
Suriana maritima
Euphorbia hirta
Euphorbia glomerifera
Euphorbia rubicunda
Phyllanthus amarus
Dodonaea viscosa
Triumfetta procumbens
Sida fallax
Calophyllum inophyllum
Terminalia samoensis
Ipomoea macrantha
Ipomoea pes-caprae.
Cordia subcordata
Heliotropium procumbens var. depressum
Tournefortia argentea
Clerodendrum inerme
Physalis angulata
Morinda citrifolia
Scaevola sericea
Pluchea symphytifolia
Tridax procumbens

BIKINI ISLET

Bikini Islet is the largest islet on the Bikini Atoll Reef. It lies at the northeast corner of the atoll, oriented northwest-southeast, 2-1/2 miles long, one half mile wide at widest diameter along the Center Baseline Road. Its maximum area is 560 acres of which approximately 522 are vegetated. The terrain is essentially flat, with no natural elevation more than 10-12 feet above high tide level.

Prior to the first attempt at return of the Marshallese inhabitants, practically the entire island surface was planted with coconut palms, on a right angle square grid pattern, 30 feet apart. A few older palms remained from pre-test groves and are much taller than those of the 1969 plantings. At present most of the area is covered by this stand of young coconuts, but growth in height and spread of leaves, as well as survival, vary a great deal. The causes of this variation are mostly not apparent after our brief survey. Spontaneous vegetation is universally present between the palm trees, varying from thin grass and sedge ground-cover to dense scrub and spontaneous regeneration of coconut seedlings, this especially around the bases of the trees.

The same three principal map units in the coconut plantation are used here as on Eneu. The most conspicuous difference is that, on Bikini, *Dodonaea*, though usually present, seldom occurs as a dominant in the woody undergrowth. *Tournefortia* and *Scaevola* are the two principal components. *Pandanus* may generally be more common. Herbaceous ground cover here is locally of *Fimbristylis*, locally of *Cassytha*, more often of *Lepturus*, or, in more open areas a mixture of these with *Eustachys* and *Cenchrus*. In places the woody undergrowth has been cleared by dragging a heavy door after a tractor. This may well have resulted in interpretation of such areas as unit 2 rather than 1. On this islet extensive areas that must have been planted to coconuts are now almost lacking in palms and are mapped as unit 7. No reason is suggested for this.

Map units 4, 5 and 6 have not been recognized on Bikini Islet, except for a tiny bit of No. 6 on the middle seaward coast.

No. 7, mixed broadleaf forest, lacking coconuts, or almost so, is much more extensive on Bikini than Eneu. This may be because the attempted resettlement took place here. A considerable strip back of the houses was apparently not planted to coconuts, and this has been dominated by mixed scrub forest, classed as unit 7. *Tournefortia* and especially *Scaevola*, have become especially luxuriant here. Also there is an added component, tending to dominate some areas near the houses to the extent that it almost constitutes an additional map unit. This is *Leucaena leucocephala*, a tall shrub or slender tree with very fine feathery leaves. Its seedlings are extremely shade-tolerant, and it may eventually out-compete some or all the component species of unit 7, and perhaps others, too. It is said to have been brought by the resettled Bikinians as an ornamental. Generally unit 7, on Bikini, includes more *Cordia* and less *Dodonaea* than on Eneu.

Unit 8, tall grass and weeds, is very prevalent on Bikini, but not in areas large enough to map at the scale practical for this survey. It occurs especially along the principal road the length of the island, around houses and other buildings and in places bulldozed or cleared for any reason and left for even a short time. It is notable for the tall stature attained by weedy species ordinarily much smaller, such as *Euphorbia glomerifera*, *Euphorbia hirta*, *Amaranthus dubius*, *Eustachys petraea*, *Phyllanthus amarus*, *Cenchrus echinatus*, *Portulaca oleracea*, and *Heliotropium procumbens* var. *depressum*. This tendency is also apparent in some woody plants in other units. A locally abundant species in this unit, not seen on Eneu, is *Paspalum setaceum*, found in a grassy area at the southeast end of the main road, in the old camp site.

Unit 9, confined to the airstrip on Eneu, is not seen on Bikini.

Unit 10, the beach ridge scrub forest, is similar on both islets, and prevalent on both. Perhaps

Cordia is more abundant in it on Bikini. It occurs on beach-ridges around much of the periphery of the islet.

Unit 11 is added on Bikini Islet to accommodate the experimental gardens connected with the resettlement project, but the areas are too small to be very noticeable, except as openings in the prevailing coconut vegetation.

Plants observed growing without cultivation in 1985 were:

Pandanus tectorius
Cenchrus echinatus
Dactyloctenium aegyptium
Digitaria insularis
Digitaria setigera
Eleusine indica
Lepturus repens
Paspalum setaceum
Thuarea involuta
Fimbristylis cymosa
Cocos nucifera
Tacca leontopetaloides
Artocarpus altilis
Boerhavia albiflora
Pisonia grandis
Portulaca australis
Portulaca oleracea
Cassytha filiformis
Leucaena leucocephala
Suriana maritima
Euphorbia hirta
Euphorbia glomerifera
Phyllanthus amarus
Dodonaea viscosa
Triumfetta procumbens
Hibiscus (hybrid)
Sida fallax
Calophyllum inophyllum
Carica papaya
Terminalia samoensis
Polyscias guilfoylei
Ipomoea macrantha
Ipomoea pes-caprae
Cordia subcordata
Heliotropium procumbens var. depressum
Tournefortia argentea
Clerodendrum inerme
Vitex trifolia var. bicolor
Physalis angulata
Pseuderanthemum carruthersii var. atropurpureum
Guettarda speciosa
Morinda citrifolia
Scaevola sericea
Conyza canadensis
Tridax procumbens

Plants noted as growing only when tended by man:

Zea mays
Musa sapientum
Casuarina equisetifolia
Brassica petsai or B. pakchoi
Medicago sativa
Vigna marina
Citrus aurantifolia
Citrullus lanatus var. caffrorum
Cucurbita sp.
Terminalia catappa
Plumeria obtusa
Capsicum annuum
Solanum lycopersicum
Plumeria rubra
Ipomoea batatas

AEROKOJLOL ISLET

This is an elongate islet lying on the south reef of Bikini Atool. Its vegetation has been profoundly disturbed, as on a 1978 air photo there are distinct indications of an airstrip much overgrown.

The vegetation generally is a dense scrub or scrub-forest of Scaevola, Tournefortia, some Pandanus and Guettarda, tangled with Ipomoea macrantha. There is much dead wood, fairly generally in the parts examined. In the east end, inland, there is an area of coconut trees, around the traces of an old camp. This was not examined for vegetation.

In the extreme west end are areas of rather open Scaevola and Tournefortia with almost no herbaceous growth, except scattered Fimbristylis tufts. Fimbristylis is common along the tops of beaches, with a very few small Lepturus tufts. Suriana is occasional along the lagoon shore, Pemphis very rare, more inland. The substrate for both of these is sand or fine gravel.

Plants seen on Aerokojlol were:

Lepturus repens
Fimbristylis cymosa
Cocos nucifera
Suriana maritima
Triumfetta procumbens
Pemphis acidula
Terminalia samoensis
Ipomoea macrantha
Cordia subcordata
Tournefortia argentea
Guettarda speciosa
Scaevola sericea

BWIKOR ISLET

This is a small triangular islet on the north reef of Bikini Atoll. Its vegetation is rather simple. In 1978, when the available air photos were made, they showed an open stand of, probably, principally Tournefortia argentea tending to be closed, probably mostly Scaevola at the two lagoon corners and a patch of Scaevola (?) on the middle of the northeast side. An elongate very brackish pond lies parallel and somewhat inland from the lagoon shore. A massive exposure of fossil beach-rock caps the apex of the triangle. Probably some of the beach-ridge vegetation on the photo may be Scaevola.

In 1985, the vegetation is mostly closed and, for the most part, is dominated by Scaevola sericea, a stand 2-4 m tall on the beach ridges, lower, 1-2 m tall, and semi-open in the interior. The spaces between the Scaevola bushes is occupied by a loose to sparse mixture of graminoid herbs-- principally Fimbristylis and Lepturus. Boerhavia albiflora locally forms a ground-cover. Around the pond Pemphis acidula is common, with Fimbristylis, but with no vascular wet ground plants. In and around the edges of the pond is an abundance of blue-green algae and the green Cladophora. A school of a dozen or so large milk-fish (Chanos chanos) live in the pond, apparently well-nourished by the algae. Shrubs occasionally found in the predominantly Scaevola scrub are Guettarda, Pemphis, and very rare, Pandanus tectorius. Along the northeast beach-ridge are one or more Cordia, and the vines, Ipomoea macrantha and Ipomoea pes-caprae. The latter spreading down the broad beach from a dense ground-cover locally on the berm of the ridge.

The curious thing about this vegetation is that almost all of the Tournefortia are dead, emergent and bare from the Scaevola scrub. No explanation of this phenomenon is apparent. Some Scaevola plants, also, are dead, especially on the lagoon beach ridge.

Plants observed are:

Pandanus tectorius
Lepturus repens
Fimbristylis cymosa
Boerhavia albiflora
Portulaca oleracea?
Suriana maritima
Triumfetta procumbens
Pemphis acidula
Ipomoea macrantha
Ipomoea pes-caprae
Cordia subcordata
Tournefortia argentea
Guettarda speciosa
Scaevola sericea

ODRIK-LOMILEK-AOMEN ISLETS

This series of islets, connected with Bwikor, to the west, by a very long, scarcely vegetated sand spit, are connected by very well-vegetated sand isthmuses. These islets, likewise were sparsely vegetated as shown by the air photos in 1978. Now there is practically a solid stand of Scaevola scrub, 2-4 m tall with scattered Tournefortia emergents to 6-7 m., living and presumably healthy.

Around the small elongate pond are Suriana bushes. A few Pemphis are scattered in the scrub. Small openings are dominated by a luxuriant stand of Fimbristylis cymosa.

On the isthmus between Lomilik and Aomen and on the western part of Aomen are open meadows of Fimbristvlis and Lepturus, mostly surrounded by Scaevola. On the 1978 air photos these areas seem to be without vegetation.

The Tournefortia on these islets seems, generally, healthy.

Plants observed were:

Lepturus repens
Fimbristylis cymosa
Cocos nucifera
Caesalpinia cf. bonduc or major (seedlings only)
Canavalia cf. sericea (seedlings only)
Suriana maritima
Pemphis acidula
Cordia subcordata
Tournefortia argentea
Scaevola sericea

NAM ISLET

Nam is one of the larger islets on Bikini Atoll Reef, located on the approximate northwest corner of the reef. Its western point was truncated by the "Bravo" hydrogen bomb blast in 1954.

The island surface is more or less flat, of coral sand and gravel with boulders of coral conglomerate scattered here and there in the interior and very numerous back of the west beach. These possibly may have been thrown inland by the blast.

The vegetation of the islet is essentially a scrub of Scaevola sericea, mostly very dense 10-15 feet high, the thick stems intricately tangled, with practically no herbaceous ground cover in the dense areas. In several areas, the east and south parts, this scrub is of lower stature and semi-open to open. Here and there is a patchy ground cover of Boerhavia and Lepturus. with some small areas of Portulaca lutea and Triumfetta. In these areas Ipomoea macrantha clambers over the shrubs locally. Cassytha, abundant on other large islets, is conspicuous by its complete absence on Nam, though Taylor reported it as present in 1946.

It is tempting to speculate that the peculiarities, such as dead vegetation on this and other islets, missing species, abnormally large stature, for examples, may be effects of radiation from the blast or fallout, but in absence of more than the most circumstantial evidence for such phenomena, I have refrained from such speculations except for one or two most obvious cases

There is little or no scrub forest on Nam, though in certain areas emergent Tournefortia is common enough to give the impression from a distance of scrub forest. There was formerly a little open scrub forest along the truncated west shore, but a belt of this from the beach ridge back a few tens of meters is now dead except for several partly dead Tournefortia and some young Scaevola just beginning. A few small Pisonia are present in the scrub-forest remnants back of this dead strip, also a few small trees of it southeast of the center of the islet.

These several variations are all merely aspects of the basic Scaevola scrub vegetation that characterizes most of the smaller islets of Bikini except the six small ones on the southwest reef which are, for some reason, more lush and are notable for small Pisonia forests. On the map of Nam (not reproduced here) these variants are designated as follows:

a. Dense Scaevola scrub 10-15 feet high, little else.
b. Scaevola more open, lower stature, some herbaceous ground cover.
c. Dense Scaveola with emergent Tournefortia in some numbers.
d. Dead Tournefortia and Scaevola, with live Boerhavia and Portulaca

The total flora observed on Nam during this survey is listed below:

Lepturus repens
Fimbristylis cymosa
Cocos nucifera (one small tree only seen well inland)
Boerhavia albiflora
Boerhavia "repens"
Boerhavia tetrandra
Tournefortia argentea
Pisonia grandis
Portulaca lutea
Portulaca oleracea ?
Triumfetta procumbens
Ipomoea macrantha
Ipomoea pes-capre (seedling only seen well inland)
Cordia subcordata
Guettarda speciosa
Scaevola sericea

BOKAETOKTOK ISLET

This is the second tiny islet from the northwest on the southwest reef of Bikini Atoll. It is about 120 m long, rather egg-shaped with the largest end to the northwest. It has the reputation of being one of the least disturbed of Bikini islets, but this only means that no serious clearing or bulldozing has taken place since the testing ceased. There are great iron chains, scattered in the interior and at both ends. What these were for is not evident, but only gigantic machinery could have put them there. The forest here appears to be relatively young, probably post-bomb-test.

The island is well vegetated, the broader northwest end and down the middle are covered by a forest of Pisonia grandis, a broad-leafed soft-wood tree that elsewhere reaches enormous size. Those on Bokaetoktok are all less than 10 inches thick and no more than 30 feet tall. They form a rather complete canopy over about 3/4 of the island.

Nothing is known of the growth rates of Pisonia or other coral island trees, but it seems safe to state that the present vegetation has grown up since testing was stopped in 1958. The characteristic layer of raw-humus in Pisonia forest has not formed to anything like its normal depth of a few inches, nor has much phosphate rock developed as might be expected.

The south, southeast and east coasts are lined by a wide zone of open to semi-open scrub vegetation of Scaevola and Tournefortia. In the openings in this are stands of Portulaca lutea, Lepturus repens, and Boerhavia. principally B. albiflora. The beach ridge on the east or lagoon coast has good sized trees, mostly Tournefortia and Pisonia, with Scaevola shrubs. Several Guettarda and Cordia trees are found on this coast.

The vegetation here is simple, indeed. Only the following species were found during our visit:

Lepturus repens
Boerhavia albiflora
Boerhavia repens
Pisonia grandis
Portulaca lutea
Cordia subcordata
Tournefortia argentea
Guettarda speciosa
Morinda citrifolia
Scaevola sericea

OROKEN

This is the third of the small islets on the southwest reef, somewhat larger than Bokaetoktok. It likewise seems to have vegetation probably not much over 25 years old, and to have been disturbed before that.

Now about 3/4 or more of the surface is covered by a fine forest of *Pisonia grandis* with an "A" soil-horizon of raw humus not nearly as thick as in a mature *Pisonia* grove. The canopy of this forest is complete, possibly reaching 40 feet, with tree-trunks up to a foot in diameter. There is no undergrowth, which is typical of *Pisonia* forest, and the ground is strewn with large angular cobbles and boulders, many of which are of typical brown, white-speckled phosphate rock. This is a sure indication of an earlier mature *Pisonia* forest. The north corner and the east end and southeast coast of the islet are covered by an open scrub or scrub forest of *Tournefortia*, mixed with some *Pisonia*, but almost no *Scaevola*. The openings in this are occupied by almost pure stands of a rather low form of *Portulaca lutea*, with some mats of *Boerhavia*, possibly *B. repens* or an unusual form of *B. tetrandra*, with a little *B. albiflora*. The beach ridge on the east and part of the north sides is covered by a good stand of *Lepturus repens*. On the southwest side is a very small patch of *Scaevola* scrub, with a *Guettarda* shrub and several *Morinda citrifolia* shrubs or small trees.

Again, this islet has very simple vegetation. The following species were present:

Lepturus repens
Laportea ruderalis
Boerhavia albiflora
Boerhavia repens
Pisonia grandis
Portulaca lutea
Tournefortia argentia
Guettarda speciosa
Morinda citrifolia
Scaevola sericea

TABLE 1:COMBINED LIST OF VASCULAR PLANT SPECIES:
(See Notes at end of list)

Pandanaceae

Pandanus tectorius Parkinson (I & A)
Both the edible-fruited and the small-fruited "wild" forms are present.
Bikini I; Eneu I. (T); (Lomilik-T); Bwikor I.

Poaceae

Cenchrus echinatus L. (X)
Bikini I.(T); Eneu I.

Chloris inflata Link (X)
(Bikini I.-T)

Dactyloctenium aegyptium (L.) Beauv. (X)
Bikini I.; Eneu I.

Digitaria insularis (L.) Mez (X)
Tricachne insularis (L) Nees
Bikini I. (T.).

Digitaria setigera Roth (I)
Digitaria microbachne (Presl) Henr.
Bikini I. (T)

Eleusine indica (L.) Gaertn. (X)
Bikini I.

Eustachys petraea (Sw.) Desr. (X)
Bikini I.; Enue I.

Lepturus repens (Forst. f.) R. Br. (I)
Bikini I. (T); (Bokonjebl I. T); (Nam I T); Bokontuak I T); (Jalete I. (T); Oroken I. T; (Enidrik I. T); Aerokojlol I.; Eneu I.

Paspalum setaceum Michx. (X)
Bikini I.

Thuarea involuta (Forst f.) R. Br. (I)
Bikini I. (T)

Cyperaceae

Fimbristylis cymosa R. Br. (I)
Bikini I. (T); Eneu I.; Aerokojlol I.

Arecaceae

Cocos nucifera L. (A)
Bikini I. (T); Eneu I. (T); (Bokonjebl I. T); Aerokojlol I. Nam I.; Lomilik I.; Aomen I.

Liliaceae (s. l.)

Crinum asiaticum L. (A)
(Bikini I. T)

Taccaceae

Tacca leontopetaloides (L.) 0. Ktze. (A? or I)
Bikini I. (T); (Eneu I. T); (Nam I. T)

Moraceae

Artocarpus altilis (Park.) Fosb. (A)
Bikini I. (T).

Urticaceae

Laportea ruderalis (Forst. f.) Chew (I)
Oroken I.

Amaranthaceae

Achyranthes canescens R. Br. (I)
(Enidrik I. T)

Nyctaginaceae

Boerhavia albiflora Fosberg (I)
Bikini I. (T); (Enidrik I. B); Nam I. (T); Bwikor I.; Bokaetoktok I.; Oroken I.

Boerhavia tetrandra Forst. f. (I)
Eneu I.; (Aerokojlol I. T); (Enidrik I. T); (Lukoj I. T); (Jalete I. T); (Oroken I. T); Nam I. T.

Boerhavia repens L. (I)
Oroken I.; Bokaetoktok I.

Pisonia grandis R. Br. (I)
Bikini I. (T); Eneu I. (T); Oroken I.; Bokaetoktok I.; (Bokdrolul I. B)

Portulacaceae

Portulaca australis Endl. (I)
Portulaca quadrifida sensu Taylor
Bikini I.; Eneu I.; (Nam I. T); (Lomilik I. T).

Portulaca lutea Sol. ex Forst. f. (I)
(Bikini I. T); Eneu I.; Oroken I. (T); Bokaetoktok I.; Nam I.; (T).

Portulaca oleracea L. (X)
Bikini I. (T); Aerokojlol I.; (Bokdrolul I. B); Bwikor I.?

Lauraceae

Cassytha filiformis L. (I)
Bikini I. (T); (Rojkora I. T); Eneu I. (T); (Aerokojlol I. T); (Enidrik I. T); (Nam 1. T); (Bokdrolul I. B)

Hernandiaceae

Hernandia sonora L. (I)
Hernandia ovigera sensu Taylor
(Bikini I. T).

Fabaceae

Caesalpinia sp. (prob. C. bonduc (L.) Roxb. or C. major (Medic.) Dandy & Exell (I)
(Bikini I. T); Odrik I. (seedlings only).

Canavalia cf. sericea A. gray (I)
Lomilik I. (seedling only)

Delonix regia (Bojer) Raf. (X)
Bikini I. (planted only)

Leucaena leucocephala (Lam.) de Wit (X)

Bikini I.

Sophora tomentosa L. (I)
(Bikini I. T)

Surianaceae

Suriana maritima L. (I)
Bikini I. B; (Bokantuak I. T); (Enaelo I. T); (Bokonjebl I. T); Eneu I. B; (Aerokojlol I. T); (Enidrik B); (Oroken B); (Bokdrolul I. B); (Nam T)

Simarubaceae

Soulamea amara Lam. (I)
(Eneu I. T); (Nam I. T).

Euphorbiaceae

Euphorbia hirta L. (X)
Bikini I.; Eneu I.

Euphorbia glomerifera (Millsp.) Wheeler (X)
Bikini I.; Eneu I.

Euphorbia rubicunda Bl. (X)
Eneu I.

Phyllanthus amarus Schum. (X)
Bikini I.; Eneu I.

Sapindaceae

Dodonaea viscosa L. (I)
Bikini I.; Eneu I.

Tiliaceae

Triumfetta procumbens Forst. f. (I)
Bikini I. B; (Bokonjebl I. T); Eneu I. (T); Aerokojlol I. (T); (Enidrik I. T); (Bokondrolul I. B); Nam I. (T); Bwikor I.; Odrik I.

Malvaceae

Hibiscus (hybrid) (X)
Bikini I. (planted)

Hibiscus tiliaceus L. (I?)
(Bikini I. T)

Sida fallax Walp. (I)
Bikini I. (T); Eneu I.; (Nam I. T).

Clusiaceae

Calophyllum inophyllum L. (I)
Bikini I.; Eneu I.

Caricaceae

Carica papaya L. (X)
Bikini I. (T)

Lythraceae

Pemphis acidula Forst. (I)
(Bokonjebl I. T); Aerokojlol I.; (Enidrik I., T, B); (Jalete B); Bwikor I.; Odrik I.

Rhizophoraceae

Bruguiera gymnorhiza Lam. (A)
Bruguiera conjugata sensu Taylor
(Bikini I. T).

Combretaceae

Terminalia samoensis Rech. (I)
Terminalia litoralis sensu Taylor
Bikini I. (T); (Enaelo I. T); Eneu I. (T); Aerokojlol I; (Enidrik I. (B)); (Lomilik I. T).

Araliaceae

Polyscias guilfoylei (Bull) Bailey (X)
Bikini I. (planted)

Apocynaceae

Neisosperma oppositifolia (Lam.) Fosb. & Sachet (I)
Ochrosia parviflora sensu Taylor
(Bikini I. T); (Eneu I. T).

Convolvulaceae

Ipomoea macrantha R & S (I)
Ipomoea alba sensu Taylor
Bikini I. (T); Eneu I. (T); Aerokojlol I.; (Enidrik I. T); (Jalete I. T); Nam I. (T); Bwikor I.

Ipomoea pes-caprae L. ssp. brasiliensis (L.) van Ooststr. (I)
Bikini I.; Eneu I.; Nam I.; Bwikor I.

Boraginaceae

Cordia subcordata Lam. (I)
Bikini I. (T); Eneu I.; (Aerokojlol I. T); (Nam I. (T); Bwikor I.

Heliotropium procumbens var. depressum (C. & S.) Fosberg (X)
Bikini I.; Eneu I.

Tournefortia argentea L.f. (I)
Bikini I. (B); (Bokantuak I. (T); (Enaelo I. T); Eneu I. B; Aerokojlol I. (T); (Enidrik I. T); Oroken (T); Bokaetoktok I.; (Bokdrolul I. B); Nam I. (T); Bwikor I.; Odrik I.; Lomilik I.; Aomen I.

Verbenaceae

Clerodendrum inerme (L.) Gaertn. (I)
Bikini I., Eneu I.

Vitex trifolia var. bicolor (Willd.) Moldenke (X)
Bikini I.

Solanaceae

Physalis angulata L. (X)
Bikini I.; Eneu I.

Acanthaceae

Pseuderanthemum carruthersii var. atropurpureum (Bull) Fosb. (X)
Bikini I.

Rubiaceae

Guettarda speciosa L. (I)
Bikini I. (B); (Bokantuak I. T); (Enaelo I. T); (Bokonjebl I. T); Eneu I. (T): Aerokojlol I. (T); (Enidrik I. T (B)); Oroken (T); Bokaetoktok I.; (Bokdrolul I. (B)); Nam I. (T); Bwikor I.

Morinda citrifolia L. (I?)
Bikini I. (T); Eneu I. (T); (Jalete I. T); Oroken I.; Bokaetoktok I.; (Nam I. T).

Goodeniaceae

Scaevola sericea Vahl (I)
Scaevola frutescens sensu Taylor
Bikini I. B; (Bokantuak I. T); (Enaelo I. T); (Bokonjebl I. T); Eneu I. (T); Aerokojlol I. (T); (Enidrik I. T); Oroken I. (T); Bokaetoktok I.; (Bokodrolul I. B); Nam I. (T): Bwikor I.; Odrik I.; Lomilik I.; Aomen I.

Asteraceae

Conyza canadensis (L.) Cronq. (X)
Bikini I.

Pluchea symphytifolia (Mill.) Gillis (X)
Eneu I.

Tridax procumbens L. (X)
Bikini I.; Eneu I.

Notes on the combined list:

T means reported by Taylor, if in ( ) with an islet name, found by him but not by present survey on that islet. If in ( ) following an islet name, found on that islet by both surveys.

B means reported by Bogusch, a plant physiologist with the 1949 Applied Fisheries Laboratory Survey.

The islet names have been brought into accord with those used by the BARC and the Lawrence-Livermore projects.

The plant names have been brought into accord with those accepted by Fosberg, Sachet and Oliver (1979, 1981 and in press), and several corrected further in accord with recent changes in identities and nomenclature.

Following each species name in the list is a letter in ( ) as follows:

[(E) means endemic to the Marshall Islands - none of the species found or reported are so marked, as none are endemic.]

(I) means indigenous to the Marshalls but not endemic.

(A) means suspected to have been introduced in pre-European time by the Marshallese people.

(X) means introduced by man in post-European contact time.

No plants are known to have been collected or reported from Bikini prior to 1946, though Kanehira or other Japanese botanists may have collected some and not published the records. In 1946, during the "Crossroads Survey" initiated by Lt. Cdr. Dr. Roger Revelle, Prof. Wm. Randolph Taylor, of the Botany Dept., University of Michigan, made a large collection on Bikini and several other atolls in the northern Marshall Islands. Many of these were algae, Prof. Taylor's specialty. In his book, Plants of Bikini (1950), he reported 39 species of vascular plants from Bikini Atoll, and briefly described the land vegetation. Of the species reported by Taylor, nine were on none of the islets visited by us. Two of the nine missing species were exotics, the rest probably native. 24 species not reported by Taylor were collected on the present survey. Of these six are indigenous, the remaining 18 are exotics. Not included in the list are a number of species only growing under present cultivation by man, most of them in the experimental gardens planted and cared for by the rehabilitation personnel (Lawrence Livermore laboratory). Cultivated species planted by the Marshallese and still persisting are included in the list. Of the total present spontaneous flora (56 species), 26 are native; 5 are of aboriginal introduction and 25 exotic. One of the 28 (Tacca) is doubtfully native. Two others, (Caesalpinia and Canavalia) were seen as beach drift seedlings only.

Not much can be concluded from these figures except that the high proportion of exotics indicates the obvious fact that there has been much human influence. The low total number of species, present and reported earlier, indicates a rigorous, unfavorable environment, with little diversity. The carrying capacity for people is likely to be low, though marine resources may partly offset scarcity due to unfavorable conditions for locally produced food plants, and to accumulation of radioactivity making the plants unfit to eat.

The species in parentheses in Tables 5 and 6 were not found by the present survey. The one in brackets may be of aboriginal introduction, as are at least three of the exotics, Cocos, Crinum and Artocarpus.

TABLE 2: Species reported by Taylor not found on this survey.

Chloris inflata
Crinum asiaticum
Achyranthes canescens
Hernandia sonora
Sophora tomentosa
Soulamea amara
Hibiscus tiliaceus
Bruguiera gymnorhiza
Neisosperma oppositifolia

TABLE 3: Species found on this survey not reported by Taylor.

Dactyloctenium aegyptium
Eleusine indica
Eustachys petraea
Paspalum setaceum
Laportea ruderalis
Boerhavia repens
Canavalia sericea
Delonix regia
Leucaena leucocephala
Euphorbia hirta
Euphorbia glomerifera
Euphorbia rubicunda
Phyllanthus amarus
Dodonaea viscosa
Hibiscus (hybrid)
Calophyllum inophyllum
Polyscias guilfoylei
Ipomoea pes-caprae
Heliotropium procumbens
Physalis angulata
Clerodendrum inerme
Pseuderanthemum carruthersii
Conyza canadensis
Pluchea symphytifolia
Tridax procumbens

TABLE 4:Species found on both surveys

Cenchrus echinatus
Digitaria insularis
Lepturus repens
Thuarea involuta
Fimbristylis cymosa
Cocos nucifera
Tacca leontopetaloides
Artocarpus altilis
Boerhavia albiflora
Boerhavia tetrandra
Pisonia grandis
Portulaca australis
Portulaca lutea
Portulaca oleracea
Cassytha filiformis
Caesalpinia sp.
Suriana maritima
Triumfetta procumbens
Sida fallax
Carica papaya
Pemphis acidula
Terminalia samoensis
Ipomoea macrantha
Cordia subcordata
Tournefortia argentea
Guettarda speciosa
Morinda citrifolia
Scaevola sericea

TABLE 5:Indigenous Species

Pandanus tectorius
Digitaria setigera
Lepturus repens
Thuarea involuta
Fimbristylis cymosa
[Tacca leontopetaloides]
Laportia ruderalis
(Achyranthes canescens)
Boerhavia albiflora
Boerhavia tetrandra
Boerhavia repens
Pisonia grandis
Canavalia sericea
(Soulamea amara)
Dodonaea viscosa
Triumfetta procumbens
(Hibiscus tiliaceus)
Sida fallax
Calophyllum inophyllum
Pemphis acidula
(Bruguiera gymnorhiza)
Terminalia samoensis
(Nesiosperma oppositifolia)
Ipomoea macrantha

Portulaca australis
Poerulaca lutea
Cassytha filiformis
(Hernandia sonora)
Caesalpinia sp.
Scaevola sericea
Ipomoea pes-capre
Cordia subcordata
Clerodendrum inerme
Guettarda speciosa
Morinda citrifolia

TABLE 6 Exotic Species

Cenchrus echinatus
(Chloris inflata)
Dactyloctenium aegyptium
Digitaria insularis
Eleusine indica
Eustachys petraea
Paspalum setaceum
Cocos nucifera
(Crinum asiaticum)
Artocarpus altilis
Portulaca oleracea
Delonix regia
Leucaena leucocephala
Euphorbia hirta
Euphorbia glomerifera
Euphorbia rubicunda
Phyllanthus amarus
Hibiscus (hybrid)
Carica papaya
Polyscias guilfoylei
Heliotropium procumbens
Physalis angulata
Vitex trifolia
Pseuderanthemum carruthersil
Canyza canadensis
Pluchea symphytifolia
Tridax procumbens

DISCUSSION:

This section is arranged roughly in accord with the outline in the "Scope of Work...." document provided.

(a) The requirement for baseline information was carried out to the extent that time permitted. Remarks on successional status, based on short term reconnaissance, must be regarded as tentative indeed. Some such remarks are offered in (h) below, but are based largely on previous experience on other atolls, none of which had been exposed to the treatment afforded Bikini. Such ideas on succession may, therefore, be accepted as "educated guessing." The "plant communities" described are more in the nature of mappable units of vegetation, or cover types, than technically determined plant communities, but are what could be recognized in the time allotted.

(b) The checklist of species is reasonably complete, with names brought up to date. Marshallese names are not included, since no Bikinian informants were available. The designations of Indigenous, of Aboriginal introduction, or Exotic, have some queries, as there is considerable doubt as to the status of some of the species.

(c) To the best of my knowledge, no species on Bikini are endangered, or likely to be considered so, or even threatened, as all are widespread, mostly strand plants or exotics, as is usually the case with low coral island floras. These atoll floras are mostly too young to have evolved any local species or well-marked varieties.

Several species, such as Terminalia samoensis. Neisosperma oppositifolia and Soulamea amara (the last two not seen on this survey) may be considered rare enough on Bikini to merit special protection, in order to preserve the indigenous diversity, and as possible habitats for rare insects. One tree of the Terminalia was located on the second Baseline Road about 50 yards in from the seaward shore. Another, not seen by me, was found along the south part of the air-strip on Eneu, by Dr. Robison.

(d) Plants and Vegetation types of such significance as to merit special protection: the abundance of Cordia subcordata (Marshallese - kono) on Bikini Islet, also, but less so on Eneu, suggests that given time for the trees to mature, an important resource of fine wood for carving and other uses for high-grade timber is present in this species. Some of the trees are already of good size. This species is not likely to produce long saw-logs, as it tends to send out branches near the ground. Hence its primary use is for carving. However, this tendency may be lessened by permitting the trees to remain in rather close stands until they reach a good height. We know of no silvacultural standards for this species, but some will surely be developed if a demand for its wood is encouraged. This is one useful plant the use of which will not be prevented by any accumulation of radioactivity, as the plant is not eaten.

I would suggest protection of the two small stands of Pisonia and Pisonia with Cordia centrally located on Eneu Islet. Pisonia does not produce useful wood, but is a favorite nesting tree for black noddy and fairy terns. There are also undoubtedly other organisms dependent on it. It is an irreplaceable part of the process leading to formation of atoll phosphate rock. This is not, of course, a short term benefit, but phosphate will be important to any culture dependent on plants, as far as we can see in the future.

The Pisonia forests on Bokaetoktok and Oroken islets, and perhaps on the other islets on the southwest reef, should also be protected, for the same reasons given above. They are even now the homes of the largest sea-bird populations on the atoll. They are also functioning examples of a fascinating ecological or eco-geological process - the formation of atoll phosphate rock. This phenomenon was described in two published papers some years back (Fosberg 1954, 1957). This formation has since been found to have occurred on coral islands throughout the Indo-Pacific region, as far west as the islands off the east coast of Africa. However, there are almost no intact Pisonia forests left in that entire region. The few tiny ones on these southwest islets may soon be the only examples of the process of formation of atoll phosphate rock left in the world. I elaborated the formation of atoll phosphate rock back in the 1950's but it has never been studied in detail. There are few diagenetic processes that can be studied and followed to completion in one person's lifetime, but this is one, hence it is of great interest.

The large stands of Dodonaea viscosa are of botanical and may be of potential practical, interest. The wood of the Hawaiian relatives (aalii) of this species produce an extremely hard wood, used in lieu of metal by the ancient Hawaiians. The trees of this species on Bikini, and especially Eneu islets reach an unusually large size and some use may well be developed for the wood of these trees.

Finally, attention should be directed to the vegetation of the beach ridges on the islets, especially the large ones. Salt spray is one of the limiting factors to horticultural and plantation productivity on coral islands. Many useful plants can only be grown on these low islands if protected by windbreaks. This beach-ridge vegetation is a very effective natural windbreak, as the Marshallese on many other atolls very well know.

The coconut plantations on Ailuk, for example have crescent-shaped bands of tree and shrub vegetation protecting the windward sides of the islets that have plantations, markedly increasing their productivity. This protection also makes taro-pits more successful and enables other plants than taro to be grown in these pits. If the Bikinians are ever to be even partly self-sufficient they will have to depend on crop plants that can stand a little salt, but that produce much better crops if protected from spray-bearing winds.

These wind-breaks also afford protection to people and structures against at least moderate storms.

(e) The principal technique to encourage plant growth on these islets is that described above in (d), of protecting and encouraging the beach-ridge vegetation to serve as wind-breaks around the periphery of the islets. If additional wind-breaks are needed in the interior parts of the islets, we can suggest rows of Casuarina equisetifolia. augmented by lower growing dense shrubs such as Suriana, Pemphis. and Scaevola. all salt-resistant and adapted to this habitat.

On open sand or compacted coral a dark greenish or blackish gelatinous blue-green alga often grows in profusion after rains. As this begins to dry it may be raked up and spread around garden plants and worked into the soil. This alga, Nostoc commune is known to be a nitrogen-fixer, and will improve the chemical and the physical properties of the soil. Fertilizers are mostly expensive, but here is one that may be had for the gathering.

Another plant that will improve the nitrogen content of the soil is the beach pea, Vigna marina. This is an atoll plant, but we did not find it on Bikini. However, it might get a start there if seeds from other islands were sown during a rainy season. I have seen it on islands that must be as dry as Bikini.

It is difficult to suggest plants to be brought in without knowing what is the particular purpose to be served. Indiscriminate introduction may be a detriment rather than a benefit. The introduction of the salt-grass, Paspalum dislichum for example, while it may have served as a soil stabilizer, was a disaster to taro culture on Likiep Atoll in 1950.

If the unlikely (to me) project of removal of the top layers of soil is carried out, I would suggest encouraging the native Lepturus repens, Boerhavia albifiora, and Fimbristylis cymosa to cover and stabilize the raw surfaces. Vigna marina would also serve this purpose if it can be made to grow under those conditions. Leucaena and Tournefortia will in all probability come in of their own accord and provide a woody cover, if that is desired.

A suggestion that may already have been considered would be to remove the vegetation from Bikini islet, take it to a reef flat or small islet where contamination would not be a problem and burn it or let it rot. If there are radionuclides accumulated, such as radio-cesium, this would remove whatever was there, especially if done several times, and it would be cheaper and less damaging than removal of soil. For simple vegetation, such as covering surfaces exposed by soil-removal, or vegetation removal, rather than bringing in new exotic plants, the effects of which are uncertain, I would suggest encouraging plants already present, as can be readily seen on disturbed or bull-dozed areas, roadsides, experimental garden plots, etc. Both weeds, such as Eustachys, Euphorbia spp., Cenchrus, Heliotropium, Paspalum, Cynodon, etc. and native pioneer species, such as Lepturus, Scaevola, Tournefortia, Dodonaea, Cordia, Fimbristylis, and Guettarda seem to do very well on such bare habitats, even with no help. Most of them could perhaps be encouraged by simply gathering their fruits and fruiting inflorescences and scattering them on the bare ground, especially during rainy periods. Light fertilizer applications, emphasizing minor and trace nutrients, would probably help. If additional woody species are desired, Casuarina and Leucaena are species already present that grow well, though Leucaena, especially, may be hard to get rid of when it is no longer wanted.

My suggestion of an approach to decontamination by repeatedly removing the vegetation with its accumulated load of Ce 137 has apparently been considered and rejected because it would take too long. I think there is still room for further discussion of this method, and consider it further on below.

(f) Perhaps the best way to minimize adverse effects on vegetation would be to discourage indiscriminate bulldozing as the solution to all problems. Avoiding burning of trash, dried-up weeds, coconut leaves and husks would be another way. Planning so that new construction would be done on already disturbed and denuded areas rather than simply clearing a new place would make a great difference, if encouragement to vegetation is desirable. Usually no consideration at all is given to preserving the landscape, even on coral islands, where vegetation has practical as well as aesthetic benefits.

(g) The simple, quantitative effects of previous nuclear testing, construction, and resettlement activities on vegetation have perhaps been minimal. The islands are all practically completely vegetated at present, except for places where disturbance has been very recent - roads, airstrip, experimental plots, etc. The total biomass may be as great or greater than at the time when the people were first removed.

One very curious phenomenon was observed on the largest islets that could conceivably be due to some of the human activities, though I have no suggestion as to its possible cause. This was the fact that many, but not all, of the species present, seem to attain a much greater stature than commonly observed elsewhere for the same species. Clearly some factor in the environment is very favorable. Why it does not affect all the species is also a mystery.

Most of the apparent effects of the listed human activities are changes in the character of the vegetation. A few species previously present are now missing or at least so rare as not to be noticed on the present survey (see Table 2). Others are more abundant than they would probably have been (e.g. Dodonaea). Many new exotics are now present. Some of these (e.g. Eustachys) are very abundant.

Much of the present vegetation is in earlier stages in succession than before. The large areas of Scaevola and Tournefortia scrub and scrub-forest are undoubtedly the result of destruction of previous vegetation and exposure of areas of open ground. Most of the coconut plantations were destroyed, or nearly so. They have not been replanted on most of the islets, especially the smaller ones. On the two largest islets, almost all of the coconut palms are young, from the replanting in mid- and late-sixties. Hence their stature is mostly less than 8-10 m. Because of lack of tending, the undergrowth between the trees in the better habitats is very rank. Because of lack of harvesting, seedling coconut palms form practically impenetrable tangles in some areas.

One of the conspicuous effects of man's activities on the larger islets is the lack of any logical patterns to the distribution of vegetation types in relation to obvious habitat zonations. The extreme disturbance - construction, bulldozing, and the bomb blasts - has confused the distribution and abundance of species so that it is most difficult to understand or predict the development of the vegetation. Even the soil patterns, normally comparatively simple on coral atolls, are here confused, and frequently not what would be expected, given the topographic character and vegetation of a place.

Most noticeable, perhaps, of all human effects is the abundance and composition of the exotic, or weed vegetation. On no other atoll have I ever seen Eustachys dominant in any vegetation type. Leucaena is not ordinarily an important component of atoll vegetation, but here it is locally abundant, even dominant. Several weedy Euphorbia species are unusually abundant.

(h) While vegetational succession on coral atolls is, in my opinion, simpler and with fewer stages than are usual on higher islands and in most continental situations, it has been little studied and is not at all well-understood. It is even difficult to say what constitutes a climax in these often extreme environments and in vegetation comprising so few species.

On moderately dry atolls, such as Bikini, the Pisonia grandis forest has the appearance of climax, but there are a few observations of spots where it seems to be giving way to either a mixture of species or to what will eventually be a pure stand of Neisosperma (formerly Ochrosia oppositifolia). If a floating fruit of this species is thrown by a storm over the beach ridge, into a mixed or a Pisonia forest, and germinates, it seems probable that, given time, a Neisosperma forest will replace whatever is there. However, such a fortuitous occurrence may never happen in a particular place. So, what is the climax? In a single-species forest, a single event may initiate profound change.

It would seem probable that rates of change of at least the earlier stages in atoll vegetation could be determined, within limits, by dating the ages of particular stands from known dates of the last typhoons that had denuded the particular islets concerned. However, no one has ever bothered to make the necessary observations and calculations to do this. Hence, even in such favorable situations we have no basis for estimating rates or predicting stages.

On Bikini there is at least one datable event - the bomb-testing that is datable down to a 12-year period, and, perhaps in the cases of islets denuded by the Castle-Bravo Shots, to a single point in time. Unfortunately, no one seems to have placed on available record what happened to particular islets, except those that disappeared altogether.

Many of the smaller islets at present have a young pioneer vegetation of Scaevola and Tournefortia shrubs. There is little or no indication of older trees. This may be an indication that these islets were denuded during the tests. If so, we have a rough idea of how long it takes for a Scaevola-Tournefortia scrub to develop on a denuded coral limestone substrate. It is reasonably certain that the subsequent changes in this vegetation will take much longer than the time elapsed to date, but there is no way to estimate how long. It is not even certain that the Scaevola-Tournefortia will give way to a different stage, but likely the ultimate vegetation, in ordinary human time-frames will be a mixed forest formed by a gradual invasion of tree species that in their seedling and sapling stages are more shade tolerant than are the two present dominants, Scaevola and Tournefortia.

The tiny islets on the southwest reef are commonly spoken of as relatively undisturbed. They do give this impression. However, closer examination shows evidence of profound disturbance. Fragments of an enormous iron chain on Bokaetoktok could not have been placed in the interior of the island except by enormous heavy machinery or a close-by nuclear blast. Study of an apparently intact Pisonia forest on Oroken Islet showed that the tree trunks are no more than 20-30 cm diameter. A mature forest of this type has enormous trunks a meter or more in diameter. My guess is that these fast-growing soft-wood trees might reach 20-30 cm in 25 or so years, suggesting that these islets may have been completely denuded during the tests and that these forests are really young. In pioneer vegetation like this, succession can be compressed to one or two stages, depending on initial floristic composition. If Pisonia fruits were present in quantity it is quite conceivable that a mature-looking Pisonia forest could develop in 25 years. In any event, these islets are of sufficient interest to warrant their protection in their present "undisturbed" state (see(d)).

However, it must be reemphasized that any statement of rates of succession in atoll vegetation is little more than guessing.

Summary of impacts of previous perturbations:

Up to 1946, the human impacts on the Bikini vegetation were mainly those resulting from subsistence agriculture and commercial copra plantations. This produced the palm-dominated landscape of the popular picture of the South Sea coral island. Only on very small islets and the windward exposures of the plantation islets with their natural windbreaks, was there any significant natural vegetation. From 1946 on, the combined impacts of "construction, nuclear testing, cleanup, resettlement, and human occupation of Bikini Atoll" has changed this landscape and obscured any environmentally related pattern that had survived, or resulted from the activities of the Marshallese, especially on the larger islets. These changes are mostly only inferred, as no records exist, or at least none have been made available to me, of what the vegetation landscape was like at any stage of these mega-perturbations.

It is probable that a short grassy stage occurred at first, but equally likely that, except on very unfavorable spots, woody vegetation Scaevola and Tournefortia scrub - soon replaced the grass. For a decade or so this was allowed to develop with little disturbance. Then, in mid to late 1960's, the two largest islets were completely replanted to coconuts. It is probable that to facilitate this, the woody vegetation was removed, probably by bulldozing.

Regrowth of herbaceous and woody vegetation undoubtedly ensued, until the Bikinians were brought back. They may likely have kept this regrowth more or less under control, at least after the coconut trees began to reach bearing age. I have seen no records of this entire period. After the people were removed again, the regrowth in the plantations tended to outstrip or at least equal the growth of the coconut palms. After the trees began bearing, and the nuts went unharvested, thickets of seedling coconut trees were added to the regrowth, especially around the bases of the bearing trees.

The land around and back of the row of houses along the lagoon shore of Bikini Islet was either never planted to coconuts or was almost completely cleared by the Marshallese. It is now densely covered by broad-leaf scrub forest. At some period, roads were bulldozed across the islet at intervals, and also some lengthwise ones. Some of the roads were kept clear of vegetation, others were overgrown and may be indistinguishable from the undergrowth vegetation in the plantations.

Since the Lawrence-Livermore project was started, some areas were cleared as experimental plots. Some areas of plantation were dragged clear of undergrowth. The result of all of these perturbations, the present vegetation on the two largest islets, is a mosaic of cover types and intermediate or transitions between cover types that defies understanding. These cover-types, in a broad way, probably reflect differences in soil fertility, and especially of intensity of salt spray and ground-water salinity, but continued disturbance obscures these differences.

Probable impact of future clean-up and re-settlement programs:

The plans for "cleanup" that I am aware of are: (1) Removal and disposal of upper 40 cm of soil and (1a) simply leaving the bare subsoil surface to develop a new profile, (1b) replacing it with a layer of soil brought from an uncontaminated area elsewhere or (1c) plant and fertilize to develop new profile. (2) Heavily fertilize with high potassium chemical additives, to lessen the uptake by plants of radio-cesium. (3) Irrigate heavily with sea-water to wash the radioactive isotopes down into the ground water and flush them out into the sea. To these three I would add a fourth, which may or may not have been considered - the repeated removal of accumulated radioactive isotopes to where they will not recontaminate the areas to be utilized. (I do not regard any of these as very practical, 1, 3, and 4 because of expense, 2 because it leaves the contamination in the soil, to be picked up in food plants after the U.S. or the Bikinians get tired of the continued expense for fertilization.) Practicality of No. 4 would depend on finding out how much accumulation takes place in the vegetative biomass.

The idea of decontamination by repeated removals of vegetation has apparently been discussed and rejected (see BARC Interim report p. 31 and BARC Report #1, p. 31). Whether or not such rejection is justified would depend very much on information that I do not have. I am informed that calculations have been made that suggest that 200,000 metric tons of green biomass would have to be removed over a period of several or more croppings of vegetation. I have no information either on the amount of biomass in the present standing crop of natural and exotic vegetation or on how much biomass is produced by a year's growth. Nor it it known to me whether all species of plants accumulate Ce 137 at the same rate, nor what the annual production of biomass is for each important plant species. All plants are not equal in these qualities, I am sure. It might be worth while to do some experimenting on these two processes. The effects on Ce 137 accumulation of fertilizing with a K-deficient fertilizer to determine if the Ce 137 accumulation can be speeded up or augmented. Determination of which plants would be the most effective and what their capabilities in biomass production and Ce 137 accumulation are under different conditions might be worth doing since as much as $50,000,000 may be at stake. The following list of plants might be considered, to start with, as they all seem to be well adapted to the Bikini conditions and to yield considerable bulk of plant material:

Tournefortia argentea
Scaevola sericea
Leucaena leucocephala
Dodonaea viscosa
Pluchea symphytifolia
Cordia subcordata
Tamarix aehylla (not present now)
Morinda citrifolia
Guettarda speciosa
Tacca leontopetaloides
Suriana maritima
Hibiscus tiliaceus
Vitex trifolia
Clerodenrdum inerme
Atriplex (large species) (not present now)
Casuarina equisetifolia

Experiments on these with fertilizers to increase growth would be desirable.

Of course, if all of the above - suggested experiments have been tried and their results carefully applied to different models, and the indications are that too many years would be required, or that the expense would be substantially greater that that of soil removal, we needn't consider the method further. Much would depend on how much the present standing crop would weigh and how much biomass could be produced on the island per year.

One aspect that might be considered, also, is that if this method should be marginally practical, it would provide employment for the Bikinians that are to be resettled on Eneu for as many years as the decontamination is required. If we are to spend millions of U.S. dollars, we could do worse than to spend it providing employment for the resettled Bikinians rather than to bring in contract labor to carry out the planting and harvesting.

The possible impacts of these programs, vegetation-wise may be as follows:

(1a) My impression is that the bare subsoil would in a few years be covered by a scrub of Scaevola and Tournefortia, with a probable admixture, at least at first, of grasses such as Lepturus, Eustachys and Cenchrus and perhaps the sedge, Fimbristylis and various herbaceous weed species. These plants would slowly add humus to the soil and, perhaps, make possible the invasion of other, less tolerant, plant species. A more diverse vegetation would probably develop, but perhaps too slowly to be significant. The people could, and undoubtedly would, greatly alter this by fertilizing and cultivation. They would undoubtedly try to reestablish coconut plantings. These would not likely be very productive, even if they succeeded, on this sterile soil.

(1b) It would be hard to predict the vegetation that would develop after addition of a layer of soil from elsewhere. It would depend very much on where the soil came from, how fertile it would be, and what seeds were buried in it. The only experience with this process on a large scale that I know of is on Maupiti Island coral islets in the Society Islands. Here the result is a heavy growth of various weeds, which the people then kill with herbicides and burn, to make room for their commercial watermelon plantings. What the ultimate consequences of this will be are not yet apparent. About all I could predict, for Bikini, would be a rank growth of weeds, which the people would have to contend with if they wanted to carry on any horticulture or agriculture.

(2) This program should not alter the present vegetation much, except to make the coconut trees grow better and the undergowth in the plantations even more rank where it is prevalent now, and to make it appear in the present sparse or bare areas. New weeds would doubtless be introduced and some cultivated species might become naturalized. The present behavior and spread of Leucaena leucocephala may be a good indication of what other plants might do if introduced. The tendency for some species to become unusually tall and luxuriant, observed on the present survey, may also be an indication of possible consequences of heavy fertilization. I have no suggestion of a reason for the phenomenon, except that it must be related in some way to disturbance. Both indigenous and exotic

species are involved.

My reservations about this plan are based on the fact that the contamination is not removed, but merely allowed to remain in the soil and ground water .

(3) The immediate effect of flooding with sea-water on a large scale would probably be the elimination of all but the most salt-tolerant species. If the flooding were done in a dry season a salt-crust might form that would eliminate all vegetation. New vegetation would appear after rains had washed out the salt, but it would be of extremely halophytic species, possibly Fimbristylis, Lepturus, Scaevola, Tournefortia and Suriana.

The flooding would probably have to be done repeatedly, and attempts by the people to encourage vegetation might be very discouraging. The relatively low rainfall on Bikini would make vegetation-recovery a very slow process.

(4) This would be a slow process, but would possibly be less expensive and less damaging to the entire environmental complex than most of the other plans. It could be accelerated if it should turn out that certain species accumulated more radio-isotopes than others. These species could be encouraged by reseeding. The whole process might be speeded up by fertilizing with a potassium-deficient fertilizer, causing the picking up by the plants of more radioactive cesium. A critical factor would be the effective removal of the plant biomass and its disposal in areas where contamination made little or no difference.

On the list a) to e), I can offer a few comments not already mentioned earlier in this report:

a) Although there are, in the Bikini flora, no plants that are especially rare, or even of particular interest (except for the abundant "kono" or Cordia subcordata. which when of large size furnishes an excellent and attractive wood for carving). I would suggest protection for all indigenous plant species where practical. Most of these will have little or no value under present conditions. So long as support from outside, from U.S. or other friendly nation is forthcoming, the medicines and other plant products are no longer used. Even the knowledge of them is largely being lost. However, there is no assurance, in the current unsettled state of the world, that support from outside will always be available or even that contact with the rest of the world will not be broken off. In such an event, wild plants might become again very important. It is a commonly known fact that on low islands, aboriginal peoples have found uses for practically every species in their floras. Some of the knowledge of these plants and their uses may persist. If contact were to be interrupted, the native (and even some of the exotic) plants may suddenly become important again. Preserving substantial populations of plants, may be a valuable insurance against future need, in addition to providing the diversity needed to support a functioning ecosystem as well as to provide variety to keep life interesting and avert monotony. Those plants believed to be of aboriginal introduction are among the most likely to eventually be of importance, and stands of them are well worth protecting.

Kono (Cordia) mentioned above, should not only be protected wherever practical, but might be planted on contaminated or other unused ground.

(b) The only plant community represented in Bikini that seems especially favorable for seabirds is the Pisonia forest, where fairy terns, black noddies and red-footed boobies commonly nest. However, the sandy areas on Eneu would be suitable for wedge-tailed shearwater or mutton-birds, except that seabirds do not usually stay on islets inhabited by people. Earlier in this report preservation of the small islets on the southwest reef has been discussed and recommended.

(c) Native plants on Bikini are not of outstanding horticultural value, though several, such as Scaevola, Cordia, Clerodendrum and beach-morning-glories have been planted as ornamentals in places too salty for many other ornamentals. *Morinda* and *Guettarda* also, would be of value in such situations. If it should ever become fashionable to take advantage of the cooling effect of the tradewinds by building dwellings on the windward sides of the islets these plants might be very useful.

The scrub or scrub-forest on beach ridges forms a most useful windbreak to protect horticultural plantings on atoll islets. On other Marshall atolls such windbreaks protect even coconut plantations.

(d) If Nam or the windward reef-flats of other islets are ever used as spoil deposits for contaminated soil from Bikini islet the weed-seeds, and seeds of native plants such as *Lepturus*, *Scaevola*, *Fimbristylis*, *Tournefortia*, etc. already in the soil would soon provide a vegetative cover for these areas. This could perhaps be hastened by plugging rhizome fragments of bermuda grass (*Cynodon*) into the surface of the deposited spoil. However, this does not seem to me to be much of a problem. Only if the material were deposited during a prolonged dry period might the revegetation be delayed, and then replanting would not be very effective. I do not know of any salt-resistant plant the seeds of which are available in large quantities. Perhaps *Atriplex semibaecata*, from Australia but naturalized in Hawaii, might be easily harvested in sufficient amounts.

(e) If Bikini and Eneu are, indeed, effectively decontaminated, enough so that food plants raised locally would be safe to eat, "taro-pits," excavated down to the ground-water table could be made, well in from the shores. These should be protected by wind-breaks to avoid salt-spray damage. Many plants, in addition to the various taros, could be grown in and around such pits, if protected from salt spray.

It is very likely that the resettled Bikinians will plant coconuts on the undecontaminated islets. This could be risky if the accumulation of radionuclides in the coconuts is very great. It is too much to expect that the people will refrain from drinking the coconut water and using the meat.

The resettled Bikinians will undoubtedly bring exotic ornamentals with them to plant around their dwellings rather than using native plants, except for possibly *Morinda*, which is used for various purposes, and some of the *Pandanus* varieties that still persist from former plantings.

CONCLUSIONS AND RECOMMENDATIONS;

The present vegetation of Bikini Atoll still contains most of the species present in pre-nuclear test time, as indicated by the collections of W.R. Taylor in 1946. A few species have disappeared, or are not common enough to have been found in the 1985 survey. In addition, a number of exotics have appeared and some have become common. The proportions of the species have undoubtedly changed but with no records of previous species composition this cannot be assessed. On the larger islands patterns of distribution of vegetation types have been confused by various perturbations, mostly due to human agencies. Correspondence with environmental variations has become vague and hard to read. On the smaller islets vegetation patterns have become very simplified, or have always been simple. No information is available on former vegetation of these smaller islets.

Recovery of vegetation after the nuclear tests has been rapid, but with a high proportion of pioneer species, such as *Scaevola*, *Tournefortia*, *Lepturus* and *Fimbristylis*. On most of the smaller islets the vegetation appears to be almost entirely of a pioneer character, dominantly scrub and scrub-forest of *Scaevola* and *Tournefortia*. This applies even to larger islets such as Nam and Aerokojlol.

On the larger islets, Bikini and Eneu, a number of common species are observed to reach an unusually large stature. No explanation for this is evident.

Most of my recommendations are scattered in appropriate places in the text report with the pertinent information and a few, of general application, are summarized here:

1. On denuded areas, such as where contaminated soil is removed, and where it is disposed of, allow natural revegetation to take place. Work with nature rather than fighting her.

2. Bring in new exotics only when good reasons exist, then try to choose ones that seem not likely to result in troublesome side effects.

3. Attempt agriculture (or horticulture) for production of food only when radioactive contamination is low enough to avoid danger of accumulation in edible parts of plants.

4. Preserve the vegetation of beach ridges, especially on windward sides of islets, to lessen influence of salt spray.

5. Maintain populations of native species wherever practical, to preserve diversity and encourage the survival of old uses of these species, and as insurance in case of failure of outside support assistance.

6. Preserve, so far as possible, the present abundance of kono (Cordia) as a source of wood for carving and cabinet type woodwork.

7. Maintain the six tiny islets on the southwest reef in their present condition as reserves of natural diversity and bird and turtle refuges.

8. Do not encourage replanting of coconuts on still-contaminated islets.

9. Encourage scientific investigation of causes of unusual growth in stature of some plant species on Eneu and Bikini.

10. Discourage burning of vegetable trash--fallen coconut leaves, discarded husks, wind-thrown trees and branches, etc. in order to build up humus accumulation in soil.

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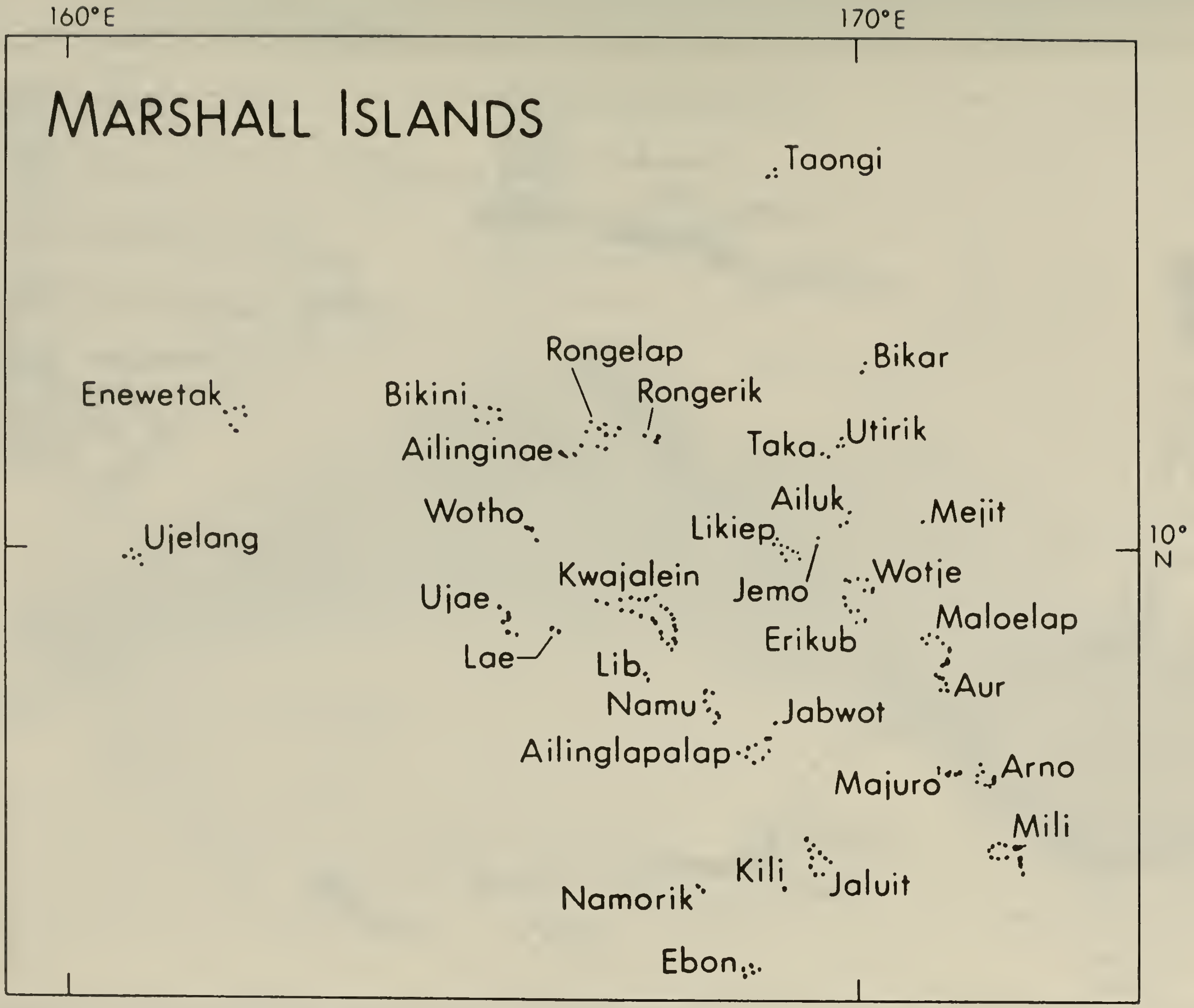


Figure 1 Map of Marshall Islands showing the position of Bikini Atoll.

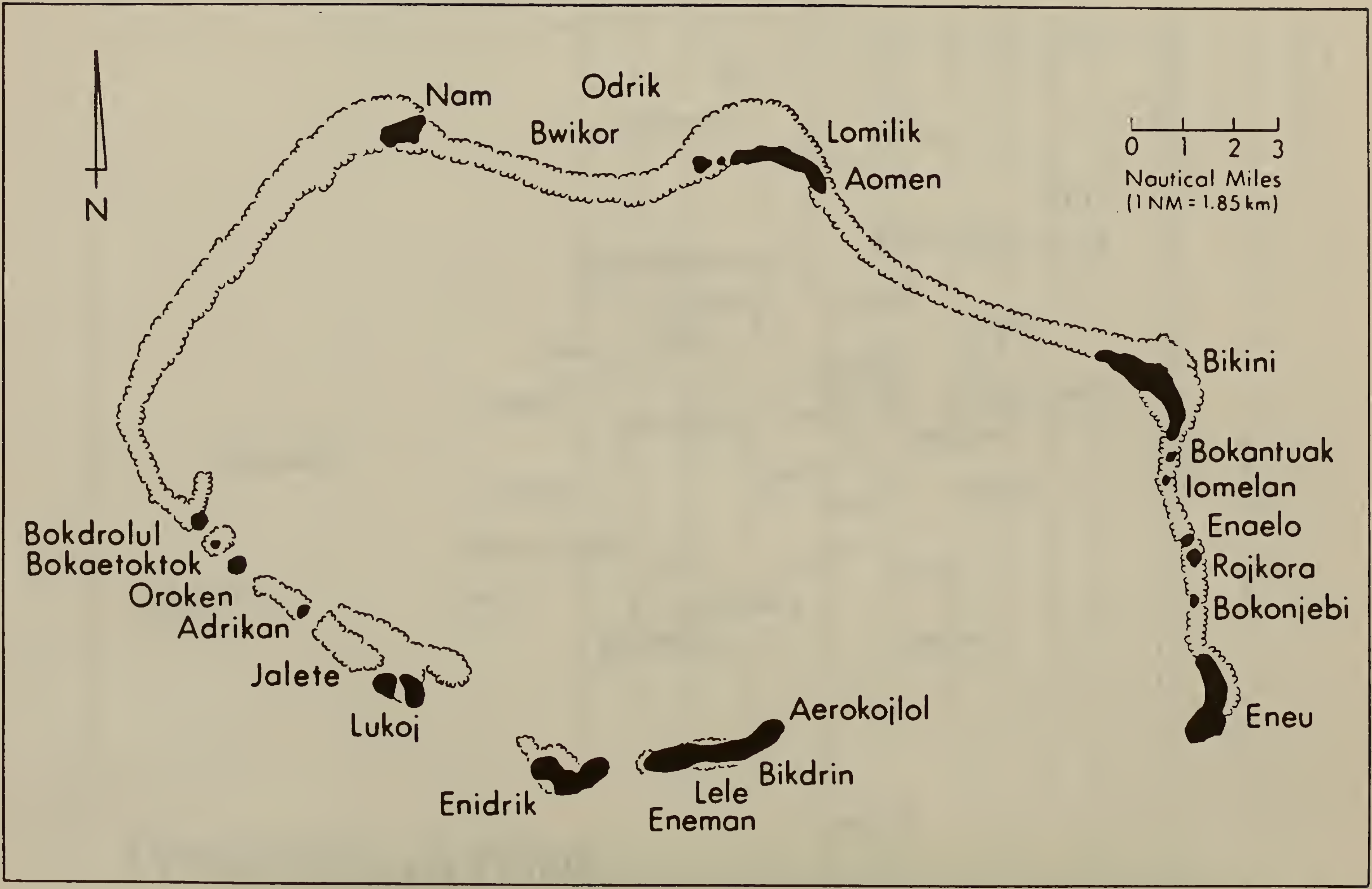
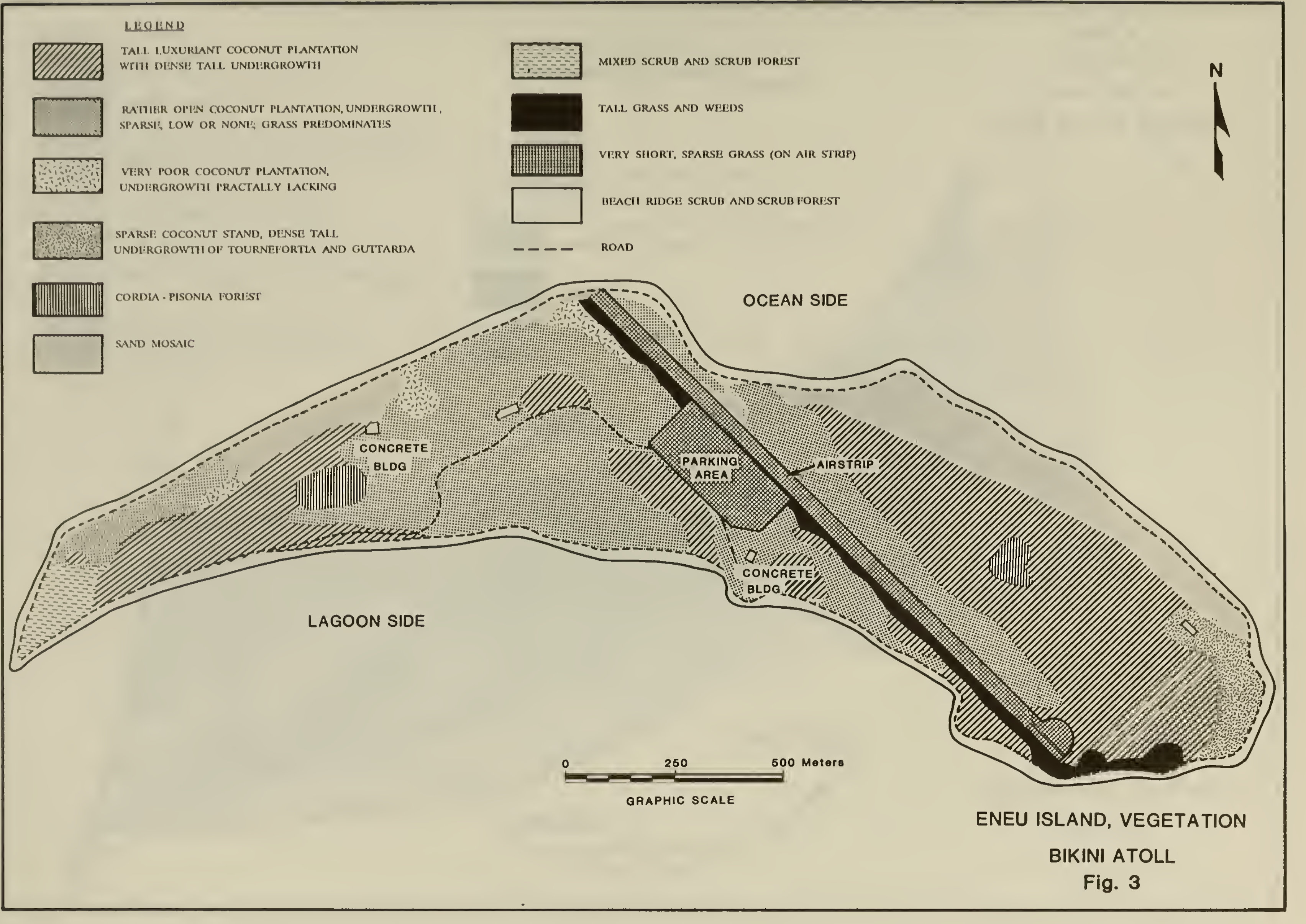
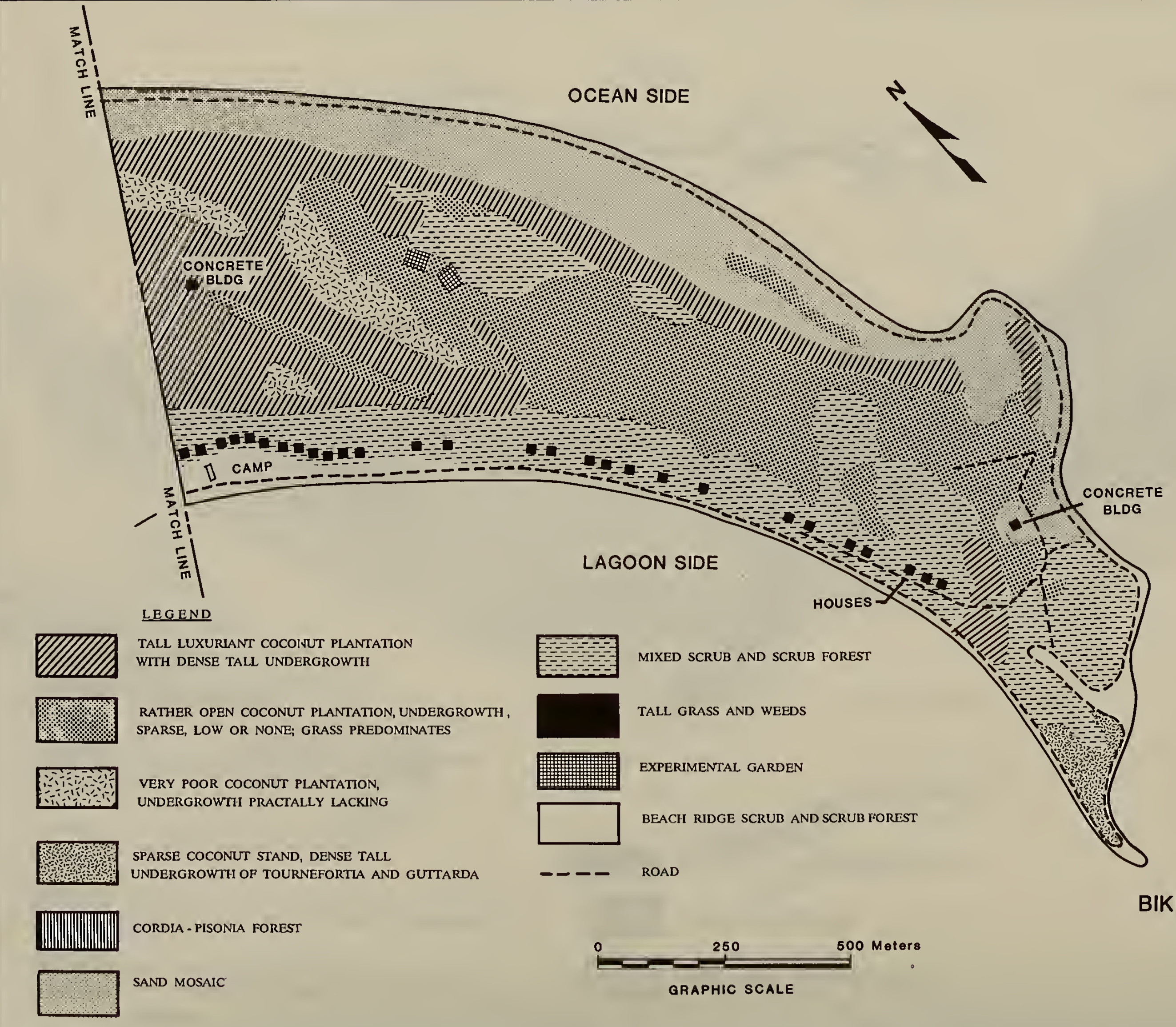


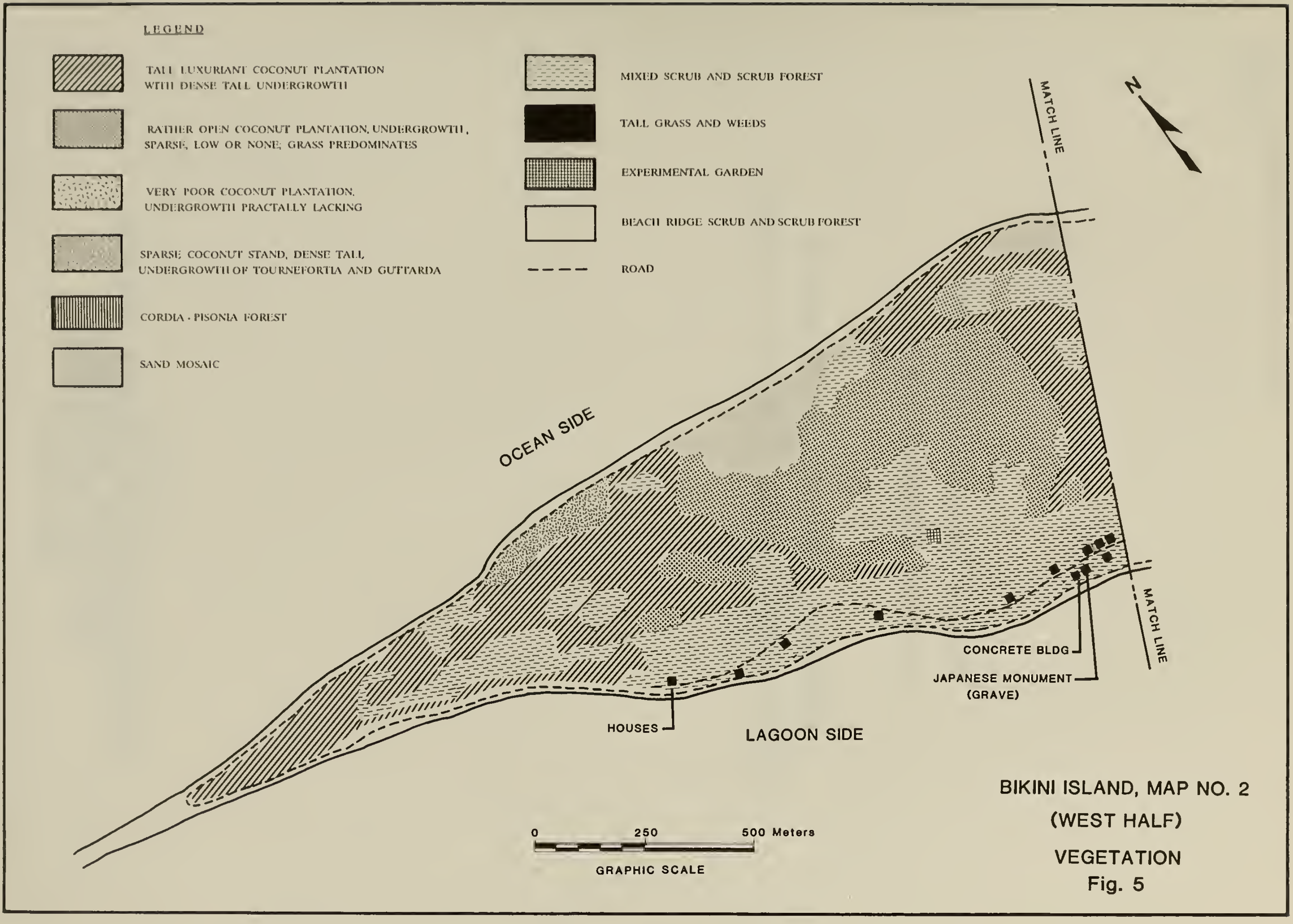
Figure 2 Map of Bikini Atoll showing islets



ENEU ISLAND, VEGETATION
BIKINI ATOLL
Fig. 3



BIKINI ISLAND, MAP NO.1
(EAST HALF)
VEGETATION
Fig. 4



BIKINI ISLAND, MAP NO. 2
(WEST HALF)
VEGETATION
Fig. 5

ATOLL RESEARCH BULLETIN
NO. 316

THE VERTEBRATES OF ROTUMA
AND SURROUNDING WATERS

BY

GEORGE R. ZUG, VICTOR G. SPRINGER,
JEFFREY T. WILLIAMS AND G. DAVID JOHNSON

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ABSTRACT

The vertebrate fauna of Rotuma consists of over 425 fish species, no amphibians, 11 terrestrial reptiles, 15 land birds and two native mammals. The zoogeographic affinity of the Rotuman fish fauna is with the Pacific plate fauna; in contrast, the affinity of the reptile fauna is with the Fijian fauna. A species list of Rotuman occurrence is provided for each of the four vertebrate groups as well as brief descriptions of the marine and terrestrial habitats.

INTRODUCTION

Rotuma is a small cluster of islands lying near the margin of the Pacific lithospheric plate at 12°30'S 177°E. Politically, these islands are part of Fiji, although they are separated from the Fiji islands by a water gap of over 450 km. They are distant from all other island groups, the closest being Niulakita, Tuvalu, approximately 350 km to the northeast. The Rotuman group consists of a large island, called Rotuma (ca. 43 km^2), and nearly a dozen islets (<1 km^2) sitting on a submarine reef/limestone bank (ca. 200 km^2) whose outer edge forms a narrow fringing reef. Several of the islets lie close (<1 km) to the northeastern and southeastern coasts of the main island. A small chain of islets and submerged reefs extends along the northwestern edge of the submarine bank, approximately 3-5 km from the main island.

All the islands are volcanic in origin (Woodhall, in press). Rotuma, the largest island, is a shield volcano of alkali-olivine basalt and hawaiite with over a dozen cones projecting above 100 m, but only six extending slightly over 200 m. The surface of Rotuma is composed largely of an admixture of lava flows, scoria and tuffs of Recent and late Pleistocene age. Weathering and erosion have been

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slight in a geological sense, but enough to produce a thin mantle of soil (even on the slopes of the cones), drainage systems without permanent streams, and narrow coastal plains of beach and outwash materials.

The climate of Rotuma is wet and warm. Records for the past 20 years show no months without rain and an average annual rainfall of 335 cm (Gill, 1977, in Woodhall, op. cit.). Rare dry periods of up to three months have occurred, however. Rainfall varys from light, misty showers to torrential downpours. In general, the daily temperature regime goes from early morning lows of 24-25°C to midafternoon highs of 31-32°C.

Our purpose for visiting Rotuma centered on its isolated position on what we thought then was the common margin of the India-Australia and Pacific lithospheric plates. The margin, however, is a fossil one, now replaced with an area of more recently formed ocean bottom and island chains that geologists have grouped into a region, which they call the Melanesian Borderlands. Springer (1982) demonstrated that the biota, particularly the shorefishes, of the Pacific plate was recognizably different from that of the continental plates to the west. We wished to determine whether the relationships of the Rotuman biota, particularly fishes and reptiles, were with the continental or Pacific plates.

Prior to our collecting, only slightly more than 100 species of shorefishes were known from Rotuma (Boulenger, 1897a) , or less than 15% of the total fish fauna that could be expected to occur there, based on our knowledge of the fish faunas of other Pacific plate island groups. All of Boulenger's species have wide distributions and are, therefore, biogeographically uninformative. We needed more representative collections, which could be made using modern collecting techniques. Similarly, the reptilian fauna was last surveyed in 1892 (Boulenger, 1897b). Not surprisingly, this fauna also consisted predominantly of widespread Southwest Pacific species, with three exceptions, two skinks otherwise restricted to the Fijian islands and an endemic gecko. The gecko was represented only by a single poorly preserved specimen. Was it actually a unique population and, if so, what is its closest relative? In addition to confirming the composition of the Rotuman herpetofauna, we wished to determine if a unique gecko species did exist on Rotuma and, if it did, to investigate aspects of its biology.

Acknowledgements.-- We visited Rotuma from 6-26 May 1987 through the courtesy of the chief and elders of the Malha'a District and Mr. Rave Fonmoa. Mr. Fonmoa, his family and friends (esp., Charley, Iliasa, Fuata, Savike, Hernan, Atta, Emilia, Lili) provided exceptional support for our field work while on Rotuma. We were also most ably assisted by Sesewa (Fijian Marine Fisheries Laboratory) and Joe Libby (Smithsonian diving officer) during the fish surveys. The Rotuma survey would have been impossible without the logistic and moral support of Dr. A.E. Lewis and the Marine Fisheries Laboratory of the Fijian Ministry of Primary Industries. The entire survey was funded by a grant from the Max & Victoria Dreyfus Foundation. We wish to thank all of these individuals and organizations for making the survey successful.

Numerous colleagues generously provided assistance with identifications of the Rotuman fishes. We greatly appreciate their aid (all the species in a listed taxon may not have been identified by the individual listed): G.R. Allen (Pomacentridae); W.D. Anderson, Jr. (Lutjanidae); K. Carpenter (Caesionidae); J. Clayton (Acanthuridae); D.M. Cohen (Bythitidae, Ophidiidae); B.B. Collette (Hemiramphidae, Scombridae); R. Cressey (Synodontidae); W.N. Eschmeyer (Caracanthidae, Scorpaenidae); A. Gerberich (Chaetodontidae, Lethrinidae, Lutjanidae); A.C. Gill (Pseudochromidae); S. Jewett (Gobiidae); L. Knapp (Platycephalidae); J.E. McCosker (Muraenidae, Ophichthidae); E. Murdy (Gobiidae); T.W. Pietsch (Antennariidae); J.E. Randall (Apogonidae, Cirrhitidae, Holocentridae, Labridae, Serranidae); W.F. Smith-Vaniz (Carangidae); W. Starnes (Priacanthidae); K. Tighe (Xenocongridae); R.P. Vari (Teraponidae); R. Winterbottom (Gobiidae). L.W. Kroenke critically reviewed the geotectonic discussion

MARINE HABITATS

We made only a cursory survey of Rotuman marine habitats. Because of interdistrict political strife, our collecting was almost entirely restricted to areas outside the barrier reef and to the lagoon adjacent to the Malha'a District. During most of our visit, much of the lagoon was subject to strong currents, which precluded the successful use of ichthyocides, our primary means of sampling near-shore and reef fishes.

Rotuma is almost completely surrounded by a barrier reef, which is less than 400 m offshore for most of the coast. We saw no mangroves or permanent freshwater streams, although Fijian Fisheries personnel (1983) reported the presence of mangroves and a small permanent stream. The shore includes extensive stretches of beach rock, lava boulders and rubble, and/or limestone interspersed with patches of sand. There are few small, white-sand beaches and extensive muddy-sand bays, the latter with marine spermatophytes and spotty dead and live coral. In many areas, low masses of dead and live coral fill the lagoon, which frequently dries during low tides. Large areas of living coral appeared to be restricted to some of the satellite islets lying outside the barrier reef of Rotuma Island proper.

FISHES

Except for a few hook-and-line caught specimens, collections of fishes were made exclusively with the use of rotenone, from the shoreline to depths of 41-42 m. A complete list of species obtained is not possible, because some groups of fishes have not been sorted by specialists and some specimens represent undescribed species.

Boulenger (1897a) published the only listing of Rotuman shore fishes; he listed 108 species, about a fourth of the number listed below. Without examining Boulenger's specimens (deposited at the British Museum), it is not possible to determine the degree to which our lists of species overlap. Undoubtedly, a large majority of Boulenger's species are included among those listed herein; however, several definitely are not; for instances: *Monacanthus scopas* (=*Amanses scopas*), *Fierasfer homei*, *F. gracilis*, *F. parvipinnis*, *Coris greenoughii* (=*C. gaimardi*), *Naseus unicornis* (=*Naso unicornis*), *Hemigymnus fasciatus*, *Synancia verrucosa* (=*Synanceia verrucosa*). All of these species are widely distributed and would be expected to occur at Rotuma, although our survey did not record their presence.

In 1983, the Fisheries Division of the Ministry of Primary Industries (then Ministry of Agricultue and Fisheries) prepared a limited number of photocopies[1] of the results of a fisheries survey of Rotuma. The report mentioned about 85 species, most from deep water well offshore and not collected or seen by us or reported by Boulenger). The number of species of fishes known from Rotuman waters is about 425. We make no prediction as to the total number that occurs there, except that it may well approach the 999 species reported for Samoa (Wass, 1984).

Although the following list is incomplete, it still offers insights into the composition and biogeographic affinities of the Rotuman fish fauna. In addition to fish captured during our survey, we have included the food fish species found by the Fiji Fisheries survey (1983), but not

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[1] The report, *The Fishery Resources of Rotuma*, is available in the library, Division of Fishes (Natl. Museum of Natural History).

collected or observed during our survey; these species are identified (F). Species observed or collected are identified as: collected (C); observed (O); discarded (D). Species not reported from Samoa (Wass, 1984) are noted with an asterisk.

Sharks & Rays

Carcharhinidae
- *Carcharhinus albimarginatus* (F)
- *Carcharhinus melanopterus* (O)
- *Triaenodon obesus* (O)

Dasyatididae
- *Dasyatis kuhlii* or *Taeniura lymna** (O)

Hexanchidae
- *Heptranchias** (F) (and/or?) *Hexanchus* (F)

Mobulidae
- *Manta birostris* (F)

Orectolobidae
- *Nebrius* sp. (F)

Sphyrnidae
- *Sphyrna* sp. (F)

Squalidae
- *Etmopterus** (F) (and/or?) *Centrophorus** (F) (and/or?) *Squalus* (F)

Bony Fishes

Acanthuridae
- *Acanthurus glaucopareius* (C)
- *Acanthurus guttatus* (C)
- *Acanthurus lineatus* (C)
- *Acanthurus nigricauda* (C)
- *Acanthurus nigrofuscus* (C)
- *Acanthurus olivaceus* (C)
- *Acanthurus pyroferus* (F)
- *Acanthurus triostegus* (C)
- *Ctenochaetus binotatus* (C)
- *Ctenochaetus striatus* (C)
- *Naso lituratus* (C)
- *Zebrasoma veliferum* (C)

Albulidae
- *Albula* sp. (F)

Ammodytidae
- *Ammodytes* sp.* (C)

Antennariidae
Antennarius *coccineus* (C)

Aploactinidae
Paraploactis sp.* (C)
Apogonidae
Apogon *angustatus* (C)
Apogon *bandanensis* (C)
Apogon *coccineus* (C)
Apogon *doryssa** (C)
Apogon *erythrinus** (C)
Apogon *exostigma* (C)
Apogon *fraenatus* (C)
Apogon *gracilis** (C)
Apogon *kallopterus* (C)
Apogon *nigrofasciatus* (C)
Apogon *novemfasciatus* (C)
Apogon *nubilis** (C)
Apogon *savayensis* (C)
Apogon sp. (C)
Apogon *unicolor** (C)
Apogonichthys *perdix** (C)
Archamia *fucata* (C)
Cheilodipterus *macrodon* (C)
Cheilodipterus *quinquilineatus* (C)
Foa *brachygramma** (C; as *F*. *vaiulae* in Wass?)
Fowleria *isostigma* (C)
Gymnapogon *urospilotus* (C)
Gymnapogon spp.* (C; at least two species)
Pseudamia *gelatinosa* (C; as *P*. *polystigma* in Wass)

Atherinidae
Genus and species unidentified (C)

Aulostomidae
Aulostomus *chinensis* (C)

Balistidae
Balistapus *undulatus* (C)
Melichthys *vidua* (C)
Pseudobalistes sp. (F)
Rhinecanthus *aculeatus* (C)
Rhinecanthus *rectangulus* (O)
Sufflamen *chrysopterus* (C)

Belonidae
Ablennes *hians* (F)

Blenniidae
Alticus sp. (C)
Aspidontus *taeniatus* (C)
Cirripectes *fuscoguttatus* (C)
Cirripectes *polyzona* (C; as *C*. *sebae* in Wass)

Cirripectes stigmaticus (C)
Cirripectes variolosus (C)
Ecsenius portenoyi (C; as *E. oculus* in Wass)
Ecsenius opsifrontalis (C)
Enchelyurus ater (C)
Entomacrodus caudofasciatus (C)
Entomacrodus decussatus (C)
Entomacrodus sealei (C)
Entomacrodus striatus (C)
Entomacrodus thalassinus (C)
*Glyptoparus delicatulus** (C)
Istiblennius andamensis (C; as *I. interruptus* in Wass)
Istiblennius chrysospilos (C; as *I. coronatus* in Wass)
Istiblennius edentulus (C)
Istiblennius periophthalmus (C; as *I. cyanostigma* and *I. paulus* in Wass)
Meiacanthus atrodorsalis (C)
Nannosalarias nativitatus (C)
Plagiotremus rhinorhynchos (C)
Plagiotremus tapeinosoma (C)
Praealticus sp. (C)
Stanulus seychellensis (C)

Bothidae
Genus and species unidentified (C)

Bythitidae
Brosmophyciops pautskei (C)
Dinematichthys sp. (C)
?*Dinematichthys* sp. (C)

Caesionidae
*Caesio teres** (C)
*Pterocaesio marri** (C)
Pterocaesio tile (C)

Callionymidae
Diplogrammus goramensis (C)
*Synchiropus laddi** (C)

Caracanthidae
Caracanthus maculatus (C)
Caracanthus unipinna (C)

Carangidae
Carangoides ferdau (F)
Caranx ignobilis (F)
Caranx lugubris (F)
Caranx melampygus (C)
Caranx sexfasciatus (F)
Elegatis bipinnulatus (F)
Seriola rivoliana (D)

Chaetodontidae
Chaetodon auriga (C)
Chaetodon citrinellus (C)
Chaetodon ephippium (C)
Chaetodon lunula (C)
Chaetodon mertensii (C)
Chaetodon ornatissimus (C)
Chaetodon pelewensis (C)
Chaetodon reticulatus (C)
Chaetodon trifascialis (C)
Chaetodon trifasciatus (C)
Chaetodon ulietensis (O)
Chaetodon vagabundus (O)
Forcipiger flavissimus (C)
Heniochus chrysostomus (C)

Cirrhitidae
Amblycirrhites bimacula (C)
Cirrhitichthys falco (C)
Cirrhitus pinnulatus (C)
Paracirrhites arcatus (C)
Paracirrhites forsteri (C)

Congridae
Conger cinereus (C)

Coryphaenidae
Coryphaena hippurus (F)

Creediidae
Chalixodytes tauensis (C)
Limnichthys donaldsoni (C)

Diodontidae
Diodon hystrix (C)

Ephippididae
Platax orbicularis (C)

Gempylidae
Promethichthys prometheus (F)
Ruvettus pretiosus (F)
*Thyrsitoides marleyi** (F)

Gerreidae
Gerres oyena (C)

Gobiesocidae
Genus and species unidentified (C)

Gobiidae
Amblygobius bimaculatus (C)
Amblygobius nocturnus (C)

- Amblygobius phalaena (C)
- Asterropteryx semipunctatus (C)
- Bryaninops ridens* (C)
- Callogobius sp. A (C)
- Callogobius sp. B (C)
- Callogobius sp. C (C)
- Eviota albolineata* (C)
- Eviota disrupta (C)
- Eviota distigma (C)
- Eviota melasma (C)
- Eviota nebulosa* (C)
- Eviota prasina* (C)
- Eviota pseudostigma (C)
- Eviota punctulata* (C)
- Eviota zonura (C)
- Eviota sp. a (C)
- Eviota sp. b (C)
- Fusigobius neophytus (C)
- Fusigobius sp. (C)
- Gnatholepis sp. (C)
- Gobiodon rivulatus (C)
- Gobiodon sp. A (C; brown, chin grooves deflected anteriorly)
- Gobiodon sp. B* (C; brown, 2 bars below eye, straight chin grooves)
- Gobiodon sp. C(*?) (C; pale, 5-6 bars on head, no chin grooves)
- Istigobius decoratus (C)
- Istigobius rigilius (C)
- Lotelia sp.* (O)
- Nemateleotris magnifica (O)
- Paragobiodon echinocephalus (C)
- Paragobiodon lacunicolus (C)
- Paragobiodon melanosomus* (C)
- Paragobiodon xanthosomus (C)
- Priolepis semidoliatus (C)
- Ptereleotris evides (C)
- Ptereleotris heteroptera (C)
- Rotuma lewisi*
- Trimma caesiura (C)
- Trimma emeryi (C)
- Trimma eviotops (C)
- Trimma okinawae* (C)
- Trimma (C; two undescribed species)
- Valenciennea sp. (C)
- Xenisthmus clara (C)
- Xenisthmus cf. clara (C)
- several unidentified genera and species (C)

Hemiramphidae

- Hyporhamphus dussumieri (C)

Holocentridae
Myripristis adustus (C)
Myripristis berndti (C)
Myripristis kuntee (C)
Myripristis murdjan (C)
Myripristis pralinus (C)
Myripristis violaceus (C)
Neoniphon sammara (C)
Plectrypops lima (C)
Sargocentron caudimaculatum (C)
Sargocentron diadema (C)
*Sargocentron lepros** (C)
Sargocentron microstoma (C)
Sargocentron punctatissimum (C; as *S. lacteoguttatum* in Wass)
Sargocentron spiniferum (C)
Sargocentron tiere (C)
Sargocentron tiereoides (C)
Sargocentron violaceum (C)

Kuhliidae
Kuhlia mugil (C)

Kraemeriidae
Kraemeria sp. (C)

Kyphosidae
Kyphosus sp.(O)

Labridae
Anampses twistii (C)
Bodianus axillaris (O)
Cheilinus diagramma (C)
Cheilinus oxycephalus (C)
Cheilinus undulatus (C)
Cheilinus unifasciatus (C)
Choerodon jordani (C)
Cirrhilabrus sp. (C)
Epibulus insidiator (C)
Gomphosus varius (C)
Halichoeres biocellatus (C)
Halichoeres hortulanus (C)
Halichoeres margaritaceus (C)
Halichoeres marginatus (C)
Halichoeres trimaculatus (C)
Labroides bicolor (C)
Labroides dimidiatus (C)
Labropsis australis (C)
Macropharyngodon meleagris (C)
Pseudocheilinus evanidus (C)
Pseudocheilinus hexataenia (C)
Pseudodax moluccanus (C)
Stethojulis bandanensis (C)

Thalassoma hardwicke (C)
Thalassoma purpureum (C)
Thalassoma quinquevittatum (C)
*Thalassoma trilobatum** (C)
Wetmorella nigropinnata (C)

Lethrinidae
Gnathodentex aurolineatus (C)
*Gymnocranius griseus** (F)
Gymnocranius lethrinoides (F)
*Gymnocranius robinsoni** (F)
Lethrinus amboinensis? (F)
Lethrinus elongatus (F)
Lethrinus harak (C)
Lethrinus mahsena (C)
Lethrinus rubrioperculatus (C)
Monotaxis grandoculis (C)
Wattsia mossambica (F, as *Gnathodentex mossambicus*)

Lutjanidae
Aphareus furca (C; formerly *A. furcatus*, W.D. Anderson, Jr., pers. comm.)
Aphareus rutilans (F)
Aprion virescens (F)
Etelis carbunculus (F)
Etelis coruscans (F)
Etelis radiosus (F)
Lutjanus bohar (F)
Lutjanus fulvus (C)
Lutjanus gibbus (C)
Lutjanus kasmira (C)
*Lutjanus malabaricus** (F)
*Paracaesio caeruleus** (F)
*Paracaesio gonzalesi** (F)
Paracaesio kusakarii (F)
Paracaesio stonei (F)
*Pristipomoides argyrogramminicus** (F)
Pristipomoides auricilla (F)
Pristipomoides filamentosus (F)
Pristipomoides flavipinnis (D)
Pristipomoides multidens (F)
*Pristipomoides typus** (F)
Pristipomoides zonatus (D)

Malacanthidae
Malacanthus brevirostris (C)

Monacanthidae
Cantherhines pardalis (C)
Oxymonacanthus longirostris (O)
*Pervagor janthinosoma** (C)

Moringuidae
- Moringua sp. (C)

Mugilidae
- Crenimugil crenilabis (F)
- Liza vaigiensis (C)
- Valamugil engeli (C)
- Valamugil seheli (F)

Mugiloididae
- Parapercis cephalopunctata (C)
- Parapercis clathrata (C)

Mullidae
- Mulloides flavolineatus (C)
- Mulloides vanicolensis (C)
- Parupeneus barberinus (C)
- Parupeneus moana (C; as trifasciatus in Wass)
- Parupeneus cyclostomus (C; as chryserydros in Wass)
- Parupeneus pleurostigma (C)
- Upeneus taeniopterus (F; as U. arge)

Muraenidae
- Gymnomuraena zebra (C)
- Gymnothorax buroensis (C)
- Gymnothorax fimbriatus (C)
- Gymnothorax margaritophorus (C)
- Gymnothorax rueppelliae (C)
- Gymnothorax undulatus (C)
- Gymnothorax zonipectis (C)
- Uropterygius macrocephalus* (C)

Ophichthidae
- Callechelys marmorata (C)
- Callechelys melanotaenia (C)
- Leiuranus semicinctus (C)
- Muraenichthys sp.* (C)
- Myrichthys colubrinus (C)

Ophidiidae
- Brotula multibarbata (C)
- Brotula townsendi (C)

Ostraciidae
- Ostracion meleagris (C)

Pempherididae
- Parapriacanthus guentheri* (C)
- Pempheris oualensis (C)

Platycephalidae
- Thysanophrys chiltonae (C)
- Thysanophrys otaitensis (C)

Plesiopidae
Plesiops coeruleolineatus (C)

Pleuronectidae
Samariscus triocellatus (C)

Pomacanthidae
Centropyge bispinosus (C)
Centropyge flavissimus (C)
Pygoplites diacanthus (C)

Pomacentridae
Amphiprion chrysopterus (C)
Amphiprion melanopus (O)
Amphiprion perideraion (C)
Chromis acares (C)
Chromis agilis (C)
Chromis iomelas (C)
Chromis margaritifer (C)
Chromis viridis (C; as *C. caerulea* in Wass)
Chromis weberi (C)
Chromis xanthura (C)
Chrysiptera biocellata (C)
Chrysiptera cyanea (C)
Chrysiptera glauca (C)
Chrysiptera leucopoma (C)
Dascyllus aruanus (C)
Dascyllus reticulatus (C)
Dascyllus trimaculatus (C)
Neopomacentrus metallicus (C)
Plectroglyphidodon dickii (C)
Plectroglyphidodon johnstonianus (C)
Plectroglyphidodon lacrymatus (C)
Plectroglyphidodon leucozona (C)
*Pomacentrus bankanensis** (C)
Pomacentrus coelestis (C)
*Pomacentrus philippinus** (C)
Pomacentrus vaiuli (C)
Stegastes albifasciatus (C)
Stegastes fasciolatus (C)
Stegastes lividus (C)
Stegastes nigricans (C)

Priacanthidae
Heteropriacanthus cruentatus (C)

Pseudochromidae
Pseudoplesiops multisquammata (C; as *Chlidichthys* sp. in Wass)
Pseudoplesiops rosae (C)
Pseudoplesiops sp. (C)

Scaridae
- Scarus ghobban (C)
- Scarus gibbus (D; photographed)
- Scarus sordidus (C)

Scombridae
- Acanthocybium solandri (F)
- Auxis thazard (F)
- Grammatorcynus bilineatus (C)
- Gymnosarda unicolor (D)
- Katsuwonus pelamis (F)
- Scomberomorus commerson* (F, verification desired)
- Thunnus albacares (F)

Scorpaenidae
- Pterois radiata (C)
- Scorpaenodes hirsutus (C)
- Scorpaenodes kelloggi* (C)
- Scorpaenodes parvipinnis (C)
- Scorpaenodes scaber* (C)
- Scorpaenopsis sp. (C)
- Scorpaenopsis diabolus (C)
- Scorpaenopsis fowleri (C)
- Sebastapistes tinkhami* (C)
- Taenianotus triacanthus (C)

Serranidae
- Aethaloperca rogaa* (C)
- Cephalopholis argus (C)
- Cephalopholis igarashiensis (F)
- Cephalopholis leopardus (C)
- Cephalopholis spiloparaea (C) (as C. sp. in Wass?)
- Cephalopholis sonnerati (F)
- Cephalopholis urodeta (C; formerly C. urodelus)
- Epinephelus chlorostigma* (F)
- Epinephelus cylindricus* (F)
- Epinephelus fuscoguttatus (F)
- Epinephelus maculatus (F)
- Epinephelus magniscuttis* (F)
- Epinephelus microdon (F)
- Epinephelus morrhua (F)
- Epinephelus septemfasciatus* (F)
- Epinephelus spilotoceps* (C)
- Grammistes sexlineatus (C)
- Liopropoma susumi (C)
- Plectranthias longimanus* (C)
- Pseudogramma bilinearis (C)
- Pseudogramma polyacantha (C)
- Variola albomarginata* (F)
- Variola louti (C)

Siganidae
- Siganus punctatus (C)

Soleidae
   Genus and species unidentified (C)

Sphyraenidae
   Sphyraena barracuda (D)

Symphysanodontidae
   Symphysanodon typus* (C)

Syngnathidae
   Choerichthys brachysoma* (C)
   Corythoichthys flavofasciatus (C)
   Corythoichthys intestinalis (C)
   Cosmocampus banneri* (C)
   Doryrhamphus dactyliophorus (C)
   Doryrhamphus excisus (C)
   Doryrhamphus melanopleura (C)
   Micrognathus andersonii* (C)
   Phoxocampus diacanthus (C)

Synodontidae
   Saurida gracilis (C)
   Synodus binotatus (C)
   Synodus englemani (C)
   Synodus variegatus (C)

Teraponidae
   Terapon theraps* (C)

Tetraodontidae
   Arothron hispidus (C)
   Canthigaster amboinensis (C)
   Canthigaster janthinoptera (C)
   Canthigaster solandri (C)
   Canthigaster valentini (C)

Tripterygiidae
   Enneapterygius sp. (C)
   Helcogramma chica (C)
   Helcogramma ellioti (C)
   Helcogramma fuscopinna* (C)
   Helcogramma hudsoni (C)

Xenocongridae
   Kaupichthys atronasus (C)
   Kaupichthys brachychirus (C)
   Kaupichthys hyoproroides (C)
   Kaupichthys sp. A (C)
   Kaupichthys sp. B (C)

Zanclidae
   Zanclus cornutus (O)

TERRESTRIAL HABITATS AND VEGETATION

The flora of Rotuma was not formally surveyed or identified by any member of the expedition. Nonetheless, the impressions and observations of the flora and its zonation by a zoologist (G.R.Z.) may be useful to inform the reader of the types of habitats currently available to terrestrial vertebrates and to serve as a historical record.

Topographically, the island consists of a series of three terraces: the first is littoral and partially underwater at low tide and completely submerged at high tide. The second is the coastal terrace and extends from the supralittoral zone to the beginning of the hill slopes. The third terrace is at mid elevation along the slopes of the hills and forms a central plateau of gentle undulations from which the hill tops (remanent volcano cones) arise abruptly and steeply. Although this is an overgeneralization, it does convey an impression of the landscape better than the narrow contour lines on a topographic map; it also identifies the different soil and vegetation zones.

The coastal terrace is narrow, typically 100-150 m or narrower throughout most of the island, except for the eastern and northeastern ends of the island, where it may be 1 km in extent. The soil is predominantly sandy. This terrace is the area of human habitation, mixed with small garden plots, small coconut grooves, and patches of secondary forest. The latter exist in areas of heavy lava rubble or areas simply not needed presently for gardening. The central plateau occupies the entire center of the island (eastern portion) at an approximate elevation of 30-60 m. The soil is predominantly a reddish brown "clay". The plateau is an area of intense agriculture; coconut plantations predominate, cocoa groves are a recent agricultural introduction, taro, cassava and yam gardens, and infrequent small patches of bush (secondary growth forest) are also present.

The boundary between the littoral and the coastal terrace is an abrupt and usually vertical bank, the base of which is awash at high tide. Most beaches exist only at low tide and are predominantly of lava rubble or flows interspersed with patches of sand. The coastal terrace and the central plateau are separated by a slope of variable length and inclination, typically less than 30° slope and 1 km in width. The soil ranges from dark-brown humus or clay mixed with small lava rubble to jumbled lava blocks. Secondary growth forest covers the majority of the slope area, although small coconut groves or small gardens are scattered throughout. The forest is in various stages of growth with fairly open canopied forest of 5-10 m to more closed canopied forests of 15-20 m. Understory vegetation occurs throughout, but is nowhere so dense as to be impenetrable. Not surprising for such a small island with long human occupation, there is no area of undisturbed forest, although some trees may be centuries old; we measured one tree with a 9 m dbh on the top of Mt. Suelhof. Within the older secondary forest, trees with buttresses were not uncommon although few had dbh >1 m, and in the older forest, most trees were >40 cm dbh, and coconut palms were a common species in all stages of forest regrowth. The slopes of the higher peaks also bore secondary growth forests, most in early stages of regeneration, and often one side was cleared to the top for gardening or coconut plantations. Slopes are steep, often >30° inclination with clay soil.

Rainfall is heavy and frequent in Rotuma, thus the interior of the forest is quite moist with numerous epiphytes; ferns are probably the dominant epiphytic plant. Moss is also common on trees and rocks.

MAMMALS

Aside from the assorted domestic mammals (cattle, horses, pigs, goats, dogs and cats), only two wild species were observed, a rat and a bat.

The bat (presumably *Emballonura*) was observed infrequently and only singly in or adjacent to the forest; it had a weak fluttering flight pattern. No fruit bats presently occur on the islands; Rotumans declared their absence.

The rat, *Rattus exulans*, is widespread from the houses of the coast to the gardens and plantations of the central plateau. Only a single rat was captured and tentatively identified; it is likely that *R. rattus* and/or *R. norvegicus* are also present.

BIRDS

The following list of land birds derives from Clunie's (1984) excellent handbook and follows the order of his presentation. Miscellaneous observations are appended.

Egretta sacra (reef heron). Although this is a common bird of the shoreside in the Fiji Islands, we saw none in Rotuma.

Anas superciliosa (black duck). Not observed. *Gallus gallus* (jungle fowl). Feral chickens were regularly seen in the secondary growth forest or along its margin. The few roosters seen as they fled possessed the jungle fowl color pattern; however, their morning calls remain like their domestic brethren and not the higher pitch, rougher-sounding call of their Asian ancestors.

Gallirallus philippensis (banded rails). This species is common. Typically 6-8 would be seen for every kilometer of road in the morning. They occur singly or in pairs, feeding on the road. They seldom flew.

Porphyrio porphyrio (purple swamphen). Not observed.

Columbia vitiensis (white-throated pigeon). Not observed.

Ptilinopus porphyraceus (crimison-crown fruit pigeon). This species may have been observed once, but the fleeting observation of a small pigeon was too brief for adequate confirmation of its identity.

Ducula pacifica (Pacific pigeon). This large pigeon was seen and heard daily. They feed in the treetops singly or in small groups (2-3). From a distance, the head, neck and chest are grey, and back and wings a dark metallic blue.

Eudynamis taitensis (long-tailed cuckoo). Not observed.

Tyto alba (barn owl). A single individual was seen at noon (sunny day), in flight, in a large coconut plantation on the island's central plateau.

Collocalia spodiopygia (white rumped swiftlet). Not observed.

Halcyan chloris (white-collared kingfisher). Not observed.

Lalage maculosa (Polynesian triller). A common species observed most frequently in gardens and along the edge of secondary growth forest.

Myiagra vanikorensis (Vanikoro broadbill). Not observed.

Myzomela cardinalis (cardinal honey eater). The honey eater is the most abundant of Rotuma's birds. It occurs everywhere, feeding as a gleaner on outer branches in the forest or dangling from seed heads of weeds in open areas. Young fledglings were seen during our mid May visit.

Aplonis tabuensis (Polynesian starling). This species is also extremely abundant and occurs in all habitats, although my impression is that it prefers the more open habitats. Its diet includes overripe papayas and chili peppers, of the latter it selects only the ripe red ones and swallows them whole.

Clytorhynchus vitiensis (lesser shrikebill). The shrikebill is a forest species, feeding primarily among the tree branches, but occasionally descending to the forest floor to catch an insect. Large insects are subdued by repeatedly and rapidly striking them against the perch branch.

Only a few shore- and sea birds were observed, several inadequately for positive identification.

Arenaria interpres (ruddy turnstone). Small flocks (3-6) were seen several times, usually feeding among the rocks of the littoral area and once on the airstrip.

Pluvialis dominica (lesser golden plover). This plover was seen everyday, as often in the grassy areas within the villages as in the littoral areas; they usually occurred in small groups of 2-3.

Fregata (frigate-bird). Frigate-birds were common around Uea and its adjacent islets, but were rarely seen near the main island. They were not observed sufficiently close to identify them as lesser or greater frigates.

Gygis alba (white tern). This was the commonest tern near-shore and over the island.

Phaethon lepturus (white-tailed tropic bird). These birds were seen regularly (every other day) gliding high over the central plateau. They generally occurred singly, but six were observed in one flock.

cf. Sterna A small dark tern was often seen flying close to water outside the reef. It appeared to be slightly smaller than the white tern and had a light or white patch on its head.

Sula leucogaster (brown booby). This species was also commonly seen outside of the reef.

REPTILES

Eight species of lizards were observed and collected in Rotuma. The Pacific boa (Candoia bibronii) was reported from the island by Boulenger (1897b) and persists according to the Rotumans; however, they see it rarely. The lizards are:

Emoia concolor (green tree skink). Not observed. The specimen reported by Boulenger is present in the British Museum, and examination confirms its identification.

Emoia cyanura (copper-striped skink). This terrestrial skink is the most abundant lizard. It occurs in all habitats from human dwellings to the forest.

Emoia nigra (black skink). The black skink is the largest Rotuman lizard and is fairly common. In habits, it is terrestrial to semi-arboreal, feeding and seeking shelter in rock or wood piles as well as climbing high in trees.

Emoia trossula (barred skink). Although this skink may also feed on the ground, it appears to be the most arboreal of the observed Rotuman skinks. The skink is commonly seen clinging head down on the side of trees in open areas, such as coconut plantation and fence rows, but it also occurs in secondary growth forest. It is abundant.

Gehyra mutilata (stump-toed gecko). This gecko appears to be restricted to buildings.

Gehyra oceanica (oceanic gecko). This is the largest gecko in Rotuma. Although it occurs on buildings, it is predominantly a forest inhabitant, living in upright dead trees and holes of living ones.

Lepidodactylus gardineri (Rotuman forest gecko). This gecko is the only endemic Rotuman reptile. It lives in termite galleries in dead tree branches and trunks.

Lepidodactylus lugubris (mourning gecko). This gecko is nearly always associated with human habitation. Only one series of specimens was collected away from dwellings in an erect rotten tree trunk adjacent to a pasture.

Lipinia noctua (moth skink). In Rotuma, this skink was found only in forested and arboreal situations, e.g., palm axils, beneath bark or in termite galleries of dead trees.

Nactus pelagicus (Pacific slender-toed gecko). This gecko was also observed only in forested situations, during the day beneath surface detritus and at night on the sides of trees.

DISCUSSION

The geographical position and geotectonic history of Rotuma place this small cluster of islands at a faunistic boundary and lead to the question of whether the affinities of the Rotuman fish fauna are with the fauna of the Pacific plate, India-Australia plate, or with the main islands of Fiji. The main Fijian islands harbor a considerable number of endemic fish species. Rotuma, however, lies about 450 km north of the nearest reefs of these islands. Rotuma is also moderately isolated from the nearest neighboring island, Niulakita, Tuvalu (about 350 km to the northeast) on the Pacific lithospheric plate. There are numerous shallow, submarine banks that decrease the isolation of the island and provide stepping stones for dispersal: eastward to the Samoa Islands, westward to the Santa Cruz Islands; and southward to Fiji. These stepping stones were more closely connected during periods of glacial sea level lowering; Gibbons (1985:113) shows the distribution of land masses in the southwest Pacific during the last ice age, 18,000 years ago.

The geotectonic history of Rotuma is important for an understanding of its biota. Beginning in the middle Eocene (ca. 45 million years ago - MYBP), the convergence boundary where island arc volcanism was occurring between the India-Australia and Pacific plates included stretches along the coast of New Guinea and along the then combined New Caledonia-Norfolk Ridge (Kroenke, 1984). In late Eocene-early Oligocene (ca. 38 MYBP), there was an extensive northeastern shift in position of the convergence boundary and the beginning of island-arc volcanism along the new boundary. Volcanic islands formed along the new boundary, and from late Eocene-early Oligocene to early Miocene (ca. 21 MYBP), the various linear island chains ranging from New Britain and New Ireland east to Fiji were established. The formation of these island chains trapped a large area of the Pacific plate between them and the margin of the India-Australia plate (Kroenke, 1984), effectively adding this portion of the Pacific plate to the India-Australia plate. The volcanic structure on which Rotuma rests appears to have formed initially in the Tertiary on the margin of the India-Australia lithospheric plate bordering the old Vitiaz Trench (Woodhall, in press, and references cited therein). Possibly this structure was formed along with the linear island chains between New Britain and Fiji.

In mid-Miocene, about 13.5 MYBP, the Samoan Islands began to form (Natland and Turner, 1985) on the Pacific Plate just east of Fiji. Stepping-stone islands quite possibly existed between Fiji and Samoa at this time. About 10 MYBP, the ocean floor (i.e., the trapped portion of the Pacific plate) behind the convergence zone began subducting the island arcs that had formed along the zone in the late Eocene-early Oligocene (Kroenke, 1984). Consequently, the contiguous, linear chains of island arcs (and Rotuma?) that were once well out on the Pacific plate (at least surrounded by Pacific plate) moved west and/or south, overriding the northeastern margin of the India-Australia plate.

About 8 to 6 MYBP the New Hebrides Arc began a clockwise rotation and the Fiji Arc began a counterclockwise rotation associated with ocean-floor spreading that formed the North Fiji Basin (Kroenke, 1984). The effects of these rotations were to: separate Fiji from the New Hebrides and increase the distance between the two; increase the distance between Fiji and the Samoa Islands; and increase the distance of both the New Hebrides and Fiji islands from Rotuma, which essentially remained in place, near the forearc side of the old Vitiaz Trench. From the late Pliocene to Pleistocene, renewed volcanism (probably a result of plate reorganization in the area) capped the original, older edifice of Rotuma with younger volcanics (Woodhall, in press).

A reasonably complete modern listing of the fishes of Fiji (excluding Rotuma) has not been published. Fowler's (1959) compilation is too incomplete and inaccurate for an analysis of faunistic affinities. Our knowledge of the

Fijian fish fauna derives from a large Fijian collection made in 1982 by VGS and associates and several other large Fijian collections made recently by others (e.g., Royal Ontario Museum). The number of fish families (and species) present at Fiji (Springer, 1982) is greater than is found at either Rotuma or Samoa. Many species of fishes were believed to be endemic to Fiji prior to our trip to Rotuma, and none of these were taken subsequently at Rotuma. Among these endemics are several species of blenniids (Smith-Vaniz, 1976; Springer, 1988a), all of which are replaced at Rotuma and Samoa by different, but closely related species; for example: Ecsenius fijiensis at Fiji, E. opsifrontalis at Rotuma, Samoa, and other Pacific plate localities; Ecsenius pardus at Fiji, E. portenoyi endemic to Rotuma and Samoa; Plagiotremus flavus at Fiji, P. laudandus at Rotuma, Samoa, and many other localities in the western and central Pacific; Meiacanthus ovalauensis at Fiji, M. atrodorsalis at Rotuma, Samoa, and many other localities in the western and central Pacific; Alticus sp. "A" at Fiji, Alticus sp. at Rotuma and Samoa.

The fishes of Samoa are reasonably well known. Wass (1984) reported 999 species from Samoa, approximately 40 of which were undescribed or unknown elsewhere. Wass believed that most of these 40 species probably occurred outside the Samoa area, and we concur. About 60 species (noted with an asterisk in Table 1) that we report from Rotuma, were not included in Wass' list. Perhaps one of these, Rotuma lewisi Springer (1988b), a gobioid, may prove to be a Rotuman endemic, but we believe that all but a few of these Rotuman species also occur at Samoa. The gobioid is a tiny, cryptic species, easily overlooked.

Of the species in our Rotuma list, most appear to be widely distributed and, therefore, provide little information on the biogeographic relationships of Rotuma. Those species that we consider informative for biogeographic purposes are: Alticus sp., Cirripectes variolosus*, Cirripectes fuscoguttatus*, Ecsenius opsifrontalis*, Ecsenius portenoyi**, Entomacrodus sealei*, Chalixodytes tauensis*, Paraploactis sp.**. Terapon theraps**, Amphiprion chrysopterus*. Of these ten species, six (marked with *) are widely distributed Pacific Plate endemics (Springer, 1982), three (**) are representative of higher taxonomic groups that are widely distributed in the Indo-west Pacific but absent from the Pacific plate except marginally, and the tenth, Alticus sp., was discussed above. Several, non-Pacific plate families are known marginally on the plate at Samoa, and at Fiji, but are unknown at Rotuma: Opistognathidae, Plotosidae, Triodontidae, and Uranoscopidae (a single species of each at Samoa). Only one family, Aploactinidae (represented by Paraploactis), is known from both Rotuma and Fiji, but unknown at Samoa. The Rotuma fish fauna, therefore, shows its closest biogeographic relationships with Pacific Plate localities, and especially Samoa.

The terrestrial fauna of Rotuma show four biogeographic patterns. The first is the Polynesian gateway pattern (Robinson, 1975) with Rotuma lying in the string of islands between the Solomons and Samoa and serving as one of the stepping stones in species dispersal from northern Melanesia to western Polynesia. Among the reptiles, *Emoia nigra* best represents this pattern, occurring abundantly in the Solomons, Rotuma and Samoa, also occurring to the south in Fiji. A number of birds (e.g., *Gallirallus philippensis*, *Lalage maculosa*, *Apolonis tabuensis*) also show the Polynesian gateway pattern. A Polynesian distribution is shown by a few birds (e.g., *Myzomela cardinalis*) extending westward from Polynesia to Rotuma but not beyond. There are no reptiles with this pattern, and to the contrary, two species (*Emoia concolor*, *Emoia trossula*) link Rotuma more closely to Fiji than to Samoa. This linkage is reinforced by the absence of *Emoia adspersus* from Rotuma but its presence in Samoa, Futuna and Tuvalu, and the occurrence of *Emoia murphyi* and *E. samoensis* (sister species to the two aforementioned Rotuman-Fijian *Emoia*). The distribution of *E. trossula* is unlike that of any other Pacific reptile, occurring on Rotuma, widely in the Fiji islands, on some of the Tonga islands and on Rarotonga in the Cook islands. The final pattern is the existence of a Rotuman endemic, *Lepidodactylus gardineri*. The interspecific relationships of this gecko genus are not known. *L. gardineri* is clearly not related to the widespread parthenogenetic *L. lugubris* and is not especially similar to the endemic bisexual species of Tonga and Fiji. Bisexual *Lepidodactylus* are unknown for Tuvalu, Wallis/Futuna or Samoa.

Overall the geographic affinties of the Rotuman lizard fauna are with the Fijian fauna. The bird fauna combines elements of both the Samoan and Fijian faunas. The mammal fauna is too small and of widespread species to be useful in a biogeographic sense.

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THE PALAUAN AND YAP MEDICINAL PLANT STUDIES OF MASAYOSHI OKABE, 1941-1943

BY

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AND LESLIE A. PRAY

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ABSTRACT

Masayoshi Okabe visited the Palau and Yap Islands to study the local medicinal plants and diseases treated through their use. He made reports of his findings (1941a, 1943a) in Japanese. In this paper the authors present for the first time in the English language a published record of Okabe's findings.

INTRODUCTION

On September 25, 1513, from a hilltop on the Isthmus of Panama, conquistador Vasco Nunez de Balboa looked down upon and, in the name of Ferdinand II of Spain, christened the vast ocean before him the "South Sea." Since then, the paradise islands of the Pacific have continued to be the setting for much enterprise in behalf of European, American and Asian powers.

Micronesia is one of three major geographic regions in Pacific Oceania. It comprises three main island chains, one of them being the Caroline Archipelago of which Palau and Yap are a part. Ruiz Lopez de Villalobos of Spain was the first European explorer to set foot on the shores of Palau, in 1543 (Smith, 1983a). Spain, though exerting little authority, would claim sovereignty over the islands for the next three centuries. In the meanwhile, British and American traders frequented the islands in an effort to expand their rich Far East trade lines by scouting the Pacific itself for tradeable items such as pearl shell and the sweet-smelling sandalwood. Whalers too roamed the Pacific in search of the luxurious North Pacific sea otter fur that so delighted the Oriental tastes (Oliver, 1961).

Following the Spanish-American War, Germany purchased the Caroline and Mariana Islands, excepting Guam, from Spain in 1899. For the next fifteen years, Palau and Yap were considered German protectorates during which time several new tropical industries prospered, most notably that of copra, the dried meat of the coconut from which oil was extracted for use in soap, margarine and nitroglycerine (Oliver, 1961). In 1909, the Germany South Sea Phosphate Company opened a phosphate mine in Angaur, the southernmost Palauan island (Okabe, 1940a).

In October 1914, the League of Nations mandated the Micronesian Islands to Japan. Although the Japanese did not move to Micronesia to stay until after World War I, they had since Spanish times been active traders in the Carolines, and hence there was a significant Japanese population already living on the islands (Oliver, 1961). The islands were awarded to Japan as a mandate, not a possession, and Japan was required to make certain agreements with other nations at the Peace Conference. However, Japan honored few of her promises, and Japanese Micronesia quickly became

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known to the rest of the world as the "Islands of Mystery." Japan later withdrew from the League of Nations and no longer held the islands under the "mandate" pretense. They were now a part of her walled empire whereto tens of thousands of Japanese colonists migrated (Oliver, 1961).

Palau was the strategic command center of the Japanese empire (Naval Intelligence Division, 1945). Though western Koror had been used by the Germans before 1914 as a government station, Palau's capital city was not developed into a modern settlement until Japan took occupancy. It was the site of Malakal Harbor, the principal port of call for overseas shipping, as well as the Nanyo Cho office (administrative headquarters), and several other offices such as the agricultural experimental station and hospital (Naval Intelligence Division, 1945). The Japanese Navy took control of Germany's phosphate mine in Angaur and also began a bauxite mining operation on Babelthuap, Palau's largest island. The only important Japanese settlement in the Yap Islands was Yap itself, on which bauxite and nickel mines were opened in 1937 (Naval Intelligence Division, 1945). Okabe (1943a) described Yap as being "the most primitive" of the Japanese islands.

Japan's Micronesia territories stored a new wealth of resources and potential economic harvest. In fact, during this time the Ministry of Welfare campaigned to prevent all importations (Okabe, 1940b). Although most Japanese colonists sent to the islands were military personnel, many were civilians with interests in the islands' natural resources and their potential to boost the Japanese economy in the world market. Masayoshi Okabe was one such person sent to the islands to study, in his case, the potential for medicinal plant cultivation.

Evidently medicinal plants had been of interest to Japan even before Okabe visited the Pacific. An earlier report, "Medicinal Plants of the South Seas," was completed by Shigenori Kawagoe in 1917. Kawagoe visited the Pacific in 1914-1915 and collected more than 650 economic plant species, of which seventy-two were medicinal, and he published immediately due to the "urgent need" of such a publication. Mention of Palau and Yap was scanty, for Kawagoe listed only five medicinal plants of Yap (Kawagoe, 1917a, 1917b).

GEOGRAPHY

The Palau and Yap Islands are two of the major groups of the Caroline Archipelago in the western Pacific Ocean. Their tropical geography makes them an ideal spot for a wealth of agricultural pursuits. When Japan took occupancy, the government was apparently interested in exploiting as much of the islands' ecology as possible, including, in addition to the numerous food resources, medicines from both indigenous and exotic wild plants.

The approximately two hundred or more Palauan Islands are at the westernmost end of the Carolines, about 800 km east of the Philippines, extending from lat. 6 50' to 8 15'N and long. 133 50' to 134 45'E. All of the islands excepting Angaur lie within a mostly barrier (separated from the coast by a lagoon) and sometimes fringing (attached to shore) reef system, 80 km long and 27 km wide at its widest point. In a recent magazine article (FitzGerald, 1987), it was noted that Palau's reef system, particularly that surrounding the 37 km Rock Island chain south of Babelthuap, with its 700 coral and 1500 fish species, attracts divers, photographers and biologists from all over the world. It is "as close as you could get to paradise in the Pacific" (Kluge, 1986).

The larger Palauan islands are mostly volcanic, and the smaller are raised limestone and low coral atolls. Vegetation consists mostly of lowland rain forest (Campnosperma, Manilkara, Calophyllum, Eugenia, Ficus, tree ferns) and mixed forest in the southern end. The swamp alluvial soil near the coast supports dense belts of mangrove forest with interspersed stretches of barren, sandy beach. Some virgin forest still remains on various southern islands of the group. However, most of the original vegetation of the Palau Islands had been cleared through the centuries for coconut plantations and phosphate mines, as well as by the local people themselves through their slash and burn agricultural methods (Oliver, 1961). In addition to copra, Palau's subsistence crop production (their main agricultural enterprise) includes cassava, taro, sweet potato and banana. Most soil types are well suited to agricultural forest cultivation and carefully managed clean-tilled crop cultivation (Smith, 1983a; see also Cole et al., 1987).

The Yap Islands are located northeast of Palau, at lat. 9 33' and long. 138 09'E. They consist of four volcanic main islands including Yap itself, and 15 coral atolls. The island chain lies within a fringing reef system. Vegetation consists of evergreen rain forest, savanna woodland, and mixed forest. As in Palau, Yap's main agricultural enterprise is subsistence crop production. Its major crops are cassava, taro, sweet potatoes, yams, bananas and coconuts. Most soils are suitable for the production of agricultural forest crop and carefully managed clean-tilled crop (Smith, 1983b; see also Falanruw et al., 1987).

OKABE'S TRAVELS AND OBSERVATIONS

The ancestral medicinal culture of the Palau and Yap islanders is based wholly on the medicinal properties of the wild plants of the islands. When Okabe visited the islands in the early 1940's, the secrets of this art were known only to the "omkar" (Palau) or "tafalai" (Yap), names by which the native practitioners were known, and passed down through the generations from one heir to the next. The traditional folk culture was however being diluted by the facilities and ways of modern Japanese medicine (Okabe, 1940b, 1941a, 1943a). Okabe's intent was to record the tradition so that scientists could in time use this information in their search for new medicines. In the introductory paragraph of one of his reports, Okabe observes: "thinking of the motive of discovery of such invaluable drugs as cocaine and quinine having originated in folk medicines of a native tribe in South America, study of folk medicine should not be disregarded" (Okabe, 1941a, 1943a). Two and one-fifth percent of all Japanese imported tropical plant materials in 1936 were medicines. Clearly tropical medicinal plant cultivation had great potential. There was a wealth of knowledge in the native tradition. It was Okabe's belief that medicinal plants could and ought to be cultivated for economic profit on the part of the Japanese pharmaceutical industry (Okabe, 1940b).

Okabe's first voyage to Palau was to the island of Peleliu to study its coral reef vegetation. There is no mention in his report (Okabe, 1940a) of the medicinal value of the plants he surveyed. During that same year, Okabe (1940b) published a synopsis of medicinal plants known to exist on all the Palau Islands, though this report was not based on his own observations but was rather a compilation from Makino and Nemeto, "Flora Japonica." Okabe lists 100 Palauan plant species. It is interesting that so many of these species are introduced (65 introduced compared to 35 indigenous). Presumably the native peoples had learned well through the generations the healing properties of the plants introduced by colonists. Apparently, experimental testing of the cultivability of medicinal plants was already underway at this time, for Okabe describes its progress in some detail.

Okabe published an account of his own observations on the Palau Islands the following year (Okabe, 1941a). He gathered his information from the native Palauan people designated as "Kanakas." Okabe collected specimens of each plant, altogether totalling eighty-two species. The family best represented is Euphorbiaceae with six species and next Verbenaceae with five species. Most species are herbs, and the plant part most often used is the young leaf.

Okabe's latest paper (Okabe, 1943a) contains a rewrite of the earlier paper on Palau as well as a list of plants known to be used for medicinal purposes on the Yap islands. The listing of plants in the present article is a reproduction of the lists from the 1941a and 1943a reports. There are some additions to the second draft of the Palau chapter that merit attention. The plants listed are those used by the indigenous Kanakas, as well as by people termed by the translator, and therefore we must presume by Okabe himself, as "Chamorro". It must be cautioned, however, that the term "Chamorro" is more properly referable to people of the Marianas; we are not aware of the true origin of the people designated as "Chamorro" by Okabe. A total of 88 species is listed.

A thorough investigation must include studies of all tribes and islands, for there were differences (Okabe, 1941a). This was evidently Okabe's intent. He had by 1943 extended his knowledge of the medicinal plants on Palau by studying the Chamorros, and he surveyed the Yap Islands. Okabe's Yap list contains 95 species. The family best represented is Fabaceae with eleven species, and the plant part most often used is the leaf. As is the case with plants on Palau, the flower is least often used. Unlike the data of Palau, in his Yap list Okabe credits the persons from whom he received information. Most of it was gathered from native tribal persons, some from an earlier publication (Nakamura), and a few from a Columbian missionary.

LITERATURE

Other Okabe papers to which we had no access are listed in Johnston (1975). These include Okabe (1940c), cited in Uchinomi, of which no description of its contents are noted; Okabe (1941b), in which Okabe lists 88 species of plants used by the Kanakas; Okabe (1941c), which contains a listing of medicinal plants from Jaluit; Okabe (1941d), cited in Uchinomi, of which no description of its contents are noted; Okabe (1943b), a paper cited in Sachet and Fosberg (1955), of which no description of its contents are noted. Sachet and Fosberg (1955) does not include a citation for Okabe (1943b). It does however include Okabe (1941c) as well as Okabe (1941e) which was not included in Johnston's bibliography. The Okabe (1941e) article contains a listing of 179 plant species from Jaluit and a brief description of the vegetation of Jaluit.

Following is a list of the publications on medicinal flora of Palau and Yap cited by Okabe: Makino & Nemeto (1931)(Okabe's list of 100 species in his 1940b article come from this source); Nakamura (Okabe lists plants originally published by Nakamura in the chapter on Yap medicinal plants in the 1943a article. Okabe also cites Nakamura in a chapter on a comparative study of medicinal plants used on other islands, in the 1941a article but not included in the 1943a rewrite. In this chapter, Okabe lists 24 plants used medicinally in Yap as well as Palau); Narabayashi (Okabe cites Narabayashi in that same 1941a chapter). See Literature Cited for more complete information.

The Japanese horticulturist Yasuhei Ashizawa visited the Palau Islands in 1954 to report on the success of plants introduced during the Japanese administration. On his list of 99 plants are 13 species known to have been used medicinally (Ashizawa, 1954).

A more recent investigation into the medicinal flora of the Palau Islands was made by Salsedo & Smith (1987; see also Salsedo, 1970), who surveyed "every village and hamlet in Palau," from August 1968 through August 1970. They collected a total of 190 plant species. Their list does not coincide with that of Okabe. Plants used to treat venereal disease exemplify well the differences. Okabe observes that "there are a number of remedies for gonorrhoea" (Okabe, 1941a, 1943a). Venereal disease was introduced by the European and American colonists during their explorations and quests for economic treasure in the Pacific. An 1862 native population count in Yap was 10,000, and had since fallen to 3,713 by 1935. An earlier 1783 estimate was 40,000. Venereal disease as well as tuberculosis and dysentery are listed as "prime causes of depopulation" (Naval Intelligence Division, 1945). Okabe further remarks that medicinal plant cures for gonorrhoea are proven effective and ought to be scrutinized for pharmaceutical value. He lists a total of 13 treatments for gonorrhoea, including one of the Chamorros that was not listed in the 1941 report. There are two treatments listed for syphilis (Okabe, 1943a). Salsedo and Smith list only eight treatments for venereal disease, and furthermore some of the cures Okabe lists are not included in the Salsedo and Smith report, and vice versa. It appears that a number of formerly effective cures had fallen into disuse during the post-war era.

For example, one gonorrhoea treatment listed by Okabe is "young leaves of agaseel and of akabui, 10 each are mixed and eaten." Agaseel is Eugenia reinwardtiana DC. (Myrtaceae), and akabui is Piper betle L. (Piperaceae). In Salsedo and Smith, the young leaves of E. reinwardtiana are used to treat chest pains, and the local name is listed as kesiil. The young leaves of P. betel are used as an aborting agent, and its local name is listed as kebui. See also R.A. DeFilipps (1987) for additional references to other literature on medicinal plants of Palau and Yap, as well as on other floristic studies of the Pacific Islands.

For purposes of historical completeness we believe that it would be valuable to record here and have published for the first time in the English language the medicinal plants and their uses as found by Okabe on Palau and Yap. With very few exceptions, the nomenclature conforms to the checklists of Fosberg et al. (1979, 1982, 1988). For translation preparation of Okabe's reports, see Literature Cited. Other reports on Micronesian vegetation written in the Japanese language have been translated under circumstances described by Fosberg (1950). Dr. F. Raymond Fosberg, Smithsonian Institution, has noted (pers. comm., 1988) that only a few, if any, herbarium voucher specimens were collected by Okabe to afford later verification of species identification.

LISTING OF PLANTS AND THE DISEASES TREATED BY THEIR USE

In the listings by family presented alphabetically below, the sequence begins with ferns, followed by monocots and dicots. All information regarding Palauan medicinal plants is from Okabe (1941a, 1943a), unless otherwise specified. All information regarding Yap medicinal plants is from Okabe (1943a). In cases where Okabe, in his studies of Yap, noted in which district he learned of the treatment, the district is specified. When two or more plants are used in one treatment, the treatment is stated under the name of only one plant species, this plant being in almost all cases the first species named in the treatment. In most cases, the wording is Okabe's, but often we found it necessary to alter the grammatical structure of the sentences so they may read more easily. In some instances, however, the meaning of the sentences was not clear, and in this case we did not alter the grammar. Also included are poisonous plants of Palau (Okabe 1941a, 1943a). In addition to the plants listed below, there are three poisonous sea weeds of Palau which Okabe mentioned, but he did not include their Latin binomial nor indicate what part of the plant is poisonous. Okabe did not refer to any poisonous plants of Yap.

PTERIDOPHYTA

MARATTIACEAE

Angiopteris evecta (Forst. f.) Hoffm.
DERMARM, DERMULM (Palau); GOB (Yap; note: another "Gob" is Polypodium scolopendria (Polypodiaceae)). Palau: Leaves are tied around the head to cure headache. Yap: (1) (Ugiri Dist.) In the case of ptomaine poisoning, leaves of "gob" are crushed together with copra, and the sap is drunk three times a day. (2) (Ugiri Dist.) For sarcoma, leaves are crushed together with leaves of "agakai" (plant species not stated), and the sap is applied twice a day. See Antrophyum plantagineum (Polypodiaceae), Alpinia carolinensis (Zingiberaceae), Wollastonia biflora (Asteraceae), and Inocarpus edulis (Fabaceae) for other uses.

OPHIOGLOSSACEAE

Helminthostachys zeylanica (L.) Hook.
DODOAN. Yap (Map Dist.): For lacquer poisoning, coconut oil is heated and applied to the affected part by means of the "flower-stalk" of this plant. See Adenostemma lanceolatum (Asteraceae) and Solanum torvum (Solanaceae) for other uses.

Ophioglossum pendulum L.
TSCHAS. Yap: For usage, see Erythrina variegata (Fabaceae).

Ophioglossum reticulatum L.
RUUS, RUNS (Palau); GABACHAK (Yap). Palau: When stung by a swordfish, the plant is crushed and applied to the wound. Yap (Nif Dist.): When stung by a ray fish, sap of the plant is mixed with boiled coconut oil. The vapor is led to come into contact with the affected part, which is smeared with the oil when the oil cools down.

PARKERIACEAE

Ceratopteris thalictroides (L.) Brongn.
TIEL AWOEK, TEERAEK. Palau: For depilation, leaves are crushed together with leaves of "ermar" and "ushikeraker" (plant species not stated), and sap is applied to the hair (1941a). In the 1943a listing, names are slightly different: leaves are crushed together with a species named "ermaruushkerarker " (plant not listed) and applied to hair as depilatory.

POLYPODIACEAE

Acrostichum aureum L.
WELBROB. Yap: For usage, see Polyscias grandiflora (Araliaceae) and Crateva speciosa (Capparidaceae).

Adiantum philippense L.
OMEEREL AKESEBEKU, OMEERELAKESEBEKU, OEREL AKESEBEKU. Palau: Leaves are crushed and applied to a wound.

Antrophyum plantagineum (Cav.) Kaulf.
REM. Yap: For bed-wetting, the sprouting leaves are crushed together with sprouting leaves of "gob" (Angiopteris evecta or Polypodium scolopendria), and the juice is drunk.

Asplenium nidus L. sensu lato
BUKL BURU, BKURBRU (Palau); KUYOP (Yap). Palau: For usage, see Polypodium scolopendria (Polypodiaceae) and Vittaria incurvata (Polypodiaceae). Yap: When bitten by a centipede, fronds are pressed and the sap is applied to the bite. See also Procris pedunculatum (Urticaceae).

Blechnum orientale L.
RILEG. Yap (Map Dist.): Young leaves are put into water until it smells badly, and a small quantity is taken daily for invigoration, chiefly for children between ages two and six.

Cheilanthes tenuifolia (Burm. f.) Sw.
TERIBUK. Yap: For usage, see Alpinia carolinensis (Zingiberaceae).

Davallia solida (Forst. f.) Sw.
TSCHOCHOROOR. Yap: For usage, see Morinda citrifolia (Rubiaceae).

Polypodium scolopendria Burm. f.
EPAP (Palau); GOB (Yap; note: another "Gob" is Angiopteris evecta). Palau: For a cold, the Chamorros mix and crush the leaves with those of Asplenium nidus, Premna serratifolia , and Erythrina variegata, and the juice is drunk (1943a only). Yap: For uses of "gob," though never specified as to whether Polypodium or Angiopteris, see Angiopteris evecta (Marattiaceae), Antrophyum plantagineum (Polypodiaceae), Alpinia carolinensis (Zingiberaceae), Wollastonia biflora (Asteraceae), and Inocarpus fagifer (Fabaceae).

Pteris sp.
RIMATZ. Yap: see Alpinia carolinensis (Zingiberaceae).

Thelypteris parasitica (L.) Tard.
KILKURD, KIRKURD. Palau: For obstipantia, twenty young leaves are crushed together with ten young leaves of Melastoma malabathricum, to which half a cup of water is added, filtered through the fibrous network of a coconut leaf-base, and drunk.

Vittaria incurvata Cav.

ALBERU. Palau: Two or more (should be an "even number") new leaves are mixed with the same number of Asplenium nidus leaves, crushed, and the sap is applied to a wound; it will then work as a styptic. For other uses, see Averrhoa bilimbi (Oxalidaceae).

MONOCOTYLEDONAE

AMARYLLIDACEAE

Crinum asiaticum L.

BIS-ERAD (Palau); GIEIP, GIEIF (Yap). Palau: Root is crushed and applied to a bruise, then wrapped with a leaf of the plant. Yap: For beriberi, leaves and scapes are crushed together with aerial roots of Ficus prolixa, and scapes are crushed together with aerial roots of Ficus prolixa, and the sap is drunk. Vomiting afterwards does not affect the treatment. For another usage, see Alpinia carolinensis (Zingiberaceae).

ARACEAE

Alocasia sp.

ABIS, A-BIS. Palau: (1) Juice from rotten leaves is applied to a burn. (2) The stem is crushed and sap is obtained as an aphrodisiac (1941a; n.b. 1943a says as "narcotic.") (3) Sap of stem and leaves is poisonous. See also Codiaeum variegatum (Euphorbiaceae).

Alocasia macrorrhiza (L.) G. Don var. macrorrhiza

RAII. Yap: (1) (Giripes Dist.) To treat rat bite, the bud and leaves are crushed and applied to the affected part. (2) (Whole island) Sap of the crushed stem is drunk as an aphrodisiac. See also Rhus taitensis (Anarcardiaceae).

Colocasia esculenta (L.) Schott

AB'RAK, ABRAK, ABR'RAK, ABRAKK (Palau); TARO (Yap). Palau: (1) For lacquer poisoning, scraped copra is wrapped up in a Colocasia leaf, roasted and then applied to the body. (2) Sap of stem and leaves is poisonous. Yap (Ugiri Dist.): Sprouts are crushed and the sap is applied to an aching tooth.

Cyrtosperma chamissonis (Schott) Merr.

RAKK. Yap: (1) (Ugiri Dist.) Leaves are roasted, and when hot enough are placed onto a bruise. (2) For intestinal parasites, bracts and sprouting leaves are crushed and the sap is drunk two or three times a day.

Epipremnum carolinense Volk.

TOILAL, TOIRAL (Palau); GMOI, GUMOI (Yap). Palau: (1) In childbirth, safe delivery is expected by taking the juice squeezed out of six leaves, diluted with water, three times a day. (2) As an emmenagogue, the leaves are crumpled and steeped in water, which turns red, and is filtered through the fibrous network of a coconut leaf-base and drunk. (3) Sap of leaves and stem is poisonous. Yap (Giripes Dist.): For tuberculosis, young leaves of this plant and of Costus speciosus are crushed together, and the sap is drunk together with coconut milk. Also see Decaspermum fruticosum (Myrtaceae).

Rhapidophora engleri Kanehira

ORII. Palau: (1) An afterbirth can easily be expelled by taking the juice pressed out of the leaves. (2) Sap of stem and leaves is poisonous.

ARECACEAE

Arecha catechu L.

A-BU, A-BUU, ABUU (Palau); BUH (Yap; n.b. another "buh" is Schizostachyum lima of

Poaceae). Palau: (1) Seed is wrapped in leaf of Piper betle and chewed for a cold; cold is cured after perspiration. (2) To cure stomach ache, eight roots are crushed together with young leaves about six centimeters long (1941a; n.b. 1943a says sprouts about six centimeters long) of Pandanus macrojeanneretia and eight leaves of Codiaeum variegatum with a cup of water, strained through the fibrous network of a coconut petiole-base, and added to copra which has been scraped from the end of the coconut bearing the germination pores ("eyes") and which has been strained through the coconut fiber; this mixture is then ingested. It is believed that the patient will not recover if this potion is "injured" by birds, insects, rats, or stepped on by humans. (3) To stop bed-wetting, the soft, unripe fruit is pressed, and the juice is diluted with water and drunk. (4) As an emmenagogue, new roots are crushed together with new leaves of Pandanus macrojeanneretia, eight leaves of Codiaeum variegatum, and copra shaved fresh from the end of the coconut with the germination pores, then filtered through the fibrous network of a coconut leaf-base, and drunk. See Codiaeum variegatum (Euphorbiaceae) for another usage.

Yap: (1) For arthritis, the sprouting buds of this plant and of Cocos nucifera are wrung together and the juice is drunk. (2) (Ugiri Dist.) Roots of this plant ("rikekembuh") are crushed together with pitcher-leaves of Nepenthes mirabilis and unripe fruit of Inocarpus fagifer, and the sap is warmed together with coconut milk and drunk for gonorrhea. (3) (Whole island) As a condiment, the unripe fruit is wrapped in a leaf of Piper betle, some lime is added, and it is chewed. When leaf of Piper betle is unavailable, the leaf of Callicarpa candicans is substituted. Also see Aidia cochinchinensis (Rubiaceae).

Cocos nucifera L.

A-RYUS, ARYUS, ARIUS (Palau); NIU, NYU (Yap). Palau: (1) Oil is rubbed on head to treat a cold. (2) Sliced copra is applied to a wound. (3) Coconut oil is spread over an abscess. (4) Coconut oil is spread over arthritis-affected part two to three times a day. (5) Sap of young, red pericarp of coconut and coconut milk are mixed, and taken for amoebic dysentery. (6) As an entiemetic, the inner pericarp of a young, unripe coconut (should be red in color) is shaved and pulverized, and taken together with coconut milk. (7) As a febrifuge, coconut oil is spread over the head and body. (8) To stop bed-wetting, juice is pressed out of the exocarp of an unripe coconut and drunk. (9) Coconut oil is applied to a burn. (10) Juice squeezed out of rotten leaves is applied to a burn. (11) Hot coconut oil is dripped onto an insect bite. (12) When washing hair and body, grated copra wrapped in coconut fiber is used. (13) For seasickness, young pericarp of coconut is chewed.

The use of coconut for medicinal purposes in Palau is quite extensive; its usage is recorded under the names of twelve additional plant species: Colocasia esculenta (Araceae), Areca catechu (Arecaceae), Cordyline fruticosa (Liliaceae), Curcuma longa (Zingiberaceae), Acanthus ebracteatus (Acanthaceae), Ageratum conyzoides (Asteraceae), Terminalia catappa (Combretaceae), Ipomoea indica (Convolvulaceae), Codiaeum variegatum (Euphorbiaceae), Derris elliptica (Fabaceae), Abroma augusta (Sterculiaceae) and Phaleria nisidai (Thymelaeaceae). It is used mostly in the form of copra, then coconut oil, and lastly coconut milk.

Yap: (1) (Ugiri Dist.) For a headache cure, the petiole of a leaf is shaved finely and pushed into the nostrils to make them bleed. (2) Bark of coconut is beaten with the "mafalei," upon which "wech" (burned and pulverized limestone) is spread, and the juice which is pressed out is dripped onto a cut. For this treatment, a coconut palm should be selected from those growing near the road. (3) (Whole island) For a deficiency of mother's milk, coconut honey ("achief") is taken from flower-stalk and chewed together with copra, which eventually becomes mucilaginous; it is then taken. (4) (Ugiri Dist.) For diarrhoea, a young coconut ("etibai") is crushed together with the young leaves of Wollastonia biflora and the sap is drunk. (5) For leprosy, myriapods called "agur" are put into coconut oil, left until they are decomposed, and applied to the affected part, which has been stuck by a needle to release pus. (6) (Ugiri Dist.) To relieve over-eating effects, the outer skin (husk) of a coconut is squeezed and the sap is drunk. (7) To treat a husky voice, a leaf-base ("parei") is squeezed and the sap obtained, to which half the quantity of rain water is added, heated, and taken twice a day. (8) (Whole island) To keep mosquitoes away, the rotten roots are burned. (9) (Whole island) As a toilette, the whole body is rubbed with copra, and then washed with sea water. The use of coconut for medicinal purposes in Yap is recorded under the names of thirty-two additional plant species, which due to the length of such a list are not included here. It is used mostly in the form of coconut milk, then coconut oil, copra, and lastly coconut leaf.

Cocos nucifera L. (young fruit)
IRIU. Yap (Ugiri Dist.): If wounded on a battlefield, a young coconut is roasted by fire and pressed over the cut to make juice drip onto it. Afterwards, the stem of Costus speciosus is tapped and the juice is spread on the cut. Then there will be no fear of swelling or suppuration.

BROMELIACEAE

Ananas comosus (L.) Merr.
ONGOL GOBARD, OGOROGOBALT. Palau: Unripe fruit is roasted and eaten as a vermifuge.

COMMELINACEAE

Murdannia nudiflora (L.) Brenan
FUNOO. Yap: For otitis media, ten young stems are pressed and the sap is dripped into the ear once a day. See also Premna serratifolia (Verbenaceae).

CYPERACEAE

Cyperus brevifolius (Rottb.) Hassk.
DEUS. Palau: To treat a wart, the tip of the wart is cut open, and juice pressed out of the plant is smeared over the wart.

DIOSCOREACEAE

Dioscorea sp.
DOOK. Yap: for usage, see Bulbophyllum profusum (Orchidaceae).

FLAGELLARIACEAE

Hanguana malayana (Jack) Merr.
EWOEIS, EWAIS. Palau: For ringworm, the juice from the basal white portion of young leaves is applied several times.

LILIACEAE

Cordyline fruticosa (L.) Chev.
ASIS (Palau); RICH (Yap). Palau: (1) For ophthalmia, young leaves are crushed, and the greenish juice is put into a shallow basin and diluted with water. The face is then dipped into the basin, and the eye is opened and washed. (2) For epistaxis, the root is crushed together with young leaves and fruit of Acanthus ebracteatus, and copra, a part of the juice is drunk, and the rest is poured into the ear. See also Acanthus ebracteatus (Acanthaceae) and Abroma augusta (Sterculiaceae) for other uses. Yap (Map Dist.): For lacquer poisoning, a young tree is taken and its leaves are rubbed on the affected part. See also Alpinia carolinensis (Zingiberaceae).

MUSACEAE

Musa sp.
ILASS, IRAS. Palau: For gonorrhea, the juice of stem and leaves is drunk. See also Crateva speciosa (Capparidaceae).

Musa sp.
MURGUEB. Yap: (1) Young sprouts from an old stock are crushed with the stem and leaves of Costus speciosus, and the juice is drunk to alleviate stomach ache. (2) (Ugiri Dist.) Young plant is pressed, and the juice is used for rinsing a cut. (3) Juice from the stem is squeezed out and applied to a sarcoma, which is then tied around "with skin." (4) Unripe bananas are boiled in soup and taken to treat amoebic dysentery. (5) For tuberculosis, stem of banana is cut hollow and the sap accumulated in it is drunk. (6) For fainting, stem of the banana is squeezed and pushed into the mouth. (7) (Ugiri Dist.) Sprouts are crushed and the sap is applied to an aching tooth. (8) (Whole island) Outer skin of banana stem ("keginedinai") is made pliable and used as a bandage.

ORCHIDACEAE

Bulbophyllum profusum Ames
PAU. Yap: For insect bites, young leaves are crushed together with a germinating plant of Dioscorea sp., and the sap is applied to the bite.

Dendrobium brachyanthum Schltr.
BAGARUEL. Palau: For a deficiency of (mother's) milk, juice pressed from the crushed leaves is drunk. Deficiency of milk is also treated by drinking a broth of fish boiled in sea water.

Nervilia aragoana Gaud.
TIRIMOFON, TIRIMOF. Yap (Ganif Dist.): Root tubers are crushed, and the sap is drunk for tetrodon poisoning.

Nervilia palawensis Schltr.
ODODUTREGIL. Palau: For ophthalmia, the tuberous roots are pressed, and the juice squeezed out, which is applied to the eye (1943a; n.b. 1941a says applied to the eye drop by drop).

Taeniophyllum sp.
BUKITANG, BUKITAN. Palau: Swelling of an abscess goes down if a whole Taeniophyllum plant and leaves of Crateva speciosa are mixed and applied.

PANDANACEAE

Pandanus sp.
TYUYOI. Yap: For a deficiency of mother's milk, roots are crushed together with flower buds of Hibiscus tiliaceus, the sap is mixed with coconut oil and taken several times a day.

Pandanus macrojeanneretia Mart.
ELTOCHOT, ELTOOT. Palau: For usage, see Arecha catechu (Arecaceae), Codiaeum variegatum (Euphorbiaceae), and Hibiscus tiliaceus (Malvaceae).

POACEAE

Centosteca lappacea (L.) Desv.
MOIBIPUL, MOIBIPUUL. Palau: (1) Leaves are crushed with leaves of Glochidion ramiflorum, and the sap is applied to a wound. (2) Leaves are crushed, and the sap is applied to a wound.

TACCACEAE

Tacca leontopetaloides (L.) O. Ktze.
TSCHOBCHOB. Yap: For usage, see Hibiscus tiliaceus (Malvaceae).

ZINGIBERACEAE

Alpinia carolinensis Koidz.

TIFIF. Yap: (1) (Giripes Dist.) For a cold, leaves are mixed with the leaves of Eugenia javanica, Guettarda speciosa, "gob" (does not indicate whether Angiopteris evecta or Polypodium scolopendria), Cheilanthes tenuifolia and Decaspermum fruticosum, and rubbed over the whole body, starting with the head. (2) For a cold, leaves are crushed together with the young leaves of Cordyline fruticosa, leaves of Eugenia javanica and of Cheilanthes tenuifolia, Pteris sp., and roots of Carica papaya. The juice pressed out is taken three times a day for three days. New juice is to be had on the fourth day. (3) (Ururu Dist.) Young sprouting buds, leaves and root tuber are crushed together, and the juice is applied to sarcoma. (4) (Ugiri Dist.) Young leaves of this plant and of Crinum asiaticum are mixed and eaten as an emetic. (5) (Ugiri Dist.) This plant is crushed together with Curcuma longa, and the juice is drunk with coconut milk twice a day as an anti-emetic.

Costus speciosus (Koen.) Sm.

SAUER. Yap: For usage, see Epipremnum carolinense (Araceae), Cocos nucifera (Arecaceae), and Musa sp. (Musaceae).

Curcuma longa L.

TELAP, TERAPP (Palau); GUCHOL (Yap). Palau: As a cosmetic for the toilette, roots are ground into a fine powder, mixed with coconut oil, and put on forehead or other parts of the body. Yap (Whole island): The roots of "gchol" make up "rem" which is mixed with coconut oil and used in toilette. Also see Alpinia carolinensis (Zingiberaceae).

Zingiber sp.

IYOL. Yap (Rumon Dist., Rii Village): For leprosy, roots are ground down and mixed with lime and then applied to the affected part.

Zingiber sp.

YOI. Yap (Ugiri Dist.): Root is crushed together with young leaves of Ocimum sanctum and of lemon, and taken with coconut milk as a heart medicine.

DICOTYLEDONAE

ACANTHACEAE

Acanthus ebracteatus Vahl

KOL'LIL, KORIR. Palau: For otitis media, four fruits of Acanthus, two roots of Cordyline fruticosa, and four leaves and two young roots (about 3 cm. long) of Bruguiera gymnorhiza are mixed and pounded. Scrapings of copra (taken from the end of the seed bearing the three germination pores, or "eyes") are added. The mixture is filtered through the fiber of a coconut leaf-base, and the juice thus obtained is injected into the ear. Also see Cordyline fruticosa (Liliaceae).

Blechum brownei Juss.

MALAI. Yap (Ururu Dist.): For framboesia, stems are leaves are squeezed, and the sap is applied to the affected part, which is then wrapped in a leaf of Morinda citrifolia and heated from above.

ANACARDIACEAE

Rhus taitensis Guill.

GARAHDE. Yap (Ururu and Giripes Dists.): New leaves of this plant and of Oxalis corniculata, Alocasia macrorrhiza, and Xylocarpus granatum are crushed, and the juice is applied to the wound.

Semecarpus venenosus Volk.

TONGET, TOHNGET. Palau: The latex of the trunk is poisonous.

Spondias pinnata (L.F.) Kurz
TITIMML, TI TIMML, TETIMML, TETIMMUL. Palau: (1) About one handful of shavings of the reddish part of the inner bark and a similar portion of the same from Eugenia javanica are crushed together. The juice is diluted with water and drunk for amoebic dysentery. (2) For ophthalmia, ten new leaves are squeezed, and the juice is applied to the eye (1943a; n.b. 1941a says applied to the eye drop by drop).

APOCYNACEAE

Cerbera manghas L.
KAMARIDECH, KAMARIDOKK. Palau: Fruit and latex are poisonous.

ARALIACEAE

Polyscias grandifolia Volk.
EBUN. Yap: And even number of branches of this plant and of Acrostichum aureum are gathered in secret, then chewed, and the resulting juice is spread onto a cut. Leaves are then put on the cut and replaced twice daily, in morning and evening.

ASTERACEAE

Adenostemma lanceolatum Miq.
RUBURB. Yap: For leprosy, leaves and stems are crushed together with leaves of Helminthostachys zeylanica and applied to the affected part.

Ageratum conyzoides L.
AGMAK, AGMAKK. Palau: To make the head of an abscess burst, coconut oil is first applied, and then a leaf of A. conyzoides is placed over it.

Glossogyne tenuifolia (Labill.) Cass. ex Less.
OHL. Yap (Ururu Dist.): Leaves and stems are pressed, and the juice thus obtained is applied to a cut.

Wollastonia biflora (L.) DC. sensu lato
GESIL, NGESIL (Palau); SUH (Yap). Palau: For gonorrhea, a handful of young leaves is mixed with a handful of young leaves of Piper betle and eaten raw. Yap: (1) (Kamif) For stomach ache, the cortex is peeled off the stem, and the juice squeezed out of it is taken with copra once a day. (2) (Map and Giripes Dists.) Leaves and stems are squeezed, and the juice is spread onto a wound. (3) (Ugiri Dist.) When injured at sea, young leaves are crushed together with those of Morinda citrifolia, and the juice is applied to the wound. (4) (Ugiri Dist.) When injured in the mountains, young leaves are mixed and crushed together with those of Ocimum sanctum, "gob" (which of the two species is unspecified), and Piper betle, and the juice is applied to the wound twice a day. (5) Bark of the root is crushed together with young leaves of Ludwigia octovalvis, and the sap is then drunk together with coconut milk three time a day for gonorrhea. See also Cocos nucifera (Arecaceae).

BIGNONIACEAE

Dolichandrone spathacea (Lit.) K. Schum.
RIRIU. Yap: For framboesia, bark is squeezed together with young stem and flower stalk of Croton sp., and the sap is poured into heated coconut oil; when cooled down, it is applied to the affected part of the body.

CAPPARIDACEAE

Crateva speciosa Volk.

EDEPSUMBEL, EDEPSUNBEL, EDEPSUMBERUW (Palau); ABEECH (Yap). Palau: A handful of young sprouts of this species and of Clerodendrum thomsonae from which skin has been pared, and of Allophylus ternatus (n.b. Allophylus included only in 1941a treatment) are mixed and crushed together, then applied to a bruise and wrapped with a banana leaf. The affected part will become hot in two minutes, at which time the poultice is replaced with another. Yap: (1) (Ugiri Dist.) For stomach ache, bark from a curved part of a branch is crushed, and the juice pressed out is drunk with water. (2) (Ururu and Giripes Dists.) Young leaf is bruised and applied to a cut, being replaced every other day. (3) (Ururu Dist.) Leaves are crumpled and applied to a bruise. (4) (Ururu Dist.) A leaf is applied to a sarcoma. (5) (Nif Dist.) For myelitis, leaves are crushed together with leaves of Acrostichum aureum and Allophylus timoriensis; the sap is then filtered through the brown fibrous network of petiole-base of a coconut leaf, and the sap is drunk three times. Dosage each time is half a coconut shell cup. (6) Leaves and bark are wrapped in "mareniw" (brown fibrous network from the base of coconut leaf), and put into a young coconut ("tob") cut crosswise, then squeezed in the sap several (an even number of) times, and then taken twice a day for gonorrhea. (7) (Rumon Dist., Rii Village) For leprosy, bark is shaved, and the sap is applied to the affected part.

CARICACEAE

Carica papaya L.

BOBAI, BOPAI (Palau); POPAI (Yap). Palau: (1) Roots are mixed with leaves of Allophylus ternatus and sniffed to relieve headache. (2) If root of C. papaya is beaten and the bad odor is smelled, then "bad blood" will run, and cure will result for headache. (3) Decoction of the root is drunk by Chamorros as a febrifuge (1943a only). Yap: (1) (Ururu Dist.) Roots are sniffed to treat a headache. (2) Male flowers are put into hot water and taken as an anti-emetic.

CASUARINACEAE

Casuarina litorea L. var. litorea

AGASU, AGAS. Palau: (1) For toothache, juice pressed out of the bark is mixed with sea water and held in the mouth. If the mouth is rinsed every day, the teeth will be strengthened. (2) For abortion, the Chamorros take an infusion of the bark or a quantity of lemon juice (1943a only).

COMBRETACEAE

Lumnitzera littorea (Jack) Voigt

MEKEKAD, MEKEKAZ. Palau: Bark is poisonous.

Terminalia catappa L.

AMIAKA (Palau); KER (Yap). Palau: (1) Bark is mixed well with a whole plant of Cassytha filiformis and copra, crushed together, and the juice which is squeezed out is drunk for gonorrhea. (2) For gonnorhea, bark from two pieces of stems, two to three centimeters in diameter and seven to eight centimeters in length, is shaved, crushed and filtered through the fibrous network of a coconut leaf-base. This is drunk with coconut milk. If a handful of Cassytha filiformis is crushed and filtered as usual and taken with water, no recurrence will take place. The coconut shell from which copra or milk has been taken should be buried in the earth. (3) For framboesia, young leaves are mixed together with young leaves of Glochidion ramiflorum, crushed and applied to the affected part. For other uses, see Pterocarpus indicus (Fabaceae) and Citrus limon (Rutaceae). Yap: (1) (Ururu Dist.) The bark is tapped, and the latex is spread on a cut. (2) (Ugiri Dist.) Leaves and fruit are crushed together and put onto a sarcoma. (3) (Whole island) As a stain for teeth, leaves are boiled together with a black clay ("buh") and applied to the teeth at bedtime. See also Allophylus timoriensis (Sapindaceae).

CONVOLVULACEAE

Ipomoea indica (Burm.) Merr. var. indica
ORI-YEMAD, ORIYEMAD, ORIEMAD. Palau: (1) Milky juice of the plant is applied to a wound and pressed down with a crumpled leaf of the plant. (2) Leaf of the plant, spread with coconut oil, is applied to an abscess; it will then draw pus very well.

Ipomoea littoralis Bl.
TOHRUH, TOHRUH, TOHRUH (Palau); GELEW, GELOW (Yap). Palau: (1) Leaves are mixed with a handful of young leaves of Pongamia pinnata, crushed, applied to an abscess and then warmed. (2) Crushed stem and leaves are applied to an abscess to draw out the pus. Yap: (1) (Nif Dist.) For stomach ache, leaves are beaten to squeeze out juice, which is taken once a day together with coconut milk. (2) (Ururu Dist.) Leaves and stem are crushed, and the juice is applied to a cut. (3) To treat fluor-albus, twenty flowers are gathered by the patient herself and eaten as they are.

Ipomoea pes-caprae ssp. brasiliensis (L.) v. Ooststr.
KOBEAS OL, KOBIAS-OL. Palau: For usage, see Symplocos racemosa (Symplocaceae).

Merremia hederacea (Burm. f.) Hall. f.
WATCHAGAR. Yap: For usage, see Pueraria sp. (Fabaceae).

Merremia umbellata (L.) Hall. f.
KEBIAS. Palau: For fever in/of the mouth, the young buds (1941a only; n.b. 1943a says central leaves) are crushed and eaten.

CRASSULACEAE

Kalanchoe pinnata (Lam.) Pers.
No local name given. Yap: (1) (Ugiri Dist.) For headache, leaves are heated and placed on the affected part of the head. (2) Leaves are baked and plastered onto sarcoma.

EUPHORBIACEAE

Codiaeum variegatum (L.) Bl.
KESUK, KSUK. Palau: (1) Juice of the crushed leaves is drunk to cure diarrhoea. (2) For gonorrhea, eight leaves are mixed and squeezed together with a handful of flowers of Averrhoa bilimbi and a bit of copra from the end of the coconut with the germination pores. The mixture is then diluted with water and drunk. (3) For gonorrhea, the young leaves are mixed well with the soft, white part of the young leaves of Pandanus macrojeanneretia, coconut milk, and sap of the root of Areca catechu (1941a only; n.b. in 1943a: root of Alocasia sp.). The mixture is then drunk. (4) For syphilis, sap of the leaves is pressed out and mixed with copra, kneaded and applied to the affected part. (5) For framboesia, juice of the leaves is mixed with coconut milk and spread over the affected area. Forother uses, see Arecha catechu (Arecaceae), Pterocarpus indicus (Fabaceae) and Artocarpus altilis (Moraceae).

Croton sp.
GATUNG. Yap: For uses, see Dolichandrone spathacea (Bignoniaceae) and Ormocarpum cochinchinensis (Fabaceae).

Euphorbia chamissonis (Kl. & Gke.) Boiss.
OGEKAD. Palau: Latex of stem is poisonous.

Excoecaria agallocha L. var. agallocha
AYAS (Palau); BAT (Yap). Palau: Latex of trunk is poisonous. Yap (Map Dist.): To alleviate

constipation, sap obtained by tapping the bark is drunk with water once a day.

Glochidion ramiflorum Forst.
AGOLM, AGORM, AGOMAR (Palau); GOMOL (Yap). Palau: (1) Young leaves are crumpled and applied to a wound. (2) For obstipantia, fresh leaves are eaten. For other uses, see Terminalia catappa (Combretaceae), Macaranga carolinensis var. grandifolia (Euphorbiaceae), Centosteca lappacea (Poaceae) and Citrus limon (Rutaceae). Yap: For usage, see Decaspermum fruticosum (Myrtaceae).

Macaranga carolinensis var. grandifolia Pax & Hoffm.
ABDEL, ABUDOEL, ABDEEL, BEDEL (Palau); BIDI (Yap). Palau: (1) A handful of young leaves is crushed while fresh, and the sap is taken four to five times per day to relieve stomach ache. (2) A handful of fresh, young leaves of Macaranga and of Glochidion ramiflorum is mixed together when fresh, crushed, and the juice is drunk for stomach ache. (3) Juice pressed from the leaves is drunk to relieve diarrhoea. (4) For obstipantia, four to six young leaves are crushed, and the juice is drunk (in 1941a, translator notes that this plant may be "debe el" (Citrus limon) rather than "bedel"; in 1943a, plant is listed as "paderu," for which no Latin binomial is given). Yap: An even number of leaves, inflorescences and buds is crushed and mixed with a few drops of coconut oil. The paste is then plastered onto a bruise.

Phyllanthus amarus Sch. & Th.
UKERERALIP, UKURERALIP (Palau); RURUDAI (Yap). Palau: (1) For arthritis, a decoction of stem and leaves is taken several times a day. (2) Decoction of the whole boiled (1943a only; 1941a does not say "boiled") plant is taken for dyspepsia. (3) For gonorrhea, a decoction of leaves and stems is drunk. (4) For hemorrhoids, a decoction of leaves and stems is taken (1941a); leaves and roots are boiled in water and taken (1943). See also Allophylus ternatus (Sapindaceae) and Piper ponapense (Piperaceae). Yap (Nif Dist.): A decoction is taken for gonorrhea.

FABACEAE

Albizia lebbek Benth.
GMOGMOL. Yap: (1) (Ururu Dist.) For myelitis, the roots and bark are crushed together with the bark of Pterocarpus indicus, and the sap is drunk with coconut oil. (2) (Ugiri Dist.) For myelitis, bark of the root is crushed together with the leaves and fruit of Capsicum frutescens, and the sap is drunk with coconut milk.

Canavalia ensiformis (L.) DC.
WARIMOK. Yap (Ugiri Dist.): For neuralgia, leaves and stems are crushed together with the leaves of Morinda citrifolia, Allophylus timoriensis, Premna serratifolia , and of Derris trifoliata, and the sap is applied to the affected part of the body. New ingredients should be gathered and applied daily. For another usage, see Vigna marina (Fabaceae).

Cassia sophora L.
GIGIOL. Yap: For usage, see Pterocarpus indicus (Fabaceae).

Derris elliptica (Roxb.) Benth.
DUP, DUB, DUUP, DUUB (Palau); YUBU (Yap). Palau: (1) Root decoction mixed with coconut oil is spread onto prurigo-affected skin to relieve itch. (2) For ringworm, the juice of Derris is mixed together with coconut oil and applied to the affected part. (3) To exterminate crab-lice, juice obtained from a crushed root is applied, and the hair is then washed in sea water. (4) Roots are poisonous. Yap (Ururu and Giripes Dists.): Young leaves are crushed, and the juice is spread on a cut.

Derris trifoliata Lour.
KEMOGEM, KEMOKEM (Palau); GABATI (Yap). Palau: (1) Ten new leaves and ten full grown

leaves (1941a only; n.b. 1943a says instead of "full grown," "middle-aged") are crushed, kneaded with a small quantity of sea water, applied to the wound and bandaged. (2) Young leaves are crushed together with the young leaves of Callicarpa elegans, and the juice pressed out is drunk for amoebic dysentery. Yap: For usage, see Canavalia ensiformis (Fabaceae) and Allophylus timoriensis (Sapindaceae).

Erythrina variegata L.
No local name given (Palau); RAAL (Yap). Palau: For usage, see Polypodium scolopendria (Polypodiaceae). Yap: (1) (Map Dist.) For stomach ache, leaves and bark are finely cut, and the pressed out juice is drunk twice daily. (2) (Ugiri Dist.) For dyspepsia, the shaved bark is crushed together with the young leaves of Ophioglossum pendulum and taken three times a day with coconut milk.

Inocarpus fagifer (Park.) Fosb.
BOI. Yap: (1) (Ugiri Dist.) Leaves are crushed together with leaves of "gob" (species not designated between Angiopteris evecta and Polypodium scolopendria) and applied to a cut. See also Areca catechu (Arecaceae).

Ormocarpum cochinchinense (Lour.) Merr.
GAGET. Yap: (1) (Map Dist.) In the case of tetrodon poisoning, two fresh fruits are eaten. (2) (Map Dist.) For framboesia, the sprouting buds of this plant and of Croton sp. and "warakuh" (Latin binomial not stated) are crushed together and applied to the affected part.

Pongamia pinnata (L.) Merr.
KISAKUS. Palau: To relieve diarrhoea, ten young leaves are crushed together with four new leaves of Phaleria nisidai and drunk with water. See also Ipomoea littoralis (Convolvulaceae).

Pterocarpus indicus Willd.
ARAS (Palau); RATZ (Yap). Palau: Leaves and bark are mixed with bark of Terminalia catappa and leaves and bark of Codiaeum variegatum, and the sap pressed out is taken three times a day for amoebic dysentery. Yap: (1) (Ururu Dist.) Bark of this plant (n.b. plant is spelled "ratch") and leaves of Cassia sophora are crushed together and the juice thus extracted is drunk for amoebic dysentery. (2) (Ururu Dist.) For exhaustion, the bark is shaved and crushed, and the sap is drunk with coconut milk three times a day. (3) (Map Dist.) For neuralgia, leaves and bark are crushed together, and the sap is drunk with water. (4) (Giripes Dist.) For neuralgia, young leaves are crushed together with young stems of Cayratia trifolia, and the juice is put into the sap of coconut and drunk together with coconut milk. See also Albizia lebbek (Fabaceae).

Pueraria sp.
DEDAI. Yap (Kanif): For stomach ache, the leaves are crushed together with leaves of Merremia hederacea and Eugenia javanica, and the juice thus obtained is filtered, put into coconut milk and drunk once a day. After being pressed three times, it is discarded.

Vigna marina (Burm.) Merr.
MAKEDERIP. Yap: For arthritis, young buds of this plant and of Premna serratifolia , Hibiscus tiliaceus and Canavalia ensiformis are crushed together, and the juice is taken with coconut milk three times a day. See also Morinda citrifolia (Rubiaceae).

FLACOURTIACEAE

Pangium edule Reinw. ex Bl.
ARIAMMEL, ARIAMML. Palau: Seeds and bark are poisonous. See also Symplocos racemosa (Symplocaceae).

GUTTIFERAE

Calophyllum inophyllum L. var. inophyllum
APTAHAS, APTAKAS, ABTAKAS. Palau: Young leaves are eaten to relieve stomach ache.

Mammea odorata (Raf.) Kosterm.
RUBODOR. Yap: (1) (Ururu Dist.) For dyspepsia, the bark is shaved, and the sap is pressed out and drunk with coconut milk. (2) For treatment of swelling of lymphatic glands around the neck, the fruit, young leaves and bark are crushed, coconut oil is added, then squeezed. This is applied to the affected part two or three times a day and is renewed after four days. See also Xylocarpus granatum (Meliaceae).

HALORAGIDACEAE

Haloragis chinensis var. yapensis Tuyama
POFPOF. Yap: Leaves and stem are pressed, and a cupful of the sap thus obtained is drunk as a febrifuge.

LAMIACEAE

Ocimum sanctum L.
ERAMAL. Yap: For ophthalmia, the leaves and stem are pressed, and the sap is used. See also Zingiber sp. (Zingiberaceae), Wollastonia biflora (Asteraceae) and Premna serratifolia (Verbenaceae).

LAURACEAE

Cassytha filiformis L.
TECHELEL A CHULL, TEERELAUR (Palau); BUKK (Yap). Palau: (1) For gonorrhea, a decoction of the whole plant is drunk. (2) For gonorrhea, decoction of leaves and stem is taken (1943a only). See also Terminalia catappa (Combretaceae). Yap: (1) (Ururu Dist.) Crushed plant is mixed with salt water and applied to a bruise. (2) (Ururu Dist.) For neuralgia, leaves and stems are pressed, and the sap is drunk with coconut milk twice a day.

LECYTHIDACEAE

Barringtonia asiatica (L.) Kurz
ABTUUL, ABDUUL. Palau: Fruit is poisonous.

Barringtonia racemosa (L.) Spreng.
KORANGES, KORAGAS. Palau: For usage, see Artocarpus altilis (Moraceae).

LYTHRACEAE

Pemphis acidula Forst.
AGIS, AGES, AZUS. Palau: The red bark is finely shaved, wrapped up in the fibrous network of a coconut leaf-base, dipped into warmed sea water and then applied to a toothache.

MALVACEAE

Hibiscus tiliaceus L.
KARAMAL (Palau); GAAL (Yap). Palau: For gonorrhea, a handful of flower buds is crushed together with eight pieces of white, tender root of Pandanus macrojeanneretia (5-6 cm. long), filtered through the fibrous network of a coconut leaf-base and drunk. Yap: (1) (Ugiri Dist.) Young leaves are crushed together with new stems of Tacca leontopetaloides, and the sap is taken

with water to cure a bruise. (2) (Giripes Dist.) To have an easy delivery, when a woman is five months pregnant, she inserts crumpled leaves of this plant into "her privates," replacing them every other day. In certain villages, leaves of *Vavaea pauciflora* are used instead. (3) (Ugiri Dist.) To have an easy delivery, branches from which the bark has been stripped off are hung upside down, and the mucilage is then scraped by means of a coconut rope. Wood ash of *Inocarpus edulis* is mixed with this mucilage, and something like dough is made. This is put into a coconut shell and dissolved with coconut milk, to which coconut oil is added and then taken twice daily. It is commenced when throes are felt for the first time and is continued until the time of delivery. (4) For diarrhoea, the bark is pressed, and the sap is drunk once or twice together with juice of a young coconut. See also *Vigna marina* (Fabaceae), *Pandanus* sp. (Pandanaceae) and *Premna serratifolia* (Verbenaceae).

MELASTOMATACEAE

Melastoma malabathricum var. *mariannum* (Naudin) Fosb. & Sachet (ined.)
MATAKUI, MATAKUI. Palau: For usage, see *Thelypteris parasitica* (Polypodiaceae).

MELIACEAE

Vavaea pauciflora Volk.
MESEI. Yap (Giripes Dist.): Wood of this plant is used as an incense. See also *Hibiscus tiliaceus* (Malvaceae).

Xylocarpus granatum Koenig
EMOGUL. Yap: (1) (Giripes Dist.) For amoebic dysentery, the bark is crushed together with the young leaves and bark of *Mammea odorata*, and the sap is drunk. (2) (Otao Dist.) For hemiplegia, shaved bark is crushed, and the sap is drunk with coconut milk three times a day. See also *Rhus taitensis* (Anacardiaceae).

MORACEAE

Artocarpus altilis (Park.) Fosb.
AMUDU, AMDOW. Palau: Bracts of young *Artocarpus* bud (1941a only; in 1943a, leaves instead of buds), young leaves of *Codiaeum variegatum* and of *Barringtonia racemosa* are mixed and crushed, and the juice thus obtained is injected into the ear for otitis media.

Ficus prolixa var. *carolinensis* (Warb.) Fosb.
AU. Yap: For usage, see *Crinum asiaticum* (Amaryllidaceae).

Ficus tinctoria Forst. f. var. *tinctoria*
WOTCHOGAI. Yap: As a stimulant for throes (of childbirth), ten pieces of root about 30 cm. long, with the skin off, are ground together with coconut oil and taken with coconut milk.

MYRTACEAE

Decaspermum fruticosum Forst.
WARRARG, WARARG. Yap (Map Dist.): For treatment of stomach ache, young leaves of this plant are crushed together with those of *Glochidion ramiflorum* and *Epipremnum carolinensis* to press out the juice, which is taken together with coconut milk three times a day. A half coconut shell cup is one dose. See also *Alpinia carolinensis* (Zingiberaceae).

Eugenia javanica Lam.
ARBOTEL, ARBOTLE (Palau); ALPHAS (Yap). Palau: In childbirth, in case of injury at the time of delivery, smear a leaf-infusion onto the injured area. For another usage, see also *Spondias pinnata* (Anacardiaceae). Yap (Ugiri Dist.) As an anti-emetic,the hard leaves are crushed together

with old leaves of Abroma augusta, and the sap is taken with coconut milk from time to time. See also Alpinia carolinensis (Zingiberaceae) and Pueraria sp. (Fabaceae).

Eugenia reinwardtiana (Bl.) DC.
AGESIIL, AGASEEL. Palau: For gonorrhea, ten young leaves are mixed with ten young leaves of Piper betle and eaten raw.

Psidium guajava L.
GUAVA. Yap: For gonorrhea, a decoction of leaves is drunk.

NEPENTHACEAE

Nepenthes mirabilis (Lour.) Druce
No local name given (Palau); AAD (Yap). Palau: For gonorrhea, the Chamorros use an infusion of the dried (in shade) whole plant (1943a only). Yap: For usage, see Inocarpus fagifer (Fabaceae).

ONAGRACEAE

Ludwigia octovalvis (Jacq.) Raven
MESEII. Yap (Ururu Dist.): For tuberculosis, heartwood (perhaps "mesei," Vavaea pauciflora, is actually referred to here) is shaved, and the decoction thereof is drunk about three times. For another usage, see Wollastonia biflora (Asteraceae).

OXALIDACEAE

Averrhoa bilimbi L.
EMGURUS, EMGURS. Palau: Young leaves are crumpled, and the sap is applied to a wound. If the wound is large, leaves of Vittaria incurvata are added, and the pressed out juice is applied. See also Codiaeum variegatum (Euphorbiaceae).

Oxalis corniculata L. var. corniculata
GOUGUS. Yap: For usage, see Rhus taitensis (Anacardiaceae).

PIPERACEAE

Piper sp.
ETOL. Palau: Six leaves are crushed, and the juice is applied to an aching tooth.

Piper betle L.
A-KABUI, AKABUI (Palau); AKABUI (Yap). Palau: For uses, see Areca catechu (Arecaceae), Wollastonia biflora (Asteraceae) and Eugenia reinwardtiana (Myrtaceae). Yap: For uses, see Areca catechu (Arecaceae) and Wollastonia biflora (Asteraceae).

Piper ponapense C. DC.
KESIBIBUI, KESHPIBUI. Palau: (1) Leaves are crushed together with the leaves of Phyllanthus amarus and leaves of Citrus limon, and the juice pressed out is drunk as an invigorator. (2) For ophthalmia, young leaves are mixed and crushed with leaves of Clerodendrum thomsonae, and the juice is applied to the eye, drop by drop.

RHAMNACEAE

Colubrina asiatica (L.) Brongn.
No local name given. Palau: Chamorros drink a decoction of this plant in the incipiency of amoebic dysentery (1943a only).

RHIZOPHORACEAE

Bruguiera gymnorhiza (L.) Lam. f. gymnorhiza
ADEGES, AGEGIS. Palau: For usage, see Acanthus ebracteatus (Acanthaceae).

RUBIACEAE

Aidia cochinchinensis Lour.
KELMUSU, KERMS (Palau); GASMATZ (Yap). Palau: (1) For syphilis, a decoction of the young leaves is drunk. (2) A decoction of leaves is taken like tea as a beverage. Yap (Ugiri Dist.): For tuberculosis, the bark is crushed together with the skin of betel nut ("kuruebuh") and young sprouts of "buh" (Schizostachyus lima or Areca catechu) and taken with coconut milk. In this case the coconut should be of a green color called "yowra."

Guettarda speciosa L.
WARAO. Yap: For monthly troubles, the fruit, young leaves and bark are crushed together, and the sap is drunk by the woman. See also Alpinia carolinensis (Zingiberaceae).

Hedyotis fruticulosa (Volk.) Merr.
EMUDELAUH, EMDERAW. Palau: For lacquer poisoning, leaves are crushed and the juice is applied.

Ixora casei Hance
GACHUW. Yap: (1) Leaves are mixed with crumb (sic) of copra and taken with coconut milk, for stomach ache. (2) Decoction of the young leaves is drunk to cure nausea.

Morinda citrifolia L. var. citrifolia
NGEL, AGERU (Palau); MAGARWEK (Yap). Palau: To cure diarrhea, two unripe fruits are pounded together with four new leaves of Phaleria nisidai and taken with water. For another usage, see Phaleria nisidai (Thymelaeaceae). Yap: (1) (Ururu Dist.) Leaf of this plant is wrapped around a wound to which bruised leaves of "sowari" (Latin binomial not given) have been applied. (2) (Ugiri Dist.) For neuralgia, young leaves and fruit are crushed together, and the sap is drunk with coconut milk three times a day. Dosage each time is one half a coconut shell cup. (3) (Map Dist.) Leaves are baked and placed on a chancre. (4) For pains in throat, fruit and young leaves are crushed together with leaves and stems of Davallia solida and of Vigna marina, and taken with coconut milk. (5) (Whole island) Roots are substituted for soap. See also Blechum brownei (Acanthaceae), Wollastonia biflora (Asteraceae) and Canavalia ensiformis (Fabaceae).

Mussaenda frondosa L.
EREIROI (Palau); PETCH (Yap). Palau: (1) As an emetic, eight new ("new" 1943a only) green leaves and eight fruits are crushed together and taken together with a cup of water. (2) For lumbago, eight pieces each of young leaves and fruit are crushed together and drunk together with a cup of water. Anything bad inside will be thrown up, and swelling of the testicles will go down. Yap (Nif Dist.): The young fruit is pressed and taken with water for gonorrhea.

Oldenlandia sp.
BUKBUKGININ, BUKBUKUGININ. Yap (Giripes Dist.): Leaves and stems are crushed and mixed with coconut oil and spread onto a sarcoma.

RUTACEAE

Citrus sp.
BEKERSIU, PEKERJUW. Palau: To exterminate crab-lice, juice is applied to the hair.

Citrus sp.

MALCHEIANGED, MARGEYAN-ID. Palau: For usage, see Citrus limon (Rutaceae).

Citrus sp.
GURGUR. Yap (Whole island): For lice, juice is applied to the hair, which is then rinsed.

Citrus limon (L.) Burm. f.
DEBE EL, DEPEER. Palau: (1) For stomach ache, four or six young leaves are crushed, and the juice is drunk. When pain is acute the bark of the same tree is also added. (2) For amoebic dysentery, young leaves and bark are mixed with young leaves and bark of Glochidion ramiflorum and young leaves and bark of Terminalia catappa, and the juice pressed out is drunk. (3) Juice from the roasted fruit is applied to a fish "sting." (4) For fainting, a handful of young leaves is mixed together with a handful each of young leaves of Citrus sp. and Clerodendrum thomsonae, crushed, rolled into a round pellet and put into the mouth. The patient will vomit bad blood and recover. (5) For seasickness, the fruit is eaten (1941a only). For other usages, see Macaranga carolinensis (Euphorbiaceae), Piper ponapense (Piperaceae) and Allophylus ternatus (Sapindaceae).

SAPINDACEAE

Allophylus ternatus (Forst.) Radlk.
EBERUDES, EBERDES. Palau: (1) Ten or twenty young leaves are mixed with six tender stems and leaves of Phyllanthus amarus, crushed together and the odor is smelled, to relieve headache. The Allophylus leaves are later eaten, or else six Phyllanthus stems are eaten raw, to complete the cure for headache. (2) Leaves crushed with leaves of Callicarpa candicans are applied to arthritis and warmed. (3) For tuberculosis, young leaves are crushed together with new leaves of Clerodendron thomsonae, Citrus limon (1941a only) and "urkerakar" (no Latin binomial given), and the juice thus obtained is drunk. For other uses, see also Carica papaya (Caricaceae) and Crateva speciosa (Capparidaceae).

Allophylus timoriensis (DC.) Bl.
AGER. Yap: (1) (Map Dist.) To treat headache, the leaf is crushed, rubbed and sniffed. (2) (Ugiri Dist.) Leaves and fruit are crushed together with those of Terminalia catappa, and the juice is applied to a cut. (3) (Giripes Dist.) When the eye, or eyes or nose ache, the leaves are chewed with young leaves of Derris trifoliata, and the vapor (breath) is blown onto the affected part of the body through a fine bamboo tube. For other uses, see also Crateva speciosa (Capparidaceae) and Canavalia ensiformis (Fabaceae).

Dodonaea viscosa (L.) Jacq.
GOICHAP. Yap (Map Dist.): Juice oozing from the crumpled leaves is applied to a wound.

SOLANACEAE

Capsicum frutescens L.
DEBIL. Yap: For usage, see Albizia lebbek (Fabaceae).

Nicotiana tabacum L.
TAMABOW. Yap (Ugiri Dist.): When stung by a ray fish, this plant and lime ("etch") are mixed and chewed in the mouth, and the sap is applied to the wound.

Physalis angulata L. var. angulata
No common name given. Palau (Chamorros): For hemorrhoids, a decoction of the leaves and roots is taken (1943a only).

Solanum torvum Sw.
RAWELNAGAFI. Yap: For leprosy, leaves are crushed together with leaves of Helminthostachys zeylanica, mixed with coconut oil and applied to the affected part. At the same time, four or five

ripe fruits of both species are eaten fresh every day.

SONNERATIACEAE

Sonneratia alba J.E.Sm.

ABRUK. Yap: For excessive bleeding during menstruation, branches and aerial roots of this plant are wrapped in a coconut leaf, chewed by the patient and the sap is swallowed down. It is taken three times a day until the bleeding stops.

STERCULIACEAE

Abroma augusta (L.) L.f.

LAP, RAP (Palau); RAP (Yap). Palau: (1) For gonorrhea, the root is mixed and crushed together with young leaves of Cayratia trifolia, root of Cordyline fruticosa and copra. The pressed-out juice is filtered through the fibrous network of a coconut leaf-base, then diluted with water and drunk. (2) Sap of the roots is drunk as an aphrodisiac (1941a only; 1943a says as "narcotic"). (3) The spines are poisonous. Yap: For usage, see Eugenia javanica (Myrtaceae).

SYMPLOCACEAE

Symplocos racemosa var. palauensis (Koidz.) Nooteb.

KAPTUI, KAPUTUI. Palau: For gonorrhea, a handful of bark is mixed together with four pieces of young leaves of Pangium edule and young leaves of Ipomoea pes-caprae (cut about 3 cm. (1941a), 5 cm. (1943a) in length), crushed, and a cupful of water is added. The material is then pressed, filtered through the fibrous network of a coconut leaf-base and drunk.

THYMELAEACEAE

Phaleria nisidai Kaneh.

ONGAEL, ONGAEL. Palau: (1) Young leaves are mixed with coconut oil and applied to an abscess; then the pus oozes out. (2) Leaves are crumpled and wrapped in a leaf of Morinda citrifolia and applied to a bruise; bruise gradually will become hot, whereupon the leaves are replaced. (3) For constipation, four fresh leaves are eaten. (4) For constipation, four leaves are crushed together with two fruits of Morinda citrifolia, and the juice thus obtained is diluted with water and drunk. (5) For an abortion, about six fresh leaves are eaten. For other usages, see Pongamia pinnata (Leguminosae) and Morinda citrifolia (Rubiaceae).

URTICACEAE

Laportea interrupta (L.) Chew

YOYOL. Yap: To alleviate stomach ache, the red, ripe fruit is chewed.

Procris pedunculatum (Forst. f.) Wedd.

OFROP. Yap (Giripes Dist.): As treatment for rat bite, young leaves are crushed, and the sap is applied to the affected part. Then Asplenium nidus is crushed, and its sap is drunk.

VERBENACEAE

Callicarpa candicans (Burm. f.) Hochr. sensu lato

ADOPP, ADUP, ATOP (Palau); GARWAW (Yap). Palau: Branches and leaves are poisonous. See also Allophylus ternatus (Sapindaceae). Yap: For usage, see Areca catechu (Arecaceae).

Callicarpa elegans Hayek

EMRERT, EMLERT, EMULERT. Palau: Branches and leaves are poisonous. See also Derris trifoliata (Fabaceae).

Clerodendrum buchananii var. fallax (Lindl.) Bakh.
BUTE ELEAL, BUTEERAR, BTEERAL. Palau: (1) Young leaves are crushed, and the juice is drunk to cure stomach ache. (2) Chamorros apply the juice pressed out of the stem and leaves for ringworm (1941a only).

Clerodendrum thomsonae Balf.
IUTEKIL, INTEKIL, IUTEKIRA, IUTEKIRU. Palau: For uses, see Crateva speciosa (Capparidaceae), Piper ponapense (Piperaceae), Citrus limon (Rutaceae) and Allophylus ternatus (Sapindaceae).

Premna serratifolia L.
OSUM, OSUUM (Palau); AAL (Yap). Palau: For framboesia, the milky juice (latex) is spread over the affected part. See also Polypodium scolopendria (Polypodiaceae). Yap: (1) (Ururu Dist.) For an abortion, young leaves are cooked in a small quantity of sea water and taken while still hot. If taken within three months of pregnancy, it is said to be quite effective. (2) (Ugiri Dist.) For neuralgia, young leaves of this plant and of Hibiscus tiliaceus are crushed together with leaves of Ocimum sanctum and leaves and stems of Murdannia nudiflora, to which a small quantity of coconut oil is added, and then applied to the affected part of the body. For other uses, see Canavalia ensiformis and Vigna marina (both Fabaceae).

VITACEAE

Cayratia trifolia (L.) Domin
PERDAKL, PERTAKL, PERDAWAKL (Palau); SESEMTENIMEN, SESEMTEMENIN (Yap). Palau: (1) For framboesia, roasted stem and leaves are applied to the affected area. (2) Sap obtained from the stem is made use of as an aphrodisiac (1941a; n.b. 1943a says as "narcotic"). (3) Sap of stem and leaves is poisonous. See also Abroma augusta (Sterculiaceae). Yap: (1) (Nif Dist.) When a chicken has bad eyes (ophthalmia), the leaves and stem are crushed, and the juice is applied to the eye. (2) (Whole island) Juice of leaves and stems is drunk as an aphrodisiac. See also Pterocarpus indicus (Fabaceae).

Vitis vinifera L.
Referred to by Okabe as "GRAPE VINE." Yap (Ugiri Dist.): Decoction of leaves and stems is taken for a cold.

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DISTRIBUTION DES REPTILES TERRESTRES EN POLYNESIE ORIENTALE

PAR

IVAN INEICH ET CHARLES P. BLANC

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DISTRIBUTION DES REPTILES TERRESTRES EN POLYNESIE ORIENTALE

PAR

IVAN INEICH *, 1 ET CHARLES P. BLANC*

RESUME

Après avoir dressé le catalogue des représentants de l'herpétofaune terrestre dans les îles et atolls de Polynésie orientale, nous dégageons les caractéristiques biogéographiques du peuplement. La distribution de chaque espèce est discutée en fonction des fréquences d'occurence, de l'aire chorologique globale, des particularités biologiques mais aussi des lacunes dans les inventaires disponibles.

MOTS-CLE : Herpétofaune, Polynésie orientale, groupe Pitcairn, île de Pâques, Clipperton, distribution, inventaire faunistique, zoogéographie.

ABSTRACT

A faunistic account of the terrestrial reptiles occurring on islands and atolls of Eastern Polynesia is provided along with a description of their biogeographic characteristics. The distribution area of each species is presented in relation to frequencies of occurrence, maximum area of coverage, biology and limits of the present state of knowledge.

KEY-WORDS : Herpetofauna, Eastern Polynesia, Pitcairn Group, Easter Island, Clipperton Island, distribution, faunistic list, zoogeography.

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INTRODUCTION

En Polynésie orientale, les seuls représentants terrestres de l'herpétofaune sont des lézards ; le serpent marin *Pelamis platurus* est l'unique Ophidien qu'on y rencontre (I. Ineich, 1986, 1988 b). Une connaissance précise des distributions chorologiques étant une base nécessaire à la plupart des études biogéographiques, il nous est apparu opportun d'intégrer nos échantillonnages récents (1981-1983 ; 1985-1986), ainsi qu'une petite collection réunie en 1980 par G. Pasteur, dans une synthèse générale des données bibliographiques et muséologiques qui nous furent accessibles.

Nous mentionnerons les principales étapes de la découverte de l'herpétofaune terrestre dans la région considérée qui englobe les cinq archipels de Polynésie française : Société, Tuamotu, Gambier, Australes et Marquises, ainsi que le groupe des îles Pitcairn, les îles de Pâques et Clipperton.

Un des problèmes spécifiques posés par l'exploitation de la bibliographie concerne la toponymie insulaire : nous fournirons en annexe un index synonymique aussi exhaustif que possible.

A partir du catalogue chorologique de l'herpétofaune terrestre, une analyse zoogéographique du peuplement sera dégagée.

1. HISTORIQUE

La découverte de l'herpétofaune polynésienne est liée à la réalisation de collections scientifiques rassemblées soit au cours de grandes expéditions, soit par des scientifiques en mission, des naturalistes ou des amateurs isolés.

1.1. LES GRANDES EXPEDITIONS SCIENTIFIQUES.

1.1.1. La première description est, à notre connaissance, celle du "Gekko de Nuku Hiva" (= *Gehyra oceanica*) en 1820, dans les mémoires de l'Académie Impériale de Saint-Petersbourg, par W.G. Tilesius von Tilenau, médecin de Leipzig, naturaliste et dessinateur, embarqué a bord du navire "La Nadjedjeda" (= L'Espérance), lors de l'expédition russe commandée par Adam Ivan Krusenstern, qui se déroula du 7 août 1803 au 19 août 1806, et atteignit Nuku Hiva le 7 mai 1804 (J. Brosse, 1983 : 118). Cette description, malgré son antériorité par rapport à celle de R.P. Lesson (1830) qui comprend également une représentation graphique (1826 b) du *Gecko oceanicus*, ne peut être valide car l'auteur n'attribue pas un binôme au taxon. Par conséquent, *Gehyra oceanica* (Lesson, 1826) est la dénomination à retenir pour ce gecko.

1.1.2. Des progrès rapides suivent aussitôt, dûs à une série d'expéditions de circumnavigation :

* le 11 août 1822, sur la corvette "La Coquille", le commandant Louis Isidore Duperrey et son second, Jules Sébastien César Dumont d'Urville, sont accompagnés par deux médecins naturalistes, le chirurgien-major Prosper Garnot et le second chirurgien, également pharmacien, René Primevère Lesson qui collectèrent plus de 60 espèces d'Amphibiens et de Reptiles dont 15 à 20 nouvelles pour la science.

Dans l'archipel de la Société, R.P. Lesson effectue des récoltes à Tahiti du 3 au 18 mai 1823 : "deux Geckos, dont le Gecko hemidactyle, et trois Scinques, dont celui à queue bleue et à raies dorées", et à Bora Bora, du 18 mai au 3 juin de la même année : "un Gecko et le Scinque à queue bleue". Ces collections permettent à R.P. Lesson de mentionner (1826 a) et dessiner (1826 b : pl. IV, fig. 2) puis, un peu plus tard, décrire *Scincus cyanurus* (= *Emoia cyanura*) (1830 : 49) dont les types ne sont plus conservés au Muséum de Paris (I. Ineich, 1987 a) et *Gecko oceanicus* (= *Gehyra oceanica*) (1826 b : pl. II, fig. 3 ; 1830 : 42), dont les exemplaires sont au Muséum de Paris (MHNP 1776 et 6608) mais qui fut déjà décrit en 1820, sans que Lesson en soit informé. La terra-typica des deux espèces est respectivement Tahiti ; Tahiti et Bora Bora (orthographiés O-Taïti et Borabora). Dans le même ouvrage (1830 : 48), cet auteur décrit *Scincus noctua* (= *Lipinia noctua*), après en avoir donné une représentation (1826 b : pl. IV, fig. 4) avec pour terra typica Oualan (champs de canne à sucre). Cette localité, mentionnée sous le terme de Ualan par C.E. Burt et M.D. Burt (1932) et Qualan par A. Loveridge (1948), correspond à l'île Kusaie de l'archipel des Carolines.

Dès cette époque, l'appauvrissement oriental de l'herpétofaune polynésienne est souligné par R.P. Lesson (1826 a : 23) : "Les lézards et les scinques sont d'autant moins nombreux, qu'on s'avance vers l'Est. C'est ainsi que plusieurs espèces fort intéressantes s'arrêtent à Oualan, tandis que toutes les îles de l'Océanie ont indistinctement le joli petit scinque à raies dorées et à queue azurée des Moluques. Il en est de même pour les geckos : le *lacerta vittata* (sic), par exemple, se trouve depuis Amboine jusqu'à la Nouvelle-Irlande, et à Taïti, comme à Borabora, on ne rencontre plus que l'hémidactyle".

En fait, une étude récente (I. Ineich, 1987 a) a permis de montrer que le taxon nommé *Scincus cyanurus* par R.P. Lesson (1826 b, 1830), généralement appelé *Emoia cyanura* (Lesson, 1830) dans la littérature, correspond à deux espèces le plus souvent syntopiques : *Emoia cyanura* (Lesson, 1826) et *Emoia pheonura* (Ineich, 1987) ainsi qu'à une troisième, endémique de l'île Clipperton et syntopique avec *E. pheonura* : *Emoia arundelii* (Garman, 1899). Il n'est, par conséquent, pas possible de savoir si la dénomination *E. cyanura* employée dans les travaux antérieurs à cette révision se rapporte à l'une, à l'autre, aux deux ou aux trois espèces du complexe *cyanura*. Nous désignerons ici par *E. cyanura sensu lato* tous ces cas ambigus. Les problèmes liés à l'attribution spécifique correcte des types de Lesson ont été traités par ailleurs (I. Ineich, 1987 a et b).

En ce qui concerne le représentant du genre *Cryptoblepharus*, sachant qu'il n'appartient pas à l'espèce *boutonii* (E.R. Brygoo, 1986), nous le désignerons par *C. poecilopleurus* (Wiegmann, 1835) en attendant la nécessaire révision de son statut (I. Ineich, 1987 b : 58-59).

A.M.C. Duméril et G. Bibron, en 1836, décrivent *Hemidactylus garnotii* à partir des deux exemplaires récoltés à Tahiti par R.P. Lesson et P. Garnot, conservés au Muséum de Paris (réf. G 373, MHNP 2318 et 2318 A). Nous suivrons l'avis de A.G. Kluge et M.J. Eckardt (1969 : 658-659) préconisant de conserver la désignation *H. garnotii*, malgré l'antériorité du binôme *H. peruvianus* fondé par Wiegmann, en 1835, sur un seul individu originaire de Tacna au Pérou et faisant partie des récoltes de F.J.F. Meyer lors d'un voyage de circumnavigation ; ce binôme ne fut, d'ailleurs, plus utilisé par la suite et la localisation correcte du type est douteuse (Crombie et Dixon, en préparation) et pourrait résulter d'une erreur de manipulation en muséum.

* A.M. Adamson (1939) cite cinq geckos et trois scinques pour l'archipel des Marquises et signale l'ouvrage de L.E. Cheesman (1927) qui mentionne cinq geckos et deux scinques à Tahiti.

* de 1842 à 1846, le chirurgien en chef Arnoux, sur la corvette "Le Rhin", récolte du matériel herpétologique en Nouvelle-Zélande, Nouvelle-Calédonie, Australie, Tasmanie et aux Marquises. Ces collections, remises au Muséum de Paris (MHNP) en 1846, comprennent :

- un *Emoia cyanura* (réf. Sc 626/14, MHNP 2913) étiqueté par erreur de Nouvelle-Zélande, d'où ce taxon est absent, sous la double dénomination *E. cyanurum* (= *Eumeces cyanurus*) ;

- cinq exemplaires (réf. G 473/1) d'un Gekkonidae identifiés de trois façons différentes : *Hoplodactylus maculatus*, *Hoplodactylus pacificus*, *Platydactylus pacificus* Gray et mentionnés à tort des Marquises. Le genre *Hoplodactylus* Fitzinger, 1843 renferme neuf espèces, toutes certainement endémiques de la Nouvelle-Zélande ou des îles voisines (A.H. Whitaker, 1984 ; A.M. Bauer et A.P. Russell, 1986), les deux plus largement distribuées étant *H. maculatus* (Gray, 1845) et *H. pacificus* (Gray, 1842) ;

- l'holotype de *Nactus arnouxii* décrit par A.H.A. Duméril (1851 : 44), avec une mention de localité erronée : Nouvelle-Zélande (MHNP 5210). Nous ne suivrons pas ici l'opinion de A.G. Kluge (1983 : 470), mais celle de G.R. Zug (1985 : 153). Ce dernier, en dépit de l'antériorité de ce binôme, suggère de conserver celui proposé par C. Girard, en 1858, *Nactus pelagicus* (autrefois *Gymnodactylus pelagicus* ou *Cyrtodactylus pelagicus*) pour deux syntypes originaires des Fidji et Samoa : "I have retained herein the historical and commonly used name for this species, to avoid the confusion that will result from the replacement of a widely used name with one that has been mentioned in the literature only in reference to its uncertain provenance". La désignation *Nactus arnouxii* est beaucoup plus usitée actuellement et devra être préconisée ; elle ne peut être employée avant que la Commission Internationale de Nomenclature Zoologique n'ait statué.

Nous noterons que les localisations d'Arnoux relatives à la Nouvelle-Zélande et aux Marquises ont vraisemblablement été interverties. A l'exception de *Gehyra oceanica* et *Lepidodactylus lugubris*, signalés par C. Mc Cann (1955 : 20, 25) des îles Mokohinau au Nord de la Nouvelle-Zélande et non collectés depuis, aucun des taxons présents en Polynésie orientale ne se rencontre en Nouvelle-Zélande (G.S. Hardy, 1977 ; comm. pers., 10.01.1985).

* La frégate autrichienne Novara effectue un voyage dans le Pacifique Sud de 1857 à 1859. F. Steindachner (1867) décrira *Euprepes novarae* à partir du matériel rapporté de Tahiti par cette expédition. Ce taxon sera placé en synonymie avec *Lipinia noctua* (Lesson, 1826) par L. Stejneger (1899).

1.1.3. Dans la première moitié du 20ème siècle, une expédition allemande, deux expéditions américaines et une mission franco-belge limitées respectivement aux îles du Pacifique Sud pour les deux premières, à la Polynésie française seule pour la seconde et à l'île de Pâques pour la dernière, rassemblent des collections scientifiques importantes, parfois complétées par des observations écologiques.

\- Le Senckenberg Museum de Frankfort am Main organise la "Hanseatische Südsee Expedition" qui débute en février 1909. Elle atteint l'archipel des Australes le 26 juin, puis Tahiti et le 4 juillet, l'atoll surélevé de Makatea d'où elle repart vers les Samoa. L'expédition s'achève fin octobre 1909 (E. Wolf, 1915). Les Drs. E. Wolf et G. Friedericis collectent, en Polynésie française, 37 geckos des quatre espèces les plus courantes et 106 scinques des trois espèces alors connues. L'ensemble de ce matériel sera étudié par R. Sternfeld (1920).

\- La Whitney South Sea Expedition (R.C. Murphy, 1924), au cours de laquelle R.H. Beck récolte plusieurs lots constituant ainsi une collection considérable de plus de 1700 individus pour la seule Polynésie orientale. De novembre 1920 à mai 1921, un premier lot de 106 spécimens est récolté sur huit îles des archipels de la Société, des Australes et des Marquises et sur l'île de Christmas en Polynésie. Ce matériel est étudié par K.P. Schmidt en 1921. Il comprend : *Lepidodactylus lugubris* (Duméril & Bibron, 1836), *Gehyra oceanica* (Lesson, 1826), *Gehyra mutilata* (Wiegmann, 1834), *Emoia cyanura* (sensu lato), *Lipinia noctua* (Lesson, 1826) et *Cryptoblepharus poecilopleurus* (Wiegmann, 1835). Un deuxième lot, composé de 224 individus des six espèces précédentes récoltées dans les mêmes archipels et celui des

Tuamotu, est décrit par K.P. Schmidt, en 1922. En 1923, A.I. Ortenburger étudie trois lots supplémentaires récoltés, de novembre 1921 à décembre 1922, sur les cinq archipels de Polynésie française et les îles du groupe Pitcairn. *Hemidactylus garnotii* Duméril & Bibron, 1836 porte à sept la liste taxonomique des Reptiles polynésiens. Enfin, un quatrième envoi de deux lots, originaires des archipels de la Société, des Australes et des Tuamotu, est décrit par A.I. Ortenburger, en 1924.

L'ensemble du matériel récolté par cette expédition est l'objet, en 1932, d'une synthèse biogéographique par C.E. Burt et M.D. Burt qui, avec *Nactus pelagicus* (Girard, 1858), complète à huit le nombre d'espèces de Reptiles terrestres collectées dans cette région, l'île de Clipperton incluse. Notons au sujet de cette dernière espèce, que ses populations semblent bisexuées dans toute la partie occidentale de son aire et parthénogénétiques à partir des Fidji et plus à l'Est (C. Moritz & D. King, 1985 ; C. Moritz, 1987).

- La mission franco-belge récolte, de juillet 1934 à avril 1935, sur l'île de Pâques (H. Lavachery, 1935), 10 exemplaires de *Cryptoblepharus poecilopleurus* déposés au Muséum de Bruxelles, auxquels seront adjoints, en 1975, 63 spécimens de la même espèce et de même provenance.

- La Pacific Entomological Survey, sous les auspices du Bernice P. Bishop Museum, durant laquelle les collectes conduites par E.P. Mumford et A.M. Adamson, sur une suggestion, à Atuona, de K.P. Schmidt participant lui-même à la Crane Pacific Expedition du Field Museum of Natural History, rassemblent, à partir de 1928, 223 spécimens sur neuf îles des Marquises et à Tahiti. L'étude de cette collection (K.P. Schmidt et W.L. Necker, 1933) permet de découvrir une neuvième espèce pour l'herpétofaune de Polynésie orientale : *Hemiphyllodactylus leucostictus* Stejneger, 1899 (placé par la suite en synonymie avec *H. typus* Bleeker, 1860), dont trois spécimens furent récoltés aux Marquises à Eiao, Hiva Oa et Motane. Notons, toutefois, que cette collection renfermait huit espèces, *Nactus pelagicus* n'y étant pas incluse.

1.2. LES COLLECTIONS INDIVIDUELLES.

G.E. Magnesson et P.K. Humphreys, étudiants du Professeur W.W. Tanner, collectent, durant six semaines en 1950, à Takaroa, Tahiti et aux Marquises, 28 lézards déposés à la Brigham Young University, à Provo (Utah). V.M. Tanner (1952) identifie six des huit espèces de la liste de K.P. Schmidt et W.L. Necker (1933) : *Hemiphyllodactylus typus* et *Cryptoblepharus poecilopleurus* ne sont pas représentés.

Parmi les récoltes déposées au Muséum de Paris, nous mentionnerons celles de :

* Père Delmas, en 1924 : trois individus originaires des Marquises : *Lipinia noctua* (Sc 683/2, MHNP 1924-124 et 125) et *Gehyra oceanica* (G 244/7, MHNP 1924-126).

* Landret : collectes réalisées à Tahiti ; *Emoia cyanura* (MHNP 1979-3825 et 3828) ; *Emoia pheonura* (MHNP 1979-3826 et 3827) ; *Lipinia noctua* (MHNP 1979-3822 à 3824) ; *Gehyra oceanica* (MHNP 1979-3814 à 3821) ; *Gehyra mutilata* (MHNP 1979-3813).

* Y. Plessis, en 1965-1966 : *Lipinia noctua*, deux exemplaires de Moruroa (MHNP 1979-3833) et Maturei Vavao (1979-3834) ; les autres collectes sont toutes de Moruroa : *Cryptoblepharus poecilopleurus* (1979-3835 et 3836) ; *Lepidodactylus lugubris* (1979-3832) ; *Gehyra oceanica* (1979-3829 à 3831).

* J.P. Chevalier, en 1966 : *Gehyra oceanica*, trois exemplaires (MHNP 1979-3829 à 3831) de l'atoll de Moruroa.

* Mercier : *Gehyra oceanica*, un individu (G 244/11, MHNP 6581) provenant des Marquises, étiqueté *Hemidactylus oceanicus* Lesson.

* F. Legros, en 1980 : *Lepidodactylus lugubris* (MHNP 1980-1068) de Tahiti, identifié par erreur comme *Gehyra variegata*, absent de Polynésie et qui fut déjà l'objet de confusions identiques (Y. Okada, 1930 ; A.G. Kluge, 1982).

* G. Pasteur, en 1980 : *Cryptoblepharus poecilopleurus*, 33 exemplaires (MHNP 1985-201 à 233) provenant des îles Bora Bora, Moorea et Tahaa, archipel de la Société.

* J.C. Thibault : collectes réalisées sur l'atoll surélevé de Makatea (archipel des Tuamotu) ; *Emoia cyanura* (MHNP 1987-1202 à 1218) ; *Lipinia noctua* (MHNP 1987-1219 à 1222) ; *Cryptoblepharus poecilopleurus* (MHNP 1987-1200 à 1201) ; *Lepidodactylus lugubris* (MHNP 1987-1228 à 1235) ; *Gehyra oceanica* (MHNP 1987-1223 à 1227).

* J.C. Thibault : collectes effectuées sur l'atoll de Fangataufa (archipel des Tuamotu) en janvier 1987 (J.C. Thibault, en prép. : DIRCEN) : *Emoia pheonura* (MHNP 1987-1236 à 1259) ; *Lipinia noctua* (MHNP 1987-1286 à 1289) ; *Cryptoblepharus poecilopleurus* (MHNP 1987-1273 et 1274) ; *Gehyra mutilata* (MHNP 1987-1275 à 1285).

* J.C. Thibault : collectes réalisées sur l'île d'Eiao (archipel des Marquises) du 13 au 31 juillet 1987 : *Emoia cyanura* (MHNP 1988-3001 à 3010) ; *Emoia pheonura* (MHNP 1988-3011 à 3013) ; *Lipinia noctua* (MHNP 1988-3014 à 3016) ; *Lepidodactylus lugubris* (MHNP 1988-3017 à 3020) ; *Gehyra oceanica* (MHNP 1988-3021 à 3031) ; *Gehyra mutilata* (MHNP 1988-3032 et 3033) ; *Hemiphyllodactylus typus* (MHNP 1988-3034).

1.3. NOS COLLECTIONS.

Le matériel biologique à la base de ce travail, près de 6000 lézards, paraîtra considérable à ceux qui ne sont pas familiarisés avec les très fortes densités atteintes par beaucoup de Reptiles insulaires. Il faut encore préciser que cet échantillon concerne neuf espèces collectées sur environ 30 des 118 îles qui composent les cinq archipels de Polynésie française. En fait, malgré le nombre impressionnant de lézards étudiés, très souvent, en considérant par exemple une seule île, un seul sexe ou une seule classe démographique, le nombre d'exemplaires disponibles n'est pas suffisant pour obtenir un résultat significatif. Les collectes ont été réalisées par :

* 1980 (78 exemplaires) : G. Pasteur : archipel de la Société.

* 1981 (388 exemplaires) : Ch.P. Blanc : archipels de la Société, des Tuamotu et des Gambier.

* 1982 (1010 exemplaires) : Ch.P. Blanc principalement mais aussi F. Blanc et G. Vergonzane : archipels de la Société, des Tuamotu et des Australes.

* 1983 (745 exemplaires) : Ch.P. Blanc principalement, mais aussi F. Blanc et J.P. Pointier : archipels de la Société, des Tuamotu et des Marquises.

* 1985 (941 exemplaires) : I. Ineich : archipel de la Société ; G. Marquet : archipel des Australes.

* 1986 (2616 exemplaires) : I. Ineich : archipel de la Société ; Ch.P. Blanc et I. Ineich : archipel des Tuamotu ; B. Salvat : archipel des Tuamotu (Tepoto et Napuka) ; G. Marquet : archipel des Australes et Tahiti ; A. L'Hévéder : île de Pâques.

Le détail de la distribution spatiale et temporelle de toutes ces collectes se trouve dans I. Ineich (1987 b : 125-135).

2. CATALOGUE CHOROLOGIQUE

La liste des espèces mentionnées est établie par archipel puis par île, atoll et motu (petit îlot récifal) classés selon un ordre alphabétique et totalisant, avec l'île de Clipperton, 78 localisations insulaires. Les données se référant aux collections du Muséum de Washington (USNM) proviennent de R.I. Crombie (non publié).

2.1. ARCHIPEL DE LA SOCIETE.

Cryptoblepharus poecilopleurus : Société, sans autre mention (Boulenger, 1887 : 347 - Baur, 1897 - de Rooij, 1915)
Hemidactylus garnotii : Société, sans autre mention (Kluge & Eckardt, 1969)

BORA BORA

Emoia cyanura sensu lato (coll. Pasteur - Crombie, coll. USNM)
Emoia cyanura (cette étude)
Emoia pheonura (cette étude)
Cryptoblepharus poecilopleurus (coll. Pasteur - cette étude)
Lipinia noctua (cette étude)
Lepidodactylus lugubris (Crombie, coll. USNM - cette étude)
Gehyra oceanica (Lesson, 1830 - coll. Pasteur - cette étude)

HUAHINE

Emoia cyanura (cette étude)
Emoia pheonura (cette étude)
Cryptoblepharus poecilopleurus (cette étude)
Lipinia noctua (cette étude)
Lepidodactylus lugubris (cette étude)
Gehyra oceanica (cette étude)
Gehyra mutilata (cette étude)

MAUPITI

Emoia cyanura (cette étude)
Emoia pheonura (cette étude)
Cryptoblepharus poecilopleurus (cette étude)
Lipinia noctua (cette étude)
Lepidodactylus lugubris (cette étude)
Gehyra oceanica (cette étude)

MEHETIA

Emoia cyanura sensu lato (Ortenburger, 1924 - Burt & Burt, 1932)
Emoia pheonura (cette étude)
Cryptoblepharus poecilopleurus (cette étude)
Lipinia noctua (Ortenburger, 1924 - Burt & Burt, 1932)

MOOREA

Emoia cyanura sensu lato (Schmidt, 1922 - Burt & Burt, 1932 - coll. Pasteur - Blanc et al., 1983)
Emoia cyanura (cette étude)
Emoia pheonura (cette étude)
Cryptoblepharus poecilopleurus (Schmidt, 1922 - Burt & Burt, 1932 - coll. Pasteur - Blanc et al., 1983)

Lipinia noctua (Stejneger, 1899 - Schmidt, 1922 - Burt & Burt, 1932 - coll. Pasteur - Crombie, coll. USNM - Blanc et al., 1983)
Lepidodactylus lugubris (Schmidt, 1922 - Burt & Burt, 1932 - coll. Pasteur - Blanc et al., 1983 - Cuellar, 1984)
Gehyra oceanica (Schmidt, 1922 - Burt & Burt, 1932 - coll. Pasteur - Blanc et al., 1983)
Gehyra mutilata (Schmidt, 1922 - Burt & Burt, 1932 - Blanc et al., 1983)
Hemidactylus garnotii (cette étude)
Hemiphyllodactylus typus (cette étude)

MOPELIA

Emoia cyanura sensu lato (Ortenburger, 1923 - Burt & Burt, 1932 - Sachet, 1983)
Cryptoblepharus poecilopleurus (Ortenburger, 1923 - Burt & Burt, 1932 - Sachet, 1983)
Lipinia noctua (Ortenburger, 1923 - Burt & Burt, 1932)
Lepidodactylus lugubris (Sachet, 1983)
Gehyra oceanica (Ortenburger, 1923 - Burt & Burt, 1932)
Gehyra mutilata (Ortenburger, 1923 - Burt & Burt, 1932)

RAIATEA

Emoia cyanura sensu lato (coll. Pasteur)
Emoia cyanura (cette étude)
Emoia pheonura (cette étude)
Cryptoblepharus poecilopleurus (cette étude)
Lipinia noctua (coll. Pasteur - cette étude)
Lepidodactylus lugubris (Ortenburger, 1923 - Burt & Burt, 1932 - cette étude)
Gehyra oceanica (cette étude)

SCILLY

Emoia cyanura sensu lato (Ortenburger, 1923 - Burt & Burt, 1932 - Rivière & Pichon, 1979)
Cryptoblepharus poecilopleurus (Ortenburger, 1923 - Burt & Burt, 1932 - cette étude)
Lipinia noctua (Ortenburger, 1923 - Burt & Burt, 1932)
Lepidodactylus lugubris (Ortenburger, 1923 - Burt & Burt, 1932 - cette étude)
Gehyra oceanica (Ortenburger, 1923 - Burt & Burt, 1932)
Gecko non identifié (Rivière & Pichon, 1979)

TAHAA

Emoia cyanura (cette étude)
Emoia pheonura (cette étude)
Cryptoblepharus poecilopleurus (coll. Pasteur)
Lipinia noctua (cette étude)
Lepidodactylus lugubris (coll. Pasteur - cette étude)
Gehyra oceanica (cette étude)

TAHITI

Cinq geckos et deux scinques (Cheesman, 1927 in Adamson, 1939 : 63)
Emoia cyanura sensu lato (Lesson, 1826 a et b, 1830 - Stejneger, 1899 - Sternfeld, 1920 - Schmidt, 1921, 1922 - Burt & Burt, 1932 - Tanner, 1952 - Fichier Muséum Bruxelles - Crombie, coll. USNM - Blanc et al., 1983)
Emoia cyanura (cette étude)
Emoia pheonura (cette étude)
Cryptoblepharus poecilopleurus (Cocteau, 1836 - Duméril & Bibron, 1839 - Duméril, 1851 - Girard, 1858 - Fitzinger, 1860 - Hallowell, 1860 - Steindachner, 1867 - Strauch, 1868 - Duméril et al., 1881 - Schmidt, 1921 - Burt & Burt, 1932 - Crombie, coll. USNM - Blanc et al., 1983 : observé mais non récolté)
Lipinia noctua (Steindachner, 1867 - Stejneger, 1899 - Sternfeld, 1920 - Schmidt, 1921 - Ortenburger, 1923 - Burt & Burt, 1932 - Schmidt & Necker, 1933 - Crombie, coll. USNM - MHNP 1979-3822 à 3824 - Blanc et al., 1983)
Lepidodactylus lugubris (Duméril & Bibron, 1836 - Boettger, 1893 - Stejneger, 1899 - Sternfeld, 1920 - Schmidt, 1921 - Burt & Burt, 1932 - Schmidt & Necker, 1933 - Tanner, 1952 - Brown & Parker, 1977 - Fichier Muséum Bruxelles - coll. Pasteur - Crombie, coll. USNM - MHNP 1980-1068 (G245/3) - Blanc et al., 1983)
Gehyra oceanica (Lesson, 1826 a et b, 1830 - Sternfeld, 1920 - Schmidt, 1921 - Ortenburger, 1923 - Burt & Burt, 1932 - Schmidt & Necker, 1933 - Tanner, 1952 - Fichier Muséum Bruxelles - Crombie, coll. USNM - Blanc et al., 1983 - MHNP 1979-814 à 3821)
Gehyra mutilata (Sternfeld, 1920 - Schmidt, 1921 - Ortenburger, 1923 - Burt & Burt, 1932 - Tanner, 1952 - Crombie, coll. USNM - MHNP 1979-3813 - Blanc et al., 1983)
Hemidactylus garnotii (Duméril & Bibron, 1836 - Stejneger, 1899 - Roux, 1913 - Sternfeld, 1920 - MHNP 2318 et 2318A (G373) - cette étude)
Hemiphyllodactylus typus (Crombie, coll. USNM)
Nactus pelagicus (Crombie, coll. USNM)

TETIAROA

Emoia cyanura sensu lato (Sachet & Fosberg, 1983)
Gehyra oceanica (Sachet & Fosberg, 1983)
* Ile Onetahi
Emoia cyanura (Crombie, coll. USNM)
Gehyra oceanica (Crombie, coll. USNM)

TUPAI

Emoia cyanura sensu lato (Blanc et al., 1983)
Emoia cyanura (cette étude)
Emoia pheonura (cette étude)
Cryptoblepharus poecilopleurus (Blanc et al., 1983)

Lipinia noctua (Blanc et al., 1983)
Lepidodactylus lugubris (Blanc et al., 1983)
Gehyra oceanica (Blanc et al., 1983)

2.2. ARCHIPEL DES TUAMOTU.

Lipinia noctua : Tuamotu, sans autre mention (Oliver & Shaw, 1953 - Schwaner, 1980)
Lepidodactylus lugubris : Tuamotu, sans autre mention (Parker, 1936)

AHE

Emoia cyanura sensu lato (Ortenburger, 1923, 1924 - Burt & Burt, 1932)
Cryptoblepharus poecilopleurus (Ortenburger, 1923, 1924 - Burt & Burt, 1932)
Lipinia noctua (Ortenburger, 1923, 1924 - Burt & Burt, 1932)
Lepidodactylus lugubris (Ortenburger, 1924 - Burt & Burt, 1932)
Gehyra oceanica (Ortenburger, 1923, 1924 - Burt & Burt, 1932)
Gehyra mutilata (Ortenburger, 1923 - Burt & Burt, 1932)

AKI AKI

Gehyra oceanica (Burt & Burt, 1932)
Nactus pelagicus (Burt & Burt, 1932)

AMANU

Cryptoblepharus poecilopleurus (Burt & Burt, 1932)

ANAA

Emoia cyanura sensu lato (Sternfeld, 1920 - Schmidt, 1922 - Burt & Burt, 1932)
Cryptoblepharus poecilopleurus (Sternfeld, 1920 - Schmidt, 1922 - Burt & Burt, 1932)
Lipinia noctua (Sternfeld, 1920 - Schmidt, 1922 - Burt & Burt, 1932)
Lepidodactylus lugubris (Sternfeld, 1920 - Schmidt, 1922 - Burt & Burt, 1932)
Gehyra oceanica (Sternfeld, 1920)

APATAKI

Emoia cyanura sensu lato (Ortenburger, 1924 - Burt & Burt, 1932 - cette étude)
Emoia cyanura (cette étude)
Emoia pheonura (cette étude)
Cryptoblepharus poecilopleurus (Ortenburger, 1924 - Burt & Burt, 1932 - cette étude)
Lipinia noctua (Ortenburger, 1924 - Burt & Burt, 1932 - cette étude)

Lepidodactylus lugubris (Ortenburger, 1924 - Burt & Burt, 1932 - cette étude)
Gehyra oceanica (Ortenburger, 1924 - Burt & Burt, 1932)

ARATIKA

Emoia cyanura sensu lato (Ortenburger, 1924 - Burt & Burt, 1932)
Cryptoblepharus poecilopleurus (Ortenburger, 1924 - Burt & Burt, 1932)
Lipinia noctua (Ortenburger, 1924 - Burt & Burt, 1932)
Lepidodactylus lugubris (Ortenburger, 1924 - Burt & Burt, 1932)
Gehyra oceanica (Ortenburger, 1924 - Burt & Burt, 1932)

ARUTUA

Emoia cyanura sensu lato (Ortenburger, 1924 - Burt & Burt, 1932)
Cryptoblepharus poecilopleurus (Ortenburger, 1924 - Burt & Burt, 1932)
Lipinia noctua (Burt & Burt, 1932)
Lepidodactylus lugubris (Ortenburger, 1924 - Burt & Burt, 1932)

FAAITE

Lepidodactylus lugubris (Ortenburger, 1924 - Burt & Burt, 1932)
Gehyra oceanica (Ortenburger, 1924 - Burt & Burt, 1932)

FAKAHINA

Emoia cyanura sensu lato (Burt & Burt, 1932)

FAKARAVA

Emoia cyanura sensu lato (Schmidt, 1922 - Ortenburger, 1924 - Burt & Burt, 1932)
Cryptoblepharus poecilopleurus (Ortenburger, 1924 - Burt & Burt, 1932 - Crombie, coll. USNM - cette étude)
Lipinia noctua (Ortenburger, 1924 - Burt & Burt, 1932)
Lepidodactylus lugubris (Ortenburger, 1924 - Burt & Burt, 1932 - cette étude)
Gehyra oceanica (Ortenburger, 1924 - Burt & Burt, 1932)

FANGATAUFA

Emoia pheonura (MHNP 1987-1236 à 1259)
Cryptoblepharus poecilopleurus (MHNP 1987-1260 à 1272)
Lipinia noctua (MHNP 1987-1286 à 1289)
Gehyra oceanica (MHNP 1987-1273 et 1274)
Gehyra mutilata (MHNP 1987-1275 à 1285)

HAO

Emoia cyanura sensu lato (Schmidt, 1922 - Burt & Burt, 1932)
Lipinia noctua (Schmidt, 1922 - Burt & Burt, 1932)
Lepidodactylus lugubris (Schmidt, 1922 - Burt & Burt, 1932)
Gehyra oceanica (Schmidt, 1922 - Burt & Burt, 1932)

Gehyra mutilata (Schmidt, 1922 - Burt & Burt, 1932)

HITI

Emoia cyanura sensu lato (Ortenburger, 1924 - Burt & Burt, 1932)
Cryptoblepharus poecilopleurus (Ortenburger, 1924 - Burt & Burt, 1932)
Gehyra oceanica (Schmidt, 1922 - Burt & Burt, 1932)
Gehyra mutilata (Ortenburger, 1924 - Burt & Burt, 1932)

KATIU

Emoia cyanura sensu lato (Ortenburger, 1924 - Burt & Burt, 1932)
Cryptoblepharus poecilopleurus (Ortenburger, 1924 - Burt & Burt, 1932)
Lipinia noctua (Ortenburger, 1924 - Burt & Burt, 1932)
Gehyra oceanica (Ortenburger, 1924 - Burt & Burt, 1932)
Gehyra mutilata (Ortenburger, 1924 - Burt & Burt, 1932)

KAUEHI

Emoia cyanura sensu lato (Ortenburger, 1924 - Burt & Burt, 1932)
Cryptoblepharus poecilopleurus (Ortenburger, 1924 - Burt & Burt, 1932)
Lipinia noctua (Ortenburger, 1924 - Burt & Burt, 1932)
Lepidodactylus lugubris (Ortenburger, 1924 - Burt & Burt, 1932)
Gehyra oceanica (Ortenburger, 1924 - Burt & Burt, 1932)

KAUKURA

Emoia cyanura sensu lato (Ortenburger, 1924 - Burt & Burt, 1932)
Emoia pheonura (cette étude)
Cryptoblepharus poecilopleurus (Ortenburger, 1924 - Burt & Burt, 1932)
Lipinia noctua (Ortenburger, 1924 - Burt & Burt, 1932)
Gehyra oceanica (Ortenburger, 1924 - Burt & Burt, 1932)

MAKATEA

Emoia cyanura sensu lato (Sternfeld, 1920)
Emoia cyanura (MHNP 1987-1202 à 1218 - cette étude)
Cryptoblepharus poecilopleurus (de Rooij, 1915 - Sternfeld, 1920 - Mertens, 1931 - MHNP 1987-1200 à 1201 - cette étude)
Lipinia noctua (Sternfeld, 1920 - MHNP 1987-1219 à 1222)
Lepidodactylus lugubris (Sternfeld, 1920 - MHNP 1987-1228 à 1235 - cette étude)
Gehyra oceanica (Sternfeld, 1920 - MHNP 1987-1223 à 1227 - cette étude)
Gehyra mutilata (Sternfeld, 1920)

MAKEMO

Emoia cyanura sensu lato (Ortenburger, 1924 - Burt & Burt, 1932)
Cryptoblepharus poecilopleurus (Ortenburger, 1924 - Burt & Burt, 1932)
Lipinia noctua (Schmidt, 1922 - Ortenburger, 1924 - Burt & Burt, 1932)
Lepidodactylus lugubris (Ortenburger, 1924 - Burt & Burt, 1932 - Crombie, coll. USNM)
Gehyra oceanica (Schmidt, 1922 - Burt & Burt, 1932)

Gehyra mutilata (Ortenburger, 1924 - Burt & Burt, 1932)

MANIHI

Emoia cyanura sensu lato (Ortenburger, 1924 - Burt & Burt, 1932)
Emoia cyanura (cette étude)
Emoia pheonura (cette étude)
Cryptoblepharus poecilopleurus (Ortenburger, 1924 - Burt & Burt, 1932 - cette étude)
Lipinia noctua (Ortenburger, 1924 - Burt & Burt, 1932 - cette étude)
Lepidodactylus lugubris (Ortenburger, 1924 - Burt & Burt, 1932 - cette étude)
Gehyra oceanica (Ortenburger, 1924 - Burt & Burt, 1932)
Gehyra mutilata (Ortenburger, 1924 - Burt & Burt, 1932)

MARIA

Emoia cyanura sensu lato (Ortenburger, 1923 - Burt & Burt, 1932)
Lepidodactylus lugubris (Ortenburger, 1923 - Burt & Burt, 1932)

MARUTEA

Emoia cyanura sensu lato (Burt & Burt, 1932)
Cryptoblepharus poecilopleurus (Burt & Burt, 1932)
Lipinia noctua (Burt & Burt, 1932)
Lepidodactylus lugubris (Burt & Burt, 1932)

MARUTEA SUD

Emoia cyanura sensu lato (Ortenburger, 1923)
Cryptoblepharus poecilopleurus (Ortenburger, 1923)
Lipinia noctua (Ortenburger, 1923)
Lepidodactylus lugubris (Ortenburger, 1923)

MATAIVA

Emoia cyanura sensu lato (Ortenburger, 1924 - Burt & Burt, 1932)
Cryptoblepharus poecilopleurus (Ortenburger, 1924 - Burt & Burt, 1932)
Lipinia noctua (Ortenburger, 1924 - Burt & Burt, 1932)
Lepidodactylus lugubris (Ortenburger, 1924 - Burt & Burt, 1932)
Gehyra oceanica (Ortenburger, 1924 - Burt & Burt, 1932)

MATUREI VAVAO

Emoia cyanura sensu lato (Ortenburger, 1923 - Burt & Burt, 1932)
Lipinia noctua (MHNP 1979-3834)

MORUROA

Emoia cyanura sensu lato (Sternfeld, 1920 - Chevalier et al., 1968)
Lipinia noctua (MHNP 1979-3833)
Cryptoblepharus poecilopleurus (MHNP 1979-3835 et 3836)
Lepidodactylus lugubris (MHNP 1979-3832)

Gehyra oceanica (MHNP 1979-3829 à 3831)
Un Gecko (Chevalier et al., 1968 : 86)

NAPUKA

Cryptoblepharus poecilopleurus (Ortenburger, 1923 - Burt & Burt, 1932)
Lepidodactylus lugubris (cette étude)

NIAU

Emoia cyanura sensu lato (Sternfeld, 1920 - Schmidt, 1922)
Cryptoblepharus poecilopleurus (Sternfeld, 1920 - Schmidt, 1922 - Burt & Burt, 1932)
Lipinia noctua (Sternfeld, 1920 - Schmidt, 1922 - Burt & Burt, 1932)
Lepidodactylus lugubris (Schmidt, 1922 - Burt & Burt, 1932)
Gehyra mutilata (Sternfeld, 1920)

NIHIRU

Emoia cyanura sensu lato (Schmidt, 1922 - Burt & Burt, 1932)
Gehyra oceanica (Burt & Burt, 1932)
Gehyra mutilata (Schmidt, 1922)

RANGIROA

Emoia cyanura sensu lato (Ortenburger, 1923 - Burt & Burt, 1932 - Crombie, coll. USNM)
Emoia pheonura (cette étude)
Cryptoblepharus poecilopleurus (Ortenburger, 1923 - Burt & Burt, 1932 - Crombie, coll. USNM)
Lipinia noctua (Ortenburger, 1924 - Burt & Burt, 1932 - Crombie, coll. USNM - cette étude)
Lepidodactylus lugubris (Ortenburger, 1923 - Burt & Burt, 1932 - Crombie, coll. USNM)
Gehyra oceanica (Ortenburger, 1923, 1924 - Burt & Burt, 1932 - Crombie, coll. USNM)
Gehyra mutilata (Crombie, coll. USNM)

RARAKA

Emoia cyanura sensu lato (Ortenburger, 1924 - Burt & Burt, 1932)
Lipinia noctua (Stejneger, 1899 - Ortenburger, 1924 - Burt & Burt, 1932 - Crombie, coll. USNM)
Lepidodactylus lugubris (Ortenburger, 1924 - Burt & Burt, 1932)
Gehyra oceanica (Ortenburger, 1924 - Burt & Burt, 1932 - Crombie, coll. USNM)

RAROIA

Emoia cyanura sensu lato (Ortenburger, 1924 - Burt & Burt, 1932 - Morrison, 1954)
Cryptoblepharus poecilopleurus (Morrison, 1954)
Lipinia noctua (Ortenburger, 1924 - Burt & Burt, 1932 - Morrison, 1954)

Lepidodactylus lugubris (Morrison, 1954)
Gehyra oceanica (Ortenburger, 1924 - Burt & Burt, 1932
- Morrison, 1954)

* Faregare, motu
Emoia cyanura sensu lato (Crombie, coll. USNM)

* Kahongi, motu
Emoia cyanura sensu lato (Crombie, coll. USNM)
Cryptoblepharus poecilopleurus (Crombie, coll. USNM)

* Mataira, motu
Lepidodactylus lugubris (Crombie, coll. USNM)
Gehyra oceanica (Crombie, coll. USNM)

* Ngarivarivari, motu
Gehyra oceanica (Crombie, coll. USNM)

* Ngarumaoa, motu
Lepidodactylus lugubris (Crombie, coll. USNM)
Gehyra oceanica (Crombie, coll. USNM)

* Oneroa, motu
Emoia cyanura sensu lato (Crombie, coll. USNM)
Cryptoblepharus poecilopleurus (Crombie, coll. USNM)
Lepidodactylus lugubris (Crombie, coll. USNM)
Gehyra oceanica (Crombie, coll. USNM)

* Onigehuihui, motu
Gehyra oceanica (Crombie, coll. USNM)

* Opakea, motu
Emoia cyanura sensu lato (Crombie, coll. USNM)
Cryptoblepharus poecilopleurus (Crombie, coll. USNM)
Gehyra oceanica (Crombie, coll. USNM)

* Orare, motu
Emoia cyanura sensu lato (Crombie, coll. USNM)
Cryptoblepharus poecilopleurus (Crombie, coll. USNM)
Lipinia noctua (Crombie, coll. USNM)

* Oteteo, motu
Emoia cyanura sensu lato (Crombie, coll. USNM)

* Otikaheru, motu
Cryptoblepharus poecilopleurus (Crombie, coll. USNM)

* Takoke, motu
Emoia cyanura sensu lato (Crombie, coll. USNM)
Cryptoblepharus poecilopleurus (Crombie, coll. USNM)
Lepidodactylus lugubris (Crombie, coll. USNM)

* Tenuka Haupapatia, motu
Emoia cyanura sensu lato (Crombie, coll. USNM)
Cryptoblepharus poecilopleurus (Crombie, coll. USNM)
Lipinia noctua (Crombie, coll. USNM)

TAHANEA

Emoia cyanura sensu lato (Ortenburger, 1924 - Burt & Burt, 1932)
Cryptoblepharus poecilopleurus (Ortenburger, 1924 - Burt & Burt, 1932)
Lipinia noctua (Ortenburger, 1924 - Burt & Burt, 1932)
Gehyra oceanica (Ortenburger, 1924 - Burt & Burt, 1932)

TAIARO

Emoia cyanura sensu lato (Sternfeld, 1920 - Ortenburger, 1924 - Burt & Burt, 1932)
Cryptoblepharus poecilopleurus (Ortenburger, 1924 - Burt & Burt, 1932)
Lipinia noctua (Sternfeld, 1920 - Ortenburger, 1924 - Burt & Burt, 1932)
Gehyra oceanica (Ortenburger, 1924 - Burt & Burt, 1932)

TAKAPOTO

Emoia cyanura sensu lato (Ortenburger, 1923, 1924 - Burt & Burt, 1932 - Rivière, 1979 - Blanc et al., 1983)
Emoia cyanura (cette étude)
Emoia pheonura (cette étude)
Cryptoblepharus poecilopleurus (Ortenburger, 1924 - Burt & Burt, 1932 - Blanc et al., 1983)
Lipinia noctua (Ortenburger, 1923, 1924 - Burt & Burt, 1932 - Blanc et al., 1983)
Lepidodactylus lugubris (Ortenburger, 1924 - Burt & Burt, 1932 - Blanc et al., 1983)
Gehyra oceanica (Ortenburger, 1923, 1924 - Burt & Burt, 1932 - Blanc et al., 1983)
Gehyra mutilata (Ortenburger, 1924 - Burt & Burt, 1932 - cette étude)
Gecko des cocotiers et Gecko des maisons (Rivière, 1979:28)

TAKAROA

Emoia cyanura sensu lato (Schmidt, 1922 - Ortenburger, 1924 - Burt & Burt, 1932)
Emoia pheonura (cette étude)
Cryptoblepharus poecilopleurus (Schmidt, 1922 - Ortenburger, 1924 - Burt & Burt, 1932)
Lipinia noctua (Schmidt, 1922 - Ortenburger, 1924 - Burt & Burt, 1932)
Lepidodactylus lugubris (Schmidt, 1922 - Ortenburger, 1924 - Burt & Burt, 1932 - Tanner, 1952 - cette étude)
Gehyra oceanica (Schmidt, 1922 - Ortenburger, 1923, 1924 - Burt & Burt, 1932)
Gehyra mutilata (Schmidt, 1922 - Burt & Burt, 1932)

TAKUME

Emoia cyanura sensu lato (Ortenburger, 1924 - Burt & Burt, 1932)
Cryptoblepharus poecilopleurus (Ortenburger, 1924 - Burt & Burt, 1932)
Lipinia noctua (Ortenburger, 1924 - Burt & Burt, 1932)
Lepidodactylus lugubris (Ortenburger, 1924 - Burt & Burt, 1932)
Gehyra oceanica (Ortenburger, 1924 - Burt & Burt, 1932)

TENARARO

Gehyra oceanica (Ortenburger, 1923 - Burt & Burt, 1932)

TEPOTO

Lepidodactylus lugubris (cette étude)

TIKEHAU

Emoia cyanura sensu lato (Ortenburger, 1923 - Burt & Burt, 1932)
Emoia pheonura (cette étude)
Cryptoblepharus poecilopleurus (cette étude)
Lipinia noctua (Ortenburger, 1924 - Burt & Burt, 1932 - cette étude)
Lepidodactylus lugubris (cette étude)
Gehyra oceanica (Ortenburger, 1924 - Burt & Burt, 1932 - cette étude)
Gehyra mutilata (cette étude)

TIKEI

Emoia cyanura sensu lato (Sternfeld, 1920 - Ortenburger, 1923
- Burt & Burt, 1932)
Cryptoblepharus poecilopleurus (Ortenburger, 1923 - Burt & Burt, 1932)
Lipinia noctua (Sternfeld, 1920 - Ortenburger, 1923
- Burt & Burt, 1932)
Lepidodactylus lugubris (Ortenburger, 1923 - Burt & Burt, 1932)
Gehyra oceanica (Ortenburger, 1923 - Burt & Burt, 1932)

TOAU

Emoia cyanura sensu lato (Ortenburger, 1924 - Burt & Burt, 1932
- Crombie, coll. USNM)
Cryptoblepharus poecilopleurus (Ortenburger, 1924 - Burt & Burt, 1932
- Crombie, coll. USNM)
Lipinia noctua (Ortenburger, 1924 - Burt & Burt, 1932
- Crombie, coll. USNM)
Lepidodactylus lugubris (Ortenburger, 1924 - Burt & Burt, 1932)
Gehyra oceanica (Ortenburger, 1924 - Burt & Burt, 1932)

TUREIA

Emoia cyanura sensu lato (Ortenburger, 1923 - Burt & Burt, 1932)
Cryptoblepharus poecilopleurus (Ortenburger, 1923 - Burt & Burt, 1932)
Gehyra oceanica (Ortenburger, 1923 - Burt & Burt, 1932)

2.3. ARCHIPEL DES GAMBIER.

AKAMARU

Emoia cyanura sensu lato (Ortenburger, 1923 - Burt & Burt, 1932)
Lipinia noctua (Ortenburger, 1923 - Burt & Burt, 1932)

MANGAREVA

Emoia cyanura sensu lato (Ortenburger, 1923 - Burt & Burt, 1932
  - Cochereau, 1974 - Blanc et al., 1983)
Emoia cyanura (cette étude)
Lipinia noctua (Ortenburger, 1923 - Burt & Burt, 1932
  - Cochereau, 1974 - Blanc et al., 1983)
Lepidodactylus lugubris (Blanc et al., 1983)
Gehyra oceanica (Cochereau, 1974)
Gehyra mutilata (Blanc et al., 1983)
Hemidactylus garnotii (Kluge & Eckardt, 1969 - Blanc et al., 1983)

TOTEGEGIE, motu

Cryptoblepharus poecilopleurus (Blanc et al., 1983)

2.4. ARCHIPEL DES AUSTRALES.

KARAPORO, motu

Cryptoblepharus poecilopleurus (Ortenburger, 1923 - Burt & Burt, 1932)

RAEVAVAE

Emoia cyanura sensu lato (Schmidt, 1921 - Ortenburger, 1924
  - Burt & Burt, 1932)
Lipinia noctua (Schmidt, 1921 - Burt & Burt, 1932)
Gehyra oceanica (Schmidt, 1921 - Burt & Burt, 1932)
Gehyra mutilata (Schmidt, 1921 - Burt & Burt, 1932)

RAPA

Emoia cyanura sensu lato (Ortenburger, 1923 - Burt & Burt, 1932)
Cryptoblepharus poecilopleurus (Schmidt, 1921 - Ortenburger, 1923
  - Burt & Burt, 1932 - Crombie, coll. USNM)
Lipinia noctua (Ortenburger, 1923 - Burt & Burt, 1932)
Lepidodactylus lugubris (Ortenburger, 1923 - Burt & Burt, 1932
  - Crombie, coll. USNM)
Hemidactylus garnotii (Ortenburger, 1923 - Burt & Burt, 1932
  - Kluge & Eckardt, 1969 - Crombie, coll. USNM)

RIMATARA

Emoia cyanura sensu lato (Sternfeld, 1920 - Schmidt, 1921
- Burt & Burt, 1932)
Cryptoblepharus poecilopleurus (Sternfeld, 1920 - Schmidt, 1921
- Burt & Burt,1932)
Lipinia noctua (Sternfeld, 1920 - Schmidt, 1921, 1922)
Gehyra oceanica (Sternfeld, 1920 - Schmidt, 1921 - Burt & Burt, 1932)
Gehyra mutilata (Sternfeld, 1920, 1921 - Schmidt, 1922
- Burt & Burt, 1932)
Hemidactylus garnotii (Sternfeld, 1920)

RURUTU

Emoia cyanura sensu lato (Schmidt, 1921 - Burt & Burt, 1932)
Emoia cyanura (cette étude)
Emoia pheonura (cette étude)
Cryptoblepharus poecilopleurus (cette étude)
Lipinia noctua (Schmidt, 1921 - Burt & Burt, 1932 - cette étude)
Lepidodactylus lugubris (cette étude)
Gehyra oceanica (cette étude)
Gehyra mutilata (cette étude)

TUBUAI

Emoia cyanura sensu lato (Schmidt, 1921 - Burt & Burt, 1932)
Emoia cyanura (cette étude)
Emoia pheonura (cette étude)
Cryptoblepharus poecilopleurus (Schmidt, 1921 - Burt & Burt, 1932
- cette étude)
Lipinia noctua (cette étude)
Lepidodactylus lugubris (Schmidt, 1921 - Burt & Burt, 1932
- cette étude)
Gehyra oceanica (cette étude)
Gehyra mutilata (cette étude)

VAVITAO

Emoia cyanura sensu lato (Burt & Burt, 1932)
Lipinia noctua (Burt & Burt, 1932)
Gehyra oceanica (Burt & Burt, 1932)
Gehyra mutilata (Burt & Burt, 1932)

2.5. ARCHIPEL DES MARQUISES.

Emoia cyanura sensu lato : Marquises, sans autre mention
(Mertens, 1934)
Lipinia noctua : Marquises, sans autre mention (Mertens, 1934
- Oliver & Shaw, 1953 - Schwaner, 1980
- MHNP 1924-124 et 125 (Sc683/2))

Cryptoblepharus poecilopleurus : Marquises, sans autre mention (Mertens, 1934)
Lepidodactylus lugubris : Marquises, sans autre mention (Mertens, 1934 - Parker, 1936)
Gehyra oceanica : Marquises, sans autre mention (Mertens, 1934 - MHNP 6581 (G244/11) et 1924-126 (G244/7))
Gehyra mutilata : Marquises, sans autre mention (Mertens, 1934)
Hemidactylus garnotii : Marquises, sans autre mention (Mertens, 1934)

EIAO

Emoia cyanura (MHNP 1988-3001 à 3010)
Emoia pheonura (MHNP 1988-3011 à 3013)
Cryptoblepharus poecilopleurus (Ortenburger, 1923 - Burt & Burt, 1932)
Lipinia noctua (Ortenburger, 1923 - Burt & Burt, 1932 - Schmidt & Necker, 1933 - MHNP 1988-3014 à 3016)
Lepidodactylus lugubris (Ortenburger, 1923 - Burt & Burt, 1932 - MHNP 1988-3017 à 3020)
Gehyra oceanica (Schmidt & Necker, 1933 - MHNP 1988-3021 à 3031)
Gehyra mutilata (Burt & Burt, 1932 - MHNP 1988-3032 et 3033)
Hemidactylus garnotii (Schmidt & Necker, 1933)
Hemiphyllodactylus typus (Schmidt & Necker, 1933 - MHNP 1988-3034)

FATU HIVA

Emoia cyanura sensu lato (Ortenburger, 1923 - Burt & Burt,1932 - Schmidt & Necker, 1933 - Crombie, coll. USNM)
Emoia cyanura (cette étude)
Emoia pheonura (cette étude)
Lipinia noctua (Ortenburger, 1923 - Burt & Burt, 1932 - Schmidt & Necker, 1933 - cette étude)
Lepidodactylus lugubris (Schmidt & Necker, 1933 - cette étude)
Gehyra oceanica (Crombie, coll. USNM)
Gehyra mutilata (Ortenburger, 1923 - Burt & Burt, 1932 - Schmidt & Necker, 1933)

FATU HUKU

Emoia cyanura sensu lato (Ortenburger, 1923 - Burt & Burt, 1932)
Cryptoblepharus poecilopleurus (Ortenburger, 1923 - Burt & Burt, 1932)
Lipinia noctua (Schmidt & Necker, 1933)
Gehyra oceanica (Schmidt & Necker, 1933 - Crombie, coll. USNM - cette étude)
Gehyra mutilata (Schmidt & Necker, 1933)

HATUTU

Cryptoblepharus poecilopleurus (Schmidt & Necker, 1933)
Gehyra mutilata (Schmidt & Necker, 1933)

HIVA OA

Emoia cyanura sensu lato (Schmidt, 1921 - Ortenburger, 1923

- Burt & Burt, 1932 - Crombie, coll. USNM)
Emoia cyanura (cette étude)
Emoia pheonura (cette étude)
Lipinia noctua (Ortenburger, 1923 - Burt & Burt, 1932 - Schmidt & Necker, 1933 - cette étude)
Lepidodactylus lugubris (Ortenburger, 1923 - Burt & Burt, 1932 - Schmidt & Necker, 1933 - cette étude)
Gehyra oceanica (Ortenburger, 1923 - Burt & Burt, 1932 - Schmidt & Necker, 1933 - Crombie, coll. USNM - cette étude)
Hemidactylus garnotii (Schmidt & Necker, 1933 - Kluge & Eckardt, 1969)
Hemiphyllodactylus typus (Schmidt & Necker, 1933)

MOTANE

Emoia cyanura sensu lato (Ortenburger, 1923 - Burt & Burt, 1932 - Schmidt & Necker, 1933)
Lipinia noctua (Ortenburger, 1923 - Burt & Burt, 1932 - Schmidt & Necker, 1933)
Lepidodactylus lugubris (Schmidt & Necker, 1933)
Gehyra oceanica (Schmidt & Necker, 1933)
Gehyra mutilata (Schmidt & Necker, 1933)
Hemidactylus garnotii (Schmidt & Necker, 1933)
Hemiphyllodactylus typus (Schmidt & Necker, 1933)

NUKU HIVA

Emoia cyanura sensu lato (Schmidt, 1922 - Ortenburger, 1923 - Burt & Burt, 1932 - Tanner, 1952 - Crombie, coll. USNM)
Emoia cyanura (cette étude)
Emoia pheonura (cette étude)
Cryptoblepharus poecilopleurus (Duméril et al., 1881)
Lipinia noctua (Schmidt, 1922 - Ortenburger, 1923 - Burt & Burt, 1932 - cette étude)
Lepidodactylus lugubris (Schmidt, 1922 - Burt & Burt, 1932 - Tanner, 1952 - cette étude)
Gehyra oceanica (Tilenau, 1820 - Schmidt, 1922 - Ortenburger, 1923 - Burt & Burt, 1932 - Tanner, 1952 - cette étude)
Gehyra mutilata (Schmidt, 1922 - Ortenburger, 1923 - Burt & Burt, 1932 - Tanner, 1952 - cette étude)
Hemidactylus garnotii (Tanner, 1952 - Kluge & Eckardt, 1969)

TAHUATA

Emoia cyanura sensu lato (Schmidt & Necker, 1933)
Emoia pheonura (cette étude)
Lipinia noctua (Schmidt & Necker, 1933 - cette étude)
Lepidodactylus lugubris (Schmidt & Necker, 1933 - cette étude)
Gehyra oceanica (Schmidt & Necker, 1933 - cette étude)
Gehyra mutilata (Ortenburger, 1923 - Burt & Burt, 1932 - Schmidt & Necker, 1933)

UA HUKA

Emoia cyanura sensu lato (Ortenburger, 1923 - Burt & Burt, 1932)
Emoia cyanura (cette étude)
Emoia pheonura (cette étude)
Cryptoblepharus poecilopleurus (Ortenburger, 1923 - Burt & Burt, 1932)
Lipinia noctua (cette étude)
Lepidodactylus lugubris (Schmidt & Necker, 1933 - cette étude)
Gehyra oceanica (Ortenburger, 1923 - Burt & Burt, 1932 - cette étude)
Gehyra mutilata (cette étude)
Hemidactylus garnotii (cette étude)

UA POU

Emoia cyanura sensu lato (Schmidt, 1922 - Ortenburger, 1923 - Burt & Burt, 1932 - Schmidt & Necker, 1933)
Emoia cyanura (cette étude)
Emoia pheonura (cette étude)
Lipinia noctua (Ortenburger, 1923 - Burt & Burt, 1932 - Schmidt & Necker, 1933 - cette étude)
Lepidodactylus lugubris (Schmidt & Necker, 1933 - cette étude)
Gehyra oceanica (Schmidt & Necker, 1933 - cette étude)
Gehyra mutilata (Schmidt & Necker, 1933 - cette étude)
Hemidactylus garnotii (Schmidt & Necker, 1933 - Kluge & Eckardt, 1969)

2.6. GROUPE PITCAIRN, ILES DE PAQUES ET CLIPPERTON.

CLIPPERTON

Emoia cyanura sensu lato (Burt & Burt, 1932)
Emoia arundelii (Garman, 1899 - Heller, 1903 - Van Denburg & Slevin, 1914 - Sachet, 1962 - Ineich, 1987 a - MHNP 1981-162)
Emoia pheonura (Ineich, 1987 a)
Gehyra mutilata (Sachet, 1962)

DUCIE

Emoia cyanura sensu lato (Ortenburger, 1923 - Burt & Burt, 1932)
Un gecko identifié comme G. oceanica ou L. lugubris par Chapin (in Rehder & Randall, 1975)

HENDERSON

Emoia cyanura sensu lato (Ortenburger, 1923 - Burt & Burt, 1932 - Fosberg et al., 1983)
Cryptoblepharus poecilopleurus (Mertens, 1931 : 138)
Un gecko non identifié par Fosberg et al., 1983 : 22

OENO

Emoia cyanura sensu lato (Ortenburger, 1923 - Burt & Burt, 1932)
Lepidodactylus lugubris (Ortenburger, 1923 - Burt & Burt, 1932)

PAQUES

Emoia cyanura sensu lato (Fichier Muséum Bruxelles ?)
Cryptoblepharus poecilopleurus (Garman, 1908 - Donoso Barros, 1950, 1966 - Fichier Muséum Bruxelles - Crombie, coll. USNM - cette étude)
Lepidodactylus lugubris (Garman, 1908 - Donoso Barros, 1950, 1966 - Fichier Muséum Bruxelles ?)
Gehyra oceanica (Fichier Muséum Bruxelles)
Gehyra mutilata (Donoso Barros, 1966)
Un grand gecko (Garman, 1908)

PITCAIRN

Emoia cyanura sensu lato (Ortenburger, 1923 - Burt & Burt, 1932 - Fichier Muséum Bruxelles)
Lipinia noctua (Ortenburger, 1923 - Burt & Burt, 1932 - Zweifel, 1979 - Fichier Muséum Bruxelles)
Lepidodactylus lugubris (Ortenburger, 1923 - Burt & Burt, 1932)
Gehyra mutilata (Ortenburger, 1923 - Burt & Burt, 1932)

3. ANALYSE ZOOGEOGRAPHIQUE

Nous ne prendrons en compte, ici, que les 78 îles hautes et atolls pour lesquels nous ayons des informations herpétologiques (Tableau 1), soit 59 % de la liste des toponymes figurant dans notre annexe, à l'exclusion des motus. Ces derniers, en effet, sont parfois de très petite taille et leur peuplement est susceptible d'être restreint par des conditions inadéquates de milieu ou par la compétition des populations déjà en place.

3.1. DISTRIBUTION EN POLYNESIE ORIENTALE.

Le nombre d'îles et atolls d'où les dix espèces de lézards sont mentionnées, ainsi que leurs fréquences, sont regroupés dans le tableau 2.

3.1.1. Sept espèces, quatre Scincidae et trois Gekkonidae, ont une large distribution. Nous rapporterons, ci-dessous, la liste des localisations insulaires d'où ces taxons n'ont, à ce jour, pas été mentionnés.

Tableau 1 : Distribution de l'herpétofaune terrestre de Polynésie orientale.
Ec. s.l. = *Emoia cyanura sensu lato* ; Cp. = *Cryptoblepharus poecilopleurus* ; Ln. = *Lipinia noctua* ; Ll. = *Lepidodactylus lugubris* ; Go. = *Gehyra oceanica* ; Gm. = *Gehyra mutilata* ; Hg. = *Hemidactylus garnotii* ; Ht. = *Hemiphyllodactylus typus* ; Np. = *Nactus pelagicus*.

	SCINCIDAE			GEKKONIDAE					
	Ec. s.l.	Cp.	Ln.	Ll.	Go.	Gm.	Hg.	Ht.	Np.
SOCIETE									
Bora Bora..........	!+!	!+!	!+!	!+!	!+!	! !	! !	! !	! !
Huahine............	!+!	!+!	!+!	!+!	!+!	!+!	! !	! !	! !
Maupiti............	!+!	!+!	!+!	!+!	!+!	! !	! !	! !	! !
Mehetia............	!+!	!+!	!+!	! !	! !	! !	! !	! !	! !
Moorea.............	!+!	!+!	!+!	!+!	!+!	!+!	!+!	!+!	! !
Mopelia............	!+!	!+!	!+!	!+!	!+!	!+!	! !	! !	! !
Raiatea............	!+!	!+!	!+!	!+!	!+!	! !	! !	! !	! !
Scilly.............	!+!	!+!	!+!	!+!	!+!	! !	! !	! !	! !
Tahaa..............	!+!	!+!	!+!	!+!	!+!	! !	! !	! !	! !
Tahiti.............	!+!	!+!	!+!	!+!	!+!	!+!	!+!	!+!	!+!
Tetiaroa...........	!+!	! !	! !	! !	!+!	! !	! !	! !	! !
Tupai..............	!+!	!+!	!+!	!+!	!+!	! !	! !	! !	! !
TUAMOTU									
Ahe................	!+!	!+!	!+!	!+!	!+!	!+!	! !	! !	! !
Aki Aki............	! !	! !	! !	! !	!+!	! !	! !	! !	!+!
Amanu..............	! !	!+!	! !	! !	! !	! !	! !	! !	! !
Anaa...............	!+!	!+!	!+!	!+!	!+!	! !	! !	! !	! !
Apataki............	!+!	!+!	!+!	!+!	!+!	! !	! !	! !	! !
Aratika............	!+!	!+!	!+!	!+!	!+!	! !	! !	! !	! !
Arutua.............	!+!	!+!	!+!	!+!	! !	! !	! !	! !	! !
Faaite.............	! !	! !	! !	!+!	!+!	! !	! !	! !	! !
Fakahina...........	!+!	! !	! !	! !	! !	! !	! !	! !	! !
Fakarava...........	!+!	!+!	!+!	!+!	!+!	! !	! !	! !	! !
Fangataufa.........	!+!	!+!	!+!	! !	!+!	!+!	! !	! !	! !
Hao................	!+!	! !	!+!	!+!	!+!	!+!	! !	! !	! !

Tableau 1 (suite) : Distribution de l'herpétofaune terrestre de Polynésie orientale.

	Ec. s.l.	Cp.	Ln.	Ll.	Go.	Gm.	Hg.	Ht.	Np.
Hiti	!+!	!+!	! !	! !	!+!	!+!	! !	! !	! !
Katiu	!+!	!+!	!+!	! !	!+!	!+!	! !	! !	! !
Kauehi	!+!	!+!	!+!	!+!	!+!	! !	! !	! !	! !
Kaukura	!+!	!+!	!+!	! !	!+!	! !	! !	! !	! !
Makatea	!+!	!+!	!+!	!+!	!+!	!+!	! !	! !	! !
Makemo	!+!	!+!	!+!	!+!	!+!	!+!	! !	! !	! !
Manihi	!+!	!+!	!+!	!+!	!+!	!+!	! !	! !	! !
Maria	!+!	! !	! !	!+!	! !	! !	! !	! !	! !
Marutea	!+!	!+!	!+!	!+!	! !	! !	! !	! !	! !
Marutea Sud	!+!	!+!	!+!	!+!	! !	! !	! !	! !	! !
Mataiva	!+!	!+!	!+!	!+!	!+!	! !	! !	! !	! !
Maturei Vavao	!+!	! !	!+!	! !	! !	! !	! !	! !	! !
Moruroa	!+!	!+!	!+!	!+!	!+!	! !	! !	! !	! !
Napuka	! !	!+!	! !	!+!	! !	! !	! !	! !	! !
Niau	!+!	!+!	!+!	!+!	! !	!+!	! !	! !	! !
Nihiru	!+!	! !	! !	! !	!+!	!+!	! !	! !	! !
Rangiroa	!+!	!+!	!+!	!+!	!+!	!+!	! !	! !	! !
Raraka	!+!	! !	!+!	!+!	!+!	! !	! !	! !	! !
Raroia	!+!	!+!	!+!	!+!	!+!	! !	! !	! !	! !
Tahanea	!+!	!+!	!+!	! !	!+!	! !	! !	! !	! !
Taiaro	!+!	!+!	!+!	! !	!+!	! !	! !	! !	! !
Takapoto	!+!	!+!	!+!	!+!	!+!	!+!	! !	! !	! !
Takaroa	!+!	!+!	!+!	!+!	!+!	!+!	! !	! !	! !
Takume	!+!	!+!	!+!	!+!	!+!	! !	! !	! !	! !
Tenararo	! !	! !	! !	! !	!+!	! !	! !	! !	! !
Tepoto	! !	! !	! !	!+!	! !	! !	! !	! !	! !
Tikehau	!+!	!+!	!+!	!+!	!+!	!+!	! !	! !	! !
Tiku	!+!	!+!	!+!	!+!	!+!	! !	! !	! !	! !
Toau	!+!	!+!	!+!	!+!	!+!	! !	! !	! !	! !
Tureia	!+!	!+!	! !	! !	!+!	! !	! !	! !	! !

Tableau 1 (fin) : Distribution de l'herpétofaune terrestre de Polynésie orientale.

	Ec. s.l.	Cp.	Ln.	Ll.	Go.	Gm.	Hg.	Ht.	Np.
GAMBIER									
Akamaru............	!+!	! !	!+!	! !	! !	! !	! !	! !	! !
Mangareva..........	!+!	! !	!+!	!+!	!+!	!+!	!+!	! !	! !
Totegegie..........	! !	!+!	! !	! !	! !	! !	! !	! !	! !
AUSTRALES									
Karaporo, motu.....	! !	!+!	! !	! !	! !	! !	! !	! !	! !
Raevavae...........	!+!	! !	!+!	! !	!+!	!+!	! !	! !	! !
Rapa...............	!+!	!+!	!+!	!+!	! !	! !	!+!	! !	! !
Rimatara...........	!+!	!+!	!+!	! !	!+!	!+!	!+!	! !	! !
Rurutu.............	!+!	!+!	!+!	!+!	!+!	!+!	! !	! !	! !
Tubuai.............	!+!	!+!	!+!	!+!	!+!	!+!	! !	! !	! !
Vavitao............	!+!	! !	!+!	! !	!+!	!+!	! !	! !	! !
MARQUISES									
Eiao...............	!+!	!+!	!+!	!+!	!+!	!+!	!+!	!+!	! !
Fatu Hiva..........	!+!	! !	!+!	!+!	!+!	!+!	! !	! !	! !
Fatu Huku..........	!+!	!+!	!+!	! !	!+!	!+!	! !	! !	! !
Hatutu.............	! !	!+!	! !	! !	! !	!+!	! !	! !	! !
Hiva Oa............	!+!	! !	!+!	!+!	!+!	! !	!+!	!+!	! !
Motane.............	!+!	! !	!+!	!+!	!+!	!+!	!+!	!+!	! !
Nuku Hiva..........	!+!	!+!	!+!	!+!	!+!	!+!	!+!	! !	! !
Tahuata............	!+!	! !	!+!	!+!	!+!	!+!	! !	! !	! !
Ua Huka............	!+!	!+!	!+!	!+!	!+!	!+!	!+!	! !	! !
Ua Pou.............	!+!	! !	!+!	!+!	!+!	!+!	!+!	! !	! !
PITCAIRN									
Ducie..............	!+!	! !	! !	!?!	!?!	! !	! !	! !	! !
Henderson..........	!+!	!+!	! !	!?!	!?!	! !	! !	! !	! !
Oeno...............	!+!	! !	! !	!+!	! !	! !	! !	! !	! !
Pitcairn...........	!+!	! !	!+!	!+!	! !	!+!	! !	! !	! !
PAQUES									
Pâques.............	!?!	!+!	! !	!+!	!?!	!+!	! !	! !	! !
CLIPPERTON									
Clipperton.........	!+!	! !	! !	! !	! !	!+!	! !	! !	! !

- Scincidae.

Aucune espèce de Scincidae n'est connue des atolls suivants, tous de l'archipel des Tuamotu : Aki Aki, Faaite, Tenararo.

Parmi les trois espèces de Scincidae, nous noterons les absences suivantes :

* *Emoia cyanura sensu lato* : archipel des Tuamotu : Aki Aki, Amanu, Faaite, Napuka, Tenararo ; archipel des Marquises : Hatutu ;

* *Cryptoblepharus poecilopleurus* : archipel de la Société : Tetiaroa ; archipel des Tuamotu : Faaite, Fakahina, Hao, Maria, Maturei Vavao, Nihiru, Raraka, Tenararo ; archipel des Gambier : Akamaru, Mangareva ; archipel des Australes : Raevavae, Vavitao ; archipel des Marquises : Fatu Hiva, Hiva Oa, Motane, Tahuata, Ua Pou ; groupe Pitcairn : Ducie, Oeno, Pitcairn ; Clipperton ;

* *Lipinia noctua* : archipel de la Société : Tetiaroa ; archipel des Tuamotu : Aki Aki, Amanu, Faaite, Fakahina, Hiti, Maria, Napuka, Nihiru, Tenararo, Tureia ; archipel des Marquises : Hatutu ; groupe Pitcairn : Ducie, Henderson, Oeno ; Pâques ; Clipperton.

- Gekkonidae.

Cette famille n'a pas été signalée de Mehetia (arch. de la Société), Amanu, Fakahina, Maturei Vavao (arch. des Tuamotu). Une espèce de gecko non déterminée a, par ailleurs, été citée de Scilly (arch. de la Société), Moruroa (arch. des Tuamotu), Ducie et Henderson (groupe Pitcairn). En plus de ces absences ou localisations incertaines, nous indiquerons la liste des îles et atolls d'où n'ont pas été mentionnées les deux espèces les plus fréquentes :

* *Lepidodactylus lugubris* : archipel de la Société : Mehetia, Tetiaroa ; archipel des Tuamotu : Aki Aki, Amanu, Fakahina, Hiti, Katiu, Kaukura, Maturei Vavao, Nihiru, Tahanea, Taiaro, Tenararo, Tureia ; archipel des Australes : Raevavae, Rimatara, Vavitao ; archipel des Marquises : Fatu Huku, Hatutu ; Clipperton ;

* *Gehyra oceanica* : archipel de la Société : Mehetia ; archipel des Tuamotu : Amanu, Arutua, Fakahina, Maria, Marutea, Marutea Sud, Maturei Vavao, Napuka, Niau ; archipel des Gambier : Akamaru, Totegegie ; archipel des Australes : Rapa ; archipel des Marquises : Hatutu ; groupe Pitcairn : Oeno, Pitcairn ; Clipperton.

Pour *Gehyra mutilata*, connu seulement de 36 localisations, nous renvoyons au catalogue chorologique.

3.1.2. Trois espèces de Gekkonidae ne sont, par contre, connues que d'un nombre limité de points de collecte :

- *Hemidactylus garnotii* : Tahiti et Moorea (arch. de la Société) ; Mangareva (arch. des Gambier) ; Rapa et Rimatara (arch. des

Tableau 2 : Présence et fréquences des neuf espèces de Reptiles terrestres connues de Polynésie orientale (à l'exception des îles de Pâques et Clipperton).

TAXONS	Présence sur les îles et atolls (n=78)	Fréquence sur les îles et atolls où des Reptiles sont mentionnés	Fréquence sur les îles et atolls où la famille est représentée
SCINCIDAE	74	0.95	--
Emoia cyanura sensu lato	70	0.90	0.95
Cryptoblepharus poecilopleurus	53	0.68	0.72
Lipinia noctua	59	0.76	0.80
GEKKONIDAE	69	0.88	--
Lepidodactylus lugubris	52	0.67	0.75
Gehyra oceanica	57	0.73	0.83
Gehyra mutilata	36	0.46	0.52
Hemidactylus garnotii	11	0.14	0.15
Hemiphyllo-dactylus typus	05	0.07	0.07
Nactus pelagicus	02	0.03	0.03

Australes) ; Eiao, Hiva Oa, Motane, Nuku Hiva, Ua Huka et Ua Pou (arch. des Marquises).

- *Hemiphyllodactylus typus* : Tahiti et Moorea (arch. de la Société) ; Eiao, Hiva Oa et Motane (arch. des Marquises).

- *Nactus pelagicus* : Tahiti (arch. de la Société) ; Aki Aki (arch. des Tuamotu).

Outre la faiblesse des récoltes pour cette dernière espèce, il est à noter qu'elle n'a plus jamais été récoltée au cours des dernières décennies. Sa présence actuelle n'est pas confirmée et elle n'a pas été incluse dans les listes proposées par L.G. Seurat (1934) et A.M. Adamson (1939), ni dans notre clé de détermination des Reptiles terrestres de Polynésie française (Blanc *et al.*, 1983) ; R. Mertens (1934 : 37), dans son étude générale des faunes herpétologiques insulaires, mentionne huit espèces de Polynésie orientale, et omet *Hemiphyllodactylus typus*. La collecte récente (mars 1986) d'un exemplaire de cette espèce, après six mois de terrain sur l'île haute de Moorea, par l'un de nous (I. Ineich), confirme sa présence mais aussi sa rareté.

3.2. TAUX DE PRESENCE.

Le tableau 3 indique, pour chaque archipel, la fréquence des sept espèces ou complexes d'espèces que nous avons retrouvés dans nos échantillonnages récents. Les Scincidae apparaissent plus densément distribués que les Gekkonidae. Parmi ces derniers, *Hemidactylus garnotii* n'est pas connu des Tuamotu et semble n'avoir une large dispersion qu'aux Marquises.

3.3. POSITION DE LA POLYNESIE ORIENTALE DANS L'AIRE CHOROLOGIQUE.

Nous indiquerons, approximativement d'Ouest en Est, l'extension globale des divers représentants de l'herpétofaune terrestre, hors de Polynésie orientale, en mentionnant les principaux pays et îles ou archipels rapportés par la littérature, et notamment les auteurs suivants :

Allison, 1982 ; Amerson, 1971 ; Amerson & Shelton, 1976 ; Amerson *et al.*, 1982 a et b ; Angel, 1935 ; Baker, 1979 ; Baker, 1947 ; Biswas & Sanyal, 1980 ; Blanc, 1972 ; Brown, 1954, 1956, 1980 ; Brown & Alcala, 1961, 1970, 1978 ; Brown & Fehlmann, 1958 ; Brown & Gibbons, 1986 ; Brown & Marshall, 1953 ; Brown & Parker, 1973, 1977 ; Brown *et al.*, 1980 ; Burt & Burt, 1932 ; Cagle 1946 a et b ; Cheke, 1984 ; Cheke & Lawley, 1983 ; Chrapliwy, 1956 ; Chrapliwy *et al.*, 1961 ; Church, 1962 ; Church & Lim, 1961 ; Clapp, 1975, 1977 ; Clapp & Kridler, 1977 ;

Tableau 3 : Fréquence des sept espèces les plus largement distribuées en Polynésie française. Le nombre total d'îles et atolls par archipel et le pourcentage des îles et atolls prospectés par archipel sont les suivantes : Société : 14 (86 %) ; Tuamotu : 76 (55 %) ; Australes : 7 (86 %) ; Marquises : 11 (91 %).

ARCHIPELS TAXONS	SOCIETE (12 îles et atolls)	TUAMOTU (42 atolls)	AUSTRALES (6 îles et atolls)	MARQUISES (10 îles)
SCINCIDAE				
E. cyanura sensu lato	1.000	0.875	1.000	0.900
C. poecilopleurus	0.916	0.762	0.666	0.500
L. noctua	0.916	0.738	1.000	0.900
GEKKONIDAE				
L. lugubris	0.833	0.714	0.500	0.800
G. oceanica	0.916	0.786	0.833	0.900
G. mutilata	0.333	0.333	0.833	0.900
H. garnotii	0.166	-	0.333	0.600

Clapp *et al.*, 1977 ; Clapp & Sibley, 1971 a et b ; Cogger *et al.*, 1983 ; Crombie, non publié ; Crombie & Dixon, en préparation ; Cuellar, 1984 ; Cuellar & Kluge, 1972 ; Downst, 1948 ; Dryden & Taylor, 1969 ; Duméril *et al.*, 1881 ; Duméril, 1851 ; Edgren, 1950 ; Ely & Clapp, 1973 ; Fisher, 1948 ; Fowler, 1914 ; Frankenberg, 1984 ; Frankenberg & Werner, 1981 ; Fugler, 1966 ; Gibbons, 1985 ; Girard, 1858 ; Grant, 1957 ; Greer, 1982 ; Hardy & McDiarmid, 1969 ; Hardy, 1977 ; Heatwole, 1975 ; Hediger, 1934 ; Henderson *et al.*, 1976 ; Higgins, 1943 ; Hunsaker, 1966 ; Hunsaker & Breese, 1967 ; Ingram & Covacevich, 1981 ; Jones, 1979 ; King, 1978 ; Kluge, 1982, 1983 ; Kluge & Eckardt, 1969 ; Lanza, 1983 ; Lieberman & Lieberman, 1970 ; Liner & Dundee, 1969 ; Lloyd *et al.*, 1968 ; Loveridge, 1946 (1974), 1948 ; Marcellini, 1971 ; Marshall, 1975 ; McCann, 1953, 1955, 1974 ; McCoy & Busack, 1970 ; McCoy, 1980 ; McCoy & Webber, 1984 ; McGregor, 1904 ; Mechler, 1968 ; Mertens, 1931, 1933 a et b, 1934, 1964 ; Mitchell & Hadle, 1980 ; Moritz, 1987 ; Moritz & King, 1985 ; Nussbaum, 1980 ; Okada, 1930 ; Oliver & Shaw, 1953 ; Ota, 1986 a et b ; Ota et Yamashita, 1985 ; Parker, 1925, 1936 ; Pernetta & Black, 1983 ; Pernetta & Watling, 1978 ; Peters & Donoso Barros, 1970 ; Pianka & Smith, 1959 ; Quay, 1974 ; Room, 1974 ; Schmidt, 1927 ; Schnee, 1901, 1904 ; Schwaner, 1980 ; Schwaner & Brown, 1984 ; Scott *et al.*, 1977 ; Shreve, 1938 ; Slevin, 1930, 1934 ; Smith, 1923, 1937 ; Smith, 1942 ; Smith & Grant, 1961 ; Stejneger, 1899 ; Sternfeld, 1918 ; Stoddart & Taylor, 1971 ; Tanner, 1952 ; Taylor & Elbel, 1958 ; Tinker, 1980 ; Vinson & Vinson, 1969 ; Vogt, 1912 ; Webb, 1972 ; Werner, 1899, 1901 ; Whitaker, 1970 ; Zug, 1985 ; Zweifel, 1979.

Le signe (?) indique une incertitude relative à la présence du taxon considéré. Les termes obsolètes sont remplacés par leurs équivalents actuels : Fanning (Ligne) ; Hawaii (Sandwich) ; Irian Jaya (Nouvelle-Guinée hollandaise) ; Kiribati (archipel des Gilbert) ; Mariannes (Ladrones) ; Samoa (îles des Navigateurs) ; Sulawesi (Célèbes) ; Vanuatu (Nouvelles-Hébrides). Deux toponymes n'ont pu être localisés avec certitude : Santa Helena et Suli.

3.3.1. Scincidae.

- *Emoia cyanura sensu lato* :

Philippines, Sulawesi, Moluques, Papouasie Nouvelle-Guinée, Irian Jaya, archipel de l'Amirauté, archipel de Bismarck (Nouvelle-Irlande, Nouvelle-Bretagne, Nouvelle-Hanovre), Carolines, Mariannes, Marshall, Kiribati, Salomon, Santa Cruz, groupe des Torres, Vanuatu, Fidji, Wallis, Tongareva, Tongatabu, groupe Tonga, Samoa, Danger, Tokelau, Hawaii, Pérou d'où un exemplaire unique est connu (Crombie & Dixon, en préparation). Une première approche de la distribution respective de chacun des deux taxons *E. cyanura* et *E. pheonura* est donnée par I. Ineich (1987 a).

- *Cryptoblepharus poecilopleurus* :

Papouasie Nouvelle-Guinée (?), Mariannes (Saïpan), Salomon (rare), Bonin, Vanuatu, Wake, Johnston atoll, Marcus, Fidji, Tongareva, Phoenix, Danger, Tokelau, Samoa, Cook, Malden, Hawaii, côtes Ouest Equateur (?), Chili, côtes Ouest Pérou (?).

- *Lipinia noctua* :

Moluques, Sulawesi, Papouasie Nouvelle-Guinée, Irian Jaya, Palau, Carolines, Amirauté, Bismarck (Nouvelle-Hanovre), Salomon (rare), Vanuatu, Marshall, Kiribati, Fidji, Tongatabu, Danger, Tokelau, Samoa, Hawaii.

3.3.2. Gekkonidae

- *Lepidodactylus lugubris* :

Mascareignes (Maurice), Chagos (Diego Garcia), Inde, Sri Lanka, Andaman, Nicobar, Birmanie, îles Cocos Keeling, Péninsule malaise, Taïwan, Ryu Kyu, Philippines, Bornéo, Moluques, Sulawesi, Papouasie Nouvelle-Guinée, Palau, Carolines, Mariannes (Tinian, Saïpan et Guam), Marshall, Kiribati, Phoenix, Johnston atoll, Australie (Queensland), Salomon, Bismarck, Nouvelle-Calédonie, Vanuatu, Fidji, Rotuma, Tonga, Tongareva, Danger, Tokelau, Samoa, Cook, Ligne, atoll Caroline, Palmyra, Malden, Mexique, Nicaragua, Panama, Colombie, Equateur, Brésil (Rio de Janeiro).

- *Gehyra oceanica* :

Mariannes (Saïpan), Papouasie Nouvelle-Guinée et îles voisines, Kiriwina, Australie (Queensland), Salomon, Marshall, Santa-Cruz, Banks, Vanuatu (île Pentecôte), Fidji, Tonga, Tongareva, Danger, Tokelau, Samoa, Cook, Ligne, Hawaii (?). Pour l'archipel des Hawaii, cette espèce fut signalée une seule fois de l'île d'Oahu par Garman (1908). Elle n'est plus jamais mentionnée depuis sur tout l'archipel, malgré les nombreux inventaires herpétologiques. Ce serait donc la seule espèce de Polynésie orientale, avec *Nactus pelagicus*, absente aux Hawaii et il est difficile d'en fournir une explication. Elle ne semble nulle part aussi abondante qu'en Polynésie française.

- *Gehyra mutilata* :

Madagascar, Séchelles, Agalega, Mascareignes, Afrique de l'Est (?), Inde (Sud), Sri Lanka, Andaman, Nicobar, île Christmas (Océan Indien), îles Cocos Keeling, Péninsule malaise, Thaïlande, Indochine, Haïnan, Japon, Chine (Sud), Taïwan, Sumatra, Java, Bornéo, Philippines, Ryu Kyu, Palau, Carolines, Mariannes, Papouasie Nouvelle-Guinée et îles voisines, Salomon, Tokelau, Samoa, Hawaii, Mexique (Ouest et Sud, introduction).

- *Hemidactylus garnotii* :

Inde (Nord-Ouest ; Darjeeling), Bengladesh, Sikkim, Thaïlande, Péninsule malaise, Laos, Vietnam (Nord), Nicobar, Haïnan, Bornéo, Philippines, Hong Kong, Chine, Nias, Sumatra, Java, Lombok, Sumbawa, Sumba, Florès, Timor, Amboine, Papouasie Nouvelle-Guinée, Salomon, Nouvelle-Calédonie, Loyautés, Fidji, Pearl Harbour, Hawaii, Pérou et Brésil (validité mise en doute par Crombie & Dixon, en préparation), Floride (introduction).

- *Hemiphyllodactylus typus* :

Mascareignes, Inde (Sud et Est), Sri Lanka, Birmanie, Thaïlande, Nicobar, Sumatra et îles proches, Bornéo, Philippines, Palau, Papouasie Nouvelle-Guinée, Salomon, Fidji, Hawaii.

- *Nactus pelagicus* :

Papouasie Nouvelle-Guinée, Australie (Queensland), Salomon, Carolines, Nouvelle-Calédonie, Loyautés, Banks, Vanuatu, Marshall, Fidji, Tonga, Samoa, Danger.

La Polynésie orientale occupe vers l'Est une position géographique excentrique dans l'aire des dix espèces recensées.

Leurs distributions englobent :

* les Océans Indien et Pacifique pour les Gekkonidae suivants :

Lepidodactylus lugubris, *Gehyra mutilata*, *Hemidactylus garnotii* et *Hemiphyllodactylus typus*.

* l'Indonésie (en partie), la Mélanésie et le Pacifique tropical pour :

Emoia cyanura sensu lato, *Lipinia noctua*.

* la Nouvelle-Guinée et le Pacifique tropical pour :

Cryptoblepharus poecilopleurus, *Gehyra oceanica* et *Nactus arnouxii*.

Les côtes ouest américaines sont atteintes par cinq espèces, avec cependant des doutes quant à la crédibilité des localisations de certains spécimens et l'installation effective de populations indigénisées pour les espèces suivies du signe * : *Emoia cyanura** *sensu lato*, *Cryptoblepharus poecilopleurus*, *Gehyra mutilata*, *Lepidodactylus lugubris* et *Hemidactylus garnotii**. Remarquons que ce dernier gecko fut introduit avec grand succès en Floride (Mitchell & Hadle, 1980).

Il est intéressant de noter que deux espèces de Reptiles terrestres : *Hemidactylus frenatus* (Gekkonidae) et *Ramphotyphlops braminus* (Typhlopidae), serpent qui se reproduit parthénogénétiquement (Nussbaum, 1980), ont une large distribution indo-pacifique jusqu'aux côtes américaines. Bien que non signalées jusqu'ici en Polynésie orientale, elles sont à rechercher. Leur distribution est, en effet, particulièrement vaste et elles sont toutes deux connues des Mariannes et des Hawaii ; *H. frenatus* atteint les Samoa. Nous rapportons ici les localisations relevées dans la bibliographie, complétées par nos propres observations.

- *Hemidactylus frenatus* :

Afrique (Sud et Est : Somalie), Comores, Madagascar, Agalega, Mascareignes (Maurice), Chagos (Diego Garcia), Maldives, Sri Lanka, Inde, Népal, Bengale, Andaman, Nicobar, Assam, Birmanie, Thaïlande, Siam, Annam, Cambodge, îles Cocos Keeling, île Christmas (Océan Indien), Malaisie, Haïnan, Chine (Sud), Taïwan, Ryu Kyu, Japon, Corée, Sumatra, Java, Bornéo, Timor, récif Ashmore, Amboine, Philippines, Palau, Papouasie Nouvelle-Guinée, Australie (Queensland), Mariannes (Saïpan, Tinian et Guam), Salomon, Suli, Santa Helena, Samoa, Hawaii, Mexique, Guatémala.

- *Ramphotyphlops braminus* :

Afrique : côtes Ouest (Côte d'Ivoire, Togo, Bénin, Cameroun) et Est (Mozambique, Tanzanie, Somalie), Madagascar, Séchelles, Inde, Sri Lanka, Indochine, îles Cocos Keeling, île Christmas (Océan Indien), Haïnan, Chine (Sud), Taïwan, Japon, Ryu Kyu, Philippines, Papouasie Nouvelle-Guinée, Australie (Queensland), Mariannes (Tinian, Saïpan et Guam), Salomon, Hawaii, Mexique (Ouest), Guatémala, Sud de la Floride (introduction).

4. DISCUSSION

4.1. SECURITE DES INVENTAIRES.

Les artéfacts possibles concernent aussi bien les absences que les présences. Un échantillonnage incomplet peut avoir pour origine une durée de prospection insuffisante ou des conditions météorologiques défavorables. C'est ainsi que nos propres récoltes aux Marquises ne renferment aucun *Cryptoblepharus poecilopleurus*, pourtant signalé des îles de Fatu Huku, Nuku Hiva et Ua Huka que nous avons investiguées. Ce Scincidae ne figure d'ailleurs pas non plus dans la collection de douze individus réalisée par G.E. Magnesson et P.K. Humphreys, en 1950, à Nuku Hiva (Tanner, 1952). Inversement, une espèce peut avoir été signalée à tort d'une île par suite d'une erreur d'étiquetage, sinon d'une détermination incorrecte. Il est vraisemblable que la mention "Tahiti" recouvre souvent une signification plus large que la seule île de ce nom et concerne, parfois, au moins tout l'archipel de la Société.

Hormis les artéfacts répertoriés, il est certain que cet inventaire reste très incomplet : nous avons vu que notre catalogue chorologique se limite à 78 localisations insulaires, soit 59 % du nombre total d'îles, atolls et motus de taille importante en Polynésie orientale. Ainsi, nos prospections récentes, le plus souvent fort brèves, sur 27 îles et atolls, ont permis d'apporter, pour les neuf espèces dont la présence est certaine, un total d'environ 50

Tableau 4 : Confrontation des récoltes effectuées par la Whitney South Sea Expedition avec nos échantillonnages (fréquence chaque famille et de chaque espèce par famille).

AUTEUR	Burt & Burt (1932) (n=1719) Cette étude (n=2223)								
Famille	Scincidae				Gekkonidae				
TAXON ARCHIPEL	**SCIN.**	E.c. s.l.	Cp.	L.n.	**GEKK.**	L.l.	G.o.	G.m.	H.g.
n = 143	0.699	0.620	0.150	0.230	0.301	0.302	0.511	0.187	-
SOCIETE									
n = 981	0.758	0.626	0.164	0.210	0.241	0.510	0.451	0.034	0.005
n = 1385	0.741	0.442	0.152	0.406	0.259	0.548	0.415	0.036	-
TUAMOTU									
n = 148	0.608	0.389	0.311	0.300	0.392	0.948	0.052	-	-
n = 47	1.000	0.404	-	0.596	-	-	-	-	-
GAMBIER									
n = 32	0.562	0.222	0.055	0.723	0.437	0.857	-	0.071	0.071
n = 56	0.732	0.439	0.220	0.341	0.268	0.200	0.333	0.200	0.267
AUSTRALES									
n = 382	0.788	0.528	0.262	0.209	0.212	0.420	0.543	0.037	-
n = 88	0.659	0.362	0.051	0.586	0.341	0.100	0.267	0.633	-
MARQUISES									
n = 680	0.784	0.595	-	0.405	0.216	0.592	0.306	0.088	0.014

localisations nouvelles. Le secteur des Tuamotu du Sud reste le plus mal connu.

La fiabilité des inventaires peut être estimée en confrontant deux séries d'échantillonnages, d'un nombre suffisamment élevé de spécimens, sur les mêmes archipels. La comparaison de nos récoltes avec celles de la Whitney South Sea Expedition, d'après la synthèse de C.E. Burt et M.D. Burt (1932), est remarquable (Tableau 4) ; toutefois, une telle concordance n'implique pas que tous les habitats aient été correctement investigués et que des espèces rares n'aient échappé aux collecteurs. Les Gekkonidae, nocturnes, sont bien moins échantillonnés que les Scincidae, diurnes, et très rarement collectés en milieu forestier, de nuit.

4.2. FREQUENCES DE DISTRIBUTION.

L'examen des tableaux 1 et 2 montre que les Scincidae sont présents sur 95 % des 78 îles et atolls pour lesquels nous ayons des informations sur la faune herpétologique, tandis que les Gekkonidae ne le sont que sur 88 %. Cet écart conduirait à attribuer aux Scincidae des capacités de dissémination supérieures à celles généralement reconnues chez les Gekkonidae qui possèdent pourtant de nombreuses adaptations positives aux transports (C. Mc Cann, 1953). O. Cuellar (1984), d'après une étude par homogreffes sur *Lepidodactylus lugubris*, admet que le peuplement des îles Hawaii est peut-être issu d'une seule femelle colonisatrice originaire de l'archipel de la Société, ce qui est inacceptable (I. Ineich, 1988 a). Le rôle exact de l'homme dans la dissémination de ces taxons reste encore à déterminer ; il ne devait pas toujours être prédominant (I. Ineich, 1987 b et I. Ineich et Ch.P. Blanc, 1987).

Il est incontestable que les Scincidae sont plus aisément visibles que les Gekkonidae, tous nocturnes, bien que la plupart de leurs espèces soient fréquentes dans les habitations et à leur proche périphérie. Parmi les premiers, *Emoia cyanura sensu lato* est, de loin, le plus largement répandu. Les deux espèces de ce complexe sont héliophiles, eurytopes et faciles à détecter car elles vivent souvent au sol, en populations abondantes et très actives. *Cryptoblepharus*, surtout arboricole, est restreint à la frange côtière. *Lipinia noctua*, très discret, est nettement plus difficile à apercevoir, ce qui pourrait expliquer, au moins en partie, que sa distribution, qualifiée de "spotty" (R.C. Zweifel, 1979), nous apparaisse moins dense. Notons, à ce propos, que dans les îles de la Société, certainement les mieux prospectées, les quatre espèces sont présentes sur la presque totalité des 11 îles et atolls pour lesquels nous ayons des informations herpétologiques.

Il est plausible, par ailleurs, que les valences écologiques puissent limiter la distribution d'une espèce comme *Hemidactylus garnotii*. Son absence des Tuamotu pourrait s'expliquer par un habitat forestier non représenté sur les atolls de cet archipel.

Aux Hawaii et aux Philippines, il semblerait, en effet, que cette espèce soit préférentiellement localisée dans les forêts (Hunsaker & Breese, 1967 ; Brown & Alcala, 1978). Cette hypothèse paraît douteuse car nous avons récolté ce gecko dans des habitations, à Mangareva et à Ua Huka, mais exclusivement en forêt sur un pandanus et sur les façades externes non éclairées du Centre de l'Environnement d'Opunohu à Moorea. Son anthropophilie est vérifiée sur l'archipel des Fidji (J.R.H. Gibbons, comm. pers., 05/06/1985).

De même, *Cryptoblepharus poecilopleurus*, que nous avons surtout collecté sur les troncs de cocotiers proches de plages sablonneuses et sur des motus, trouve peu d'emplacements favorables aux Marquises, archipel composé principalement d'îles hautes.

CONCLUSION

Ce bilan des acquisitions sur la distribution des Reptiles terrestres en Polynésie orientale met en évidence la précarité de nos connaissances sur ce groupe zoologique, pourtant seul représentant des Tétrapodes Hétérothermes. Il permet de préciser nos lacunes et d'inciter à la poursuite des inventaires. Bien que de valeur uniquement indicative, il représente un outil de travail utile en orientant les investigations complémentaires.

En dépit des réserves formulées, il semble bien que les deux espèces du genre *Emoia* soient les plus largement disséminées. Dans l'état actuel de nos connaissances, ces Scincidae ne présentent que peu d'adaptations positives favorables au transport et à l'indigénisation comparativement aux Gekkonidae (McCann, 1953 ; Kluge & Eckardt, 1969 ; Cuellar & Kluge, 1972 ; Cuellar, 1984 ; Gibbons, 1985 ; Ineich & Blanc, 1987).

Malgré la fréquence de la parthénogénèse, chez les espèces présentes avec certitude (*L. lugubris* ; *H. garnotii*), signalées et non retrouvées (*N. pelagicus*) ou potentielles (*R. braminus*), il nous semble important de remarquer que ce type de reproduction ne permet pas, a priori, une meilleure dissémination que la sexualité couplée soit à l'oviparité, soit à l'ovoviviparité (chez *L. noctua*).

Si ce n'est leur anthropophilie relative et leur présence sur la frange littorale, il nous apparaît difficile de dégager des caractéristiques communes aux neuf taxons représentés dans les collectes récentes, et capables d'expliquer leur distribution en Polynésie française, sur une surface supérieure à celle de l'Europe, constituée à plus de 99 % d'étendues océaniques, car la surface totale des terres émergées ne dépasse guère la moitié de celle de la Corse.

Ce document a également servi d'assise à des recherches sur l'existence d'éventuelles micro-différenciations insulaires (I. Ineich, 1987 b). En combinant les données de Biogéographie évolutive avec celles d'Ecologie et de Génétique, le modèle biologique que constitue l'herpétofaune terrestre de Polynésie orientale devrait permettre une meilleure connaissance des nombreux problèmes biogéographiques et écologiques liés à l'insularité (I. Ineich et Ch.P. Blanc, 1987).

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ANNEXE :

INDEX TOPONYMIQUE

DE POLYNESIE ORIENTALE.

Remarque : Les termes actuels sont en italique, les autres sont généralement placés en synonymie. Les coordonnées sont celles mentionnées dans la littérature consultée.

Acteon, groupe (arch. des Tuamotu) * atoll

Adams (voir Ua Pou ou Nuku Hiva)

Agakauitai (arch. des Gambier) * île haute

Ahe (arch. des Tuamotu) 14°30'SUD 146°20'OUEST * atoll

Ahi (voir Ahe)

Ahii (voir Ahe)

Ahounoui (voir Ahunui)

Ahunui (arch. des Tuamotu) * atoll

Aimeo (voir Moorea)

Aĩmĩo (voir Moorea)

Akamaru (arch. des Gambier) 23°08'SUD 134°55'30"OUEST * île haute

Aki Aki (arch. des Tuamotu) 19°17'40"SUD 138°42'OUEST * atoll comblé

Akiaki (voir Aki Aki)

Amanu (arch. des Tuamotu) 17°43'SUD 140°39'OUEST * atoll

Amat, Isla d' (voir Tahiti)

Anaa (arch. des Tuamotu) 17°30'SUD 145°30'OUEST * atoll

Anegada (voir Ducie)

Angatau (arch. des Tuamotu) * atoll

Anguilles, îles des (voir Mututunga)

Anou-Anouraro (voir Anuanuraro)

Anou-Anourounga (voir Anuanurunga)

Anuanuraro (arch. des Tuamotu) * atoll

Anuanurunga (arch. des Tuamotu) * atoll

Apataki (arch. des Tuamotu) 15°30'SUD 146°20'OUEST * atoll

Arakcheev (voir Fangatau)

Aratika (arch. des Tuamotu) 15°33'25"SUD 146°39'OUEST * atoll

Arc, île de l' (voir Hao)

Ariane, rocher (voir Thomasset)

Aroutoua (voir Arutua)

Arutua (arch. des Tuamotu) 15°10'SUD 146°40'20"OUEST * atoll

Augier, atoll d' (voir Tatakoto)

Aukena (arch. des Gambier) * île haute

Au-'ura (voir Kaukura)

Aura (voir Kaukura)

AUSTRALES, arch. des

Aventure (voir Motutunga)

Barclay de Tolly (voir Raroia)

Barrow (voir Vanavana)

Bass, îlots de (voir Marotiri)

Bass, rochers de (voir Bass)

Baux (voir Nuku Hiva)

Bedford (voir Tenararo)

Bellinghausen (voir Bellingshausen)

Bellingshausen (arch. de la Société) 15°50'SUD 154°30'OUEST * atoll

Bird (voir Reitoru)

Blake (voir Tupai)

Bola Bola (voir Bora Bora)

Bonne Espérance (voir Reka Reka)

Bora Bora (arch. de la Société) 16°27'SUD 151°52'45"OUEST * île haute

Boudoir, Le (voir Mehetia)

Bourbon, archipel (voir Société)

Bow (voir Hao)

Byam Martin (voir Ahunui)

Cadmus (arch. des Gambier)

Carlshov de Kotzebue (voir Aratika)

Carolinas, Islas (voir Société)

Carshov (voir Aratika)

Carysfort (voir Tureia)

Chain (voir Anaa)

Chaîne, île de la (voir Anaa)

Chanal (voir Hatutu)

Charles Saunders, île (voir Maiao)

Chichagov (voir Tahanea)

Clermont Tonnerre (voir Reao)

Clipperton (île isolée) 10°18'SUD 109°13'OUEST * île haute

Clute (voir Hiti)

Cockburn (voir Ahunui)

Coral Atoll Archipelago (voir Tuamotu)

Crocker (voir Haraiki)

Croker (voir Haraiki)

Cumberland, île de (voir Nengo Nengo)

Cyterre (voir Tahiti)

Dangereux, archipel (voir Tuamotu)

De Lostange (voir Nengo Nengo)

Deans (voir Rangiroa)

Déception, îles de la (voir Tuamotu)

Désappointement, îles du (voir Tepoto _et_ Napuka)

Désolation, îles de la (voir Tuamotu)

Dominica (voir Hiva Oa)

Duc de Gloucester, îles du (voir Anuaruraro, Anuanurunga _et_ Nukutipipi)

Ducei (voir Ducie)

Ducie (groupe Pitcairn) 24°40'SUD 124°48'OUEST * île haute

Egmont, île d' (voir Vairaatea)

Eiao (arch. des Marquises) 08°02'SUD 140°41'OUEST * île haute

Eiau (voir Eiao)

Eimeo (voir Moorea)

Elisabeth (voir Henderson _ou_ Toau)

Eliza (voir Hiti _ou_ Tepoto)

Eloignée deux fois sacrée (voir Raiatea)

Emeraude, îles d' (voir Marquises)

Estancélin (voir Maturei Vavao)

Etablissements français de l'Océanie (POLYNESIE FRANCAISE)

Fa'aau (voir Niau)

Faaite (arch. des Tuamotu) 16°45'SUD 145°10'OUEST * atoll

Fakahina (arch. des Tuamotu) * atoll

Fakaina (voir Fakahina)

Fakarava (arch. des Tuamotu) 16°10'SUD 145°35'OUEST * atoll

Fakarawa (voir Fakarava)

Fakareva (voir Fakarava)
Fangahina (voir Fakahina)
Fangahiva (voir Fakahina)
Fangatau (arch. des Tuamotu) * atoll
Fangataufa (arch. des Tuamotu) * atoll
Fanua Ura (voir Scilly)
Fatou Hiva (voir Fatu Hiva)
Fatou Houkou (voir Fatu Huku)
Fatouhiva (voir Fatu Hiva)
Fatu Hiva (arch. des Marquises) 10°24'SUD 138°40'OUEST * île haute
Fatu Huku (arch. des Marquises) 09°26'SUD 138°56'OUEST * île haute
Fatuhiva (voir Fatu Hiva)
Fatuhuku (voir Fatuhuku)
Fatuuku (voir Fatu Huku)
Fédéral (voir Nuku Hiva)
Fenua Ura (voir Scilly)
Fetuku (voir Fatu Huku)
Franklin (voir Tupai ou Nuku Hiva)
Freemantle (voir Eiao)
Freycinet (voir Amanu)
Furneaux (voir Marutea)
Gambier, île (voir Mangareva)
GAMBIER, archipel des
George III (voir Tahiti)
Gesellschafts-Inseln (voir Société)
Gloucester, île de (voir Paraoa)
Gloucester, îles Duc (voir Anuanuaro, Anuanurunga et Nukutipipi)

Greg (voir Niau)

Greig (voir Niau)

Hagemeister (voir Apataki)

Hagenmeister (voir Apataki)

Hancock (voir Hatutu)

Hao (arch. des Tuamotu) 18°15'SUD 140°55'OUEST * atoll

Hao-rangi (voir Hao)

Haou (voir Hao)

Hapu (voir Ua Pou)

Haraiki (arch. des Tuamotu) * atoll

Harp (voir Hao)

Harpe (voir Hao)

Hatoutou (voir Hatutu)

Hatu Iti (arch. des Marquises)

Hatutaa (voir Hatutu)

Hatutu (arch. des Marquises) * île haute

Hau (voir Hao)

Havai (voir Raiatea)

Havai'i (voir Fakarava)

Havaiki (voir Fakarava)

Henderson (groupe Pitcairn) 24°25'SUD 128°19'OUEST * île haute

Heraiki (voir Haraiki)

Héréhérétoué (voir Hereheretue)

Hereheretue (arch. des Tuamotu) 19°52'SUD 145°OUEST * atoll

Hiaou (voir Eiao)

Hiau (voir Eiao)

Hiavaoa (voir Hiva Oa)

Hikouerou (voir Hikueru)

Hikueru (arch. des Tuamotu) * atoll

Hiti (arch. des Tuamotu) 16°45'SUD 144°08'OUEST * atoll

Hiti (voir Tahiti)

Hiti-Ai-Te-Rangi (voir Pâques)

Hiti-Tautau-Mai (voir Moruroa)

Hititeairagi (voir Pâques)

Hitte-Tamaroo-Eiree (voir Moruroa)

Hiva Hoa (voir Hiva Oa)

Hiva Oa (arch. des Marquises) 09°47'SUD 138°47'OUEST * île haute

Hiva Tau Aro (voir Tuamotu de l'Ouest)

Hiva Tau Tua (voir Tuamotu de l'Est)

Hivaoa (voir Hiva Oa)

Holt (voir Taenga)

Hood (voir Fatu Huku <u>ou</u> Fatu Hiva)

Houahinelti (voir Huahine)

Houahine Iti (voir Huahine)

Houahine Noui (voir Huahine)

Houahouna (voir Ua Huka)

Houaîne (voir Huahine)

Houapou (voir Ua Pou)

How (voir Mopelia)

Howe (voir Mopelia)

Huaheine (voir Huahine)

Huahine (arch. de la Société) 16°43'SUD 151°06'45"OUEST * île haute

Huahine-iti (voir Huahine)

Huahine-nui (voir Huahine)

Huahuna (voir Ua Huka)

Huapu (voir Ua Pou)

Hull (voir Maria, arch. des Australes)

Imaia (voir Moorea)

Jefferson (voir Ua Pou)

Kahiki (voir Tahiti)

Kairagi (voir Pâques)

Kamaka (arch. des Gambier) * île haute

Karaporo, motu (arch. des Australes) 27°38'20"SUD 144°18'40"OUEST

Katiou (voir Katiu)

Katiu (arch. des Tuamotu) 16°31'SUD 144°12'10"OUEST * atoll

Katui (voir Katiu)

Kauehi (arch. des Tuamotu) 15°59'48"SUD 145°09'30"OUEST * atoll

Kaukoura (voir Kaukura)

Kaukura (arch. des Tuamotu) 15°43'SUD 146°50'36"OUEST * atoll

Kawehe (voir Kauehi)

King (voir Taiaro)

Kings, island (voir Taiaro)

King George (voir Takapoto et Takaroa)

Knox (voir Eiao)

Kon Tiki (voir Raroia)

Koutouzov (voir Makemo)

Krusenstern (voir Tikehau)

Kruzenstern (voir Tikehau)

La Dominica (voir Hiva Oa)

La Encarnacion (voir Ducie)

Labyrinthe, Le (voir Tuamotu)

Lancaster, récif (arch. des Australes)

Langdon (voir Hatutu)

Lazareff (voir Mataiva)

Lazarev (voir Mataiva)

Lincoln (voir Motu One)

Lointaines, îles (voir Tuamotu)

Lord How (voir Mopelia)

Lord Howe (voir Mopelia)

Low, Archipel (voir Tuamotu)

Lucie (voir Ducie)

Luna-Puesta (voir Ducie)

Maatea (voir Makatea)

Madalena (voir Fatu Hiva)

Maettia (voir Mehetia)

Magdalena (voir Fatu Hiva)

Mahetia (voir Mehetia)

Maiao (arch. de la Société) 17°40'SUD 150°38'OUEST * île haute

Maiao Iti (voir Maiao)

Maiaoiti (voir Maiao)

Maitea (voir Mehetia)

Makaroa (arch. des Gambier) * île haute

Makatea (arch. des Tuamotu) * atoll soulevé

Makemo (arch. des Tuamotu) 16°26'SUD 143°56'OUEST * atoll

Makima (voir Makemo)

Manga Reva (voir Mangareva)

Mangareva (arch. des Gambier) 23°08'SUD 134°55'30"OUEST * île haute

Manihi (arch. des Tuamotu) 14°30'SUD 145°55'OUEST * atoll

Manouhangi (voir Manuhangi)

Manuae (voir Scilly)

Manuhangi (arch. des Tuamotu) * atoll

Manui (arch. des Gambier) * île haute

Manulrangi (voir Nengo Nengo)

Mapetia (voir Mopelia)

Mapihaa (voir Mopelia)

Marchand (voir Ua Pou ou Nuku Hiva)

Maria (arch. des Australes) * atoll

Maria (arch. des Tuamotu) 21°53'SUD 136°20'OUEST * atoll

Marokau (arch. des Tuamotu) * atoll

Marotiri (arch. des Australes) * île haute

Maroutea (voir Marutea)

Maroutea Sud (voir Marutea Sud)

Marquise de Mendoza, îles de la (voir Marquises)

Martin, Sir Henry (voir Nuku Hiva)

MARQUISES, archipel des

Marua (voir Maupiti)

Marutea (arch. des Tuamotu) 16°54'SUD 143°20'OUEST * atoll

Marutea Nord (voir Marutea)

Marutea Sud (arch. des Tuamotu) * atoll

Massachusetts (voir Ua Huka)

Masse (voir Eiao)

Mata ki te Rangi (voir Pâques)

Matahiva (voir Mataiva)

Mataiva (arch. des Tuamotu) 14°53'30"SUD 148°43'30"OUEST * atoll

Matakiterani (voir Pâques)

Matea (voir Moruroa)

Matilda, Rocher (voir Moruroa)

Mattea (voir Mehetia)

Maturei Vavao (arch. des Tuamotu) 21°27'SUD 136°28'OUEST * atoll

Matureivavao (voir Maturei Vavao)

Mauitea (voir Marutea)

Maupihaa (voir Mopelia)

Maupiti (arch. de la Société) 16°27'SUD 152°15'OUEST * île haute

Maura (voir Mopelia ou Maupiti)

Maurua (voir Maupiti ou Tepoto)

Meatia (voir Mehetia)

Meetia (voir Mehetia)

Mehetia (arch. de la Société) 17°53'SUD 148°05'OUEST * île haute

Melville (voir Hikueru)

Metakiteragi (voir Pâques)

Miloradovitch (voir Faaite)

Miloradowitch (voir Faaite)

Minerve (arch. des Gambier) * île haute

Mobidie (voir Maupiti)

Moerenhout (voir Maria, arch. des Tuamotu)

Mohotane (voir Motane)

Mohotani (voir Motane)

Moller (voir Amanu)

Möller (voir Amanu)

Moorea (arch. de la Société) 17°34'15"SUD 150°00'30"OUEST * île haute

Mopéha (voir Mopelia)

Mopelia (arch. de la Société) 16°52'SUD 154°00'OUEST * atoll

Morane (arch. des Tuamotu) * atoll

Morea (voir Moorea)

Morée (voir Moorea)

Moruroa (arch. des Tuamotu) 21°49' SUD 138°48'OUEST * atoll

Moses, récif (arch. des Australes)

Motane (arch. des Marquises) 10°SUD 138°56'OUEST * île haute

Motou Iti (voir Tupai)

Motouiti (voir Tupai)

Motoutounga (voir Motutunga)

Motu (voir Tetiaroa)

Motu Iti (voir Hatu Iti ou Tupai)

Motuiti (voir Tupai)

Motu One (arch. des Marquises) * îlot de sable

Motu One (voir Bellingshausen)

Motu Teiku (arch. des Gambier) * île haute

Mototanga (voir Motutunga)

Motutunga (arch. des Tuamotu) * atoll

Mourouroa (voir Moruroa)

Mururoa (voir Moruroa)

Muzuroa (voir Moruroa)

Nahuhangi (arch. des Tuamotu) * atoll

Nairsa (voir Rangiroa)

Naisa (voir Rangiroa)

Napouka (voir Napuka)

Napuka (arch. des Tuamotu) 14°10'40"SUD 141°12'50"OUEST * atoll

Naquka (voir Napuka)

Narcisse (voir Tatakoto)

Nengo Nengo (arch. des Tuamotu) * atoll

Nengo-Nengo (voir Nengo Nengo)

New York (voir Eiao)

Nexsen (voir Hatutu)

Nganati (voir Ahunui ?)

Nian (voir Niau)

Niau (arch. des Tuamotu) 16°11'SUD 146°22'OUEST * atoll

Nigeri (voir Nihiru)

Nihera (voir Nihiru)

Niheru (voir Nihiru)

Nihirou (voir Nihiru)

Nihiru (arch. des Tuamotu) 16°41'SUD 142°53'OUEST * atoll

Nombril du monde, le (voir Pâques)

Nouka-Hiva (voir Nuku Hiva)

Noukahiva (voir Nuku Hiva)

Noukouhiva (voir Nuku hiva)

Noukoutawake (voir Nukutavake)

Noukoutipipi (voir Nukutipipi)

Nouvelle Cythère (voir Tahiti)

Nukahiva (voir Nuku Hiva)

Nukitipipi (voir Nukutipipi)

Nuku Hiva (arch. des Marquises) 08°57'SUD 140°15'OUEST * île haute

Nukuhiva (voir Nuku Hiva)

Nukutavake (arch. des Tuamotu) * atoll comblé

Nukutipipi (arch. des Tuamotu) * atoll

O-Taiiti (voir Tahiti)

Obeteroah (voir Rurutu)

Oeno (groupe Pitcairn) 24°00'30"SUD 130°40'OUEST * atoll

Oheteroa (voir Rurutu)

Oheteroah (voir Rurutu)

Ohiti (voir Hiti)

Ono (voir Oeno)

Oropaa (voir Tikehau)

Osnabrug, île haute d' (voir Mehetia)

Osnaburg (voir Moruroa)

Osnaburgh (voir Mehetia)

Osnalbruck, île d' (voir Moruroa)

Osten Saken (voir Katiu)

Otaha (voir Tahaa)

Otaheite (voir Tahiti)

Otahiti (voir Tahiti)

Otaiti (voir Tahiti)

Ouahouka (voir Ua Huka)

Ouaïne (voir Huahine)

Oura (voir Takapoto)

Oulietea (voir Raiatea)

Palliser, îles (voir Tuamotu du Nord)

Pallisier (voir Toau, Niau _et_ Kaukura)

Papa-iti (voir Bellingshausen)

Papa-tea (voir Makatea)

Papahena (voir Tureia)

Pâques, île de 27°10'SUD 109°26'OUEST * île haute

Paraoa (arch. des Tuamotu) * atoll

Pararo (voir Paraoa)

Pascua, Isla de (voir Pâques)

Passeers (voir Pâques)

Passion, île de la (voir Clipperton)

Peacock (voir Ahe)

Peard (voir Mangareva)

Pernicieuses, Isles (voir Tuamotu)

Philipps (voir Makemo)

Pic de la Boudeuse (voir Mehetia)

Pinaki (arch. des Tuamotu) * atoll comblé

Pitcairn (groupe Pitcairn) 25°03'37"SUD 130°08'23"OUEST * île haute

PITCAIRN, groupe d'îles

Pomoti (voir Tuamotu)

Pomotou (voir Tuamotu)

Pomotu (voir Tuamotu)

Pora-Pora (voir Bora Bora)

Porapora (voir Bora Bora)

Pouka-Pouka (voir Pukapuka)

Pouka Rouha (voir Pukarua)

Poukaroua (voir Pukarua)

Poukarouha (voir Pukarua)

Predpriatie (voir Fakahina)

Président Thiers, récif (arch. des Australes)

Prince Guillaume Henri, île du (voir Nengo Nengo)

Prince Henry, île du (voir Manuhangi)

Puka-Puka (voir Pukapuka)

Pukapuka (arch. des Tuamotu) 14°48'SUD 138°49'OUEST * atoll

Pukaroa (voir Pukarua)

Pukarua (arch. des Tuamotu) * atoll

Raeffsky, îles (voir Tuamotu centrales)

Raevavae (arch. des Australes) 23°55'SUD 147°48'OUEST * île haute

Raiatea (arch. de la Société) 16°50'SUD 151°25'OUEST * île haute

Raïatia (voir Raiatea)

Rairoa (voir Rangiroa)

Raivavae (voir Raevavae)

Rangiatea (voir Raiatea)

Rangiroa (arch. des Tuamotu) 15°05'15"SUD 147°58'34"OUEST * atoll

Rapa (arch. des Australes) 26°36'SUD 144°22'OUEST * île haute

Rapa, Grande (voir Pâques)

Rapa Iti (voir Rapa)

Rapa Nui (voir Pâques)

Raraka (arch. des Tuamotu) 16°08'SUD 145°00'40"OUEST * atoll

Raroia (arch. des Tuamotu) 15°56'SUD 142°22'OUEST * atoll

Ravahere (arch. des Tuamotu) * atoll

Ravaivai (voir Raevavae)

Reao (arch. des Tuamotu) 18°28'SUD 136°28'OUEST * atoll

Récréation, île de la (voir Makatea ?)

Reine Charlotte, île de la (voir Nuku Hiva ou Nukutavake)

Reine du Pacifique (voir Tahiti)

Reitorou (voir Reitoru)

Reitoru (arch. des Tuamotu) * atoll

Reka Reka (arch. des Tuamotu) * atoll

Remitara (voir Rimatara)

Révolution, îles de la (voir Marquises)

Rimatara (arch. des Australes) 22°40'SUD 153°25'OUEST * île haute

Rimitara (voir Rimatara)

Riou (voir Ua Huka)

Roahonga (voir Ua Huka)

Robert (voir Eiao)

Roberts (voir Eiao)

Roggewin (voir Makatea)

Roi Georges, île du (voir Tahiti)

Roi Georges, îles du (voir Takapoto et Takaroa)

Rurick (voir Arutua)

Rurutu (arch. des Australes) 22°29'SUD 151°20'25"OUEST * île haute

Russes, îles (voir Tuamotu)

Sable, île de (voir Motu One)

Sagittaria (voir Tahiti)

Saken (voir Katiu)

San Carlos (voir Pâques)

San Juan Bautista (voir Henderson)

San Pedro (voir Motane)

San Valerio (voir Henderson)

Sanders, île Sir Charles (voir Maupiti ou Maiao)

Santa Christina (voir Tahuata)

Santa Cristina (voir Tahuata)

Santa Magdalina (voir Fatu Hiva)

Sarles (voir Pukarua)

Scilly (arch. de la Société) 16°31'SUD 154°43'OUEST * atoll

Serle (voir Pukarua)

Sir Henry Martin (voir Nuku Hiva)

SOCIETE, archipel de la

Solide, île du (voir Ua Huka)

Soumises, îles (voir Tuamotu)

Taahuata (voir Tahuata)

Taapouta (voir Takapoto)

Taenga (arch. des Tuamotu) * atoll

Tahaa (arch. de la Société) * île haute

Tahanea (arch. des Tuamotu) 16°52'SUD 144°58'OUEST * atoll

Tahiti (arch. de la Société) 17°38'SUD 149°30'OUEST * île haute

Tahiti Iti (voir Tahiti)

Tahiti Nui (voir Tahiti)

Tahouata (voir Tahuata)

Tahu Ata (voir Tahuata)

Tahuata (arch. des Marquises) 09°56'21"SUD 139°06'OUEST * île haute

Taiaro (arch. des Tuamotu) 15°46'SUD 144°37'OUEST * atoll

Taiti (voir Tahiti)

Takapoto (arch. des Tuamotu) 14°32'08"SUD 145°14'30"OUEST * atoll

Takaroa (arch. des Tuamotu) 14°22'10"SUD 144°58'30"OUEST * atoll

Takouma (voir Takume)

Takoumé (voir Takume)

Takume (arch. des Tuamotu) 15°39'30"SUD 142°06'15"OUEST * atoll

Takurea (voir Takume)

Taouéré (voir Tauere)

Taravai (arch. des Gambier) * île haute

Tatakoto (arch. des Tuamotu) * atoll

Tauere (arch. des Tuamotu) * atoll

Taumotu (voir Tuamotu)

Tchitschag (voir Tahanea)

Tchitschagof (voir Tahanea)

Te Pito Te Henua (voir Pâques)

Teapi (voir Pâques)

Tehaena (voir Tahanea)

Tekaouhangoaru (voir Pâques)

Tekokoto (arch. des Tuamotu) * atoll

Tematangi (arch. des Tuamotu) * atoll

Temiromiro (voir Bellingshausen)

Temoe (voir Timoe)

Tenararo (arch. des Tuamotu) 21°18'SUD 136°44'OUEST * atoll

Tenarunga (arch. des Tuamotu) * atoll

Teookea (voir Takaroa)

Teoukea (voir Takaroa)

Tepoto Nord (arch. des Tuamotu) * atoll

Tepoto Sud (arch. des Tuamotu) * atoll

Tetiaroa (arch. de la Société) 17°00'SUD 149°34'OUEST * atoll

Thomasset, rocher (arch. des Marquises)

Thrum Cap (voir Akiaki)

Tikahau (voir Tikehau)

Tikai (voir Tikei)

Tikehau (arch. des Tuamotu) 14°52'SUD 148°15°15"OUEST * atoll

Tikei (arch. des Tuamotu) 20°35'35"SUD 143°19'15"OUEST * atoll comblé

Tikeĭ (voir Tikei)

Tiku (voir Tikei)

Timoe (arch. des Gambier) * île haute

Tiokea (voir Takaroa)

Toau (arch. des Tuamotu) 15°58'SUD 145°49'30"OUEST * atoll

Tobia (voir Tupai)

Todos Los Santos (voir Anaa)

Tongariki (voir Pâques)

Toopbai (voir Tupai)

Totegegie (arch. des Gambier) 23°06'SUD 134°52'OUEST * îlot extérieur

Touamotou (voir Tuamotu)

Toubouaï (voir Tubuai)

Toureia (voir Tureia)

Tovau (voir Toau)

Trevennen (voir Ua Pou)

TUAMOTU, archipel des

Tuanake (arch. des Tuamotu) * atoll

Tubai (voir Tupai)

Tubuai, îles (voir Australes)

Tubuai (arch. des Australes) 23°21'45"SUD 149°35'35"OUEST * île haute

Tubuai Manu (voir Maiao)

Tuhuata (voir Tahuata)

Tupai (arch. de la Société) 16°15'SUD 151°50'OUEST * atoll

Tupaia (voir Tupai)

Tupea Manno (voir Tupai ou Maiao)

Tupia (voir Tupai)

Tupuaemanu (voir Maiao)

Tupuai (voir Tubuai)

Tupuai manu (voir Tupai ou Maiao)

Tureia (arch. des Tuamotu) 20°47'SUD 138°30'OUEST * atoll

Two Brothers (voir Tupai)

Ua Huka (arch. des Marquises) 08°55'SUD 139°34'OUEST * île haute

Ua Pou (arch. des Marquises) 09°24'SUD 140°05'OUEST * île haute

Ua Pu (voir Ua Pou)

Uahuka (voir Ua Huka)

Uapu (voir Ua Pou)

Ulietea (voir Raiatea)

Uliethea (voir Raiatea)

Uporu (voir Tahaa)

Vahanga (arch. des Tuamotu) * atoll

Vahitahi (arch. des Tuamotu) * atoll

Vaihou (voir Pâques)

Vaïhu (voir Pâques)

Vairaatea (voir Moruroa)

Vana Vana (voir Vanavana)

Vanavana (arch. des Tuamotu) * atoll

Vathu (voir Pâques)

Vavau (voir Bora Bora)

Vavitao (arch. des Australes)

Vavitu (voir Raevavae)

Vertes, îles (voir Tuamotu)

Vincennes (voir Kauehi)

Vliegen (voir Rangiroa)

Volkhonski (voir Takume)

Wainwright (voir Akamaru)

Washington (voir Ua Huka ou Ua Pou)

Whytoohee (voir Napuka)

Wilkes, île (voir Raraka)

Witgenstein (voir Fakarava)

Wittengenstein (voir Fakarava)

Wittgenstein (voir Fakarava)

Wolkonski (voir Takume)

Yermolov (voir Taenga)

Yeux dans le ciel, les (voir Pâques)

York (voir Moorea)

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CONTENTS

A GEOMORPHOLOGICAL RECONNAISSANCE OF COËTIVY ATOLL (SEYCHELLES, INDIAN OCEAN)

BY

P. A. KAPLIN[1] AND P. A. PIRAZZOLI[2]

ABSTRACT

A preliminary geomorphological description is given of this sandy Holocene island, fringed by discontinuous beachrocks. There is no evidence of past sea levels higher than the present one.

INTRODUCTION

Located in the western Indian Ocean about 145 miles SSE of Mahé, at a distance of a few dozen miles from the southernmost tip of the Seychelles Bank (7°05' to 11' S - 56°15' to 18' E), Coëtivy is a sandy, elongated, whale-shaped island, 9 km long and 0.25 to 1.6 km wide, stretching in a NNE to SSW direction. This island was formed on the east side of an almost rectangular shoal, which is about 180 km^2 in surface area, 20 to 30 m deep, and rises steeply from depths of more than 2500 m. The island bears the name of the Chevalier de Coëtivy, who sighted it on 3 July 1771 while in command of the "Ile de France" (Lionnet, 1970).

Although large collections of marine and terrestrial fauna were made at Coëtivy in 1905 (Gardiner & Cooper, 1907), as late as 1970 Stoddart regretted that no account had been written on this island and to our knowledge, none has been written since.

In addition to the 1:200 000 chart n° 724 published by the Hydrographic Office of the British Navy, a more detailed map (1:12 500) was published in 1979 (n° 204P) by the British Directorate of Overseas Survey for the Republic of the Seychelles. Information on the physical factors which influence reef evolution in the Indian Ocean has been summarized by Stoddart (1971). The local spring tidal range can be estimated at about 1.5 m.

This paper is based on geomorphological observations made on 10 January 1986 by members on an international expedition that reached Coëtivy aboard the R/V "Professor Shtokman" of the Institute of Oceanology of the Academy of Sciences of the U.S.S.R. (for a preliminary report on this expedition, see Kaplin et al., 1986).

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GEOMORPHOLOGICAL FEATURES OF COETIVY ISLAND

Coëtivy Island consists of sandy sediments that have accumulated, for the most part, on the northern section of an isolated strip of reef flat, 13 km long and 1.2 to 2.2 km wide.

Along the east coast a dead reef flat, almost completely capped by foraminiferal sand and coral debris, is exposed here and there at low tide. No distinct edge to the reef flat can be distinguished because it consists of a more or less wide strip of green sea grass Thalassodendron ciliatum (= Cymodocea ciliata), which slopes gently oceanwards, and baffles the wave action (Fig. 1).

The beach, generally two or three dozen metres wide, consists of white sand and of beachrock. The beachrock, which is mostly restricted to the east coast, is always found to be less than 1 m above MSL, i.e. within the vertical range of the present tide and normal wave action. A schematic profile, representative of the southeast shore is shown in Fig. 2.

The beachrock of the east coast consists of calcirudite and calcarenite deposits rich in coral, coralline algae, foraminifers and alcionarian spicules. Residual porosity of the total rock volume ranges between 30 and 50 %. Intergranular cements consist of a) aragonite isopachous fringes which commonly exhibit truncated crystals, b) fibrous aragonite rims and c) micritic rims all of which exhibit textural patterns that are typical of those found in sands lithified in the marine vadose (intertidal) environment.

In the central part of the east coast the beachrock extends offshore forming a spit out to the middle of the reef flat (Fig. 3), indicating erosion and a landward migration of the shoreline. The composition and the intergranular cements of the beachrock spit are similar to those described above. The distribution of beachrock around the island is shown schematically in Fig. 4, together with the main geomorphological features observed in the island. Traces of erosion (exposed roots of vegetation, sand cliffs on the beach, etc.) are particularly common on the western side of the island, where Gardiner & Cooper (1907) noted similar erosion features back in 1905.

A profile measured by theodolite levelling across transect E-E' is shown in Fig. 5.

Along the northeast coast of the island, the white colour of the beach is completely obscured by a thick cover of dead Thalassodendron, which forms mounds up to 2 m high (Fig. 6).

One or two lines of recent discontinuous coastal ridges are commonly found behind the shoreline. Sand dunes have developed mainly near the northeast and the southern coasts. Remnants of older coastal ridges delimit the shape of a former, smaller island, and swampy depressions commonly form along the central axis of the island.

No evidence could be found in Coëtivy of Pleistocene or Late Holocene stillstand above present sea level. Although the island has generally prograded laterally during the late Holocene, erosion appears to have been predominant, at least since the beginning of this century.

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We thank V. Medvedev and Y. Pavlidis (Institute of Oceanology, Academy of Sciences, USSR) for surveying the south part of the island, V. Demidenko and S. Nikolaev (Faculty of Geography, Moscow State University, USSR) for theodolite levellings, L.F. Montaggioni (Université de la Réunion, France D.O.M.) for petrological analysis, Ms. M. Delahaye (Institut Océanographique, Paris) and I. Macintyre for revising the English text and Ms. V. Collard & D. Maraine (CNRS-Intergéo, Paris) for typing the manuscript.

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Figure 1. The east margin of Coëtivy consists most of the time of a gently sloping *Thalassodendron* (=*Cymodocea*) seaweed cover. The water level is 0.15 m below MSL.

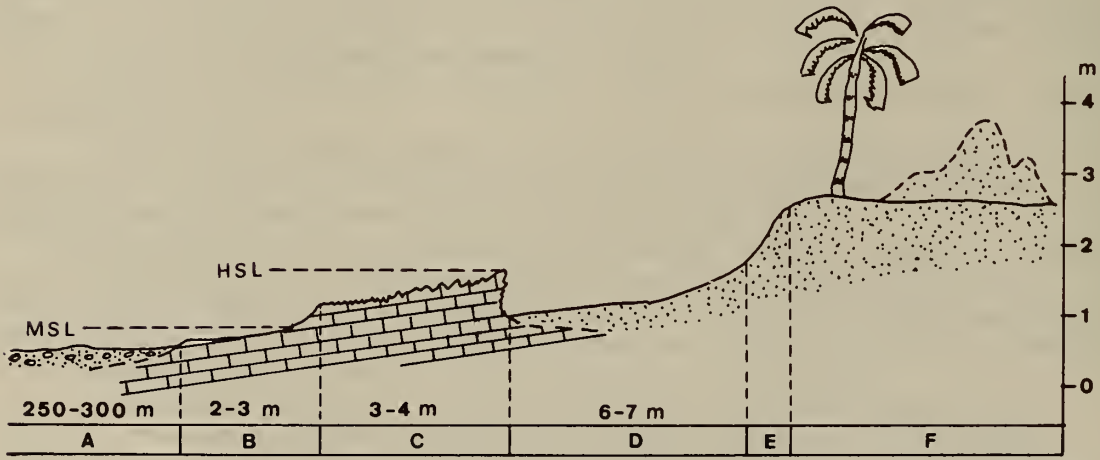

Figure 2. Schematic idealized profile of the southeast shore of Coëtivy. A : reef flat ; B-C : beachrock ; D : sandy beach ; E : erosion slope ; F : island surface. Elevations are given approximately above the zero of marine charts.

Figure 3. This beachrock spit stretching into the middle of the reef flat marks the position of a former shoreline. The water level is 0.15 m below MSL.

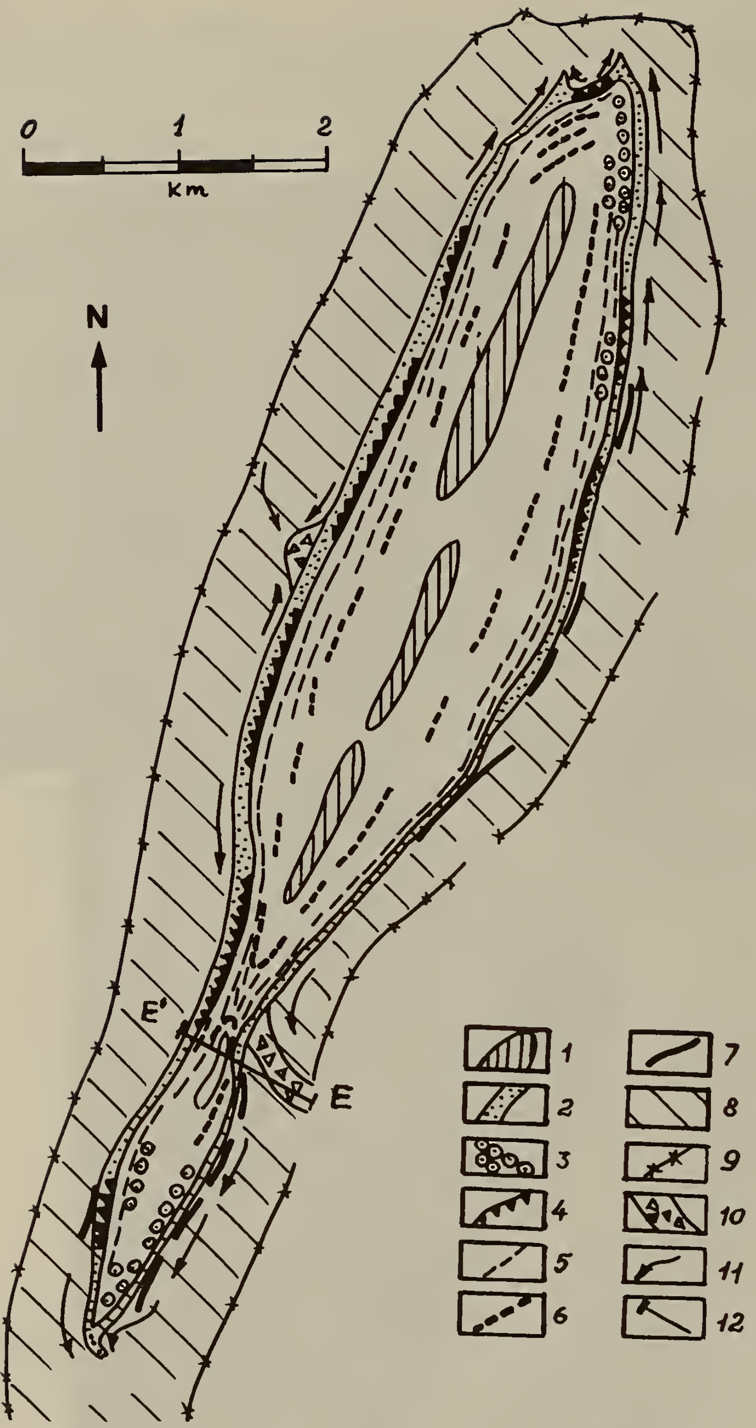

Figure 4. Geomorphological sketch of Coëtivy Island. 1 : swampy depression ; 2 : beach ; 3 : dunes ; 4 : sand cliff or erosion slope ; 5 : modern coastal ridge ; 6 : ancient coastal ridge ; 7 : beachrock ; 8 : reef flat ; 9 : outer reef margin ; 10 : accumulation of massive debris ; 11 : direction of sediment migration ; 12 : location of the E-E' cross-section (see Fig. 5).

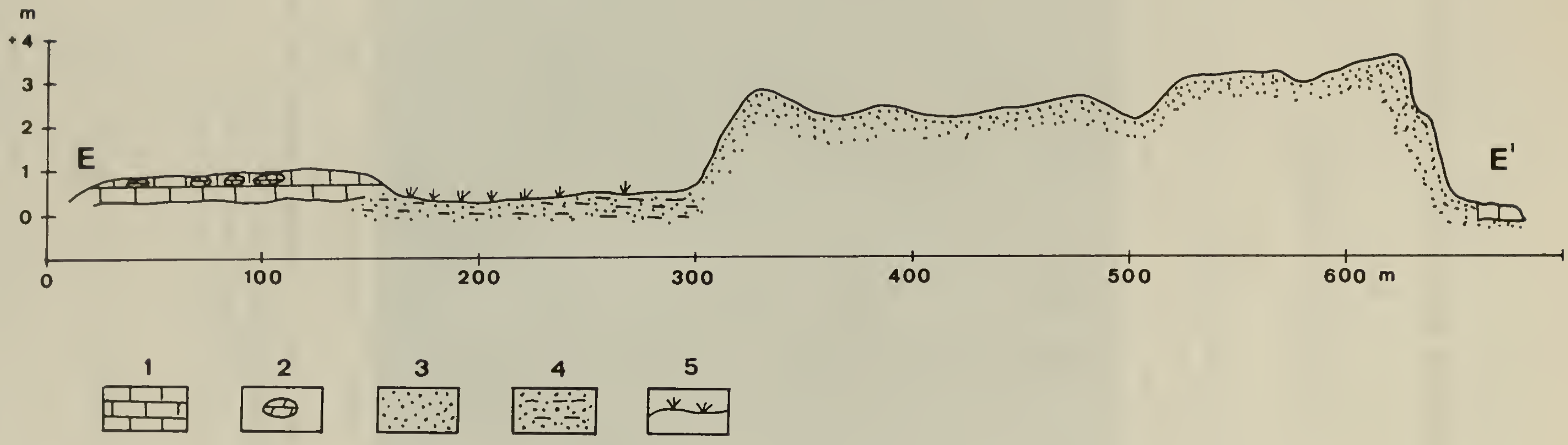

Figure 5. Cross-section in the south part of Coëtivy Island (for location, see Fig. 4). 1 : reef rock ; 2 : boulder debris of corals and reef rock ;3 : sand ; 4 : silty sand ; 5 : seaweeds. Altitudes are related to the zero of marine charts.

Figure 6. Accumulation of piled up dead seaweed on the northeast coast of Coëtivy Island.

A TOKELAU FISHERIES BIBLIOGRAPHY

BY

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The following list of references was compiled in mid-1988 by searching various libraries and collections in the South Pacific region. In addition, individuals known to have worked in Tokelau in a fisheries-related subject were contacted. Because much of the documentation on aspects of marine resources in Tokelau is informal in nature, the bibliography contains both published and unpublished material. At the end of each entry on the following list there is an abbreviation which indicates where the reference was found. These acronyms correspond to the following locations:

FAO/SP	- FAO/UNDP Regional Fishery Support Programme UNDP Private Mail Bag Suva, Fiji
FFA	- Forum Fisheries Agency Box 629, Honiara Solomon Islands
Nelson Lib	- Nelson Library Apia, Western Samoa
OTA	- Office for Tokelau Affairs Box 865, Apia, Western Samoa
SPC	- South Pacific Commission B.P. D5, Noumea, Cedex New Caledonia
SPC Lib	- Library
SPC ENV	- Environment Programme
SPC Fish	- Fisheries Section
SPC Tuna Lib	- Tuna Programme Library
USP Lib	- Library University of the South Pacific Box 1168, Suva, Fiji

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A HISTORICAL NOTE ON THE ENDANGERED *SANTALUM BONINENSIS* (SANTALACEAE) OF THE OGASAWARA ISLANDS: EARLY REPORTS BY TAKASI TUYAMA

BY

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ABSTRACT

Santalum boninensis (Nakai) Tuyama is an endangered plant species of the Ogasawara (Bonin) Islands of Japan. The early reports of this species made by the Japanese botanist Takasi Tuyama (1939, 1940) are presented for the first time in the English language, including his comments on the urgent need for conservation of the species.

CURRENT STATUS

The subject of this article is *Santalum boninensis* (Nakai) Tuyama, *Botanical Magazine Tokyo* 52(621): 467 (1938), with amplified description by Tuyama, *op. cit.* 53(625): 5 (1939); basionym: *Exocarpus boninensis* Nakai, *Botanical Magazine Tokyo* 43(513): 440 (1929). It is an endangered plant species of the present-day flora of the Bonin Islands. On Chichijima, the largest of the Bonin Island groups, *S. boninensis* occurs as a small shrub; on Hahajima, it grows as a large tree. *S. boninensis* is a hemiparasite; its host plant on Chichijima is *Distylium lepidotum* (Hamamelidaceae), and on Hahajima it is *Hibiscus glaber* (Malvaceae) (Woolliams, 1979; see also Ono & Okutomi, 1985, in which *S. boninensis* is listed). Its native habitat is restricted to seven localities on Chichijima and three localities on Hahajima. Each of these isolated populations has been reduced below critical size and cannot afford continual normal reproduction by spontaneous pollination (Ono *et al.*, 1986). Interestingly, although *Hibiscus glaber* has not been included in an IUCN Conservation Category, *Distylium lepidotum* is classified as vulnerable. Various endemic plant species of the Bonin (Ogasawara) Islands are being cultivated at the Waimea Arboretum and Botanical Garden in Haleiwa, Oahu, Hawaii. However, *S. boninensis* is not currently in propagation at Waimea (K. Woolliams, pers. comm., 1988).

THE SETTING OF THE ISLANDS

The Bonin (Ogasawara) Islands form the southern part of a chain of islands stretching south from Japan. They consist of some twenty islands which lie between the parallels 26 30’ and 27 40’ N and between 142 00’ and 142 15’ E, with a total area of only 7500 ha. (27 sq. mi.). Geologically, the chain is continued to the south by the Volcano Islands (Kazan retto) and then by the Marianas.

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The Bonins may be divided into three groups (Tuyama, 1953):

1. The Parry, or Mukojima, Group to the north, consisting of four islets, with the highest flat-topped peak less than 100 m. (330 ft.) above sea level.
2. The central Beechey, or Chichijima, Group, consisting of eight islands, with the highest peak at about 219 m. (720 ft.) above sea level.
3. The Bailey (Coffin), or Hahajima, Group to the south, consisting of nine islands, with the highest peak about 512 m. (1680 ft.) above sea level.

The Bonins are believed to have been formed during Tertiary times (Asami, 1970) through the eruption of subterranean volcanoes. Due to severe marine erosion, the islands are now steep and hilly, with little level land, and some of the smaller islets consist merely of bare rock.

Although the island group is to the north of the north-east trade wind belt, it lies within the warm Japan Stream. Thus the Bonins are subtropical with an annual mean temperature of 23.0 C (73.4 F) (Ono et al., 1986) as compared to other places at the same latitude. There is neither snow nor frost, and the temperature never falls below 5 C (41 F). The islands are usually situated under a stable oceanic high atmospheric pressure system known as the "Ogasawara High Pressure."

The Bonin Islands are isolated from other landmasses by more than 1,000 km. (620 mi.) and, as noted by Ono et al. (1986), have never been historically connected to any landmass. The flora is thought most closely related to that of Indo-Malaya and South China; but, as stated by Tuyama (1953), "an old and latently strong connection between the Oceanic and Polynesian floras must be noticed." Forests are dominated by subtropical hardleaf evergreen trees and shrubs such as those listed in Ono et al. (1986) and Tuyama and Asami (1970): Machilus, Morus, Hibiscus, Pouteria, Ochrosia and Boninia, the latter a rutaceous plant and one of the islands' two endemic genera of flowering plants. About 500 species, including some varieties, of vascular plants have been reported. Of these, about 43% are considered endemic (Yamazaki, 1970), or more than 50% of the shrubs and trees (Tuyama, 1970). In their 1979-1982 survey, Ono and Kobayashi (1980, 1985), Ono et al. (1986) recorded over 260 species and varieties of vascular plants of which they considered 112, or 43.1%, to be endemic. Additional floristic studies of the islands are referenced by DeFilipps (1987).

HISTORICAL PERSPECTIVE

The Bonin Islands are thought to have been first sighted by the Spaniard Villalobos around 1543 (Cholmondeley, 1915), but Spain never pushed her claim. The earliest well-authenticated visit by the Japanese was that of the merchant Chozaemon in 1670. Following this visit, the islands were named the Gunin, or Uninhabited, Islands; the later Western name of Bonin is probably a corruption of Gunin (Naval Intelligence Division, 1945).

The first authenticated Western visitors were American and English whalers in the 1820's. Of the later visits, one of the most important was that of Captain Beechey in 1826, whose account of the islands long remained one of the principal sources of information; during his visit he proclaimed British sovereignty on the group. Commodore Perry, on his voyage of 1853, disregarded the British claim and purchased land for an American coaling station; in the process he drew up a simple code of laws for the settlers.

After an unsuccessful Japanese colonizing venture in 1861, a second expedition arrived in 1875 and renewed a declaration of Japanese sovereignty. Two years later the Bonins were formally annexed, with neither Britain nor the United States disputing the action. All of the settlers were offered Japanese citizenship, but only Japanese settlers were allowed to enter from that time on. During this period of colonization, as mentioned by Tuyama (1953), "Owing to the dense population and the inadequate forestry administration, the original forest of the Bonin Group was mostly destroyed. Of the total area, 20% is cultivated field, 10% grassy field or barren rocks, 65% bushy wood, and the tall forests which maintain the original features are seen only in restricted areas in Peel and Bailey Islands."

During World War II, the inhabitants were removed from the islands. United States military occupation followed the war along with settlement by some European inhabitants. According to Ono et al. (1986), for the 25 years during and after the war, while almost entire islands were left uninhabited, many introduced weeds, trees and escaped crops invaded the islands, destroying the original vegetation. Ono goes on to say "After restoration of the islands to Japan in 1968, former inhabitants began to return and the population has been increasing gradually; now about 1800 people live on the two islands of Chichijima and Hahajima. Since the restoration to Japan, most parts of the islands have been designated as a National Park. However the vegetation of the islands is still under heavy pressure from human impact. The most important factors are over-grazing by naturalized sheep, reduced water supply, and competition with naturalized or escaped weeds and crops."

HISTORICAL LITERATURE AND TUYAMA'S ORIGINAL REMARKS ON S. boninensis

The first official Japanese expedition to the Bonin Islands was made by the Tokugawa government, soon after the first recorded reports of the islands made by castaways in 1670. A report of this expedition was never published, due to Japan's strict seclusion policy; the Tokugawa government did not wish the population to be informed of foreign affairs. The first published account of the Bonins was not made until 1786 by the patriot Shihei Hayashi, whose book San Goka Tsu Ran Dzu Setsu (A General Sketch of the Three Countries, with Illustrations) included a short account of the islands. A copy of the book was taken out of Japan and brought to Siberia by a Dutchman, and then translated by the German philologist J. Klaproth and published in the French language in 1832. An extract from this translation appeared in Francis Lister Hawks' Narrative of the Expedition of an American Squadron to the China Seas and Japan, 1856. This translation refers to a "red sandal wood" tree in the Bonin Islands.

The next person to become interested in the presence of this sandalwood was the Japanese botanist Takasi Tuyama. Although the first mention of a sandalwood in the Bonins may have been as early as 1832 (Klaproth translation), Tuyama notes that this is actually a "mistranslation" which refers instead to Melia (Meliaceae), rather than a species of Santalum. Presumably, in the original Japanese publication by Hayashi in 1786, the plant in question also was a mahogany misrepresented as a sandalwood. Therefore, no true Santalum was known to occur in the Bonin Islands until the "Exocarpus," later transferred to Santalum, was described by Nakai in 1929 following his field observations of it in 1928 (Tuyama, 1951). Following are relevant, edited excerpts from Tuyama's 1939 and 1940 articles describing and commenting upon the original discovery of S. boninensis, published for the first time in English. Dr. F. Raymond Fosberg (1950) has described the circumstances under which the translations of Tuyama's articles were made.

> "It is quite interesting to find a species of Santalum within the dominion of Japan; particularly in war time when importation of sandalwood is restrained, its discovery attracts much attention. It was first discovered by Mr. H. Toyoshima, Director of Ogasawara Forestry Office. He guided Prof. Nakai, who was coaching students of Tokyo University at the time, to Kominato, Fukurosawa-mura, Chichi Shima, where Ligustrum ovalifolium is said to occur. It was a small rocky hill, situated near the sea and where Commodore Perry landed years ago. There was nothing of much interest except Hibiscus tiliaceus. The plant in question was a small shrub with opposite leaves. Prof. Nakai at once assumed it belonged to Santalaceae, and confirmed it is parasitic on the root of Hibiscus tiliaceus. He afterwards found many more individuals of the same plant on rocky hills between Kiyose to Okumura. On the herbarium specimens sent by Mr. Toyoshima, a name, Exocarpus boninensis, was given. Afterwards, I have a recollection of having a branch given to me by Prof. Nakai himself at Kominato.
>
> "Several years later I was entrusted to investigate the flora of the Bonins, but did not have an opportunity of seeing fresh flowers. In the spring of 1936, specimens of flowers were sent by Mr. M. Okabe, Technician at the Forestry Office of the Island. On examination, a question arose whether

the plant belongs to Santalum. The fact was informed to Mr. Okabe, and to Dr. K. Watanabe who is a student of parasitic plants; meanwhile I was taking a cautious attitude. In May the following year ample material was sent by Mr. Okabe, and as a result it was confirmed that the plant belongs to Santalum. Having been sanctioned by Prof. Nakai, a new combination Santalum boninense was published."

TUYAMA (1939) ON THE DISTRIBUTION OF Santalum boninensis

"Observations of S. boninensis have since been extended by Mr. Toyoshima and others, and according to Mr. Okabe's investigation, it occurs on Chichi Shima: Mikadsuki-yama, Miyano-hama, Kiyose, Oku-mura, Asshi-yama, Fukiage-dani, and Renju-dani; on Haha Shima: Higashi-dai and Minami-saki, and there are 616 individuals more than 1 m. tall. This species occurs, like other species of Santalum, on dry, stony hills with good drainage and in full sun.

"The host plants are Hibiscus tiliaceus (reported by Nakai), Osteomeles lanata, Rhaphiolepis integerrima, Juniperus taxifolia, Distylum lepidotum (so far by Tuyama), Wikstroemia pseudoretusa, Osmanthus insularis, Hibiscus glaber, Pandanus boninensis, Trachelospermum foetidum, Miscanthus boninensis (so far by Okabe). (It seems the plant is not selective as to host, but so far Sideroxylon ferrugineum growing near by has not been confirmed to be a host.)"

TUYAMA'S PLEAS FOR CONSERVATION OF S. boninensis

"As a rule, the plants of an island isolated in an ocean, and having no connection with other lands, present a unique aspect. The older the island the longer the period of isolation, and therefore, the stronger the degree of uniqueness. The Galapagos Islands near Central America, Islas Juan Fernandez off the coast of Chile, and the Hawaiian Islands are regarded as examples of this. If we are to pick an example among the Japanese Archipelago, the Bonin Islands present a good one. Such isolated groups of islands are usually regarded as remnants of larger islands or remains of a continent. On such islands, one often finds numerous rare species of plants, but the number of individuals is rather small and the area of distribution is limited to certain valleys or mountain summits.

"The plants of this genus (Santalum) have been prized from olden times in China and India as the material of Buddhistic images or perfume, and on that account merchant ships of many countries, contending with each other, went over to Fiji and Hawaii to obtain material. It is recorded that some of them even carried on war with the aborigines for the purpose. It has therefore resulted in reckless cutting. In Hawaii there occur eight species of this genus, and they were apparently fairly abundant, but at present no large specimens are seen, and they stand on the brink of extirpation. That of Juan Fernandez (S. fernandezianum) has been totally annihilated. The Bonin species has been found comparatively recently, perhaps due to the less degree of fragrance, yet it is doubtless necessary to conserve it.

"Santalum boninense is a very interesting species from the systematic and phytogeographical points of view. If analysis of its properties is favorable, it will be of industrial importance, and requires good protection. In Formosa the cultivation of S. album is said to do rather poorly, which may be improved by comparing with S. boninense in the Bonins. The Santalum on Juan Fernandez became extinct, without the knowledge of cause, within one year, and that on Hawaii and Fiji has been almost exterminated as a result of the indiscriminate felling, and young saplings only are seen now. According to Rock (1916), propagation by seed has not been successful on Hawaii.

"According to An Outlook of the Bonin Islands and Forests edited and published by the Bonin Government, 1914, "In the 2nd year of Bunkyu (1862) 40 immigrants arrived from the Island of Hachijo, they, from the fear of vermin in the luxuriant forests, destroyed the forests by fire. On the other hand, the Japanese Government, with a view to acting up to the principles of reclamation, let the immigrants select land on their own accord, provided them with bounty, gave them agricultural implements and household utensils, paid building expenses or supplied them with staple commodity. Thus, the treatment of the immigrants went beyond bounds, resulting in a vicious custom. Many of them, therefore, received bounty on the pretext of reclamation, acquired precious wood, or burned forests to grow the Judas ear (or Jew's ear, the edible fungus *Auricularia auricula-judae*), or felled priceless trees secretly. Thus, the forests of the Bonins had been almost completely disafforested during the 20 years from 1876 up to 1899, when forest management was started." According to Mr. Okabe, "An old man, who has been residing on these islands for years, says, about 1890-1891 when sugar manufacture sprang up and much fuel was required, he remembers having burnt some wood with an aroma."

"If a comparison is made (between such deforestation and the original state of the vegetation) with the *Narrative of the Expedition of an American Squadron to the China Seas and Japan* (1856), a striking difference can be noted. It runs as follows: "The course was up the ridge of the hill, and as it continued to the summit the vegetation became more and more profuse, until the expanding tops of the palms, the crowding together of the trunks of the trees, and the dense network of the hanging vines, so blotted the sun that the path was covered with a deep shade, through the darkness of which the eye could hardly penetrate to a greater distance, in any direction, more than twenty or thirty feet."

Recent observations (Woolliams *et al*., 1979; Ono *et al*., 1986) have confirmed that *S. boninensis* has survived to the present time in its precarious position as a member of the Ogasawara flora, and it continues to require protective measures to ensure its existence in the future.

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ISLAND NEWS AND COMMENTS

Brief Reviews of Island Floras

Plants are the most ubiquitous and obvious features of almost all island landscapes. They are basic to all island ecology, and any island ecological study necessarily involves a consideration of the flora. Accurate knowledge of the identities and characteristics of the plants that are components of the ecosystems studied would seem to be essential. That this is not always realized or accepted by ecologists is one of the reasons why so much of the work that has been done on island ecology is superficial and even unsound. The same is, of course, true of the animal components of the ecosystems.

Acceptance of the above at once poses the problem of how to determine the identities of the usually very numerous plant species on the islands studied. Clearly, voucher specimens must be collected and preserved. Identifications are based on these. The usual procedure, then, is to take the specimens to someone who is reputed to know what they are, and ask him to provide names. If there were experts available on the floras of all islands or island groups, part of the problem might be solved, if the experts were not too busy. The fact is that there are many islands for which no floristic experts are available. Even more important is the need of the ecologist, himself, to have a working knowledge of the flora of the island or islands he is working on. This may be acquired, if the ecologist is lucky, by extended working in the field with an expert on the flora. Some useful knowledge may be gained by studying specimens identified by others, especially if these are specimens collected and prepared by the ecologist, himself. There is no good substitute for "hands-on" experience with living plants.

Lacking a willing expert, the ecologist usually has to resort to collecting and identifying the plants, himself. If he has ready access to an adequate herbarium (collection of dried and identified plant specimens) he can do this, if he has some elementary training in taxonomic botany. This latter should clearly be a part of the education of anyone who calls himself an ecologist. A necessity (not always available) is a flora of the island or region under study.

A flora is a book or paper on the plants of a place or area. Floras range from mere lists of the names of the plants, not very useful except to one who has a usable knowledge of plants; to popular picture-books, always incomplete and frequently inaccurate as to identities of the plants illustrated; to annotated lists, more informative but not much help to the ecologist unfamiliar with the plants of the region; to descriptive floras of all degrees of detail, with or without keys for identification, illustrated or not. Floras also range in geographical coverage from those of a single coral islet or rock - e.g. Vostok, Dulcie Atoll and Rose Atoll, to major floras of larger islands or groups - e.g. Guam, Ceylon, the Hawaiian Islands, or the Fiji Islands, or to comprehensive regional floras such as the Flora Malesiana, covering the great islands from the Philippines to New Guinea, not yet completed but more than ten volumes to date and enormously useful.

Even to list the available island floras would be a major task. Two comprehensive lists of floras of the world, including islands do exist, those by Blake and Atwood and by Frodin, which are indispensable. To extract a list of island floras from these would be a worthwhile project.

For Atoll Research Bulletin readers, brief reviews and comments on recent or current island floras may be of use or interest. The following list are examples. One may mention, here, the fact that any flora starts to become out of date, or obsolete, at the time it is published. New discoveries, often stimulated by the new flora, itself, and taxonomic and nomenclatural changes very soon make a new edition or whole new flora desirable. However, few floras ever become useless. All have information pertinent to the place and time which may never be completely available elsewhere. Also, since floras are normally arranged systematically and indexed, such information remains retrievable.

FLORA VITIENSIS NOVA, by A. C. Smith, Pacific Tropical Botanical Garden, publisher. Four volumes published, 1: 1979; 2: 1981; 3: 1985; 4: 1988; two more in preparation.

This is a magnificent and important work, over 50 years in preparation, by one of the outstanding systematic botanists of this century. This is a descriptive flora (descriptive only to generic level), with comprehensive and very useful keys. It is unusual in that major attention is given to typification, especially at generic and specific levels. The arrangement of families is in most respects according to the Takhtajan (and Cronquist) scheme, discussed in the introduction. The introduction also includes an extremely useful discussion of taxonomic philosophy, methodology, editorial practice, nomenclature, and a valuable concise treatment of Fijian geography, geological background and phytogeography, and a history of botanical exploration in Fiji, with information on collections made. A beautiful series of color and black and white photos illustrates the landscape, interesting botanical features, and vegetation of the islands. The first three volumes of this work have been reviewed elsewhere. The fourth volume, comprising many gamopetalous families, has recently appeared. It fully continues the meticulous tradition of the preceding volumes. The author was assisted by S. P. Darwin in treating the large family Rubiaceae. One could scarcely imagine a better collaboration on this difficult family, though the rather narrow splitting of genera in some cases might be questioned.

The two remaining volumes are eagerly awaited by all persons seriously interested in Pacific botany. One could only wish that a worker as able and dedicated as A. C. Smith were available for each of the other major Pacific island groups.

FLORA OF THE CAYMAN ISLANDS, by George R. Proctor, 1984. Kew Bulletin Additional Series XI, 834 pp., 256 figures, available from H. M. Stationery Office Government Bookshops.

The main function of a "manual" type of flora, quick and accurate identification of the plants of a given area is admirably accomplished with Dick Proctor's book, which has now been available for four years. The area covered, the Cayman

Islands, northwest of Jamaica and south of middle Cuba, in the Caribbean, not familiar to many before but now, as almost everywhere in the island world, attracting more and more tourists, has long needed a flora, more than ever now. There are three of these islands, Grand Cayman, Little Cayman, and Cayman Brac, roughly aligned west to east. They are of elevated limestone, total land area about 102 square miles, relatively low and flat, Cayman Brac being the most rugged and reaching an altitude of 43 m. On Grand Cayman "The Mountain" is somewhat over 6 or 8 m. The core limestone is hard, massive, white of mid-Tertiary age, and much more recent reef limestones surround this central core. The surfaces are much eroded, providing a variety of habitats.

An extensive chapter on Environment and Plant Communities, well illustrated by profile diagrams and photographs, by M. A. Brunt is a valuable feature of the book. It describes and discusses the vegetation, bringing out the fact that practically no undisturbed dryland vegetation remains, and that human activity has reduced most of the former forest or woodland to thicket (scrub).

Phytogeographically the flora is related mainly to that of Jamaica, somewhat also to Cuba and the other Greater Antilles, with minor elements southwestward and to the widespread pantropical flora.

Taxonomically the approach is commendably conservative, not indulging in the all-too-common excessive family and genus splitting that has been rather common in the region. 601 indigenous and naturalized species are recorded, belonging to 389 genera, arranged in 121 families. Cultivated plants are not treated, though occasionally they are mentioned. Families, genera, species, and varieties are described and keyed with keys that work.

Synonymy is kept to a bare minimum, too much so for botanical tastes, but unconfusing for the novice who may not understand how a plant can have several names. Specimens are cited by island, collector and number. A brief statement of distribution and habitat is given for each species. Vernacular names are usually provided. Practically every genus is illustrated by a clear, well-executed line drawing. Errors seem almost lacking.

All in all, this is a very useful and satisfactory book. Dick Proctor is to be congratulated.

FLORA OF THE BAHAMA ARCHIPELAGO, by Donovan S. Correll and Helen B. Correll. 1982. 1692 pp., 715 figs. J. Cramer, Vaduz.

This massive book, the culminating achievement in the outstanding career of Don Correll and his wife, Helen, is one of the best manual-type floras ever written. It covers the vascular plants of an enormous insular area, the Bahamas, comprising 35 principal islands, 700 cays, and about 2400 vegetated rocks, a total land area of about 14,500 sq. km, scattered in a sea area 1000 km long and 480 km greatest width. The islands are low, maximum 65 m elevation, entirely of limestone, lithified or loose sediments, with diverse micro-topography.

The flora comprises 1350 species, 21 infraspecific units, belonging to 660 genera, arranged in 144 families. The family arrangement is traditional, Engler and Prantl, with genera and species alphabetical within the families. Practically every genus is illustrated by an excellent line drawing, mostly by Ms. Pricilla Fawcett. The keys are concise, bracket-style, and eminently workable. Every entity, at all levels, is described. Brief statements of habitat and distribution are provided. A table of distribution by 11 island areas for which herbarium specimens were seen, summarizes the geography of each species. It was obviously impractical to cite specimens without producing a multivolume work, though such specimens exist to thoroughly document the work, and the principal herbaria containing them are listed. Synonymy is limited to that pertinent to the Bahamas. Taxonomy is reasonably conservative, with comments about problematical cases.

In the preface are outlined and discussed the history of Bahama botany, the circumstances of the production of this work, and extensive acknowledgements.

This book is one of the rare instances in my experience where no criticism is appropriate. It will long be a model of how floristic manuals should be written. Our great appreciation is offered to the authors (senior author now deceased).

PLANT LIFE OF THE GREAT BARRIER REEF AND ADJACENT SHORES, by A. B. Cribb & J. W. Cribb. 1985. 294 pp. illus. Univ. Qld. Press, St. Lucia, London, N. Y.

This is a timely, well-prepared, beautifully illustrated popular book covering the more obvious plants of Australia's immense Great Barrier Reef. It is only claimed to be a popular book, but the beautiful and well-chosen color photos, and the limited but informative text, written by competent botanists convey much information of use to botanists, marine biologists and ecologists.

The book comprises six chapters, glossary, references, and index of plant names. For each plant are given family name, scientific binomial, vernacular name, description, interesting remarks on occurrence and uses, and a color photo. The first chapter is a description and explanation of the Coral Reef, setting the stage, setting, and functions of the plants. Then follow chapters on Seaweeds, the Islands, Plants of the Shore, Flowering Plants in the Sea, and Flotsam. The plants that a visitor - scientist, tourist, or scuba-diver - is likely to see are all or mostly there. One may not always agree with the names given, but most of the differences are matters of opinion. The chapter on flotsam interesting fruits, seeds, and other beachcombers' treasures of plant origin is an interesting and useful innovation in such books. Certainly this book is indispensable for anyone planning even a casual visit to Queensland's Great Barrier Reef.

A REVISED HANDBOOK TO THE FLORA OF CEYLON, Dassanayake, M. D. and F. R. Fosberg, eds., 1980 - . 6 vols. continuing, Amerind Pub. Co., New Delhi.

The flora of Ceylon has a special significance as one of the two tropical floras available to Linnaeus, and furnishing the types of a substantial number of the widespread tropical plants named by him. The specimens on which his Flora Zeylanica were based, collected by Paul Hermann, Dutch botanist, in the 17th Century, are good, for the period when they were collected, but leave something to be desired by modern standards.

In the late 19th Century, Henry Trimen, with help from Joseph Hooker, provided the island of Ceylon with a five volume flora, A Handbook to the Flora of Ceylon, that for its time, was one of the outstanding floras of any tropical area. It was written before many modern taxonomic ideas, and particularly the type method in nomenclature, were in vogue. Furthermore, by the late 1960's, it was completely unavailable. It was time for a major revision to replace this not very available handbook.

A major cooperative project, to augment the collections of Ceylon plants and to produce a new flora, was undertaken by the Smithsonian Institution, at the suggestion of, and under the direction of F. R. Fosberg.

Authorities on the different plant families in the flora were invited to participate, and were enabled to spend several months or more, collecting and studying the plants in the field, with the aim of providing treatments of their groups for the new flora. Field explorations were continued under this arrangement, using U.S. excess foreign currency funds, provided under Public Law 480 to cover the costs. The work of the invited botanical participants was voluntary on their part and, except for their travel and field expenses, funded by their own institutions. Publication is taking place, funded by the Smithsonian Excess Foreign Currency Program.

Six volumes have appeared to date, printed in India, with most of the editorial work by Professor Dassanayake, of the University of Peradeniya. Several more volumes are in press or preparation.

The arrangement of the families is in the order in which manuscripts are received from their authors and can be edited. The intended volume on the grass family, by several authors, is all in hand and was being coordinated and edited by the late Dr. T. R. Soderstrom. It was unfinished at his death, and the editing is being completed by Prof. Neil Harriman.

The treatments of the families are descriptive, with keys, discussion, and citation of specimens. They vary somewhat, as no rigid editorial control was imposed. Hence, they reflect their authors' ideas and standards, rather than those of the editors. They provide a firm basis for continued work on the plants of the wonderful island, or mini-continent of Ceylon (now officially called Sri Lanka).

The books may be procured, while the supply lasts, from the Botany Department of the Smithsonian Institution.

FLORA MALESIANA, van Steenis, C.G.J., ed. 1950-continuing, 11 vols. to date, Ryksherbarium, Leiden; pub. Nijhoff, Dordrecht, Netherlands.

This is a flora in the most comprehensive sense, with descriptions, synonymy, keys, morphological and ecological discussion, bibliography, and usually an illustration for each genus. The scope is Malesia - the hundreds of islands that comprise Indonesia, Malaysia, Philippines, New Guinea, Bismarck Archipelago and the Solomon Islands. Series I covers the seed plants, Spermatophyta, Series II, the vascular spore-bearing plants, Pteridophyta. Volume 1 of series I is an incomparable Cyclopaedia of Collectors, brief accounts of all of the hundreds of people who have collected specimens and information on Malesian plants. This was done by Mrs. M. J. van Steenis-Kruseman, wife of the editor. The greater part of this compilation was done under World War II imprisonment, at the library of the Bogor herbarium. The other 10 volumes have been prepared by the Flora Malesiana staff and many experts recruited from and with the cooperation of botanical institutions in many parts of the world. It is a truly international enterprise, though centered in the Netherlands. Though its declared scope is the flora of Malesia, it is an indispensable asset for anyone working on the plants of anywhere in the Indo-Pacific region. It is hoped that support and cooperation will continue and bring about completion of this enormous enterprise. It is and will always be a monument to the imagination and tireless energy of the late Professor van Steenis.

Some Plants of Kiribati, an Illustrated List, R. Overy, Ivan Polunin and W. G. Wimblett, 146 color photos, Tarawa, Kiribati.

The Gilbert Islands, known to western geography for well over 150 years, and now principal component of the new Republic of Kiribati, do not have a descriptive flora, nor.even until very recently (ARB 295, 1987) a complete list of the plants growing in the archipelago. To fill this vacuum the Kiribati National Library and Archives has sponsored a document entitled "Some Plants of Kiribati, an Illustrated List" containing 146 color photos, as well as Gilbertese names and uses, of Plants found in the Gilberts. This book, under the authorship of R. Overy, Ivan Polunin and W. G. Wimblett (herein abbreviated 0.P.W.), was issued in a very limited edition (30 copies), in Tarawa, 1982.

A copy was supplied to us for comment and to have the botanical names checked for accuracy, and a request was made for any necessary corrections. Each species included is illustrated by a color photo, but there are no citations of specimens, though some were said to have been sent by the authors to Fiji for verification of identifications. Examination of the photos shows a distressing proportion of incorrect names. The book only treats less than 150 out of a list, probably not quite complete, of 260 species and varieties, 95 of them probably indigenous. We do not agree with the statement on p. III that there are probably no truly native species on these atolls. We estimate that there may be between 75 and 100.

To provide an interim list with correct names, so far as can be determined from specimens available and reliable published records, we have made a compilation, published as ARB No. 295.

The principal herbarium collections that we have seen are those made by Catala, Moul, Sachet, Herbst and Allerton, Madeson, and Raulerson. We have also examined various older specimens that we have encountered in various herbaria.

Flora of the Galapagos Islands, by I. W. Wiggins and D. M. Porter (1971), Stanford Univ. Press, 998 pp., $37.50.

An excellent example of manual type flora, this is indispensable for anyone dealing with the plants of this famous archipelago. Families, genera, species and lesser taxa are described very adequately and listed with pertinent synonymy and references. Distribution maps and drawings are provided for most genera, with remarks on their distribution and ecology. An introduction covers, adequately but briefly, the geography, history, climate, geology, soil and vegetation zones, fauna history of botanical collections, scope and method of work and materials examined. A beautifully reproduced set of 96 color photos of landscape, birds, vegetation and individual plants add greatly and aids visualization of this strange environment. The keys are workable, and with the drawings, make identification of almost any plant in these islands easy and reliable. The authors had the cooperation of a number of excellent specialists in different difficult plant groups.

VOLCANOES AND ISLANDS: BRIEF REVIEWS

The awesome subject of volcanoes has interested and impressed a wide range of people since the days of the destruction of Pompeii and Herculaneum by Vesuvius, and undoubtedly for a long time before that. In the last few years there have appeared a number of books on volcanoes, widely differing in nature, style of writing and aimed at different audiences. Considered together they give a good picture of volcanic phenomena, though it would take many books to give an adequate geographic coverage. And there is no questioning the fact that most of the books will tell the person who has had first-hand experience with volcanoes in eruption much more than one who has not seen volcanoes or only dead or dormant ones. Fascination with volcanoes is easy to develop, especially once one has seen one in action. That it may be a fatal fascination is occasionally demonstrated, as at Mt. Helens a few years ago, or at Myojin Reef some years back when a boatload of Japanese volcanologists got too close and were never seen again.

What makes the study of volcanoes particularly interesting and appropriate for those, especially scientists, who are concerned with islands, is that so many islands, especially almost all "oceanic islands", are volcanoes, and owe their origin and special features to volcanic activity and processes.

Volcanoes, active, dormant, and long dead, are well-distributed over the earth's surface, active ones being especially common in the "ring-of-fire" around the periphery of the Pacific Ocean, where the continental "tectonic plates" impinge on the margins of the "Pacific Plate" and several lesser oceanic plates. Volcanism takes place along mid-oceanic ridges, where the earth's crust is pulling apart, and on plate edges where "subduction" and "overthrusting" create enormous pressures and heat, and pieces of crust are forced down into the molten or semi-molten mantle layer. Here they are melted and become masses and reservoirs of "magma" or molten rock. These, under the pressures created, both by tectonic movements and by volatilization of some rock-components and melting of others, spew forth through cracks and weak places in the crust, to form "montes ignivomes" or or fire-vomiting mountains, commonly called volcanoes. Under the plates, away from their margins, are also occasional "hot-spots" where the temperatures are such as to melt the crust, and magma is forced up through cracks and conduits and pours forth as lava. Of this are mountains and islands made. One such "hot-spot" is considered responsible for the Hawaiian Island Chain, continued northward as the Emperor Sea-mount Chain.

The following series of notices or brief review will call attention to vivid accounts, descriptions, and vasts amounts of information about these tremendous phenomena recent and contemporary episodes in the building of the earth and the creation of oceanic islands. That most of the books reviewed are popular, but still accurate and very informative, speaks well for the writing abilities of the members of the volcanologic profession, and for the state of knowledge about volcanic phenomena. Scientific books do not have to be dull, or written in jargon.

My selection of books for review is simply determined by their availability to me and limitation of time to search them out and read them. There may well be other, perhaps as good or even better, books that have not come to my attention. Those reviewed all appear to me to be interesting to one to whom the formation and history of islands is important.

Krakatau 1883--The volcanic eruption and its effects, by Tom Simkin and Richard S. Fiske, 464 pages, Smithsonian Institution Press, 1983. Washington, D.C. /Cloth $29.00; paper $15.00.

This book, published on the 100th anniversary of the second most famous volcanic eruption in history, can only be described as a tour-de-force, bringing together, organizing, and interpreting everything recorded and otherwise available about this world-shaking event. Though not the greatest eruption in historic times, but next to that of Vesuvius in 79 A.D., Krakatau is probably the most written about. To bring together such a mass of recorded information was a notable accomplishment. The result is perhaps the most comprehensive account of a "classic geophysical event" available -- 88 eyewitness descriptions, all official records, accounts of the destruction by ash-falls, earthquakes, tsunamis and nuees ardentes, as well as miscellaneous information on such phenomena as pumice-rafts, noise heard thousands of km away, world-wide observations of vivid sunsets, etc. provide the primary information.

All of the interpretive accounts by later writers, including the first English translation of Verbeek's major monograph of the eruption, written in 1885, and all available information on post-eruption changes and recolonization, revegetation, and subsequent eruptive activity are set forth in detail. This makes an overwhelming mass of information, more than most minds can grasp and assimilate. The authors, however, sift and integrate this and weave a most convincing and understandable interpretive account. The volume is a basic for the science of volcanology, and for the study of the original colonization of plants and animals of new volcanic islands.

Volcanoes in the Sea, the Geology of Hawaii, ed. 2, by Gordon A. Macdonald, Agatin T. Abbott, and Frank I. Peterson, 1983, 517 pages, a revised and augmented version of the notable book of the same title published in 1970 by the first two authors, both published by the University of Hawaii Press, Honolulu. Price of second edition $29.95.

Fortunate is the ecologist who has available for the region in which he works an understandable, comprehensive account of its geology and physiography. This serves as a physical framework and historical background for the biological phenomena he is investigating. Such an account, in a highly readable and magnificently illustrated form, has been available for the Hawaiian Islands since 1970, in the first edition of the work here reviewed. Work on the ecology and geography of the state of Hawaii has benefitted enormously from it during the 14 years between the two editions.

This second edition, revised and reorganized, and with much of the new understanding of the dynamics of the earth accomplished in the last decade incorporated, by Frank Peterson, serves the above described function even better than its predecessor. In addition to being an enormously successful textbook for the amateur volcanologist, such as this reviewer, with the addition of the new chapter on "Plate Tectonics and the Origin of the Hawaiian Islands", it becomes a means for the amateur geographer, also such as this reviewer, to understand the new concepts of the behavior of our planet as a whole. Phenomena of many sorts, observed but poorly understood earlier, now fall into place in a wellfounded theoretical framework, extremely useful in many related sciences, but also providing the deep intellectual satisfaction of an understanding of the system of which we are a part.

The Volcano Letter /1925-1955/, R. S. Fiske, T. Simkin and E. A. Melsen, eds., 1987, Smithsonian Inst. Press, 530 issues, plus index.

The Volcano Letter, a serial leaflet issued over a period of 30 years, by the Hawaiian Volcano Observatory, Kilauea Volcano, Hawaii is a veritable mine of information on volcanoes, volcanism, and related topics, but one which until the appearance of the present volume, was difficult to consult. A publication of from 1 to 4 sheets at a time, even of interesting material such as in this one, is likely to be discarded, sooner or later, rather than being kept. Librarians regard them as a nuisance - they are accustomed to handling books and substantial bound journals, rather than single or folded sheets. Full sets are rare, indeed. Hence, the appearance of the complete 530 issues, bound in a large handsome volume, is an important event in the history of volcanology, both professional and amateur.

Its founder, the renowned volcanologist T. A. Jaggar, also founder and longtime director of the Hawaiian Volcano Observatory, situated on the rim of Kilauea Volcano, undertook both to educate and interest the public on volcanoes and volcanism, and to keep a detailed published record of every manifestation of activity by Kilauea, one of the most closely observed volcanoes on earth. Jaggar and his successors over the years brought together an enormous amount of information, world-wide in scope, much of it either not recorded elsewhere, or only in ephemeral news items or personal notes. Browsing through these leaflets, one with any interest in what goes on in the earth and the origin of certain widespread landscape types, finds it hard to stop turning the pages and continuing reading.

The editors, the Mineral Sciences Department of the U.S. National Museum of Natural History, the Smithsonian Institution Press, and the Atherton Seidell Fund are to be thanked and congratulated for making this great source of information readily available. No natural science library of any consequence will want to be without it.

Planet Earth - Volcano, T. A. Lewis and staff, eds., 1982, Time-Life Books, Alexandria, Va., 176 pages, profusely illustrated.

While most popular books on volcanoes concentrate on the relatively tame, easily observed shield volcanoes, this one starts with a detailed account of one of the most fiercely explosive of volcanoes, Mont Pelee, on Martinique, Lesser Antilles. This mountain, in 1902, destroyed a city and killed its 30,000 inhabitants in a few minutes time. This fascinating and terrible narrative goes on to bring in the origin, in central France, of early volcanology, accounts of the persons involved, the development of modern volcanology, description and diagrammatic representation of how the internal mechanism of volcanoes functions. The book is a fascinating volcanic history of the earth, from the destruction of Pompeii, with accounts of the great eruptions and the different kinds of volcanoes and eruptions, the developing methods of studying them, and ending with the dramatic story of Mount St. Helens, in the western Washington Cascade Range.

This is a small book, but I could not suggest a more comprehensive and still vivid portrayal of this aspect of the world's most dynamic complex of processes.

Volcanoes, Earth's Awakening, by Katia and Maurice Krafft, 1980, Hammond, Maplewood, N. J., 160 pages of text, figures and color plates.

This is a popular book, the main feature of which is an abundance of some of the most spectacular and beautiful photos of volcanic phenomena ever made. A very informative introduction explains the history of volcanology, its main ideas and principles, with maps on mercator projection showing the outlines and directions of movement of the earth's tectonic plates and accompanying phenomena, and of the distribution of active volcanoes.

The rest of the text is principally a very informative explanation of, and captions for, the extraordinary collection of photos. This text is marred for some of us by almost disgustingly extravagant language. Many of the photos and much of the discussion are of insular volcanoes, e.g. Stromboli, Piton de la Fournaise, Aleutians, Katmai, and the Icelandic ones. Any amateur volcanologist would be interested and informed by perusing this book.

Volcano, by Maurice and Katia Krafft. 1975, published by Harry N. Abrams, N.Y., 174 pages, 55 color plates, 5 powerful engravings, and 14 diagrams, 8 tables.

This, though still a popular book, is an entirely different sort of book from the one by the same authors noted above. It is essentially a primer of volcanology, with a strange introduction by Eugene Ionesco, a series of poems on the volcano theme, by Max Gerard, 5 engravings designed to convey the essence of volcanism, by several artists, and are markable series of color photos, mostly by the authors and their associates. A series of tables by M. Krafft give some statistics on the performance of volcanoes throughout the world. At least one of these tables, the 7th of 8 unnumbered tables, page 166, giving a camparison of the energy produced by a number of volcanoes, expressed in terms of number of hydrogen bombs. Since hydrogen bombs are not at all uniform in size or yield, this table is essentially meaningless and should not be taken seriously.

The text is calculated to give those with no geological background the information necessary for an elementary understanding of the structure and dynamics of the planet we live on, and the mechanics and significance of volcanoes in this context. This didcussion is graphically illustrated by 14 bold diagrams which reinforce the ideas outlined in the text.

This has not much to offer to the person with an up-to-date background in geology and geophysics, but the color plates are some of the best we have ever seen, and far more varied than those in most books about volcanoes. It is also a sumptuously produced book. The poems will be rewarding to those who appreciate blank verse. The engravings convey the essence of volcanic art.

The Volcanic History of Taranaki, by V. E. Neall, 1974, 17 pages, published by Egmont National Park Board, New Plymouth, N.Z.

This attractive booklet, was written to help visitors to Mount Egmont understand and appreciate what they are seeing. Taranaki District of New Zealand, forms a roudded peninsula extending into the sea on NorthIsland's west coast. Its principal features are four volcanic centers, on a line extending from New Plymouth, southward, the oldest being Sugar Loaves and Paritutu dome at New Plymouth, active 1,750,000 years ago. Next is Kaitake, active, 575,000 years ago, then Pouakai, active 240,000 years ago, and Egmont, active from 70,000 years ago until 100 years ago, since when it has been dormant. The booklet describes and interprets the series of events marking the formation, development and decline of the first three volcanoes, and the building of majestic Mt. Egmont, the dominating feature of Taranaki District (the author neglected to give its summit elevation). A useful feature of the book is explanation of volcanic terms in language an average tourist can understand. The explanation follows events in chronological order over almost the last 2 million years. The booklet is well illustrated with excellent black and white photos. It is a tiny booklet, but fills a need.

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The Belize Barrier Reef Ecosystem: An assessment of its Resources, Status and Management. by J. S. Perkins, 1983. 1-141, Al-A41, New York Zoological Society.

It is almost a truism that an important scientific investigation or program should have, in addition to the traditional data-gathering and analytical phases, a synthetic phase in which the facts brought out in the analysis are put together, related, and their over-all significance developed. Though this seems obvious, it is not even attempted in many investigations, and when undertaken, it frequently proves to be a refractory and frustrating enterprise in spite of modern computers and modelling. Not all minds are equally adept or versed in both of these major aspects of the scientific process. Sometimes a different person must undertake the desired synthesis.

The work under consideration shows that the synthesis need not be elaborated by the person or persons conducting the investigation, but can be brought together by a perceptive person from works of one or more others. It is an example of an eminently successful synthesis of a mass of information, much of it from a number of reports of investigations of the Belize Cays--atolls and barrier reef islets. These are mostly by David Stoddart and colleagues (ARB nos. 87, 95, 104, 131, 256, 257, 258, 259) and in the volume recently published on the reef-system around Carrie Bow Cay by the Smithsonian (Rützler and Macintyre eds. 1982)

The report considered here is well organized. In order to be understandable to non-ecologists it is written in clear, jargon-free English. It has a geographical introduction describing the country and especially the remarkable barrier reef and sand-cay system. Much attention is given to its scenic and biological resources and their interactions and functioning as a living ecosystem.

The history of man's influence on the Barrier Reef islets, starting with Maya occupation, is documented by reports of many archaeological sites and historical and archaeological accounts of aboriginal and European colonial occupation. After presenting the nature and history of this complex, man's present relation to it is described. Economic data are presented, the degree to which the natural resources have been and are being exploited, especially the fisheries, is explained. The growing importance of tourism is emphasized and the potential loss of much of the benefit of this if the biological resources of the reefs are over exploited.

Short descriptions of each class of resources are given, with information on governmental input and control, if any, of utilization. Relation of industrial activities to natural and scenic resources is discussed at some length. Research and education in these contexts are considered. Related governmental structure and legislation are outlined, and their effectiveness or lack of it, pointed out. The economy and its relation to conservation, as well as social structure, attitudes and customs are related to all of the preceding considerations.

A series of appendices bring together the factual data concerning the resources available.

Woven into the total paper are recommendations on how the resource system may be managed on a sustained basis. One may only hope that the authorities of the new nation, who seem to want the best for the citizens, will pay attention to the author's recommendations.

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Holocene Reefs of Bermuda by Alan Logan, 1988 Sedimenta XI. University of Miami, Miami Beach, Florida 33139. $7.00. 62p.

This guidebook on the reefs of Bermuda is the latest addition in the SEDIMENTA series published by the Fisher Island Station's Comparative Sedimentology Laboratory. It is an excellent addition to the set of guidebooks published during the Third International Coral Reef Symposium on the reefs of Barbados, Belize, Grand Cayman, Jamaica, Panama and St. Croix -- which are still available from the Univesity of Miami.

Although the Bermuda reefs contain depauperate coral and gorgonian fauna, they form a diversity of reef structures that have attracted the attention of a wide variety of marine scientists. This guidebook introduces you to the major reef types, their dominant biological and geological characteristics and a comparison with other western Atlantic coral reefs. Other topics covered include, cryptic communities, the aggressive interaction between coral species, coral diseases, coral growth rates, bioerosion, diagenesis and sedimentary characteristics. None of their sections are extensive in their coverage of the topic but they do provide the reader with an excellent introduction to the literature on reef studies in Bermuda with well-conceived illustrations and high quality reproductions.

Finally, there is an outstanding appendix that provides the visitor with a choice of three well documented field trips of the various Bermudian reef types. There is also a systematic list of stony corals and hydrocorals backed up with a set of excellent illustrations of the colonies and close-up photographs of corallite patterns.

This is a nicely prepared guidebook and an absolute must for both scientists and non-scientists who need an introduction to the reefs of Bermuda.

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The Natural History of Enewetak Atoll, Volume I, The Ecosystem:Environments, Biotas, and Processes, DOE/EV/00703-T1-Vol. 1(DE87006110) 228p., and Volume II, Biogeography and Systematics,DOE/EV/00703-T1-Vol. 2 (DE87006111) 348p., 1987, D. M. Devaney, E. S.Reese, B. L. Burch, and P. Helfrich (Eds.), U.S. Department of Energy,Office of Scientific and Technical Information, Oak Ridge, Tennessee.

Ernst Reese is to be congratulated for his dedication and perseverance in ensuring the publication of these unique volumes on the natural history of a Pacific atoll. Although other atolls of the world have been the focus of entensive research, in particular the Aldabra and Mururoa Atolls, these Enewetak volumes represent the first time that a systhesis of the research from one atoll has been brought together in a single comprehensive publication.

"The Natural History of Enewetak Atoll" represents an overview of the research activities of over 1000 individuals, mostly marine biologists, who worked at, what is now known as the Mid-Pacific Marine Laboratory--some old-timers will fondly remember it as the Eniwetok Marine Biological Laboratory. Volume I consists of a series of review chapters on a wide variety of basic topics including history, geology, oceanography, and most extensively marine biology--containing excellent chapters of the subtidal and intertidal ecology, reef processes and trophic studies. Other chapters focus on the terrestrial ecology, meteorology, biology of rodents and avifauna. These well illustrated articles provide the reader with an outstanding introduction to the natural history of Enewetak and reminds us of some of the major contributions to the understanding of reef ecosystems that were accomplished at this site.

The first volume also provides us with the setting for the detailed taxonomic reports that comprise Volume II. The majority of the 31 chapters in this volume are basically species checklists of predominantly marine invertebrates along with fish, algae and fungi. The terrestrial groups covered include plants, insects, reptiles, birds and mammals. The chapters in this volume vary widely in detail--from simple lists of species to well-illustrated compilations of species with comments on their biogeography and working keys to identify the species. In particular, the non-specialist will appreciate the chapters on sea anemones, brachiopods, bryozoans, molluscs, holothurians and fishes.

These natural history volumes of Enewetak have set a standard for others to follow in terms of assembling a comprehensive documentation of the research activities of an atoll ecosystem. Such investigations are carried out by specialists in many disciplines who published in an ever-increasing variety of journals. Reese and his colleagues have provided an exceptional reference publication which will not only assist those who will visit Enewetak in the future, but also all of us who work on coral reefs and their associated islands.

As a U.S. Government publication, these volumes are available to U.S. residents for $61.90 from Dr. E. S. Reese, University of Hawaii at Manoa, Department of Zoology, Edmondson Hall, 2538 The Mall, Honolulu, Hawaii 96822. All others are faced with a cost of $123.80 US and should address their requests to NTIS Energy Distribution Center, P.O. Box 1300, Oak Ridge, TN 37831. For further inquiries please contact Ernst Reese.

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Korallenriffe, Ihre Verbreitung, Tierwelt und Ökologie [Coral Reefs, their Distribution, Animal World and Ecology], by Helmut Schuhmacher. BLV Verlagsgesellschaft Müchen, Bern, Wien (1976). With 205 Photographs (127 in color) and 28 drawings.

This attractive little book is a comprehensive, generously illustrated summary of what is interesting to know about coral reefs. The author is a young but experienced field researcher who not only knows the relevant literature but can also add personal observation and interpretation to his subject. No specialized knowledge (except some basic German reading ability) is necessary to follow the clear and concise text. Definitions, glossaries (including English terms), summaries and ample illustration make the book easy to use and keep the interest alive.

The introduction reminds the reader of the fascination he has always felt when reading or hearing about coral reefs. The subsequent chapters define reefs, indicate where they occur and show what they look like. The reef provinces of the Indo-Pacific and Atlantic regions are described separately and then compared in terms of reef abundance and diversity of corals and associated animals. Main reef types and their occurrence, structure and zonation are discussed. Then the book focuses from reef-building (limestone secreting) organisms, in general, to hermatypic coelenterates and stony corals, in particular, highlightling morphological and anatomical features, processes of reproduction, symbiosis' nutrition and calcification, and ecological requirements. A chapter on coral predators, eroders and competitors leads to discussion of reef origin, formation, growth and dynamics and culminates in the historical dispute over the origin of atolls and coral isles. Finally, the author explores environmental conditions and diversity and associations of organisms in the various reef zones and habitats, and behavioral patterns that develop in the reef community.

Emphasis of this book is on Indo-Pacific reefs because of their quantitative importance and the author's experience in the Red Sea. Important works on structure, zonation and communities of Atlantic reefs are unfortunately neglected, thus making the volume less useful for readers heading for this part of the undersea world. There are no literature citations in the text. A section on suggested further reading in the back of the book contains several poor choices and omits many important references. Highly specialized monographs and articles should also be arranged separately from college textbooks and popular accounts. A certain scantiness of text on reef associated organisms is off-set by the wealth of well chosen illustrations, particularly the top quality color photographs. The drawings are neat and could have been increased in number to replace some of the poorer black and white photographs. All figure captions are informative, include common as well as scientific names of organisms and reflect the scientific competence of the author.

As a whole Schuhmacher's Korallenriffe is superior to anything in its genre, and translation into English, at least, can be recommended with confidence. It is a handy vademecum for the sport diver and nature lover, as well as a stimulant and refresher for the student and naturalist.

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LES ASCIDIES DE POLYNESIE FRANCAISE. THE ASCIDIANS OF FRENCH POLYNESIA. C. Monniot and F. Monniot. Memoirs du Muséum National D'Histoire Naturelle-Zoologie. Toma 136 (Volume 136). 200 FF

This is the first taxonomic paper published on ascidians from this area and it is quite understandable that the dynamic husband and wife team of Claude and Francoise Monniot, who have collected and studied ascidians from most areas of the world, would be the first to study ascidians from Polynesia. This work is in French with English and French summaries.

The majority of the specimens were collected from the islands of Tahiti, Moorea and Tikehau, plus a few from Tupai, Mataiva, Rangiroa and Hao. Following an introduction of the growth relationships of ascidians in that particular area, a description is given of the three islands that served as major collecting sites (Moorea, Tahiti and Tikehau); the collecting depths, temperatures, and associated animals are discussed, followed by a brief discussion on techniques used. Next, the authors give a very detailed diagnosis of the 92 species of ascidians that were found in Polynesia, 39 of which are new. Twenty-seven of the new species belong to the family Didemnidae. Each new species is illustrated showing abdomen, gonad and thorax. There are scanning electron microscope plates of spicules and illustrations of parts of colonies of the new species of Didemnidae and others provided in the back of the text. There was one S.E.M. plate that I would like to have seen included, that of Didemnum digestum Sluiter, 1909. The Monniots compared the spicules of a new species, Didemnum uturoa to the spicules of Didemnum digestum. The authors provided a plate of the new species and it would have been helpful to have an S.E.M. spicule plate of the previously described species adjacent to the plates of the new species for comparison, even though the comparison is made in the text. The 39 species diagnosed include specimens from the families Didemnidae, Polycitoridae, Polyclinidae, Cionidae, Perophoridae, Corellidae, Ascidiidae, Styelidae, Pyuridae, and Molgulidae. The families Cionidae and Molgulidae are reported for the first time in this area with one new species described for each family. The other new species that were described were from the families Polycitoridae, Perophoridae, Ascidiidae, Styelidae, Pyuridae, and Polyclinidae.

The authors discuss the distribution of ascidians in the four different types of biotopes. The four types of biotope include the external slope, barrier reef, the zone of patch reefs, and deep lagoon. The barrier reef is the most productive, at least in Moorea, because of the constant nutrient supply from wave bursts and the proliferation of algae. In the external slope the waves are very strong and this zone has suffered many tornados, and few species can survive the turbulence. Those that are found on the external slope live under coral and in the crevices, protected from the turbulence. In the patch reef, where there is no wave surge, ascidians are found a few meters from the surface and not much deeper. The deep lagoon has a cloudiness of sediment with sediment deposits on the corals and only a small number of the species were reported.

There is a discussion on the proportions of colonial and solitary ascidians, the percentage being 84% colonial to 16% solitary, which has been found to be typical of the tropical Pacific Ocean. Colonial forms also dominate in the Atlantic but not by such a large margin. Longevity, primarily through budding, is most likely the reason for this difference. Finally the authors discuss the numerous new species of Didemnidae and their dominance over other families and the possible reasons for this dominance. They note seven reasons for this but listed two different reasons under number five as one reason, so there are actually eight reasons detailed that play a key factor in Didemnidae dominance:

1. Spicules. The authors' discussion is contradictory because they list the spicules as a reason for Didemnidae dominance and then mention that it has not been proven that having spicules is an advantage to this family.
2. The surface of the oral siphon in relation to the volume of the colony (very large openings) assuring entrance of nutrients.
3. Branchial volume compared to cells of other tissues. The authors discuss the fact that the Didemnidae have, among the Aplousobranchia, the largest relationship of volune branchie/volume viscera, another assurance of large amounts of nutrients.
4. Small height or stature of individual adults. There is a discussion of the capacity of zooids to reproduce sexually at a much quicker rate when they are producing small individuals and using less energy than it would take to produce larger individuals.
5. Mode of incubation of the larvae.
6. Mode of budding. It is advantageous for the Didemnidae to reproduce by budding from the esophagus and the abdomen simultaneously.
7. Mobility of the colonies - Occupation of the substrates. Mode of budding of Didemnidae assures longevity on a particular substrate and contributes to extension of the colony.
8. Algal symbionts. The presence of algae satisfies the need for photosynthesis where sunlight is lacking.

This volume can be recommended for beginners as well as established ascidiologists. It would be an asset to any invertebrate library.

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ATOLL RESEARCH BULLETIN

Henderson Island Issue

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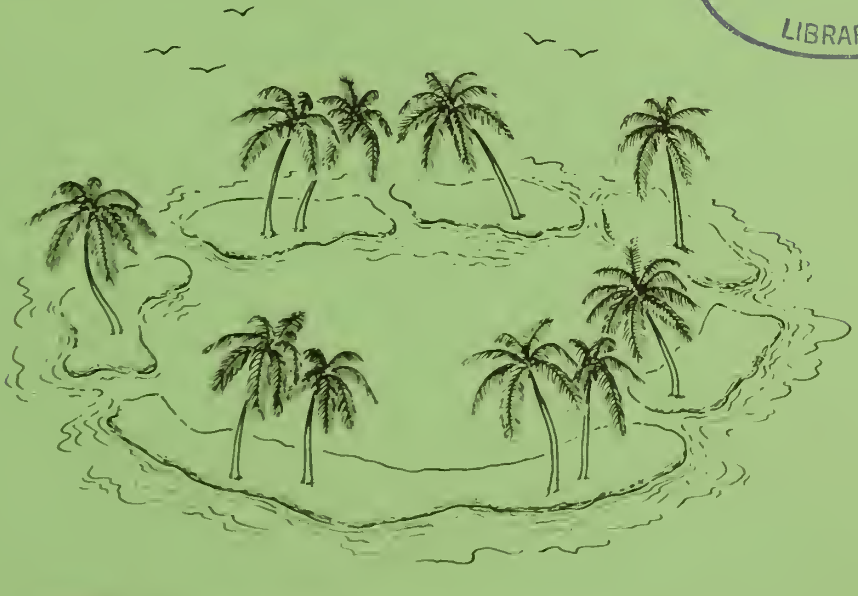

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ATOLL RESEARCH BULLETIN

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Articles submitted for publication in the Atoll Research Bulletin should be original papers in a format similar to that found in recent issues of the Bulletin. First drafts of manuscripts should be typewritten double spaced. After the manuscript has been reviewed and accepted, the author will be provided with a page format with which to prepare a single-spaced camera-ready copy of the manuscript.

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October 1989

S. Dillon Ripley
March 1980

HENDERSON ISLAND

DEDICATION TO S. DILLON RIPLEY

We are happy to dedicate this issue, presenting the first scientific results of the Smithsonian 1987 Expedition to Henderson and Neighboring Islands, to S. Dillon Ripley. He is the author of a classic monograph on the rail family of birds and was particularly interested in an endemic flightless rail from Henderson and its island home. He has heartily supported our efforts to promote this expedition, and was instrumental in bringing it about. We only regret that he could not participate in it and study this pristine bird habitat.

Born in 1913, in New York City, Dr. Ripley has had a memorable career in science, especially ornithology, and in public life. His long series of scientific positions, expeditions, and major publications have been detailed elsewhere and are well known. His scientific stature as the world authority on the birds of South Asia and the Himalayas, and on several families of birds, is recognized world-wide. His crowning achievement has been, as its eighth Secretary, to guide the Smithsonian Institution to its present stature as the world's greatest, most widely known and respected, repository, promoter, and dispenser of human knowledge. His two decades at the helm of this Institution have seen unparalleled growth, increase in scope and effectiveness, and brightening of its public image. At present, in retirement, he continues to advise the Institution, and to carry on his scientific work. He will long be known and remembered as one of America's great scientific figures. May he have many more productive and satisfying years.

Results of the 1984 Smithsonian Henderson Island Expedition

Henderson island is a small elevated coral island in the south central Pacific Ocean, just south of the Tropic of Capricorn, longitude 128°20' W, latitude 24°20' S. It is one of a scattered group of four islands east of, or forming an eastern extension of, the vast Tuamotu Archipelago. They are, west to east, Oeno Atoll, Pitcairn Island, Henderson Island, and Ducie Atoll. They are among the most remote of all islands from continental land masses and remote, even, from groups of high islands, except for nearby Mangareva, the nearest being the Austral, Society and Marquesas groups. There is no suggestion that there has ever been any connection between them or with any other land. Only Pitcairn has had any human inhabitants in historic time. Archeologic traces of earlier temporary occupation by Polynesians have been found on Henderson. Lack of fresh water would have made lengthy habitation difficult or unlikely.

Previous exploration, and available natural history information, known to the authors up to 1983 was summarized by Fosberg, Sachet and Stoddart, Atoll Research Bulletin no. 272, 1983. Since then, a party of amateur explorers was brought to Henderson by "Operation Raleigh" in 1986. They hacked a trail from the North Beach southward for some distance, perhaps to the south end. No scientific results from this visit have come to our attention. One exotic plant, Setaria verticilata, found at North Beach by the Smithsonian party may have been accidentally introduced by the Raleigh group. One native herbaceous species, Senecio stokesii, apparently with some pioneer or weedy tendencies, has spread along the cut trail, reported by the Smithsonian party. Coconuts were planted along this trail, either by the Raleigh party or by possible visitors from Pitcairn. Small groves of coconut palms are found at North Beach and Northwest Beach, planted earlier by the Pitcairners. Otherwise the island appears to be in relatively undisturbed condition.

In the early 1980's an American millionaire proposed to build a home on Henderson and bulldoze the vegetation to make a cattle ranch. He had ample means to do this and was willing to pay for the privilege. A small group of scientists interested in island ecology and related disciplines, waged a campaign, ultimately successful, to prevent this destruction of one of the very few remaining pristine island ecosystems.

These, and associated scientists concerned with oceanic islands, then felt that, in the face of such threats, an "across the board" investigation of this uninhabited elevated coral-limestone island was a matter of highest priority. In order to protect it, we must know and understand the island in order to be able to demonstrate its uniqueness and scientific importance.

Plans for a lengthy, one to two months or more, visit were frustrated by lack of funds, budget cuts, as the expense involved would be major. This idea has not been given up, but meanwhile opportunities for a short, preliminary visit were sought. In 1987, through the interest and generosity of George and Ann Nichols, owners of R/V Rambler, a 100-foot three-masted staysail schooner, such an opportunity was offered and a small expedition of five scientists was able to spend nine days on Henderson and to have short visits to Pitcairn, Oeno, and Ducie, with stops also on Easter Island and the Marquesas.

The scientists included the leader, Wayne Mathis, Smithsonian entomologist; Thomas Spencer, then of Manchester University, now of Cambridge University, geomorphologist; Susan Schubel, of New York State Museum, avian paleontologist; Gary Graves, Smithsonian ornithologist; and Gustav Paulay, of University of Washington, zoologist and general naturalist. Prof. David R. Stoddart, then of Cambridge University, now of University of California, Berkeley, geographer and expert on islands extraordinary, was scheduled to participate, but delays in starting and conflicts with teaching duties made last-minute cancellation necessary.

From a base at Northwest Beach, the party was able to explore the north coast, the Northwest Beach area, and the northern third of the plateau and gain a reasonable view of the general geography, surficial geomorphology, vegetation, ornithology, fossil history, marine and insect fauna. Substantial collections of insects and other land invertebrates, marine invertebrates, vertebrate fossils, and land plant and bird specimens were collected.

The east, south and southwest coasts and the southern half of the plateau remain little-known, to even a reconnaissance extent. Much of the coast-line is of perpendicular or undercut limestone cliffs, and is very difficult and dangerous to work if the sea is at all rough. The east coast, exposed to the Southeast Trade Wind swells is especially difficult. Only a well-supported and well-equipped expedition with ample time will yield a thorough knowledge of Henderson Island. Visits at several seasons would be desireable, as the subtropical climate is surely seasonal.

Oeno and Ducie Atolls would also justify more time, though their terrestial biotas are meagre. This very fact might yield ecological insights obscured by the complexity of richer biotas and more complex environments.

The papers in this issue give valuable information from the results of the field observations. Critical study of material collected remains to be done, and other papers, in more specialized journals will appear in due course.

This expedition should be looked upon as a precursor to the planned comprehensive study mentioned above, with broader coverage and time available for study of ecological processes operating on this fascinating island.

Acknowledgments

Several people, especially the crew and owners of the R/V Rambler, provided direct assistance and greatly facilitated our work on the islands as well as on the ship. They include: George and Ann Nichols, the skipper and owners of the R/V Rambler, and their children Pierce and Dominica; Lawrence Schuster and his daughter Talilla; Buck Moravec; Jimmy and Cannan Hewson; and Margaret Wilmot. We note with sadness the passing of George Nichols, who suffered a heart attack while skiing this past spring. Marsha Sitnik and David Challinor helped immeasurably with finances, paper work, and the coordination of innumerable logistical matters. The Pitcairn Islanders extended gracious hospitality and complete access to their Island for the few days spent there. Their generosity will not be forgotten. Lastly we thank Mr. Terence D. O'Leary, then Governor of the Pitcairn Island Group, for permission to conduct the field work and to collect specimens.

F.R. Fosberg

ATOLL RESEARCH BULLETIN

NO. 322

TECTONIC AND ENVIRONMENTAL HISTORIES IN THE PITCAIRN GROUP, PALAEOGENE TO PRESENT: RECONSTRUCTIONS AND SPECULATIONS

BY

T. SPENCER

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October 1989

TECTONIC AND ENVIRONMENTAL HISTORIES IN THE PITCAIRN GROUP, PALAEOGENE TO PRESENT: RECONSTRUCTIONS AND SPECULATIONS

BY

T. SPENCER [1]

ABSTRACT

Interpretation of SEASAT geoid anomaly data and improved seafloor mapping of the south-central Pacific suggest a complex tectonic history for the islands of the Pitcairn group. While Oeno atoll formed at ~ 16m.y.BP at a 'hotspot' now south of the Easter microplate, subsequent progressive island development at Henderson (13m.y.), Ducie (8m.y.) and Crough seamount (4m.y.) resulted from the lateral leakage of magma from the Oeno lineation along an old fracture zone, itself originating during the Tertiary reorientation of the Pacific plate. At all four islands cessation of volcanism was followed by subsidence and the development of a carbonate cap. By comparison, Pitcairn has been the product of recent (<1m.y.) volcanic activity along an independent, subparallel hotspot lineation. Nevertheless, this activity has interacted with the older island chain by transforming Henderson Island, through the process of lithospheric flexure, into an uplifted atoll with ~ 30m of relief.

These tectonic processes have been accompanied by changes in sea level and oceanographic conditions. As the Holocene record shows, the deciphering of the sea level record at these islands is difficult; sea level change has been a response not only to glacio-eustatic processes but also to a range of isostatic, and possibly geoidal, effects. Although the Pitcairn group at ~24°S occupies a marginal position for reef growth and development, reconstructions of palaeoceanographic conditions for the Tertiary and Quaternary suggest that the tropical water masses were largely unaffected by either changes in ocean circulation systems or climatic cooling and that water temperatures in the past have been very similar to those experienced at the present time.

INTRODUCTION

Until recently the tectonic and environmental history of the south-central Pacific has been poorly understood. Previous reconstructions of ocean basin and island histories have had to rely upon the relative paucity of information supplied fron infrequent and low density bathymetric traverses of research vessels. However, within the last decade the application of new remote-sensing technologies, improved mapping of the sea floor and the transfer of deep-drilling techniques refined in more accessible oceans has vastly expanded the volume of information available from even the remotest parts of the south Pacific.

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Thus, for example, critical phases in the geological history of the oceanic lithosphere in this region took place in the early Miocene, a time period for which sea-floor magnetic anomalies are few and broadly separated in age, yielding more conjectural estimates for sea-floor spreading rates than at subsequent time periods. However, following the operation of the altimeter satellites GEOS-3 and more particularly SEASAT, variation in the height of the sea surface - the marine geoid - is now known throught the south Pacific (e.g. Sandwell 1984) to a height of accuracy of 10-30 cm and a horizontal resolution of 10-50 km. Geoidal signals have a high level of correlation with sea-floor topography and have thus been used to discover previously undetected bathymetric features (e.g. Sabers et al. 1988), precise seamount geometry then being determined by multi-beam sonar mapping (e.g. Pontaise et al. 1986).

As the following syntheses demonstrates, degree of detail of this kind has revolutionised the level of explanation of regional geodynamics and environmental change in the south-central Pacific. As a result, some preliminary reconstructions of tectonic and environmental histories for the Pitcairn group can be attempted.

PLATE-TECTONIC EVOLUTION OF THE SOUTH-CENTRAL PACIFIC

TERTIARY RE-ORIENTATION OF THE PACIFIC PLATE.

At the beginning of the Palaeogene (65 million years B.P.) the prototypes for all the major oceans were already in existence. The Pacific was a multi-plate ocean, separated by subduction zone margins from the Asian and, in all probability, the Australian plate and bounded to the east by a complex series of mid-ocean ridges and triple junctions from the Farallon, Kula and Phoenix plates (Williams 1986; Figure 1). Although the Pacific Ocean was gradually reduced in size during the Palaeogene, with rates of subduction exceeding those of seafloor spreading, the Pacific plate itself increased in size at the expense of the plates on its western margin. The re-orientation of the plate, from a NNW to WNW spreading direction at ~42 million years B.P., preserved in the hot-spot traces of intra-plate islands and seamounts, most notably by the 'bend' in the Hawaiian Islands - Emperor Seamounts chain, is well known. Of equal significance in the South Pacific, however, was the collision of the Pacific-Kula-Farallon boundary with the Farallon-Americas trench at ~26 million years B.P. This event stopped all seafloor spreading and subduction in this region and initiated direct coupling between the Pacific and Americas plate. This fusion created a major, progressive re-orientation of seafloor spreading patterns and plate geometries as follows: i) ~20 million years B.P.: clockwise rotation of the southern portion of the Pacific-Farallon ridge and the development of the Galapagos rift; ii) ~10 million years B.P.: break-up of ridge south of Baja California and ridge 'jumps' and iii) ~5 million years B.P.: development, from the north, of the Gorda-Juan de Fuca-San Andreas-Gulf of California spreading system with eastward ridge jump below Baja California and westward shift of the Galapagos triple junction (Herron 1972, Herron and Tucholke 1976, Handschumacher 1975).

These adjustments were echoed in progressive plate re-orientations between 15-30^0 which have been fully documented by Okal and Cazenave (1985) using a full SEASAT dataset. At 40 million years B.P., spreading was taking place along the Mendoza and Roggeveen ridges (terminology : Mammerickx et al. 1980), offset 500 km by the transform fault of the Austral Fracture Zone (Figure 2a). Between 36 and 25 million years B.P. the Mendoza ridge propagated south, causing ridge re-orientation and the development of two fracture zones : FZ1, a re-orientation and re-located version of the Austral Fracture Zone and FZ2, dividing the northern and southern sections of the Roggeveen ridge (Figure 2b); Okal and

Cazenave 1985, Sailor and Okal 1983, Okal and Bergeal 1983). Both these fracture zones are orientated N95°E, intermediate between the strike of the ancient Farallon ridge (N70°E) and the orientation of spreading of the present East Pacific rise (N110°E), are 400-500 km in length and may be associated with comtemporary seismic activity (Figure 3; Okal and Cazenave 1985, Okal et al. 1980).

The southern Roggeveen and the Mendoza ridges subsequently 'jumped' westwards at 20 and 18 million years B.P. respectively, completing the re-alignment of the Pacific plate boundary with a straightening of the spreading system, and perhaps providing the western boundaries of the present Easter micro-plate (Figure 2c) - f); Hey et al. 1985).

STRUCTURAL TRENDS AND ISLAND AGES : SOUTHERN TUAMOTU ARCHIPELAGO AND PITCAIRN ISLAND.

The islands of the Pitcairn Group- Ducie and Oeno atolls, Henderson Island and Pitcairn Island itself - lie between 23.9°S - 24.7°S and 124.7°W - 130.7°W. The islands are both widely spaced and isolated from their nearest neighbouring groups : Ducie atoll is 1000 km west of the Easter micro-plate; Oeno atoll is 450 km east of the Minerve reefs and the Gambier Islands (Figure 3). Henderson Island rises from water depths of ~3,500 m; similarly, Pitcairn Island has been constructed from a sea floor at least 2,000 m and perhaps 3,500 m below the ocean surface. By comparision, Oeno atoll appears to rise from the southern side of a broad plateau at 1,600 m and Ducie atoll is probably not a simple feature (Mammerickx et al. 1975) but the surface expression of a complex collection of seamounts (Canadian Hydrographic Service 1982). Further to the east, clearly present in the SEASAT geoid but omitted from bathymetric charts, is a major structure topped by two seamounts reaching 1,000 m below present sea level at 25°S, 122.2°W and 24.8°S, 121.7°W; Okal (1984) has proposed that this feature be known as Crough Seamount. Geoidal signatures have revealed further seamounts around 25.6°S, 121.2°W and 26.2°S, 121.8°W (Okal and Cazenave 1985). Finally, the presence of several small seamounts near the East Pacific Rise is indicated by a cluster of geoidal anomalies. The regional synthesis of these recently-discovered submerged features indicates a much more complex and extensive island group lineation than has been apparent up to now from the disposition of islands above sea level. The alignment and spacing of the islands is strongly suggestive of an origin related to a relatively-fixed melting anomaly, or 'hotspot', to the east of the islands and seamounts.

Island chain hotspot traces should show a progressive increase in island age away from the hotspot itself in the direction of plate motion. However, given island morphologies in the Pitcairn Group, the only established dates for island genesis are from Pitcairn Island where potassium-argon dating of exposed volcanics has identified two phases of volcanism, at 0.46-0.63 and 0.76-0.93 million years B.P. The latter period probably represents the main phase of island construction (Duncan et al. 1974). Basaltic lavas which form the islands of Mangareva, Aukena and Makapu, Gambier Islands, cooled between 5.2 and 7.2 million years B.P. (Brousse et al. 1972) and recovered basalts from Fangataufa atoll and Mururoa atoll have been dated to 7.1-9.1 million years B.P. and 6.5 and 8.4 million years respectively (Brousse 1985), Duncan and Claque 1985). Volcanic migration rates have been calculated at 12.7 ± 15.5 cm yr^{-1} (Duncan and Claque 1985) for the Pitcairn-Gambier sequence and at 10.7-11.0 cm yr^{-1} (Brousse 1985) when extended to Mururoa atoll. These propagation rates are comparable to the values calculated for other S.

Pacific island chains (e.g. Austral-Cook Islands: 10.7 ± 1.6 cm yr^{-1}; Marquesas: 10.4 ± 1.8; Society Islands: 10.9 ± 1.0; Duncan and Claque 1985).

Unfortunately, however, Pitcairn Island's evolution throws little light on the origins of the other islands of the Pitcairn Group. Although almost certainly underlain by volcanics, none of the carbonate caps of Ducie, Oeno or Henderson have been deep-drilled to reach basement basalts. In the absence of such direct data, current reconstruction must be based upon the interpretation of the marine geoid.

SEASAT DATA AND ISLAND ORIGINS : OENO, HENDERSON, DUCIE AND CROUGH

Methodological comment

Fundamental to the concept of plate tectonics is the notion of a strong, rigid lithosphere overlying a weak, fluid asthenosphere. Lithospheric rigidity can be determined by studying the response of oceanic lithosphere to surface loads. By comparing calculated profiles of flexure, computed from known or assumed load shapes, with observed bathymetry, patterns of island uplift and subsidence, seismic refraction results and gravity and/or geoid anomlies, it appears that the most useful first-order model of oceanic plate behaviour is that in which the lithosphere is modelled as a thin elastic plate overlying weak substratum (e.g. McNutt and Menard 1978, Watts 1978). As oceanic lithosphere cools with age (e.g. Parsons and Sclater 1977) it thickens and becomes less responsive to surface loads. Not surprisingly, therefore, summaries of flexure studies (Figure 4) show that the elastic thickness of the lithosphere, T_e, increases with the age of the plate at the time of loading, estimated by subtracting the age of the load from the age of the seafloor (Watts et al. 1980, Watts and Ribe 1984). thus, for example, seamounts formed on young lithospheres are associated with low values of T_e (e.g. 5 km elastic thickness of age = 5 million years) whereas islands produced on old lithosphere are characterised by high values of T_e (e.g. 25 km elastic thickness of age = 80 million years). These differences are preserved through time and thus indicate whether islands were formed either at mid-ocean spreading ridges on thin oceanic plate or at mid-plate locations on much thicker lithosphere. This distinction is reflected in geoidal signature: on-ridge genesis is indicated by small amplitude (0.4-0.5m per km seamount height), short-wavelength geoidal anomalies whereas off-ridge origin is shown by large amplitude (1.4-1.5 m/km), large-wavelength perturbations (Watts and Ribe 1984; Figure 5).

Geodynamics and island ages in the Pitcairn Group

SEASAT geoid anomaly data in the south-central Pacific shows that the broad plateau of the Tuamotu Archipelago has no strong geoidal signature; furthermore, thick (27 km) oceanic lithosphere has been reported beneath the island of Rangiroa (Talandier, in Okal and Cazenave 1985). Both these lines of evidence suggest an on-ridge origin for the plateau and its islands. In the southern Tuamotus, the atolls of Tatakato, Pukaruha and probable Reao conform to this explanation and Okal and Cazenave (1985) have suggested that these islands formed at a hotspot near to, and then on, the junction of the Austral Fracture Zone and the Mendoza mid-ocean ridge (Figure 2a). It seems likely that the meeting of the hotspot and the Austral Facture Zone triggered the southerly propogation of the Mendoza ridge (see above) and the subsequent deactivation of the Austral Fracture Zone and concomitant initiation of the FZ1 fracture zone (Figure 2b). When the spreading system jumped westwards, the hotspot became an off-ridge melting anomaly on the Farallon plate, generating the seamount sequence on the Sal-y-Gomez ridge (Figure 2c) -f) and see Duncan and Hargraves 1984, Schilling et al. 1985). By comparison, the more southerly Tuamotu atolls, from Hao south-east to the Acteon group and Marutea, show strong geoidal signals, indicating that they must have formed off-ridge. Importantly, SEASAT date for Oeno, Ducie and Crough seamount also suggest an off-ridge origin. Unfortunately, no comparable data is available for Henderson Island but given its location it seems reasonable to assume an off-ridge origin for Henderson as well. The extension of the Hao-Marutea trace passes through the location of Oeno and predicts the present position of the hotspot to be ~300 km south of the south-western boundary of the Easter micro-plate (Figure 3). Henderson Island, Ducie and Crough seamount, however, do not fall on this alignment but form a linear chain at a 15° angle to it (Figure 3). Okal and Cazenave (1985) have suggested that this deviation has resulted from the interaction of the hotspot with the line of lithosperic weakness represented by the old fracture zone FZ2, with, following the theory of Morgan (1978), lateral leakage from the hotspot leading to the successive construction of Henderson, Ducie and Crough.

If such speculations on island origins are correct, then what ages can be assigned to the islands within the Pitcairn group, aside from Pitcairn Island itself? Okal and Cazenave (1985) give ocean floor age estimates of 10 million years for Crough Seamount, 14 million years for Ducie, 19 million years for Henderson and 27 million years for Oeno. In the vicinity of Pitcairn Island, Duncan et al. (1974) have suggested that the plate has an age of 30 million years. Using the methodology of Cazenave and Dominh (1984), where the comparison of observed and theoretical geoid heights is used to define a best fit of lithospheric flexural rigidity (D) and effective elastic thickness (T_e), Okal and Cazenave (1985) have calculated the age of the plate at the time of loading, or flexural age, as 5-7 million years. This would suggest the following island ages (±1 million years):- Crough Seamount : 4 million years; Ducie : 8 million years; Henderson : 13 million years; and Oeno : 16 million years. These dates, however, can only be seen as first approximations as the flexural age is not a true measure of the age of the plate at time of loading because of the likelihood of plate re-heating at the time of island emplacement (for theory : Detrick and Crough 1978, McNutt 1984). Interestingly, in the Central Pacific a range of geophysical anomalies indicate low elastic thickness over the region between - 10°S to -30°S and from 120° to - 160°W (Cochran 1986, McNutt and Fischer 1986, Calmant and Cazenave 1987). McNutt and Menard (1982) and Calmant and Cazenave (1986) have interpreted these low thicknesses as indicative of thermal rejuvenation.

Cessation of volcanic activity and island subsidence subsequently led to the development of carbonate caps, of unknown thickness, on the islands of Oeno, Henderson and Ducie (and Crough?). With the later, and independent, development of the Duke of Gloucester Islands - Pitcairn Island hotspot lineation, Henderson was affected by lithospheric flexure processes. On the relatively thin and deformable lithosphere of the South Pacific, the emplacement of relatively young (<2 million years) volcanoes, as a result of 'hotspot' activity, has produced a near-volcano moat and a peripheral bulge, or arch, at some distance from each load. The coincidence of sea-level coral reefs with this radius has resulted in the formation of raised reef islands (McNutt and Menard 1978). Flexural moats have been defined around some mid-plate volcanoes (e.g. Hawaii: Ten Brink and Watts 1985, Watts et al. 1985; Marquesas: Fischer et al. 1986) and reef limestone uplift, apparently associated with flexure, demonstrated from the Society Islands (Pirazzoli 1983), the N.W. Tuamotu Archipelago (Lambeck 1981a, Pirazzoli and Montaggioni 1985) and the southern Cook Islands (Lambeck 1981b, Stoddart et al. 1985, Spencer et al. 1987, Calmant and Cazenave 1986). In the Pitcairn group lithospheric flexure under the weight of the Pitcairn Island has resulted in - 30 m of uplift at Henderson. The raised reef topography of

Henderson, and estimates of the rate of flexure-controlled uplift, are considered in more detail by Spencer and Paulay (this volume).

In summary, therefore, the final patterning of the islands of the Pitcairn group appear to have been derived from three different tectonic settings: old hotspot (Oeno); leakage from old hotspot (Henderson-Crough); and young hotspot (Pitcairn Island), with further tectonic activity at Henderson. Thereafter, the development of island morphologies within the group has been a reaction to mid-latitude environmental change; this is considered in more detail below.

Geodynamics and island age: complications and speculations

Although the scenario outlined in some detail above is an attractive one, recent SEASAT studies in the area to the south-west of the Cook-Austral Islands archipelago have revealed, inportantly, the presence of further fracture/fault zones with the same alignment (N95°E) as FZ1 and FZ2 but extending linearly over much greater distances than Okal and Cazenave's (1985) fractures, in excess of 1000 km (Diament and Baudry 1987). Rather than regarding such lineations as the short-lived (~8million years; Okal and Cazenave 1985) product of mid-ocean ridge re-orientation, it has been suggested that these features indicate far more fundamental intra-plate deformations, being either the result of differential movement between the northern and southern sections of the Pacific plate or the consequence of changes in the absolute motion of the plate as a whole (Diament and Baudry 1987).

Such ideas have resurrected the notion of a south Pacific 'hotline', linking melting anomlies from the Tonga trench to the Nazca plate (Bonatti and Harrison 1976, Bonatti et al. 1976, Turner and Jarrard 1982). This hypothesis has found support from the detection of gravity undulations, of 150-200 km wavelength and trending WNW in the direction of plate motion, between the East Pacific Rise and French Polynesia by Haxby and Weissel (1986). They suggest that such features result from small-scale thermal instabilities beneath young lithosphere being organised into longitudinal rolls by the shear from fast-moving plates. Interestingly, such patterns are predicted by some convection models (e.g. Richter 1973). SEASAT altimeter data further suggests that such small-scale convection develops within 5 to 10 million years of the initiation of plate cooling (Haxby and Weissel 1986); thereafter this pattern is 'frozen in' to the lithosphere (Buck 1985, Buck and Parmentier 1986).

Finally, however, it should be noted that two further models have been proprosed to explain these undulations: compressive buckling (McAdoo and Sandwell 1985) and tensional cracking (Winterer and Sandwell 1987) of the lithosphere. Clearly, careful bathymetric work will be required to discriminate between these different explanations before a more conprehensive 'hot-line' hypothesis can be formulated.

ENVIRONMENTAL HISTORY OF THE SOUTH-CENTRAL PACIFIC

The growing inventory of high-quality deep-sea cores from the Deep Sea Drilling Project (DSDP) and the determination of fine resolution down-core environmental records from core lithology, stable isotopes and microfloral and microfaunal assemblages now permits the reconstruction of palaeoclimatic and palaeoceanographic conditions, for precise time slices, as far back as the beginning of the Palaeogene.

Clearly, however, such reconstructions are dependent upon the spatial coverage of deep-sea core sites. Unfortunately, the density of sites in the Pacific Ocean is poor by comparison with the Atlantic Ocean and biased towards the northern hemisphere and the eastern equatorial region. Thus, only broad inferences can be made, as yet, as to former circulation patterns and sea surface palaeotemperatures in the south-central Pacific.

Methodological comment

A key tool in environmental reconstruction of ancient oceans is oxygen isotope stratigraphy. $^{18}O/^{16}O$ ratios in foraminifera from deep-sea sediments have been used as indicators of past climates since it was demonstrated in the 1950s that ^{18}O enrichment ($\delta^{18}O$) in foraminifera varies with ^{18}O in the water from which their carbonate skeletons have been precipitated but differs from the water value by an amount determined by temperature (e.g. Epstein 1953, Emiliani 1955; but see also Shackleton 1984 for problems of temperature calibration and potential effects of within-sediment diagenesis of skeletal calcite). However, the deep-sea palaeotemperature record is complicated by historical fluctuations in ocean isotopic composition. It is generally agreed that there have been changes in isotopic composition of the order of 1.0-1.6 (180 per mil to PDB standard) resulting from the repeated growth and decay of isotopically light ice sheets on the Northern Hemisphere continents (Shackleton 1967, 1984) but the interpretation of the Tertiary record has proved more problematical. One hypothesis (Matthews and Poore 1980) suggests that there have been no significant changes in low latitude sea surface temperatures in the Cenozoic and, therefore, that the fluctuations in the oxygen isotope record only reflect changes in global ice volumes. This hypothesis, however, challenges the widely-held view (e.g. Shackleton and Kennett 1975, Savin 1977, Woodruff et al. 1981) that Antarctica was essentially ice-free until the middle Miocene and, therefore, that the Palaeogene isotopic record is one of temperature change in the deep ocean. Recently more accurate oxygen isotope measurements (Shackleton 1986), whilst providing general support for this second model, have shown the interpretation to be too simplistic, and it now seems likely that ice was present in Antarctica in the early (Shackleton et al. 1984b), middle (Keigwin and Keller 1984) and latest (Miller and Fairbanks 1985) Oligocene. These arguments need to be borne in mind when interpreting the oxygen isotope record of the past 70 million years.

TERTIARY PALAEOGEOGRAPHY AND PALAEOCEANOGRAPHY

Shackleton's (1984) compilation of oxygen isotope data (Figure 6) shows that the early Cenozoic was characterised by high temperatures at both low- and mid-latitudes and thus relatively small equator-to-pole and surface-to-bottom temperature gradients. Dramatic cooling of both mid-latitude and deep-ocean waters occurred at the Eocene-Oligocene boundary (Figure 6; Keigwin 1980) and there was a further divergence, of mid-latitude and deep-ocean water temperatures, in the middle Miocene (Savin et al. 1981, Shackleton and Kennett 1975, Woodruff et al. 1981). Evidence for increasingly vigorous atmospheric-oceanic circulation, at both 15-16 myr B.P. and 9-5 myr B.P., associated with climatic deterioration, is provided by the appearance of diatomites in Pacific rim sedimentary sequences (Ingle 1981), increasing biogenic silica accumlation (from 16 myr B.P., peak at 8 myr B.P.: Leinen 1097) and rising calcium carbonate supply rates (peaking 14-15 myr B.P.: Van Andel et al. 1975) in the equatorial Pacific. Changes towards large grain sizes in the particle-size distribution of aeolian dust from 11.8 myr B.P. imply a significant intensification of the southern hemisphere tradewinds (Rea and Bloomstine 1986); this mirrors the better-known North Pacific record (e.g. Rea and Janecek 1982, Rea et al. 1985).

It has been suggested that these events in the Pacific Ocean were indirectly driven by palaeogeographic changes, themselves the result of the re-arrangement of plate boundaries; thus an attractive scenario argues that the Oligocene development of the Circum-Antarctic Current, as Australia and, later, South America, became detached from Antarctica, progressively isolated the Antarctic from lower latitude influences and resulted in cooler, polar temperatures, increased presence of sea-ice, cooler bottom water temperatures and, ultimately, the development of a major continental ice sheet on East Antarctica (Kennett 1977, 1982). Allied to the establishment of this high-latitude, circum-global circulation was the modification and ultimate loss of the circum-equatorial Tethys seaway, firstly by the mid- to early late-Miocene closure of the Indo-Pacific passage in the Indonesian region as a result of the continued northward migration of Australia/New Guinea (Edwards 1975, Hamilton 1979), and secondly by the late Miocene constriction - Pliocene closure of the Atlantic-Pacific connection through the isthmus of Panama (Keigwin 1978).

These palaeogeographic changes both steepened pole-to-equator temperature gradients and altered the pattern of atmospheric and oceanic circulation towards their present arrangement. In the equatorial region these changes enhanced surface productivity of ocean waters by diverting large volumes of water into westerly boundary currents which were then returned as an intensified surface circulation and by the development of an equatorial undercurrent (Figure 7). As a result, east v. west Pacific biogeographic differences were reduced and replaced by a latitudinal provincialism (Kennett et al. 1985). However, and importantly, these changes took place around the largely unaffected subtropical gyres.

QUATERNARY ENVIRONMENTS: SEA LEVEL CHANGE IN THE PLEISTOCENE

The oxygen isotope record from deep-sea cores (Figure 8) indicates strong climatic fluctuations from ~ 3.2 myr B.P. (Shackleton and Opdyke 1977, Shackleton et al. 1984a). There have been 10 completed glacial-interglacial cycles in the last one million years, with 8 cycles, at approximately 100,000 yr intervals, since 0.73 myr B.P. (Shackleton and Opdyke 1973). Each cycle shows a characteristically 'saw-toothed' pattern of slow, progressive ice build-up and rapid de-glaciation (Broecker and Van Donk 1970; Figure 8).

The mass and melting history of contential ice sheets can also be derived from radiometrically-dated coral reef sequences preserved by uplift on tectonically active coasts. The difference between the altitude of a reef of known age and the present sea level provides a precise measure of the past sea level if the tectonic component can be estimated and substracted (e.g. Haiti: Dodge et al. 1983; Barbados: Matthews 1973). Using these principles, a particular fine record of sea level change has been constructed from the Huon Peninsula, New Guinea (Chappell 1974), Bloom et al. 1974, Chappell 1983) where coral reef terraces have been preserved along a rapidly rising (0.9-3.5 m kyr^{-1}) coastline. The sea-level curve from this locality has been recently refined, following comparison with the deep-sea core oxygen isotope record (Chappell and Shackleton 1986; Figure 9). The curve shows, for the last glacial-interglacial cycle fast rising sea levels (up to 8m kyr^{-1}) during the major post-glacial transgressions, culminating in interglacial high sea level stands between 118-138,000 yr B.P. (reef complex VII) and from 8,200 yr B.P. (reef I). The Last Interglacial sealevel on the Huon Peninsula (124,000 yr B.P.; reef VIIa) is assumed to have reached ~ 6.0 m above present sea level, as elsewhere around the globe (Moore 1982). Estimates for low sea levels prior to these transgressions, determined by maximum ice volumes, have been set at -130 m, less that the levels of -135 to -165 m suggested by evidence from northern Australia but in excess of the values of -90 to 110 m reported from the eastern seaboard and Gulf of Mexico coasts of the USA (Chappell and Shackleton 1986). Such differences are to be expected as they relate not only to the record of sea level change but also to the behaviour of the continental margins. Slower rising sea levels (up to 2.5 m kyr^{-1}) were recorded by Huon fringing reef development at 100,00 (reef VIa), 81,000 (Va), 59,000 (IVa), 45-40,000 (IIIa-IIIb) and 28,000 (II) yr B.P. (Figure 9). These reefs represent a series of high sea level interstadials falling progressively further below present sea level at -9±3m, -19±5m, -28±3m, -41±4m and -44±2m respectively (Figures 9, 10). Low sea levels between interstadials have proved difficult to define in the absence of dateable reef deposits but inference suggests a range of 37 to 55 m below present sea level (Aharon and Chappell 1986).

In the South Pacific, presumed Last Interglacial (i.e. reef complex VII) reef limestones reach 3.48 m above present sea level at Ngatangiia and 2.2 m at Nikao, Rarotonga, Southern Cook Islands, and have been attributed to glacio-eustatic fluctuations in sea level (Stoddart et al. 1985). At Makatea Island, NW Tuamotu Archipelago, cliff-veneering apron reefs, bounded at their upper margin by notch lines and caves 5-8 m above present sea level (Montaggoni et al. 1985) have been assigned to the time interval 100-140,000 yr B.P. on the basis of limited uranium-series age determinations (Veeh 1966). In the Southern Cook Islands, Last Interglacial reef limestones on Mangaia (101-135,000 yr B.P.: Veeh 1966, Spencer et al. 1987) reach 14.5 m above present sea level; raised reefs presumed to be contemporaneous with the Mangaian deposits attain heights of ~10 m or more on Atiu, Mauke and Mitiaro. Finally, at Henderson Island, presumed Last Interglacial reef units also reach ~10 m above present sea level (Spencer and Paulay, this volume). Apart from Rarotonga, all these reef limiestones exhibit upper altitudinal limits considerably above characterstic Last Interglacial elevations, they must, therefore, indicate an additional component of tectonic uplift superimposed upon the sea levels associated with glacio-eustatic sea level changes. For all these localities it has been argued that uplift has resulted from the up-arching of oceanic lithosphere under loading from neighbouring volcanoes of Pleistocene age (McNutt and Menard 1978, Lambeck 1981a, 1981b, Spencer and Paulay this volume). However, it is difficult to apply this explanation to Rurutu, Austral Islands, where Last Interglacial (188-126,00 yr B.P.) limestones reach 8-10 m above present sea level and mid-plate thermal rejuvenation, in association with mid-plate hotspots, may also have been involved (Pirazzoli and Veeh 1987).

In spite of these tectonic processes, uplift rates have not been sufficient at these mid-ocean settings to raise interstadial reefs above present sea level (see Figure 9). Thus at Henderson Island where the uplift rate over the last 125,000 years has been estimated at between 0.04 and 0.09 m/1000 yr (Spencer and Paulay, this volume), deposits equivalent to New Guinea reef complex VIa should be found at ~0 to -5 m; thus they may floor the contemporary reef flat and form the shallow terrace offshore. By extension, reef complexes Va and IVa should be found in water depths of ~ -11 to 16 m and -20 to -25 m respectively; they may, at least in part, from the second, deeper coral ledge at Henderson and the broad offshore shelves, with their shelf breaks at 25-30 m, seen at Ducie atoll.

QUATERNARY ENVIRONMENTS: PALAEOCLIMATOLOGY AND PALAEOCEANOGRAPHY

As well as adapted to relatively rapid fluctuations in sea level, Pleistocene coral reefs in the Pitcairn Group must also have been subjected to a varying climatic and oceanographic environment.

It is possible to successfully reconstruct palaeoceanographic conditions by the application of biological transfer function techniques, orignally devised by Imbrie and Kipp (1971), to micropalaeontological data. When mapped over the ocean floor, mathematically-defined micro-faunal assemblages from surface sediments show a close fit to water mass and current distributions. Thus changes in assemblages within cores indicates different oceanographic conditions. It is further possible to express assemblage information in terms of physical or ecological variables; in particular, equations which express sea surface temperature as a function of various assemblage have been derived using regression analysis. The down-core application of such transfer functions permits estimates of past temperatures to be made (e.g. CLIMAP Project Members 1976, 1984).

Reconstruction of sea surface temperatures for the Last Interglacial ocean suggests little change from present conditions: 60 per cent of the estimates from deep-sea cores differ from today's values by amounts less than the typical ±1.0 to 1.5°C standard error of estimate (CLIMAP Project Members 1984). However, within the southern hemisphere sub-tropical gyre palaeotemperature estimates from core V19-53 (17°S; 113°W) suggest a southern summer (February) mean sea surface temperature of 29.3°C and a souther winter (August) temperature of 27.°C, in each case 3.9°C warmer than the equivalent present sea surface temperature at that latitude (Table 1). Were such changes to have extended south they would have had important implications for the maintenance of reef growth at Henderson, Oeno and Ducie. However, not all the deep-sea core evidence suggests such changes in temperature (Table 1).

For the last glacial maximum, at 18,000 yr B.P., deep-sea core evidence suggests that the Southern Ocean as a whole was cooler by 2°C (CLIMAP Project Members 1976). Similar reconstruction from $^{18}0/^{16}0$ ratios in reef molluscs (Konishi et al. 1974, Fairbanks and Matthews 1978, Shackleton and Matthews 1977), allowing for global ice volume effects, have given comparable results. In particular, careful studies using specimens of the giant clam *Tridacna gigas* from the Huon terrace sequences by Aharon and Chappell (1986) have suggested a cooling of 2-3°C in surface ocean temperature from early (reef complexes VI-V) to late (IV-V) interstadials in the last glacial-interglacial cycle. However, as with the pre-Pleistocene and Last Interglacial record, little temperature change appears to have affected the mid-latitude gyre of the south-central Pacific (CLIMAP Project Members 1976), a pattern repeated for the Indian and S. Atlantic Oceans (Moore et al. 1981). In the north Pacific, ocean surface temperatures have been reconstructed as similar to those at present (Thompson 1981) or, for the vicinity of Hawaii, perhaps up to 2°C warmer (Rind and Peteet 1985). Rather than temperature change, the northern hemisphere glaciations led to further intensification of the atmospheric-oceanic circulation.

The south-east Trades are the driving force of surface currents in the eastern equatorial Pacific. Studies of quartz abundance distribution in core V19-29 (3°'S, 83°56'W) have suggested that the tradewinds were more intense during the glacial phases, in particular between 73-61 x 10^3 yr B.P. and 43-16 x 10^3 yr B.P. (Figure 11; Molina-Cruz 1977). Changing distributions of radiolarian assemblages in deep-sea core (Moore et al. 1981) indicate that the strengthing of the glacial trades was accompanied by a more meridional pattern of wind stress and an intensification of the equatorial surface circulation, with increased equatorial countercurrent and decreased equatorial undercurrent (Romine 1982). The eastern boundary flows showed greater westward penetration with Peru Current upwelling reaching its most westerly at the glacial maximum (Romine and Moore 1981).

Stoddart's (1973) calculation of the effect of glacial sea surface temperatures on the extent of the reef seas suggests a simple, latitudinal shift towards the equator of the area of the south Pacific able to support coral growth (Figure 12). However, from the more comprehensive deep-sea core coverage now available it is clear that the major glacial to inter-glacial changes in climatic and oceanographic conditions produced variations in the intensity of circulation not latitudinal migrations of the climatic belts (Figure 12). The expansion of the polar seas at high latitudes resulted in the compression of the areas occupied by the sub-polar and subtropical-transitional water masses and left the tropical water masses largely intact. Whilst the islands of the Pitcairn Group may have been subjected to a windier and perhaps stormier glacial climate, with greater contrasts between windward and leeward shores, it is unlikely that water temperatures were appreciably cooler or more inimical to coral growth than at the present time (Figure 12).

HOLOCENE SEA LEVEL CHANGE IN THE SOUTH-CENTRAL PACIFIC

The explanation of global Holocene sea level changes lies in the interaction between the volume, melting history and location of sources of meltwater from the decay of ice sheets and deformation of the earth's crust due to both the unloading of continental ice (glacio-isostasy) and the loading of the oceans by meltwater (hydro-isostasy) (Farrell and Clark 1976). Both these sets of controls have varied considerably in their magnitude at-a-point in time over the globe and at-a-point in space during the Holocene transgression, thus giving rise to a range of Holocene sea level curves not only between different oceanic areas (e.g. Peltier et al. 1978) but also between continental margins and oceanic islands (Walcott 1972) and within ocean basins (e.g. Nakiboglu et al. 1983, Lambeck and Nakada 1985).

There is widespread evidence through the south-central Pacific for a higher-than-present Holocene sea level of ~±1.0m between ~6,000 years B.P. and ~2,000 years B.P. (Figure 13). Field observations suggest that this event is represented on at least some of the islands of the Pitcairn Group.

At Ducie atoll, the lagoon shore of the largest *motu*, Acadia Island (Rehder and Randall 1975), is characterised by superficially cemented sheets and slabs of coral rubble, estimated to be 0.30-0.45 m above present mean sea level at the lagoon edge. The morphology of these deposits varies along the lagoon shore: at the eastern extremity of the island the deposits appear to represent lithified, coalescing washover fans (Plate 1) whereas on the central lagoon shore extensive areas of exfoliating sheets, comparable to the Holocene conglomerates described from French Polynesia by Montaggioni and Pirazzoli (1984) are characteristic (Plate 2). Towards the western end of the *motu* these sheets are replace by boulder streams of uncemented coral heads, separated by areas of coral stick gravel (Plate 3).

On the south-western margin of the main wooded island at Oeno atoll (Figure 14) a lower beachrock unit with locally abundant acroporids appears bevelled and overlain by an upper beachrock unit containing corals and *Tridacna* Plate 4). Massive beachrocks also locally overlie the bevelled beachrock and on the north-west coast appear to provide the basement for island sediments (Figure 14).

By comparison with the atolls, however, there is less evidence for a Holocene high stand on Henderson Island. The reasons for this are partly topographical: the presumed high stand deposits on Ducie and Oeno have accumulated, and subsequently been preserved, on lagoon shores whereas the inner reef environment on Henderson offers no such protection (and see Spencer and Paulay this volume). However, additional tectonic and tectonically-related factors must also be considered.

Attempts to model Holocene sea level change in the Pacific basin have been complicated by the presence of two unknowns: the melting histories of the Late Pleistocene ice sheets (and specifically the relative contributions of Arctic and Antartic ice) and the flow in the lower mantle, or mantle viscosity. In addition, local hydro-isostatic adjustments take place around islands (Nakada 1986) and on continental shelves (Chappell et al. 1982) because of the differential loading between island interiors and outer margins and inner and outer continental shelves respectively; fortunately, however, such effects are unimportant at scales of 10 km or less. Finally, however, the possible role of migratory geoidal highs in determining the sea level record, first postulated by Mörner (1976), also needs to be evaluated in reef environments (Nunn 1986).

The sea level record can in turn be masked by non-related tectonic processes. One such process is the subsidence of young volcanic islands; subsidence rates of 1-2 mm yr^{-1}, over 8,000 years, and 0.14-0.15 mm yr^{-1}, over 5,000 years, have been suggested for Oahu, Hawaiin Islands (Nakiboglu et al. 1983) and Moorea-Tahiti, Society Islands (Pirazzoli and Montaggioni 1985) respectively. Furthermore, Pirazzoli and Montaggioni (1985) have argued that regional variations in Holocene sea level curves between the Society Islands and the N.W. Tuamotu atolls (and perhaps within the Societies themselves (Pirazzoli 1983)) have resulted from lithospheric flexure around the Tahiti-Moorea volcanic load. Presumably such arguments might be used to differentiate sea level histories between flexure-affected Henderson on the one hand and Ducie and Oeno atolls on the other.

Taking these complications into account, and using constrained values for mantle viscosity and favoured melting models from the comparison of model sea level curves with observed records from N. Australia and New Zealand (Lambeck and Nakada 1985, Lambeck and Nakiboglu 1986), it is clear that the Pacific high stand at ~6,000 years B.P. was largely due to the control of mantle viscosity, with the potential contribution of Antartic ice controlling the 'peakedness' of the event (Lambeck and Nakada 1985, Nakada and Lambeck 19867). The model fit to observed values provides a useful first approximation, although high sea levels appear to have been sustained into a period when model predictions suggest a gradual fall in sea level (Figure 15). Clearly more detailed observations, with radio-carbon dating control, from the Pitcairn group would be useful in the refining of sea level models for this period.

CONCLUSIONS

This review has shown that while our knowledge of the genesis and evolution of the south-central Pacific, and of the Pitcairn group of islands within this region, has been considerably increased on the last decade, large gaps still remain in our understanding of volcanic island development and attendant coral reef construction.

While remarkable progress has been made through the use of remotely-sensed data many of the research questions which have been generated by these studies now require direct field-testing. This might be achieved by programmes of deep-drilling, to both ocean floor and island basements, and by more comprehensive geological and geomorphological surveys than have hitherto been achieved.

Although there have been noteable exceptions, mid-plate, mid-latitude locations have been relatively neglected in scientific terms by comparison with plate-marginal settings and both high and low latitude environments. However, a much greater knowledge of the processes active at intra-plate settings at intermediate latitudes will be required for forthcoming reconstructions of global tectonic and environmental histories and the predictions at and around remote islands such as those of the Pitcairn group are of significance, both to answer specific research hypotheses and in much broader contexts.

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Core	Location	SST_W (°C)[1]			SST_S(°C)[1]		
		5e[2]	Atlas[3]	Core Top[4]	5e[2]	Atlas[3]	Core Top[4]
V19-53 (Moore et al. 1980)	17°01'S 113°31'W	27.0 ±3.0	23.1	23.9	29.3 ± 1.5	25.4	28.3
V32-126 (Thompson 1981)	35°19'N 117°55'E	18.9 ±1.5	16.0	16.8	27.0 ±1.5	24.6	25.2
V21-146 (Moore et al. 1980)	37°41'N 163°02'E	17.3 ±2.4	14.5	13.5	24.8 ±1.8	24.0	22.0

[1] SST_W = winter sea surface temperature in February (N. Hemisphere) or August (S. Hemisphere).
SST_S = summer sea surface temperature in August (N. Hemisphere) or February (S. Hemisphere).

[2] Last Interglacial seasonal sea surface temperature (with standard error of estimate) from transfer functions applied to deep sea core.

[3] Modern SST from atlas values.

[4] Holocene SST from core top sediments

TABLE 1 SEA SURFACE TEMPERATURES IN SELECTED MID-LATITUDE DEEP-SEA CORES: ISOTOPIC STAGE 5e COMPARED TO MODERN ESTIMATES

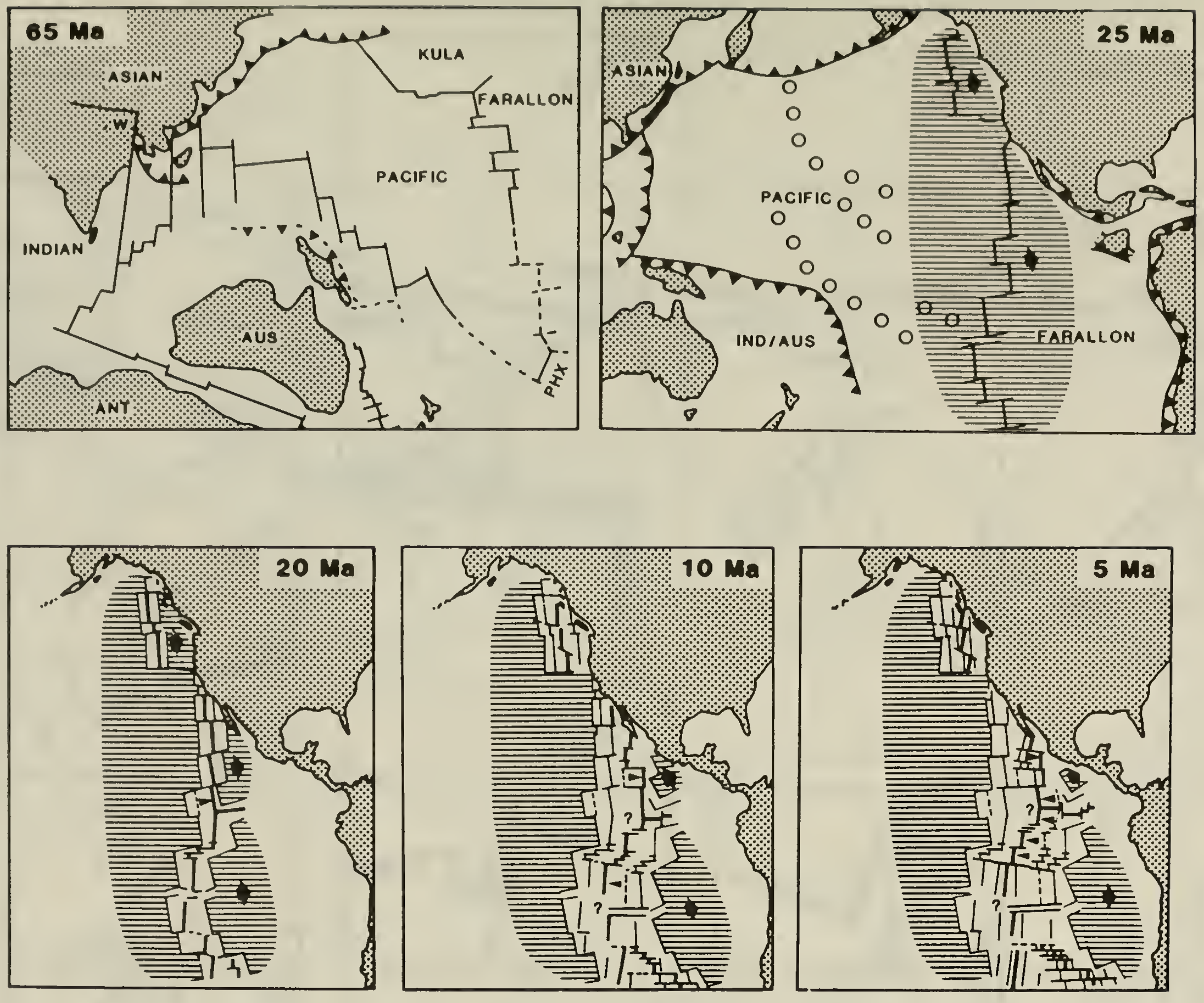


Figure 1. The Pacific at the beginning (65 million years B.P.) and end (25 million years B.P.) of the Palaeogene (after Williams 1986) and subsequent plate boundary reorganisation 20 to 50 million years B.P. (after Handschumacher 1975 and other sources). Open circles indicate island chains of volcanoes and seamounts.

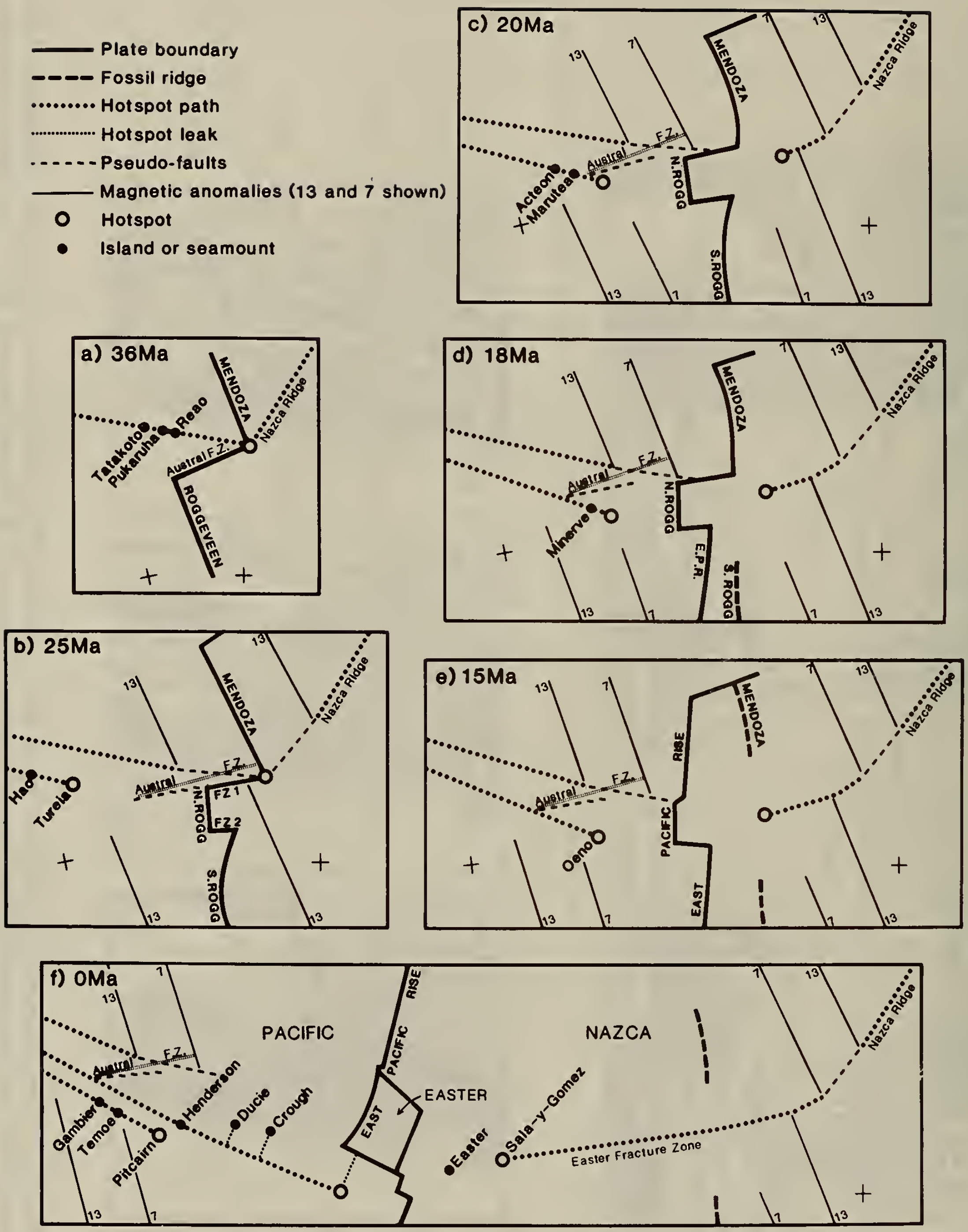


Figure 2. Plate tectonic evolution of the south-central Pacific 36 millions years B.P. to present (after Okal and Cazenave 1985). Island/Seamount names noted only on first time-frame appearance.

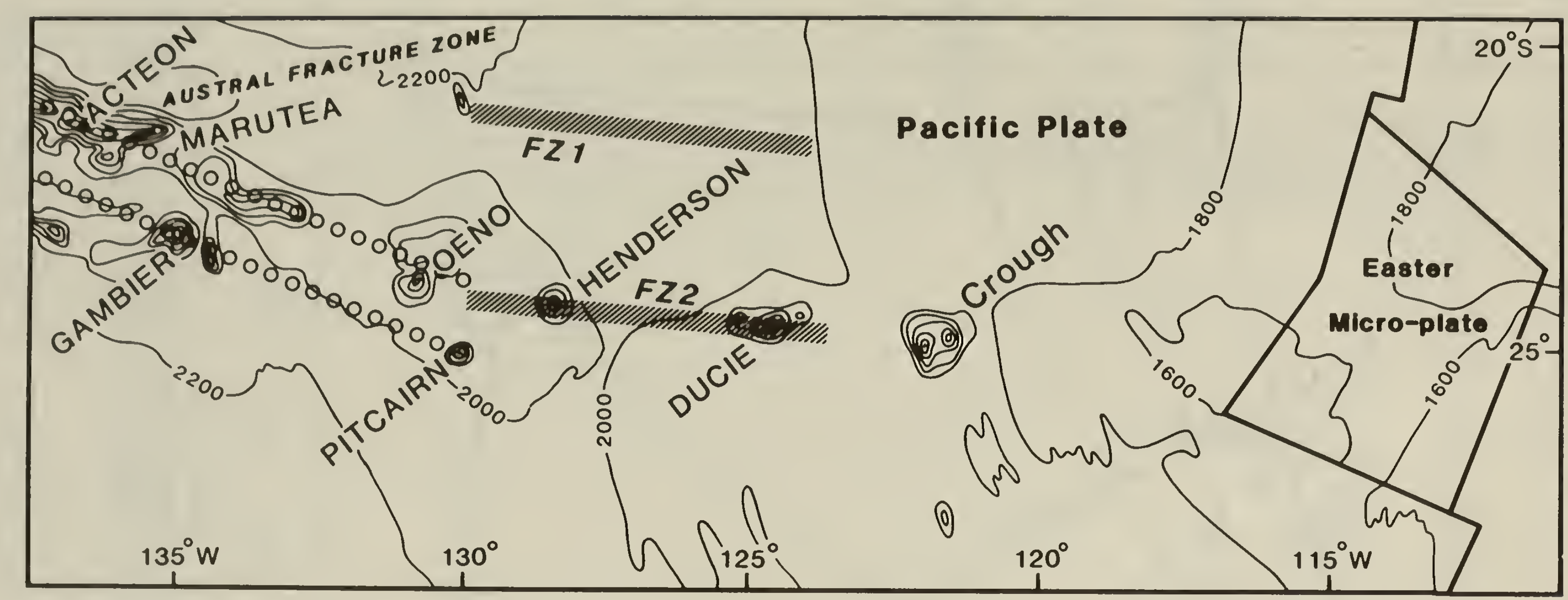


Figure 3. Regional bathymetry; and principal tectonic features and lineations (after Okal and Cazenave 1985).

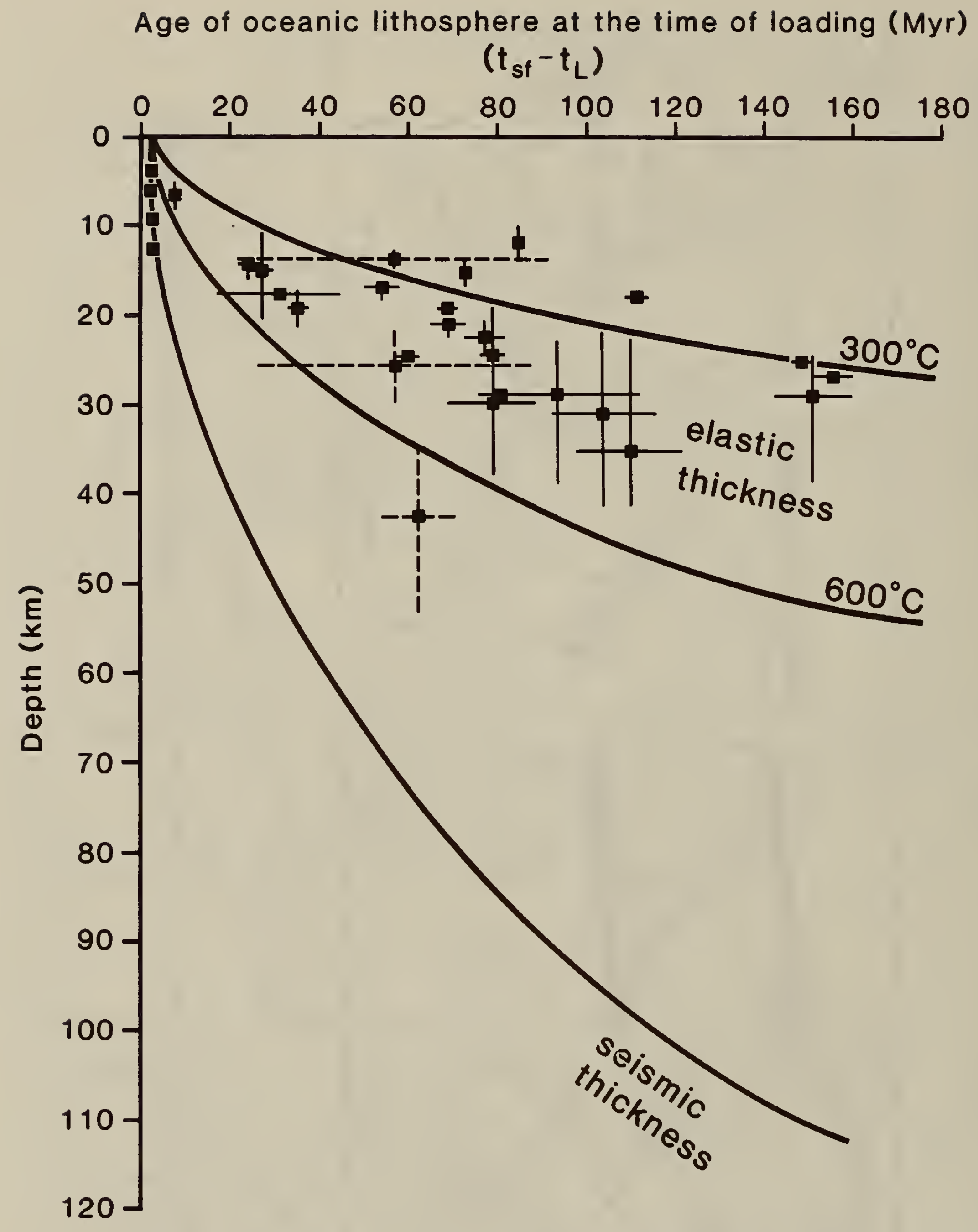


Figure 4. Elastic thickness of oceanic lithosphere, T_e, as a function of the age of lithosphere at time of loading t_{sf} = age of seafloor; t_L = age of load (after Watts and Ribe 1984). 300° and 600° isotherms from cooling plate model of Parsons and Sclater (1977).

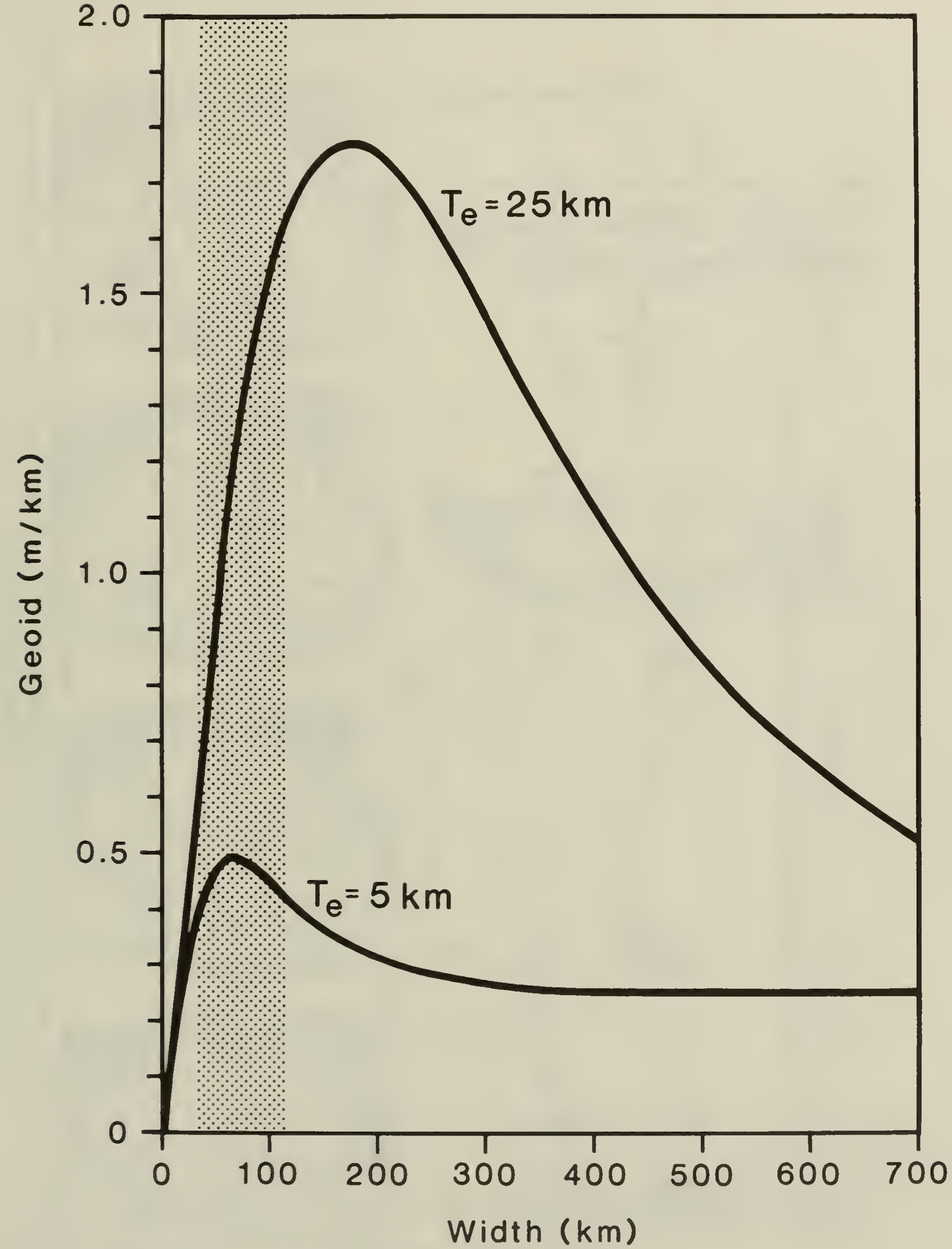


Figure 5. Maximum amplitude of geoid anomaly associated with two-dimensional seamount model. Upper curve for emplacement off-ridge (T_e = 25 km), lower curve for on-ridge origin (T_e = 5 km). Abscissa represents e^{-1} width of Gaussian seamount topography and vertical band indicates range of widths for typical oceanic seamount. Ordinate shows maximum geoid anomaly amplitude over feature 1 km high (after Watts and Ribe 1984).

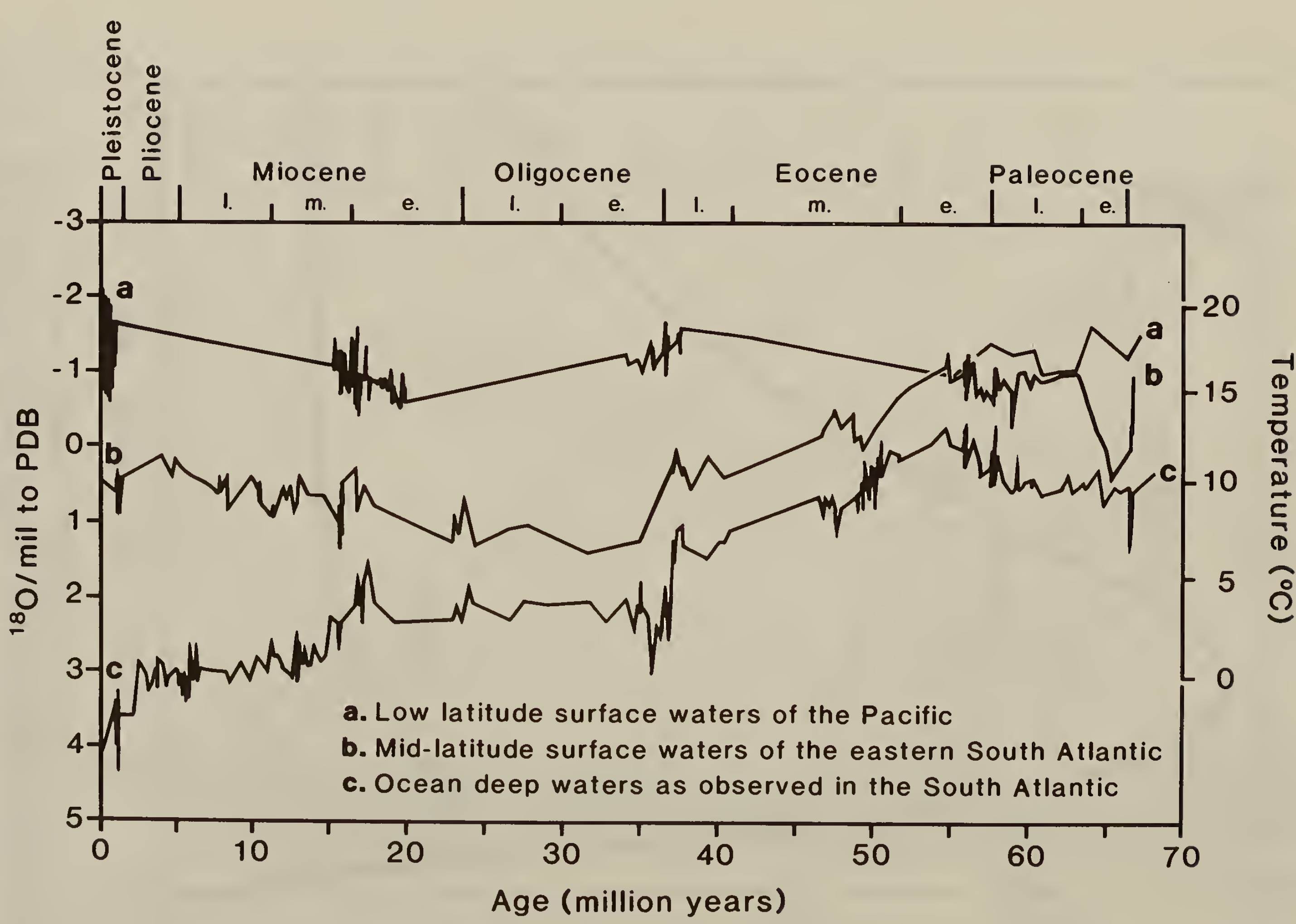
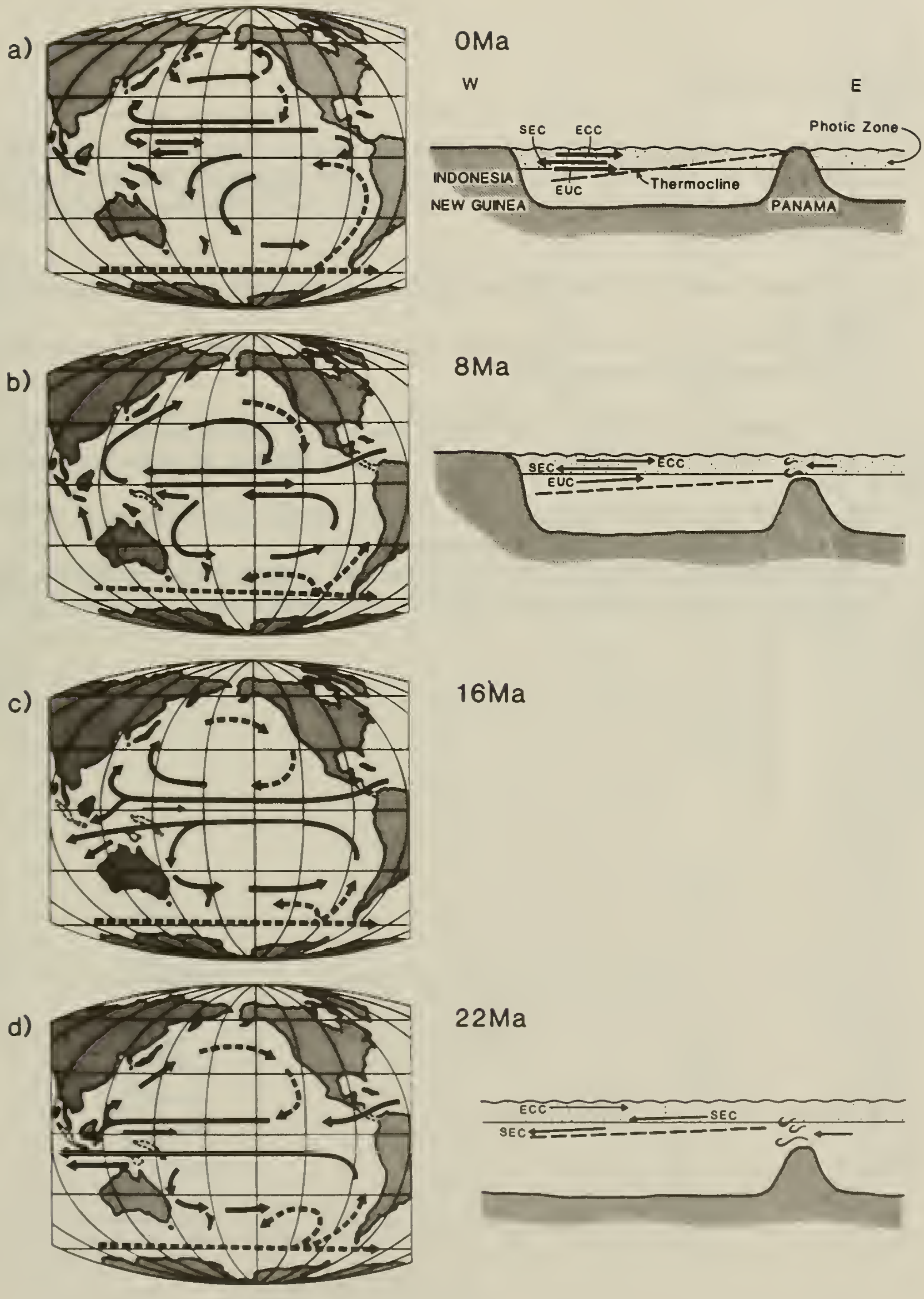


Figure 6. Oxygen isotope records for the last 70 million years (after Shackleton 1984). Temperature scale applicable only in the absence of Antarctic ice sheet before Middle Miocene; presence of Antarctic ice prior to this period would yield temperatures slightly higher than indicated on the temperature scale.


a)
0Ma
W
E
SEC
ECC
Photic Zone
INDONESIA
NEW GUINEA
EUC
Thermocline
PANAMA
b)
8Ma
SEC
ECC
EUC
c)
16Ma
d)
22Ma
ECC
SEC
SEC

SEE PRECEDING PAGE

Figure 7. Inferred circulation patterns of surface and near surface waters in the Pacific Ocean at 22, 26 and 8 million years B.P. and suggested changes in surface water-mass structure in the equatorial Pacific, early Miocene to present (after Kennett et al. 1985).

On maps: broken arrows indicate cold currents; solid arrows indicate warm currents.
On sections: SEC South Equatorial Current; ECC Equatorial Countercurrent; EUC Equatorial Undercurrent.

22-16 million years B.P.: Both Indonesian and C. American seaways open to surface waters; thermocline relatively deep in absence of undercurrent; ECC weak.
8 million years B.P.: Indonesian seaway closed and formation of EUC; thermocline shallower; ECC moderately strong.
Modern ocean: C.American seaway closed; all surface water circulation more vigorous; further raising of thermocline into photic zone, particularly in E. Pacific.

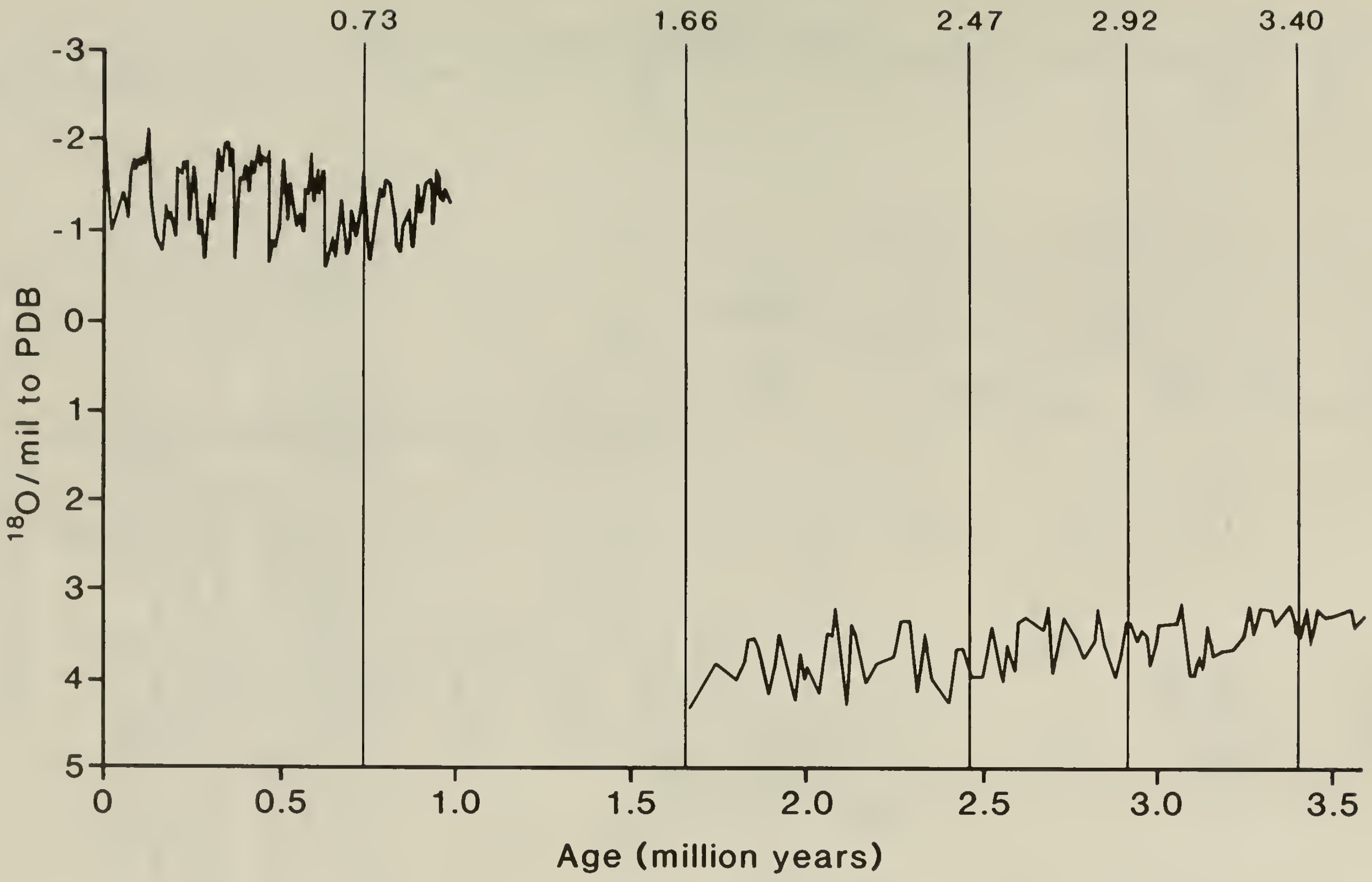


Figure 8. Oxygen isotope records from the Pacific Ocean. Top left: Pacific deep-sea core V28-238 (after Shackleton and Opdyke 1973). Bottom right; core V28-179 (after Shackleton et al. 1984a). Time control horizons: Brunhes normal chron (0.73 Myr), Olduvai normal subchron (1.66 Myr), Matuyama reveresed chron (2.47 Myr), Kaena reversed subchron (2.92 Myr) and Gauss chron (3.40 Myr).

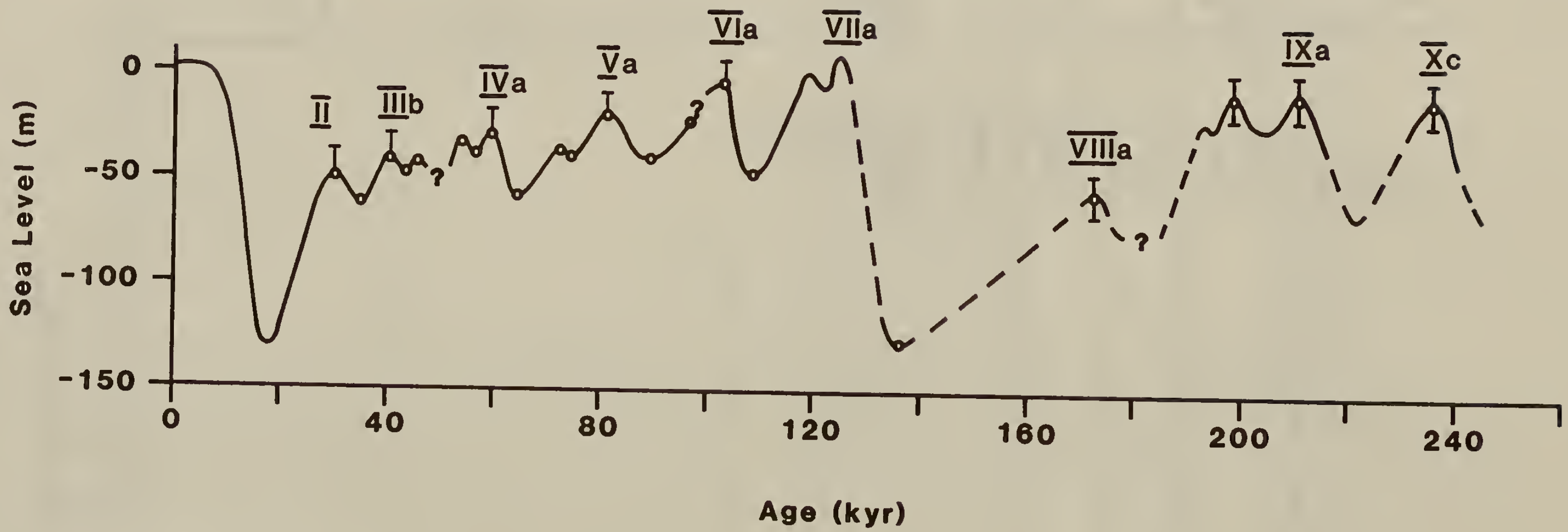


Figure 9. Latest sea-level curve for Huon Peninsula, New Guinea, with re-calculations after detailed correlation with ^{18}O record of Pacific core V19-30 (after Chappell and Shackleton 1986).

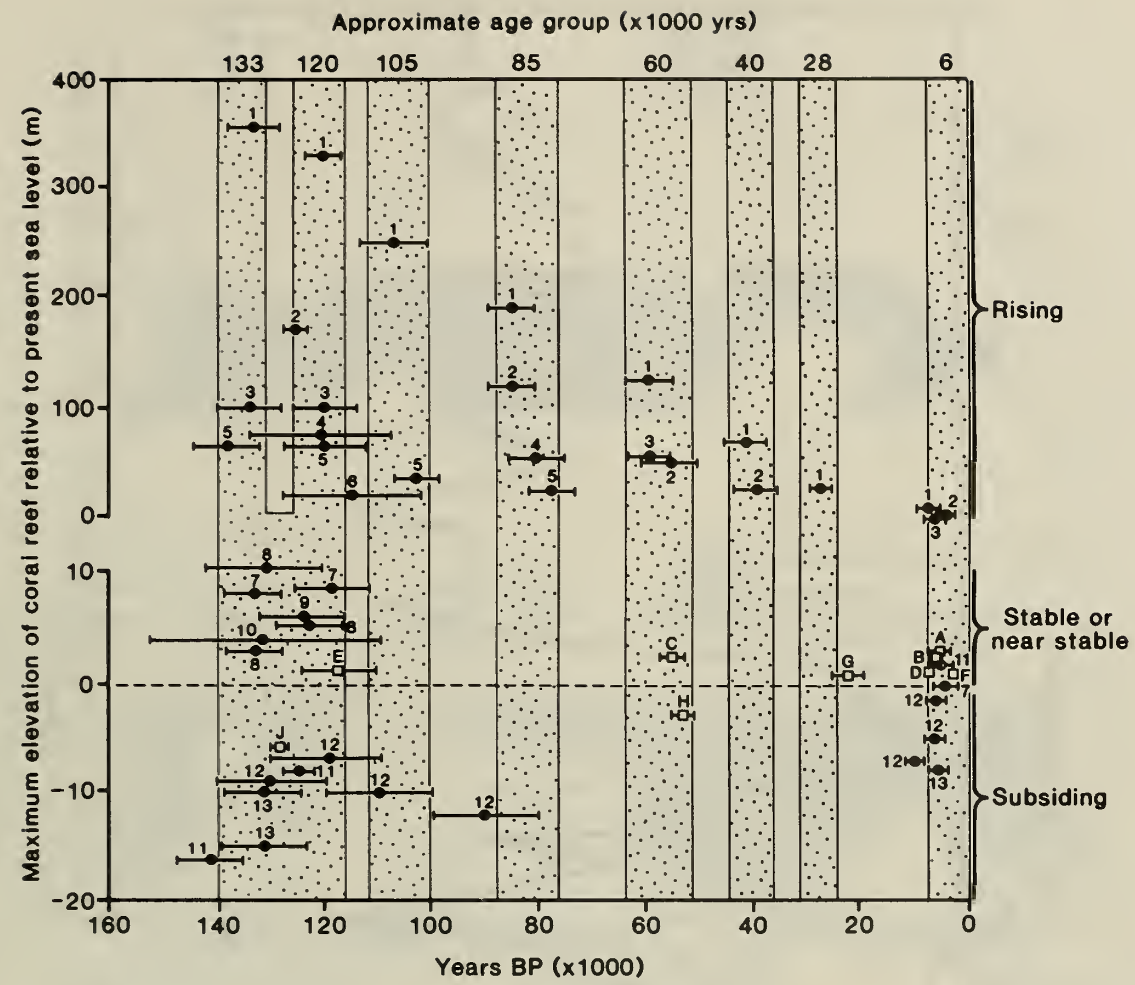


Figure 10. Chronology of late Quaternary coral reef occurrences (closed circles; after Aharon and Chappell 1986) and island phosphates (open squares; after Roe and Burnett 1985) from the Indo-Pacific biogeographical province plotted against the present position relative to mean sea level. Bars represent 1 S.D error of multiple dates.
Coral reef database: 1. Huon/New Guinea; 2. Ryukyu/Minami Daito; 3. Efate/Vanuatu; 4. Torres Island/Vanuatu; 5. Atauro/Timor; 7. Oahu/Hawaii; 8. Rottnest/W. Australia; 9. Aldabra; 10. Tuamotu Archipelago; 11. Great Barrier Reef; 12. Mururoa; 13. Enewetak.

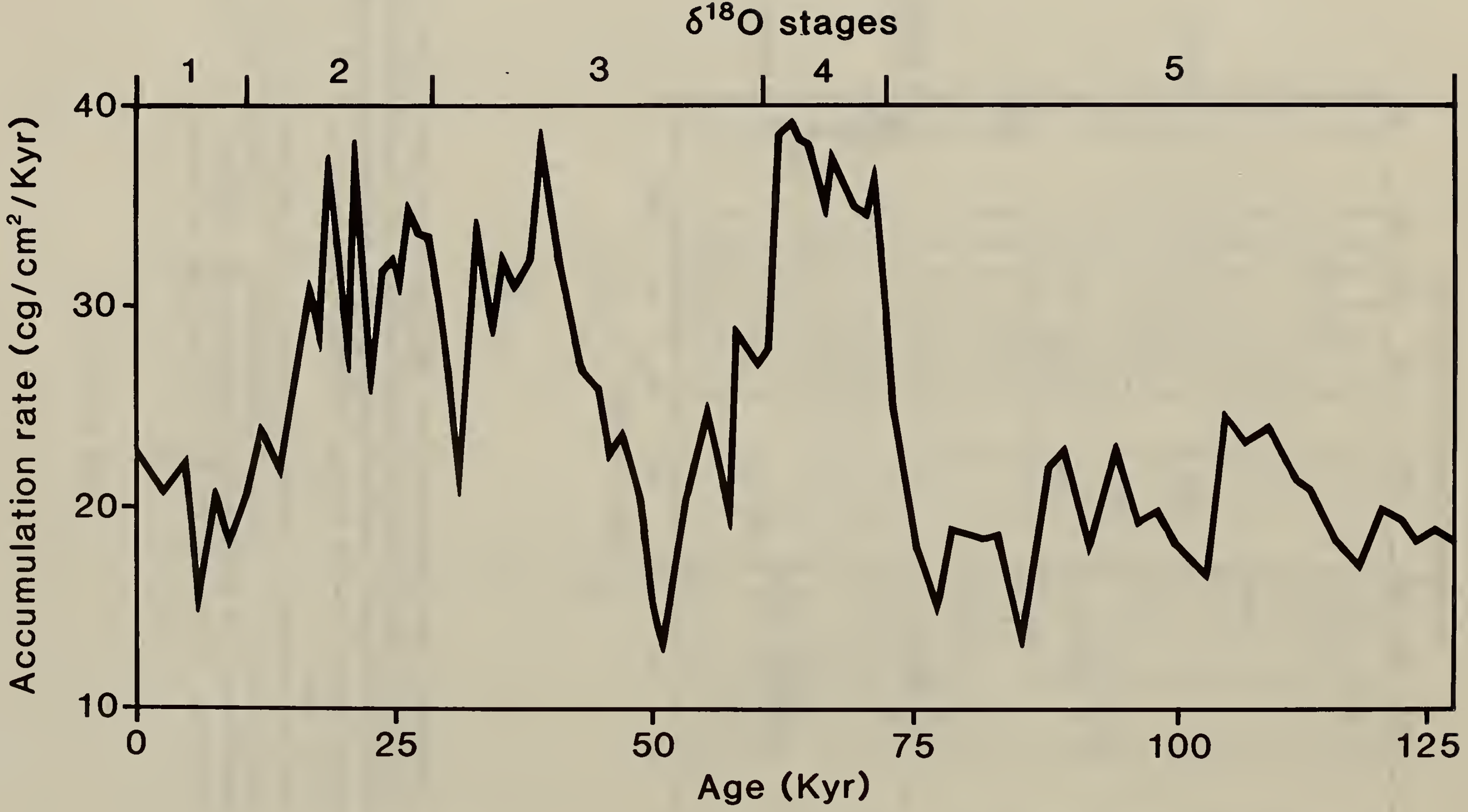


Figure 11. Downcore record of quartz accumulation in Pacific core V19-29 (3°35'S 83°56'W). (After Molina-Cruz 1977 and Romine and Moore 1981).

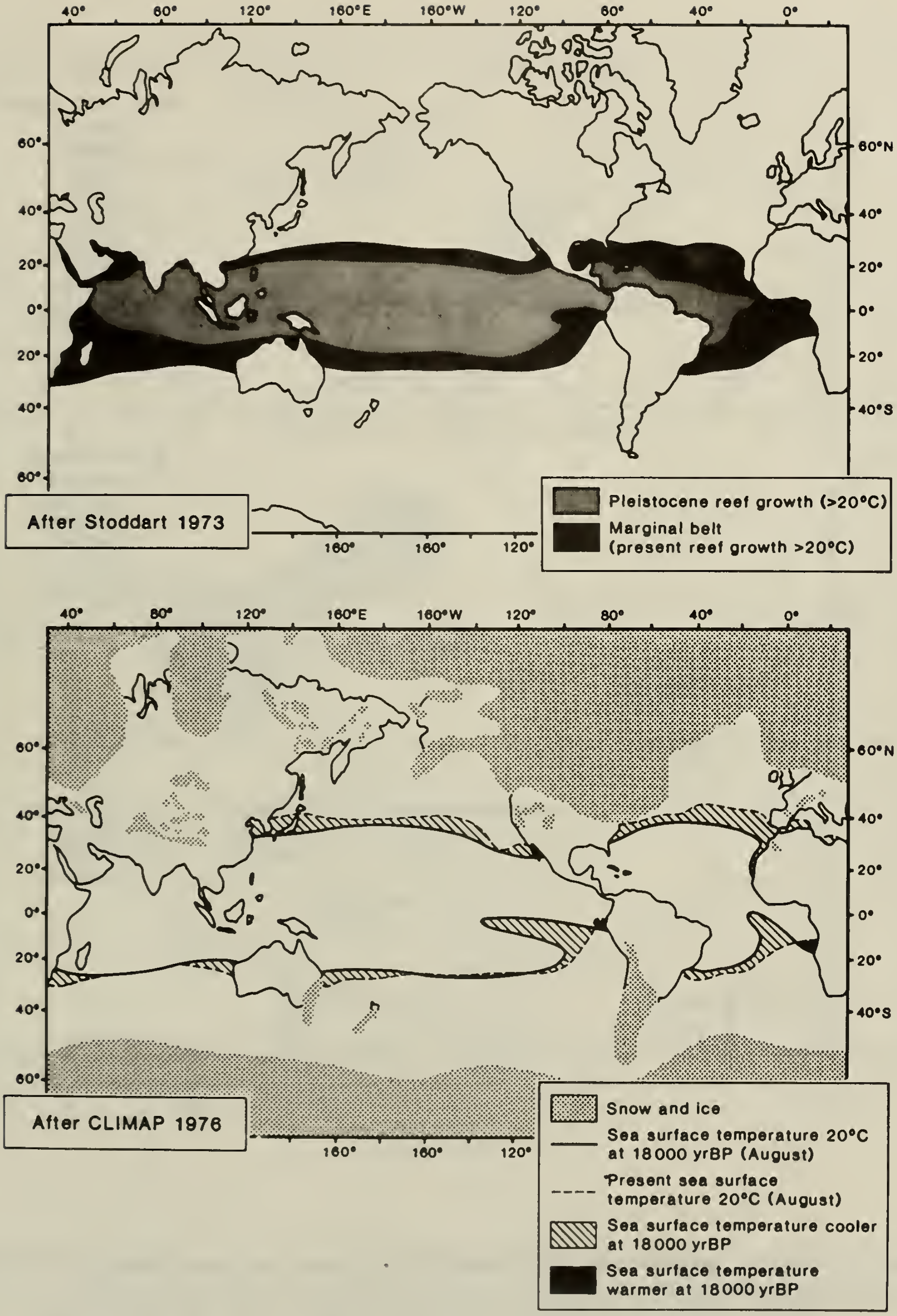


Figure 12. Possible changes in the extent of the reef seas, 18 x 10^3 yr B.P. v. present. In each case the isotherm of 20°C is taken as the effective limit of reef formation (Stoddart 1973. CLIMAP Project Members 1976).

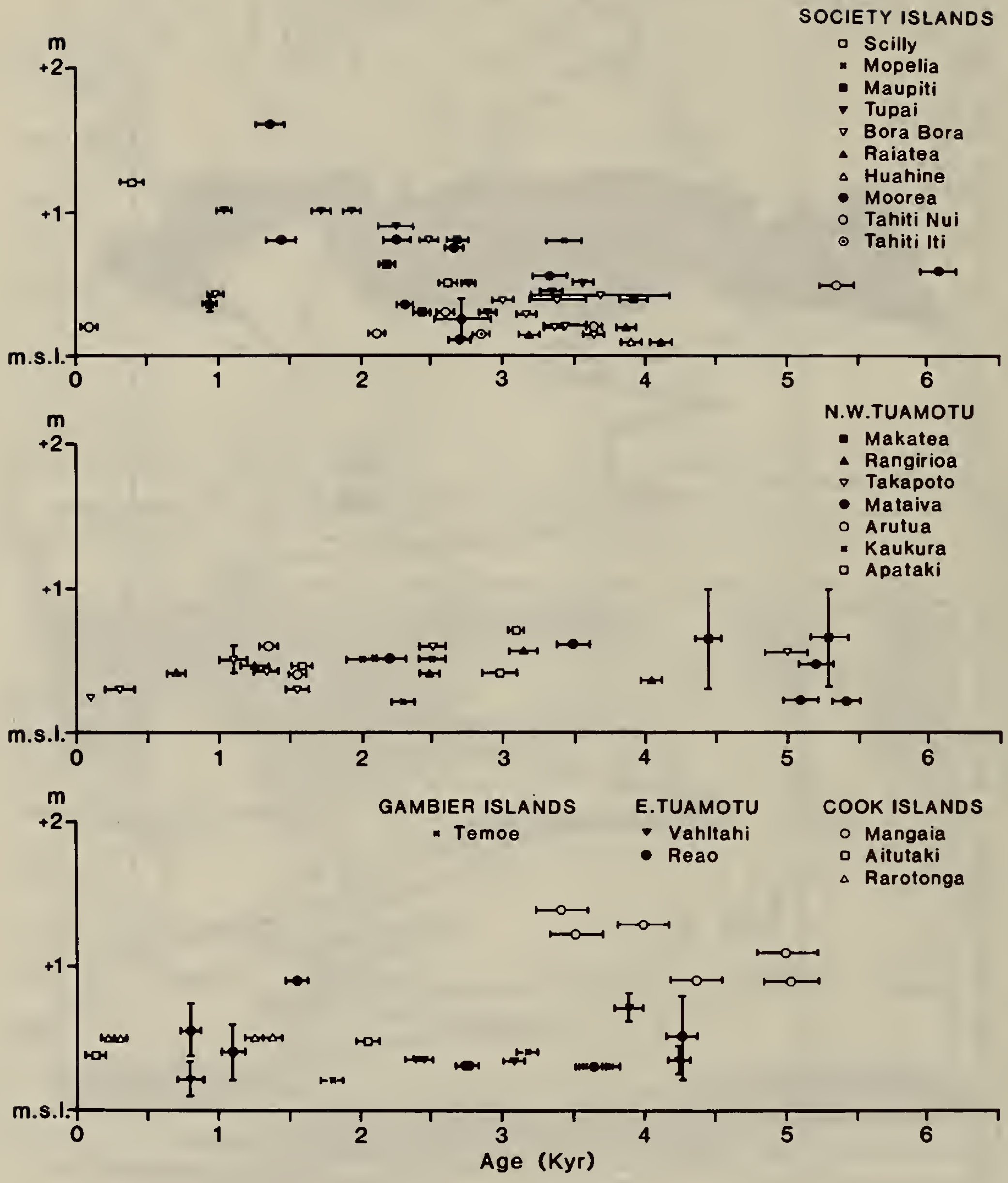


Figure 13. Time - elevation plot of sea levels in Polynesian archipelagoes, 6 x 10^3 yr B.P. to present.
Society Islands : Delibrias and Pirazzoli 1985; N.W. Tuamotu Pirazzoli 1985, Montaggioni et al. 1985, Pirazzoli and Montaggioni 1986; Gambier Islands: Pirazzoli 1987a, 1987b; E. Tuamotu: Pirazzoli et al. 1987a, 1987b; Cook Islands: Schofield 1970, Yonekura et al. 1984, 1985. Austral Islands: Pirazzoli 1987b.

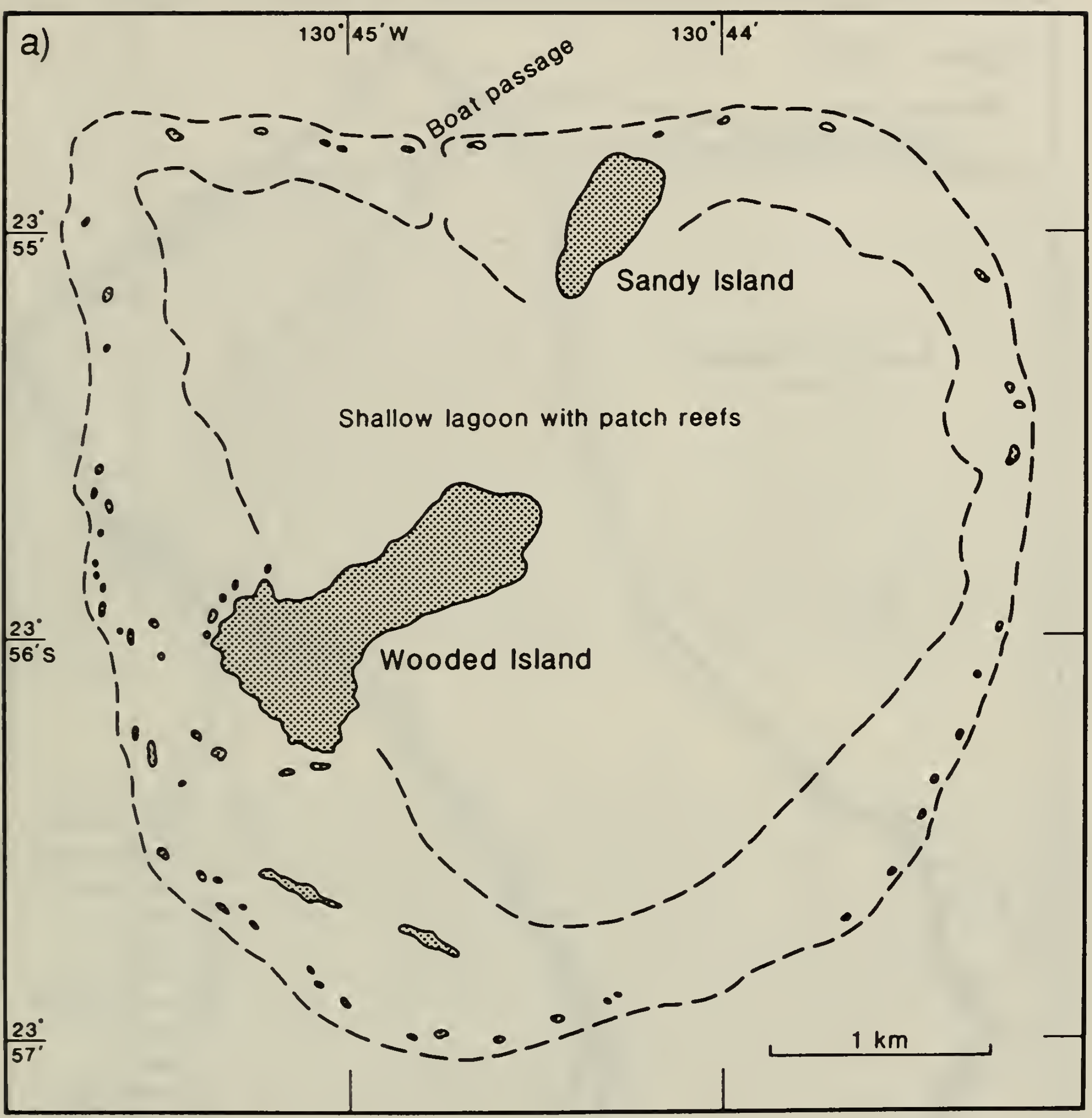


Figure 14. Geomorphology of Oeno Atoll, Pitcairn Islands. a) General plan form (after Admiralty Chart) b) Geomorphological map of wooded island. (see next page)


Oeno Atoll
Wooded Island
50 0 100 200
metres
N
Mixed woodland
Coconut woodland
T Tournefortia
C Cocoa
W Pandanus
S Suriana
F Ferns (Polypodium)
L Lepturus
B Boerhavia
Sc Scaevola
Beachrock (upper unit)
Beachrock (lower unit)
Beachrock (massive)
Beach sand
Rubble pavement
Coral rubble ridge
Fine sand berm
Boulders and cobbles
W~ Fallen tree
Undercut cliffline
1 Sediment sample
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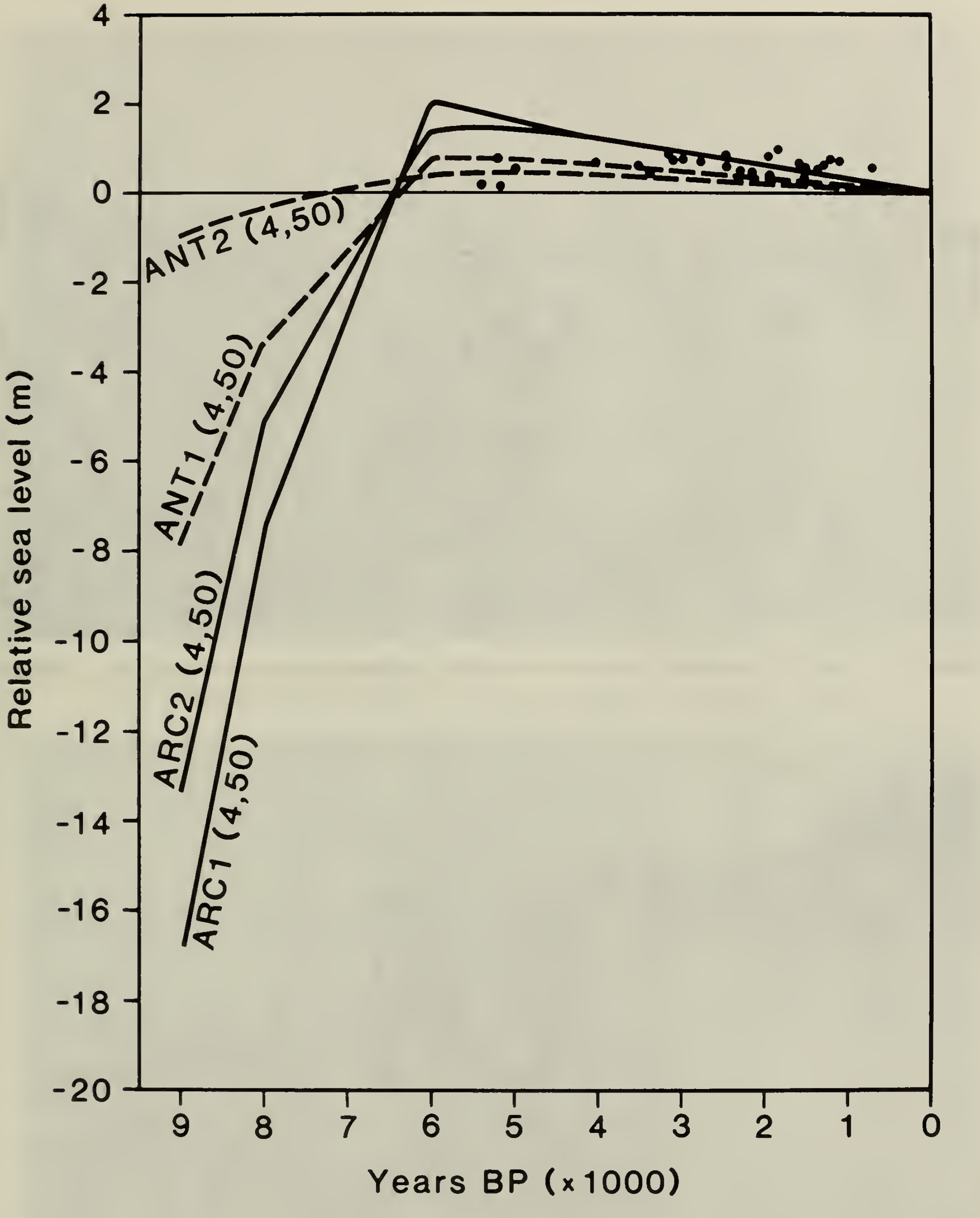

Figure 15. Relative sea-level models for the 'far field' as a function of ice load, mantle viscosity and lithospheric thickness (after Nakada and Lambeck 1987). Ice-melt models: ARC1,2: Arctic ice only; ANT1,2: Arctic and Antarctic ice. (4, 50): Upper mantle viscosity = 10^{21} Pa, lower (>670 km) mantle viscosity = 10^{23} Pa; 50 km thick lithosphere. Observed sea levels (closed circles) = N.W. Tuamotu archipelago (Pirazzoli and Montaggioni 1986).

Plate 1. Cemented washover fans of coral stick rubble, eastern end of lagoon shore, Acadia Island, Ducie atoll.

Plate 2. Pitted sheets of lagoon conglomerate spreads, central section of lagoon shore, Acadia Island, Ducie atoll. Lagoon margin at +0.30 - +0.45 m above mean sea level.

Plate 3. Boulder streams of coral heads with intervening flats of coral sticks, western end of lagoon shore, Acadia Island, Ducie atoll.

Plate 4. Lower bevelled beachrock unit overlain by more massive upper beachrock unit at S.W. point of wooded island, Oeno atoll.

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GEOLOGY AND GEOMORPHOLOGY OF HENDERSON ISLAND

BY

T. SPENCER AND GUSTAV PAULAY

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T. SPENCER[1] AND GUSTAV PAULAY[2]

ABSTRACT

The 1987 expedition to the Pitcairn group was able to perform a spatially-limited reconnaissance of the structure and topography of Henderson Island and of the more common elements of its fossil fauna; this paper presents a number of observations and hypotheses which need to be tested by further work. Henderson is an uplifted atoll with a large fossil lagoon that preserves many depositional features. The entire lagoon basin surveyed iscovered with pebble sized or larger coral debris, finer sediments being largely absent. The fossil coral fauna is well preserved and diverse, and the old lagoon probably had excellent communication with the surrounding ocean. The rate of uplift, excellent preservation and predominance of recent species among the fossils, abundant depositional features in the interior basin, and limited extent of erosional features all point to the recency of uplift, supporting the hypothesis that hotspot volcanism at Pitcairn Island has been responsible for the regional flexure of the Pacific plate with up-arching and uplift at Henderson. We provisionally assign a Pleistocene age to all exposed deposits. Embayments within the 30m cliffs which encircle Henderson are characterised by core reef buttresses and two apron reefs: an upper fossiliferous reef unit and a lower low limestone unit which we tentatively assign to the Penultimate and Last Interglacial periods respectively.

INTRODUCTION

Raised reef limestone islands provide, generally, an indication of the thermal processes associated with oceanic lithosphere (e.g. Detrick and Crough 1978, Crough 1984, Menard 1986) and, specifically, important observational data to test models of crustal loading by relatively young (<2 m.y.) mid-plate volcanoes (e.g. McNutt and Menard 1978, Lambeck 1981a, 1981b, Pirazzoli and Montaggioni 1985). A comparison of theoretical models and field observations in the south Pacific has demonstrated the need for both the careful determination of raised reef altitudes and the geomorphological evaluation of the significance of such features (Spencer et al. 1987). Raised limestone sequences also provide important locations for the study of carbonate diagenesis (e.g. Schroeder and Purser 1986), including dolomitization (Schlanger 1981, Schofield and Nelson 1978, Bourrouilh-Le Jan 1982), and the genesis of island phosphorites (Hutchinson 1950). Related to these studies, the radiometric dating of emergent fossil corals, allied to a knowledge of the environment of

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deposition from diagnostic coral and molluscan assemblages, allows for the reconstruction of regional sea level histories and the determination of rates of tectonically-determined uplift in varied settings (e.g. plate margin: Huon Peninsula, New Guinea, Chappell and Veeh 1978; mid-plate: Bourrouilh-Le Jan 1985). Raised reef islands thus provide the opportunity to study the interplay between these tectonic, geochemical and environmental processes; they supply input for modelling and simulation exercises (Chappell 1980, Paulay and McEdward in prep.) on reef growth and island morphology; and they occupy an important position in the establishment of general theory on volcanic island development and attendant reef construction.

Of the raised limestone islands found on the Pacific plate (for distribution: Bourrouilh-Le Jan 1977) Henderson Island (Figure 1) falls within the category of raised atoll with preserved lagoon (Fosberg 1985; for the range of island-atoll types: Scott and Rotondo 1983). As such it can be broadly compared, at least in terms of gross appearance, to Nauru and Banaba in the Central Pacific, to Rennell (Taylor 1973), the Loyalty Islands (Bourrouilh-Le Jan 1977) and islands of the Lau Ridge, eastern Fiji (Nunn 1987) in the western Pacific and to Makatea (Montaggioni et al. 1985a, 1985b) and Niue (Schofield 1959) in the south-west Pacific. Some comparisons can also be made with the 'makatea' islands of the Southern Cook Islands (Marshall 1927, Wood and Hay 1970, Stoddart et al. 1985, Stoddart and Spencer 1987, Spencer et al. 1989).

In this paper we consider first, the contemporary sedimentary environments of Henderson Island; secondly, the environmental record preserved in the littoral margin and cliff face sequences; and thirdly, the topography and palaeo-environments of the central depression. These descriptions allow for a preliminary reconstruction of the island's genesis and history.

METHODS

The 1987 expedition concentrated upon (i) topographic levelling, (ii) observations of the morphology and stratigraphy of limestones with sampling for subsequent petrological examination and (iii) collections of fossil corals for both environmental reconstruction and dating purposes. Fieldwork, which was largely restricted to the north-west and north beaches and the areas inland from these coasts, was supplemented by the study of available aerial photographic cover (flown 3 May 1985).

The geomorphological data are summarized in a series of topographic profiles (Figures 2-8) surveyed by 'Abney' clinometer and graduated tape from sea level. Unfortunately, the tidal regime at Henderson has yet to be accurately determined. It is clear, however, that the island experiences a semidiurnal tidal rhythm, as at Ducie Atoll, 360 km to the east (Rehder and Randall 1975). Field observations would seem to agree with Fosberg et al.'s (1983) statement that Henderson's tidal range is probably similar to that of the Gambier Islands and the eastern Tuamotu Archipelago where the range at spring tide is 1.0m. With a knowledge of tidal stage at time of survey, individual profiles were adjusted to a common datum of mean sea level. It is important to stress that local micro-topography on Henderson is often severe, with the amplitude of upstanding pinnacles and erosional clefts often in excess of 1.0m. The compromises which such terrain introduces into field survey are further exacerbated by the density of vegetation cover. This not only impedes forward progress but also dangerously hides from view deeply dissected substrates. We estimate that errors involved in the establishment of a common datum and in ground survey require established altitudes to carry error terms of ±70 cm. Horizontal survey errors were not determined.

Exhaustive sampling for fossil corals and molluscs was undertaken at known locations on the surveyed profiles and also within the central depression along trails mapped by compass bearing and ground distance measurements. These sample locations were supplemented by collections from near the seaward margins of the cliff limestones.

CONTEMPORARY ENVIRONMENTS

The plan form of Henderson Island is shown in Figure 1. According to Fosberg et al. (1983), Henderson has a greatest length of 9.6 km, a maximum width of 5.1 km and an area of 36 km^2. Comparison of the Admiralty Chart, on which these measurements were based, with recent aerial photographyconfirms these general statistics. The only region where there appears to be a potential discrepancy between the chart and the photographic cover is in the area of the North-east Point but, most unfortunately, the Point itself was obscured by cloud cover when the aerial photographs were taken.

The island's perimeter has been calculated at 26.4 km; of this, 16.5km (63 per cent) is encircled by a fringing reef, principally along the entire length of the east coast (and not just the east beach: compare with the Admiralty chart), the north coast, and to just south of the north-west cove. The south-west coast and the south point area of the island are characterised by vertical cliffs undercut at sea level to give a cavernous coastline. Wave attack, even under moderate sea conditions, frequently throws spray to over 30m, above the height of the cliff margin (Plate 1). Fallen blocks, some of considerable dimensions, attest to the process of cliff retreat by undermining marine erosion. Indeed, a comparison of Figure 3 in St. John and Philipson (1962) with Plate 4 in Paulay and Spencer (this volume), photographs of the northern section of the north-west coast taken 53 years apart, shows an additional blockfall over this period.

There is no algal ridge margin to the reef edge at Henderson Island; rather the reef is a gently-sloping limestone platform that remains shallowly submerged and constantly inundated by the surf, even at low tide. The reef platform was investigated at the north beach. It consists of a smoothed reef plate, runnelled and dotted by small (<1cm) holes and covered by a thin algal turf. The seaward end of the platform has many large, deep (0.5m), well-scoured potholes that frequently coalesce to form shallow channels. A few loose or slightly cemented rocks on the reef lie near the landward margin with the limited loose sand found on the reef flat concentrated under them. The reef platform at Henderson varies in width from 20-50m at the north-west beach to 40-75m at the north beach. Estimates from aerial photography suggest maximum lagoon widths of closer to 100m offshore from the east beach.

The reef platform terminates seaward at a line of breakers in a rugged, dissected reef front of vertical to undercut reef promontories separated by a maze of channels. Due to the lack of a protecting algal ridge, water is continuously piled onto the reef flat by surf and drains through larger grooves that extend onto, rather than through, the reef. These grooves provide the best landing sites, and are better developed on the the north-west rather than the north beach. Field observations, including by SCUBA, by the 1987 expedition showed that the jagged reef front gives way to a typical spur-and-groove topography at 3-5m water depth. Thereafter, the fore-reef slopes rapidly and without interruption to at least 50m off the north-west shore. The north-west fore-reef is dominated by reef spurs to 15m, but in deeper water the widening sand and rubble chanels that separate the spurs become dominant, and by 40m coalesce to form a wasting slope. The north beach outer slope has only limited sand channels dissecting the reef front and slopes gently to ~ 30m where it steepens and continues uninterrupted to at least 75m. An algal turf with trapped sand dominates the fore-reef surface and living corals usually account for less than 10 per cent of the cover (measured at 6% at 10.5m off the north shore).

Millepora dominates the coral fauna to a depth of 5-10m, while *Pocillopora* species (especially *Pocillopora* sp. 1 and *P. woodjonesi*) are the most common corals in deeper water. The rarity of *Acropora* on the present reef contrasts markedly with its abundance in the ancient fossil lagoon, as well as on nearby Ducie.

Both the fore-reef and reef platform are wider off the north than off the north-west beach, correlating with the pronounced embayment on the north coast. Shallow but wide embayments, as off the north of Henderson, are often associated with wider reefs on other Polynesian islands e.g. on Niue or Rurutu (Austral Islands).

THE MARGINAL CLIFFS: STRUCTURE, STRATIGRAPHY AND ENVIRONMENTAL HISTORY

The cavernous and undermined cliffs of the south coast are impossible of access from the sea. Furthermore, it seems likely that depositional units of relatively young age accreted to the island core will have been, at best, severely modified and, at worst, removed by wave attack and cliff collapse. The most complete stratigraphic sequences on Henderson are, therefore, preserved in the broad embayments within the main marginal cliffs. In this paper we consider the north-west (Figures 9, 13, Plate 2) and north beach (Figures 10, 14, Plate 3) areas but it seems likely that a similar stratigraphy is preserved in the eastern embayment; reconnaissance shows the presence of limestone units and abundant caves (Plate 4).

Ground survey has established that the marginal cliffs on the northern and north-western shores reach heights of 30.7m and 30.2m respectively. Whereas the cliffs of the south-west coast and the south point appear to be relatively unbroken, the north-western and, particularly, the northern embayments are backed by cliffs which are composed of a series of discrete limestone buttresses, with vertical or even overhanging slopes, separated by slopes of 25-30°. Where buttresses are encountered the cliff margin lies at between 26 and 27m above present sea level (Plate 5). The prominent buttress above the central north beach contains large colonies of *Lobophyllia corymbosa*, *Montastrea curta*, *Favia rotumana*, *Leptoria phrygia*, *Pocillopora eydouxi* (Plate 6), an abundant plate coral (likely *Montipora aequituberculata*), *Fungia scutaria* and a large (3m+) massive *Porites* colony (coral sample: FHEN-23).

Multiple levels of former sea level notches are preserved within the buttresses. The highest of these features is best seen at profile 4, north-west beach where a prominent notch is preserved at 24.8m above present sea level (Figure 5). This notch may correspond to a small bench at 24.5-25.1m on profile 5 (Figure 6) and to notches seen at the tops of limestone buttresses between the north and north-western embayments and at Awahou Point. On profile 4, this notch is a well-developed, laterally extensive feature, 1.44m high and 0.6m deep with a sand fill to the rear of the notch (Figure 5). The notch (coral collecting station FHEN-3) is filled with coarse sand and well rounded cobbles of coralline origin, suggestive of a high energy, beach deposit. Shells of two gastropods, the intertidal limpet *Patella flexuosa* and the intertidal to shallow subtidal *Turbo argyrostomus*, are commonly cemented in the notch, together with large, intact branches of *Pocillopora eydouxi* and *Acropora* colonies (Plate 7). The excellent preservation of the branching corals contrasts strongly with the polished, rounded coral cobbles and worn intertidal shells, and suggests that they were deposited during a second, low energy phase that post-dated notch formation. A much more pronounced notch characterises the limestone buttress in the central section of the north beach (profile 1, Figure 2). The broad notch floor commences at 19.7m above sea level and slopes upwards over ~4m to the rear of the notch; over a 35m-long section this varies in height between 21.0 and 21.6m. The notch roof intersects the buttress at 2.5-3.0m above the notch floor. It is surprising, however, that this well-developed and unambiguous sea level feature is not found elsewhere on the north and north-western coasts (except perhaps at 21.2m on profile 7: Figure 8) and even appears restricted to the central section of the north beach. It would be interesting to know whether or not this level is represented on the east coast.

Below the major constructional buttresses, and forming a veneer on the outer slope of the island, is a fossiliferous reef unit of generally limited width but considerable vertical extent (Figures 13, 14). The contact of this unit with the main cliff face is marked by a break of slope at 16.0m (profile 3: Figure 4) to 16.9m (profile 1: Figure 2) or, in the case of profile 7 (Figure 8) a notch at 16.2m above present sea level. Associated with this contact are caves (cave entrance, profile 2: 18.0m (Figure 3) cave floor, profile 3: 17.3m (Figure 4) and, possibly, a cliff shelf (base of shelf, profile 4: 17.9m (Figure 5)). The cave on profile 2 is ~20m in length behind a hemispherical entrance 2.2m in height. The main passageway varies in width from 1.4-4.1m but a low chamber to the north of the main conduit increases the overall cave width to over 9m (Figure 11; and see Schubel this volume for cave floor sediment characteristics). It is suggested that the cave/shelf level (Plate 9) relates to a sea level stillstand and erosion level associated with the deposition of the fossiliferous reef unit. At 9.6-11.4m on profile 2 (Figure 3; coral collecting station FHEN-11) the fossiliferous reef unit is exposed as a rich coral conglomerate, terminated to the south by a mostly featureless limestone. The deposit is dominated by *Pocillopora* sp(p)., *Astreopora* cf. *moretonensis*, massive *Porites* sp(p)., *Porites* cf. *mordax*, *Psammocora ?obtusangula*, *Coscinaraea columna*, *Acropora* sp., and *Plesiastrea* cf. *versipora*. About 50m to the south, the fossiliferous reef unit is well exposed between 7.6-11.1m on profile 7 (Figure 8; HW4-11) and contains a similar fossil assemblage: *Pocillopora eydouxi*, *Pocillopora* sp(p)., *Pavona* sp. 1 and *Montastrea* sp. 1. Additional exposures are found at the eastern end of the central section of the north beach. Here the fossiliferous reef unit is exposed in a 3-5m high cliff, its base at ~ 2.0m above mean sea level (Figure 10; coral collecting stations FHEN-20/22). At this locality the unit is composed of two facies. The lower facies (FHEN-20/21) exhibits abundant *Pavona* sp. 1, *Astreopora moretonensis* and *Pocillopora* sp(p)., as well as specimens of ?*Pocillopora eydouxi*, *Fungia scutaria*, *Plesiastrea* cf. *versipora* and massive *Porites* sp(p). The upper facies is ~1m in thickness and composed of coral stick rubble (Plate 9) in a poorly cemented sand matrix (FHEN-22). Embedded corals include *Pocillopora* sp. 1, *Astreopora* cf. *moretonensis*, massive *Porites* sp(p). and *Porites* cf. *mordax*.

There are several topographic breaks and sea level features within the fossiliferous reef unit. These include a notch at 14.3-15.1m (profile 2; Figure 3), which is also reflected in a shelf at 15.0m on profile 7 (Figure 8), and a range of cliffed sections and slope inflections, with breaks of slope at between 12.5-14.0m for the top, and 11.6-11.9m for the base, of these slope elements. Erosion within this height band may have been related to the deposition of the low limestone unit which fronts the fossiliferous reef unit. On profile 7, north-west beach (Figure 8) an erosional embayment reveals the fossiliferous reef unit behind the low limestone unit (and see Figure 13). The contact between these two units, marked variously by either a change in slope angle, or a notch or a small cliff, has been established at 8.7m on profile 2 (Figure 3) and at between 9.4 and 10.6m on profiles 2-6 (Figures 3-7). This contact is marked, easily seen and shows considerable lateral continuity. It is possible to trace the junction between the north beach and the north-west embayment (Plates 11, 12); estimates from ship survey and photographic record suggest that in this region the contact varies in height between 7.6-11.9m, with an average altitude of 10.0m. The low limestone unit is also well seen at the southern end of the north-west beach (Plate 12) where the upper limit appears to fall between 8.4-10.5m, with a mean height of 9.7m above sea level.

The low limestone unit is represented by a thin deposit plastered onto the cliffed headlands; this extends to form a low fringing terrace, up to 40m in width, in the embayments of the north and north-west beaches. This terrace is divided into two sections. The upper section slopes downward to terminate at a well-defined margin (seen on five of the seven profiles) at 7.3-8.3m. This forms the top of a small cliff whose base is found at 6.3-7.0m above sea level. Below this cliff, the lower section of the terrace forms a highly dissected and often stepped profile, either composed of a series of joint-controlled blocks or characterised by a number of deep (>1m) clefts in a pitted surface topography, ending in a marginal cliff whose upper surface varies in height between 2.6 and 3.7m above sea level. These heights , however, have no significance but merely indicate the degree of shoreward retreat within a unit which slopes upwards onshore. Fallen blocks in front of the seaward margin of the terrace, and remnants of blocks offshore, show that marine erosion is currently active. On the north-west beach, for example, at high tide waves break not on the reef edge but at the terrace margin.

At the eastern end of the central section of the north beach the low limestone unit is divided by a series of steep (>30^0), narrow (~1.5m) gullies which exit on the terrace surface (e.g. profile 5, Figure 6; Plate 13). These features may represent the grooves of a groove-and-spur fore-reef topography. Fossil groove-and-spur features of a similar scale have been described from Last Interglacial reef limestones on Mangaia, Southern Cook Islands (Stoddart et al. 1985). Some of the grooves on Henderson Island are roofed over at their seaward margins in a manner reminiscent of similar fossil grooves on Mauke and Mitiaro, Southern Cook Islands. Although the exits of the grooves and the lower groove walls are characterised by large colonies of *Montastrea* sp. 1, the Henderson grooves (Plate 13), unlike the groove-and-spur features of the Southern Cooks, are not lined with a wide range of well-preserved encrusting corals. The low limestone unit is, in fact, very poor in preserved corals with only the occasional colony of *Montastrea* sp. 1 and, uniquely, a large colony of *Porites* sp. at 1.8m above present sea level near the seaward margin of profile 6 (Figure 7).

At the north-west beach, the low limestone unit terrace is characterised not by narrow grooves but by broader embayments which widen seawards. The embayments are floored by a bevelled bedrock ramp (Figure 13) which slopes upwards from the beach foot within the intertidal zone to a small cliff, 20cm in height and with a base at 2.2m above present sea level, which marks the ramp's erosional contact with the cliffed margin of the low limestone unit. In some places, there is clear evidence for the bevelling of *Montastrea* sp. 1 in growth position within the ramp (Plate 15). On profile 4 (Figure 5) the ramp includes a smooth dome at 1.9m above sea level which resembles the exfoliating coralline algal crusts described from Vahitahi, eastern Tuamotu Archipelago by Pirazzoli et al. (1987b). Locally at its seaward margin the ramp is overlain by beachrock; individual plates may be 0.35m in thickness and extend up the ramp to a height of 0.8m above present sea level (Figure 13). The upper plates of this beachrock are frequently composed of cemented coral sticks. Similar agglomerations of coral rubble, with typical acroporid branch diameters of 0.5-0.8cm, plaster the contemporary notch, related to present sea level, in the cliffed margin to the terrace. In addition, on the north-west beach, coral debris on the bevelled ramp forms cemented blocks or pillars up to 0.8m above mean sea level. It seems likely that these deposits are the product of storm wave attack and subsequent transport from the coral ledges offshore. Accumulation and ensuing cementation has clearly been locally variable, and we ascribe no significance to the height of these deposits.

THE CENTRAL DEPRESSION: TOPOGRAPHY AND PALAEO-ENVIRONMENTS

Although many of the early descriptions of Henderson, made from the sea, stressed the apparent flatness of the top of the island, the 1934 Mangarevan Expedition recorded the presence of a shallow depression in the island's interior (St. John and Philipson 1962, Fosberg et al. 1983). This they interpreted as a former lagoon, thus adding weight to the explanation of the Henderson topography as being that of an elevated former atoll. The 1987 expedition was able to confirm the presence of both an interior depression and lagoonal deposits on Henderson Island.

On the north-west coast inland from the immediate cliff top margin the island limestones reach 31.3m, and generally exceed 29.0m, above sea level (Figure 12). In this area the surface topography is characterised by both joint-bounded limestone blocks 0.2-0.5m in height and pinnacles with an amplitude in excess of 1.0m. At a larger scale the limestones also exhibit straight-sided basins 0.5m deep and 2.0m in diameter and solution holes with vertical walls up to 2.5m high and flat floors 3m in width. The top of this surface is, however, covered by patches of loose, uncemented coral rubble, composed of both small coral sticks (*Acropora* spp., *Pocillopora eydouxi*, *Pavona* sp. 1), as well as small coral colonies (massive *Porites* sp(p)., *Montastrea* sp. 1, branching *Acropora* spp.) and frequent *Turbo argyrostomus* and *Tridacna maxima* shells, even on the cliff margin at 30.7m above sea level. The abundance of *Pocillopora eydouxi* and *Turbo* indicates that this area, as expected from its physiography, was probably part of the outer reef flat of the original atoll (coral collecting station FHEN-4).

Although the surface topography is irregular, there is clearly a regional slope downwards into the island's interior (Figure 12). However, no continuous slope profiling was undertaken by the 1987 expedition across this area and, therefore, the heights which follow with regard to the central depression should be seen as rough first estimates only.

The contact between the island rim limestones and the central depression is marked, first, by an area of pinnacle-pitted limestone ~26m above sea level and 220m from the cliff-top margin (Plate 15). It is not clear from our field surveys and available aerial photography whether this landform forms a band encircling the central depression or is only present in more localised patches. The pinnacle-pitted limestone is a landscape of sharp, recrystallised limestone pinnacles and deep solution pits with a vertical relief of ~2m, and lacks the coral rubble that characterises the plateau surface elsewhere. While fossils of *Montastrea* sp. 1 are commonly visible in cross-section, branching corals that form most of the coral rubble elsewhere were not seen, although this could be due to excessive remineralisation of their finer structure. *Turbo* shells were also noted embedded in this landscape. The pinnacle-pitted limestone is followed by a rugged yet marked slope, of 3m vertical fall over 15-20m horizontal distance, down to the interior depression at an estimated 22m above sea level and 300-350m inland (Figures 12, 15). Over the next 300m (i.e.to the end of our trail) the level floor of this depression is characterised by a largely uniform cover of coral sticks, dominated by branches of *Acropora* spp. but with *Pavona* sp. 1 and less commonly *Porites* cf. *mordax* also ubiquitous and locally dominant. Scattered amongst this rubble are entire colonies of these branching species as well as massive *Montastrea* sp. 1, *Favia rotumana*, *Favia stelligera*, *Montastrea curta*, *Plesiastrea* cf. *versipora*, plates of *Astreopora* cf. moretonensis and small *Fungia* spp. Although these corals lie uncemented to each other, many appear to be in growth position, perfectly preserved, often allowing identification to the species level (Plates 16, 17). However, the branching skeletons fracture easily on contact and *in situ* diagenesis has altered the original aragonitic skeletons to low magnesium calcite. While coral rubble forms most of the substrate, other fossils (molluscs, echinoderms, crustaceans) are rare. An essentially identical community was encountered in the north shore interior (see below); and it is possible that most of the central lagoon has similar cover (coral collecting stations: FHEN-6/9).

The topography of the central depression as reached from the north coast is rather different. (Figure 12). Unlike the narrow transition zone from limestone bedrock to coral-covered depression on the north-west coast interior, and although lagoonal deposits appear to be first encountered 300m inland from the cliff top, pinnacled limestone outcrops are present over 1 km from the island margin (Figures 12, 16). On the north coast the island rim reaches, in a pinnacled zone, a maximum height of 33.6m above sea level 250m from the cliff edge (Figure 12). The wide expanse of makatea seaward of the highest point could represent a former outer reef flat backed by an atoll rim. *Motu* on this rim might have been characterised by emergent limestone (e.g. cf. *feo* limestones, N W Tuamotu archipelago). However, it is likely that the solid limestone that outcrops at, and dominates, the present cliff-top margin both here and on the north-west shore corresponds to the cemented reef flat that surrounded the atoll lagoon.The clear presence of a cliff-top ridge topography from aerial photography further suggests that a similar palaeo reef flat is present above the south-west cliffs (Figure 1). Inland from this makatea zone on the north coast, a series of basins are encountered between well-defined limestone outcrops. The basin floors are 30-31m above sea level and are generally characterised by *Montastrea* sp. 1 and valves of *Tridacna* . There does appear, however, to be a greater diversity of corals near the limestone outcrops as coral rubble is often banked up around the basin margins. We suggest that these basins represent a very shallow lagoon margin. Beyond this zone of alternating basins and limestone outcrops, a much more diverse lagoonal assemblage is encountered. It comprises the following genera and species:-

Very common	*Acropora* group 3
	Pavona sp. 1
	Porites cf. *mordax*
	Favia stelligera
Common	*Montastrea* sp. 1
	Acropora groups 1+ 2
	Montastrea curta
	Astreopora cf. *moretonensis*
Occasional	*Favia rotumana*
	Plesiastrea cf. *versipora*
	Fungia scutaria
	?Fungiid sp(p).
	Pocillopora damicornis
	Pocillopora sp(p).
	Leptoria phrygia
	Scolymia vitiensis
	Psammocora ?obtusangula
	Montipora spp.

The fossil lagoon appears to have had considerable interchange with the surrounding ocean. This is indicated by the following features:

1) Great coral diversity. That faunal diversity of atoll lagoons is directly related to the extent of water exchange with the surrounding ocean is especially well documented for corals (Salvat 1967, Chevalier 1979). Thus in the Tuamotu archipelago, closed Taiaro atoll has only one coral living in the lagoon whereas Takapoto atoll, where two shallow passages break the island rim, has 21 lagoonal species in a total fauna of 63 species (Chevalier 1976, Kuhlmann and Chevalier 1986). At Aitutaki (S.Cook Islands), an almost-atoll where one large and many small passages allow water exchange between ocean and lagoon, 60 of the total count of 68 non-acroporid scleractinians are found within the lagoon

(Paulay 1988). On Henderson 22 of the 26 fossil coral species (15 of 17 genera) encountered were found in lagoonal deposits (Table 1).
2) Prodigious coral growth, such that the whole laggon thus far investigated is filled with coral rubble and
3) the concomitant lack of sediments finer than coral rubble, indicating either rapid coral growth filling the lagoon with coral rubble faster than fine sediments could be produced, or loss of such sediments to the surrounding ocean through vigourous water exchange.We are not aware of any contemporary atolls that exhibit such uniformly coarse bottom sediments.
4) The presence of corals requiring oceanic water conditions, such as *Pocillopora eydouxi* and *Pavona maldivensis*, and the rarity of species that are usually common under more stagnant conditions, such as *Pocillopora damicornis* or massive *Porites* spp. (cf. Paulay, 1988).

There are few differences in species composition between the north and north-west fossil communities, the most notable being *Leptoria phrygia*, a species occasionally encountered both on the north coast fossil fore-reef and lagoon but not on the north-west coast. Interestingly, *Leptoria* is currently only known from southern, subtropical localities within French Polynesia: the Austral, Rapa and Gambier Islands (Chevalier 1974, 1980, Faure 1985). It has not been recorded living in the Tuamotu Archipelago or Society Islands (Chevalier 1979, 1981) or the Pitcairn group (Paulay, this volume). *Leptoria* has been recovered, however, from cores into Pleistocene limestones on Fangataufa atoll, southern Tuamotus (Chevalier and Repellin 1978) which together with the present find suggests considerable range constriction of this species since the Pleistocene. Further into the northern areas of the lagoonal depression, local topographic highs, with a distinctive non-forest vegetation cover (see Paulay and Spencer, this volume) consist of large accumulations of *Acropora* sticks (A. group 3; Plate 18) with only a few other corals present. These include *Montastrea* sp. 1 (Plate 17), *Favia stelligera*, *Porites* cf. *mordax*, *Acropora* group 2, *Pocillopora* sp(p). and *Pavona* sp. 1. We interpret these areas as large lagoonal patch reefs. Additional distinct reef complexes up to 15m across are found both in the north and north-west interior, composed of associations dominated by massively branching (5cm + branch diameter) *Acropora* (A. group 2; Plate 16) and large tabloid *Acropora* (A. group 1).

INTERPRETATION

Reconstructions of the plate-tectonic history of the south-east Pacific (see Spencer, this volume) suggest that initial island-building at Henderson took place at ~13 m.y. BP; thereafter, with the cessation of volcanism, island subsidence and the development of a carbonate cap followed. Fosberg et al. (1983) have suggested that Henderson Island stands comparison with the makatea islands of the central and southern Pacific and, therefore, that the limestones which comprise the core of the island are of mid-Tertiary age. By extension, the central depression has been interpreted by these authors as a karst erosion feature and, as such, characterised by residual pinnacles and columns of limestone rather than a depositional topography of lagoonal patch reefs. Such a history requires a period of emergence; presumably this would have taken place in the late Tertiary (Miocene-Pliocene) and would have been accompanied by the severe meteoric alteration of emergent carbonates and the commencement of dolomitization (e.g. Schlanger 1981). The degree of emergence of Henderson is in the range of Tertiary makatea islands: intermediate between Makatea Island (113m, N.W.Tuamotu Archipelago), Rurutu(100m, Austral Islands) and Mangaia (73m, S. Cook Islands) on the one hand, and Atiu (22m), Mauke (15m) and Mitiaro (11m; all S. Cook Islands) on the other (Montaggioni et al. 1985a, Stoddart et al. 1985, Stoddart and Spencer 1987, Spencer et al. 1987, 1989). The physiography and sediments of the central depression on Henderson, however, suggest a young age. Although field observations clearly show that on the north coast near the depression margin lagoonal deposits drape an older, erosional topography, the rest of the plateau surface is covered by very well preserved, unconsolidated coral skeletons. Moreover, putative depositional patch reefs are encountered further inland and it seems probable that more original depositional structures might be encountered as the centre of the island is approached. Indeed, no unambiguous erosional features were seen within the central lagoonal deposits. In addition, the cliff-top of the island on both the north and north-west coasts shows the presence of well-preserved, framework-building corals in original depositional features. None of the uplifted islands in French Polynesia or the S. Cook Islands have such clearly depositional, lagoonal features, or as well preserved coral fossils that lack advanced diagenesis on their core reefs. Henderson also lacks an accumulation of phosphorites (Fosberg et al., pers. obs.), unless they have been buried beneath the lagoonal deposits. Their absence could otherwise be explained by 1) a lack of upwelling areas and large sea bird rookeries (at least at the present time) and 2) a lack of time for accumulation of such deposits. Thus although it seems possible that Pleistocene deposits fringe an older (?Tertiary-?early Pleistocene) core on Henderson, it is likely that the entire surface structure of the island is of Pleistocene age. It is to be hoped that petrological studies of limestone samples collected on the shore to central depression transect on the north-west coast will test between these two competing hypotheses. A Pleistocene age would lend support to the hypothesis that uplift at Henderson has been the product of lithospheric flexure consequent upon the formation of Pitcairn Island within the last million years (see below, and Spencer, this volume).

A Pleistocene age for the island is further supported by palaeontological estimates. Since the proportion of extant species in a fossil assemblage decreases with increasing age, one may use the percent extant species (Lyellian percentage) in a fossil deposit as a crude indicator of its time of formation. Stanley et al. (1980) and Stanley and Campbell (1981) present Lyellian curves for bivalve and gastropod faunas from Japan, California and the Western Atlantic where early Pleistocene mollusc assemblages have Lyellian percentages of 70-90%. Similarly, Wells (1954) provides estimates of Lyellian proportions for Oligocene to Recent corals from Indonesia with the separation of Pliocene to Pleistocene occuring at ~70% living species. Preliminary identification of fossil corals from Henderson (Table 1) indicates that 95% of the 21 corals identified to species level are still extant. Similarly, all fossil molluscs identified to date are known to be living (Paulay, in prep.).

If, as suggested by the lithospheric flexure model of McNutt and Menard (1978), uplift at Henderson has been the product of crustal loading by the volcano of Pitcairn Island 200 km to the west-southwest, then this emergence probably dates from the mid-Pleistocene. Potassium-argon (K-Ar) dating of exposed volcanics on Pitcairn has identified two phases of volcanism, at 0.46-0.63 and 0.76-0.93 m.y. BP. Petrological studies and palaeo-magnetic chronologies suggest that the older of these two phases represents the main island-building stage and that island construction could have been rapidly achieved between 0.85-0.93 m.y. BP (Duncan et al. 1974). Rapid shield-building has been characteristic of many mid-plate Pacific volcanoes (Jarrard and Clague 1977). Assuming an average age of 0.90 m.y. for Pitcairn Island then the average rate of tectonically-induced uplift at Henderson since this time has been ~1m 25kyr^{-1} (4cm kyr^{-1}). This is comparable to the rate of island uplift calculated for Mangaia, Southern Cook Islands under crustal loading from the Pleistocene volcano of Rarotonga (Stoddart et al. 1985). The sea level features within the coral buttresses at 24-25m and 21-22m above present sea level may represent stillstands during island emergence. Once sea level fell below these levels the lagoon became a subaerial feature and subject to terrestrial weathering processes, including the commencement of diagenesis within the stranded and emergent coral communities. Subsequent sea level fluctuations were not of a sufficient magnitude to re-flood the lagoon. The two main reef units preserved below the reef buttresses represent the interaction between tectonic uplift and glacio-eustatic sea level fluctuations. We suggest that the fossiliferous reef unit which reaches 16.9m (profile l; Figure 2) represents coral growth associated with the high sea level stand of the Penultimate Interglacial (>200-400 kyr BP) and that the low limestone unit and terrace, averaging 10.0m above present sea level at its contact with the fossiliferous unit, dates from the Last Interglacial (100-140 kyr BP) sea level high stand. Fossil corals from known altitudes have been collected from both units and it is hoped that uranium-series and electron-spin resonance (ESR) dating of these samples will establish a firm chronology for reef growth and sea level change during the late Pleistocene at Henderson.

The Henderson reef limestones can be compared to other coralline islands in Polynesia which are widely believed to have been affected by lithospheric flexure. At Makatea Island the Penultimate Interglacial and Last Interglacial deposits form cliff-veneering apron reefs reaching altitudes of 20-25m and 5-8m respectively (Veeh 1966, Montaggioni 1985). On Mangaia, Southern Cook Islands, Last Interglacial reef limestones (uranium-series dates: 101-135 kyr BP, Spencer et al. 1989) contact Tertiary makatea, and perhaps older Pleistocene limestones, at 14.5m above sea level. Both these islands, like Henderson, are regarded as falling on the crest of the arch in the moat-and-arch response to lithosphere loading and thus should show the greatest degree of tectonic uplift. These predictions appear to be validated by the degree of uplift on islands beyond the radius of the crest of the arch: thus in the atolls of the N.W. Tuamotus Pleistocene *feo* limestones are found at 2-10m above sea level (Delesalle 1985, Pirazzoli 1985, Harmelin-Vivien 1985) and in the Southern Cook Islands deposits as yet undated but provisionally identified as of Late Pleistocene age reach elevations of 12.2m on Atiu, 10.0m on Mauke and 9.8m on Mitiaro (Spencer et al. 1987, 1989). These heights compare with the height of presumed Last Interglacial reefs on Rarotonga, Southern Cook Islands, assumed to be unaffected by tectonic uplift, which reach a maximum altitude of 3.5m above present sea level (Stoddart et al. 1985). Assuming the Last Interglacial limestones on Henderson Island were formed under a sea level at ~13.0m above present sea level at ~120 kyr BP yields an average uplift rate since that time of 9-4 cm kyr^{-1}.

Surprisingly, there is little evidence on Henderson Island for the higher-than-present Holocene sea level of ca. +1.0m between 6,000 and 2,000 yr BP which is so prevalent throughout Polynesia (see Spencer, this volume). The reasons for this may relate to the lack of full reef development around Henderson for there is no sheltered lagoon or intertidal reef flats within which micro-atolls might have developed at, and subsequently reflected, a raised Holocene sea level. In addition, the lack of a modern algal ridge around the island makes the preservation of a fossil algal ridge, as on Suwarrow, Northern Cook Islands (Scoffin et al. 1985), Mangaia, Southern Cook Islands (Yonekura et al. 1986), Reao, eastern Tuamotu Archipelago (Pirazzoli et al. 1987a) and Makatea Island (Montaggioni et al. 1985b), unlikely. Finally, unlike many Polynesian barrier reefs and atolls, there are no obvious sites for the accumulation of conglomerate deposits which may record high sea level stands (Montaggioni and Pirazzoli 1984). It is perhaps to be expected, therefore, that the possible evidence that is present on Henderson for a Holocene high sea level is erosional in nature, in the form of the bevelled ramps which terminate at 2.2-2.4m above present sea level.

CONCLUDING REMARKS

Henderson Island, like many raised reef islands, clearly preserves an important record of climatic, oceanographic and biogeographic change in the south Pacific. What is also clear is that the 1987 expedition was only able to perform a spatially-limited reconnaissance of the structure and topography of the island. It can only be hoped that the geology and geomorphology described here provides a context and a basis for more detailed studies which should be undertaken on Henderson in the coming years.

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Table 1. Fossil corals of Henderson Island

Species	Lo	Fo	Bu	Or	La	Loc
Pocillopora eydouxi		X	X	X	X	H
Pocillopora damicornis					X	P
Pocillopora sp. 1		X				H
Pocillopora sp(p).	X	X	X	X	X	?
Acropora group 1 =						
Acropora hyacinthus					X	T
+*Acropora cytherea*					X	P
+*A.* sp(p).					X	?
Acropora group 2 (= *A.robusta* spp. group)		?		X	X	?
Acropora group 3 (= *A.valida* and/or *A. nasuta*, *A.* spp.)				X	X	?
Montipora spp.			?	?	X	?
Astreopora cf. *moretonensis*		X		X	X	H
Porites cf. *mordax*		X		X	X	T
Porites massive	X	X	X	X	X	?
Psammocora ?obtusangula		X			X	H?
Coscinarea columna		X		X		G
Pavona sp. 1		X		X	X	H
Pavona maldivensis		X			X	H
Fungia scutaria		X	X		X?	P
Fungiid sp(p). other					X	?
Scolymia vitiensis					X	H
Acanthastrea ?echinata				?	X	G
Lobophyllia corymbosa				X		G
Favia stelligera				X	X	P
Favia rotumana			X	X	X	H
Leptoria phrygia			X		X	G
Montastrea curta				X	X	H
Montastrea sp. 1	X	X		X	X	E
Plesiastrea cf. *versipora*		X		X	X	H?
TOTAL: 26	3	14	7	17	23	

Lo: low limestone unit; Fo: fossiliferous reef unit; Bu: core reef buttresses; Or: outer island slope fossils not *in situ*, thus not definitely located stratigraphically; La: central lagoon; Loc: The closest locality from where this species is known today: H: Henderson Island; P: other islands in the Pitcairn Group; T: Tuamotu Archipelago; G: Gambier Islands; E: species presumed globally extinct.

Taxonomic notes:
Pocillopora sp. 1 (= *P.* cf. *verrucosa* of Paulay and Spencer 1989): see Paulay (this volume) for a discussion of this species. *Pocillopora* sp(p). : other *Pocillopora* spp. than listed above, likely includes *P.meandrina*. *Acropora* group 1: large tabloid *A.* species, many not identified to species, includes *A. hyacinthus* and *A. cytherea* listed above, as well as at least 1 additional species. *Acropora* group 2: species with very massive branches, often 5cm+ diameter, most or all in *A. robusta* group. *Acropora* group 3: other *Acropora* species, mostly of corymbose growth form, many not identified to species, includes *A. nasuta* and/or *A.. valida* listed above as well

as other species. *Montipora* spp. : unidentifiable due to poor preservation. *Astreopora* cf. *moretonensis* (= *A.* sp. 1 of Paulay and Spencer 1989): a plate forming *Astreopora*, kindly identified by J E N Veron as *A.* cf. *moretonensis*. *Psammocora ?obtusangula* (= *P.* sp. 1 of Paulay and Spencer 1989): a subarborescent *Psammocora* that appears to be conspecific with *P. obtusangula* collected alive on Henderson; however,it is not sufficiently well preserved to allow for a definite identification. *Pavona* sp. 1 (= *P.* cf. *clavus* of Paulay and Spencer 1989): see Paulay (this volume) for a discussion of this apparently undescribed species. ?Fungiid sp(p): poorly preserved, small specimens of *Fungia* and/or *Cycloseris*. *Montastrea* sp. 1: an apparently extinct species, with second order septo-costae greatly reduced or aborted. *Plesiastrea* cf. *versipora*: fossils have consistently 12 septo-costae while recent specimens are more variable.

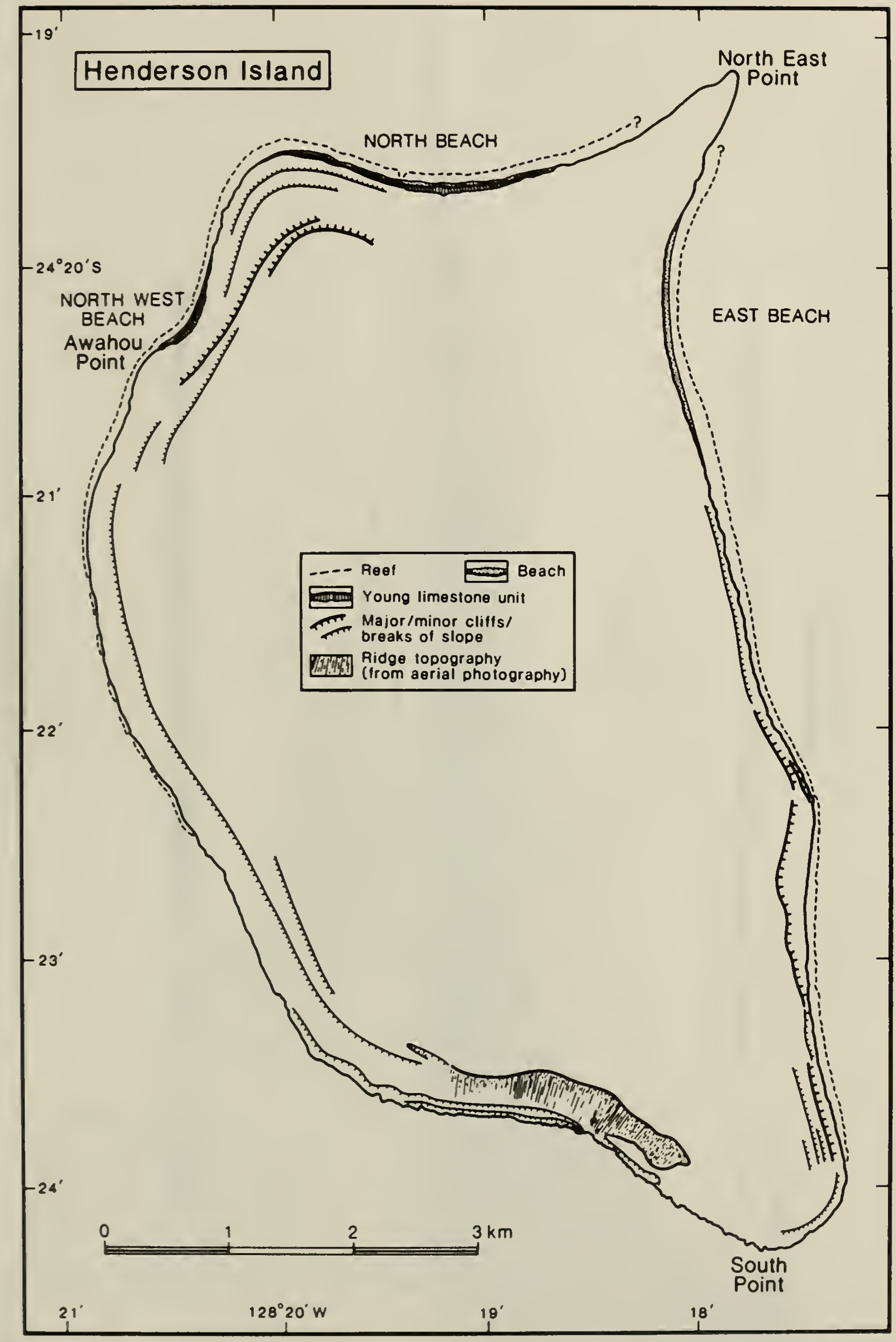

Figure 1. Henderson Island (from aerial photography sortie 035/85 and Admiralty Chart 987 (1953)).

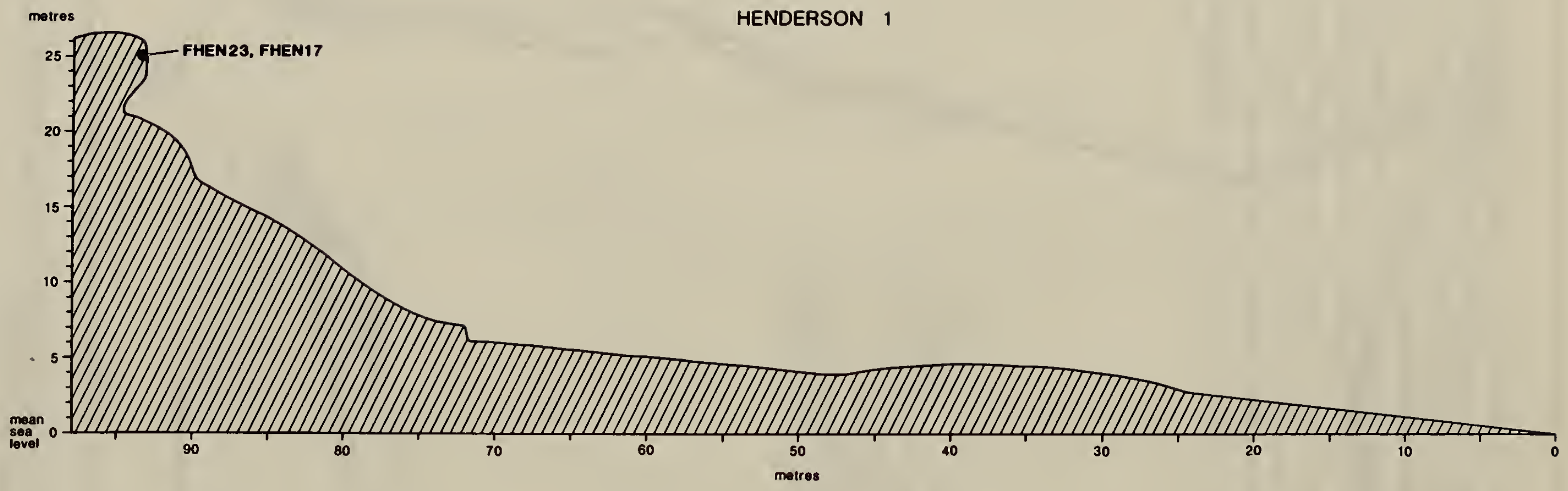

Figure 2. Profile 1, North Beach, Henderson Island (location: see Figure 10).

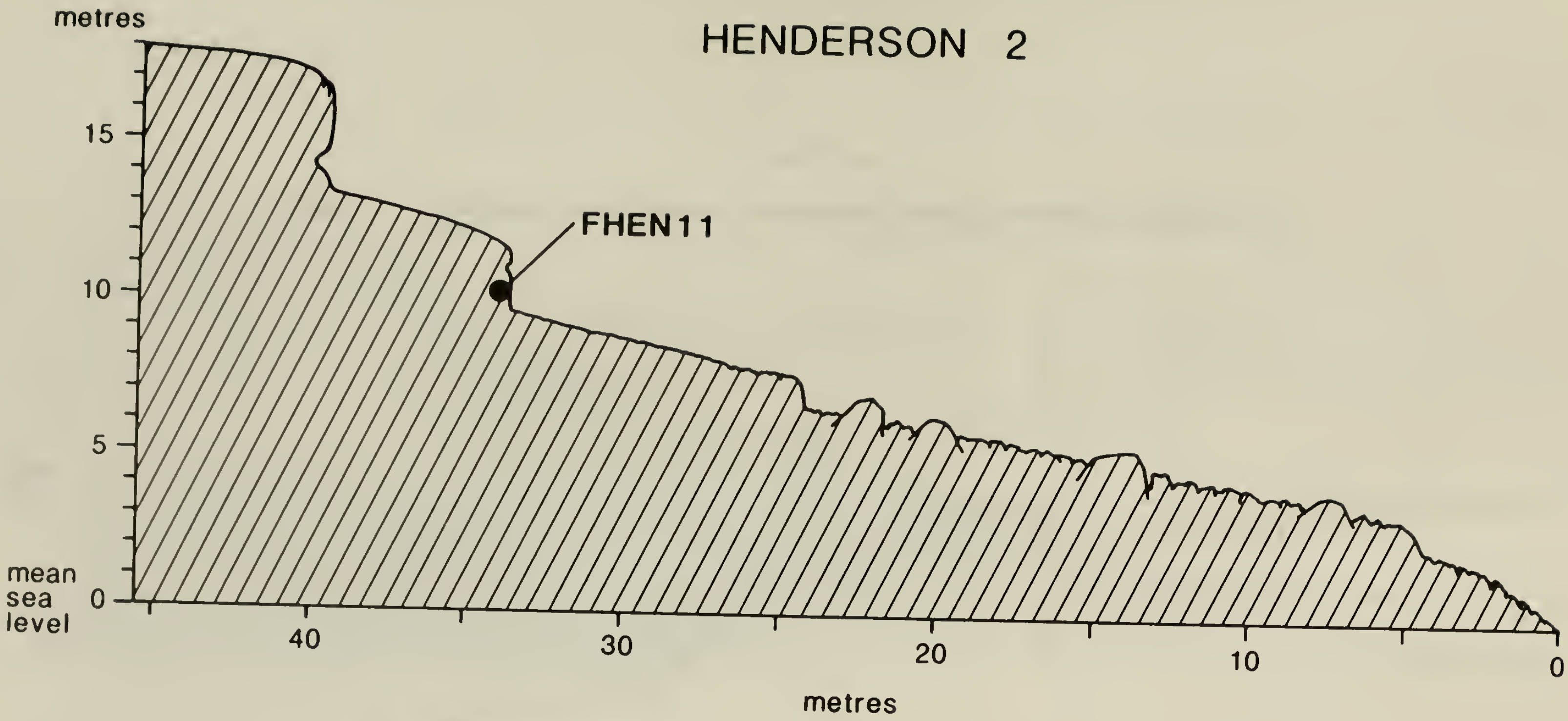

Figure 3. Profile 2, North-west Beach, Henderson Island (location: see Figure 9)

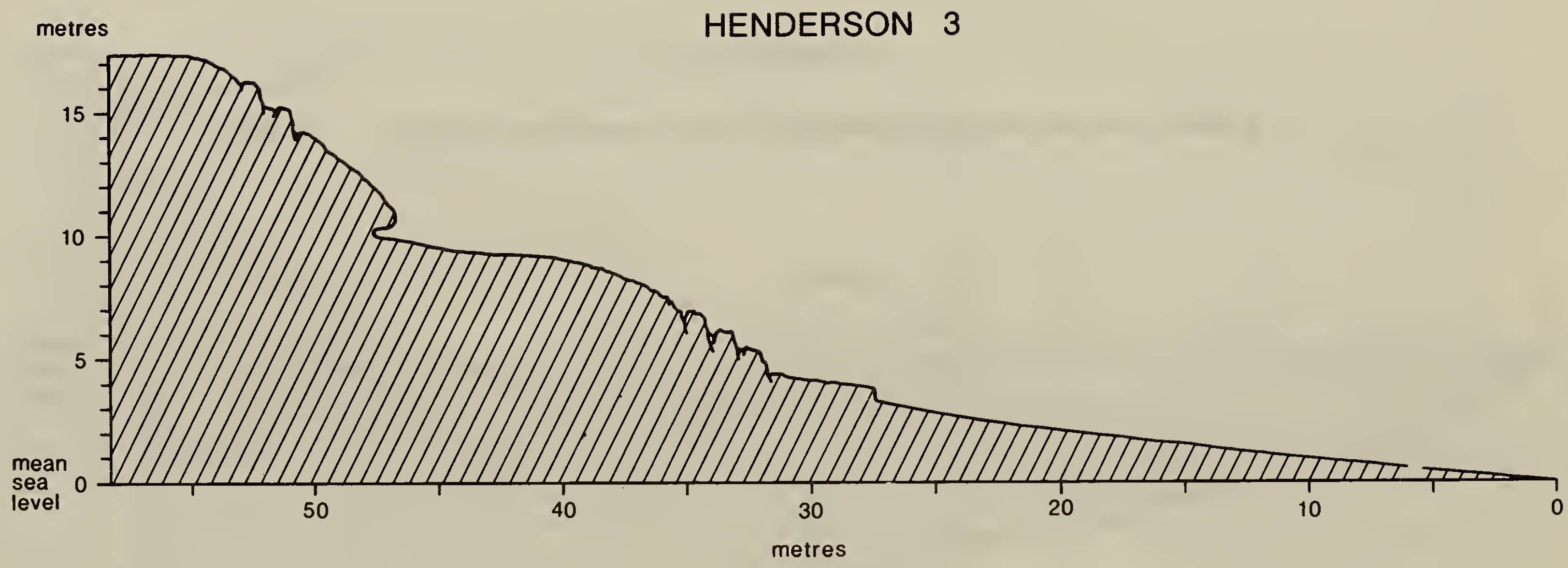

Figure 4. Profile 3, North Beach, Henderson Island (location: see Figure 10).

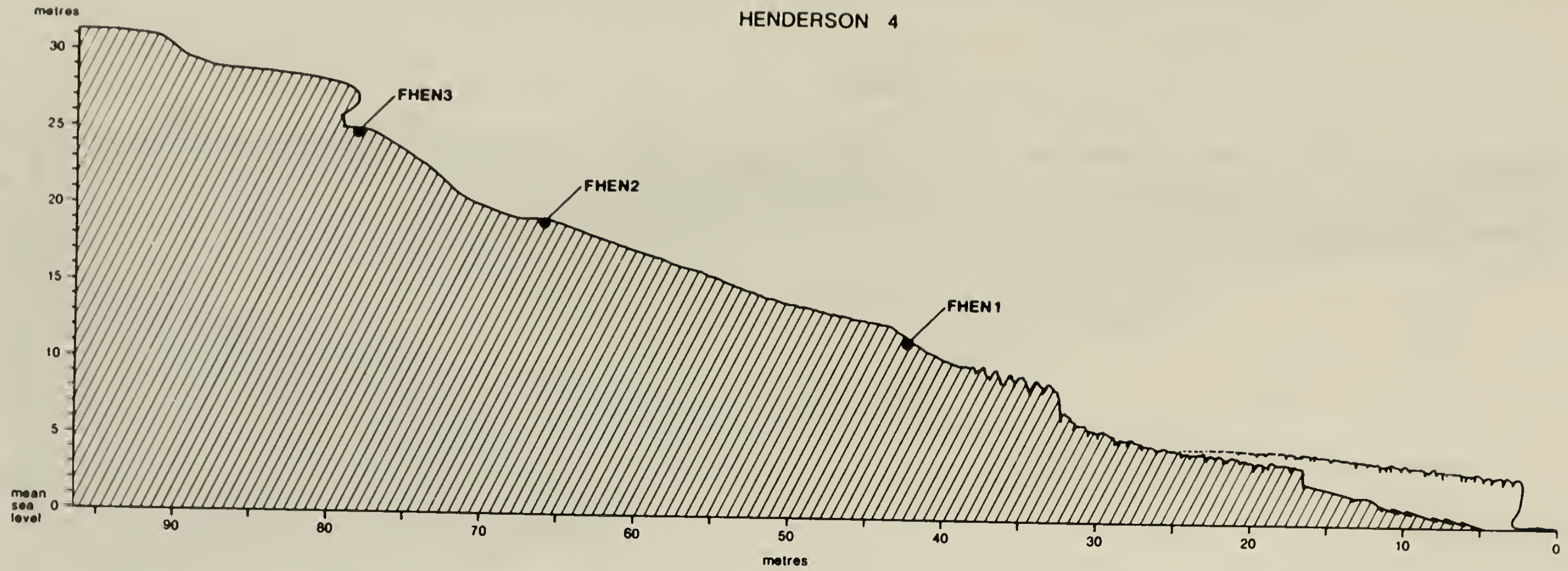

Figure 5. Profile 4, North-west Beach, Henderson Island (location: see Figure 9).

Figure 6. Profile 5, North Beach, Henderson Island (location: see Figure 10).

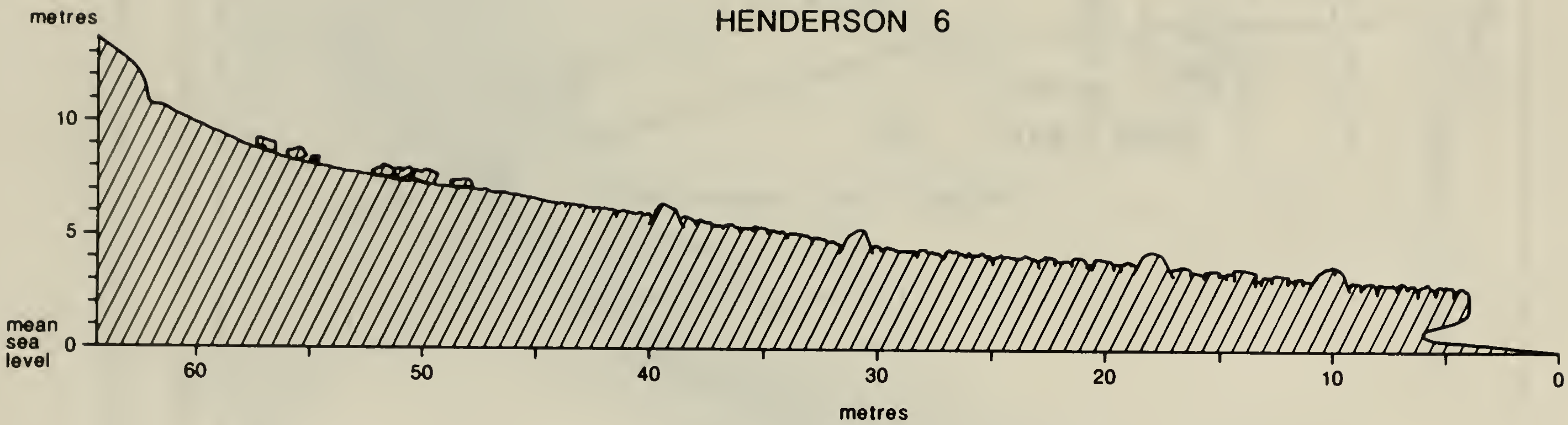

Figure 7. Profile 6, North-west Beach, Henderson Island (location: see Figure 9).

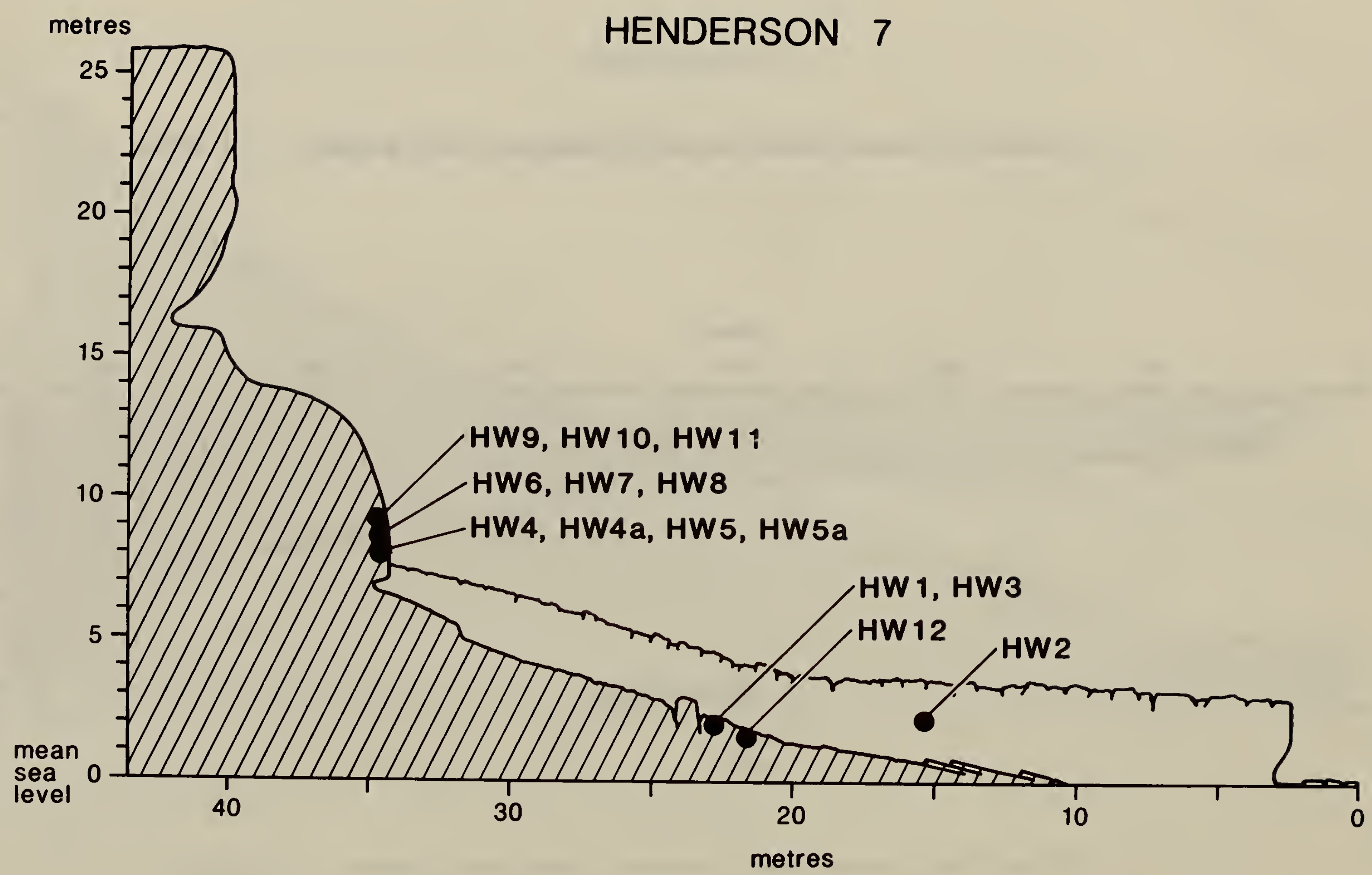

Figure 8. Profile 7, North-west Beach, Henderson Island (location: see Figure 9).

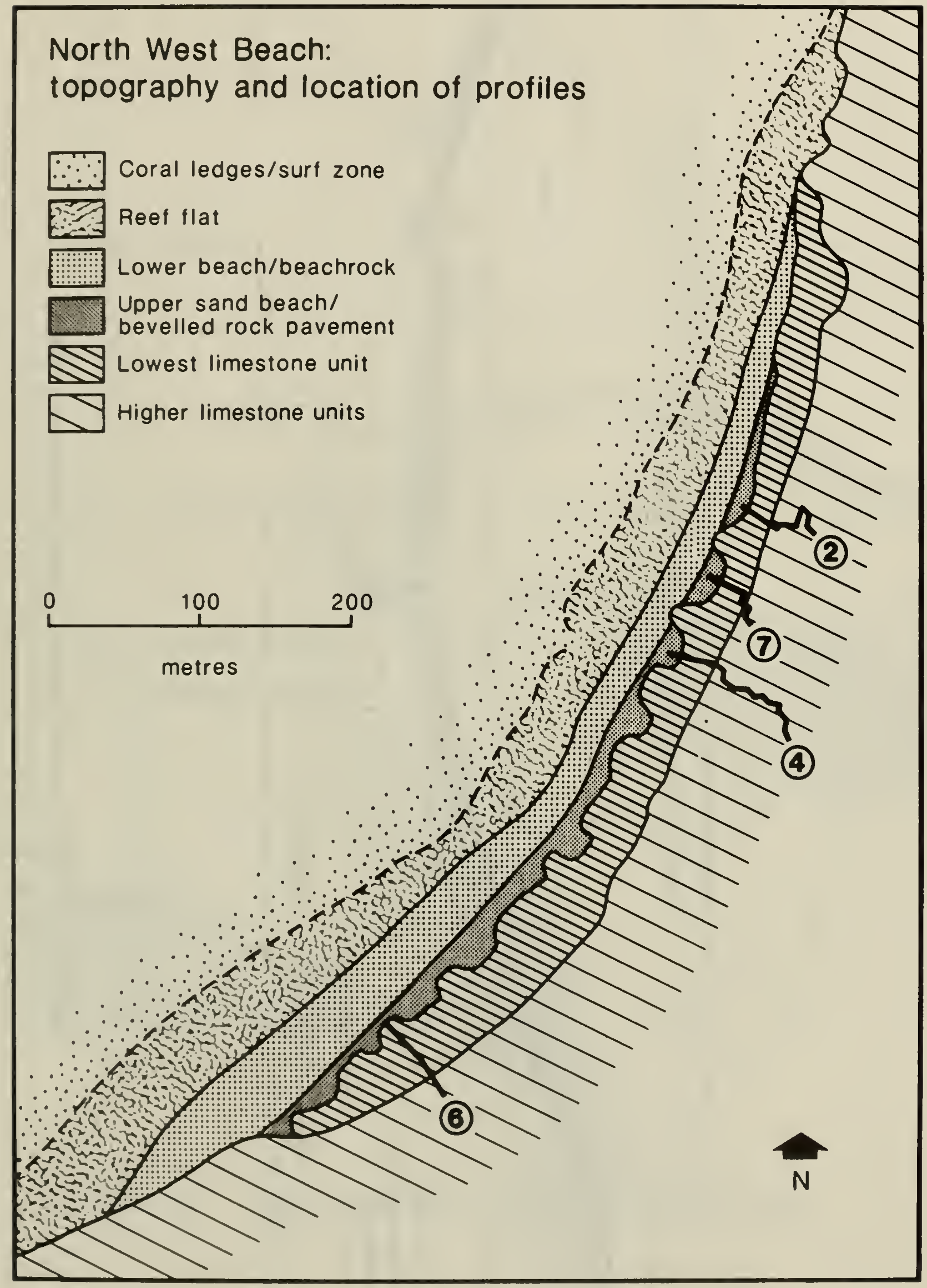

Figure 9. North-west beach: topography and location of profiles.

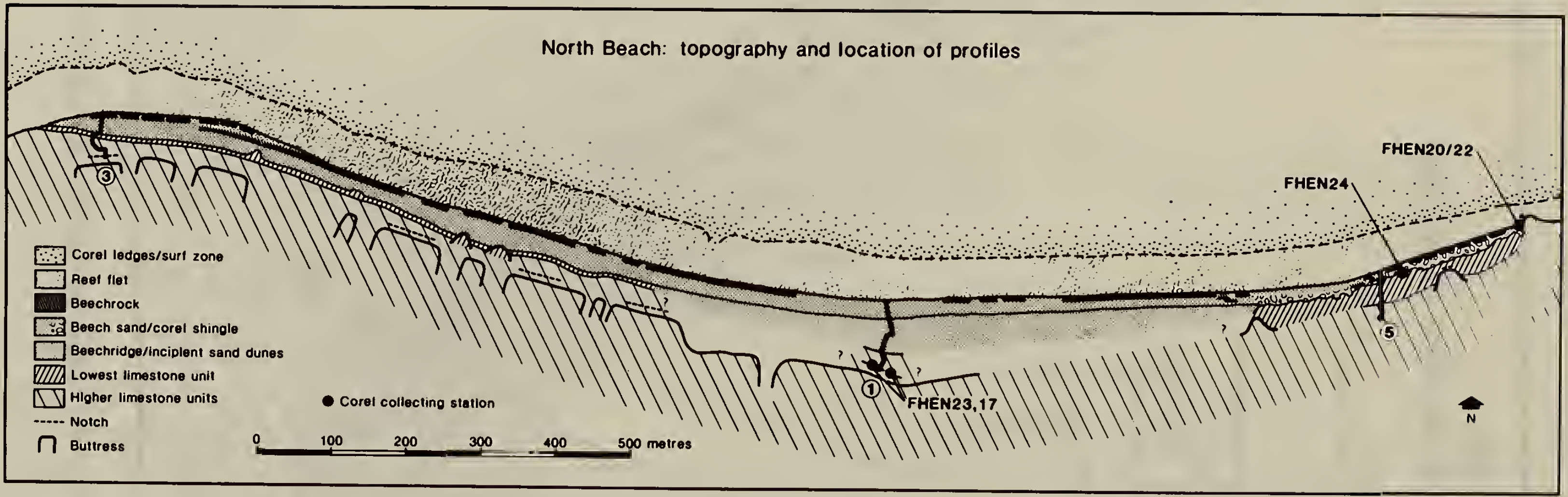

Figure 10. North beach: topography and location of profiles.

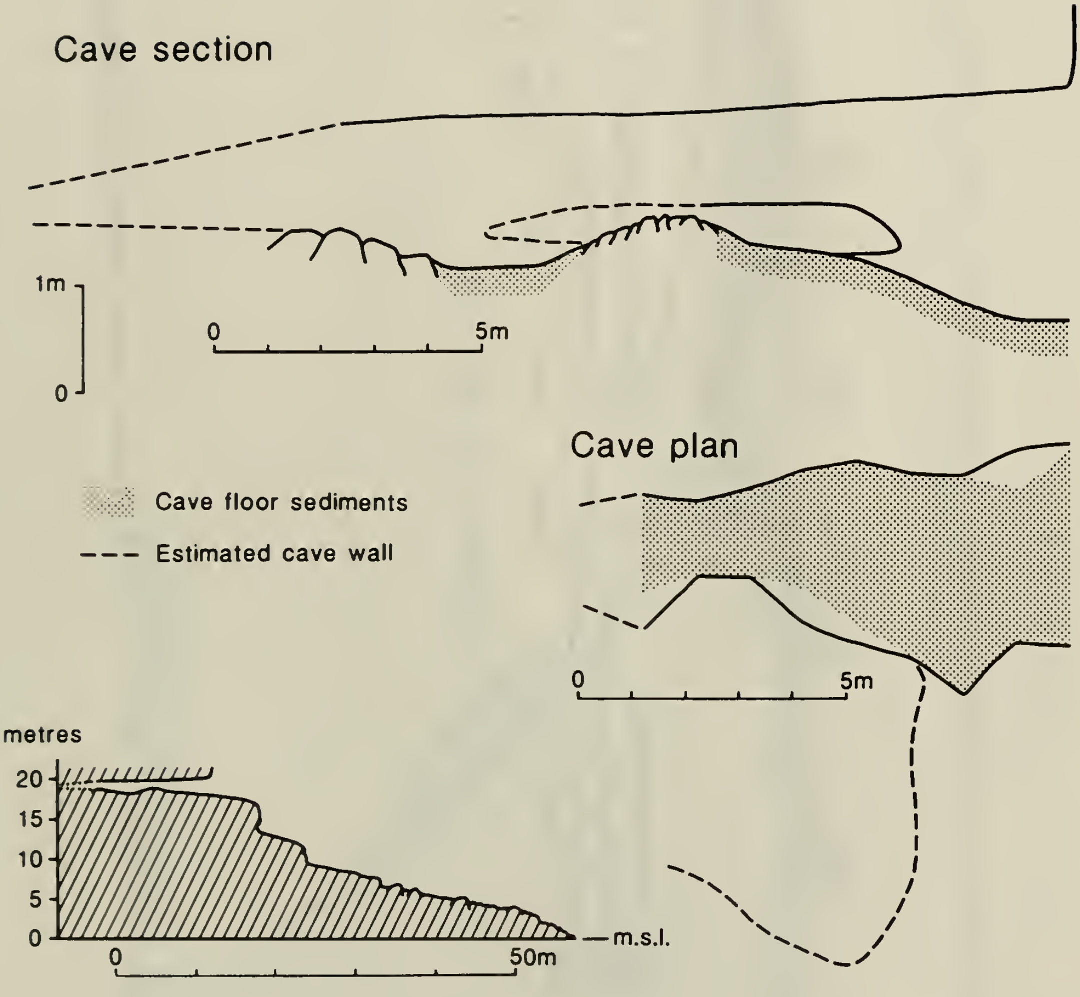

Figure 11. Cave morphometry, profile 2, North-west beach.

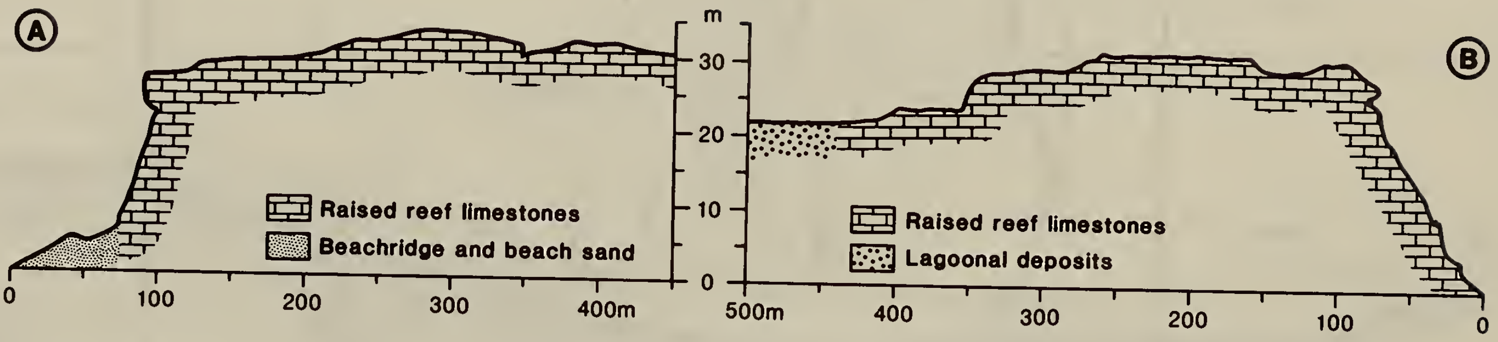

Figure 12. Topographic profiles from island cliff margin to island interior, North (A) and North-west (B) transects.

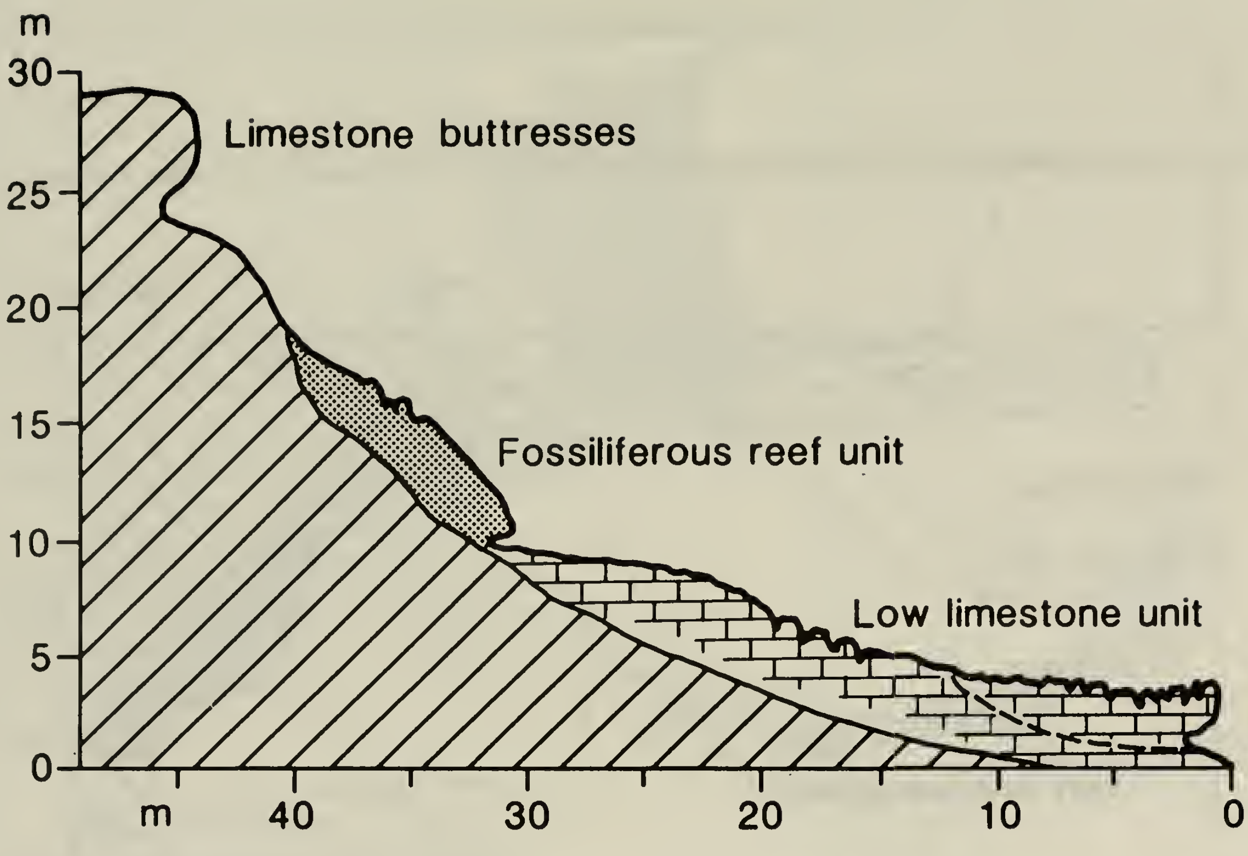

Figure 13. Summary diagram of stratigraphic units and sealevel features in north embayment, Henderson Island.

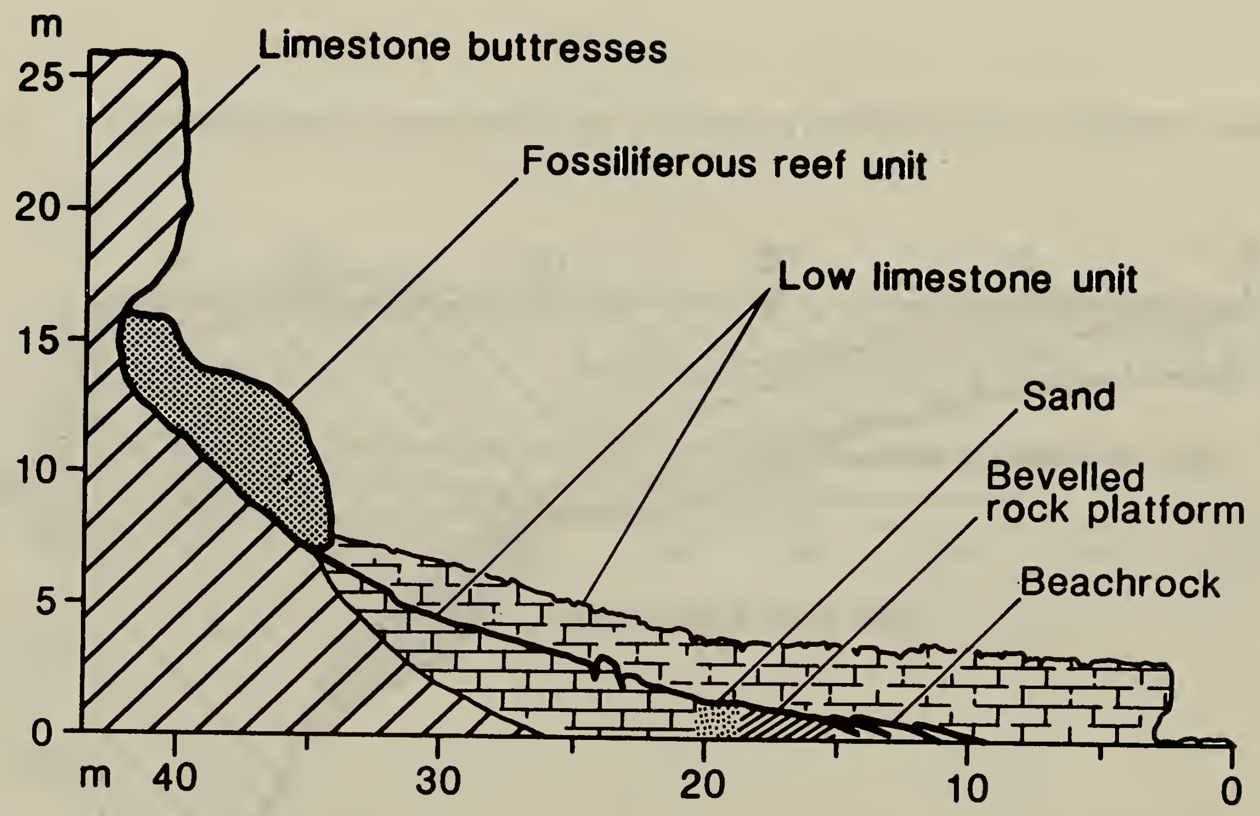

Figure 14. Summary diagram of stratigraphic units and sealevel features in north-west embayment, Henderson Island.

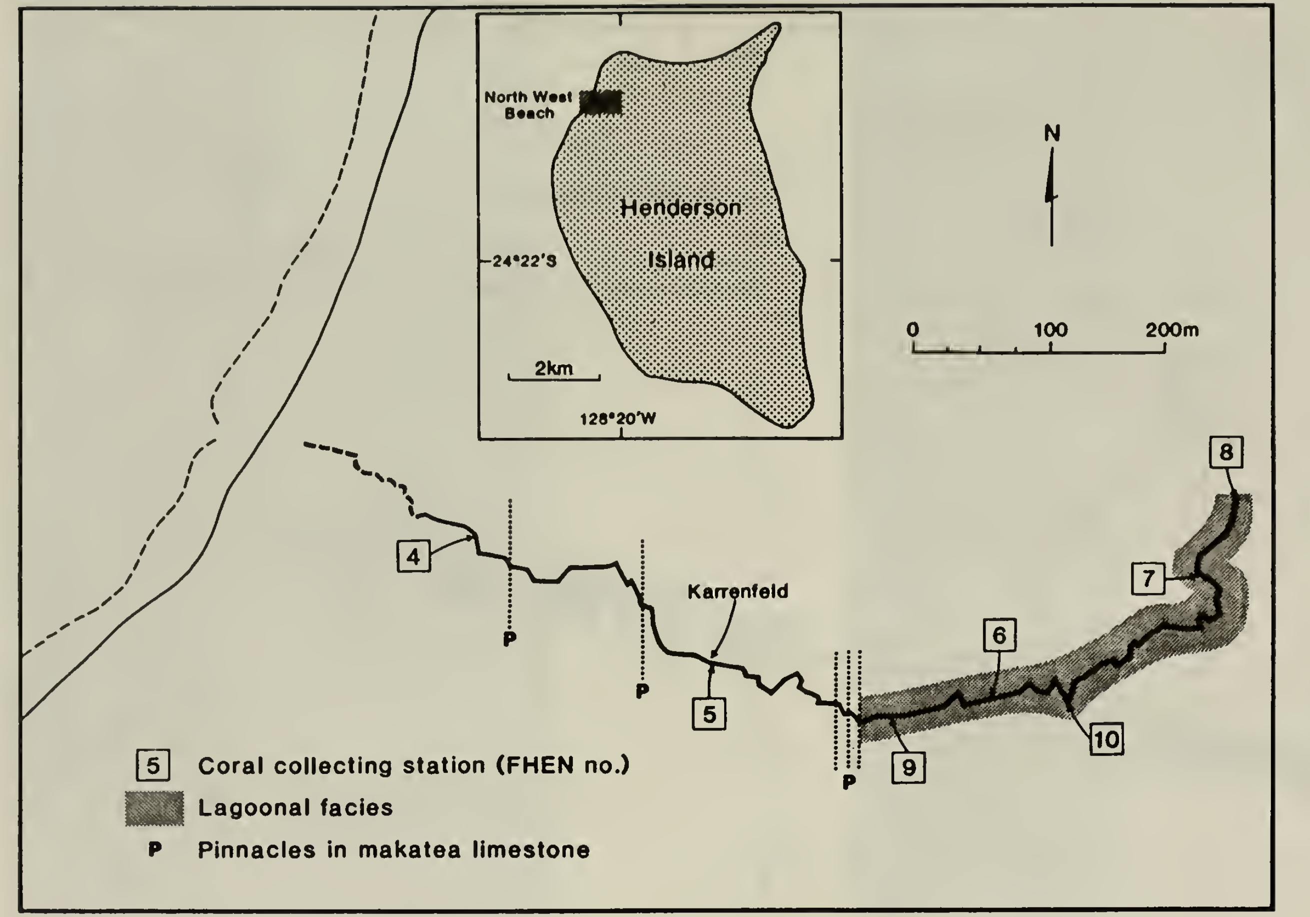

Figure 15. Plan of island cliff margin to island interior transect, North-west beach.

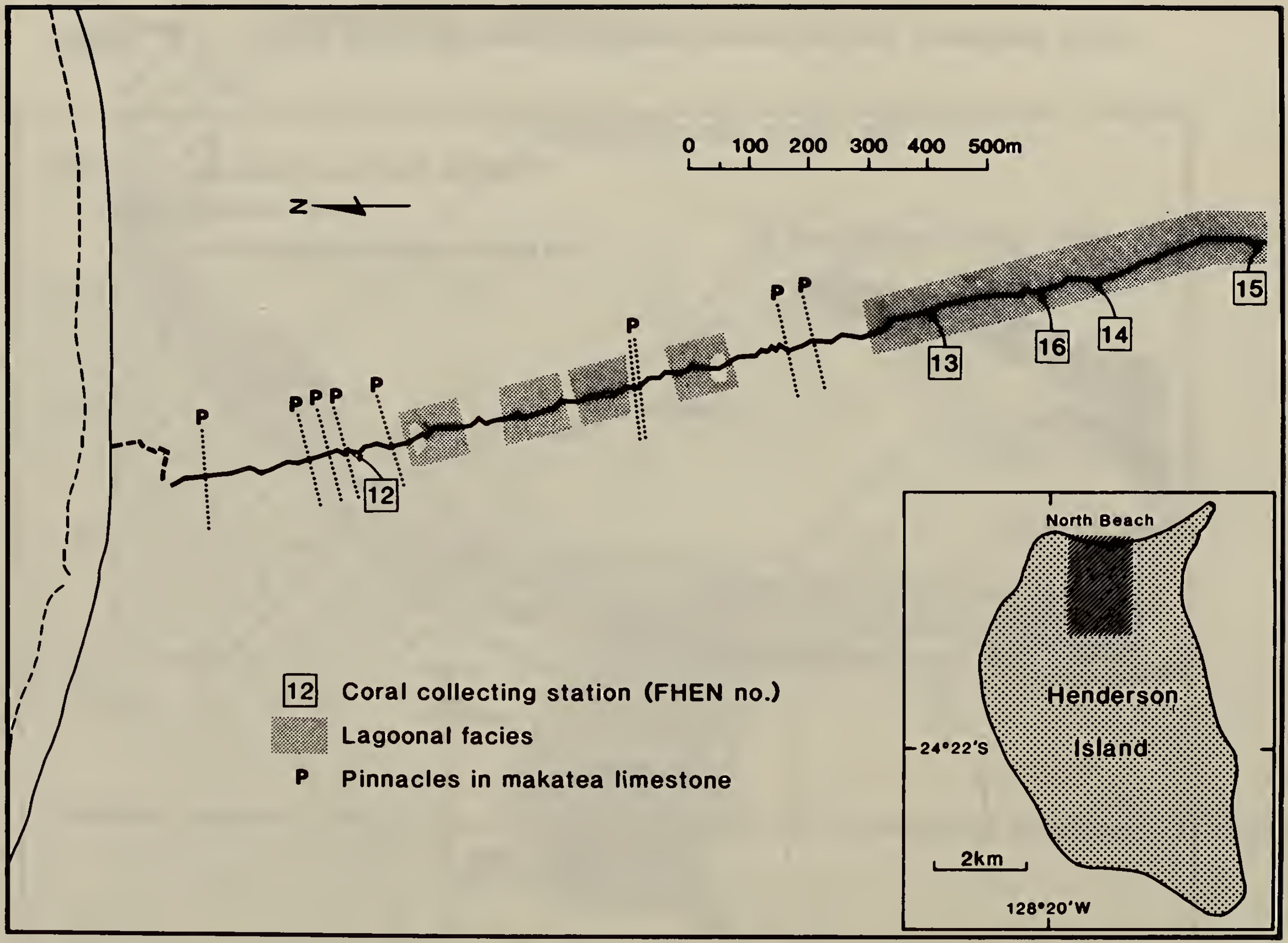

Figure 16. Plan of island cliff margin to island interior transect, North beach.

Plate 1. Western cliffs, looking south-southwest towards the south point.

Plate 2. North-west embayment and beach. Awahou Point at far right.

Plate 3. North-east Point and eastern end of North Beach, approaching Henderson from the north.

Plate 4. Northern end of East Beach and North-east Point, approaching Henderson from the east.

Plate 5. Fore-reef buttress, profile 7, North-west Beach. Notch at 16.2m above mean sea level with fossiliferous reef unit below (in foreground).

Plate 6. *Pocillopora eydouxi* in cliff face, ~ 24m above sea level, central North Beach.

Plate 7. 25m notch, profile 4, North-west Beach. Well-preserved *Acropora* sp. and sand fill in notch.

Plate 8. Coral buttress with notch level at 17-18m above sea level, eastern section, North Beach. Note post-erosional flowstone pillars within notch.

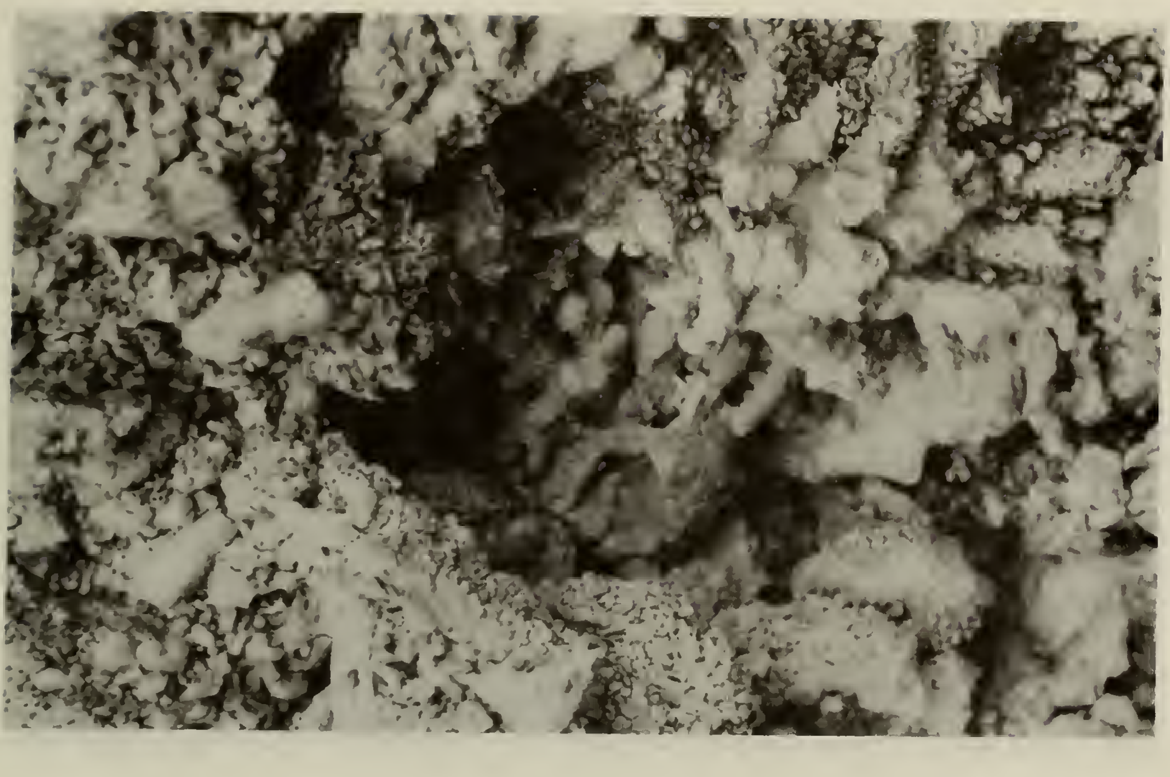

Plate 9. Upper facies, fossiliferous reef unit, eastern end of central section, North Beach.

Plate 10. Headland at western end of North Beach. Note contemporary notch and (at centre) upper boundary of low limestone unit at ~ 10m above sea level. Upper, fossiliferous reef unit and low limestone unit well distinguished in headland profile.

Plate 11. Cliffs to north of North-west Beach. Low limestone unit upper boundary marked by pale contact and large caves/overhangs.

Plate 12. Southern end of North-west Beach. Note low limestone unit as terrace, with spur-and-groove margin, in bay (to left) and as cliff front veneer at bay southern margin (to right). Fossiliferous unit and notch/cave level above with high notch level (see Plate 7) near cliff top.

Plate 13. Groove exit in low limestone unit, eastern end of central section, North Beach. Note massive *Montastrea* sp.1 colony to left and similar colonies on groove floor.

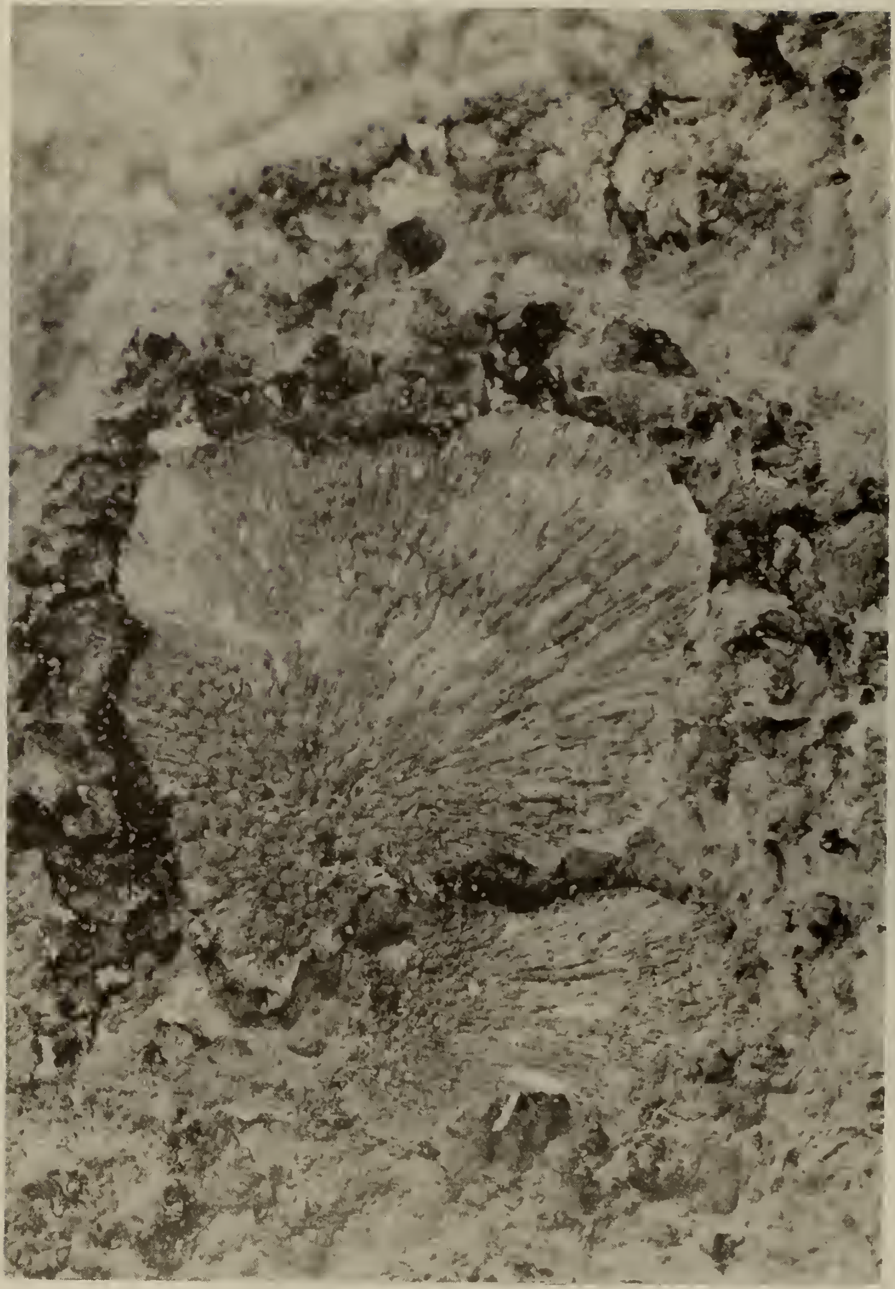

Plate 14. *Montastrea* sp. 1 in bevelled ramp, North-west Beach.

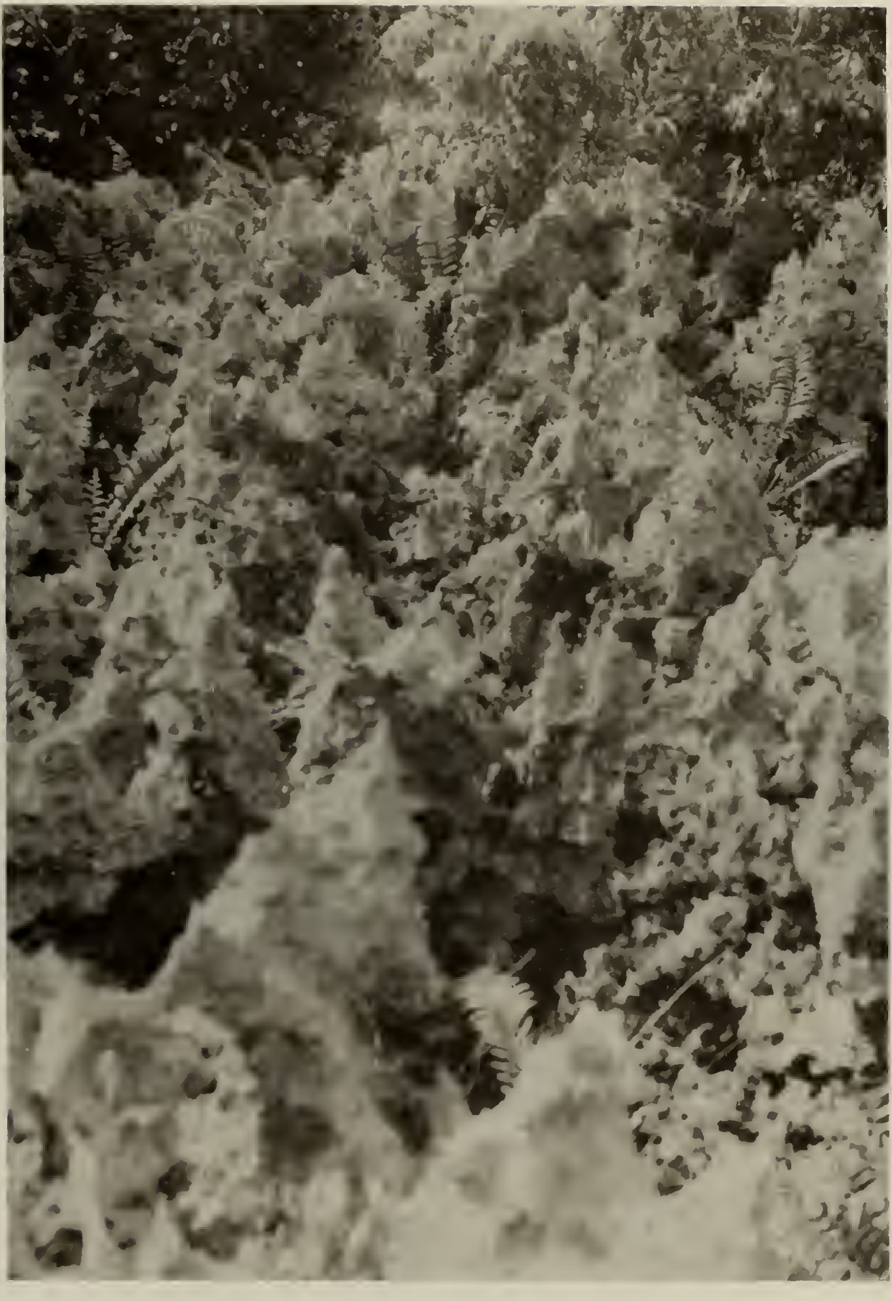

Plate 15. Pinnacle-pitted limestone on transect to island interior from the North-west Beach.

Plate 16. Massively branching *Acropora* (group 2) colony, near interior lagoon margin, North-west Beach. (Scale bar: 50 cm.)

Plate 17. *Montastrea* sp.1 with *Acropora* sticks, interior lagoon deposits, North-west Beach. (Scale bar: 50 cm).

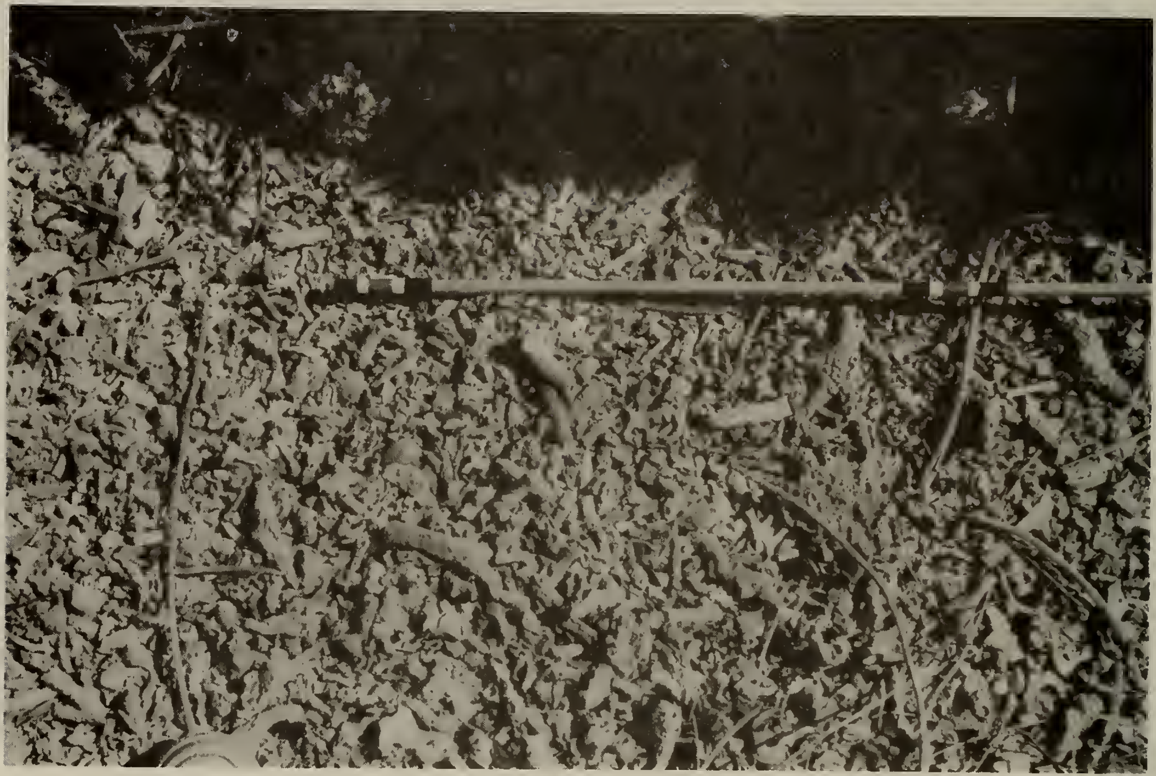

Plate 18. *Acropora* rubble of lagoonal patch reef, North Beach. (Scale bar: 50cm).

ATOLL RESEARCH BULLETIN

NO. 324

SEDIMENTS AND SEDIMENTARY ENVIRONMENTS OF HENDERSON ISLAND

BY

T. SPENCER

APPENDIX: FORAMINIFERAL COMPOSITION OF HENDERSON ISLAND BEACH SAND

BY OWEN GREEN

ISSUED BY
NATIONAL MUSEUM OF NATURAL HISTORY
SMITHSONIAN INSTITUTION
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OCTOBER 1989

SEDIMENTS AND SEDIMENTARY ENVIRONMENTS OF HENDERSON ISLAND

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T. SPENCER [1]

APPENDIX: FORAMINIFERAL COMPOSITION OF HENDERSON ISLAND BEACH SAND

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ABSTRACT

Sediment samples from fore-reef, beach face and incipient sand dune/sand sheet environments on Henderson Island show a wide range of sediment sizes and a restricted composition dominated by coral debris, molluscan fragments and, in certain size bands, benthic foraminifera. These characteristics reflect regional biogeographical gradients and local reef structure and development.

INTRODUCTION: SEDIMENTARY ENVIRONMENTS

The contemporary fringing reef at Henderson Island is restricted to a narrow reef flat, which lacks a well defined seaward margin, and a fore-reef which slopes steeply offshore.

There is no algal ridge margin to the reef edge at Henderson; rather, waves break on a series of seaward-sloping coral ledges which remain shallowly submerged at low tide. Natural breaks in these ledges provide rudimentary passages onto, rather than through, the lagoons of the north, and more particularly the north-west, beaches. The reef lagoon at Henderson varies in width from 20-50m at the north-west beach to 40-75m at the north beach. Estimates from aerial photography suggest maximum lagoon widths of closer to 100m offshore from the east beach. The reef flat consists of a smoothed reef plate, runnelled and potholed in places, largely devoid of sediment except for local aggregations around the few reef flat rocks. Large blocks on the reef flat between the north and north-west beaches are the product of limestone cliff retreat rather than storm coral blocks removed from the fore-reef slope.

The early bathymetric observations made in 1825 by H.M.S Blossom under the captaincy of F.W. Beechey (see Fosberg et al. 1983) reported that the shallowest coral ledge terminates 46m (= 50 yards) from the north beach at a water depth of 5.5m (= 3 fathoms). This surface is followed by a second ledge reaching a depth of 46m (= 25 fathoms) 183m (= 200 yards) from the beach slope - lagoon margin. To seaward of this second terrace water depths in excess of 366m (= 200 fathoms) are encountered. SCUBA observations by G Paulay (pers. comm., 1988) indicates a steeply-sloping uninterrupted fore-reef slope grading into a mobile slope of sand and coral rubble at ~ 40m. Sand channels, between reef spurs, form about half of the bottom cover on the north-west shore at -10 to -15m but they are much less prevalent off the north shore. Coral cover is low; about 6 per cent at 10m depth offshore from the north beach, and live corals are almost entirely restricted to the outer reef slope. Most of the reef surface is covered by an algal turf with living corals accounting for less than 10 per cent of the surface cover. To date, 36 species of scleractinians have been identified (G. -

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Paulay pers. comm., 1988): *Millepora* sp. dominates shallow water environments to depths of -5 to -10m, while deep water zones are characterised by an abundance of *Pocillopora* spp., especially *P. meandrina* and *P. eydouxi*.

The beaches of Henderson can be divided into the long, relatively broad beaches of open aspect on the central northern and eastern shores and the small pocket beaches, backed and flanked by low limestone outcrops, of the north-west coast and the eastern sections of the north beach. On the central north shore, the beach can be divided into a lower foreshore dominated by beachrock and poorly sorted sands and an upper, planar beach, 10-17m in width, characteristically with a 6^0 slope and backed by a beachridge, presumably the result of storm washover processes. At the eastern end of the central north beach, where the reef edge is closest to the shoreline, and the beach is composed of broken beachrock flags and coarse coral rubble banked up against low limestone outcrops (Plate 1). At the western end of the same beach, incipient sand dunes or low sand sheets are found between the limestone cliffs and the beach sands.

Beachrock is present on the landward reef flat margin of both the north and north-west beaches. It is particularly extensive, however, on the north beach where massive and runnelled seaward-dipping plates may reach 0.5m in height and 10m in width. The presence of this beachrock zone on the north beach suggests widespread contemporary beach retreat (Plate 2).

Fore-reef, beach and incipient sand dune/sand sheet environments can thus be provisionally identified at Henderson Island. This paper pursues the quantitative description, in terms of both grain-size distribution and compostion, of sediments from these three sedimentary environments.

METHODS

Nine surface sand samples were collected from the north and north-west beaches and two samples were collected from the north beach on SCUBA dives; sample locations are shown in Figure 1.

Following Stoddart (1978), grain size analyses of each pre-treated, split sample were made using standard sieves, a mechanical shaker and a sieving time of 15 minutes. The results, expressed as percentages by mass in each phi (ϕ; $-\log_2$ particle diameter in millimetres transformation) interval of the size range, were used to construct cumulative sediment-size curves and from these curves general statistics of sediment characteristics were derived.

The samples were subsequently amalgamated to half phi (ϕ) intervals for the determination of component composition by point counting on a binocular microscope stage. 200-300 grains were counted per size fraction, in excess of 9500 grains being enumerated in total for all eleven samples. All constituents were assigned to component classes down to a grain-size diameter of $+1.0\phi$ (0.50mm); the abundance of easily-identifiable components were counted as a percentage of the total sample to a grain-size diameter of $+2.0\phi$ (0.25mm).

SEDIMENT SIZE DISTRIBUTION

Table 1 lists the standard Folk and Ward statistics (Stoddart 1978) for mean size, sorting, skewness and kurtosis (M_Z, σ_I, Sk_I, K_G) from the fore-reef, beach and incipient dune environments. The cumulative frequency curves from which these statistics were derived are shown in Figures 2-3.

The fore-reef sediments exhibit a wide range of sediment sizes, indicating little post-production transport of a wide variety of source materials (Figure 2). The beach sediments are variable in composition and are comprised of coarse sands, coral shingle and admixtures of these two sediment types. Both environments show similar grain-size distributions, with a range in mean size from the Wentworth class of pebble (>2.0ϕ) to that of coarse sand (>+1.0ϕ). Neither environment contains sediment in the silt/clay classes and, in all cases, less than 0.1 per cent of the total sample mass can be attributed to sediment sizes finer than +2.75ϕ (0.15mm). This observation supports McLean and Stoddart's (1978) assertion, from the northern Great Barrier Reef, that +3.0ϕ (0.125mm) rather than the usual +4.0ϕ (0.063mm) is a more appropriate division between sands and fines in reef island sediments. Either fines are not produced in abundance at Henderson or they are efficiently transported seawards out of the fringing reef system. In spite of this truncation of the grain-size distribution, the range of sediment sizes leads to very poorly to only moderately well sorted fore-reef and beach deposits (Table 1). The very coarse sands generally show the poorest sorting as their mean size reflects the admixture of a particular wide range of particles size and sorting (Figure 4). Both the fore-reef and the majority of beach sediments exhibit a coarse tail to their grain size distributions; in the absence of fines, negatively-skewed samples are, therefore, most characteristic. By comparison, the incipient small sand dunes and sand sheets on the north beach are chiefly distinguished by the lack of such a coarse tail to their particle size distribution (Figure 3) and are thus composed of well-sorted, weakly-skewed medium sands (Table 1). The lack of both coarse and fine sediments and the predominance of medium sands supports an aeolian origin for these deposits.

SEDIMENT COMPOSITION

The coarse nature of the Henderson Island sediments is reflected in the dominance of coral blocks and sticks, and smaller fragments, in all sedimentary environments. The other important consituents are the tests of benthic foraminiferans and molluscan whole shells and fragments, with algal constituents, including *Halimeda*, forming a component of lesser significance. Echinoid debris, coralline red algae and lithoclasts are of minor importance. The gross composition of the Henderson Island sediments is compared to compositional characteristics from some Indo-Pacific atolls and the Great Barrier Reef in Table 2.

DISTRIBUTION OF SEDIMENT COMPONENTS

CORAL: Coral debris is of particular importance in the larger >0ϕ (>0.1mm) size fractions where it accounts for over 50 per cent of sediment volume in the shallow (-12m) fore-reef and beach environments (Figure 5). It is also a significant component at finer grades and it is only on the deep (-30m) fore-reef, in the 0ϕ - +1.0ϕ (1.00 - 0.50mm) particle size range, that it ceases to be the major sediment constituent.

MOLLUSC: Molluscan fragments invariably account for in excess of 10 per cent of the sediment composition by volume (Figure 5). There appears to be an approximately even distribution of gastropod and bivalve debris, although with a greater preponderance of fractured bivalve shells in the larger size fractions. Small yet intact turreted gastropods are characteristic of -0.5ϕ - 0ϕ (1.41 -1.00mm) fore-reef sediments at -12m.

BENTHIC FORAMINIFERA: The tests of these organisms account for between 12 and 31 per cent of the overall sediment composition by volume at Henderson; they are particularly important in the 0ϕ - +1.0ϕ size fractions (Figure 5). Certain tests show little breakage by comparision with other constituents and thus the foraminiferal contribution often mirrors the relatively narrrow size distribution of the original, living population. Although 25 species of foraminifera have been described from Henderson (see Appendix) only 4 of these species have been found to be volumetrically important. The whole tests of the discoid *Marginopora vertebralis* (Quoy and Gaimard) are characteristic of the -2ϕ to -1.5ϕ (4.0 - 2.83mm) size fraction on the island fore-reef where they may account for over 60 per cent of the sediment volume in narrow, dune-rippled sand channels (e.g. sample H10, -12m). In addition, broken *Marginopora* plates locally form an important component of the total composition at grain sizes of +1.0ϕ diameter and the species is found in +2.0ϕ sediments (Figure 5). The yellow-brown *Amphistegina lessonii* (d'Orbigny) is an important contributor to sediment composition in the 0ϕ - +1.0ϕ size range where it forms never less than 20, and frequently more than 40, per cent of the sediment volume. Fractured tests of *Amphistegina* are not common in, but nevertheless do contribute to, the finer size fractions (Figure 5). A quantitatively less important foraminiferan, but one which is frequently found in association with *Amphistegina* and mirrors its patterns of abundance, is *Asterigerina carinata* (d'Orbigny). The distinctive red foraminiferan *Homotrema rubrum* (Lamarck) is particularly abundant at site 1 (see Appendix) but a less important sediment component in the larger size fractions elsewhere. It is present in both discrete and encrusting forms. Other benthic foraminifera noted as being of occasional abundance include *Heterostegina depressa* (d'Orbigny), *Trioculina* sp. (d'Orbigny), *Quinqueloculina* sp. (d'Orbigny) and *Amphisorus* sp. (Ehrenberg).

CORALLINE RED ALGAE: In the absence of a true 'algal ridge' margin to the Henderson reef, the percentage of coralline red algae within the sediments is always less than 5 per cent. Nearly all the red algal sediment consists of encrustations on carbonate grains; free, articulated coralline red algae are rare. It seems likely that coralline algae are competitively smothered by the abundant fleshy algae of the algal turf, this abundance in turn being explained by low levels of herbivory (G. Paulay, pers. comm.).

HALIMEDA: The lack of a substantial contribution to sediment composition by *Halimeda* is worthy of comment. Hillis-Colinvaux (1980) has suggested, contentiously, that *Halimeda* both avoids subtropical water temperatures and is a poor dispersalist to remote areas, factors which would explain its rarity at Henderson. In biogeographic terms, it is difficult to predict the expected diversity of *Halimeda* at Henderson: Easter Island has one reported species (Hillis-Colinvaux 1980) whereas Moorea, Society Islands supports at least seven species in the lagoon alone (Payri 1988). If *Halimeda* is not excluded from Henderson by temperature or isolation, then the thick algal turf may limit its abundance through competition (G. Paulay pers. comm).

LITHOCLASTS: Grey lithoclasts derived from the erosion of the limestone cliffs of the island are found in small proportions within all three sedimentary environments and across the range of sediment sizes.

ENVIRONMENTAL DISCRIMINATION AND SEDIMENT COMPOSITION

In terms of overall sediment composition there is little variation between the fore-reef, beach and incipient dune environments (Table 3), apart from the differing relative contribution of the coral and, to a lesser extent, the benthic foraminiferan components; they form volumetrically more important components in the beach environment. In the >0ϕ size fraction, coral fragments are of lesser importance in the incipient dune environment than on the fore-reef and beach, probably because the relatively large size and high bulk density of this component is not conducive to aeolian transport. In the +0.5ϕ - +1.0ϕ size range, the major contribution of benthic foraminifera, largely a function of the abundance of *Amphistegina*, distinguishes the beach environment. In addition a carfeul study of the fore-reef statistics reveals that bentic foraminifera in total, and *Amphistegina* alone, account for 42.7 and 27.9 per cent respectively of sediment volume at shallow (-12m) depths. Field studies elsewhere have shown that large foraminifera are characteristically associated with shallow reef-front and reef flat algal meadows and that the distribution of foraminiferal detritus closely follows that of the living fauna (e.g. Heron Island, Great Barrier Reef: Jell et al. 1965). It seems likely that the foraminiferal sediment component at Henderson is derived from similar algal bed source areas, the relatively small and low bulk density test (Maiklem, 1970) being easily transported to the beach and locally concentrated at the swash line (Stoddart and Steers 1977). Environmental discimination is difficult in the +1.5ϕ - +2.0ϕ size fraction. However, it is clear that while benthic foraminifera contribute to sediment composition in the fore-reef and beach environments in these finer grades they are absent from the incipient dune sediments, probably because the tests are more suited to wave rather than aeolian transport.

CONCLUSIONS

Carbonate sediments in reef environments are derived almost entirely from reef organisms. The characteristics of these sediments reflect i) the availability of source organisms, which are controlled locally by ecological, and regionally by biogeographical, constraints, and ii) the subsequent breakdown patterns of these organisms which are determined by skeletal durability and micro-architecture. Actual sedimentary environments further reflect the interaction of these species - specific attributes with modes of transportation and local energy conditions. The combination of low biotic diversity, from a province-marginal location in the Indo-West Pacific province, and a simple reef structure yields a relatively restricted range of source materials for sediments at Henderson Island. Furthermore, the narrowness of the reef flats does not allow for great differentation of sediment sizes and components by the sorting action of transport processes. The net result at Henderson is a suite of locally-derived, poorly-sorted, wide size-range sediments, with relatively few components.

ACKNOWLEDGEMENTS

I am grateful to Gustav Paulay for the collection of sediments samples H10 and H11 and to Susan Schubel for sample H9. Gustav Paulay also kindly supplied information of fore-reef morphology and provided insights into the biogeography and ecology of *Halimeda*. I am indebted to Paul Wilson for the laboratory analyses for grain-size distributions. Compositional information on the samples would not have been possible without the help and advice of Sandy Tudhope, Tony Greer and, in particular, Owen Green.

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APPENDIX : FORAMINIFERAL COMPOSITION OF HENDERSON ISLAND BEACH SAND

Owen Green[1]

Site location: Beach location 1 (see Figure 1)

Foraminiferal component by weight : 2.73 per cent (from 4.43 g sample).

SUPERFAMILY	FAMILY	No. of frags	%	F%	SF%
Textulariacea	Textulariidae				
	Textularia ?mayori	2	0.19		
				0.19	0.19
Tawitawiacea	Tawitawiidae				
	Tawitawia sp.	1	0.09		
				0.09	0.09
Lituolacea	Lituolidae				
	Triplasia sp.	4	0.38		
				0.38	0.38
Miliolacea	Miliolidae				
	Spiroloculina antillarum	1	0.09		
	Spiroloculina sp.	2	0.19		
	Quinqueloculina bidanta	2	0.19		
	Quinqueloculina polygona	7	0.67		
	Cruciloculina triangularis	7	0.67		
	Triloculina sidebottomi	23	2.19		
	Triloculina sp.	24	2.29		
				6.29	6.29
Soritacea	Peneroplidae				
	Peneroplis pertusus	1	0.09		
				0.09	
	Soritidae				
	Amphisorus sp.	13	1.24		
	Marginopora vertebralis	153	14.60		
				15.84	
	Alveolinidae				
	Borelis pulchra	1	0.09		
				0.09	0.09

SUPERFAMILY	FAMILY	No. of frags	%	F%	SF%
Discorbacea	Discorbidae				
	Discorbis ?mira	2	0.19		
	Tretomphalus atlanticus	5	0.48		
				0.67	0.67
Planorbulinacea	Cibicididae				
	Cibicides ?lobatulus	5	0.48		
				0.48	0.48
Asterigerinacea	Asterigerinidae				
	Asterigerina carinata	196	18.70		
				18.70	
	Amphisteginidae				
	Amphistegina lessonii	269	25.67		
				25.67	44.37
Cassidulinacea	Anomlinidae				
	Anomlinella rostrata	5	0.48		
				0.48	0.48
Acervulinacea	Homotrematidae				
	Homotrema rubrum	320	30.53		
				30.53	30.53
Rotaliacea	Rotaliidae				
	Ammonia becarri	1	0.09		
				0.09	
	Elphidiidae				
	Elphidiella sp.	1	0.09		
				0.09	0.09
Nummulitacea	Nummulitidae				
	Heterostegina depressa	2	0.19		
	Eponides repandus	1	0.09		
				0.28	0.28
	TOTALS	1048	99.96		

---

[1] Department of Earth Sciences, Goldsmith's College, University of London, London SE8 3BU, UK.

Location	Environment	Sample	D_{50}	M_Z	σ_I	Sk_I	K_G
North Beach	Beach face	H1	-0.39	-0.26	1.01	+0.21	0.88
	Beach face	H2	-1.70	-1.71	0.71	+0.10	1.30
	Beach face	H3	+1.18	+0.91	1.44	-0.52	1.81
	Incipient dune	H4	+1.77	+1.71	0.42	0.16	1.01
	Beach face	H5	+0.36	-0.51	2.14	-0.45	1.25
	Beach face	H6	+0.36	-0.83	2.51	-0.54	1.37
	Beach face	H7	-3.67	-3.82	0.67	-0.29	0.65
	Beach face	H8	-2.25	-1.60	1.95	+0.43	0.57
North-west Beach	Beach face	H9	+0.57	+0.54	0.59	-0.16	1.26
North Beach	Reef-front terrace, -12m	H10	-0.52	-0.57	1.08	-0.12	1.17
	Reef-front terrace, -30m	H11	-1.75	-1.11	2.33	+0.33	0.56

Table 1. Characteristics of beach, incipient sand dune and fore-reef sediments at Henderson Island (ϕ units).

	Coral	Coralline algae	Halimeda	Foraminifera	Molluscs	(Echinoids, Bryozoans, Crustaceans)
Henderson Island	42	2	6+	18	17	1
Indo-Pacific Atolls [a]						
Bikini lagoon	1	–	43	8	8	35
Eniwetok lagoon	12	–	28	30	3	26
Cocos lagoon, Guam	45	18	11	3	15	–
Midway	25	35	6	14	12	8
Suwarrow, N. Cooks: [b]						
deep lagoon	3	–	62	27	6	1
shallow lagoon	8	5	4	64	12	1
patch reef	12	7	9	30	29	4
Great Barrier Reef: [a, c]						
Reef flat	15-28	4-8	11-34	14-54	6-11	9-13
Reef	20-40	17-40	10-30	8-20	4-15	<5
Inter-reef	5-10	0-15	5-65	15-40	20-35	5-30

+ includes other algal constituents

Sources : a = Orme (1977); b = Tudhope et al. (1985); c = Flood and Scoffin (1978)

Table 2. General composition of reef sediments, Henderson Island and other localities, Indo-Pacific reef province.

Constituent	Environment		
	Fore-reef (%)	Beach (%)	Dune (%)
Coral	37.7	43.9	37.8
	(18.8)	(24.1)	(8.5)
Mollusc	17.5	17.2	15.1
	(5.6)	(1.1)	(2.1)
Coralline red algae	2.0	1.7	2.6
	(1.0	(0.8)	(1.7)
Homotrema rubrum	0.3	0.5	0.1
	(0.3)	(0.4)	(0.2)
Amphistegina lessonii	8.5	9.5	8.5
	(10.6	(1.8)	(9.1)
Asterigerina carinata	0.7	1.5	0.4
	(1.0)	(1.9)	(0.6)
Marginopora vertebralis	4.4	3.9	9.4
	(3.9)	(1.7)	(11.9)
Heterostegina depressa	0.1	0.1	0.1
	(0.2)	(0.2)	(0.2)
Other benthic foraminiferans	4.3	4.3	1.8
	(2.5)	(0.3)	(3.1)
Other algae (+ *Halimeda*)	8.9	4.4	9.2
	(10.2)	(2.7)	(0.0)
Echinoid	0.6	0.7	0.2
	(0.4)	(0.5)	(0.3)
Lithoclasts	1.1	0.9	0.4
	(1.7)	0.8)	0.6)
Others and unknowns	7.9	7.1	4.4
	(3.30	(2.3)	(6.2)

Table 3. Component composition of Henderson Island sediments by environment. (Mean percentage composition, with standard deviation in parentheses).

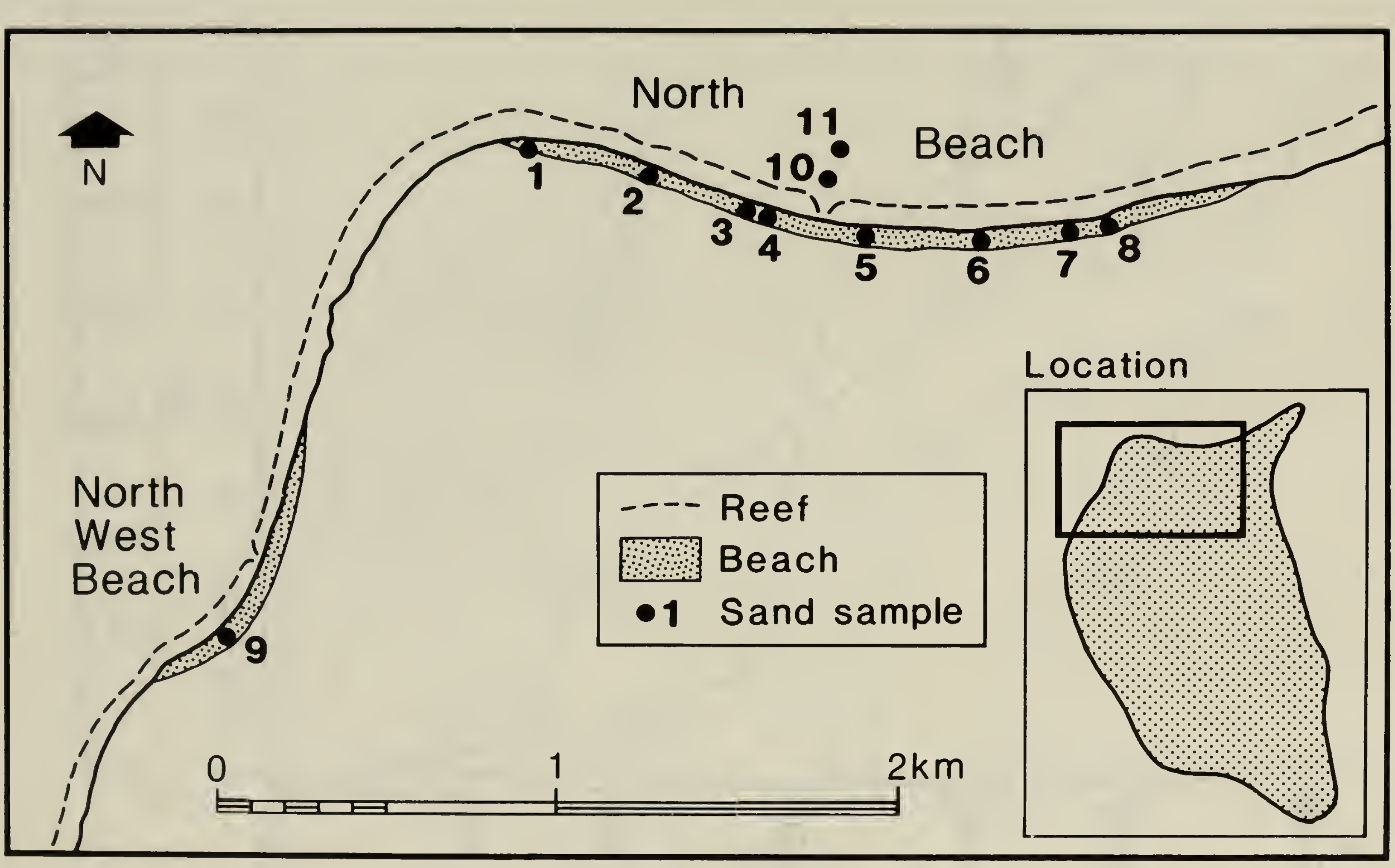

Figure 1. Location of sediment samples, Henderson Island

Figure 2. Cumulative frequency curves for fore-reef sediments, Henderson Island

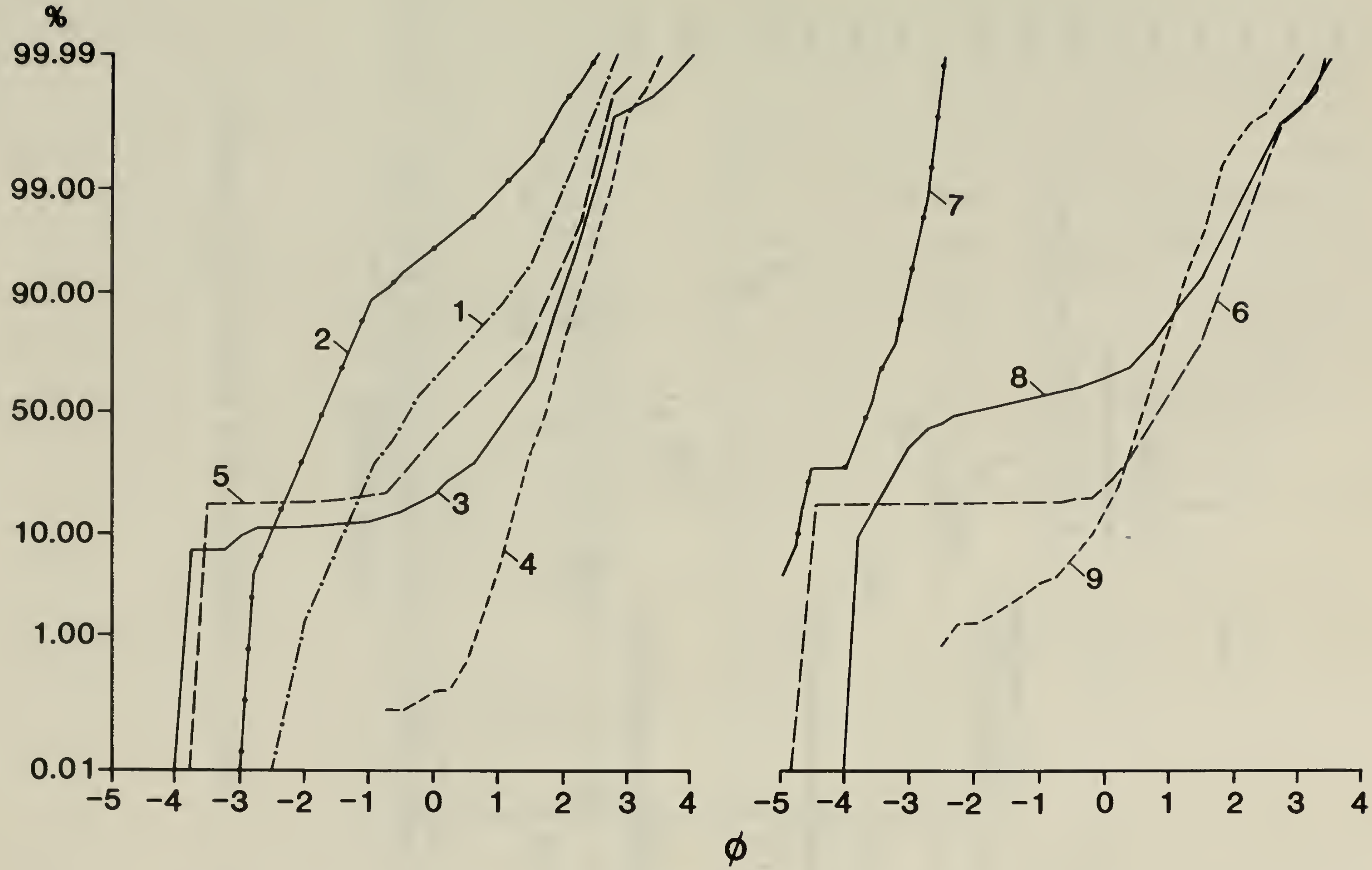

Figure 3. Cumulative size frequency curves for beach (1-3, 5-9) and incipient sand dune (4) sediments, Henderson Island

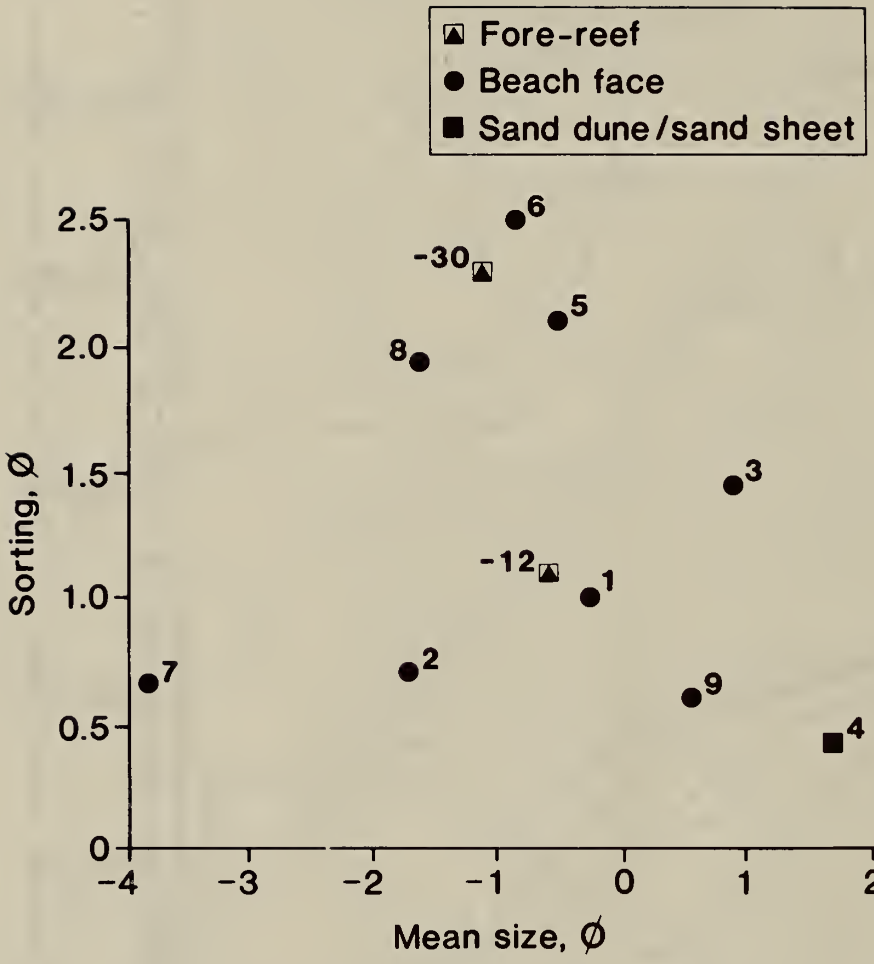

Figure 4. Mean size - sorting relationships, Henderson Island sediments.

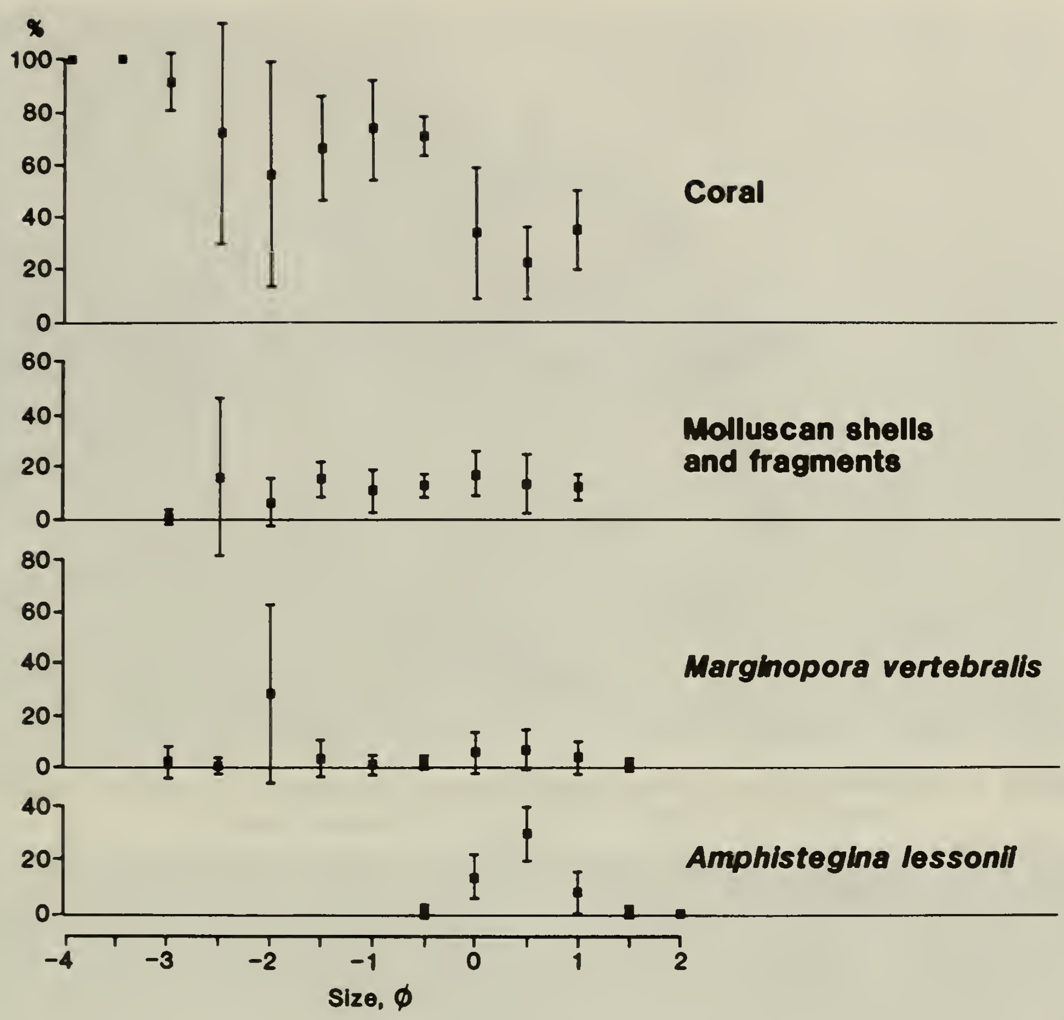

Figure 5. Percentage of selected sediment components by sediment size clases, Henderson Island sediments.

Plate 1. Fractured beach rock and coarse coral rubble beach, eastern end of central north beach, Henderson Island.

Plate 2. North beach and lagoon, looking east. Small reef passage at centre, North-east Point in distance, far left. Note extensive beachrock.

ATOLL RESEARCH BULLETIN

NO. 325

MORE BIRD BONES FROM POLYNESIAN ARCHEOLOGICAL SITES ON HENDERSON ISLAND, PITCAIRN GROUP, SOUTH PACIFIC

BY

SUSAN E. SCHUBEL AND DAVID W. STEADMAN

APPENDIX: ARTIFACTS FROM 1987 EXCAVATIONS ON HENDERSON ISLAND

BY

MELINDA S. ALLEN

ISSUED BY
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ABSTRACT

This study is based upon 2795 bird bones collected in 1987 from Polynesian archeological sites in limestone caves on Henderson Island. Two radiocarbon dates on charcoal from these sites are 400 ± 60 and 870 ± 70 yr B.P. 70% of the bird bones are of Pterodroma alba (Phoenix Petrel), which still nests on Henderson. A single bone of Gallicolumba sp. represents a new species for Henderson and the easternmost record for the genus. Other extirpated species of birds represented in the sites are Pterodroma externa (Juan Fernandez Petrel), a smaller unknown species of Pterodroma, and Nesofregetta fuliginosa (White-throated Storm-Petrel). These findings, combined with other extirpated species recorded in earlier archeological excavations, show that the resident avifauna of Henderson Island has lost two to five species of seabirds and three species of landbirds since the arrival of humans more than 800 years ago. We presume that hunting and habitat disturbance were primarily responsible for the loss of species on Henderson.

INTRODUCTION

In 1971, Y.H. Sinoto and A. Sinoto excavated several archeological sites on the north coast of Henderson Island, an island that had been regarded as uninhabited before the European exploration of the Pacific (Sinoto 1983). The bird bones from Sinoto's only stratified site, named HEN-1 (Figure 1), included the remains of three species that no longer occur on Henderson (the storm-petrel Nesofregetta fuliginosa and the pigeons Ducula galeata and Ducula cf. aurorae) and of two other species (the shearwater Puffinus nativitatis and the booby Sula sula) that visit Henderson but are not known to nest there (Steadman and Olson 1985). The sample of bird bones reported by Steadman and Olson was rather small (303 identifiable specimens). To increase the data base for the prehistoric avifauna of Henderson, as well as to learn more about the natural distribution of birds in Eastern Polynesia, SES excavated several bone-bearing deposits in limestone caves (different from HEN-1) on Henderson Island from 12 to 21 May 1987.

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MATERIAL AND METHODS

Our identifications are based upon comparisons of the fossils with modern skeletons from the National Museum of Natural History, Smithsonian Institution (USNM), the New York State Museum (NYSM), and the University of Washington Burke Museum (UWBM). The fossils from the 1987 Henderson excavations, summarized in Table 1, are catalogued in the Vertebrate Paleontology collections of USNM. Osteological nomenclature follows Baumel et al. (1979). Measurements were taken with digital calipers with 0.01 mm increments, rounded to the nearest 0.1 mm. yr B.P. = radiocarbon years before present. Unless stated otherwise, modern distributions of birds are based upon Pratt et al. (1987) for Polynesia, and Williams (1960), Bourne and David (1983), and Fosberg et al. (1983) for Henderson. Prehistoric distributions are based upon Steadman (1989).

SITE DESCRIPTIONS

Site 1, known as Lone Frigate Cave, is approximately 18 m above sea level and 350 m south of the northern edge of Henderson's Northwest Beach (Figures 1 and 2 herein; also see Figures 3 and 9 of Spencer and Paulay 1989). The entrance is 2.13 m high and the greatest interior height is approximately 3.5 m. The cave's passage extends inland for 17 m (Figure 2). The rocky terrain in front of the cave was covered with a thick growth of Pandanus, various shrubs, and tall ferns. Of the 2,795 avian fossils collected by SES on Henderson Island, 2,584 were from Lone Frigate Cave.

The floor of the main passage of Lone Frigate Cave was covered with powdery, gray calcareous sediment, with angular cobbles up to 10 cm in diameter. A layer of green mold covered most of the rocks and wall surfaces. The elevated floor in the North Chamber consisted mostly of solid limestone, with some loose calcareous sediment.

Fresh water dripped from the top of the entrance of Lone Frigate Cave for a number of days after a rain. This is one of the few sources of fresh water on Henderson, and may have been a factor in the habitation of the cave.

A 0.5 m by 0.5 m test pit just inside the entrance revealed the following stratigraphy.

Layer I (0-6 cm) is a fairly loose calcareous sediment made up of coarse sand with some brown soil, many angular to subangular pebbles and boulders, and a large number of bones. The surface, which is uneven and disturbed, appears to be a frequently and perhaps recently used site for cooking and eating.

Layer II (6-17 cm) is composed mainly of dark, moist soil mixed with medium sand and occasional angular fragments of white, chalky carbonates. This layer also has a large number of bones.

Layer III (17-30+ cm) is a gray sandy mix that yielded very few bones. In Pit 1, this layer is replaced by an indurated layer of white carbonates.

A 1 m by 1 m pit (Pit 1) was expanded from the test pit, following the stratigraphy described above. Bird bones were abundant in Layers I and II. Throughout the cave, additional collections of bones were made from the surface and by sorting carefully through piles of rubble. The rubble might have been derived from clearing the front living quarters of the cave.

The floor of the North Chamber of Lone Frigate Cave was littered with many small piles containing bones, bits of charcoal and crab claws. The bones and claws in these features were well preserved within a thin layer of calcium carbonate. Charcoal from three of these small surface piles was combined for a radiocarbon date of 870 ± 70 yr B.P., the oldest date yet determined for cultural remains on Henderson Island (see CHRONOLOGY). The piles may have resulted from the actions of crabs that scavenged food (especially cooked birds) from the fires at the cave entrance. A land crab was observed dragging the body of a hermit crab (Coenobita sp.) back into the depths of the cave as we worked there.

A second site (West End Cave) was worked at the far west end of the north beach (Figure 1). This cave is 17.3 m above sea level (Spencer and Paulay 1989, Figures 4 and 10) and has a large entrance approximately 2.7 m by 2.7 m. The main body of the cave is small (5 m by 3 m) with a maximum height of approximately 3.5 m. Three small chambers (2 m deep, 0.75 m wide) extend from the rear of the cave. 179 bird bones were collected from surface piles in Chambers 1-3 and from 0-10 cm deep in the main room. The floor of the main room is of brown soil with a disturbed surface.

A limited number of bird bones were collected from small caves and shelters behind the central coconut grove on the north beach (Figure 1). This area is heavily used by Pitcairners and other visitors, with campsites and woodpiles throughout the grove.

The few artifacts recovered during the 1987 excavations are described by M.S. Allen in Appendix 1.

CHRONOLOGY OF THE 1987 EXCAVATIONS

We obtained two radiocarbon dates on materials excavated in 1987. The dated charcoal samples were collected and stored in aluminum foil and were associated with numerous bird bones. The charcoal was pretreated by examination for rootlets, followed by acid, alkali, acid series of soakings to remove carbonates and humic acids. Benzene synthesis and counting proceeded normally. As reported, both dates are adjusted for C13/C12. The first date is 870 ± 70 yr B.P. (Beta-25244), based upon approximately 6 gm of wood charcoal from the floor surface of the North Chamber, Lone Frigate Cave. This charcoal was collected from three small accumulations of bones and crab claws (see SITE DESCRIPTIONS). The second date is 400 ± 60 yr B.P. (Beta-25245), based upon approximately 7 gm of wood charcoal from Test Pit 1, Lone Frigate Cave. This sample originally comprised 3 gm of charcoal from the 20-30 cm level, but was supplemented by 4 gm of charcoal from the 10-20 cm level when the original sample was determined to be too small.

Our dates of 870 ± 70 and 400 ± 60 yr B.P. correspond remarkably well with those obtained by Sinoto (1983, and in Fosberg et al. 1983) from the cave he excavated in 1971 on the north shore of Henderson. Sinoto's dates were 790 ± 110 yr B.P. (Isotopes-6344) from the base of cultural layer III, and 495 ± 105 yr B.P. (Isotopes-6343) from the upper part of cultural layer II. Considered together, the four radiocarbon dates suggest that Polynesians first arrived on Henderson between 900 and 800 yr B.P. After about 500 years of probably increasingly stressful occupation, Henderson was abandoned (or the people died out) between 400 and 350 yr B.P. No European accounts of Henderson, which begin with the landing of Quiros in 1606 A.D., mention the existence or any evidence of people living there. Quiros, in fact, stated specifically that Henderson was uninhabited (Fosberg et al. 1983:5). Had Polynesians been living on Henderson in 1606, they almost certainly would have made themselves known to Quiros.

SPECIES ACCOUNTS

Order PROCELLARIIFORMES

Family PROCELLARIIDAE

Pterodroma alba

Phoenix Petrel

MATERIAL: NISP = 1,961, MNI = 93; 41 crania, 43 rostra, 13 pterygoids, 1 jugal, 32 quadrates, 125 mandibles, 6 vertebrae, 38 synsacra, 71 sterna, 130 furculae, 206 coracoids, 143 scapulae, 199 humeri, 221 ulnae, 185 radii, 2 ulnare, 71 carpometacarpi, 34 manus digit II, phalanx 1, 60 pelves, 24 femora, 196 tibiotarsi, 120 tarsometatarsi. Among these bones are 820 (various elements) identified as *Pterodroma* cf. *alba*, and 46 others too fragmentary for precise identification, but clearly representing *Pterodroma* rather than *Puffinus* and indistinguishable from modern specimens of *Pterodroma alba*. Comparisons were made with the following specimens from the USNM: *Pterodroma hasitata* (598524), *P. rostrata* (576827), *P. alba* (498007, 498009, 498010), *P. inexpectata* (556261), *P. solandri* (500641), *P. brevirostris* (561316), *P. ultima* (497224), *P. neglecta* (497176), *P. arminjoniana* (500318, 500324, 500316), *P. phaeopygia* (556262), *P. externa* (498357, 498358), *P. cookii* (497150), *P. hypoleuca* (497943), *P. nigripennis* (495648), *Bulweria bulwerii* (498246), *B. fallax* (498366).

REMARKS: *Pterodroma alba* breeds in the Pitcairn Group (Ducie, Oeno, Henderson), Tuamotus, Marquesas, Kiribati, Tonga, and perhaps Kermadec Islands. It has been recorded at sea near Hawaii, the Society Islands, Samoa, and perhaps the Cook Islands. The bones of *P. alba* make up 70% of the total bird bones collected in 1987, and 54% of the total bird bones collected in 1971 (Table 2), indicating that these petrels were a major source of food for the prehistoric people of Henderson Island.

Pterodroma externa

Juan Fernandez Petrel

MATERIAL: NISP = 2, MNI = 1; 2 tibiotarsi (388630, 426539).

REMARKS: These two adult specimens are a right and left that may represent the same individual. We refer them to *P. externa* because of similarity in length (Table 3), stoutness of shaft, concavity of the proximal portion of shaft and depth of sulcus extensorius. The tibiotarsus of *P. externa* is larger than that in any of the species of *Pterodroma* known to occur on Henderson (Table 2).

This is the first record of *P. externa* from Henderson or anywhere in the Pitcairn Group. *Pterodroma externa* is known to breed only on Juan Fernandez Is., ca. 4600 km east of Henderson. It has been recorded at sea from the Hawaiian, Marshall, Gilbert, Phoenix, and Line Islands. Both specimens are from Lone Frigate Cave (USNM 388630, 8-10 m from entrance, depth 0-10 cm; USNM 426539, Pit 1, depth 0-6 cm). Because petrels do not come ashore except on breeding islands, we conclude that *P. externa* once nested on Henderson Island. Bones of this species should be sought elsewhere in the Pitcairn Group, on Easter Island, and perhaps in the Gambier or Austral Islands as well.

Pterodroma sp.

Undetermined petrel

MATERIAL: NISP = 4, MNI = 3; 3 carpometacarpi (388627, 426377, 426378), 1 ulna (428361).

REMARKS: These bones, all from Lone Frigate Cave, represent an unknown species of *Pterodroma* larger than *P. nigripennis*, *P. hypoleuca*, or *P. cooki*, but smaller than any other living species, including all those recorded on Henderson (*P. ultima*, *P. neglecta*, *P. alba*, *P. arminjoniana*, *P. externa*). Although these four fossils seem to represent a uniquely sized species of *Pterodroma*, we hesitate to use them as a basis for documenting an extirpated or extinct species for Henderson, given the uncertainties in species-level systematics and osteology of *Pterodroma*.

Puffinus nativitatis

Christmas Shearwater

MATERIAL: NISP = 1; 1 tibiotarsus (427192)

REMARKS: The breeding status of *Puffinus nativitatus* on Henderson is uncertain, although nesting is likely. This shearwater breeds through much of Polynesia (Hawaii, Kiribati, Marquesas, Tuamotus, Australs, and Pitcairn Group), including Pitcairn, Ducie, and perhaps Henderson.

Procellariidae sp.

Undetermined petrels/shearwaters

MATERIAL: NISP = 457; 11 skulls, 1 sclerotic ring, 2 mandibles, 3 atlases, 77 vertebrae, 2 synsacra, 3 sterna, 6 furculae, 2 coracoids, 18 scapulae, 3 humeri, 19 ulnae, 7 radii, 7 ulnare, 4 carpometacarpi, 3 manus digit II, phalanx 1, 65 other manus phalanges, 2 femora, 4 tibiotarsi, 3 tarsometatarsi, 215 pedal phalanges.

REMARKS: Although most of these fragmentary procellariid bones are undoubtedly of *Pterodroma alba*, they are too incomplete to identify beyond the family level.

Family HYDROBATIDAE

Nesofregetta fuliginosa

White-throated Storm-petrel

MATERIAL: NISP = 1, MNI = 1; 1 tarsometatarsus (426290).

REMARKS: This specimen is slightly longer than comparative specimens at USNM, but is indistinguishable qualitatively. *Nesofregetta fuliginosa* is the only storm-petrel that breeds widely in Oceania, with breeding records from Vanuatu, Fiji, Kiribati, Tubuai, Marquesas, Gambiers, and Samoa. It visits the Society, Tuamotu, and Marshall islands. Previous archeological records are from Mangaia, Cook Islands (Steadman 1985) and Henderson (Steadman and Olson 1985).

Order PELECANIFORMES

Family PHAETHONTIDAE

Phaethon rubricauda

Red-tailed Tropicbird

MATERIAL: NISP = 104, MNI = 6; 1 skull (427002), 1 rostrum (338560), 2 jugals (388589, 426714), 8 pterygoids (388800, 426282, 426528, 426529, 427035, 427047, 428168, 436260), 9 quadrates (388590, 388752, 388867, 426517, 426748, 426749, 426968, 428942, 428943), 12 mandibles (388839, 417154, 426337, 426538, 426712, 426713, 428169, 428874, 428985, 428989, 428990, 429006), 2 atlases (428145, 428987), 20 vertebrae (388782, 388783, 388798, 388840, 417107, 417115, 417156, 417157, 426523, 426524, 426811, 426812, 426813, 426940, 428100, 428988, 428991, 428992, 428993, 428994), 1 synsacrum (388652), 3 sterna (427001, 427006, 427007), 3 ribs (426543, 427046, 428887), 8 furculae (388655, 388767, 388832, 426332, 426924, 427226, 428984, 428996), 4 coracoids (427130, 428875, 428995, 429002), 3 scapulae (388842, 426339, 429003), 6 humeri (388670, 426892, 427136, 428672, 428872, 428998), 2 ulnae (428873, 429007), 7 radii (388653, 426338, 428876, 428986, 429001, 429004, 429005), 3 carpometacarpi (388669, 388841, 426321), 2 manus phalanges (428999, 429000), 1 femur (428719), 5 tibiotarsi (338559, 388654, 426275, 428944, 428997), and 1 tarsometatarsus (417071). Within the total number of specimens are 13 bones that, because of their fragmentary nature, are identified as Phaethon cf. rubricauda, and 3 bones as Phaethon sp. None of these is distinguishable from P. rubricauda.

REMARKS: Phaethon rubricauda is common through much of the tropical Pacific and on all islands in the Pitcairn Group. Previous archeological records include Mangaia, Cook Islands (Steadman 1985) and Henderson (Steadman and Olson 1985).

Family FREGATIDAE

Fregata minor

Great Frigatebird

MATERIAL: NISP = 2, MNI = 2; 1 jugal (426519), 1 quadrate (426547).

REMARKS: Fregata minor is widespread in the tropical Pacific, including all four islands in the Pitcairn Group.

Order CHARADRIIFORMES

Family LARIDAE

Anous stolidus

Brown Noddy

MATERIAL: NISP = 12, MNI = 4; 1 rostrum (428703), 5 coracoids (426236, 426237, 426336, 428696, 428853), 1 scapula (426654), 1 humerus (428706), 2 ulnae (426918, 427222), 2 tibiotarsi (388859, 426952).

REMARKS: This species breeds nearly throughout the tropical Pacific, including all islands in the Pitcairn Group. Anous stolidus occurs commonly in archeological sites from many islands in Polynesia.

Gygis alba

Common Fairy-Tern

MATERIAL: NISP = 151, MNI = 16; 4 crania, 2 rostra, 1 pterygoid, 10 quadrates, 9 mandibles, 6 synsacra, 9 sternae, 14 furculae, 28 coracoids, 22 scapulae, 8 humeri, 9 ulnae, 5 radii, 7 carpometacarpi, 6 manus phalanges, 8 tibiotarsi, and 3 tarsometatarsi. Included are 7 bones identified as cf. Gygis alba.

REMARKS: This distinctive bird is found nearly throughout the tropical Pacific, including all islands in the Pitcairn Group. The bones of Gygis alba from Henderson are slightly larger overall than modern specimens from the Cook Islands. Bones of G. alba are common in archeological sites from almost all regions of Polynesia.

Family SCOLOPACIDAE

Heteroscelus incanus

Wandering Tattler

MATERIAL: NISP = 1, MNI = 1; 1 ulna (428635).

REMARKS: Heteroscelus incanus breeds in Alaska and northwest Canada and migrates to the tropical Pacific, including most of Polynesia. It has been recorded on Ducie, Oeno and Henderson in the Pitcairn Group. Tattlers are most commonly found along shorelines, especially where fringing reefs are present.

Numenius tahitiensis
Bristle-thighed Curlew

MATERIAL: NISP = 2, MNI = 1; 1 scapula (426516), 1 synsacrum (388797).

REMARKS: Numenius tahitiensis ranges widely in the Pacific as it migrates from breeding grounds in Alaska to spend the fall, winter, and spring on tropical Pacific islands, especially those of eastern and central Polynesia. This curlew has been recorded on all islands in the Pitcairn Group. It prefers open habitat such as shallow reefs, beaches, fields, and airport runways.

Order GRUIFORMES
Family RALLIDAE
Porzana atra
Henderson Island Rail

MATERIAL: NISP = 6, MNI = 2; 1 coracoid (428717), 3 tibiotarsi (428276, 428832, 428857), 2 tarsometatarsi (426530, 436396).

REMARKS: This flightless rail is found only on Henderson Island. The only other rail known from the Pitcairn Group is the widespread and volant Porzana tabuensis (Spotless Crake), which has been recorded on Oeno and Ducie. Porzana atra inhabits the forest floor where it rustles through the leaves searching for food and making a "peet" call resembling that of an American Woodcock (Scolopax minor). Rails were fairly common on Henderson in 1987.

Order COLUMBIFORMES
Family COLUMBIDAE
Gallicolumba sp.
Unknown Ground-dove

MATERIAL: NISP = 1, MNI = 1; 1 tarsometatarsus (proximal end) (388744).

REMARKS: This fragmentary specimen represents a species of Gallicolumba rather than Ducula or Ptilinopus because of these characters: tuberositas musculo tibialis cranialis abuts medial foramen vascularium proximalium (located more distad in Ducula and Ptilinopus); medial foramen vascularium proximalium smaller; in medial aspect, proximal margin of shaft thinner; in plantar aspect, medial margin of shaft more smoothly recurved; sulcus flexorius longer, sharper.

USNM 388744 is larger than the tarsometatarsus of Gallicolumba erythroptera, which occurs in the Tuamotu Group today and has been extirpated in the Cook and Society Islands. The Henderson specimen is much larger than in G. rubescens of the Marquesas, but smaller than in the extinct Gallicolumba new species 2 of the Marquesas, Society, and Cook Islands (Steadman 1989). USNM 388744 resembles the tarsometatarsus of G. erythroptera and G. rubescens more than that of G. new species 2 in the smoothly curved, shallow proximo-medial margin of the shaft, the presence of a lateral foramen vascularium proximalium, and the shallower fossa infracotylaris dorsalis (Steadman in press).

This is the southeasternmost record for any species of Gallicolumba. The nearest congener is G. erythroptera, which occurs on certain islands in the southeast portion of the Tuamotu Group, about 1000 km west-northwest of Henderson.

Ptilinopus insularis
Henderson Island Fruit Dove

MATERIAL: NISP = 54, MNI = 11; 2 rostra (417136, 428679), 1 mandible (426533), 2 synsacra (426335, 428756), 5 sterna (426595, 427008, 427009, 428166, 428760), 17 coracoids (417155, 426407, 426408, 426527, 426535, 426727, 426728, 426850, 426932, 426933, 427227, 428156, 428652, 428680, 428763, 428767, 428855), 5 scapulae (426525, 426526, 426930, 428681, 428762), 3 humeri (417106, 426289, 428945), 4 ulnae (426596, 426597, 428678, 428764), 3 radii (388799, 426962, 428806), 1 pelvis (428650), 2 femora (388681, 428615), 7 tibiotarsi (426961, 428472, 428757, 428758, 428759, 428765, 428766), 1 tarsometatarsus (426849), and 1 pedal phalanx (428761).

REMARKS: This species is regarded as endemic to Henderson because it has never been recorded elsewhere. In light of the numerous range extensions of other Polynesian columbids based upon archeological specimens (Steadman 1989), we would not be surprised if P. insularis once occurred on islands other than Henderson, especially Pitcairn Island. Fruit-doves were fairly common on Henderson in 1987.

Order PSITTACIFORMES
Family PSITTACIDAE
Vini stepheni
Henderson Island Lorikeet

MATERIAL: NISP = 2, MNI = 1; 1 scapula (417131), 1 tibiotarsus (426966).

REMARKS: This small parrot is found only on Henderson Island. As with Ptilinopus insularis, whether it is truly endemic to Henderson can be tested through the collection and analysis of archeological avifaunas from adjacent islands. Lorikeets were fairly common on Henderson in 1987.

Order PASSERIFORMES
Family SYLVIIDAE
Acrocephalus vaughani taiti
Henderson Island Reed-Warbler

MATERIAL: NISP = 1, MNI = 1; 1 rostrum (428718).

REMARKS: This subspecies of the Pitcairn Island Reed-Warbler is endemic to Henderson, where it was common in 1987. No warblers are found on Ducie or Oeno.

Aves sp.
Indeterminate birds

MATERIAL: NISP = 33. These fragmentary bones are undiagnostic at any level.

DISCUSSION

The 1987 excavations on Henderson Island demonstrate that a very large sample of bird bones might be needed if the goal is to represent the prehistoric avifauna as completely as possible. The sample analyzed by Steadman and Olson (1985) included 303 identifiable bird bones representing 12 species. Our sample of nearly 2800 bones represents 16 species, seven of which were not in the smaller sample (Tables 1, 2). Likewise, the sample of 303 bones included three species not present in the larger sample.

Sampling artifacts are especially significant in recording rare species, whether seabirds or landbirds. Each of the seven species recorded in the larger but not in the smaller sample is represented by only one to four bones. The three species that occurred in the smaller but not the larger sample are represented by three to nine bones each. This relatively larger representation is related to the heavier exploitation of landbirds (6.9% versus 2.3% of all bones; Table 1) by the people responsible for the smaller sample. In spite of the great numbers of Pterodroma alba bones in both samples, this petrel still survives on Henderson. Conversely, the seemingly low numbers of bones of most landbirds reflect the loss of three species of pigeons on Henderson. Landbirds, being less transient, tend to be more vulnerable to local overexploitation. The interior of Henderson is characterized by jagged, crevassed limestone (see Kirch 1988). Despite the harsh terrain Polynesians undoubtedly ranged over the entire island seeking food and water. The lack of tillable soil on Henderson would have prevented the development of agriculture, while the steep, narrow reef and scarcity of reef passages would have made fishing a dangerous, undependable activity. All of this points to a heavy dependence upon birds for food.

Whether the depletion of birds was a primary factor in the eventual abandonment or collapse of Henderson culture, we cannot be sure. We are certain, however, that the Polynesians were involved in the loss of certain populations of seabirds and landbirds on their island. At a minimum, the Polynesian hunters reduced some bird populations to a point where the birds became more difficult to obtain. The absence of basalt for adzes and pearlshell for fishhooks (Sinoto 1983) as well as the depletion of indigenous birds contributed to the harsh existence led by the prehistoric inhabitants of Henderson Island.

ACKNOWLEDGMENTS

This research was supported by National Science Foundation Grant BSR-8607535 and the Smithsonian Institution, including private funds generously provided by S. Dillon Ripley. We thank the government and people of Pitcairn Island for permission, cooperation, and friendship. Logistical support and assistance given by the Captain and crew of R/V RAMBLER are gratefully acknowledged. We appreciate comments on the manuscript by N.G. Miller, S.L. Olson and W.N. Mathis. For access to modern specimens, we thank the staff of USNM and UWBM. Figures 1 and 2 are by D.S. Pahlavan. Figures 3-4 (Appendix) are by Virginia C. Steadman. This is contribution number 605 of the New York State Museum and Science Service.

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Table 1. Archeological avifaunas from Henderson Island. Data of Steadman and Olson (1985) are based upon bones collected by Y.H. and A. Sinoto in 1971. M = migrant. NISP = number of identified specimens. % = % of NISP in entire sample of bird bones.

	Steadman & Olson (1985)		Schubel & Steadman (herein)	
	NISP	%	NISP	%
Pterodroma alba Phoenix Petrel	165	54.4	1961	70.1
Pterodroma externa Juan Fernandez Petrel	-	-	2	0.07
Pterodroma sp. (small) Unknown petrel	-	-	4	0.14
Puffinus nativitatis Christmas Shearwater	8	2.6	1	0.07
Procellariidae sp. Unknown petrel/shearwater	-	-	457	16.4
Nesofregetta fuliginosa White-throated Storm-Petrel	3	1.0	1	0.04
Phaethon rubricauda Red-tailed Tropicbird	20	6.6	104	3.7
Sula sula Red-footed Booby	3	1.0	-	-
Fregata minor Great Frigatebird	9	3.0	2	0.07
Anous stolidus Brown Noddy	4	1.3	12	0.4
Gygis alba Common Fairy-Tern	70	23.1	151	5.4
Heteroscelus incanus (M) Wandering Tattler	-	-	1	0.04
Numenius tahitiensis (M) Bristle-thighed Curlew	-	-	2	0.07
Porzana atra Henderson Island Crake	8	2.6	6	0.2
Gallicolumba sp. Ground-Dove	-	-	1	0.07
Ptilinopus insularis Henderson Island Fruit-Dove	1	0.3	54	1.9
Ducula cf. *aurorae* Polynesian Pigeon	9	3.0	-	-
Ducula cf. *galeata* "Nuku Hiva" Pigeon	3	1.0	-	-
Vini stepheni Henderson Island Lorikeet	-	-	2	0.07
Acrocephalus vaughani taiti Henderson Island Warbler	-	-	1	0.04
Aves sp. Unknown bird	-	-	33	1.2
Totals	303	100.0	2795	100.0
% landbirds		6.9	2.3	

Table 2. Modern and prehistoric birds of Henderson Island. Modern records are derived from Williams (1960), Bourne and David (1983), and Fosberg et al. (1983). ? = recorded from Henderson, but breeding status uncertain. M = migrant (not included in landbird totals). COMBINED TOTALS = modern + prehistoric.

		PREHISTORIC RECORDS	
	MODERN RECORD	Steadman & Olson (1985)	Schubel & Steadman (herein)
SEABIRDS			
Pterodroma ultima Murphy's Petrel	X	-	-
Pterodroma neglecta Kermadec Petrel	X	-	-
Pterodroma alba Phoenix Petrel	X	X	X
Pterodroma arminjoniana Herald Petrel	X	-	-
Pterodroma externa Juan Fernandez Petrel	-	-	X
Pterodroma sp. (small) Unknown petrel	-	-	X
Puffinus nativitatis Christmas Shearwater	?	X	X
Puffinus pacificus Wedge-tailed Shearwater	X	-	-
Nesofregetta fuliginosa White-throated Storm-Petrel	-	X	X
Phaethon rubricauda Red-tailed Tropicbird	X	X	X
Sula dactylatra Masked Booby	X	-	-
Sula sula Red-footed Booby	?	X	-
Sula leucogaster Brown Booby	?	-	-
Fregata minor Great Frigatebird	X	X	X
Anous stolidus Brown Noddy	X	X	X
Anous minutus Black Noddy	?	-	-
Procelsterna cerulea Blue-gray Noddy	X	-	-
Gygis alba Common Fairy-Tern	X	X	X
LANDBIRDS			
Heteroscelus incanus Wandering Tattler	M	-	M
Numenius tahitiensis Bristle-thighed Curlew	M	-	M
Calidris alba Sanderling	M	-	-
Egretta sacra Reef Heron	?	-	-

Table 2 (continued)

	MODERN RECORD	PREHISTORIC RECORDS Steadman & Olson (1985)	 Schubel & Steadman (herein)
Porzana atra Henderson Island Crake	X	X	X
Gallicolumba sp. Ground-Dove	-	-	X
Ptilinopus insularis Henderson Island Fruit-Dove	X	X	X
Ducula cf. *aurorae* Polynesian Pigeon	-	X	-
Ducula cf. *galeata* "Nuku Hiva" Pigeon	-	X	-
Vini stepheni Henderson Island Lorikeet	X	-	X
Acrocephalus vaughani taiti Henderson Island Warbler	X	-	X
TOTALS			
Seabirds	10-15	8	9
Landbirds	4-5	4	5
All birds	14-23	12	16
COMBINED TOTALS			
Seabirds	16-18		
Landbirds	7-8		
All birds	23-29		

Table 3. Measurements (in mm) of the tibiotarsus of Pterodroma, with range and sample size. F = female. M = male. U = sex unknown.

	Length without crista cnemiali	Length from crista fibularis to distal end
P. externa Lone Frigate Cave, Henderson Island (2U)	62.6, 62.6	42.3, 42.4
P. externa Modern specimens taken at sea, Central Pacific (3F)	59.8-62.8 3	42.2-44.1 3
P. externa Modern specimens taken at sea, Central Pacific (3M)	62.9-66.7 3	42.2-46.8 3
P. alba Lone Frigate Cave, Henderson Island (11U)	53.8 52.1-55.5 11	38.8 37.3-40.0 11

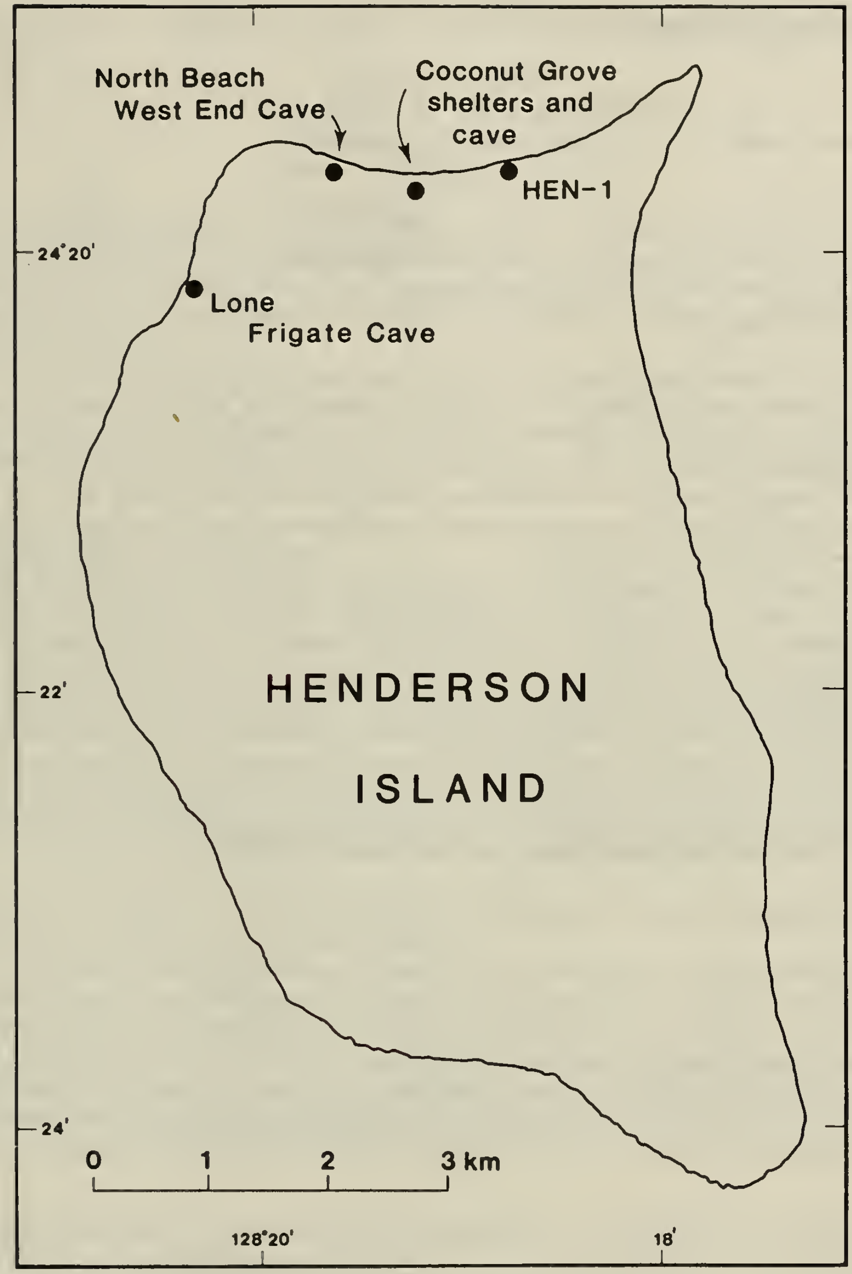

Figure 1. Henderson Island, showing localities where bird bones have been found.

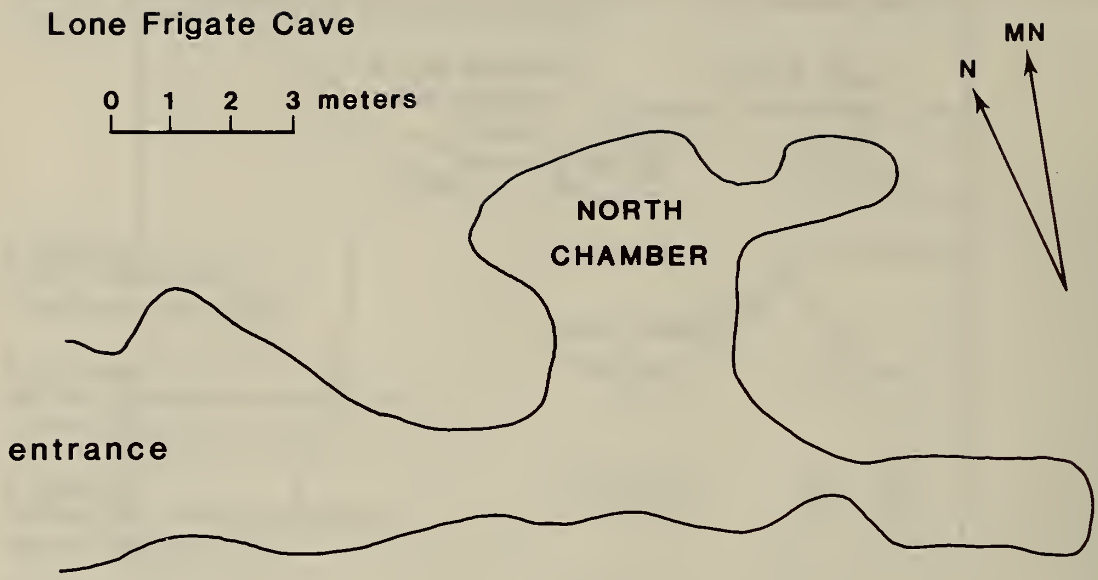

Figure 2. Plan view of Lone Frigate Cave, Henderson Island.

APPENDIX
ARTIFACTS FROM 1987 EXCAVATIONS ON HENDERSON ISLAND

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Eight potential artifacts were recovered during the May 1987 excavations at Lone Frigate Cave and West End Cave, Henderson Island. They are described below, with accompanying illustrations by Virginia Carter Steadman. The specimens will be deposited in the collections of the Department of Anthropology, National Museum of Natural History, Smithsonian Institution.

Some of the coral objects, although not culturally modified, must have been transported to the cave by humans. This is suggested both by the distance of the caves from the coast, 45 m in the case of Lone Frigate Cave and 60 m for West End Cave, and their elevation above sea level, 18 m for Lone Frigate Cave and 17.3 m for West End Cave. In addition, the sediments in both caves are predominantly terrigenous. In Lone Frigate Cave, modern human activity was indicated by matches and a few pieces of plastic. Surficial hearths in both caves also appear to be recent.

None of the Henderson artifacts recovered in 1987 is temporally diagnostic or shows affinity with any other particular East Polynesian island group. The several hundred artifacts recovered in 1971 by Sinoto (1983:59-61) on the northern coast of the island suggested a close affiliation with the Marquesas. His excavation also revealed a sequence of gradual change from predominantly exotic raw materials (i.e., pearlshell for fishhooks and basalts for adzes) to principally locally available ones, such as hammer oysters and Tridacna. The significantly greater number of bird bones and much lower concentration of artifacts in Lone Frigate and West End Caves suggest that both localities were used primarily for food processing and consumption. This contrasts with Sinoto's findings on the north shore where tool production was also an important activity.

Specimen 1 (Figure 3A, B): Unfinished fishhook. Lone Frigate Cave, surface association, 7-8 m from entrance (north side).

This unfinished fishhook is 48 mm long by 42 mm wide. It is flat and thin in cross-section with a maximum thickness of 3 mm. The bend is U-shaped and 18 mm wide. Although unfinished, it probably was going to be a jabbing form of hook. The raw material is Pinctada, as indicated by the pearly surface and the exterior shell coloration. It appears to be from one of the smaller species of pearlshell, such as Pinctada maculata, although an immature specimen of Pinctada margaritifera is also possible. The area of muscle attachment has been cut away and the edge abraded, while the exterior edge is cut, but not further finished.

Specimen 2 (Figure 3C, D): Modified limpet shell (cf. Cellana). Lone Frigate Cave, 8-10 m from entrance, rubble pile (0-10 cm).

The top of the shell has been cut away, leaving a ring 9 to 11 mm in width. One end of the ring has also been broken off. The cut edges have not been abraded or smoothed, nor have the exterior edges been modified. The intended function of the object is unclear.

Specimen 3 (Figure 3E, F): Fragment of Tridacna shell. Lone Frigate Cave, Test Pit at entrance, (0-10 cm).

This fragment, from the distal end of a Tridacna valve, is 33 mm long, 24 mm wide, and 8 mm deep. It is not possible to tell if the specimen was fractured from the rest of the valve by a cultural or natural agent. The specimen could be debitage from the production of Tridacna shell adzes such as those reported from Henderson by Sinoto (1983).

Specimen 4 (Figure 4A-C): Porites coral cobble. Lone Frigate Cave, 8-10m from entrance, North side, in rubble, (0-10 cm).

This specimen measures 60 by 46 by 24 mm. One end is broken off and it is cracked and discolored by fire. No wear facets were identified. Given its provenience Schubel thought that this specimen may have been a recent introduction to the cave.

Specimen 5 (Figure 4D, E): Porites coral cobble. Lone Frigate Cave, Test Pit at entrance, (0-10 cm).

This specimen measures 65 by 21 by 15 mm and is water-rounded. No wear facets were identified. The "stem" at one end may be the result of cultural modification, although there are no definite areas of grinding or abrasion. The specimen is of the same general shape as the coral abraders reported from Henderson by Sinoto (1983:60).

Specimen 6 (Figure 4F): Porites coral cobble. Lone Frigate Cave, Test Pit at entrance, (0-10 cm).

There are no definite wear facets on this specimen to suggest that it was used as an abrader. One end is battered, however, indicating that it may have been used in some other fashion. It measures 66 by 20 by 15 mm.

Specimen 7 (Figure 4G, H): Porites coral abrader (?). West End Cave, East wall, (0-10 cm), hearth area.

One side of this specimen is fractured and rough. The other side is smooth, suggesting its possible use as an abrader. There are, however, no definite wear facets. It measures 83 by 26 by 18 mm.

Specimen 8 (Figure 4I, J): Porites coral cobble. West End Cave, East wall, (0-10 cm), hearth area.

One end of this water-rounded cobble is broken off. There are no wear facets, although the intact end is battered as in Specimen 6. Possibly it was used as a hammerstone. It measures 55 by 35 by 22 mm.

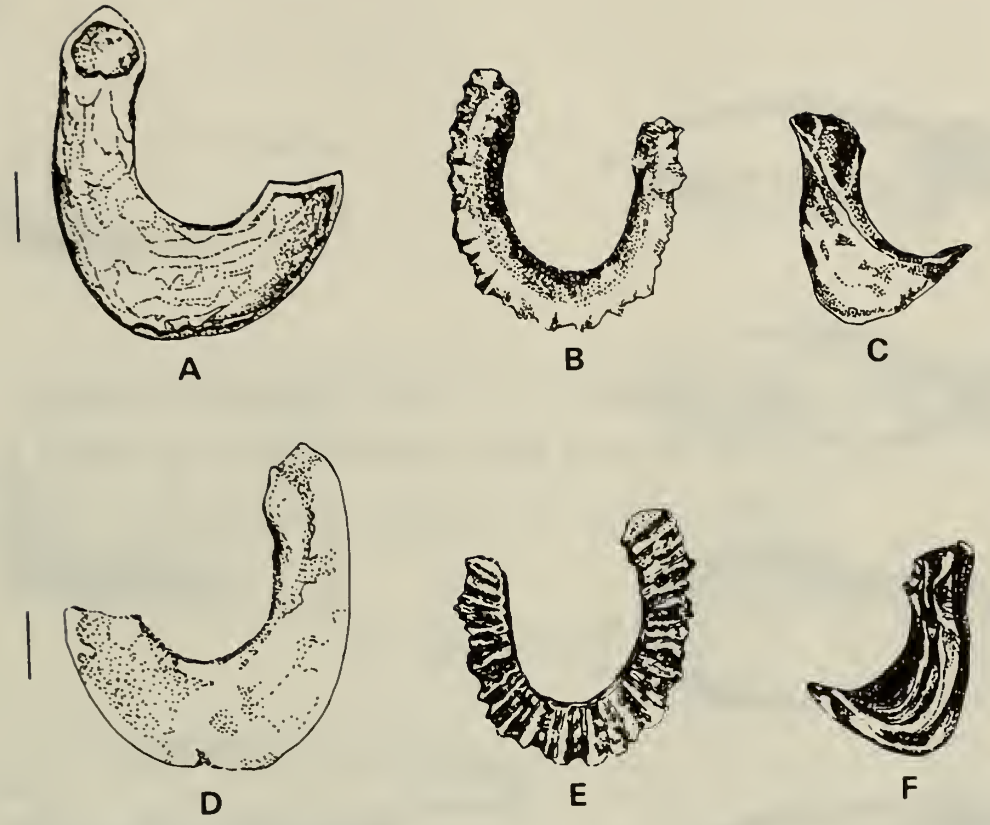

Figure 3 (above). Shell artifacts from Henderson Island. A,D. Unfinished fishhook. B,E. Modified limpet shell. C,F. Fragment of Tridacna shell. See text for detailed description. Scale bars = 1 cm.

Figure 4 (next page). Porites Coral artifacts from Henderson Island. A-C. Specimen 4. D,E. Specimen 5. F. Specimen 6. G,H. Specimen 7. I,J. Specimen 8. See text for detailed description. Scale bars = 1 cm.


A
B
C
D
E
F
G
H
I
J

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MARINE INVERTERBRATES OF THE PITCAIRN ISLANDS: SPECIES COMPOSITION AND BIOGEOGRAPHY OF CORALS, MOLLUSCS, AND ECHINODERMS

BY

GUSTAV PAULAY

ISSUED BY
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MARINE INVERTERBRATES OF THE PITCAIRN ISLANDS: SPECIES COMPOSITION AND BIOGEOGRAPHY OF CORALS, MOLLUSCS, AND ECHINODERMS

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ABSTRACT

The marine invertebrate fauna of the Pitcairn Islands consists of a depauparate assemblage of Indo-West Pacific species; 54 corals, 198 molluscs, and 58 echinoderms are recorded. I discuss the physiography and marine communities of each island and the origin and characteristics of the fauna. There is considerably variation in species composition among islands as well as through time, indicating that these peripheral islands have an unstable, dynamic fauna.

INTRODUCTION

The marine fauna of the Pitcairn Group is of particular biogeographic interest because of the group's isolation, peripheral location, and unusual physiography. Located at the southeastern edge of the Indo-West Pacific province, the Pitcairns are 390 km east of their nearest neighbor, Temoe Atoll in the Tuamotu-Gambier Islands, and 1570 km west of Easter Island. They are the easternmost islands on the Pacific plate and indeed within the Indo-West Pacific province, with the exception of faunistically depauperate and unusual Easter Island and Sala y Gomez. Situated between 24-25°S, the Pitcairns are also more austral than most other tropical Pacific islands. Two of the Pitcairn Islands have a physiography that is uncommon for the Central Pacific: Henderson is an uplifted atoll, whereas Pitcairn is a precipitous Pleistocene volcano with very little reef development. The remaining islands, Ducie and Oeno, are small atolls. Of further interest is that except for Pitcairn, the islands in the group are uninhabited and have been so for hundreds of years; they thus provide a rare glimpse of insular marine ecosystems essentially unaltered by human activities.

PAST WORK

Studies on the marine fauna of the Pitcairn Group have been infrequent. Hugh Cuming made the first collections in the archipelago, visiting Ducie, Henderson, and Pitcairn in 1827, and Pitcairn again in 1828 (Dance 1980). Although his stay was brief (11 days total, St. John 1940), several new molluscs were described from specimens he collected in the group. The next significant marine collection, again of molluscs, was made on Henderson by JR Jamieson and DR Tait in 1912; their collections were described by EA Smith (1913). The natural history expeditions that followed in the first half of this century - the Whitney South Sea Expedition in 1922, the Mangarevan Expedition in 1934, and the Templeton Crocker Expedition in 1935 - focused largely on the terrestrial biota.

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Since the 1960's, the marine fauna of the Pitcairns has received more attention. In 1964, HA Rehder collected molluscs on Pitcairn Island. In 1967 the *Pele* with HA Rehder, DM Devaney and BR Wilson on board, spent 5 days on Pitcairn and 2 on Oeno. They made 33 dredge hauls on Pitcairn, collecting in depth zones little studied elsewhere in Polynesia (Rehder 1974). In 1970-1971, the schooner *Westward*, with JE Randall and HA Rehder, spent most of its one-month stay in the group on Pitcairn, but also visited Henderson, Ducie and Oeno briefly (for <3 days each) (Randall 1973, 1978, Devaney & Randall 1973). All 3 above expeditions focused on Pitcairn within the archipelago, and the greatest collecting efforts concentrated on molluscs (Rehder in 1964, 1967, 1970-1; Wilson in 1967), echinoderms (Devaney in 1967) and fish (Randall in 1970-1), although other invertebrates were routinely taken. Results on ophiuroids and asteroids were published by Devaney (1973, 1974), Devaney & Randall (1973) and Marsh (1974). Rehder & Wilson (1975) described 3 new gastropods from Pitcairn, while Rehder & Randall (1975) and Fosberg *et al.* (1983) listed the known malacofauna of Ducie and Henderson respectively. Although most of the large collections of molluscs from Pitcairn have yet to be studied, several systematic revisions on various gastropod taxa include material from the Pitcairn Group (see table 2). Rehder & Randall (1975) provided a brief list and comments on some crustaceans, echinoderms, and corals, and Fosberg *et al.* (1983) mentioned a lobster and an echinoid. A series of papers have also been published discussing the fish fauna, including a species list for Ducie (Rehder & Randall 1975).

PRESENT WORK

The 1987 Smithsonian Expedition visited Ducie on 10 May 1987, Henderson on 12-21 May, Pitcairn on 22-26 May, and Oeno for a brief 2 hours on 28 May. On both Ducie and Henderson we collected most intensely on the fore reef using SCUBA, while reef flat and lagoonal (on Ducie) habitats were sampled less intensely. Collections on Pitcairn were limited to a few specimens brought by divers. On Oeno we landed briefly on the E end of the main islet, and I collected on the adjacent shoreline and lagoon. Accordingly, my most extensive collections are from Henderson and Ducie, while those from Pitcairn and Oeno are very limited.

Corals (Milleporina & Scleractinia), molluscs, and echinoderms were the focus of my collecting efforts, and are the taxa considered here. All species encountered are listed in tables 1-3, with the exception of a few molluscs and corals that remain unidentified. Coral collections made by Devaney in 1967 (USNM portion only) and by the *Westward* crew in 1971 (Bishop Museum, reported on by Rehder & Randall 1975) were also (re-) examined. Other invertebrates collections from the Pitcairns at the USNM and Bishop Museum were not consulted. Literature records are included from papers concentrating on the Pitcairn Group fauna and from several recent taxonomic monographs (see tables 1-3 for citations). All collections from the 1987 expedition are deposited in the National Museum of Natural History (USNM). A list of USNM catalogue numbers for all species here referred to will, once available, be deposited in the USNM Mollusc library.

PHYSIOGRAPHY AND MARINE HABITATS

Ducie: Rehder & Randall (1975) and Devaney & Randall (1973) described the physiography and marine habitats of Ducie in some detail; only a few noteworthy features will be mentioned here. The outer reef slope was investigated only off the western tip of Acadia Islet, where it forms a wide shelf, sloping gently until a break at

25-30 m depth, steepening thereafter. Rehder & Randall (1975) reported similar wide shelves off at least the NW, NE, and SW sides, most extensive (270 m wide to the break at 30 m depth) off the small SW passage. Such wide fore reef terraces appear to be common on the southernmost Polynesian islands: they are found on Rarotonga, Mangaia (Cook Islands), Rimatara, Tubuai, Raivavae, and areas of Rurutu (Austral Islands), and may represent reefs unable to reach the surface due to slower growth rates at these colder latitudes (Paulay & McEdward submitted).

An unusual feature of the fore reef area investigated is the complete absence of sands or finer sediments. Only a few pockets of coral rubble interrupt the undulating reef pavement, which is lightly dissected by a spur and groove topography best developed at depths of <10 m. The fore reef grades imperceptibly into the outer reef flat, a reef crest is entirely lacking. The reef flat investigated at the W end of Acadia Islet has minimal sand deposits, lacks live corals, and has dense populations of the sea cucumber *Holothuria atra* and the giant vermetid *Dendropoma maximum.*

The lack of fine sediments on the fore reef and reef flat is further reflected in the composition of Acadia Islet, composed entirely of storm-tossed coral and mollusc rubble, with shells of the gastropod *Turbo argyrostomus* dominating the latter. On the lagoon side, this rubble mound ends abruptly in a steep bank, ending ca. 10 m from shore at a depth of 8-9 m, uncomformably overlying the flat lagoon bottom of fine, white sand. Many irregular, heavily eroded patch reefs rise from the lagoon floor, reaching within 2-5 m of the surface. Several species of *Montipora* and *Astreopora* cf. *myriophthalma* dominate the sparse coral cover, and the sea urchin *Diadema savignyi* is common. The lagoon floor has an abundance of *Holothuria atra* and occasional *Holothuria nobilis.*

Rehder & Randall (1975) noted a large coral kill on the Ducie fore reef in January 1971, and estimated that it occurred at least a year before their visit:

> "Everyone diving at Ducie came up in wonderment at the obvious mass mortality of the corals in all areas investigated. ... At one time in the not-too-distant past, the outer reef of Ducie ... was nearly completely covered with live coral, particularly an *Acropora* with branches of only a few inches in length. The coralline red alga has not grown to the extent of bridging over the tips of the branches of this coral, whereas it completely covers the plate-like or encrusting species." (p. 16)

In contrast, we found prolific live coral cover in some of the same areas as surveyed by the *Westward.* Live coral cover was high throughout the fore reef shelf investigated: at 17 m it was 58%, decreasing abruptly above 8 m to ca. 20-30%. Colonies of several corymbose *Acropora* species, up to 40 cm across, and thin whorled plates of *Montipora aequituberculata*, up to 70 cm in diameter, dominated cover. Other common corals included *Pavona* sp. 1, *Plesiastrea versipora*, and *Cyphastrea* cf. *serailia.* The largest corals seen were ca. 1 m wide colonies of *Favia stelligera.* Unlike on Henderson where they dominate coral cover, *Pocillopora* species were not common on Ducie. In contrast to the great changes that occured in the fore reef coral community between 1971 and 1987, the lagoon fauna appears to have remained stable, in both 1971 and 1987 supporting a low cover of mostly *Montipora* species.

I reexamined all but one (*Pocillopora* sp. cf. *P. modumanensis*, a likely synonym of *P. eydouxi*; see Veron & Pichon 1976) of the 14 coral species collected in 1971 (Rehder & Randall 1975 pp. 37-38) (table 1). All 3 species collected in 1971 but not in 1987 were found solely in the lagoon by the *Westward*, a habitat we sampled very cursorially. All coral species collected on the fore reef in 1971 were well established there in 1987. The 1987 coral community, dominated by *Acropora* species and *Montipora aequituberculata*, appears also to be similar to the pre-kill (pre-1971) fauna. Rehder & Randall (1975) noted *Acropora* to dominate among the recently killed coral species of 1971, and I found the plate coral *M. aequituberculata* to have been a dominant constituent of the reef in the recent past, its colonies clearly visible where eroded surge channels expose the reef framework.

Rehder & Randall (1975) argued that the observed pattern of mass mortality may be due to the intrusion of cold water masses, considering the southern position of the island (Ducie is the southernmost atoll in the world); *Acanthaster*, of which only a single individual was found in the lagoon, was considered a less likely cause. Their hypothesis is supported by the pattern of mortality: very high on the fore reef, while the lagoon retained a considerable, although sparse, cover of mostly *Montipora* species. While *Montipora* is favored by *Acanthaster*, its lagoonal habitat would be isolated from short term intrusions of cold water flowing over the fore reef.

The two most conspicuous invertebrates noted in 1971 on the fore reef (Rehder & Randall 1975), the urchins *Diadema savignyi* and *Heterocentrotus mammillatus*, were also very common during our visit. The maintenance of dense sea urchin populations through this time period is of interest not only because it contrasts with corals, but also because *D. savignyi* abundance varies greatly among islands in Polynesia. On certain islands, e.g. Mangaia, Mauke (Cooks, in 1984), and Henderson (in 1987), these nocturnal animals occur spine-to-spine in dense populations, exposed during the day, due to a lack of sufficient crevices to hide in; in contrast, on some neighboring islands (e.g. Rarotonga in the Cooks), they are not noticeably abundant. The question arises whether the very large populations are stable or the result of occasional outbreaks. The present data from Ducie supports the former hypothesis. The presence of such large densities of diademids in the oligotrophic waters of several uplifted islands (Mangaia, Mauke, Henderson) that lack runoff does not support Birkeland's (1989) hypothesis that dense echinoid populations are due to successful larval recruitment in areas of high nutrient input.

Unexpectedly for an uninhabited atoll, fish are not abundant on the fore reef at Ducie. This was also noted by the *Westward* Expedition (Devaney & Randall 1973, Rehder & Randall 1975). Most conspicuous in 1987 were several larger predators: schools of *Caranx lugubris* and *Seriola lalandi* were ubiquitous, and the grouper *Variola louti* was common. In <0.5 m water on the reef flat, however, large serranids (*Epinephelus* sp.) and scarids were common.

It is tempting to speculate that the great abundance of invertebrate grazers (sea urchins and the gastropod *Turbo argyrostomus*) and the relative paucity of herbivorous fish on Ducie are causally related, and that such a scenario may have been more widespread in Polynesia prior to the advent of man. Human predation is usually intense on large invertebrates, including echinoids and *Turbo*, throughout Polynesia and can render such species uncommon on heavily harvested reefs. Further, predatory fish are especially susceptible to overfishing, as they are often territorial and can be readily taken by angling as well as by spears, nets, and other methods. Thus by decreasing the abundance of both the potential competitors (invertebrate grazers) and principal predators of herbivorous fish, human habitation may result in an ecosystem that is more dominated by fish herbivores, as seen on many densely settled islands today. The balance between invertebrate and vertebrate grazers can also be tipped in the other direction by human occupation, however: in heavily fished reefs in the Caribbean, populations of *Diadema antillarum* are an order of magnitude higher than elsewhere, due to reduced competition from herbivorous fish, reduced predation by balistids (Hay 1984), and presumably little human predation on the urchins themselves.

Henderson: A brief description of the reefs of Henderson Island is given by Spencer & Paulay (1989). In contrast to Ducie, the fore reef on Henderson is relatively narrow, has abundant soft sediments, and supports low coral cover. Spur and groove topography is well developed; the grooves are filled with sands that support an abundant infauna.

An algal turf covers much of the fore reef surface and is dominated by *Microdictyon boergesenii* Setchell, with *Lobophora variegata* (Lamour.) Womersley, and *Stypopodium zonale* (Lamour.) Papenfuss being also common. Coral cover was 6% at 11 m depth off the N Beach. In shallow waters, coral cover is dominated by *Millepora*, which becomes uncommon by 12 m depth; deeper waters are dominated by *Pocillopora* sp. 1, *Pocillopora woodjonesi,* and *Porites* cf. *lobata.* In contrast to Ducie as well as to the uplifted Pleistocene reefs of Henderson, acroporids are uncommon. All corals listed from Henderson (table 1) were collected on the fore reef.

The most conspicuous invertebrates on the fore reef are several sea urchins; *Diadema savignyi* is very abundant (see below), while *Echinostrephus aciculatus* and, in shallow (<10 m) water, *Echinometra oblonga,* are common. The large sea cucumber *Holothuria nobilis* is also common, especially at <15 m depths. Like on Ducie, fish are not abundant on Henderson. The black jack, *Caranx lugubris,* is most conspicuous.

The fringing reef flat that surrounds Henderson on the E, N, and NW sides lacks a reef crest and slopes gently seaward. The flat bordering the North Beach was investigated by snorkeling. Although it is banked by a beach, little loose sediment is found on the hard reef flat pavement, and the little that occurs lies underneath the few loose rocks near the landward margin of the reef.

The reef flat has a rich malacofauna. The bivalves *Arca avellana, Lima vulgaris, Chama asperella,* and especially *Isognomon perna* are common, as are several species of muricids and cones, especially *Drupa morum, Drupa clathrata, Thais armigera,* and *Conus rattus*, but also *Drupa ricinus, Morula uva, Conus miliaris, Conus nanus, Conus lividus,* and *Conus retifer.* Additional common gastropods include *Patella flexuosa, Cypraea schilderorum, Nassarius gaudiosus,* and *Strombus maculatus.* The echinoid *Heterocentrotus trigonarius* is abundant in patches along the outer reef flat, while *Echinometra oblonga* is abundant scattered across the reef. Under rocks are large populations of the irregular echinoid *Echinoneus cyclostomus* as well as occasional *Holothuria arenicola.* The only corals seen were a few colonies of *Favia rotumana.*

Pitcairn: A brief description of the underwater topography and habitats of Pitcairn are given by Devaney & Randall (1973). Coral reefs are small and isolated, most being confined to depths of over 20 m.

Oeno: Devaney & Randall (1973) give a brief description of the Oeno lagoon and fore reef. Our visit was brief and confined to the lagoon. The SE outer reef flat is strongly dissected by spur and groove topography and lacks a reef crest. The lagoon seen is uniformly shallow, ca. 1.5-3 m deep, and has an undulating bottom of rubble and sand, with scattered reefs. In the small area investigated at the eastern tip of the larger islet several species of *Montipora* dominate coral cover, with *Acropora humilis,* *Acropora secale, Pavona varians, Montastrea curta,* and *Cyphastrea* cf. *serailia* being also common. *Tridacna maxima* appears to be abundant throughout the lagoon.

MARINE FAUNA

The recorded coral, mollusc, and echinoderm species of the Pitcairn Islands are listed in tables 1-3. Noteworthy observations on the taxonomy, distribution, or ecology of selected species are presented below.

Corals:

Corals exhibit considerable geographic variation in morphology (Veron 1981), and it may be difficult to determine whether unusual forms at peripheral locations are due to genetic or ecophenotypic differences. Several species in the Pitcairn Group do not fit well into the described species they were assigned to, further collecting in the Pitcairn and Tuamotu Islands is necessary to interpret such differences. The Pitcairn fauna exhibits considerably more such odd geographic variation than the Cook Islands' fauna. Some striking examples are discusses below.

Stylocoeniella guentheri Bassett-Smith 1890

A large clump of arborescent *S. guentheri* was dredged at 37 m off Henderson Island; colonies of similar form were dredged by the *Pele* off Pitcairn from 47-63 m and 72-108 m. The fine branches characteristic of these colonies differ from the encrusting or massively columnar growth form usually exhibited by this species (Veron & Pichon 1976).

Pocillopora sp. 1

This was the most common pocilloporid seen in the Pitcairn group. It is similar to *P. verrucosa*, but differs in possessing hood-like ramifications over the calices as in *Stylophora.* I have also seen 2 colonies of this form on Aitutaki in the Cook Islands, where *P. verrucosa* is prevalent.

Pocillopora woodjonesi Vaughan 1918

Colonies of *P. woodjonesi* are fairly common on Henderson. They are reminescent of a thin *P. eydouxi*, a growth form recently also recognized off Australia as being more typical for this species than the irregular form originally described (CC Wallace pers. comm. 1988).

Montipora aequituberculata Bernard 1897

Montipora aequituberculata is one of the most common corals on the Ducie fore reef today. Its large, whorled, thin plates are also conspicuous in exposed reef sections there; it was clearly an important contributor to Holocene reef development on Ducie. While *M. aequituberculata* is uncommon on Henderson today, fossil colonies lacking surface features but exhibiting its classic growth form are locally common on the Pleistocene limestone buttresses above the North Beach (Spencer & Paulay 1989).

Porites sp. aff. *P. annae* Crossland 1952

This unusual *Porites* occurs throughout the Pitcairn Group. It is closest to *P. annae*, but is much more heavily calcified; septa and walls are very thick, and an incomplete endotheca-like blanket of aragonite often envelops calices near the top of septa such that only the septal denticles project above it. Colonies are small, and subarborescent or massive with large, projecting knobs.

Porites sp. cf. *P. lobata* Dana 1846

Instead of the typical massive growth form of *P. lobata*, most colonies from the Pitcairns have subarborescent or columnar skeletons. All specimens have well-developed pali on all 8 septa, although pali are often at a lower level than septal denticles. *Porites* cf. *lobata* is common on Henderson and occasional on Ducie.

Pavona sp. 1

This columnar *Pavona* is common throughout Southeastern Polynesia, occuring westward at least to the Cook Islands. It is intermediate in form between *P. maldivensis* and *P. clavus* / *P. minuta*. It has a columella, small calices (ca. 2 mm), few (6-9 primary) and markedly unequal septocostae with primary septocostae frequently bearing prominent septal lobes, and either a fine (1-3 cm diameter) digitate or a wide, flat-sided-columnar (cf. *P. minuta*) growth form. Colonies are usually small, but can grow to considerable size, e.g. a 4-5 m diameter colony was found on the Henderson fore reef.

Goniastrea australiensis (Edwards & Haime 1857)

Goniastrea australiensis appears to have a sporadic distribution in the Pacific, and is best represented at high latitudes; it is known from Japan, Philippines, Formosa, Great Barrier Reef, Kermadecs (Veron *et al.* 1977), Niue (Paulay 1988), Rapa (Faure 1985), and the Pitcairns. Within Polynesia it appears to be restricted to a southern, subtropical band.

Plesiastrea versipora (Lamarck 1816)

Although *P. versipora* has been recorded from several localities in the Central Pacific, most literature records are based on misidentified *Montastrea curta* (Dana 1846), a species incorrectly considered a synonym (Veron et al. 1977). Actually *P. versipora* has a sporadic distribution in Polynesia, and is known only from a few Tuamotu atolls (a specimen from Raroia is at the USNM) and from the Pitcairn Group, where it is common both living and as a Pleistocene fossil. This eastern Polynesian population appears to be isolated; the species is not known from the intensively surveyed Niue or Cook Islands (Paulay 1988), nor from other French Polynesian archipelagoes (Chevalier 1981). Its success in the Pitcairn Group is further accentuated by its persistence there since the mid-Pleistocene, despite the tremendous turnover in the coral fauna of the group since then (Paulay & Spencer 1989).

Molluscs:

Modiolus matris Pilsbry 1921

Described from the Hawaiian Islands, this colorful mytilid has a curious distribution; it is also known from the Marquesas, Raivavae (Austral), Pitcairn, Henderson, and Easter Islands (Rehder 1980, USNM collections) and thus appears to be restricted to the easternmost fringe of the Indo-West Pacific. It has a wide depth range; although usually found at 5-8 m in Hawaii (Kay 1979) specimens from the Marquesas (USNM) have been dredged as deep as 128-141 m.

Barbatia parva (Sowerby 1833)

The type locality of this species is Ducie, where it was originally collected by Cuming in 1827 (Rehder & Randall 1975). On Ducie it is abundant in crevices in the lagoonal patch reefs, and is also found attached to the undersides of slabs on the reef flat. In contrast to its habitats on Ducie, *B. parva* is known mostly from outer reef slopes elsewhere in Polynesia (Paulay 1988).

Chama "spinosa" Broderip 1835 *sensu* Lamy 1906

Closely related to *Chama asperella*, or possibly a variant of that species, *C. "spinosa"* differs in having a violet interior. Rehder (in Fosberg *et al.* 1983) listed this species as a possible variety of *C. asperella*, noting its peculiar color. It is widespread in Southeastern Polynesia (Paulay 1987).

Chama sp. 2

An apparently undescribed species with fine, honeycombed sculpture, and a yellow interior. It is also known from the Niue, Cook, Society, and Gambier Islands (Paulay 1987).

Tridacna squamosa Lamarck 1819

Tridacna squamosa was known previously eastward to the Cook Islands (Paulay 1987). We found it to be fairly common between 15-20 m on the fore reef of Ducie and occasional on Henderson. In the Cooks as in the Pitcairns it is known only from fore reef habitats (Paulay 1987). Whether its apparent absence in French Polynesia is real, or due to its somewhat inaccessible habitat is not clear.

Tridacna maxima (Roding 1798)

As *T. maxima* is intensively harvested on inhabited islands, its abundance in undisturbed settings is of interest. While *T. maxima* is abundant in the Oeno lagoon, on Henderson it is uncommon. On Ducie only a single live clam was seen on the reef flat, although the large numbers of shells embedded in the beachrock on Acadia Islet indicate that the species may have been much more common in the past, perhaps prior to the coral mortality noted above.

Cantharidus marmoreus (Pease 1867)

This small, rare trochid is known only from the Tuamotus (Cernohorsky 1980), Austral Islands (Raivavae, USNM 732211) and Henderson.

Turbo argyrostomus Linne 1758

In the Cook Islands *Turbo setosus* is common while *T. argyrostomus* is rare. In the Pitcairns the former is rare, while the abundance of *T. argyrostomus* on Ducie was phenomenal, its shells forming a significant portion of Acadia Islet. Perhaps the rarity of *T. setosus* is in part responsible for the abundance of *T. argyrostomus*.

Pseudovertagus clava (Gmelin 1791)

The abundance of this large cerithiid in the Pitcairn Group and some Tuamotu Atolls has been noted (Rehder & Randall 1975, Houbrick 1978), and is especially interesting considering its sporadic distribution and relative rarity elsewhere. *Pseudovertagus clava* appears to be restricted to a southern subtropical band from ca. 15-35°S in the Indo-Pacific (Houbrick 1978).

Recluzia johni (Holten 1802)

Two specimens found in beach drift on Henderson Island appear to be the first records for this widespread janthinid from Southeastern Polynesia.

Polinices simiae (Deshayes 1838)

Although distributed from East Africa to Easter Island, *P. simiae* is rare in most localities except along the margins of its range, at Easter, the Kermadecs, and Hawaii (Cernohorsky 1972, Rehder 1980). It is similarly common on Henderson Island.

Coralliophila latilirata Rehder 1985

The hosts of this Southeastern Polynesian endemic were previously unrecorded. I collected 2 specimens on the plate coral *Montipora aequituberculata*, and 1 on *Leptastrea* sp..

Engina fuscolineata E.A. Smith 1913

This small buccinid, originally described from Henderson, where it is common in beach drift, is also known from the Society Islands (Richard 1985).

Echinoderms:

Diadema savignyi (Audouin 1826)

Diadema savignyi is abundant on both Ducie and Henderson. I found more than one urchin per m^2 in the crevices that riddle the fore reef on Ducie. They are much less common on the Ducie reef flat, but again common in the lagoon; lagoonal urchins are larger (20-25 cm) than those on the fore reef (<15 cm). On Henderson, *D, savignyi* is so abundant that there are not sufficient crevices for them to occupy, so many remain in the open and aggregate into herds, probably for protection, carpeting large reef areas spine to spine in depths of ca. 8-30 m. I have seen similar aggregations of this species on Mangaia and Mauke in the Cook Islands.

Echinometra species-complex

Recent molecular studies on Indo-Pacific *Echinometra* have shown that at least 4 species are represented in what used to be called *E. mathaei* and *E. mathaei oblonga* (Palumbi & Metz in prep.). In the Pitcairn Group *E. oblonga* is by far the most common species; it was occasional on the reef flat on Ducie, and common on the reef flat and shallow fore reef (0-9 m) on Henderson. Two additional forms that fit 2 of Palumbi & Metz's (in prep.) species were also collected; *E.* sp. 1 with white-tipped spines, and the species tentatively assigned to *E. mathaei* (S.R. Palumbi pers. comm. 1989) with unicolored spines and abundant rod-shaped gonadal spicules packed together in bundles.

Heterocentrotus trigonarius (Lamarck 1816)

This widely distributed urchin is common throughout Polynesia, living in the surf zone on reef fronts and on outer reef flats. Populations in the Pitcairn Group are unusually dense, and consist of very large individuals having a different color pattern and shape than those in Central Polynesia. They are uniformly dark blue violet, have elongate, tapering, sharp spines (if unbroken), and grow up to 25-30 cm in diameter spinetip to spinetip. On Ducie, Henderson, and Oeno, they occur in waters up to 3 m deep on the fore reef, are abundant in the surf zone, and extend onto the outer reef flat, which, lacking a reef crest, receives considerable wave action. On Ducie, in the center of this zone, their density was estimated at up to 1-2 urchins m^{-2}. The population on Oeno is similarly dense, which together with their unusually sharp spines, made this "slate-pencil urchin" an unlikely landing hazard; several people in our landing party had spines driven into their feet through tennis shoes while crossing the reef edge. It is probably to this species and not to *Diadema* that Beechey referred to as "numerous *echini*" on the Henderson reef flat that were capable of inflicting "painful wounds" on landing (Fosberg *et al.* 1983, p. 27). The abundance of this species in the Pitcairns is at least in part the result of lack of human predation, as the species is frequently harvested by Polynesians elsewhere.

Heterocentrotus mammillatus (Linne 1758)

While *Heterocentrotus trigonarius* is ubiquitous in southern Polynesia, the only verified records of *H. mammillatus* in the region are from the Pitcairn Group and Raroia (USNM E8525) in the Tuamotus. Morthensen (1943) records this species east only to Fiji in the South Pacific, albeit it extends to Hawaii in the northern hemisphere. Thus the population in the Pitcairns and Eastern Tuamotus appears to be isolated. Within the Pitcairn Group it is very common on Ducie, rare on Henderson (we did not find any, but Randall (1978) illustrates the species from 1971), and again apparently common on Pitcairn. *H. mammillatus* lives in crevices on the fore reef between 10-20+ m depths and does not overlap with *H. trigonarius*. An excellent illustration of the urchin *in situ* is provided by Randall (1978 fig. 4), depicting the characteristic habitat and hinting at the color pattern of the Pitcairns' populations: primary spines are reddish-orange, while secondary spines are white, often with a slight suffusion of red.

Metalia spatagus (Linne 1758)

A relatively dense population of this spatangoid was found on the fore reef of Henderson Island between 10-18 m depths.

Echinoneus cyclostomus Leske 1778

Although tests of this irregular echinoid are not uncommon in Polynesia, I have rarely seen live animals before. On the north reef flat on Henderson, however, *E. cyclostomus* is common, with 10-15 huddling under occasional, loose, dead coral slabs; the animals being at most partly buried in the little sand found under the rock. They are beige with red tubefeet.

Allostichaster peleensis Marsh 1974

Described from Pitcairn on the basis of a single specimen dregded from 101-119 m, I collected another specimen of this species on the Henderson fore reef at 12-18 m depth. While the type has all arms intact, the present specimen has 4 regenerating arms, indicating, that like other members of the genus (Emson 1977), it may be fissiparous. As noted by Marsh (1974), "*Allostichaster* is a genus of southern temperate waters, Australia, New Zealand and South America so *A. peleensis* may add a temperate element to the otherwise tropical asteroid fauna of Pitcairn Island."

Actinopyga palauensis Panning 1944

Described from Palau, this large, black holothurian has since been recorded only from New Caledonia (Guille *et al.* 1986). I found it to be not uncommon on the fore reef between 10-20 m on Henderson as well as on Niue Island. In the intervening Cook Islands I have never seen it despite an intensive survey of the holothurian fauna there. Pierre Laboute (pers. comm., 1988) recalls collecting what was likely this species on Scilly Atoll (Society Iss.), however. Apparently it has a very patchy distribution.

Holothuria (Halodeima) signata Ludwig 1875

Until recently *H. (H.) signata* was thought to be a synonym of *H. (H.) edulis*, but Frank Rowe (pers. comm. 1987) concluded that the name applies to a distinctive chestnut brown *Halodeima* with cream spots covering the dorsum. I have collected it on Niue, and throughout the Cook as well as Pitcairn Islands.

Holothuria (Lessonothuria?) sp. 3

This small (5 cm), cryptic holothurian is apparently undescribed (Frank Rowe pers. comm. 1986). I have collected it in the Cooks, Niue, and Henderson Island.

DISCUSSION

The distribution of a species reflects, to varying degrees 1) the speciation event that established its original range, 2) its dispersal ability, which sets its potential range, 3) its ecology, which determines the habitats and thus areas in which it is capable of living, and 4) its changing environment, which determines the distribution of suitable habitats. I will first look at the fauna of the Pitcairn Group from the perspective of these 4 factors; then I will briefly investigate variation in species composition and abundance among the four islands that constitute the group.

1) Endemicity: Isolated islands or archipelagoes may produce endemic species by allopatric speciation. Isolation may be at the island (group) level, if the island (group) is physically isolated from its neighbors by wide areas of open ocean. Alternatively, it can be at the habitat level, as uncommon habitats can be isolated even if the islands on which they are situated on are not. At the insular level, the Pitcairn Group is not particularly isolated, its nearest neighbor, Temoe Atoll, is only 390 km distant. On the habitat level however, the terrigenous and largely reefless marine environments of Pitcairn are without parallel in the area except for Easter Island, Rapa, and the Marquesas. Thus while endemics distributed throughout the Pitcairn Group are unlikely, endemics restricted to the unusual habitats of Pitcairn Island may be expected.

A paucity of endemics was noted for the fish fauna by Randall (1978), who judged that about 2% of the fish species are restricted to the group. Among the invertebrates studied 7 of 310 (2.2%) species or subspecies are known only from the Pitcairn Group: the asteroid *Allostichaster peleensis*, the ophiuroids *Amphilimna tanyodes* and *Amphiura bountyia*, the coral *Porites* aff. *annae*, and the gastropods *Engina rosacea*, *Fusinus galatheae bountyi*, and *Ziba cernohorskyi*. Five of the 7 are known only from Pitcairn Island. Although the predominance of potential endemics on Pitcairn fits the expectations outlined above, such a conclusion is weak, as all 5 species were taken only by dredging on Pitcairn, mostly in fairly deep water (40-100 m), a habitat minimally sampled in Polynesia.

2) Dispersal limitations: The Pitcairn Group lies at the eastern edge of the Indo-West Pacific province, yet its fauna recorded herein appears to be entirely derived from the west, lacking East Pacific components. As prevailing surface currents are from the north-east, the islands lie upstream of potential Indo-Pacific source areas, making dispersal to the Pitcairns especially difficult. Similarly, continued survival of established populations may be difficult because there are no upstream islands to contribute propagules; thus populations may be more ephemeral in the Pitcairns than on islands further west (see faunal turnover below).

A direct effect of dispersal limitations is the low diversity of the Pitcairns' marine life, part of the well known trend of eastwardly-decreasing diversity through the Pacific basin (e.g. Wells 1954, Stehli et al. 1967). Although our collections are limited and many species remain to be recorded from the group, species diversity in the Pitcairns is clearly considerably less than in archipelagoes westward. Thus, while 1159 species of molluscs (Richard 1985) and 168 species of scleractinians (Pichon 1985) have been reported from French Polynesia, only 198 molluscs and 54 corals are recorded from the Pitcairns. Similarly diminished diversities were noted for the fish fauna (Randall 1978, Rehder & Randall 1975).

3) Ecological limitations: Some interesting biogeographic trends in the Pitcairn Group result from ecological limitations. Both physical limitations, such as temperature and light intensity, and biotic limitations appear to be important in structuring the marine fauna.

The cooler waters around the Pitcairns likely prevent many Indo-West Pacific species from establishing, contributing to the impoverishment of the fauna discussed above, but may also permit the survival and success of other species on the islands. A widespread faunule restricted to subtropical latitudes, spanning the Pacific from Easter Island and Sala y Gomez, through the Pitcairns, Rapa, Marotiri, Kermadecs, Lord Howe and Norfolk Islands, with some species reappearing in northern subtropical areas (especially Hawaii), has been well documented (Randall 1976, Rehder 1980, Briggs 1987). Among the invertebrates studied, 8 species appear to be restricted to this subtropical faunule (table 4). Species with such a narrowly subtropical yet longitudinally widespread distribution are not as common in the Pitcairn Group as on islands located further south: 2.6% of the Pitcairns' (24-25°S) compared with 42.5% (53 species) of Easter Islands' (27°10'S) malacofauna is so restricted latitudinally.

Such distributions may reflect physical or biotic limitations. If subtropical endemic species are so distributed because of temperature or light limitations, their restriction to so narrow a latitudinal band (24-33°) indicates considerable stenotopy with regards to those physical factors. Biotic limitations for southern endemic and amphitropical taxa has found more support (Briggs 1987, Newman & Foster 1987).

Biotic factors - predators, parasites or competitors - may exclude some species from areas they could otherwise occupy. Species so excluded may survive in other areas unoccupied by their foes. Both the variety and intensity (Vermeij 1978) of biotic interactions increases with increasing diversity, thus species are more likely excluded because of biotic interactions from high than from low diversity areas. Habitats or islands that are physically stressful or isolated and thus have low diversity faunas may serve as refuges for stress tolerant and well dispersing species susceptible to biotic limitations (Diamond 1974, Grime 1977, Briggs 1987). Coral reefs and their associated faunas are limited to a latitudinal band roughly between 30°N and 30°S. Between the tropics of Cancer and Capricorn diversity does not appear to be affected by latitude, but falls abruptly toward higher latitudes due to decreasing temperature and light intensity (Rosen 1984). Thus the southern subtropical faunule discussed coincides with this marginal band of low diversity reefs. The eastern edge of the Indo-West Pacific also has low diversity due to dispersal limitations, and in the Pitcairn fauna, at least one species, the mussel *Modiolus matris*, is restricted to it; it is known only from the Hawaiian, Marquesas, Austral, Pitcairn, and Easter Islands.

In depauparate areas species may also have access to resources unavailable to them in more diverse areas due to biotic interactions. Such ecological release may result in a greater abundance of a species or in an expansion of the resources it uses. Several species that are rarely encountered in more central Indo-West Pacific localities are strikingly common in the Pitcairn Group, including the coral *Plesiastrea versipora,* and the gastropods *Pseudovertagus clava,* and *Polinices simiae. Polinices simiae* has also been noted to be unusually common at other marginal Pacific localities: in Hawaii, Easter Island and the Kermadecs (Rehder 1980). Veron (1986) notes that while *Plesiastrea versipora* is common at high latitudes in Australia, it is relatively rare and restricted to shaded environments at low latitudes. While the pelecypod *Barbatia parva* is largely confined to outer reef slopes on most Pacific islands, on Ducie it is abundant in a variety of lagoonal and reef flat habitats. An excellent study of similar ecological release on neighboring Easter Island is given by Kohn (1978).

4) Environmental change and faunal turnover: The uplifted atoll of Henderson provides a well preserved Pleistocene fauna to compare with the living biota of the same area. Paulay & Spencer (1989) showed that since the Pleistocene there has been a greater turnover (extinction and subsequent recolonization of different species) in the coral fauna of Henderson than recorded for any other Pacific island, and that this turnover was not associated with habitat alterations implicit in Henderson's uplift or due to sea level fluctuations. The high faunal turnover is instead likely due to the marginal location of these islands and accompanying physical and dispersal limitations (Paulay & Spencer 1989).

Inter-island variation: There appears to be considerable variation among the Pitcairn Islands in species composition and community structure, reflecting in part the diverse geological history and physiography of the group (Spencer 1989), but also due to the group's peripheral location and attendant instability of its fauna (Paulay & Spencer 1989). The likely unusual marine biota of reef-poor Pitcairn Island cannot yet be compared due to lack of study. The two islands studied in most detail, Henderson and Ducie, show remarkable differences between their faunas. Among the 45 species of corals collected on the two islands, only 16 (36%) are shared. In comparison, Rarotonga and Aitutaki (Cook Islands), separated by about the same distance as Henderson and Ducie, share 78% of their combined fauna of 73 species (Paulay 1988, a study which does not include acroporids) ($G=21.5$, $p<0.001$). Although the large differences between the Ducie and Henderson faunas are certainly due in part to undersampling, considerable qualitative differences are also apparent between them. On Ducie fore reef coral cover is over 50% (although cover has undergone marked fluctuations, see above) and is dominated by *Acropora* and *Montipora* species with *Pocillopora* being occasional. On Henderson, coral cover is <10% and *Millepora* and *Pocillopora* dominate cover, while acroporids are rare. Acroporids are also significantly more diverse on Ducie (16 species, 55% of total) than on Henderson (9 species, 28% of total) ($G=4.7$, $p<0.05$). Further, the echinoid *Heterocentrotus mammillatus* is abundant on Ducie, while it is rare on Henderson.

SUMMARY

Most of the Pitcairns' marine invertebrates are widespread species distributed through several Pacific archipelagoes or the Indo-West Pacific. The location of these islands at the southeastern margin of the Indo-West Pacific province makes both the survival (due to latitudinal, climatic limitations) and continued re-establishment (due to longitudinal, dispersal limitations) of species difficult. Species diversity is therefore relatively low and the fauna appears to be somewhat unstable. Faunal instability is reflected in large short term changes in coral cover on Ducie, large temporal changes in species composition on Henderson, and considerable differences between the faunas of neighboring Ducie and Henderson.

The resulting low species diversity creates a more benign biotic environment than possible in high diversity areas, as many potential predators, parasites, and competitors are absent. This allows the survival of several species restricted to (or most common in) such marginal environments around the Indo-West Pacific fringe. There are few if any endemics restricted to the Pitcairn Group; Pitcairn Island is predicted to be most likely to support possible endemics due to its unusual physiography and habitats.

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Table 1
Pitcairn Group corals

*) 1987 collections; A) Rehder & Randall 1975; B) USNM collections (1967, Devaney coll.); +) species names preceded by a "+" are junior synonyms or misidentifications of the preceding species in the table, their source is given in parantheses; [1]) These species are discussed in more detail in the text. Duc: Ducie, Hen: Henderson, Pit: Pitcairn, Oen: Oeno.

MILLEPORINA	**Duc**	**Hen**	**Pit**	**Oen**
Milleporidae				
Millepora spp.		*		
SCLERACTINIA				
Astrocoeniidae				
Stylocoeniella guentheri Bassett-Smith 1890[1]		*	B	
Pocilloporidae				
Pocillopora damicornis (Linne 1758)			B	
Pocillopora eydouxi Edwards & Haime 1860	*A?	*?		
+?*Pocillopora* sp. cf. *modumanensis* Vaughan 1907 (A)				
Pocillopora sp. 1[1]	*A	*	B	*
+*Pocillopora elegans* Dana 1846 (A)				
Pocillopora woodjonesi Vaughan 1918[1]		*	B	*B
Acroporidae				
Montipora aequituberculata Bernard 1897[1]	*A	*?		
+*Montipora composita* Crossland 1952 (A)				
Montipora aff. *bilaminata* Bernard 1897	A			
Montipora caliculata (Dana 1846)	A	*		
Montipora cf. *capitata* (Dana 1846)		*		
Montipora complanata (Lamarck 1816)	A			
Montipora foveolata (Dana 1846)	*	*		*
Montipora grisea Bernard 1897				*
Montipora incrassata (Dana 1846)	*A			B
+*Montipora* sp. cf. *venosa* (Ehrenberg 1834) (A)				
Montipora tuberculosa (Lamarck 1816)				*
Montipora venosa (Ehrenberg 1834)				*
Montipora cf. *verrucosa* (Lamarck 1816)	*			*?
Acropora acuminata (Verrill 1864)	*		B?	B
Acropora cytherea (Dana 1846)				B
Acropora digitifera (Dana 1846)		*		
Acropora cf. *glauca* (Brook 1893)		*		
Acropora humilis (Dana 1846)	*	*		*
Acropora latistellata (Brook 1892)	*			
Acropora cf. *lutkeni* Crossland 1952	*			
Acropora cf. *microclados* (Ehrenberg 1834)	*			
Acropora nasuta (Dana 1846)	*A	*		
Acropora secale (Studer 1878)			B?	*
Acropora cf. *solitaryensis* Veron & Wallace 1984	*			
Acropora valida (Dana 1846)	*			
Astreopora myriophthalma (Lamarck 1816)	*?A		B	
Astreopora cf. *moretonensis* Veron & Wallace 1984		*		

Poritidae	**Duc**	**Hen**	**Pit**	**Oen**
Porites aff. *annae* Crossland 1952[1]	*	*	B	*
Porites australiensis Vaughan 1918	*A	*		
Porites cf. *lobata* Dana 1846[1]	*	*	B	
Siderastreidae				
Psammocora haimeana Edwards & Haime 1851		*	B	*
Psammocora obtusangula (Lamarck 1816)	*	*		
Agariciidae				
Pavona sp. 1[1]	*A	*		
+*Pavona* sp. cf. *pollicata* (Wells 1954) (A)				
Pavona maldivensis (Gardiner 1905)		*		
Pavona varians Verrill 1864		*		*
Leptoseris hawaiiensis Vaughan 1907			B	
Leptoseris incrustans (Quelch 1886)	*A	*		
Fungiidae				
Cycloseris vaughani (Boschma 1923)			B	
Fungia scutaria Lamarck 1801	*A			
Mussidae				
Scolymia cf. *vitiensis* Bruggemann 1877		*	B	
Faviidae				
Caulastrea cf. *furcata* Dana 1846			B	
Favia mathaii Vaughan 1918		*	B	
Favia rotumana (Gardiner 1899)		*		
Favia stelligera (Dana 1846)	*			
Goniastrea australiensis (Edwards & Haime 1857)[1]		*	B	
Montastrea curta (Dana 1846)	*	*		*
Plesiastrea versipora (Lamarck 1816)[1]	*A	*		*
Leptastrea purpurea (Dana 1846)		*	B?	*
Leptastrea ?transversa Klunzinger 1879		*		*
Cyphastrea cf. *serailia* (Forskal 1775)	*	*		*

Table 2
Pitcairn Group molluscs

*) 1987 collections; A) Rehder in Fosberg et al. 1983, this list includes previous records from Smith 1913; B) Rehder & Randall 1975; C) Rehder 1980; D) Paulay 1988; E) Wilson & Tait 1984; F) Rehder & Wilson 1975; G) USNM collections; H) Powell 1973; I) Emerson & Cernohorsky 1973; J) Cernohorsky 1976; K) Rosewater 1970; L) Houbrick 1986; M) Houbrick 1978; +) species names preceded by a "+" are junior synonyms or misidentifications of the preceding species in the table, their source is given in parantheses; [1]) These species are discussed in more detail in the text. Duc: Ducie, Hen: Henderson, Pit: Pitcairn, Oen: Oeno.

BIVALVIA	**Duc**	**Hen**	**Pit**	**Oen**
Mytilidae				
Modiolus auriculatus Krauss 1848				D
Modiolus matris Pilsbry 1921[1]		*	G	
Botula fusca (Gmelin 1791)			E	
Arcidae				
Arca avellana Lamarck 1819		*A		D
Barbatia parva (Sowerby 1833)[1]	*B	*A		*
Barbatia plicata (Dillwyn 1817)		*A		*
+*Acar divaricata* (Sowerby 1833) (A)				
Pinnidae				
Streptopinna saccata (Linne 1758)		*		
Pteriidae				
Pinctada ?maculata (Gould 1850)	*B			*
Pinctada margaritifera (Linne 1758)	B	*		
Isognomonidae				
Isognomon anomioides (Reeve 1858)		*		
Isognomon perna (Linne 1767)	*B	*		*
Isognomon rupella (Dufo 1840)	*B		D	
+*Isognomon dentifera* (Krauss 1848) (B)				
Pectinidae				
Chlamys coruscans (Hinds 1845)		*	D	
Chlamys sp.			D	
Excellichlamys 'parva' (Sowerby 1835)		*		
Gloripallium pallium (Linne 1758)				*
Mirapecten mirificus (Reeve 1853)		*		
Mirapecten sp.		*		
Semipallium sp.		*		
Spondylidae				
Spondylus hystrix Roding 1798		*		
Spondylus tenebrosus Reeve 1856		*		*
Spondylus sp.	B	A		
Limidae				
Lima bullifera Deshayes 1863		A	D	
Lima vulgaris (Link 1807)		*A		
+*Lima lima* (Linne 1758)				
Ostreacea				
"Ostrea" sp.	B			
Gryphaeidae				
Hyotissa hyotis (Linne 1758)			D	

Chamidae	**Duc**	**Hen**	**Pit**	**Oen**
Chama asperella Lamarck 1819	*	*		
Chama limbula Lamarck 1819	*B	*		*
+*Chama iostoma* Conrad 1837 (B)				
*Chama "spinosa"*Broderip1835 *sensu* Lamy 1906^1		*A		*
+?*Chama asperella* Lamarck 1819 (A)				
Chama sp. 2^1		*		
Chama sp.		*		
Lucinidae				
Codakia bella (Conrad 1837)	*B	*A		*
Codakia tigerina (Linne 1758)				*
Anodontia edentula (Linne 1758)		*		*
Cardiidae				
Trachycardium orbitum (Sowerby 1833) - D				
Fragum mundum (Reeve 1845)		*		
Corculum dionaeum (Broderip & Sowerby 1829)	*			
Tridacnidae				
Tridacna maxima (Roding 1798)^1	*B	*A		*
Tridacna squamosa Lamarck 1819^1	*	*A?,D		
Mesodesmatidae				
Ervilia cf. *bisculpta* Gould 1861		*		
Tellinidae				
Tellina ?bougei (G.B.Sowerby III 1909)				*
Tellina crucigera Lamarck 1818				*
Tellina scobinata Linne 1758		*A		*
+*Arcopagia scobinata* (Linne 1758) (A)				
Loxoglypta rhomboides (Quoy & Gaimard 1835)				D
Semelidae				
Semele australis (Sowerby 1832)	*B	*A		*
Semelangulus crebrimaculatus (Sowerby 1868)	B			
+*S. nebulosus* Dall, Bartsch & Rehder 1938 (B)				
Trapeziidae				
Trapezium oblongum (Linne 1758)		*A		*
Veneridae				
Venus toreuma Gould 1850			D	
Periglypta reticulata (Linne 1758)		*		
GASTROPODA				
Haliotidae				
Haliotis pulcherrima Gmelin 1791	B	*A		*
Patellidae				
Patella flexuosa Quoy & Gaimard, 1834		*A		*
Cellana taitensis (Roding 1798)			H	
Acmaeidae				
Patelloida conoidalis (Pease 1868)		*A		
Patelloida sp.aff.*chamorrorum* Lindberg&Vermeij 1985		*		
Trochidae				
Cantharidus marmoreus (Pease 1867)^1		*A		
Stomatellidae				
Broderipia iridescens (Broderip 1834)		A		
Pseudostomatella speciosa (A. Adams 1850)		A		
Turbinidae				
Turbo argyrostomus Linne 1758^1	*B	*A	G	G

	Duc	Hen	Pit	Oen
Turbo petholatus Linne 1758	B	*A		
Turbo setosus Gmelin 1791	*	*		
Astralium confragosum (Gould 1849)	B			
Neritidae				
Nerita morio (Sowerby 1833)	BC	*AC	C	C
+*Nerita haneti* Recluz 1841 (B)				
Nerita plicata Linne 1758	*B	*A		*
Littorinidae				
Littoraria coccinea (Gmelin 1791)		*AK	K	K
Nodilittorina pyramidalis pascua Rosewater 1970		*AC	C	C
Cerithiidae				
Pseudovertagus clava (Gmelin 1791)[1]	BM		M	*M
Rhinoclavis sinensis (Gmelin 1791)	BM	*A	M	*M
Cerithium ?alveolus Hombron & Jaquinot 1852		*		
Cerith. atromarginatum Dautzenberg&Bouge1933		*A		
Cerithium columna Sowerby 1834		*		
Cerithium echinatum (Lamarck 1822)	*B	*A		*
+*Cerithium rubus* Deshayes 1843 (A)				
+*Cerithium tuberculiferum* Pease 1869 (B)				
Cerithium egenum Gould 1849		A		
Cerithium sandvichense Sowerby 1865	B	*		
Royella sinon (Bayle 1880)		*A	L	
Planaxidae				
Planaxis brasiliana Lamarck 1822			C	
Vermetidae				
Dendropoma maximum (Sowerby 1825)	B	A		
Epitoniidae				
Epitonium torquatum (Fenaux 1943)		A		
Janthinidae				
Janthina janthina (Linne 1758)		*A		*
Recluzia johni (Holten 1802)[1]		*		
Cypraeidae				
Cypraea ?bistrinotata(Schilder&Schilder1937)		*		
Cypraea caputserpentis Linne 1758	*B	A		*
Cypraea childreni Gray 1825		A		
Cypraea cicercula Linne 1758		A		
Cypraea cumingii Sowerby 1832		*A		
Cypraea dillwyni Schilder 1922		*A		
Cypraea fimbriata Gmelin 1791		A		
Cypraea goodalli Sowerby 1832		*A		
Cypraea helvola Linne 1758	B	*A		*
Cypraea irrorata Gray 1828		*A		
Cypraea isabella Linne 1758		*A		*
Cypraea kingae Rehder & Wilson 1975			F	
Cypraea lynx Linne 1758		*		
Cypraea maculifera (Schilder 1932)	*B	*?,A		
Cypraea mappa Linne 1758		A		
Cypraea moneta Linne 1758	*			
Cypraea poraria Linne 1758	*	*A		
Cypraea schilderorum Iredale 1939	*B	*A		*
Cypraea scurra Gmelin 1791		A		

	Duc	Hen	Pit	Oen
Cypraea subteres Weinkauff 1881		A		
Cypraea testudinaria Linne 1758	*B	*		
Cypraea ventriculus Lamarck 1810		*A		
Triviidae				
Trivia edgari Shaw 1909		A		
Vanikoridae				
Vanikoro ?acuta (Recluz 1844)		*		
Vanikoro plicata (Recluz 1844)		A		
Vanikoro sp.		*		
Hipponicidae				
Sabia conica (Schumacher 1817)	*?,B	*		
Calyptraeidae				
Cheilea equestris (Linne 1758)		*		*
Strombidae				
Strombus maculatus Sowerby 1842	*	*		*
Lambis chiragra (Linne 1758)		A		
+*Lambis rugosa* (Sowerby 1842) (A)				
Lambis truncata (Lightfoot 1782)		A		
Naticidae				
Polinices simiae (Deshayes 1838)[1]		*A		
Natica gualteriana Recluz 1844		A		
Natica ochrostigmata Rehder 1980		*	G	
Tonnidae				
Tonna perdix (Linne 1758)		*		*
Malea pomum (Linne 1758)				*
Cassidae				
Casmaria erinaceus (Linne 1758)	B	*A		*
Cymatiidae				
Cymatium nicobaricum (Roding 1798)		*		
Bursidae				
Bursa granularis (Roding 1798)		*A		
Muricidae				
Maculotriton serriale (Deshayes 1834)		*A		
+*Maculotriton serrialis* (Laborde 1838) (A)				
Phyllocoma convoluta (Broderip 1833)		A		
Drupa clathrata (Lamarck 1816)		*A	I	
Drupa elegans (Broderip & Sowerby 1829)	B	A		
Drupa grossularia Roding 1798	*B	*A		
Drupa morum Roding 1798	B	*A	I	
Drupa ricinus (Linne 1758)	*B	*A	I	
Drupa speciosa (Dunker 1867)				I
Drupella cornus (Roding 1798)	B	*		
+*D. elata* (Blainville 1832) (B)				
Morula dealbata (Reeve 1846)		A		
Morula granulata (Duclos 1832)	B	*A		
Morula "parva" (Pease 1868)		*		
Morula uva Roding 1798	*B	*A		
Thais armigera Link 1807		*A		
+*Thais affinis* (Reeve 1846) (A)				
Thais intermedia (Kiener 1835)		A		
Nassa serta (Bruguiere 1789)	*B	*A		
Vexilla vexillum (Gmelin 1791)		A		

Coralliophilidae	**Duc**	**Hen**	**Pit**	**Oen**
Coralliophila latilirata Rehder 1985[1]	*	*		
Coralliophila violacea (Kiener 1836)	*	*		
Quoyula monodonta (Blainville 1832)		*A		
Magilopsis cf. *lamarckii* (Deshayes 1863)		*		
Rapa rapa (Linne 1758)		*		
Buccinidae				
Engina fuscolineata E.A.Smith 1913[1]		*A		
Engina rosacea (E.A. Smith 1913)		A		
Prodotia iostoma (Gray, 1834)		*A		
+*Tritonidea difficilis* E.A. Smith 1913 (A)				
Pisania decollata (Sowerby 1833)		*		
Caducifer decapitata (Recluz 1844)		*A		
Nassariidae				
Nassarius gaudiosus (Hinds 1844)		*A		
Nassarius papillosus (Linne 1758)		A		
+*Alectrion papillosa* (Linne 1758) (A)				
Fasciolariidae				
Fusinus galatheae bountyi Rehder&Wilson 1975			F	
Latirus nodatus (Gmelin 1791)	B	*A		
Peristernia nassatula (Lamarck 1822)		*		
Columbellidae				
Euplica loisae Rehder 1980			C	
Euplica turturina (Lamarck 1822)	B	*A		
+*Euplica palumbina* (Gould 1845) (A,B)				
Euplica varians (Sowerby 1834)		*A		
Pyrene flava (Bruguiere 1789)		*A	G	
+*Pyrene obtusa* (Sowerby 1832) (A)				
Colubrariidae				
Colubraria nitidula (Sowerby 1833)		A		
Colubraria sp.		*		
Vasidae				
Vasum armatum (Broderip 1833)		A		
Harpidae				
Morum ponderosum (Hanley 1858)		A		
Mitridae				
Mitra auriculoides Reeve 1845		A		
Mitra coffea Schubert & Wagner 1829		A		
Mitra colombelliformis Kiener 1838			J	
Mitra coronata Lamarck 1811			J	
Mitra litterata Lamarck 1811	*B	A		
Mitra pele Cernohorsky 1970			J	
Mitra stictica (Link 1807)		A		
Mitra testacea Broderip 1836			J	
Ziba cernohorskyi Rehder & Wilson 1975			F	
Vexillidae				
Vexillum cancellarioides Anton 1838		*		
Turridae				
Daphnella flammea (Hinds 1943)		*		
Conidae				
Conus chaldeus (Roding 1798)	*B	*A		
Conus ebraeus Linne 1758	B	*A		*
Conus flavidus Lamarck 1810	*			

	Duc	Hen	Pit	Oen
Conus geographus Linne 1758	*B	*		
Conus litoglyphus Hwass 1792		*		
Conus lividus Hwass 1792	B	*A		*
Conus magnificus Reeve 1843		*		
Conus miliaris Hwass 1792	*B	*A		
Conus nanus Sowerby 1833	*B	*A		
Conus pennaceus Born 1778		A		
Conus rattus Hwass 1792	B	*A		
Conus retifer Menke 1829	B	*A		
Conus sanguinolentus Quoy & Gaimard 1834		A		
Conus sponsalis Hwass 1792		A		
Conus tenuistriatus Sowerby 1856		A		
Conus tessullatus Born 1778		*A		
Conus textile Linne 1758		*		*
Conus tulipa Linne 1758	B	*A		
Terebridae				
Terebra affinis Gray 1834		*		
Terebra crenulata (Linne 1758)				*
Terebra maculata (Linne 1758)				*
Terebra subulata (Linne 1767)	B			
Hastula penicillata (Hinds 1844)		*		
Elobiidae				
Melampus flavus (Gmelin 1791)		*A		
Bullidae				
Bulla cf. *punctulata* A.Adams 1850		*		
Bulla sp.		A		
Aplysiidae				
Dolabrifera cf. *fusca* Pease 1868	B			
Phyllidiidae				
Phyllidia sp. ?*pustulosa* Cuvier 1804				*
Glaucidae				
Glaucus atlanticus Forster 1777		*		

Table 3
Pitcairn Group echinoderms

*) 1987 collections; x) 1987 sight records, not collected; A) Randall & Rehder 1975; B) Marsh 1974; C) Devaney 1974; D) Randall 1978; 1) These species are discussed in more detail in the text. Duc: Ducie, Hen: Henderson, Pit: Pitcairn, Oen: Oeno.

ECHINOIDEA	**Duc**	**Hen**	**Pit**	**Oen**
Diadematidae				
Diadema savignyi (Audouin 1826)[1]	*A?	*		x
Echinothrix calamaris (Pallas 1774)		*		
Toxopneustidae				
Tripneustes gratilla (Linne 1758)		*		
Echinometridae				
Echinometra mathaei (de Blainville 1825)[1]		*		
Echinometra oblonga (de Blainville 1825)[1]	*	*		
Echinometra sp. 1[1]	*			*
Echinostrephus aciculatus A. Agassiz 1863	*	*		
Heterocentrotus mamillatus (Linne 1758)[1]	*A	D	*	
Heterocentrotus trigonarius (Lamarck 1816)[1]	*A	*		x
Echinoneidae				
Echinoneus cyclostomus Leske 1778[1]		*		*
Clypeasteridae				
Clypeaster sp. ?*reticulatus* (Linne 1758)		*		
Fibulariidae				
Mortonia australis (Desmoulins 1835)		*		*
Brissidae				
Brissus latecarinatus (Leske 1778)	*			
Metalia spatagus (Linne 1758)[1]		*		
ASTEROIDEA				
Astropectinidae				
Astropecten polyacanthus Mueller & Troschel 1842			B	
Oreasteridae				
Culcita novaeguineae Mueller & Troschel 1842			*B	
Ophidiasteridae				
Dactylosaster cylindricus (Lamarck 1816)		*		
Linckia guildingi Gray 1840			*B	
Linckia laevigata (Linne 1758)			B	
Linckia multifora (Lamarck 1816)		*	B	*
Neoferdina cumingi (Gray 1840)		*		
Ophidiaster lorioli Fisher 1906			B	
Acanthasteridae				
Acanthaster planci (Linne 1758)	AB		B	
Asteriidae				
Allostichaster peleensis Marsh 1974[1]		*	B	
OPHIUROIDEA				
Ophiacanthidae				
Amphilimna tanyodes Devaney 1974			C	
Amphiuridae				
Amphiura bountyia Devaney 1974			C	
Ophiactidae				
Ophiactis sp.	*			

Ophiotrichidae	**Duc**	**Hen**	**Pit**	**Oen**
Macrophiothrix demessa (Lyman 1861)			C	C
Macrophiothrix sp.		*		
Ophiothrix purpurea Martens 1867			C	
Ophiocomidae				
Ophiocoma bervipes Peters 1851			C	C
Ophiocoma dentata Mueller & Troschel 1842		*	C	*C
Ophiocoma cf. *doderleini* Loriol 1899		*		
Ophiocoma erinaceus Mueller & Troschel 1842		*	C	C
Ophiocoma longispina HL Clark 1917			C	
Ophiocoma macroplaca (HL Clark 1915)			C	
Ophiocoma pica Mueller & Troschel 1842		*	C	C
Ophiocoma pusilla (Brock 1888)			C	
Ophiocomella sexradia (Duncan 1887)			C	C
Ophionereidae				
Ophionereis aff. *dubia* (Mueller & Troschel 1842)		*		
Ophionereis porrecta Lyman 1860			C	
Ophiodermatidae				
Ophiarachna megacantha erythema Devaney 1974			C	
Ophiopeza kingi Devaney 1974			C	
HOLOTHUROIDEA				
Holothuriidae				
Actinopyga mauritiana (Quoy & Gaimard 1833)		*		
Actinopyga palauensis Panning 1944[1]		*		
Holothuria (Halodeima) atra Jaeger 1833	*	*		x
Holothuria (Halodeima) signata Ludwig 1875[1]		*	*	*
Holothuria (Lessonothuria) sp. 3[1]		*		
Holothuria (Microthele) nobilis (Selenka 1867)	*	*	*	x
Holothuria (Platyperona) difficilis Semper 1868	*			*
Holothuria (Semperothuria) cinerascens (Brandt 1835)	*			
Holothuria (Thymiosycia) arenicola Semper 1868		*		
Holothuria (Thymiosycia) hilla Lesson 1830				*
Holothuria (Thymiosycia) impatiens (Forskal 1775)				*
Labidodemas semperianum Selenka 1867		*		
Synaptidae				
Euapta godeffroyi (Semper 1868)	*	*		
Chiridotidae				
Chiridota hawaiiensis Fisher 1907				*
Chiridota sp.		*		

Table 4
Species in Pitcairn Group that are known only from subtropical areas

Other islands from which species[1] is recorded: Eas: Easter & Sala y Gomez, Rap: Rapa & Marotiri, Aus: Australs, Gam: Gambiers, Ker: Kermadecs, LoH: Lord Howe and Norfolk, Aus: Australian subtropics and N New Zealand, Haw: Hawaiian Islands.

Species	Eas	Rap	Aus	Gam	Ker	LoH	Aus	Haw
Nerita morio	*	*	*	*				
Nodilittorina pyramidalis pascua	*							
Planaxis brasiliana					*	*	*	
Euplica loisae	*	*						
Fusinus galatheae[1]					*			
Mitra pele								*
Allostichaster peleensis[1]							*	
Ophiarachna megacantha erythema		*						

[1] Represented by related subspecies or sister species outside the Pitcairns.

ATOLL RESEARCH BULLETIN

NO. 327

DIPTERA (INSECTA) OR TRUE FLIES OF THE PITCAIRN GROUP (DUCIE, HENDERSON, OENO, AND PITCAIRN ISLANDS)

BY

WAYNE N. MATHIS

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ABSTRACT

An annotated checklist of the Diptera or true flies of the Pitcairn Group (southeastern Polynesia) with emphasis on the fauna of Henderson Island is presented. Although 59 species of Diptera are reported here, which is a substantial increase in the number of species that was known earlier, the fauna must still be considered depauparate. As is typical of oceanic islands of eastern Polynesia, the Pitcairn-Group fauna lacks many taxonomic groups. Most of the species apparently dispersed to the Pitcairn Group from other islands to the west and north, primarily within Polynesia. Only five species are apparently endemic to the Pitcairn Group, and with better sampling, even these may be found elsewhere. Two species, an otitid and a calliphorid, were known previously only from the neotropics.

INTRODUCTION

Remote and exotic, the islands of the Pitcairn Group are poorly known, especially their natural history. Our meager knowledge of them is due largely to their remoteness, which, ironically, now makes them inviting to study because their fauna and flora are relatively undisturbed. Only Pitcairn, of *Mutiny on the Bounty* fame, has been inhabited in recent times, and of the four islands comprising the Group, it alone bears the lasting imprint of human disturbance. The Pitcairn Group lies in the South Pacific along the southern boundry of Polynesia between 23-25° south latitude and 124-131° west longitude. Besides Pitcairn, which is a geologically recent volcanic island, the other islands of the Pitcairn Group are Ducie and Oeno, both low-lying atolls, and Henderson, a raised atoll.

Although remote and poorly known, the Pitcairn Group has not been totally bypassed by man, least of all Pitcairn. During the past decade, for example, an American millionaire attempted first to buy and then to lease Henderson Island, the largest island of the Group. The intent of the procurement was to establish a small settlement and construct an airfield among other developments. Through the lobbying efforts of the Royal Society of England and the Smithsonian Institution, the procurement of Henderson Island was thwarted, and Henderson has now been proposed as a world heritage site to better preserve its unique geological features and depauparate fauna and flora. A history of Henderson Island, including a summary of all previous work on the natural history of the island, was recently published by Fosberg, et al. (1983).

To better document the unique natural history of the Pitcairn Group, a Smithsonian-sponsored expedition visited these islands in 1987. The purposes of the expedition were: to conduct biological and geological reconnaissance of the islands and to gather data that are needed to determine the feasibility of more long-term research on the islands. The efforts of the Smithsonian team were primarily focused on Henderson Island because of recent threats to its conservation, its unique geology, and its much larger size.

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Because of complex logistics, limited budgets, and tight schedules, the reconnaissance work was restricted to brief stays on each of the islands. Our visits to Ducie and Oeno atolls were for a few hours on the afternoons of May 10th and 28th respectively. Nine days were devoted to Henderson (May 12-21), and four days were spent on Pitcairn (May 22-26).

As documented in Fosberg, et al., the insects of Henderson Island are virtually unknown. Less than 35 species in five orders had been recorded prior to our survey, and of these, only two were dipterans, *Dacus setinervis* Malloch and *Atherigona hendersoni* Malloch. The Diptera of the other islands are no better known. Thus, the purpose of this paper is to report on the Diptera or true flies of the Pitcairn Group that were collected on the Smithsonian expedition.

Although only two dipterous species had been reported previously from Henderson Island, we anticipated the discovery of many more. Herein, nearly 60 species are treated, and although this represents a major increase in the number of species recorded for these islands, many additional species will undoubtedly be discovered as these islands are further sampled for longer periods of time, at different seasons, and using different collecting techniques. We collected Diptera with an aerial net and a Malaise trap that was sometimes baited.

For each species treated, the following information is provided: the name of the species plus its author, year, and page of publication; immediately following these data and continuing on the same line is the name of the person who made the species determination (the author made the identification if no one is noted) and major references to the species. Thereafter as information is available are sections on "Specimens Examined" (distribution on islands of the Pitcairn Group, including the number and gender of the specimens; specimens are deposited in the USNM unless noted otherwise) and "Distribution" (generalized account of a species distribution). Information on the natural history and other comments as available and appropriate are included under a "Remarks" section.

Gustav Paulay and I were the two entomologists on the Smithsonian team, and most of the insects, including all of the Diptera, were collected by us. Determinations of species are as authoritative as possible short of revising each group to which a species belongs. For a few species, primary types were examined, but for most identifications, I relied on the expertise of specialists.

On Henderson Island, we sampled two primary sites as follows: the NW Beach from May 12-20 and the North Beach from May 17-20. From these two beaches, we made short excursions inland to a few more sites, but even the more productive of these were within the vicinity of the beaches. The inland sites will be noted more specifically in the "Specimens Examined" section for each species.

Two primary sites were sampled on Pitcairn Island. The first, and by far the more extensively collected, was Adamstown, the only settlement on the island. The settlement occupies nearly one-fourth of the island and includes a number of different habitats from the rocky shores of Bounty Bay, the only harbor of the island, to garden plots and orchards near the homes. Where appropriate, Adamstown has been annotated with the specific habitat in the listing under the "Specimens Examined" section. The second site on Pitcairn was the beach at Down Rope. Down Rope is the only sandy beach of Pitcairn, is approximately 150 meters in length, and is only accessible from a steep trail down a cliff face on the southeast side of the island.

Because of their small size, essentially all of the main islet of both Oeno and Ducie were surveyed, although very hurriedly and superficially.

In accordance with the editorial policy of this publication series, new taxa are not described herein; these will be published elsewhere.

TREATMENT OF TAXA

SUBORDER NEMATOCERA

Family Sciaridae

1. **Bradysia** sp. (det. R.J. Gagné).

Specimens Examined.--Pitcairn Island. Adamstown (2♀).

Remarks.--The genus *Bradysia* comprises numerous species, and recognition of most are based on sexually dimorphic characters of males. Thus the two female specimens that we collected cannot be distinguished at the species level.

Family Psychodidae

2. **Psychoda** sp. (det. R.V. Peterson).

Specimens Examined.--Henderson. NW Beach (4♂, 7♀).

Remarks.--All specimens were collected in a Malaise trap during the night.

Family Culicidae

3. **Aedes (Stegomyia) aegypti** (Linnaeus, 1762:470; det. Y.M. Huang).

Specimens Examined.--Pitcairn Island. Adamstown (9♂, 1♀).

Distribution.--Pantropical, mostly within the 10° C. isotherms.

Remarks.--The literature on this species is voluminous, especially as it pertains to its vectoral capacity of numerous diseases of man. This species is the common man biter on Pitcairn, and its potential there as a vector of diseases should not be overlooked.

4. **Culex (Culex) quinquefasciatus** Say, 1823:10 (det. Y.M. Huang).

Specimens Examined.--Pitcairn Island. Adamstown (1♀).

Distribution.--Cosmopolitan.

Remarks.--This species, like the preceding one, is the vector of several diseases, mostly arboviruses, of man. Caution, therefore, should be exercised to avoid establishment of these diseases on Pitcairn.

Family Chironomidae

5. **Chironomus** s.l. sp. (det. P. Cranston).

Specimens Examined.--Henderson. North Beach (1♀).

Family Ceratopogonidae

6. **Dasyhelea pacifica** Macfie, 1933:99 (det. W.W. Wirth).

Specimens Examined.--Henderson. North Beach (9♂, 3♀).

Distribution.--Oceania: Common on Marquesas and Society Islands and the Pitcairn Group.

7. **Dasyhelea fulvicauda** Macfie, 1933:101 (det. W.W. Wirth).

Specimens Examined.--Henderson. North Beach (1♀).

Distribution.--Oceania: Common on Marquesas and Society Islands and the Pitcairn Group; Oriental: Taiwan.

8. **Dasyhelea** n. sp. (in *mutabilis* group)(det. W.W. Wirth).

Specimens Examined.--Henderson. North Beach (5♂, 5♀).

Distribution.--Oceania: The Pitcairn Group.

9. **Forcipomyia (Euprojoannisia) sauteri** Kieffer, 1912:27 (det. W.W. Wirth).

Specimens Examined.--Henderson. North Beach (6♂, 5♀).

Distribution.--Oceania: The Pitcairn Group; Oriental: Taiwan.

SUBORDER BRACHYCERA

Family Dolichopodidae

10. **Chrysosoma n. sp.** (det. D.J. Bickel).
Specimens Examined.--Henderson. NW Beach (12♂, 11♀); North Beach (4♀).
Distribution.--Oceania: Society Islands and the Pitcairn Group.
Remarks.--Most of the specimens taken from the NW Beach were collected individually from the broad leaves of a shrub that was growing on top of the escarpment just above the beach.

11. **Chrysotus denticornis** Lamb, 1932:233 (det. D.J. Bickel).
Specimens Examined.--Pitcairn Island. Adamstown (4♂, 5♀).
Distribution.--Oceania: Society and Marquesas Islands and the Pitcairn Group.

12. **Cymatopus** n. sp. (det. D.J. Bickel).
Specimens Examined.--Pitcairn Island. Adamstown (14♂, 6♀).
Distribution.--Oceania: Cook Islands and the Pitcairn Group.

Family Phoridae

13. **Chonocephalus** sp. A. (det. H. Disney).
Specimens Examined.--Henderson Island. NW Beach (5♂).

14. **Chonocephalus** sp. B. (det. H. Disney).
Specimens Examined.--Henderson Island. NW Beach (4♂).

15. **Megaselia (Megaselia) scalaris** (Loew, 1866b:53; det. H. Disney).
Specimens Examined.--Pitcairn Island. Adamstown (1?, abdomen missing).
Distribution.--Pantropical.
Remarks.--*Megaselia* has hundreds of species of which most are difficult to distinguish even when the male genitalia are intact. Hence the determination of this species must be considered tentative (Disney, in litt.).

16. **Dohrniphora cornuta** (Bigot, 1857:348; det. H. Disney).
Specimens Examined.--Henderson Island. NW Beach (2♂).
Distribution.--Pantropical.
Remarks.--This species, which was originally described from Cuba, is common throughout the tropics.

Family Syrphidae

17. **Ischiodon scutellaris** (Fabricius, 1805:252; det. F.C. Thompson).
Specimens Examined.--Henderson Island. NW Beach (5♂).
Distribution.--Orient: SE Asia and Japan; Australasian: Australia; Oceania: Hawaii, Micronesia, and the Pitcairn Group.
Remarks.--This species was attracted to flowers of *Pemphis acidula* Forst. that appeared to be in the last stages of flowering in May. *Pemphis acidula* is common on Henderson as a shrub or tree between the beach and cliff face.

Family Otitidae

18. **Perissoneura diversipennis** Malloch, 1932:207.
Specimens Examined.--Henderson Island. NW Beach (60♂, 45♀); North Beach (6♂, 5♀). Oeno Atoll (7♂, 9♀).
Distribution.--Oceania: Marquesas (Fatu Uku and Hatu Tu) and the Pitcairn Group.
Remarks.--The wings of this species demonstrate considerable sexual dimorphism. Those of the male bear a pattern, whereas the female's are hyaline. This species is fairly abundant, especially on Henderson, and occurred mostly on low-lying vegetation in the shade. Adults were also attracted to human feces.

19. **Acrosticta apicalis** (Williston, 1896:375; det. G.C.Steyskal).--Malloch, 1932:206 (list, Marquesas).

Specimens Examined.--Pitcairn Island. Adamstown (1♀).

Distribution.--Widely distributed from the Neotropics, Africa, several islands of Oceania (Fiji, Samoa, Society Islands, Marquesas, Hawaii) and now the Pitcairn Group.

Remarks.--This species was collected while randomly sweeping vegetation.

20. **Euxesta stigmatias** Loew, 1868:310 (det. G.C. Steyskal).

Specimens Examined.--Pitcairn Island. Adamstown (1♂, 1♀).

Distribution.--Neotropics: Mexico and the West Indies, south to Brazil and Bolivia; Oceania: The Pitcairn Group.

Remarks.--This species was collected while randomly sweeping vegetation. Our collections on Pitcairn are the first records outside of the Neotropical Region.

Family Platystomatidae

21. **Scholastes lonchifera** Hendel, 1914:253.--Malloch, 1932:206 (list, Marquesas).

Specimens Examined.--Henderson Island. NW Beach (45♂, 40♀); North Beach (12♂, 7♀). Oeno Atoll (5♂, 5♀). Pitcairn Island. Adamstown (2♀).

Distribution.--Oceania: Society Islands (Tahiti), Cook Islands, Marquesas (Hiva Oa, Fatu Hiva, Ua Huka, Ua Pou), and the Pitcairn Group.

Remarks.--This species occurs commonly on shaded, low-lying vegetation, especially beneath coconut palms on Henderson and Oeno. The larvae of *Scholastes* breed in rotting vegetable matter, and at least one species, *S. bimaculatus* Hendel, breeds in rotting coconuts (Swezey, 1924:389-390). Adults are also attracted to human feces.

22. **Pseudorichardia flavitarsis** Macquart, 1850:121.--Malloch, 1932:206 (list, Marquesas).

Specimens Examined.--Henderson Island. NW Beach (1♂, 26♀); North Beach (1♂, 1♀). Oeno Atoll (2♂). Pitcairn Island. Adamstown (1♂, 1♀).

Distribution.--Oceania: Widespread from Fiji to the Society Islands (Tahiti), the Marquesas (Hiva Oa), and the Pitcairn Group.

Remarks.--This species is the type species of *Pseudorichardia.* Nearly all of the specimens from Henderson were taken from the sides of a tent or on vegetation near the site where birds were being prepared as museum specimens. Numerous bird skins and carcasses were usually hung or laid out to dry and apparently attracted this species.

Family Tephritidae

23. **Dacus setinervis** Malloch, 1938:112.

Specimens Examined.--Henderson Island. NW Beach (1♀). Pitcairn Island. Adamstown (2♂, 3♀).

Distribution.--This species is apparently endemic to the Pitcairn Group, where it is known from the type locality, Henderson Island, and now from Pitcairn.

Remarks.--Our previous knowledge of the Diptera of Henderson Island was limited to this and a species of Muscidae, both of which were thought to be endemic to this island. This species is now known from Pitcairn, where most specimens were collected on vegetation that had overgrown an old shed in Adamstown.

24. **Dioxyna sororcula** (Wiedemann, 1830:509; det. A.L. Norrbom).

Specimens Examined.--Pitcairn Island. Adamstown (3♂, 3♀).

Distribution.--Widespread in tropical and subtropical areas of the Old World and now the Pitcairn Group.

Remarks.--This species was originally described from specimens collected on the Canary Islands and has since been discovered to be widespread in tropical areas of the Old World. It was probably introduced to Pitcairn Island. This species lives in seeds of *Bidens.*

Family Lonchaeidae

25. **Lamprolonchaea metatarsata** (Kertész, 1901:83).

Specimens Examined.--Oeno Atoll (4♂, 4♀). Pitcairn Island. Adamstown (2♂, 4♀).

Distribution.--Widespread in Southeast Asia and Oceania.

Remarks.--This species was probably introduced to Oeno and Pitcairn, perhaps in infested fruit.

Family Lauxaniidae

26. **Homoneura hawaiiensis** (Grimshaw, 1902:84).--Hardy and Delfinado, 1980:134-135 (description and figures).

Specimens Examined.--Henderson Island. NW Beach (27♀). Oeno Atoll (11♂, 10♀). Pitcairn Island. Adamstown (2♂, 13♀).

Distribution.--Oceania: Marquesas, Society Islands, Samoa, Solomon Islands, Hawaii, and the Pitcairn Group.

Remarks.--This species was fairly common and was swept from low-lying, shaded vegetation. On the NW Beach of Henderson, most specimens were collected by sweeping ferns.

Family Milichiidae

27. **Leptometopa beardsleyi** Hardy and Delfinado, 1980:358 (det. C.W. Sabrosky).

Specimens Examined.--Henderson Island. NW Beach (2♀); North Beach (1♀). Oeno Atoll (5♂).

Distribution.--Oceania: Hawaii and the Pitcairn Group.

Remarks.--The specimen from North Beach was collected from guano-covered vegetation that was growing next to the nesting area of a masked booby (*Sula dactylatra* Lesson). In addition to the specimens noted above, a female from Oeno that is possibly a variety of *beardsleyi* was collected. Because intraspecific variation within *beardsleyi* has not been assessed and as the specimen in question is in poor condition, it is not specifically listed as this species.

28. **Desmometopa inaurata** Lamb, 1914:363 (det. C.W. Sabrosky).--Sabrosky, 1983:33 (revision).

Specimens Examined.--Pitcairn Island. Adamstown (2♂, 2♀).

Distribution.--Widespread throughout the world except for the Oriental Region. Oceania: Fiji, Samoa, Hawaii, Marquesas, and the Pitcairn Group.

Remarks.--This species was probably introduced to Pitcairn Island.

29. **Milichiella lacteipennis** (Loew, 1866a:185; det. C.W. Sabrosky).

Specimens Examined.--Pitcairn Island. Adamstown (3♀).

Distribution.--Cosmopolitan.

Remarks.--Like the previous species, this was probably introduced to Pitcairn Island.

Family Sphaeroceridae

30. **Coproica hirtula** (Rondani, 1880:38; det. A.L. Norrbom).

Specimens Examined.--Pitcairn Island. Adamstown (11♂, 9♀).

Distribution.--Cosmopolitan.

Remarks.--This is undoubtedly an introduction to Pitcairn Island.

Family Xenasteiidae

31. **Xenasteia palauensis** Hardy, 1980:218.

Specimens Examined.--Henderson Island. NW Beach (10♂, 14♀). Pitcairn Island. Adamstown (1♀).

Distribution.--Oceania: Palau and the Pitcairn Group.

Remarks.--This species was moderately common on low-lying vegetation that was growing immediately next to an open-air latrine, the contents of which apparently attracted it.

The identification of this species as *X. palauensis* must be considered tentative. When Hardy (1980:219-220) described this species he noted that several specimens other than the type series may represent this species or form a species complex of closely related species. The issue remains unresolved.

Family Chyromyidae

32. **Nannodastia horni** Hendel, 1930:70.--Sabrosky and Wirth, 1958:109-110.

Specimens Examined.--Henderson Island. North Beach (4♂, 9♀); NW Beach (6♂, 3♀).

Distribution.--Orient: Taiwan; Oceania: Hawaii and the Pitcairn Group.

Remarks.--Specimens of this species are tiny, usually less than 2 mm in length, and were collected in caves and under overhangs by sweeping a fine-meshed net just above the soil or debris on the floor. The caves and overhangs we sampled were 15-20 m above the beach on the cliff face.

Family Chloropidae

33. **Cadrema pallida** variety **bilineata** (Meijere, 1904:113; det. C.W. Sabrosky).

Specimens Examined.--Henderson Island. NW Beach (18♂, 70♀). Pitcairn. Adamstown (9♂, 15♀).

Distribution.--Widespread in the Orient and Oceania (extending to the Marquesas and south to the Pitcairn Group).

Remarks.--This species is moderately common on the beach at the high tide mark where debris had accumulated.

34. **Cadrema nigricornis** (Thomson, 1869:607; det. C.W. Sabrosky).

Specimens Examined.--Henderson Island. NW Beach (40♂, 46♀); North Beach (19♂, 8♀). Oeno Atoll (16♂, 1♀). Pitcairn Island. Adamstown (1♀).

Distribution.--Widespread in SE Asia and the Pacific islands to Hawaii, the Marquesas, and the Pitcairn Group.

Remarks.--Like the previous taxon, this species is also moderately common on the beach at the high tide mark where debris had accumulated.

35. **Cadrema samoaensis** (Malloch, 1930:246; det. C.W. Sabrosky).

Specimens Examined.--Pitcairn Island. Adamstown (3♂).

Distribution.--Oceania: Samoa (Salailua and Safune) and the Pitcairn Group.

36. **Tricimba adamsoni** Malloch, 1933:29 (det. C.W. Sabrosky).

Specimens Examined.--Pitcairn Island. Adamstown (2♀).

Distribution.--Oceania: Marquesas and the Pitcairn Group.

37. **Gaurax bicoloripes** (Malloch, 1933:30; det. C.W. Sabrosky).

Specimens Examined.--Henderson Island. NW Beach (1♀). Oeno Atoll (1♂, 1♀). Pitcairn Island. Adamstown (10♂, 4♀).

Distribution.--Oceania: Marquesas and the Pitcairn Group.

38. **Gaurax** n. sp. (det. C.W. Sabrosky).

Specimens Examined.--Henderson Island. NW Beach (24♂, 4♀). Pitcairn Island. Adamstown (1♂, 1♀).

Distribution.--Oceania: The Pitcairn Group.

Family Tethinidae

39. **Dasyrhiconoessa lasiophthalma** (Malloch, 1933:17).--Sasakawa, 1974:2 (figure of male genitalia).

Specimens Examined.--Oeno Atoll (6♂, 6♀). Pitcairn Island. Adamstown (harbor area) (17♂, 6♀); Down Rope (20♂, 5♀).

Distribution.--Afrotropical: Seychelles; Oriental: China (Hong Kong), Philippines; Oceania: Marquesas south to the Pitcairn Group.

Remarks.--The habitat for this species is beaches where debris has accumulated at or above the high tide mark. On Oeno and Pitcairn, the species occurred commonly in this habitat.

Family Canacidae

40. **Nocticanace** n. sp.

Specimens Examined.--Oeno Atoll (30♂, 11♀). Pitcairn Island. Adamstown (harbor area) (33♂, 11♀); Down Rope (2♂, 5♀).

Distribution.--Oceania: The Pitcairn Group.

Remarks.--I found this species commonly on all beaches of Pitcairn and Oeno that had large rocks (rock diameter of 0.5 m or larger) or exposed coral.

Family Ephydridae

41\. **Placopsidella marquesana** (Malloch, 1933:13).--Tenorio, 1980:270-271, 350-351 (figures and description of larva and puparium).--Mathis, 1986:11-13 (revision).

Specimens Examined.--Pitcairn Island. Adamstown (harbor area) (11♂, 3♀); Down Rope (8♂, 9♀).

Distribution.--Oceania: Widespread in Oceania between the Solomon Islands and the Pitcairn Group and as far north as Hawaii.

Remarks.--This species was moderately abundant on the rocky beach of Bounty Bay, especially among larger rocks (0.5 m in diameter or larger) that offered some protection from the direct action of waves and the sun. Discovery of this species on Pitcairn is a major extension to its distribution; previously its farthest known locality southward was the Society Islands (Bora Bora and Tahiti)(Mathis, 1986).

42\. **Hecamede granifera** Thomson, 1869:594.

Specimens Examined.--Henderson Island. NW Beach (88♂, 11♀); North Beach (56♂, 10♀). Oeno Atoll (34♂, 9♀). Pitcairn Island. Adamstown (7♂, 3♀); Down Rope (9♂, 6♀).

Distribution.--Oceania: The Marquesas (Nuku Hiva) and the Pitcairn Group.

Remarks.--The genus *Hecamede* needs revision before many of the available names can be validly applied. For the present, I am using *H. granifera* for this species in accordance with the recent catalog of Australasian and Oceanian Diptera (Mathis, 1989). A junior synonym, *H. inermis* Malloch, was used previously for the common species of *Hecamede* that occurs in the South Pacific.

This species was abundant on the beach, especially where debris had accumulated at the high tide mark. It was also common on specimens of corals and bird preparations that we had set out to dry.

43\. **Atissa** sp.

Specimens Examined.--Pitcairn Island. Down Rope (1♂).

44\. **Paratissa pollinosa** (Williston, 1896:414).

Specimens Examined.--Pitcairn Island. Adamstown (harbor area) (20♂, 7♀); Down Rope (7♂).

Distribution.--Neotropics: Dominica to St. Vincent and Panama; Oceania: Hawaii (Oahu and Maui) and the Pitcairn Group.

Remarks.--This species was collected on the rocky beach of Bounty Bay (Adamstown). Seaweed and other organic debris had accumulated at the specific site where the specimens were collected.

45\. **Nostima striata** (Lamb, 1912:326; det. J. Edmiston).

Specimens Examined.--Oeno Atoll (11♂, 1♀).

Distribution.--Oceania: The Marquesas (Hiva Oa) and the Pitcairn Group.

Remarks.--Toward the northern end of Oeno are occasional patches of moss on the moist, mostly shaded soil beneath some of the larger trees. The patches of moss were no more than a meter or two in diameter, and the specimens seemed to be very specific to these patches.

Family Drosophilidae

46\. **Drosophila (Sophophora) simulans** Sturtevant, 1919:153 (det. D.A. Grimaldi).

Specimens Examined.--Henderson Island. NW Beach (1♂, 1♀); North Beach (1♀). Pitcairn Island. Adamstown (1♂).

Distribution.--Cosmopolitan.

Remarks.--This species was probably introduced to Henderson and Pitcairn islands.

47\. **Drosophila (Sophophora) melanogaster** species group (det. D.A. Grimaldi).

Specimens Examined.--Pitcairn Island. Adamstown (10♂, 14♀).

Distribution.--Cosmopolitan.

Remarks.--This species was undoubtedly introduced to Pitcairn Island.

48. **Phorticella** n. sp. (det. D.A. Grimaldi).

Specimens Examined.--Pitcairn Island. Adamstown (5♂, 3♀).

Distribution.--Oceania: The Pitcairn Group.

Remarks.--The genus *Phorticella* Duda includes eight species (Wheeler, 1981), all of which have Oriental distributions. Thus this species would be the first from Oceania.

49. **Scaptomyza (Bunostoma) australis** Malloch, 1923b:618 (det. D.A. Grimaldi).

Specimens Examined.--Henderson Island. NW Beach (1♂, 1♀).

Distribution.--Australasian: Australia; Oceania: The Pitcairn Group.

Remarks.--This is the first record of this genus in Polynesia except for numerous species on the Hawaiian Islands.

Family Agromyzidae

50. **Liriomyza** sp. (det. A. Freidberg).

Specimens Examined.--Pitcairn Island. Adamstown (1♂, 1♀).

51. **Pseudonapomyza** sp. (det. A. Freidberg).

Specimens Examined.--Pitcairn Island. Adamstown (1♀).

Family Muscidae

52. **Atherigona hendersoni** Malloch, 1923a:184 (det. A.C. Pont).

Specimens Examined.--Henderson Island. NW Beach (40♀). Oeno Atoll (4♀). Pitcairn Island. Adamstown (17♀).

Distribution.--Oceania: Fiji, Hawaiian Islands, Pitcairn Group, Tonga, Western Samoa.

Remarks.--This is one of the more common species of Diptera to occur on these and other islands of the South Pacific.

Family Fanniidae

53. **Fannia pusio** (Wiedemann, 1830:437; det. A.C. Pont).

Specimens Examined.--Henderson Island. NW Beach (1♂, 14♀). Oeno Atoll (9♂, 3♀). Pitcairn Island. Adamstown (1♂, 1♀).

Distribution.--Oceania: Easter Islands, Fiji, Guam, Hawaiian Islands, Kiribati (Gilbert I), Pitcairn Group, Wake I, Western Samoa, New Caledonia, Afrotropical, Nearctic, Neotropical.

Remarks.--Females were collected mostly by sweeping vegetation. An occasional specimen was captured in the Malaise trap. The single male from Henderson was part of a hovering swarm between three and four m above the ground.

Family Calliphoridae

54. **Phaenicia sericata** (Meigen, 1826:53; det. N.E. Woodley).

Specimens Examined.--Henderson Island. NW Beach (11♂, 9♀). Oeno Atoll (4♀). Pitcairn Island. Adamstown (7♂, 3♀).

Distribution.--Widespread throughout most of the Old World except for Africa and now the Pitcairn Group.

Remarks.--Nearly all of the specimens we collected were taken from areas where dead animals were being prepared as museum specimens or for food.

55. **Cochliomyia macellaria** (Fabricius, 1775:776; det. N.E. Woodley).

Specimens Examined.--Pitcairn Island. Adamstown (4♂, 8♀).

Distribution.--Southern USA south to Argentina and Chile and the Pitcairn Group.

Remarks.--This species was common around chicken coops and tables where dead fish were cleaned and prepared for cooking. It is almost surely an introduction and is known by the vernacular name of primary screw-worm.

56. **Hemipyrellia** sp. (det. N.E. Woodley).

Specimens Examined.--Henderson Island. NW Beach (8♀).

Family Sarcophagidae

57. **Sarcophaga (Liosarcophaga) dux** (Thomson, 1869:534; det. T. Pape).

Specimens Examined.--Henderson Island. NW Beach (26♂, 9♀).

Distribution.--Oriental: India, Sri Lanka, Java, Philippines, China; Palearctic: S. Korea, Japan; Oceania: Guam, Hawaiian Islands, Mariana Islands, Henderson I, Samoa, Caroline Islands, Wake, Marshall Islands, Gilbert Islands; Australasian: Australia.

Remarks.--This species was attracted to bird preparations that we had laid out to dry. Females were especially common and many deposited first-instar larvae on the preparations.

Family Hippoboscidae

58. **Ornithoica pusilla** (Schiner, 1868:384; det. R.V. Peterson).--Maa, 1966:94-97 (revision).

Specimens Examined.--Henderson Island. NW Beach (2♀); North Beach (on a masked booby, *Sula dactylatra* Lesson) (10♂, 4♀).

Distribution.--Oceania: Christmas Island, Marshall Islands, Tokelau Island, Tuamotu Archipelago, Society Islands (Tahiti), and the Pitcairn Group.

Remarks.--We collected specimens of this species directly from a nesting pair of masked boobies.

59. **Olfersia aenescens** Thomson, 1869:610 (det. R.V. Peterson).

Specimens Examined.--Ducie Atoll (on a red-tailed tropicbird, *Phaethon ribricauda* Boddaert) (6♂). Henderson Island. NW Beach (1♂, 1♀); North Beach (2♂).

Distribution.--Nearly cosmotropical over tropical seas as a parasite on various species of birds.

Remarks.--Most of the specimens that we collected on Henderson were taken as they would land on us. The specimens from Ducie Atoll were taken from a nesting red-tailed tropicbird. This is one of the few widespread species that probably occurs naturally on islands of the Pitcairn Group.

DISCUSSION

This study should only be considered within the limited perspective of two weeks of intensive field work and subsequent study of the resultant collections and observations. With more extensive collecting, including rearing of adults from immatures, more specialized collecting techniques (e.g. baits, Berlese funnels), and sampling at different seasons, the fauna of Diptera will undoubtedly be found to be more diverse. The same kind of sampling artifacts apply to attempts to determine the provenance of the fauna occurring on the Pitcairn Group.

Despite these qualifications, certain patterns are apparent from the available evidence. The evidence is summarized into tables (Tables 1-4) in which the islands of the Pitcairn Group are listed with the following abbreviations: DA = Ducie Atoll; HI = Henderson Island; OA = Oeno Atoll; PI = Pitcairn Island. For data in the tables that is cited under "Distribution Elsewhere," I have depended on the information provided by the specialist who identified the species and/or the forthcoming catalog of Diptera from the Australasian and Oceanian Regions (Evenhuis, 1989). Species determined simply as "sp." in the preceding section are not listed in the tables as we know nothing about their distribution.

The most apparent pattern is that the majority of Diptera from the Pitcairn Group probably dispersed there from other islands of Polynesia, and, moreover, that the Polynesian provenance reflects the overall pattern for Oceania in general, i.e., the Polynesian fauna of Diptera came mostly from the west, primarily from other islands but also from the Orient and Australia, including New Guinea. This is particularly evident from the data presented in Table 1. The species in this table, which constitute about two-thirds of the known fauna of the Pitcairn Group, are found elsewhere in Oceania, primarily Polynesia, or continental areas to the west. Most of these species either infiltrated from the west or they have sister groups occurring on islands or continents to the west.

The next largest category of Diptera are frequently referred to as "weeds" (Table 2). These species, numbering 11 on the Pitcairn Group, are pantropical or cosmopolitan, and for the most part, their occurrence reflects man's impact on these islands. The majority of these species occur only on Pitcairn Island, which is highly disturbed and where there is fairly regular commerce by which these flies could easily have been introduced.

Table 1. Distribution of Oceanian, Australian, and/or Oriental Diptera of the Pitcairn Group

	DA	HI	OA	PI	Distribution Elsewhere
Dasyhelea pacifica		X			Marquesas, Society
Dasyhelea fulvicauda		X			Marquesas, Society, Taiwan
Forcipomyia sauteri		X			Taiwan
Chrysosoma n. sp.		X			Society
Chrysotus denticornis				X	Marquesas, Society
Cymatopus n. sp.				X	Cook Islands
Ischiodon scutellaris		X			Oceania, widespread Asian
Perissoneura diversipennis		X			Marquesas
Acrosticta apicalis				X	Oceania, widespread tropics
Scholastes lonchifera		X	X	X	Widespread Oceanian
Pseudorichardia flavitarsis		X	X	X	Oceania east of Fiji
Lamprolonchaea metatarsata			X	X	Oceania, SE Asian
Homoneura hawaiiensis		X	X	X	Widespread Oceanian
Leptometopa beardsleyi		X	X		Hawaii
Desmometopa inaurata				X	Widespread Oceanian
Xenasteia palauensis		X		X	Oceanian
Nannodastia horni		X			Hawaii, Taiwan
Cadrema pallida bilineata		X		X	Oceanian, widespread Oriental
Cadrema nigricornis		X	X	X	Oceanian, SE Asian
Cadrema samoaensis				X	Samoa
Tricimba adamsoni				X	Marquesas
Gaurax bicoloripes		X	X	X	Marquesas
Dasyrhiconoessa lasiophthalma			X	X	Oceanian, Seychelles, China
Placopsidella marquesana				X	Widespread Oceanian
Hecamede granifera		X	X	X	Marquesas
Paratissa pollinosa				X	Hawaii, Caribbean
Nostima striata				X	Marquesas
Scaptomyza australis		X			Australia
Atherigona hendersoni		X	X	X	Polynesian
Fannia pusio		X	X	X	Polynesian, New Caledonia
Sarcophaga dux		X			Oceanian, Oriental
Ornithoica pusilla		X			Widespread Oceanian

Endemism among Diptera from the Pitcairn Group is surprisingly low, with only five potential species (Table 3). Although these five are known thus far only from the Pitcairn Group, I would not be surprised to learn of their occurrence elsewhere. This potential is exemplified by the taxonomic history of *Atherigona hendersoni.* This species was originally described from specimens collected on Henderson Island (Malloch, 1923a) but has now been found as far west as Fiji and to the north as far as Hawaii (Adrian Pont, personal communication).

The neotropical otitid and calliphorid species (Table 4) that were unknown previously from Oceania are interpreted to be "baggage" that has accompanied man's arrival in recent times. The calliphorid is the primary screw worm of large mammals in the Western Hemisphere and could have arrived on Pitcairn Island with the various introductions of feral goats.

Table 2. Distribution of Cosmopolitan or Pantropical Diptera found on the Pitcairn Group

	DA	HI	OA	PI	Distribution Elsewhere
Aedes aegypti				X	Pantropical
Dohrniphora cornuta		X			Pantropical
Olfersia aenescens	X	X			Pantropical
Dioxyna sororcula				X	Old World tropics
Phaenicia sericata		X	X	X	Widespread Old World
Culex quinquefasciatus				X	Cosmopolitan
Megaselia scalaris				X	Cosmopolitan
Milichiella lacteipennis				X	Cosmopolitan
Coproica hirtula				X	Cosmopolitan
Drosophila simulans		X		X	Cosmopolitan
Drosophila melanogaster				X	Cosmopolitan

Table 3. Distribution of Endemic Diptera of the Pitcairn Group

	DA	HI	OA	PI	Distribution Elsewhere
Dasyhelea n. sp.		X			Pitcairn Group
Dacus setinervis		X		X	Pitcairn Group
Gaurax n. sp.		X		X	Pitcairn Group
Nocticanace n. sp.			X	X	Pitcairn Group
Phorticella n. sp.				X	Pitcairn Group

Table 4. Distribution of Neotropical Diptera found on the Pitcairn Group

	DA	HI	OA	PI	Distribution Elsewhere
Euxesta stigmatias				X	Widespread neotropics
Cochliomyia macellaria				X	Widespread neotropics

CONCLUSIONS

This study of the Diptera from the Pitcairn Group reveals a much richer fauna than was reported previously. The results were largely expected, however, as insects are the dominant terrestrial group on most oceanic islands, especially those of the Pacific. The order Diptera, in turn, is one of the major components of the Insecta. Furthermore, these islands had not been visited previously by a specialist on Diptera, and the use of specialized knowledge and collecting techniques would normally result in additional finds.

Despite the substantial increase in the number of known species, from two to nearly 60, the dipterous fauna of the Pitcairn Group must still be considered depauperate and very disharmonic (lacking major lineages within the groups represented). These two conditions were likewise predictable. Nearly 30 years ago, Gressitt (1961) wrote that "..the fauna of southeastern Polynesia is a poor one, both in the sense of great disharmony and in general poverty of species." This study essentially corroborates Gressitt's ovservations.

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It is with special pleasure that I dedicate this paper to Dr. S. Dillon Ripley, Secretary Emeritus of the Smithsonian Institution. His unflagging interest in all aspects of the natural history and conservation of these islands has directly resulted in their preservation and our expedition to them.

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VEGETATION OF HENDERSON ISLAND

BY

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BY

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ABSTRACT

On the basis of field surveys from the north and north-west beaches, the vegetation of Henderson Island can be classified into 11 vegetation communities: 2 in littoral environments with sandy substrates, 4 on rocky coasts and 5 associated with the limestone plateau. Apart from the cutting of 'miro' wood by Pitcairn islanders, the communities are remarkably undisturbed, with only 5 adventive species recorded. Whereas the littoral communities are clearly differentiated into well-defined zones from shore to plateau, the island interior limestone forests (canopy 5-8m, with an understorey of herbs and shrubs) show many combinations of species, resulting in a complex mosaic of forest types. 9 species or varieties are presently recognised as endemic to Henderson and all are primarily plants of the island's interior.

INTRODUCTION

The study of the vegetation communities of Henderson Island is of both great interest and importance. Henderson's vegetation is of interest in a regional context, first, biogeographically, because of the island's remoteness in the south-east Pacific Ocean (Fosberg 1984) and secondly, because its floristic composition reflects a relatively rare stage in the continuum of vegetation types, controlled by increasing elevation above sea level, from the *motus* of sea-level atolls to the 'high' islands of Polynesia constructed from both volcanic rocks and limestones (Sachet 1985). In addition, Henderson's vegetation is of great significance to the wider debate on the structure and function of island ecosystems both past and present. As a result of the island's isolation, unsuitability for sustained human habitation and lack of economic phosphate deposits, the vegetation of Henderson Island has survived Polynesian and successive Western impacts (with only 5 introduced plant species) and provides an almost unique glimpse of the natural vegetation cover of a former atoll and lagoon well-raised above present sea level (for classification of different emergent reef surfaces see Figure 1; Fosberg 1985a). Furthermore, the continued removal of the natural vegetation communities of fragile tropical island ecosystems makes the field study of locations such as Henderson doubly important (Fosberg et al. 1983, Fosberg 1985b).

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Uplifted islands are also important because they offer a rare analogue for what Pacific atolls may have been like during the low sea stands that characterised much of the Pleistocene. As tectonic uplift took place in the relatively recent past (< 1.0 my ago, Spencer and Paulay, this volume) at Henderson, the island is especially appropriate as a model for atoll environments during low sea stands (mean duration of Pleistocene low sea levels ~ 100 kyr; Shackleton and Opdyke 1976). Thus, for example, soil development on Henderson has been poor by comparison with other uplifted islands such as Niue, S.W.Pacific (Wright and van Westerndorp 1965) or the makatea islands of the Southern Cook Islands (Wood and Hay 1970). Meagre soil development has likely been the result of both the recency of uplift and the lack of source minerals other than those available in limestone and humus. By contrast, fluvial inputs from the central volcanic highlands on Mangaia, S.Cook Islands (Wood and Hay 1970) and atmospherically-sourced volcanic particles (likely to be ash; Fieldes et al. 1960, Wright and van Westerndorp 1965) on Niue have contributed considerably to pedogenesis on these islands. Henderson's lack of soil accumulation and the coarse coral rubble (see Spencer and Paulay, this volume) which covers most of the island, probably explain the low stature of the vegetation, which rarely exceeds 10m in height. This contrasts with much taller mature forests on other uplifted islands: thus, for example, the canopy of the primary forest of Niue is 20-30m high (Sykes 1970, pers. obs. G.P.).

In this paper we consider aspects of vegetation (i) structure; (ii) function and adaptation; (iii) physiognomy; and (iv) floristic composition and ecological interactions. As such, it complements the published checklists of the island's flora (St John and Philipson 1962, Fosberg et al. 1983, this volume).

CLASSIFICATION OF VEGETATION COMMUNITIES

Vegetation units on Henderson Island can be broadly equated with topographic units and/or sedimentary environments. The following classification is proposed.

A. LITTORAL VEGETATION

(a) Sandy substrates

1. Strand pioneer vegetation and seaward beachridge slope community
2. Beachridge crest and back-barrier swale community

(b) Rocky substrates

3. Limestone platform community
4. 'Miro' woodland community
5. Limestone buttress and cliff face community
6. Fern slopes community

B. LIMESTONE PLATEAU MARGIN AND ISLAND INTERIOR VEGETATION

7. Cliff top and plateau margin community
8. Pinnacled-pitted limestone community
9. Timonius scrub community
10. Limestone glade woodland community
11. Lagoonal patch reef community

It should be stressed, however, that this classification is empirical and strictly only applies to those areas of the island, primarily the north and north-west coasts, visited by the 1987 expedition (for locations; see Spencer and Paulay, this volume). It is interesting to note that 3 species (*Asplenium lobulatum*, *Fimbristylis cymosa* and *Lycium carolinense* var. *sandwichense*) only collected on one occasion, by D R Tait in 1912, are indicated by St John and Philipson (1972) as being restricted to the South Point region. Whilst coral ledges and a reef flat dissipate wave attack on the north-western, northern and eastern shores, waves break directly onto the undercut cliffs of the south-western and south coasts with sea spray being thrown to heights above that of the cliff margin under even moderate sea conditions. Thus different ecological conditions prevail at the southern end of Henderson by comparison with the northern coasts. Even within the latter region field observations suggest that there may be micro-climatic differences between neighbouring coasts; for example, the cliff face and plateau margin environments above the north-west beach appear to be moister than the corresponding areas on the north coast. One reflection of these differences may be the apparently much poorer epiphytic flora on the northern plateau; further differences are considered below.

One of the great problems in delimiting the different vegetation communities on Henderson Island is that not only are they floristically diverse but also that many species are present in more than one, and often several, different communities. The following species lists by community document all the species seen by us in each community; the accompanying text indicates which species make each community recognizable and adds information from the work of previous plant collectors. Nomenclature follows Fosberg et al. (1983, and see also this volume).

DESCRIPTION OF VEGETATION COMMUNITIES

A. LITTORAL VEGETATION

The littoral vegetation, defined as seaward of the plateau margin, has more diverse and clearly differentiated communities than the interior vegetation. This diversity and differentiation is the result of a greater variation from shore to cliff top in elevation, substrate type, exposure to sea spray, and other microclimatic factors than are found in the island interior. The arrangement of most of this variation is normal to the coast, producing well-defined zones from shore to plateau.

The most seaward community may be either on sandy substrates (1. Strand pioneer and seaward beachridge community: see below) especially along the north coast, or on solid limestone (3. Limestone platform community: see below) depending on local physiography. These shoreward communities consist of a few salt tolerant species. In their shelter follow more diverse woodland communities on gently sloping or level ground on sand (2. Beachridge crest and back-barrier swale community: see below) or on limestone rock and rubble (4. 'Miro' woodland community: see below). These latter communities include the most disturbed areas on Henderson. They serve as camp-sites to visiting parties on the north and northwest beaches, most coconuts grow here, and miro (*Thespesia populnea*) is frequently cut. The transition from this littoral terrace to the plateau is via a mosaic of steep slopes and cliff faces that bear low-lying, dense, species-rich covers (5. Limestone buttress and cliff face community; and 6. Fern slopes community: see below).

1. Strand pioneer and seaward beachridge community

The beaches of Henderson are of two types: the long, relatively broad beaches of the northern and eastern shores and small pocket beaches, typified by the north-west beach and the eastern sections of the north beach. The pocket beaches are characteristically backed by a bevelled limestone ramp and flanked by low limestone outcrops (see Spencer and Paulay, this volume); they support few plants. The north beach can be divided into a lower foreshore dominated by beachrock and poorly-sorted sands and an upper, planar beach, 15 - 25m in width. At the western end of this beach the limestone cliffs come right down to the shore and only locally are incipient, small sand dunes present between the limestones and the beach sands. These low sand sheets are characterised by clumps of the grass *Lepturus repens*. In the central section of the north beach a beachridge fronts a broad embayment in the limestone cliffs (see Spencer and Paulay, this volume for north beach plan). The dominant colonist on the seaward face of this beachridge, at ~3.0 - 4.5m above sea level, is *Scaevola sericea* (Plate 1) with *Heliotropium anomalum* and *Pemphis acidula* being locally present.

Shrubs:	*Pemphis acidula* *Scaevola sericea* var. *tuamotuensis*
Herb:	*Heliotropium anomalum* var. *argenteum*
Creeper:	*Triumfetta procumbens*
Grass:	*Lepturus repens*

2. Beachridge crest and back-barrier swale community

At the Pitcairner's campsite on the north beach, the dominant vegetation on the beachridge crest is coconut plantation. To the west of this locality the beachridge supports an extensive cover of *Tournefortia argentea* both as a bushy ground cover and as gnarled trees, 3 - 4m high. *Tournefortia* is an opportunistic species characteristic of marginal and disturbed ground (Fosberg 1953) and is restricted to the littoral vegetation on Henderson. Beneath the latter may be an understorey of *Polypodium* sp(p).

The area between the beachridge crest and the base of the limestone cliffs, reaching ~30m in width on the central north beach, is clearly a zone of transition of both micro-climate and substrate. *Pemphis acidula* , common along the seaward margin, becomes noticeably absent as this zone is traversed. In the moist, shaded localities at some distance from direct marine influence, *Procris pedunculata* and the endemic *Peperomia hendersonensis* are particularly characteristic of this shrub-dominated community.

Trees:	*Cocos nucifera* *Pandanus tectorius* *Thespesia populnea* *Tournefortia argentea*
Shrubs:	*Guettarda speciosa* *Scaevola sericea* var. *tuamotuensis* *Timonius polygama* *Tournefortia argentea*

Herbs: *Peperomia hendersonensis*
Procris pendunculata

Creeper: *Ipomoea macrantha*

Grass: *Thuarea involuta*

Ferns: *Asplenium nidus*
Polypodium sp(p).

3. Limestone platform community

The limestone platform environment is dominated at its seaward margin by dense, monospecific stands of *Pemphis* (Plates 2 and 3), in a band usually less than 5m wide, and locally festooned by orange-green strings of *Cassytha filiformis*. The '*Pemphis* forest' is a characteristic and permanent community of rocky shores on Central Pacific atolls (Fosberg 1953), as well as on other uplifted islands (pers. obs.; S.Cooks, Niue). The creeper *Triumfetta procumbens* is also found on the seaward margin of this community.

Tree: *Cocos nucifera*
Tournefortia argentea

Shrub: *Pemphis acidula*

Creepers: *Cassytha filiformis*
Triumfetta procumbens

4. 'Miro' woodland community

Inland from the *Pemphis* zone, trees become established on the last interglacial limestone unit. At the southern end of the north-west beach and particularly at the eastern end of the north beach the 3 - 5m high canopy is dominated by miro, *Thespesia populnea*, with an understorey of *Polypodium* sp(p). Gaps in the canopy and the presence of numerous logs on the limestone substrate attest to the management of this community by the Pitcairn Islanders who crop miro for wood carving. The *Thespesia* logs are surrounded by a thick litter layer of *Pandanus* leaves and *Polypodium* fronds. Under the densest miro canopy, near the foot of the limestone buttress, *Peperomia hendersonensis* appears and becomes an abundant ground cover. At the same location occasional *Timonius polygama* and *Procris pendunculata* give their first appearance. The large coconut grove on the northwest beach dominates the canopy of the seaward half of this community.

Trees: *Cocos nucifera*
Cordia subcordata
Guettarda speciosa
Pandanus tectorius
Thespesia populnea
Tournefortia argentea

Shrub: *Timonius polygama*

Herbs:	*Peperomia hendersonensis*
	Procris pedunculata
Grass:	*Thuarea involuta*
Creeper:	*Cassytha filiformis*
Ferns:	*Asplenium nidus*
	Polypodium sp(p).

5. Limestone buttress and cliff face community

Although there are individual trees of *Celtis* sp., *Pisonia grandis* and, particularly at higher levels, *Pandanus tectorius,* the steep limestone faces are dominated by a close ground cover. At lower levels this may consist of low *Timonius* (Plate 4) tangle but at greater heights the cliffs are characterised by creeping herbs. Particularly noticeable is the way in which *Sesuvium portulacastrum* covers the outer floor of the highest (20.2 - 21.5m; see Spencer and Paulay, this volume), deepest and most laterally extensive of the marine notches on the limestone buttresses of the north shore, an association clearly seen from the north beach (Plate 2). The change from a low shrub to a herb assemblage appears to be correlated with a change in substrate from poorly sorted, sandy coral rubble to solid limestone.

Trees:	*Celtis* sp.
	Pandanus tectorius
	Pisonia grandis
	Thespesia populnea
Shrubs:	*Eugenia rariflora*
	Timonius polygama
	Tournefortia argentea
Herbs:	*Euphorbia sparrmannii*
	Heliotropium anomalum var. argenteum
	Lepidium bidentatum
	Sesuvium portulacastrum
Creepers:	*Boerhavia tetrandra*
	Cassytha filiformis
	Ipomoea macrantha
Ferns:	*Asplenium nidus*
	Nephrolepsis hirsutula
	Polypodium sp(p).

6. Fern slopes community

Above the vegetation communities of the immediate coastal fringe and in between the high angle cliffs and limestone buttresses are slopes of 25 - 30° in angle up to the cliff top. This topographic unit is dominated by extensive stands of the ferns *Polypodium* sp(p). and *Nephrolepsis hirsutula.* Alternating and mixed with this fern cover, especially on the lower parts of the slope, are thickets of *Timonius* , forming a dense canopy ~ 1.5m high, draped with the parasitic *Cassytha* , and with the occasional emergent *Eugenia rariflora* reaching 2m.

Shrubs:	*Eugenia rariflora* *Pisonia grandis* *Timonius polygama*
Creeper:	*Cassytha filiformis*
Ferns:	*Nephrolepsis hirsutula* *Polypodium* sp(p).

B. LIMESTONE PLATEAU MARGIN AND ISLAND INTERIOR VEGETATION

In the simplest terms, the plateau interior of Henderson Island supports a limestone forest of large individual trees with a canopy at 5 - 8m and a wide variety of herbs and shrubs beneath that canopy, the most remarkable being the tall *Bidens hendersonensis* (Fosberg 1984). However, the way in which different species combine varies considerably across the island's surface. Some of these differences seem to be controlled by local geology. The island's interior is underlain by either jagged, pinnacled exposures of limestone or by flatter depressions, with fields of corals or areas of fragmented coral sticks, thought to represent a former atoll lagoon floor (Spencer and Paulay, this volume). Some areas of limestone bedrock may have no forest cover (8. Pinnacle-pitted limestone community: see below) or a low, tangled scrub vegetation (9.*Timonius* scrub community: see below). Similarly, a thick litter layer and pocket soils have developed over some lagoonal deposits, producing a distinctive limestone woodland (10. Limestone glade woodland: see below). It seems likely, therefore, that local changes in geology will be reflected in changes in forest floristic composition. Whereas on the northwest plateau there is an abrupt change from limestone island rim to lagoonal interior, on the northern plateau there is an alternation of bedrock exposures with lagoonal depressions (Spencer and Paulay, this volume); these differences might be expected to be echoed in forest type. Superimposed on geological constraints is the possibility of micro-climatic variation across the island top. Broad differences between the seemingly wetter north-western plateau and the drier northern plateau have already been alluded to: perhaps these differences explain the greater abundance of *Asplenium nidus* and *Nesoluma st-johnianum* on the north-west plateau and the more frequent occurrence of *Myrsine hosakae* in the northern interior. Finally, there are clearly ecological gradients from island margin to plateau interior. The plateau edge is a transition zone from the littoral limestone cliff communities, and is the only area where *Cordyline fruticosa*, *Scaevola sericea*, *Euphorbia sparrmannii*, *Caesalpinia major* and *Ipomoea macrantha* were noted on the island top (7. Cliff top and plateau margin community: see below). Further inland, these gradients are reflected in the abundance of certain species; thus *Bidens* , *Pisonia* and *Nesoluma* become more abundant as distance increases from the coasts whereas the opposite trend is exhibited by *Pandanus* . The following list shows the variety of species found within the limestone interior forest; different combinations of these species yield a complex mosaic of forest types. The communities that follow describe those associations that stand out as recognisable units within the plateau vegetation. Except for patches of *Timonius*, no area of the interior plateau is dominated by one or a few species, but supports diverse communities. It should be noted that the following list indicates only those 22 species, from a total of 41 species, which are common across much of the interior island landscape. Unfortunately our record does not include the endemic tree *Santalum hendersonense* which St John and Philipson (1962) noted as being common on the plateau top. Opinion on Pitcairn (K. Brown pers.comm. 1987), however, suggests that the species occurs only in localised clusters.

Trees:	*Celtis* sp.
	Geniostoma hendersonense
	Guettarda speciosa
	Nesoluma st-johnianum
	Pandanus tectorius
	Pisonia grandis
Shrubs:	*Alyxia* sp.
	Bidens hendersonensis var. *hendersonensis*
	Canthium barbatum f. *calcicola*
	Canthium odoratum
	Cassia glanduligera
	Eugenia rariflora
	Glochidion pitcairnense
	Ixora fragrans
	Timonius polygama
	Xylosma suaveolens var. *haroldii*
Herbs:	*Dianella intermedia*
	Procris pendunculata
Creeper:	*Morinda umbellata* var. *forsteri*
Ferns:	*Asplenium nidus*
	Davallia solida
	Polypodium sp(p).

7. Cliff top and plateau margin community

The cliff top is characterized by a dense thicket vegetation in which *Timonius*, *Canthium odoratum*, *Nephrolepis* and *Polypodium* sp(p). are abundant (Plate 5). St. John and Philipson (1962; Plate 5) also show *Xylosma suaveolens* to be an important component of the cliff top community above the north-west beach; we concur with this observation. Particularly noticeable are large individuals of *Pandanus* ; their pyramidal forms often dominate the island skyline from the sea and give, perhaps, an impression of greater abundance than is actually the case (eg. Plate 4).

Away from the immediate marginal cliffs, *Eugenia* begins to decline in abundance whereas *Celtis* sp., *Ixora fragrans*, *Cassia glanduligera* and *Glochidion pitcairnense* start to appear as important constituents of the forest community on rocky substrates. At the north beach the presence of *Cocos nucifera* and *Cordyline fruticosa* at the plateau margin is clearly related to the trail leading into the island interior. Similarly, *Caesalpinia major* is only found in association with the north coast trail (curiously, the difficulties of passage produced by this species are documented by Fosberg et al. (1983) for Henderson yet the species was not collected by the Mangarevan expedition (St. John and Philipson 1962)).

Trees:	*Cocos nucifera*
	Celtis sp.
	Pandanus tectorius
	Pisonia grandis
Shrubs:	*Canthium odoratum*
	Cassia glanduligera
	Cordyline fruticosa
	Eugenia rariflora
	Glochidion pitcairnense
	Ixora fragrans
	Scaevola sericea var. *tuamotuensis*
Shrubs:	*Timonius polygama*
	Xylosma suaveolens var. *haroldii*
Herb:	*Euphorbia sparrmannii*
Creepers:	*Boerhavia tetrandra*
	Caesalpinia major
	Cassytha filiformis
	Ipomoea macrantha
Ferns:	*Davallia solida*
	Nephrolepsis hirsutula
	Polypodium sp(p).

8. Pinnacle-pitted limestone community

Inland from the north-west beach is an area of open limestone, with limestone pinnacles up to 2 m high (Plate 6; and well illustrated by Fosberg et al. 1983, Plates 11 and 12). The horrors of traversing this terrain are well described by St. John and Philipson (1962). Although we only saw a small, perhaps 50m diameter, area of this pinnacle-pitted limestone, both its unique landscape and unusual vegetation warrants its separation as a distinctive community. The fern *Nephrolepsis hirsutula* is scattered across the top of the pinnacles while *Asplenium nidus* sits in the hollows between them. Several *Hernandia stokesii* trees grow on this barren landscape, the only area where this species was observed both by the Mangarevan (Fosberg, pers.comm. 1987) and the 1987 expedition.

Tree:	*Hernandia stokesii*
Shrub:	*Eugenia rariflora*
Ferns:	*Asplenium nidus*
	Nephrolepsis hirsutula
	Polypodium sp(p).

9. *Timonius* scrub community

Locally, the limestone forest community may be replaced by a scrub vegetation dominated by monospecific thickets of *Timonius* . This comprises an almost inpenetrable low canopy up to 3m high with an intersecting mattress of brittle dead twigs and branches below. The trees and shrubs which surround these patches are typical of the cliff top and plateau margin community (see above for species list).

Shrub:	*Timonius polygama*

10. Limestone glade woodland community

The presence of pocket soils on the lagoonal deposits of the plateau is reflected in the development of a glade woodland with a more open canopy than that of the limestone forest. This community also often supports a lush fern understorey, largely composed of *Davallia solida* and *Polypodium* sp(p) but also with *Procris* and *Morinda umbellata* var. *forsteri.* Commonly found foraging through the litter layer in this community is the Henderson Island Rail, *Porzana atra*. The dominant tree species are *Pisonia* and *Nesoluma* with occasional *Pandanus* and the relatively rare *Myrsine* . *Alyxia* sp. is often entangled throughout the canopy and parasitic *Korthalsella* spp. and epiphytic *Pyrrosia serpens* are also present. Where breaks in the canopy occur, the main gap colonist is *Senecio stokesii* with *Glochidion* and *Cassia* invading at the margins.

Trees:	*Myrsine hosakae* *Nesoluma st-johnianum* *Pandanus tectorius* *Pisonia grandis*
Shrubs:	*Canthium barbatum* f. *calcicola* *Canthium odoratum* *Cassia glanduligera* *Eugenia rariflora* *Glochidion pitcairnense* *Ixora fragrans* *Premna* cf. *serratifolia* *Xylosma suaveolens* var. *haroldii*
Shrubs:	*Korthalsella platycaula* var. *vitiensis* *Korthalsella rubescens* *Procris pedunculata* *Peperomia hendersonensis* *Senecio stokesii*
Creepers:	*Alyxia* sp. *Morinda umbellata* var. *forsteri*
Ferns:	*Asplenium nidus* *Davallia solida* *Polypodium* sp(p). *Pyrrosia serpens*

11. Lagoonal patch reef community

As well as the coral heads and acroporid sticks within the lagoonal depressions, there are larger mounds of coral rubble within these depressions which we interpret as rather more extensive patch reefs. Where large, these mounds show a distinctive vegetation cover, dominated by *Eugenia* and low *Pisonia* in a bushy habit (Plate 8).

Trees:	*Guettarda speciosa*
	Nesoluma st-johnianum
	Pandanus tectorius
Shrubs:	*Eugenia rariflora*
	Glochidion pitcairnense
	Ixora fragrans
	Pisonia grandis
	Xylosma suaveolens var. *haroldii*
Creeper:	*Morinda umbellata* var. *forsteri*
Fern:	*Polypodium* sp(p).

CONCLUDING REMARKS

Remarkably, the vegetation communites described above have been almost completely unaffected by human contact. Fosberg et al. (1983) list only four adventive species: *Cocos nucifera*, *Cordyline fruticosa*, *Aleurites moluccana* and *Achyranthes aspera* var. *pubescens*. To this list we add *Setaria verticillata* based on the collections made during the 1987 expedition. Of these five species, *Achyranthes* and *Aleurites* have not been collected since 1912 and 1922 respectively. Coconut plantations, clearly associated with campsites, are restricted to the central sections of the north beach and the north-west beach. These trees have obviously matured since the observations of the Mangarevan Expedition when the coconuts of the north-west beach were described as "all young" (Fosberg et al. 1983, 18). On the plateau surface, coconuts are restricted to the trail inland; mature trees near the cliff top and recent plantings at intervals along the trail in the interior. *Cordyline* is similarly restricted to trail-side locations and is only found near the plateau margin on the north coast. Only a single example of the *Setaria* grass, which is known from Pitcairn (Fosberg et al., this volume), was seen at the north beach camp-site, and all of it was excavated. It may have been a very recent colonist.The lime and orange trees reported by Maude in 1951, and assumed to be at the north landing (St John and Philipson 1962) were not seen on the 1987 expedition. We were not able to verify the presence or absence of introduced root crops at the north east point. The cutting of *Thespesia populnea* by the Pitcairners is largely confined to the low limestone platform near the shore and does not result in the disturbance of other vegetation communities.

Although the vegetation of Henderson Island is greatly enriched compared to neighbouring atolls, several typical atoll plants that occur in the Eastern Tuamotus or even on neighbouring Oeno Atoll are absent on Henderson, e.g. *Hedyotis romanzoffiensis*, *Sophora tomentosa*, *Calophyllum inophyllum*, *Barringtonia asiatica* and *Nesogenes euphrasioides*. Although the absence of such littoral species may in part be due to isolation, the limited extent of beaches, the lack of much reef protection, and the encroachment of the abundant 'high island' vegetation on the littoral community may also be important. The poverty of the strand flora is further reflected in our inability to find several previously reported strand plants. Of the 13 plant species that we failed to relocate from Fosberg et al.'s (1983) floristic list, 5 (*Portulaca lutea*, *Capparis sandwichiana*, *Suriana maritima*.

Lycium carolinense var. *sandwicense*, *Fimbristylis cymosa*) are predominantly littoral plants. The other species that we did not relocate include 2 introduced plants (*Achyranthes aspera* var. *pubescens* and *Aleurites moluccana*) that may have disappeared since 1934 and *Asplenium lobulatum*, *Asplenium obtusatum*, *Pittosporum aborescens*, *Sesbania coccinea*, *Santalum hendersonense* and *Meryta brachypoda*. Several of these plants are obviously rare or localised; 8 of the 13 were also not collected by the Mangarevan Expedition.

Nine species or varieties are presently recognised as endemic to Henderson (Fosberg et al. 1983, present volume): *Peperomia hendersonensis*, *Celtis* sp., *Santalum hendersonense*, *Xylosma suaveolens* var. *haroldii*, *Myrsine hosakae*, *Nesoluma st-johnianum*, *Geniostoma hendersonense*, *Alyxia* sp. and *Canthium barbatum* f.*calcicola*. All the endemics are primarily inland plants and, with the exception of *Santalum*, which we did not find in 1987, all were noted to be common in the island interior.

It seems likely that botanical collecting trips to Henderson Island will continue to be both infrequent and brief. Clearly, however, there would be value in attempting to visit the southern area of the island, not collected since Tait in 1912, and the eastern shores which must be under-collected or possibly not even collected at all. It is certain that much remains to be learnt about the vegetation communities of Henderson Island and its remarkable flora.

ACKNOWLEDGEMENTS

We are grateful to the late George Nichols and the crew of the 'Rambler' for their hospitality and great willingness to transport us to and around Henderson Island. We thank Buck Moravec for help with trail making, Lawrence Schuster for collecting plant specimens and Ray Fosberg for identifying the collections.

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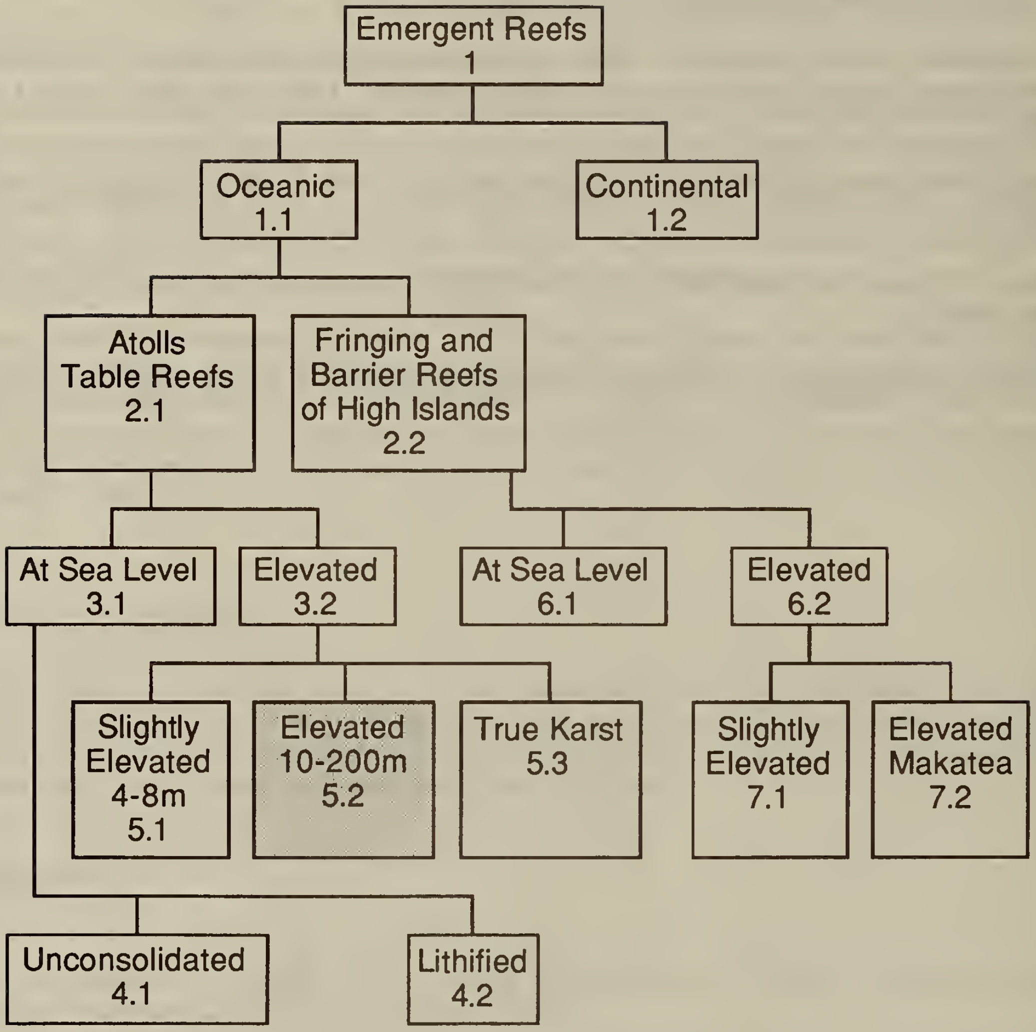

Figure 1. Diagram of classification of emerged reef surfaces (from Fosberg 1985a). Henderson Island falls within category 5.2 (Elevated 10-200m)

Plate 1. Looking west along north beach from the landing. *Scaevola sericea* var. *tuamotuensis* on seaward slope of beachridge, *Tournefortia argentea* and *Pandanus tectorius* on beachridge crest.

Plate 2. Limestone buttress, south-central north beach. Monospecific *Pemphis acidula* on low limestone platform behind beach. *Sesuvium portulacastrum* on notch floor (centre middle) of buttress.

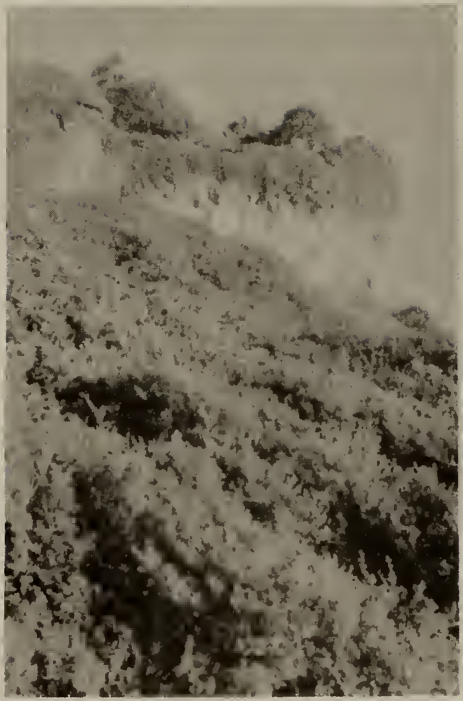

Plate 3. *Pemphis acidula* on lower limestone unit replaced by fern slopes community on higher slopes, north-west beach. Notch floor of buttress (centre right) characterized by *Sesuvium portulacastrum*, *Euphorbia sparrmannii* and *Lepidium bidentatum*.

Plate 4. Looking north from end of north-west beach. *Pemphis acidula*, *Timonius polygama* and emergent *Cocos nucifera*. Skyline *Pandanus tectorius* is typical.

Plate 5. Plateau margin scrub thicket vegetation. N. beach trail

Plate 6. Pinnacle-pitted limestone, inland from north-west beach. Limestone forest in background.

Plate 7. Limestone glade woodland community, N. beach trail. *Pisonia grandis* and *Pandanus tectorius* with predominantly fern understorey.

Plate 8. Lagoonal patch reef vegetation dominated by bushy *Pisonia grandis* and *Eugenia rariflora*.

ATOLL RESEARCH BULLETIN

NO. 329

NEW COLLECTIONS AND NOTES ON THE PLANTS OF HENDERSON, PITCAIRN, OENO, AND DUCIE ISLANDS

BY

F.R. FOSBERG, GUSTAV PAULAY,
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NEW COLLECTIONS AND NOTES ON THE PLANTS OF HENDERSON, PITCAIRN, OENO, AND DUCIE ISLANDS

BY

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T. SPENCER[3], AND ROYCE OLIVER[1]

INTRODUCTION

It may seem superfluous to add another paper on the flora of Henderson Island, so soon after the account in Fosberg, Sachet and Stoddart (1983), but the Paulay and Spencer collections added several species and additional information on some others, already known. It also provides a convenient oppertunity to make needed nomenclatural adjustments and corrections, as well as comments on variability.

45 species were collected on Henderson, including one additional exotic (Setaria), and two other previously unrecorded native plants. 16 previously listed plants (Fosberg 1983) were not found. This does not necessarily mean that they have disappeared. There was no botanist on the expedition, so the plants were collected by other members of the party in addition to their other activities, so naturally the plant collecting may not be as complete as if a full-time botanist had been available. The additional notes over and above the bare list show that, even botanically, the expedition's accomplishments were significant.

In the list the parenthetical (St. J. & P.) indicates the reference to species in the 1962 paper by St. John and Philipson. The parenthetical (Fosberg et al.) indicates the

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page reference in the paper by Fosberg, Sachet, and Stoddart in 1983. The parenthetical upper case letter sympols are the Lanjouw System (Holmgren, Keuken and Schofield 1981) symbols for the herbaria where the specimens are deposited.

For completeness, we have also listed the collections from Oeno and Ducie Atolls and Pitcairn Island. Lists of previous collections from these islands have been published by Philipson and St. John (1960) for Oeno, indicated in the list by (P. and St. J.) and St. John (1987) for Pitcairn, indicated in the list by (St. J.). We also include several additional species, collected by Miss Ross, brought to our attention by Rhys Gardner, of Auckland Institute and Museum. As a matter of information, we have recently learned of a substantial collection from Pitcairn, collected by S.P. Twyford in 1955, housed in the University of the South Pacific Herbarium in SUVA. We regret that time was not available to list and check identities of these specimens.

In all of the lists the collection data were furnished by Paulay and Spencer: the identifications and comments by Fosberg, and the manuscripts were assembled by Oliver. In all three lists, all species collected by the Smithsonian Expedition are cited with pertinent synonymy and abbreviated references to previous lists. Species not found by the Expedition are only mentioned, in the main list, if we disagree with the name used earlier or if there are comments to be made on the occurrence or matters of distribution, variation or taxonomic interest. This seems sufficient since for each of the three islands there is a published modern annotated list citing collections.

The full set of Smithsonian Expedition collections are housed in the U.S. National Herbarium (US), with duplicates, if any, at Bishop Museum (BISH), occasional extra ones are at DSIR, Christchurch (CHR) and a few other herbaria. A few earlier specimens studied are cited with the herbaria indicated.

Polypodiaceae

Asplenium nidus L. (St. J. & P. 178; Fosberg et al. 29)

Common, NW beach site, Paulay and Spencer 602 (US, BISH, BM)

Generally rather common.

Davallia solida Sw. (St. J. & P. 178; Fosberg et al. 29)

Top plateau, inland of NW beach site, Paulay and Spencer 613 (US, BISH)

Nephrolepis hirsutula (Forst. f.) Presl
Nephrolepis biserrata (Sw.) Schott (Fosberg et al. 29; St. J. & P. 178).
Nephrelopis exaltata Schott (St. J. & P. 179; Fosberg et al. 29).

Common on top of cliff, NW beach Paulay and Spencer 608 (US, BISH).

This is rather atypical, though having rhizome scales with shiny, black bases. The scales on rhachis and pinnae are very sparse, some appearing glandular, reddish, but scales woolly. The sori are not as close to the margin as usual, but not as far from it as in N. biserrata, which has been reported from the island earlier. Probably only N.

hirsutula occurs on this island.

Polypodium sp.
Polypodium scolopendria "aberrant" of Copeland, non
Burm. P. 179)

NW beach site, Paulay and Spencer 611 (US, BISH, BM).
S.l. St. John & Fosberg 15125 (BISH),

This species, probably endemic, will be described in a later publication.

Polypodium scolopendria Burm. f.
Phymatodes scolopendria (Burm f.) Ching (St. J. & P. 179)

Common at base of cliff NW beach site, Paulay and Spencer 601 (US).

A very large form., with 8-11 narrow lobes on a side, very acuminate, sinuses broad, rounded, sori in one row an each side of a lobe, round to elliptic, impressed in blade. Where Polypodium pitcairensis and P. sylvaticum Brack. fit into the P. scolopendria complex on Henderson can only be determined by more collections and study.

Pyrrosia serpens (Forst. f.) Ching
Cyclophorus blepharolepis C. Chr. (St. J. & P. 119; Fosberg et al. 29)

Top plateau, mid fossil lagoon, Paulay and Spencer 618 (US, BISH, BM); St. John & Fosberg 15154 (US), det Hovenkamp.

Poaceae

Lepturus repens (Forst. f.) R. Br. (St. J. & P. 179; Fosberg et al. 29)

N. beach, Paulay and Spencer 633 (US, BISH)

This species is said by St. John to be rare, found only at top of beaches. No. 633 is an unusual coarse form. The leaves are lanceolate, broad and short, crowded. Only one young spike is present. The glumes are narrowly lanceolate, not aristate.

Setaria verticillata (L.) Beauv. (det S.A. Renvoize)

N. beach, at landing Paulay and Spencer 660 (US).

This weedy grass is apparently a new record for the island; probably recently introduced. The specimen is depauperate, depressed, badly wilted, the panicles unusually narrow, 5 mm or less wide, 4-5 cm long.

Liliaceae

Cordyline fruticosa (L.) Chev. (Fosberg et al. 30)

Cordyline terminalis (L.) Kunth (St. J. & P. 179)

N. beach site, cliff top, Paulay and Spencer 626 (US, BISH, BM)

No. 626 is the large-leafed green form,usually, as in this case, sterile, probably dispersed throughout Polynesia by the Polynesians, and doubtless planted on Henderson by the Pitcairn people.

Dianella intermedia Endl.
Dianella intermedia var. gambierensis F. Br. (St. J. & P. 179; Fosberg et el. 30)

Occasional top plateau, fossil lagoon, Paulay and Spencer 617 (US).

Sterile specimen, but probably this species as the leaf margins are spinulose, but variety cannot be determined.

Piperaceae

Peperomia hendersonensis Yunker (1937; St. J. & P. 180; Fosberg et al. 30)

N. beach, inland, Paulay and Spencer 655 (US, BISH), nr. base of cliff NW beach 597 (US, BISH, BM)

Endemic to Henderson, apparently common.

A feature was noticed possibly unique to this species, or at least uncommon in the genus, occasional on # 655, stipules or stipule-like structures at or very slightly above axils of some leaves. These are very small, 1 mm long and wide or less, broadly ovate or triangular, slightly cordate at base, apex subcuspidate with glandular tip, somewhat carinate from tip, sides thin.

Ulmaceae

Celtis sp.
Celtis paniculata var. viridis F. Br. (St. J. & P. 180; Fosberg et al. 30)

N. beach trail, fossil lagoon-plateau, Paulay and Spencer 647 (US), beach just inland of coconut grove, 623 (US)

In forest on plateau. A distinctive form; probably does not belong in C. paniculata Planch.

Urticaceae

Procris pedunculata (Forst.) Wedd. (St. J. & P.180; Fosberg et al. 30)

Common , top terrace, NW beach side, Paulay and Spencer 600 (US).

Viscaceae

Korthalsella platycaula var. **vitiensis** (v. Tiegh.) Danser
Korthalsella vitiensis (v. Tiegh.) Engler (St. J. & P. 180, Fosberg et al. 30)

Korthalsella margaretae F. Br. new var. ? (F. Brown, Bish. Mus. Bull. 130: 60, 1935)
Korthalsella complanata sensu Danser, non (v. Tiegh) Engler

Paulay and Spencer 654 (US, BISH, BM))

There is little agreement on the status of this taxon. Its affinities are certainly with *K. platycaula* (v. Tiegh.) Engler, type from Tahiti, but what little material available from Fiji, Rurutu, Rapa and Henderson Island differs consistently from the Society Island forms in its broader, shorter elliptic segments, with strong longitudinal ridges (or veins?). A.C. Smith (Fl. Vit. Nova 3: 474, 1985) lumps this form with *K. platycaula*. His photos, fig. 189A and D., the above-mentioned features very well. St. John and Philipson 180, go the other way and recognize *K. vitiensis* as an independant species. F.B.H. Brown goes still farther and makes at least two species of it. My first impression was to treat it as *K. platycaula*, but after examinining all readily available material, I feel that it is at least merits varietal rank and am treating it so, as above. Certainly it has nothing to do with the Hawaiian *K. complanata* (v. Tiegh.) Engler, as claimed by Danser.

Korthalsella rubescens (v. Tiegh.) Engler (St. J. & P. 180); Fosberg et al. 30)

Top plateau, NW beach, *Paulay and Spencer 599* (US).

We cannot distinguish this species from *K. horneana* v. Tiegh. (ex char.) but hesitate to combine them in absence of specimens of the latter.

Nyctaginaceae

Boerhavia tetrandra Forst. f. (Fosberg et al 32)
Boerhavia diffusa var. *tetrandra* (Forst. f.) Heimerl (St. J. & P. 181)

N. beach, level of cliff notch, *Paulay and Spencer 639* (US), N. beach, cliff face *632* (US).

No. *639* is rather bushy and small-leafed for this species, with young buds only. No. *632* is of normal stature and habit, but with leaves rather broadly ovate and peduncles very long, in bud only.

Aizoaceae

Sesuvium portulacastrum L. (Fosberg et al. 30)

N. beach, cliff face, *Paulay and Spencer 634* (US, BISH, BM).

This plant is a slender, prostrate, completely green form, with small spatulate leaves and white flowers, with perianth lobes 4 mm long. It does not have the coarse habit and conspicuously gray-green leaves of var. *griseum* Degener & Fosberg.

Lauraceae

Cassytha filiformis L. (St. J. & P. 181; Fosberg et al. 31)

N. beach, cliff face, Paulay and Spencer 651 (US, BISH)

Parasitic vine, attacking various shrubs and herbs.

Hernandiaceae

Hernandia stokesii (F. Br.) Kubitzki, Bot. Jahrb. 89: 141, 1969.
Hernandia ovigera var. stokesii F. Br. Fosberg et al. 31)

Local on top plateau off NW beach Paulay and Spencer 592 (US, BISH, BM)

This shrub, local on very rough pinnacled limestone on the west side of the plateau, said to be identical with the Rapa plant of this name, is neither H. ovigera L. nor H. sonora L. and not even very close to the last named. It still must be compared with the Rapa plant, which is found in a very different habitat, as the identity depends an comparison of a single Whitney Expedition specimen, lacking data. For the present it can bear this name.

Brassicaceae

Lepidium bidentatum Montin (St. J. & P. 181; Fosberg et al 31)

Nr. top of cliff face, NW beach Paulay and Spencer 598 (US, BISH, BM)

Fabaceae

Caesalpinia major (Medic.) Dandy & Excell

N. beach, cliff top, Paulay and Spencer 630 (US, BISH)

C. bonduc (L.) Roxb. has been previously recorded from the island (St. J. & P. 181), but the present specimen, though sterile, lacks stipules or even scars of stipules, so is interperted as C. major.

Cassia glanduligera St. John (St. J. & P. 181-184)

Common on top plateau off NW beach Paulay and Spencer 591 (US, BISH, BM)

The South Pacific equivalent of the Hawaiian C. gaudichaudii H. & A.

Euphorbiaceae

Euphorbia sparrmannii Boiss. (Fosberg et al. 31)
Euphorbia ramosissima H. & A. (non Loisel.) (St. J. & P. 186)
Euphorbia pitcairnensis F. Br.

N. beach cliff, Paulay and Spencer 653 (US), N. beach, limestone cliff notch, 638 (US, BISH), N. beach 631 (US), 2/3 up steep cliff, NW beach site, 607 (US, BISH

Euphorbia pitcairnensis F. Br. is certainly conspecific with E. ramosissima H. & A., an illegitimate later homonym. E. sparrmannii includes this as well as several other similar taxa in the western Pacific. Several varieties are to be recognized, but they are not completely sorted out yet. The plant is common on the cliff-tops. It is slender, prostrate, spreading from a gnarled woody caudex. F. Brown was in error in referring to a calyx in E. pitcairnensis, mistaking the involucre or cyathium for a calyx.

Sapindaceae

Allophylus sp.

N. beach, fossil lagoon-plateau, Paulay and Spencer 637 (US).

A sterile specimen, glabrous, with leaf-shape and margin not right for the widespread strand species, A. timoriensis (DC.) Bl.

Tiliaceae

Triumfetta procumbens Forst f. (St. J. & P. 187; Fosberg et al. 32)

N. beach, top of beach, Paulay and Spencer 650 (US); Rare, on shore, NW beach 604 (US)

A prostrate creeper with yellow flowers and burr-like fruit, found on sandy beaches.

Flacourtiaceae

Xylosma suaveolens var. **haroldii** Sluemer (St. J. & P. 187; Fosberg et al. 32)

N. beach trail fossil lagoon-plateau, Paulay and Spencer 644 (US, BISH, BM), top plateau mid fossil lagoon, 620 (US, BISH, BM)

Variety endemic to Henderson; abundant in forest on Plateau, No. 644 staminate.

Lythraceae

Pemphis acidula Forst. (St. J. & P.; Fosberg et al. 32)

NW beach Paulay and Spencer 596 (US, BISH, BM, MO).

This species is usually a large shrub, but at the NW Beach in 1934 we found a fair-sized tree, which was seen again in 1987. In Paulay and Spencer, this volume, Vegetation, the species is referred to as a shrub.

Myrtaceae

Eugenia rariflora Benth. (St. J. & P.; Fosberg et al. 32)

Top plateau inland of NW beach, Paulay and Spencer 605 (US, BISH, BM).

Generally common or abundant on coastal flats, cliffs and plateau. We are tentatively maintaining this as a distinct species, though Merrill (1950) included it in the Malaysian Jossinia reinwardtiana. We have the impression that Merrill's lumping together most of the Pacific plants of this affinity (genus Jossinia Comm.)in J. reinwardtiana Bl. was perhaps a course of desperation, rather than a considered judgement. After struggling with the variability of the group, one can understand and sympathize. I have not seen the type of Myrtus reinwardtiana, and fail to get a clear concept of it from Blume's later and fuller description. The scanty material available from Malaysia does not permit a better concept. For the present, I am applying the name E. rariflora to the eastern Polynesian plant, usually a shrub, with leaves broad obovate to suborbicular very obtuse to rounded at apex, green above pale beneath, venation faint, subglabrous when mature, margins tending to be revolute; pedicels shorter than leaves, usually unbranched, fruit with conspicuous persistent sepals, tending to be erect. This does not include some plants with thinner, narrower leaves, which I leave unnamed for the present.

Myrsinaceae

Myrsine hosakae St. John (St. J. & P. 188-190; Fosberg et al. 32)

Top plateau 100-300 m inland from NW beach, Paulay and Spencer 606 (US), very rare, top plateau, fossil lagoon, inland from NW beach, 616 (US), top plateau 619 (US, BISH, BM), fossil lagoon-plateau, 25-30 m, 643 (US), N. beach trail Lagoon -plateau, 25-30 m, 636 (US), N. beach, top of plateau, Paulay and Spencer 659 (US).

This species, endemic in Henderson Island, was overlooked in our account of Eastern Polynesian species of Myrsine (Fosberg and Sachet 1975, 1971). St. John placed it next to M. ovalis Nad. of Tahiti. Suggesting relationship among species of Myrsine is, at best, uncertain. I would consider it closer to N. niauensis Fosberg & Sachet, to which M. ovalis var. wilderi Fosberg & Sachet is close. It resembles M. niauensis in the abundant very minute punctations on the upper leaf surface (which St. John failed to notice), but differs in being equally punctate on the under surface, in the lack of strong inter-marginal veins, and in the ellipsoid rather subglobose fruit. No. 616 is sterile, very coarse, and does not show the punctations very well. It may be something else. No. 606 is small-leafed, and with terminal buds on dwarf branchlets with crowded small cataphylls or scars on same, and zones of crowded scars at intevals on branchlets. These are described by St. John as "terminal scaly buds". They are not easy to interpret and should be studied carefully by the next collector of this species.

Sapotaceae

Nesoluma st-johnianum Lam & Meeuse (St. J. & P. 190; Fosberg et al 32)

N. beach, trail fossil lagoon - plateau,Paulay and Spencer 641 (US, BISH, BM, MO, CHR); top plateau, very abundant , fossil lagoon, NW beach site, 615 (US, BISH); top plateau, NW beach, Paulay and Spencer 603) (US, BISH).

An endemic tree in plateau forest. The genus is widespread but rare in the Pacific. No. 641 is in bud only, 603 somewhat more mature but still not in full flower; 615 with one mature fruit.

Loganiaceae

Geniostoma hendersonense St. John (St. J. & P. 190-192; Fosberg et al. 32)
"Species of Buddleia" Beechey ?

N. beach top plateau, Paulay and Spencer 658 (US, BISH, BM); top plateau off NW beach, common Paulay and Spencer 594 (US).

Excellent fruiting specimen # 658, capsule valves 5-9 mm long, black when dry, strongly transversely rugose. Number 594 flowering.

Apocynaceae

Alyxia sp.
Alyxia stellata sensu auct. non Forst. (St. J. & P. 192; Fosberg et el. 32)

Very common, Top plateau, NW beach site, Paulay and Spencer 621 (US)

The Henderson Island plant hitherto referred to Alyxia stellata is an endemic species, well-characterized by 4 leaves in a whorl, large inflorescences and fruit. I have had it in manuscript for some time. The present fruiting specimen helps to complete the description.

Convolvulaceae

Ipomoea macrantha R. & S. (Fosberg et al. 32)
Ipomoea glaberrima Boj. (St. J. & P. 192)

N. beach cliff path near top, Paulay and Spencer 627 (US, BISH); rare at top of cliff face, NW beach, 609 (US).

Boraginaceae

Cordia subcordata Lam. (St. J. & P. 193; Fosberg et al. 32).

N. beach, top plateau, Paulay and Spencer 657 (US, BISH)

Heliotropium anomalum var. **argenteum** Jtn.
Heliotropium anomalum var. candidum St. John (St. J. & P. 192-193; Fosberg et al 32)

N. beach, beach strand, Paulay and Spencer 635 (US),near top of cliff face, NW beach site, 612 (US, BISH)

The variety candidum said to be in Henderson Island, indeed differs sharply from the eastern Polynesian var. anomalum, in its indument, which, at least in our specimens, I would call, at least the Paulay specimens, densely sericeous, rather than pilosulus, as described by St. John. In this respect this plant resembles the Hawaiian var. argenteum, in fact, comparison of no. 635 with a good series of Hawaiian specimens show that it falls well within the range of that variety. The variation in this species needs further study, and especially careful field observation. In some varieties the flowers are strongly dimorphic, even with different fragrances.

Tournefortia argentea L. f. (Fosberg et al. 33)
Messerschmidia argentea (L. f.) I.M. Jtn. (St. J. & P. 193)

N. beach strand, *Paulay and Spencer 625* (US).

Verbenaceae

Premna cf. **serratifolia** L.
Premna integrifolia L. (St. J. & P., 193)
Premna obtusifolia R. Br. (Fosberg et al. 33)

N. beach trail, fossil lagoon plateau *Paulay and Spencer 645* (US); North beach, top plateau, *656* (US), N. beach, lagoon-plateau, *622* (US).

Apparently common on plateau.

These specimens are sterile and have entire medium-small oblong obtuse firm leaves # *622* has reticulate, almost obovate leaves, old inflorescence, several loose pyriform fruits with reflexed calyx. This species is bewilderingly variable over its Indo-Pacific-wide range.

Rubiaceae

Canthium barbatum f. **calcicola** Fosb. (St. J. * P. 193; Fosberg et al. 33)

Common in forest on Plateau off NW beach, *Paulay and Spencer 593* (US, BISH, BM)

Canthium odoratum (Forst. f.) Seem. (St. J. & P. 193; Fosberg et al. 33)

Abundant on top plateau off NW beach, *Paulay and Spencer 595* (US, BISH, POM, MO, BM, CHR)

Abundant on rough coral on plateau.

Ixora fragrans (H. & A.) Forst f. (St. J. & P. 187; Fosberg et al. 32)
Cephaelis fragrans H. & A.

N. beach trail, fossil lagoon-plateau, *Paulay and Spencer 648* (US); top plateau off NW beach *588* (US).

This is a member of *Ixora* sect. *Phylleilema*, characterized by its cymes strongly reduced and enclosed between two leaf-like, usually cordate bracts. No. *648* is sterile , no.*588* is fruiting.

Morinda umbellata var. **forsteri** (Seem.) Fosberg (St. J. & P. 194; Fosberg et al. 33)
Morinda forsteri Seem.

N beach trail, fossil lagoon-plateau, *Paulay and Spencer 646* (US); top plateau off NW beach, *589* (US).

Occasional climber in forest on western plateau, 1987 specimens sterile.

Timonius polygamus (Forst. f.) Robins. (St. J. & P. 193; Fosberg, occ. Pap. Bis. Mus. 13: 263, 1937.; Fosb. et al. 33)
Timonius forsteri DC

N. beach, cliff top, Paulay and Spencer 652 (US, BISH, BM), beach trail, fossil lagoon-plateau, 649 (US),1-300 m, NW beach site, 610 (US, BISH); top plateau off NW beach, 587 (US)

This shrub is notoriously variable in habit, leaf size and shape, and size of cyme. It is abundant in forest on the plateau and cliffs. No. 652 is staminate, with large open cymes. no. 649 is similar with smaller cymes, no. 717 similar but leaves smaller, 3.5 X 2 cm.

Goodeniaceae

Scaevola sericea var. **tuamotuensis** (St. John.) Fosb. (Fosberg et al. 33)
Scaevola taccada var. tuamotuensis St. John (St. J. & P. 194)

N. beach strand, Paulay and Spencer 628 (US, BISH, BM, CHR), N. beach 624 (US, BISH).

Typical var. tuamotuensis, prostrate and with glabrous narrowly spatulate leaves. This variety extends westward at least to the Cook Islands.

Asteraceae

Bidens hendersonensis Sherff (St. J. & P. 194, Fosberg et al. 33)

Common in central lagoon, top plateau, NW beach site, Paulay and Spencer 614 (US, BISH, BM); rare on top plateau off NW beach 590 (US, BISH).

Leaves simple, broadly elliptic, on slender petioles; inflorescence loosely corymbose, achenes less than 1 cm long, flat, thin, biaristate, pappus spine-like, with strong retrorse spinelike barbs, margins ciliate with antrosely subspreading barbs.

Senecio stokesii F. Br. (St. J. & P. 194; Fosberg et al. 33)

N. beach, trail, fossil lagoon-plateau, Paulay and Spencer 642 (US, BISH);N. beach trail, fossil plateau, 640 (US)

Apparently fairly common on plateau, becoming rather weedy in disturbed places, as along a cut path. A medium sized glabrous suffruitescent herb; originally described as endemic in Rapa. Many earlier collections available.

Additional specimens examined, Tait 36, 39 (BISH); St. John and Fosberg 15141, 15080, 15108, 15109, 15178, 15077m, all (BISH).

Henderson Island specimens of this species vary in height up to 2 m, stems simple to much-branched, especially toward apex, glabrous, leaf blade 2-12 cm x .08-7 cm, thin, elliptic to ovate or broadly ovate, apices from rounded to obtuse or, usually, acute to slightly acuminate. The original description is reasonably complete, but based only on the type, Stokes 108 (BISH) from Rapa. It also occurs on Raivavae, St. John 16036 (BISH).

The following 7 plants were seen but not collected in 1987, all quite common: Pandanus tectorius Park., Cocos nucifera L., Thuarea involuta (Forst. f.) R. & S., Thespesia populnea (L.) Sol. ex Correa, Glochidion pitcairnense (F. Br.) St. J., Pisonia grandis R. Br., and Guettarda speciosa L.

Previously recorded from Henderson but not found on this trip were the following 15 species: Asplenium lobulatum Mett., Asplenium obtusatum Forst. f., Fimbristylis cymosa R. Br., Santalum hendersonense F. Br., Achyranthes aspera var. pubescens (Moq.) Townsend, Portulaca lutea Sol. ex Forst. f., Capparis sandwichiana DC., Pittosporum arborescens Rich. ex Gray, Sesbania coccinea (L. f.) Poir. Suriana maritima L., Aleurites moluccana (L.) Willd.,Meryta brachypoda Harms, Jasminum didymum Forst. f. (?), Lycium carolinense var. sandwicense (A. Gray) Hitchc., and Fitchia nutans Hook. f. (?).

Plants of Pitcairn Island

Polypodiaceae

Davallia solida (Forst. f.) Sw.

Roadside, Paulay, Spencer and Schuster 685 (US).

Nephrolepis hirsutula (Forst. f.) Presl

Very common, Paulay, Spencer and Schuster 684 (US).

Polypodium scolopendria Burm. f.

Paulay, Spencer and Schuster 693 (US).

Thelypteris cf. parasitica (L.) Tard.

Paulay, Spencer and Schuster 694 (US).

Poaceae

Cynodon dactylon (L.) Pers.
Seashore, Paulay, Spencer and Schuster 683 (US).

Paspalum conjugatum Berg

Occasional, Paulay, Spencer and Schuster 676 (US).

Setaria verticillata (L.) Beauv.

Paulay, Spencer and Schuster 674 (US).

Sorghum halepense (L.) Pers.

Disturbed, fallow ground, rampant, Paulay, Spencer and Schuster 667 (US), 673

(US).

Commelinaceae

Commelina diffusa Burm f.

Adamstown, common, Paulay, Spencer and Schuster 691 (US).

Amaranthaceae

Alternanthera brasiliensis (L.) O. Ktze.

Roadside, Adamstown, Paulay, Spencer and Schuster 679 (US).

Nyctaginaceae

Mirabilis jalapa L.

Roadside, Adamstown, Paulay, Spencer and Schuster 669 (US).

Fabaceae

Bauhinia cf. purpurea L.

Roadside, Adamstown, Paulay, Spencer and Schuster 692 (US).

Cassia (Senna) **septemtrionalis** Viviani

S.l. Ross 31b (AK).

Dolichos lablab L.

Paulay, Spencer and Schuster 664

Erythrina variegata var. **orientalis** (L.) Merr.

Not common, Paulay, Spencer and Schuster 686 (US).

Inga ynga (Vell.) J.W. Moore

Probably planted, Ross 69 (AK).

Leucaena leucocephala (Lam.) de Wit

Paulay, Spencer and Schuster 665 (US).

Oxalidaceae

Oxalis corniculata L.

Paulay, Spencer and Schuster 696

Malvaceae

Abutilon pitcairense Fosberg

a second collection of this has come to light, thanks to Rhys Gardner.
Pitcairn Island, Ross 31-19 Pitcairn name "Foutoo" (AK 74663)

Hibiscus ornamental hybrid aff. **H. rosa-sinensis** L.

Paulay, Spencer and Schuster 675 (US).

Flaucortiaceae

Homalium taypau St. John
Main ridge, common, Paulay, Spencer and Schuster 678 (US).

Xylosma suaveolens Forst.) Forst. f.

Main ridge, very rare, Paulay, Spencer and Schuster 677 (US).

Myrtaceae

Eugenia uniflora L.

Roadside, Paulay, Spencer and Schuster 687 (US).

yzygium jambos (L.) Alston

Abundant, Paulay, Spencer and Schuster 680 (US).

Begoniaceae

Begonia sp. (probably a cultivated hybrid).

Paulay, Spencer and Schuster 655 (US).

Myrsinaceae

Myrsine aff. **niauensis** Fosb. & Sachet
Bumelia sp.

S.l. Ross, sterile, US).

Apocynaceae

Allamanda hendersonii Bull

Paulay, Spencer and Schuster 682

Convolvulaceae

Ipomoea indica (L.) Merr.

Common, Paulay, Spencer and Schuster 666 (US).

Verbenaceae

Lantana camara L.

Rampant, Paulay, Spencer and Schuster 697 (US).

Verbena bonariensis L.

Radio station (Adamstown) not seen elsewhere, Paulay, Specer and Schuster 681 (US).

Plantaginaceae

Plantago major L.

Down Niger, Paulay, Spencer and Schuster 689 (US), Adamstown, 690 (US).

Caprifoliaceae

Lonicera japonica Thunb.

Big fence, Paulay, Spencer and Schuster 672 (US).

Asteraceae

Bidens pilosa L.

Roadside, Paulay, Spencer and Schuster 668 (US).

Conyza bonariensis (L.) Cronq.

Spreading over whole island, Paulay, Spencer and Schuster 661 (US).

But heads are far smaller than usual.

Sonchus oleracus L.
Big fence, Paulay, Spencer and Schuster 671 (US).

Vernonia cinerea (L.) Less.

Adamstown Paulay, Spencer and Schuster 662

Plants of Oeno Atoll

Bryaceae

Brachymenium indicum (Doz. & Molk.) Bosch. & Lac.

W. Islet, Paulay and Spencer 711 (US)

Polypodiaceae

Polypodium scolopendria Burm. f.
Phymatodes scolopendria (Burm. f.) Ching (P. & St. J. 402)

W. Islet, Paulay and Spencer 709 (US, BISH, BM).

Fronds rather small, lobes very narrow, lower ones mostly 2 cm or less wide, upper ones narrower.

Poaceae

Lepturus repens (Forst. f.) R. Br. var.
Lepturus repens (Forst. f.) R. Br. var. repens

W. Islet, Paulay and Spencer 698

No. 698 is a tufted slender plant strongly resembling var. septentrionalis of the Northern Marshall Islands, but with triangular lanceolate glumes, rather bluntly pointed, not at all subulate or aristate. Disposition of the southern Polynesian form must await a critical consideration of the Forster specimens.

Amaranthaceae

Achyranthes velutina H. & A. f. rosea (P. & St. J. p. 402).

W. Islet, Paulay and Spencer 701 (US, BISH, BM)

Flowers bright-rose pink.

Nyctaginaceae

Pisonia grandis R. Br. (P. & St. J. 402).

W. Islet, Paulay and Spencer 703 (US, BISH, BM).

A narrow tomentose line along side of midrib and principal veins.

Boerhavia tetrandra Forst. f.
Boerhavia diffusa var. tetrandra (Forst. f.) Heimerl (P. & St. J. 402).

W. Islet, Paulay and Spencer 708 (US, BISH, BM).

An unusual small-leafed form of this widespread species, but probably this.

Lauraceae

Cassytha filiformis L. (P. & St. J. 402)

W. Islet, Paulay and Spencer 710 (US).

Brassicaceae

Lepidium bidentatum Mont. (P. & St. J. 402).

W. Islet, Paulay and Spencer 700 (US, BISH, BM)

A rather dwarfed small-leafed form.

Pandanaceae

Pandanus tectorius Park.
Pandanus faruliferus St. J. (P. & St. J. 402)

W. Islet, Paulay and Spencer 707 (US)

Terminal fragment of leaf only.

Surianaceae

Suriana maritima L. (P. & St. J. 403).

W. Islet, Paulay and Spencer 699 (US, BISH, BM, CHR)

The leaves on this collection are shorter than often seen in this species, and with a tendency to be rather scattered on the upper stems rather than in terminal rosettes as is often the case.

Boraginaceae

Tournefortia argentea L. f.
Messerschmidia argentea (L. f.) Jtn. (P. & St. J. 403).

W. Islet, Paulay and Spencer 704 (US).

Rubiaceae

Hedyotis romanzoffiensis (C. & S.) Fosb. (P. & St. J. 403).

W. Islet, Paulay and Spencer 706 (US).

Leaves and fruit unusually small, easternmost occurrence of the species.

Goodeniaceae

Sacaevola sericea var. **tuamotuensis** (St. John) Fosb.

Previously unrecorded from Oeno.

W. Islet, Paulay and Spencer 702

Fruits unusually small, 5 X 4 mm, appearing blackish when dry.

Ducie Atoll

A search was made on Ducie Atoll for plant species but only one, *Tournefortia argentea* L. f., was found, reported previously by Rehder and Randall (ARB, 183: 18, 1975), and earlier by Chapin in 1936 and Quayle (ms journal) of the Whitney Expedition in 1922, who also noted "a few rare clumps of coarse grass *Lepturus*" and "one vine of a common Tuamotu shrub = *Epigaea*?" [This may have been *Nesogenes euphrasioides* A. Gray, or *Triumfetta procumbens* Forst. f. the only Tuamotu plant even faintly resembling *Epigae*]. Cuming, who visited in 1827, in a letter to Hooker at Kew wrote of his observation on Ducie, "has a number of trees and a small stunted grass". The grass was probably *Lepturus repens* and the trees, as well as those casually mentioned by earlier visitors, were doubtless *Tournefortia*. The fact that despite careful searches neither Rehder and Randall, nor the 1987 Expedition, found any trace of other land-plants suggests that in the interval between 1922 and 1975 storm waves may have swept the island, removing or killing the two herbaceous plants. The *Tournefortia* would have survived, and now forms a low forest over much of the atoll.

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