CALIFORNIA FISH AND GAME

"CONSERVATION OF WILDLIFE THROUGH EDUCATION"

VOLUME 42 JANUARY, 1956 NUMBER 1

California Fish and Game is a journal devoted to the conservation of wildlife. Its contents may be reproduced elsewhere provided credit is given the authors and the California Department of Fish and Game.

The free mailing list is limited by budgetary considerations to persons who can make professional use of the material and to libraries, scientific institutions, and conservation agencies. Individuals must state their affiliation and position when submitting their applications. Subscriptions must be renewed annually by returning the postcard enclosed with each October issue. Subscribers are asked to report changes in address without delay.

Please direct correspondence to:

LEO SHAPOVALOV, *Editor*
Department of Fish and Game
926 J Street
Sacramento 14, California

Individuals and organizations who do not qualify for the free mailing list may subscribe at a rate of $2 per year or obtain individual issues for $0.75 per copy by placing their orders with the Printing Division, Documents Section, Sacramento 14, California. Money orders or checks should be made out to Printing Division, Documents Section.

CALIFORNIA FISH AND GAME

VOLUME 42 JANUARY, 1956 NUMBER 1

Published Quarterly by the
CALIFORNIA DEPARTMENT OF FISH AND GAME
SACRAMENTO

STATE OF CALIFORNIA
DEPARTMENT OF FISH AND GAME

GOODWIN J. KNIGHT
Governor

FISH AND GAME COMMISSION

WILLIAM J. SILVA, President
Madesta

ANDY KELLY, Commissioner
Los Angeles

CARL F. WENTE, Commissioner
San Francisco

HARLEY E. KNOX, Commissioner
San Diego

WELDON L. OXLEY, Commissioner
Redding

SETH GORDON
Director of Fish and Game

CALIFORNIA FISH AND GAME

Editorial Staff

LEO SHAPOVALOV, Editor-in-Chief ..... Sacramento
JOHN E. FITCH, Editor for Marine Fisheries ..... Terminal Island
CAROL M. FERREL, Editor for Game ..... Sacramento
J. B. KIMSEY, Editor for Inland Fisheries ..... Sacramento

TABLE OF CONTENTS

Page

Chronic Toxicity of DDT, Toxaphene, and Dieldrin to Ring-necked Pheasants ..... *Richard E. Genelly* and *Robert L. Rudd* 5

Characteristics of the Pelvic Girdle in Relation to Sex in Black-tailed and White-tailed Deer ..... *Richard D. Taber* 15

Progress Report on White Sturgeon Studies ..... *Richard L. Pycha* 23

Further Observations on Stream Survival of King Salmon Spawn ..... *Harold A. Gangmark* and *Robert D. Broad* 37

An Ecological Study of Lower San Gabriel River, California, With Special Reference to Pollution ..... *Donald J. Reish* 51

A New Method of Attaching Petersen Disk Tags With Monofilament Nylon ..... *John E. Randall* 63

Rearing Larval Scombrid Fishes in Shipboard Aquaria ..... *Harold B. Clemens* 69

NOTE

Blue-winged Teal in Del Norte County, California ..... *Charles F. Yocom* and *William A. Wooten* 81

Reviews 83

CHRONIC TOXICITY OF DDT, TOXAPHENE, AND DIELDRIN TO RING-NECKED PHEASANTS[1]

RICHARD E. GENELLY and ROBERT L. RUDD
Department of Zoology
University of California, Davis

INTRODUCTION

The use of highly toxic chemicals to control agricultural insect pests is widely accepted. However, reports of the finding of dead animals in chemically-treated areas continue to command attention. That the chemicals caused the death of the animals is difficult or impossible to establish in most cases (Dahlen and Haugen, 1954), but the evidence is strong enough to warrant intensive investigation (Mohr et al., 1952; Rudd and Genelly, 1955). Of first importance to such an investigation is a knowledge of the toxicity of each chemical agent to the principal wildlife species that might be exposed. Wildlife populations could conceivably be affected in two ways: outright killing of individual animals by single or multiple exposures to the chemical; or, a decline in the reproductive rate of the population.

The effects of DDT, toxaphene, and dieldrin on pheasant reproduction will be reported in another paper (Genelly, R. E., and R. L. Rudd, MS). The present paper reports on the responses of 224 adult ring-necked pheasants (*Phasianus colchicus*) to daily intake of small amounts of three chlorinated hydrocarbon insecticides for periods ranging up to 94 days. Experimental feeding of DDT, toxaphene, and dieldrin to 121 female pheasants began in the fall of 1953 ("Prereproductive period", Table 1) at the Yountville State Game Farm, near Yountville, California. At the conclusion of this test, in February, 1954, 90 additional females and nine male pheasants were started on selected chemical levels (Tables 1 and 2) and maintained on them for two and one-half months of the breeding season ("Reproductive period", Table 1). (Mortality of males necessitated the addition of four birds during the experimental period.)

EXPERIMENTAL CONDITIONS

In the "prereproductive" feeding tests, 130 previously uncontaminated six-month-old female ring-necked pheasants were divided among 12 holding pens (each 12 by 20 feet). A group of 10 birds was maintained as a control. All birds were weighed at the beginning of the test

[1] Submitted for publication May, 1955. The authors are indebted to a number of persons for assistance: personnel of the State Game Farm at Yountville, especially Frank James, for care and maintenance of the pheasants; Dr. S. Anderson Peoples and H. Edward Bond, of the School of Veterinary Medicine, University of California, for the chemical analyses of pheasant tissue; and E. C. Carlson of the University Insectary, for the use of seed treatment equipment. This study was carried on under Federal Aid in Wildlife Restoration Act, Project California W-45-R, "The Effects of Economic Poisons on Wildlife."

2 –25467

period and at infrequent intervals thereafter (Figure 1). During or at the conclusion of the experiment one bird at each chemical level was sacrificed for histopathological study (Table 3). No attempt was made to analyze these samples for the presence of the chemical. The birds were maintained entirely on a diet of "hen scratch" feed, which is 70 percent wheat and 30 percent a mixture of cracked corn, milo, kaffir, and hulled barley. The feed was contaminated with desired levels of chemicals by thoroughly agitating 50-pound lots of chemical and feed in an electric mixer.

In the "reproductive" feeding tests, previously uncontaminated pheasants were used—1 male and 10 females in each of 12 large breeding pens. Three of these groups of birds were kept as controls. The insecticide was mixed thoroughly with a high-protein (21 percent) diet of commercial turkey food in pellet form. Since a measured amount of scratch grain was substituted when rainy weather threatened pellet disintegration, the concentration of the chemical in the "total diet" was lower than the concentration to which the birds were usually exposed (Table 2). To minimize handling, birds were weighed only at the beginning and end of the experiment. Tissue samples of females, for chemical analysis and histological study, were obtained from birds sacrificed at the end of the study (day number 74). Tissues from several males that succumbed during the test period were analyzed for presence of the chemical (Table 3).

TABLE 1

Pheasant Mortality From Insecticide-contaminated Diets

Chemical	Prereproductive period				Reproductive period				
	P.p.m. in diet	No. of birds ♀♀	Test period, days	Mortality ♀♀	No. of test birds ♂♂	No. of test birds ♀♀	Test period, days	Mortality ♂♂	Mortality ♀♀
DDT	50	10	57	0	--	--	--	--	--
	100	--	--	--	1	10	74	0	0
	200	10	90	1	--	--	--	--	--
	400	10	90	0	4	20	74	4	0
	600	10	57	3	--	--	--	--	--
Toxaphene	25	10	51	0	--	--	--	--	--
	100	10	94	0	1	10	74	0	0
	200	10	94	0	--	--	--	--	--
	300	10	94	0	2	20	74	0	0
Dieldrin	25	11	49	0	1	10	74	1	0
	50	--	--	--	4	20	74	4	8
	70	10	20	2	--	--	--	--	--
	100	10	38	5	--	--	--	--	--
	200	10	28	6	--	--	--	--	--
Control	--	10	91	0	4	30	74	0	0

TABLE 2

Food Consumption, Insecticide Intake, and Weight Changes of Pheasants During the Reproductive Period

Chemical	Concentration of chemical p.p.m.		Mean daily consumption bird/day		Mean live weight change of females (grams)
	In mash	In total diet	Mash, gm.	Chemical, mg.	
DDT	100	90	57.2	5.72	+20
DDT	400	355	52.1	20.84	−22
Toxaphene	100	89	47.4	4.74	+ 9
Toxaphene	300	243	30.4	9.12	− 62
Dieldrin	25	22	44.6	1.12	− 14
Dieldrin	50	42	36.6	1.83	−36
Control	0	0	51.6	0.0	+64

EXPERIMENTAL RESULTS

Mortality

In the prereproductive period the deaths of only four birds could be assigned to the toxic effect of DDT at the four levels fed. One bird was observed to exhibit severe tremors the day before it died. The others may have too, but a close daily watch was not kept over the birds. All were found after death with legs rigidly extended, a position characteristic of poisoned birds. All birds on toxaphene contaminated diets survived, although at the highest level several became relatively inactive, appearing to be in serious condition. In other studies, chickens on a diet containing 200 p.p.m. (parts per million) of DDT survived for a year without toxic symptoms (Bryson et al., 1950), while 90 percent of laying hens on a diet containing 1,250 p.p.m. died within 12 weeks (Rubin et al., 1947). All New Hampshire chicks exposed to 50-100 p.p.m. of dieldrin in the diet died in 90 days (Eden, 1951).

Feeding dieldrin, begun in midwinter, produced quick mortality at levels of 70 p.p.m. and higher. At 70 p.p.m. two birds had died by the 19th day; at 200 p.p.m. six birds had succumbed by the 26th day, and the remaining four were behaving erratically; at 100 p.p.m. five of the females had died by the 38th day. Mortality was so severe at the 100 and 200 p.p.m. levels that poison was discontinued after the days mentioned above. Only the birds on 25 p.p.m. appeared to be unaffected and remained so through day 49. Meanwhile, the 10 "control" pheasants, in an adjoining pen, continued to appear normal. All of the birds were removed from the test diets by mid-February.

The feeding tests of the reproductive period were under way by March 1st. During the ensuing 74 days the females showed no signs of distress from either DDT or toxaphene. The females on 50 p.p.m. of dieldrin, however, suddenly began to die on the 60th day. Eight of them were dead by the final day (number 74). Again, there was little doubt that death was due to the chemical.

Males were definitely more susceptible to DDT and to dieldrin than were females. One male exposed to 50 p.p.m. of dieldrin suddenly died on day number 28; a replacement died 15 days later; a second replacement succumbed after only six additional days. The original male receiving 50 p.p.m. of dieldrin in another pen died on the 48th day

and was not replaced. The original male receiving 25 p.p.m. of dieldrin died on day number 59; similarly, one male exposed to 400 p.p.m. of DDT died after 42 days. A second cock at this level died after 57 days of exposure. His replacement died after only one day in the pen, but probably not because of the chemical.

The difference in the sexes in susceptibility to DDT support earlier observations on experimental feeding of DDT-coated seed rice to pheasants (Rudd and Genelly, 1955). Under similar conditions of exposure, four of six males died, while only one of six females died.

Weight Changes

Body weight changes of pheasants during the prereproductive tests were carefully followed as possible indicators of pheasant condition. The patterns of these mean weight changes varied between groups exposed to different chemicals and were not always clearly related to the degree of intoxication of the birds. In Figure 1, the beginning mean weights of all experimental groups are arbitrarily given a common beginning point. Subsequent mean weight deviations from the original means are then plotted as percentage of body weight. Individual weight variations within each group were of sufficient magnitude to render meaningless any statistical tests of significance.

DDT, even at the highest levels, seemed to have little effect on the mean weights of the groups. Indeed, these experimental birds weighed more than the control birds for most of the experimental period (Figure 1). Toxaphene, however, had a depressing effect on body weight, at least for the first month of the period—apparently because the birds disliked the contaminated feed. Checks during the breeding season (Table 2) showed that birds fed the highest levels of toxaphene probably ate only 60 percent as much food as did the control birds. But at the end of three months they seemed to have adapted to the diet, for the mean weights again approached that of the control group.

The heavy mortality among birds consuming 100 and 200 p.p.m. of dieldrin, mentioned earlier, was accompanied by rapid weight loss. The pheasants on 25 and 70 p.p.m., however, differed little from the controls in weight changes. The spring studies also showed that mean food consumption went down as concentration of insecticide in the diet went up. Moreover, the net weight changes of the females during the 74-day spring test period appeared to reflect their average degree of intoxication at each level of each chemical (Table 2). However, it is obvious from the weight fluctuations of the control birds (Figure 1) that no hard and fast rules on pheasant condition can be based on weight change alone.

Tissue Analysis

Tissue samples for chemical analysis and histological study were taken only during the reproductive period. With three exceptions (Table 3), all of these samples were from birds sacrificed on the 74th day. Tissue samples for study, taken within 15 minutes of the death of the birds and placed in Bouin's fixative, were later sectioned at eight microns, mounted on glass slides, and stained with Harris' hemotoxylin and eosin, and with Heidenhain's "azan" triple stain. Samples for chemical analysis were preserved by freezing. These tissues were

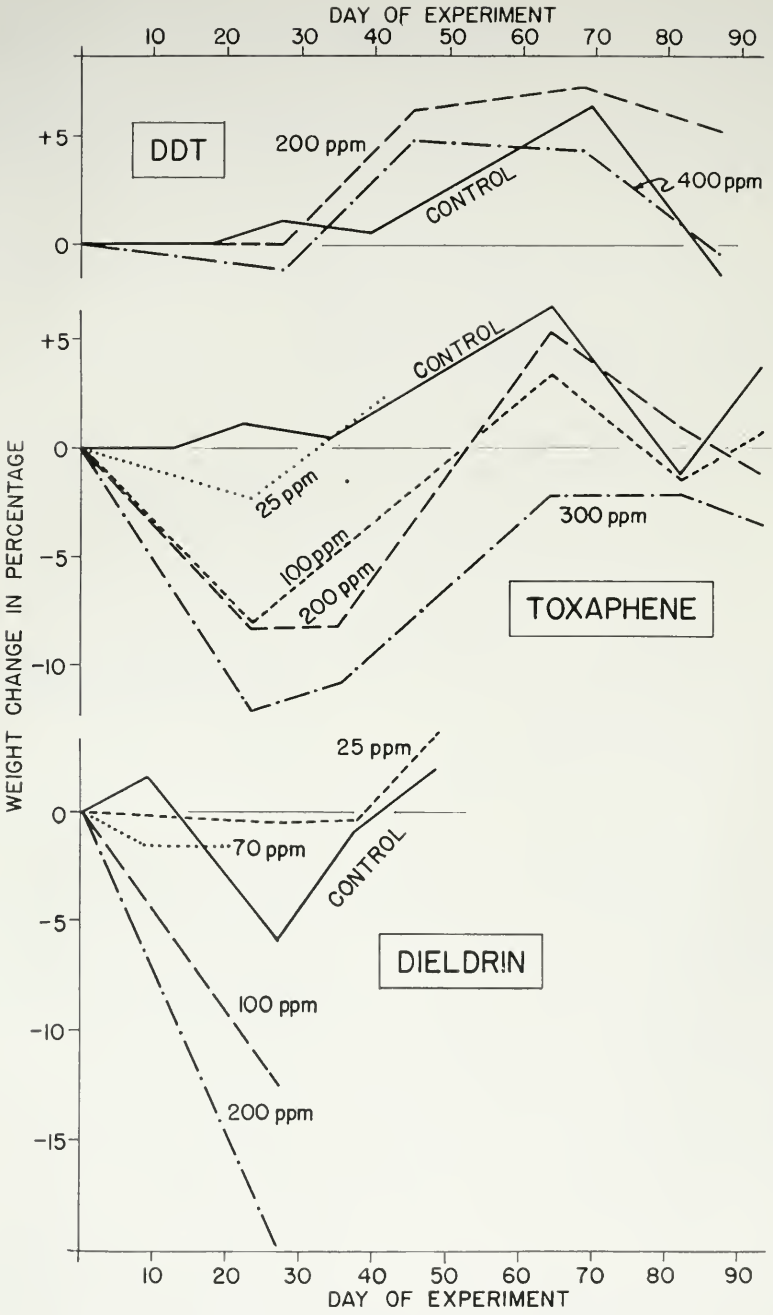

FIGURE 1. Weight changes during test period in experimental feeding of DDT, taxaphene, and dieldrin.

later pulverized in the laboratory, and extracted with benzine. After evaporation of the benzene, the material was submitted to reduction with metallic sodium and analyzed for organic chloride content by a modification of the amperometric titration method of Kolthoff and Lingane (1952). Tissues from control birds were used to determine normal organic chloride content and standard recovery rate. These values were used in computing the insecticide concentrations listed in Table 3.

TABLE 3

Chemical Analyses and Tissue Studies

Concentration in total diet (p.p.m.)	Bird no.	Sex	Experimental period in days	Tissue	Concentration of chemical in tissue (p.p.m.)	Histological findings
DDT						
90	190	♀	74	Liver	0.0	Moderate fatty change; focal damage; margination of cytoplasmic granules; some nuclear necrosis.
				Fat	1,095.0	N. E. (Not examined)
90	789	♂	74	Liver	1.55*	Light vacuolation; some peripheral granulation.
				Testis	0.0	Seemingly normal.
355	175	♀	74	Liver	146.0	Extreme fatty change; sinusoids engorged; swollen nuclei; focal damage in streaks radiating from major vessel.
				Fat	3,460.0	N. E.
355	181	♀	74	Liver	16.0	Light vacuolation only apparent effect.
				Fat	4,470.0	N. E.
	790	♂	42	Liver	52.0	N. E.
				Testis	1,290.0	N.E .
TOXAPHENE						
89	168	♀	74	Liver	0.0	Sinusoids engorged throughout liver; cells seem normal.
				Fat	292.0	N. E.
89	792	♂	74	Liver	0.0	Moderate vacuolation.
				Testis	1,510.0	Zoa in lumen; mitotic figures.
243	90	♀	74	Liver	6.1	Little effect; some vacuolation around major vessels.
243	794	♂	74	Liver	0.0	Heavy vacuolation, entire surface; no foci.
				Testis	0.0	Zoa in lumen; mitotic figures.
243	157	♀	74	Liver	4.6	Little affected; some vacuolation about major vessels.
				Fat	752.0	N. E.

TABLE 3—Continued

Chemical Analyses and Tissue Studies

Concentration in total diet (p.p.m.)	Bird no.	Sex	Experimental period in days	Tissue	Concentration of chemical in tissue (p.p.m.)	Histological findings
DIELDRIN 22	88	♀	74	Liver	0.0	Light vacuolation about vessels, none peripherally.
				Fat	1,800.0	N. E.
12	64	♀	74	Liver	0.0	Seemingly normal.
				Fat	0.0	N. E.
42	77	♀	74	Liver	0.0	Light fatty change concentrated around major vessels
				Fat	494.0	N. E.
	796	♂	28	Liver	235.0	N. E.
				Testis	32.0	N. E.
	797	♂	48	Liver	111.0	N. E.
				Testis	103.0	N. E.
CONTROL 0	31	♀	74	Liver	0.0	Slight vacuolation, otherwise normal; cytoplasmic granules uniformly distributed; cells polygonal, turgid; sinusoids normal.
				Fat	0.0	N. E.

* Not significant.

It is well known that DDT accumulates in the tissues of animals that receive the chemical in their diets (Orr and Mott, 1945; Telford and Guthrie, 1945; Laug and Fitzhugh, 1946; and others). Its highest concentration is in the fat tissue, where it is reported to reach concentrations up to 30 times that of the diet. Much less is known about the accumulation of toxaphene and dieldrin in animal tissue, but available evidence indicates a behavior similar to that of DDT (Diephius and Dunn, 1949; Anon., 1951). Our data are in essential agreement with these observations. From Table 3 it is seen that, with one exception, birds maintained on insecticide-contaminated diets accumulated quantities of the chemical in their fat. Moreover, pheasants maintained on diets containing either DDT or toxaphene had chemical concentrations in fat roughly proportional to the concentration of the material in the diet. This relationship did not hold true for the tissues of birds maintained on dieldrin, although here again the insecticide did tend to accumulate in the fat tissue. The low concentrations of the insecticides in the livers of sacrificed birds may be due to the detoxifying function of the organ, since much higher concentrations were found in the livers of birds that died of poisoning (Numbers 790, 796, 797; Table 3).

DISCUSSION

The chemicals discussed in this paper were selected for study because there had been reliable field reports of game loss from their use. Field mortality in most cases resulted from acute or short-term exposure. DDT on seed rice has caused some mortality to pheasants and waterfowl (Rudd and Genelly, 1955); toxaphene applied to row crops and irrigated pasture lands has apparently caused significant mortality of pheasants; dieldrin applied to rice for control of leaf miner resulted in verified loss of herons and egrets and in suspected loss of some other birds.

Of the chemical applications mentioned above, only DDT appears to be capable of causing game damage through continued exposure to sublethal dosages. Chronic poisoning of birds by exposure to DDT is strongly suggested in studies from the orchard areas of the State of Washington (Barnett, 1950). In those areas dosages of up to 50 and 60 pounds of DDT per acre are applied within a year. Single application rates of DDT in Californian orchards rarely exceed one and one-half pounds per acre, although two or three applications may be made annually. With the exception of the seed rice situation described above, DDT application rates in California are apparently not high enough to result in significant chronic mortality. When oils, miticides, and other insecticides are applied in the same areas in which DDT is used, these pesticides in combination with DDT may be sufficiently toxic to induce damage (*op. cit.*).

Toxaphene has a much shorter residual life than dieldrin and may not be expected to produce chronic effects of the same degree. Toxaphene is applied at rates of from 0.1 pound per acre in mosquito abatement activities to eight pounds per acre on some row crops. It is difficult to translate surface application rates into the units used in experimental analysis. The best data available indicate that values as high or higher than our experimental levels do result from normal rates of field application (Laakso and Johnson, 1949). A toxaphene emulsion applied at four pounds per acre resulted in a field concentration of 165 p.p.m. Four months later the baled alfalfa still contained 55 p.p.m. In a similar test at eight pounds per acre, the field concentration reached 560 p.p.m. and baled alfalfa contained 274 p.p.m. Toxaphene dust applied at four pounds per acre resulted in concentrations of 45 p.p.m. in the field, and four months later of 30 p.p.m. in baled hay. Domestic geese showed signs of intoxication when exposed to toxaphene spray at three pounds per acre and incurred mortality at four pounds per acre (Eyer et al., 1953). It would seem that values above two pounds per acre as spray and perhaps six pounds per acre as dust would be required to intoxicate pheasants. No direct evidence indicating chronic hazard of this chemical to any form of wildlife is available.

Dieldrin has a residual life similar to that of DDT, but its insecticidal activity is much higher (Lidov et al., 1950). There is no field evidence available to indicate any chronic hazard, although acute poisonings are well known. In general, dosages of one-half pound per acre may be used effectively without hazard to warm-blooded animals.

At one pound per acre and higher, acute mortality may be expected. Normally, such dosages of dieldrin are not necessary for efficient insect control.

SUMMARY

Two hundred twenty-four ring-necked pheasants were maintained on diets containing one of three chlorinated hydrocarbon insecticides (DDT, toxaphene, and dieldrin) for periods ranging up to 94 days. In the fall test, 3 out of 10 females on 600 p.p.m. of DDT died within 57 days; 1 out of 10 females on 200 p.p.m. of DDT died after 90 days. During the spring test, all 4 males exposed to 400 p.p.m. of DDT died, while 20 females survived similar conditions. Such sexual difference in susceptibility to DDT corroborates earlier observations.

Thirty-three pheasants, including three males, survived exposure to toxaphene fed for two to three months, even at the highest level (300 p.p.m.).

Dieldrin proved most fatal to pheasants. In the fall, 6 out of 10 females at 200 p.p.m. died within 28 days, and 5 out of 10 females at 100 p.p.m. died within 38 days. In the spring, 8 out of 20 females and all 4 males at 50 p.p.m. died within 74 days. The only male tested at 25 p.p.m. died, while 21 females survived. With dieldrin as with DDT, the males appear to be more susceptible to poisoning than are the females.

Declines in the weights of pheasants on toxaphene or dieldrin were roughly proportional to the degree of contamination of the feed. Most of the pheasants on DDT gained and maintained weights that averaged greater than those of the control birds, regardless of the concentration of the chemical. It is obvious that weight cannot be used as an exact index to the degree of intoxication of the bird.

Samples of liver, fat, and testicular tissue taken from birds sacrificed at the end of the spring test period were analyzed for chemical content and studied histologically. All birds examined had a high concentration of insecticide in the fat tissue or showed marked damage to liver cells, or both. The livers of birds that were killed by the chemical contained recoverable amounts of insecticide, in contrast to the livers of sacrificed birds.

Field evidence of game mortality in California induced by the continued intake of small amounts of insecticide (chronic poisoning) is largely lacking. Recommended DDT application rates are not high enough to result in significant chronic mortality. However, there remains the possibility that the use of a combination of pesticides on a single crop might induce game damage. Toxaphene applied at rates greater than two pounds per acre as a spray and six pounds per acre as a dust may be expected to result in acute mortality of pheasants. With dieldrin, as with toxaphene, there is no evidence of chronic poisoning under field conditions. Acute mortality accompanies applications in excess of one pound per acre, but one-half pound per acre apparently offers little hazard to warm-blooded animals.

3—25467

REFERENCES

Anonymous
1951. Insecticide storage in adipose tissue. Jour. Amer. Med. Assoc., vol. 145, no. 10, p. 735-736.

Barnett, Dan C.
1950. The effect of some insecticide sprays on wildlife. West. Assoc. St. Game and Fish Comm., 30th Ann. Conf., Proc., p. 125-134.

Bryson, M. J., C. I. Draper, J. R. Harris, C. Biddulph, D. A. Greenwood, L. E. Harris, W. Binns, M. L. Miner, and L. L. Madsen
1950. DDT in eggs and tissues of chickens fed varying levels of DDT. Advances in Chem. Ser., no. 1, p. 232-236.

Dahlen, James H., and Arnold O. Haugen
1954. Acute toxicity of certain insecticides to the bobwhite quail and mourning dove. Jour. Wildl. Mangt., vol. 18, no. 4, p. 477-481.

Diephius, Floyd, and C. L. Dunn
1949. Toxaphene in tissues of cattle and sheep fed toxaphene-treated alfalfa. Mont. State Coll. Agric. Expt. Sta., Bull. no. 461, p. 22-26.

Eden, W. G.
1951. Toxicity of dieldrin to chickens. Jour. Econ. Ent., vol. 44, no. 6, p. 1013.

Eyer, J. R., L. R. Faulkner, and R. T. McCarty
1953. The effect of toxaphene and DDT on geese in cotton fields. New Mex. Coll. Agric. and Mech. Arts, Press Bull. 1078, p. 1-6.

Kolthoff, I. M., and J. J. Lingane
1952. Polarography. 2d ed., revised and enlarged. Interscience, N. Y. 990 p. (2 vol.)

Laakso, J. W., and L. H. Johnson
1949. Toxaphene residues on alfalfa. Mont. State Coll. Agric. Expt. Sta., Bull. 461, p. 5-15.

Laug, E. P., and O. G. Fitzhugh
1946. 2, 2-bis (p-chlorophenyl)-1, 1, 1-trichloroethane (DDT) in the tissues of the rat following oral ingestion for periods of six months to two years. Jour. Pharm. and Expt. Therap., vol. 87, no. 1, p. 18-23.

Lidov, R. E., H. Bluestone, S. B. Soloway, and C. W. Kearns
1950. Alkali-stable polychloro organic insect toxicants, aldrin and dieldrin. Advances in Chem. Ser., no. 1, p. 175-183.

Mohr, R. W., H. S. Telford, E. H. Peterson, and K. C. Walker
1952. Toxicity of orchard insecticides to game birds in eastern Washington. Wash. State Coll. Agri. Expt. Sta., Circ. no. 170, 22 p.

Orr, L. W., and L. O. Mott
1945. The effects of DDT administered orally to cows, horses and sheep. Jour. Econ. Ent., vol. 38, no. 4, p. 428-432.

Rubin, M., H. R. Bird, N. Green, and R. H. Carter
1947. Toxicity of DDT to laying hens. Poultry Sci., vol. 26, no. 4, p. 410-413.

Rudd, Robert L., and Richard E. Genelly
1955. Avian mortality from DDT in Californian rice fields. Condor, vol. 57, no. 2, p. 117-118.

Telford, Horace S., and James E. Guthrie
1945. Transmission of the toxicity of DDT through the milk of white rats and goats. Science, vol. 102, no. 2660, p. 647.

CHARACTERISTICS OF THE PELVIC GIRDLE IN RELATION TO SEX IN BLACK-TAILED AND WHITE-TAILED DEER[1]

RICHARD D. TABER
School of Forestry
University of California, Berkeley

INTRODUCTION

A knowledge of morphological differences between the sexes of deer is useful for both the field man who wishes to sex a headless skeleton and the law enforcement officer who wishes to sex a butchered carcass. Three aspects of the pelvic girdle show sexual differences which are useful in this regard. The present report describes and illustrates these differences for both the Columbian black-tailed deer (*Odocoileus hemionus columbianus*) and the Virginia white-tailed deer (*O. virginianus borealis*) between the ages of two and ten years. Reliable criteria for age classes below two years have not yet been completely worked out.

The material for the black-tailed deer is from the author's collection from Lake County, California. That for the white-tailed deer originated in the State of New York, and was made available through the courtesy of Mr. C. W. Severinghaus of the New York Conservation Department.

Each specimen was assigned to an age class according to the criteria established by Severinghaus (1949) for the white-tailed deer and found applicable to black-tailed deer as well (Moreland, 1952).

The bones of the pelvic girdle are the two innominates (or os coxae or H-bones) and the sacrum (Figure 1). Each innominate is made up of three bones—the ilium, the ischium, and the pubis—which fuse firmly by about 18 months of age.

THE SHAPE OF THE PUBIC SYMPHYSIS AS AN INDICATOR OF SEX

The two pubic bones, or pubes, come together face to face at the mid-central line, and the line along which they meet is called the pubic symphysis (Figures 1 and 2). Each of the faces which oppose each other at the pubic symphysis is called a symphyseal face.

The shape of the anterior part of the symphyseal face in the male is different from that in the female. In the male it tends to be blunt, or prolonged forward slightly in its upper part, while it is rounded both above and below to give a roughly paddle-shaped outline. In the female it tends to be more slender, often dished in its upper forward part, while it may be flattened below. The symphyseal outline of the

[1] Submitted for publication September, 1955. Contribution from Federal Aid in Wildlife Restoration Project California W-31-R, "Effects of Brush Removal on Game Ranges in California," and the Museum of Vertebrate Zoology, University of California.

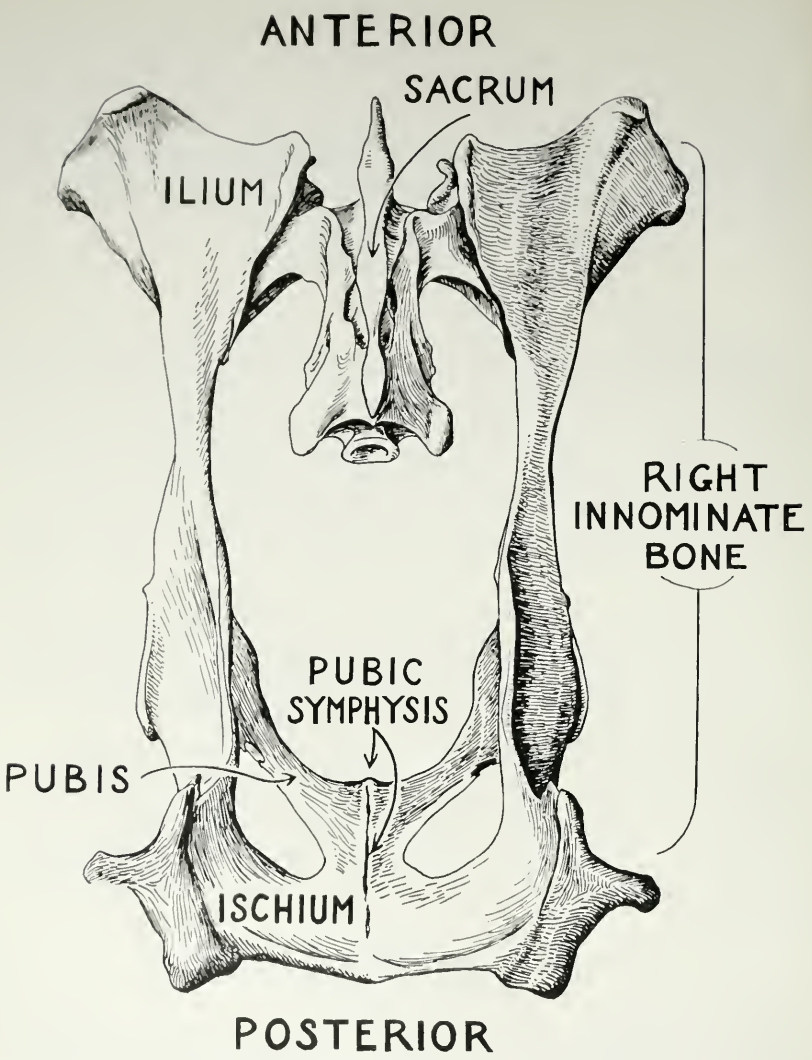

FIGURE 1. Pelvic girdle of adult doe from above, showing the bones which make it up. The tail vertebrae have been removed.

male may be likened to a soup spoon when the spoon is viewed from above, while that of the female is more like the soup spoon held upside down and viewed from the side. There is a great deal of individual variation, and the difference between the sexes, which may barely be indicated at six months of age, becomes more pronounced as age advances (Figure 2). This difference was noted by Todd and Todd (1938, p. 9), who said, "In every artiodactyl (including deer) this sexual distinction is found, the male showing a symphyseal face biconvex in outline, the female having an outline concave ventrally and convex dorsally."

Edelmann (1943, p. 372) made a similar statement, based apparently on the authority of Whering and Schaff (reference not further identified), although it is not documented: "On the pubic symphysis the pelvis of the buck is thick and like a protuberance; that of the doe is thin, flat in front and slightly hollowed. It is emphasized by

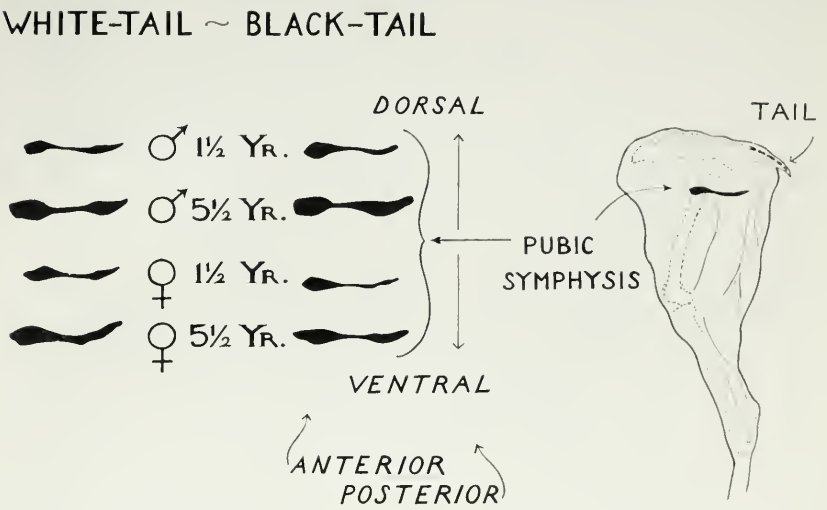

FIGURE 2. *Right.* The right hindquarter of a buck, showing the position of the bones, and especially the cut surface at the public symphsis, which is shown as solid black. *Left.* The cut surfaces, at the pubic symphysis, of both white-tailed and black-tailed deer, of both sexes, 1½ and 5½ years old.

Whering that the appearance of the symphysis can only be utilized with a degree of certainty in older deer as all the young individuals have a thickened protuberant symphysis. * * * The common stag and fallow deer show also similar sexual differences in the pelvis."

In the very young deer the two symphyseal faces are joined by cartilage. This cartilage gradually ossifies and by about the second to fourth year fuses with the adjoining ischia to bind the innominate bones rigidly together. When a carcass is cut in half, the saw cut passes longitudinally through the pubic symphysis. The shape of the cut face in an adult deer will generally indicate the sex of the deer, because it will correspond to the symphyseal face. However, if the saw cut is very wide, so that both symphyseal faces are removed by the cut, or if the cut is made off to one side, the sawn face will no longer represent the symphyseal face and sexing by this means may not be possible.

Because of the probability that deer (and other hoofed mammals, to which these remarks also largely apply) will show genetic differences in different regions, it is suggested that a reference collection of specimens of known age and sex be established for each area before an attempt is made to use this technique on a large scale.

THE SUSPENSORY TUBEROSITY OF THE ISCHIUM AS AN INDICATOR OF SEX

In the buck the penis is supported by suspensory ligaments which are attached to the arch of the ischium, or rather to the "inter-ischial bone" which forms a border around the arch of the ischium at the midventral line, binding the ischia together. Where the suspensory ligaments attach there are raised areas of bone called tuberosities. The principal ones are located halfway up the arch of the ischium—one on each side. The female does not have any such tuberosities, so the presence or absence of the suspensory tuberosity is indicative of sex (Figure 3). The tuberosities become more distinct as the buck grows older. The suspensory ligaments of the penis also attach, in part, to the median ischial tuberosities; these thus become heavier in the buck than in the doe (Figure 3).

It was stated that the suspensory tuberosity is actually a part of the inter-ischial bone rather than of the ischium itself. The inter-ischial bone is formed only in cartilage in the young deer. This cartilage extends from the region between the opposing parts (the *rami*) of the ischia around the rim of the ischial arch to the ischial tuberosities, which it covers. This cartilage is gradually ossified as age advances until, at about the second to fourth year, the portion covering the ischial tuberosities and the portion around the peak of the ischial arch have been transformed to bone and lightly fused to the underlying ischia. Within the next year or two ossification of the remainder of the inter-ischial bone is completed and fusion with the ischium at all points is accomplished. The relevance of these facts to the present discussion is this: if the pelvic girdle of a young animal is being cleaned for examination, the inter-ischial bone, which bears the suspensory tuberosities, may be separated from the rest of the pelvic girdle in the cleaning process. Obviously, care must be taken to prevent the loss of this diagnostic bone.

THE RELATIVE SIZE OF THE PUBIS AS AN INDICATOR OF SEX

Edelmann (1943), drawing on the work of Whering and Schaff, describes the sexual difference in pelvic proportions in these terms (p. 372): "The pelvis of the doe, when viewed from above appears broader, more spacious, less slender than the pelvis of the buck; the distance of the outside angles of the ilium from each other is as 50 to 40."

The relative size of the pelvic orifice, through which the fetus must pass, is understandably greater in the females of many mammalian species, especially those which, like the deer, have a pelvic girdle which does not separate along the symphysis at birth, and which bear relatively large and well developed young.

Washburn (1948) found that in humans the size and shape of the pelvic orifice are related to the differential growth of the pubis (Figure 1) in the two sexes; in the female the pubis tends to be relatively larger than in the male, and the female therefore displays a broader orifice. This is apparently the cause of the broader pelvic girdle of females in the deer as well, and use may be made of this fact in distinguishing between the sexes.

Relative proportions are most readily expressed as ratios; in this case the depth of the pubic symphysis, which tends to be smaller in

females, has been divided by the distance from the face of the pubic symphysis to the lip of the acetabulum, which tends to be larger in females (Figure 4).

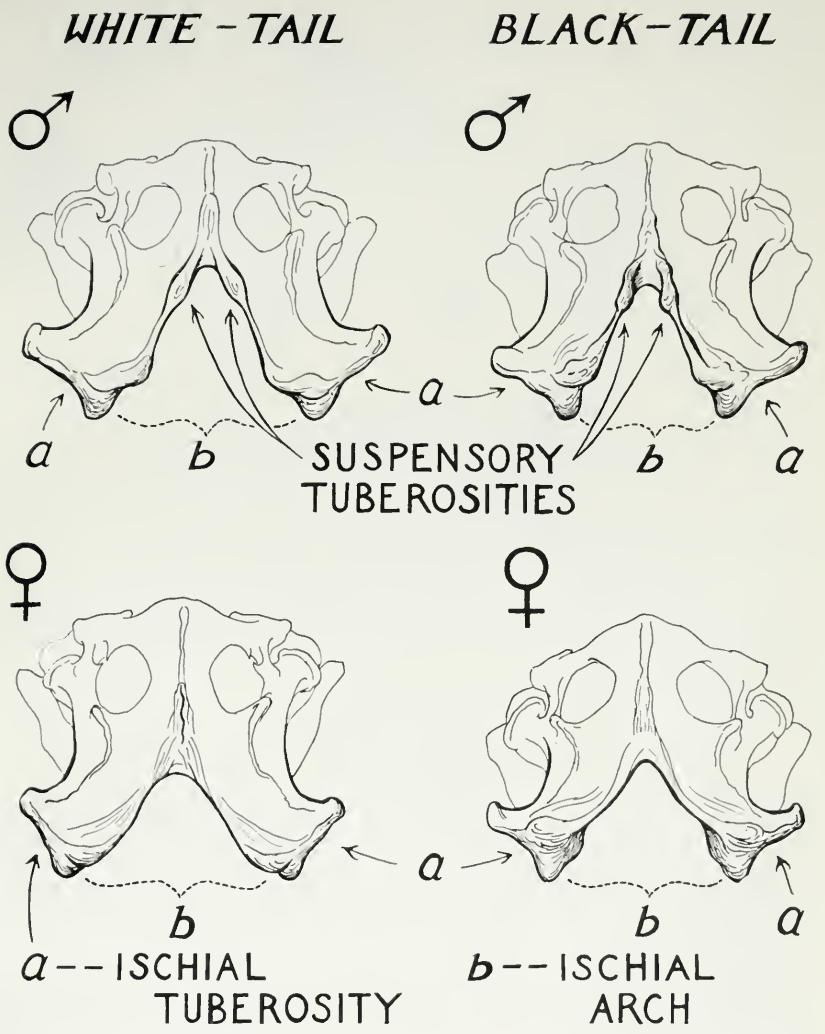

FIGURE 3. Adult white-tailed and black-tailed deer of both sexes, showing the suspensory tuberosity in the buck and its absence in the doe. These pelvic girdles are upside down and viewed from the rear.

When the depth of the symphyseal face of the pubis is taken, care must be exercised, especially in old specimens, to avoid including the inter-ischial bone in the measurement. This bone, lying between the ischia for most of its length, sends an anterior projection under the pubes at the symphysis in mid-adulthood, and when the pubic symphysis is sawn through this projection may appear superficially to be an integral part of the pubic bone.

A series of these measurements on black-tailed deer of both sexes is given in Table 1.

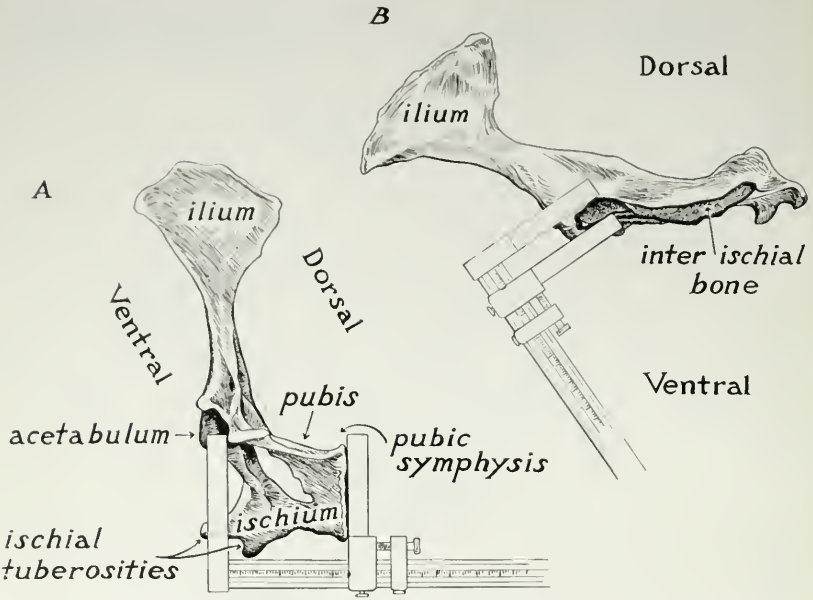

FIGURE 4. Right innominate bone of white-tailed doe, showing: A. measurement from acetabulum to pubic symphysis; and B. measurement of depth of pubic bone at the symphysis.

The values in Table 1, which are ratios

$$\left(\frac{\text{Symphysis depth}}{\text{Distance from symphyseal face to lip of acetabulum}} \times 100\right)$$

indicate that, in the black-tailed deer, bucks may be distinguished from does by this means. In the 2-3-year-old class the ratio in does was not over 35.4; that in bucks was not under 37.8. In the older classes as a whole the ratios for both sexes were lower. After three years of age the does showed no ratio greater than 28.0 and the bucks no ratio less than 32.0.

Values for the white-tailed deer, obtained in the same way, tend to be larger; the maximum for female 2-year-olds is 42.4, for 3-year-olds 35.1, and for those over 3 years 28.9, out of a total of 10 specimens of all ages. Two male specimens show a ratio of 43.6 for a 2-year-old and 35.3 for a 5-year-old. Thus, this method of sexing appears promising in the white-tailed deer but more material must be examined before it can be accepted.

The differences in ratio between the two species of deer indicate that yardsticks based on one species or race should be applied to another with caution.

TABLE 1

The Symphysis Depth—Pubis Length Ratio for 49 Adult Black-tailed Deer

Sex	Age in years							
	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10
Male	42.9	32.0	--	34.0	37.0	--	33.1	34.5
	37.8	44.5	--	--	--	--	32.0	32.0
	40.0	36.0	--	--	--	--	--	--
	43.0	--	--	--	--	--	--	--
Female	31.2	24.4	22.7	15.9	16.8	17.6	18.0	20.6
	33.6	24.2	24.8	22.0	24.0	19.4	22.0	16.4
	35.4	17.0	23.0	--	21.0	16.0	17.0	21.0
	23.0	19.0	22.0	--	28.0	19.0	--	16.0
	31.0	26.0	--	--	--	22.0	--	18.0
	--	21.0	--	--	--	--	--	26.0
	--	--	--	--	--	--	--	16.0

SUMMARY

In both the Columbian black-tailed deer and the Virginia white-tailed deer, there are three principal characteristics of the pelvic girdle which indicate sex. One is the outline of pubic symphysis, which is thick and blunt in the male and more slender and pointed in the female. The second is the presence or absence of the suspensory tuberosity on the inter-ischial bone—the point of attachment of a suspensory ligament of the penis. The third is the relative length of the pubis, which is greater in the female. This may be expressed as a ratio of pubis length (from the symphyseal face to the lip of the acetabulum) to pubic symphysis depth.

All of these characteristics become more pronounced with age.

REFERENCES

Edelmann, R. H.
1943. Textbook of meat hygiene. 8th revised edition, revised by J. R. Mohler and A. Eichhorn. Lea and Febiger, Philadelphia. 468 p.

Moreland, Raleigh
1952. A technique for determining age in black-tailed deer. West. Assoc. St. Game and Fish Comm., 32d Ann. Conf., Proc., p. 214-219.

Severinghaus, C. W.
1949. Tooth development in the white-tailed deer. Jour. Wildl. Mangt., vol. 13, no. 2, p. 195-216.

Todd, T. Wingate, and Arthur W. Todd
1938. The epiphysial union pattern of the ungulates with a note on Sirenia. Amer. Jour. Anat., vol. 63, no. 1, p. 1-36.

Washburn, S. L.
1948. Sex differences in the pubic bone. Amer. Jour. Physical Anthropol., vol. 6, no. 2, p. 199-208.

PROGRESS REPORT ON WHITE STURGEON STUDIES[1]

RICHARD L. PYCHA
University of Minnesota[2]
St. Paul, Minnesota

On April 1, 1954, for the first time in 35 years, it became legal to take sturgeon (*Acipenser transmontanus* and *A. medirostris*) in California waters. Heavy commercial fishing had led to serious depletion by 1900. Earlier, they had been abundant enough to have been considered a nuisance.

The commercial fishery was closed in 1901, reopened to a limited extent in 1910, and then closed completely in 1917.

In recent years sturgeon have again become fairly abundant. On the basis of recommendations by the Department of Fish and Game, the commission established a sport fishery in 1954, with a one-fish-per-day bag limit, a 40-inch minimum size limit, and no closed season.

In order to gather information necessary for the future management of this new sport fishery a life history study of the white sturgeon, the most important species in the fishery, was begun in July of 1954. The immediate objectives were to observe the growth of the new fishery, and to learn enough of the life history to evaluate and improve the present regulations.

Work was centered in the Sacramento-San Joaquin Delta and San Pablo Bay, where sturgeon are most abundant.

METHODS

To measure exploitation by fishermen, intensive tagging of sturgeon was carried on in San Pablo Bay from August to November, 1954. Fish were captured with salmon trammel nets 225-250 fathoms long and 5 fathoms deep. Mesh sizes ranged from 7½ to 9½ inches stretched measurement, with trammel meshes 31 inches stretched measurement. The nets were drifted across mud flats in the north half of San Pablo Bay in 6 to 12 feet of water. The 28-foot research vessel STRIPER was used for this work.

It was found that schools of sturgeon could be located by scouting for concentrations of jumping individuals. Six-foot fish made splashes that could easily be seen a mile away.

When a school was located, the net was drifted over it. As soon as three or four fish were seen to hit the net, it was reeled in. Usually 30 or more sturgeon were caught, and one drift took 115. Most of them were held securely enough to pull in over the stern roller with the net (Figure 1). Very large specimens had to be lassoed around the caudal

[1] Submitted for publication June, 1955. This work was performed as part of Dingell-Johnson Project California F-9-R, "A Study of Sturgeon and Striped Bass," supported by Federal Aid to Fish Restoration funds.
[2] Formerly Junior Aquatic Biologist, California Department of Fish and Game.

FIGURE 1. Newly tagged white sturgeon in the well of the STRIPER. The stern roller is in the right background. *Photograph by William Dillinger.*

peduncle and hauled in by two or three men. The two largest individuals, 93 and 94 inches long, were estimated to weigh approximately 300 pounds.

The fish were laid on their bellies in the well of the boat, measured with a steel tape, tagged, and then turned on their side while a one-inch section of the first pectoral ray was removed with a small hacksaw and knife. They were reasonably calm as long as they were kept upright, but could be held still only with difficulty when turned on their sides.

Several types of tags were used in tagging method experiments, including Petersen disks and stainless steel wire (type 302) on the base of the upper lobe of the caudal fin, plastic "spaghetti" type G tags inserted between two dorsal scutes, tantalum wire disk-dangler tags below the dorsal fin, and disk-dangler tags on the upper lobe of the caudal fin (Table 1). Most fish were double tagged.

TABLE 1

Numbers of Various Types of Tags Used on 1,003 White Sturgeon

Type of tag and position	*Number*
Petersen disk on caudal base	886
Plastic "spaghetti" between two dorsal scutes	641
Disk-dangler below dorsal	211
Disk-dangler on caudal base	62
Total	1,800

Altogether, 1,003 individuals were tagged.

Fin ray sections were removed from a total of 520 fish. Of these, 443 were netted, 45 were obtained from anglers, and 32 small fish ranging in length from 8 to 18 inches were taken at the fish screens of the Tracy Pumping Plant. Lengths and weights of 163 fish were obtained from

anglers and party boat operators. Total length measurements are used throughout this discussion because the data from anglers were in this form.

Fin rays were air-dried and cross-sectioned with a fine-toothed jeweler's saw. The sections were polished on one side, glued to cellulose acetate slides with "Duco" cement, and ground down to about 0.015 inch on silicon carbide paper (Pycha, 1955). They were examined under a dissecting microscope, using either transmitted or reflected light. Most sections showed annular rings clearly.

Cuerrier (1951) shows several examples of fin ray sections of lake sturgeon (*A. fulvescens*) much like those of white sturgeon.

Sections from 125 fish were damaged or were too questionable to be included in the results, leaving a total of 395 sections aged with confidence. The questionable sections came from fish scattered throughout nearly the entire size range. All sections were aged at least twice with independent determinations.

LENGTH-FREQUENCY OF SAN PABLO BAY STURGEON

The fish tagged in San Pablo Bay ranged from 31 to 94 inches in total length (Figure 2). It is believed that those over 40 inches were

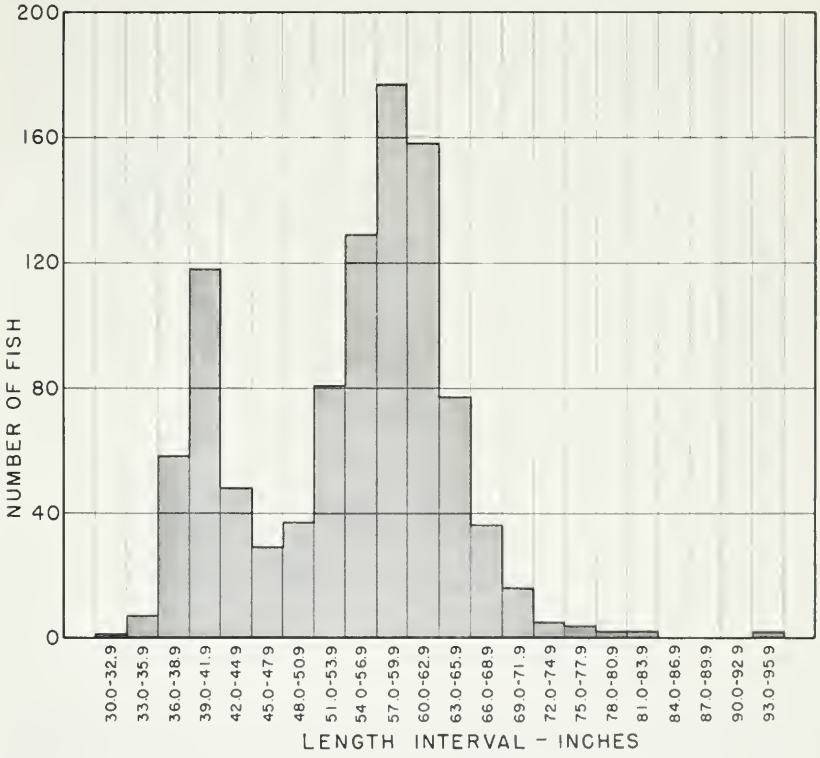

FIGURE 2. Length frequency of white sturgeon tagged in San Pablo Bay.

fully vulnerable to the nets used. The small number of fish between 42 and 51 inches is therefore probably representative of the population. Angling records from San Pablo Bay and the entire Delta area also show very few fish of that size range caught. The implications of the length-frequency distribution will be discussed in a later section.

SIZE OF SAN PABLO BAY WHITE STURGEON POPULATION

Enough tagged fish were recaptured during the netting operation to estimate the sturgeon population in San Pablo Bay in the fall of 1954. A total of 966 was tagged, and 45 were recaptured (Table 2). The population estimate is:

$$\hat{P} = \frac{\Sigma (AB)}{\Sigma C} = \frac{501{,}936}{45} = 11{,}154$$

where P = estimated population
A = number of fish tagged on a given day
B = number of fish tagged prior to the given day
C = number of recaptured fish in a given day's sample

TABLE 2

Data for Estimation of White Sturgeon Population in San Pablo Bay

Day fished	(A) Number caught	(B) Total at large	(C) Number of tagged fish recaptured
1st*	13	49	1
5th	32	155	1
6th	50	186	3
7th	48	233	1
8th	31	279	1
9th	29	309	1
10th	13	336	0
11th	30	349	2
12th	41	377	1
13th	21	416	1
14th	25	439	0
15th	22	464	0
16th	50	486	0
17th	44	533	1
18th	7	574	0
19th	68	581	2
20th	35	644	3
21st	92	676	5
22nd	115	763	10
23rd	32	868	2
24th	42	898	4
25th	35	936	5
26th	36	966	1

* Fishing was started several days before this day, but only a few fish were caught and none recaptured.

The 95 percent binomial confidence limits are 8,806 and 15,734. The recapture by commercial fishermen of two tagged fish that had migrated out of San Pablo Bay while tagging was still in progress indicated the estimate may be too large because of migration of tagged fish from the fishing area. However, the time intervals at large of the recaptured fish

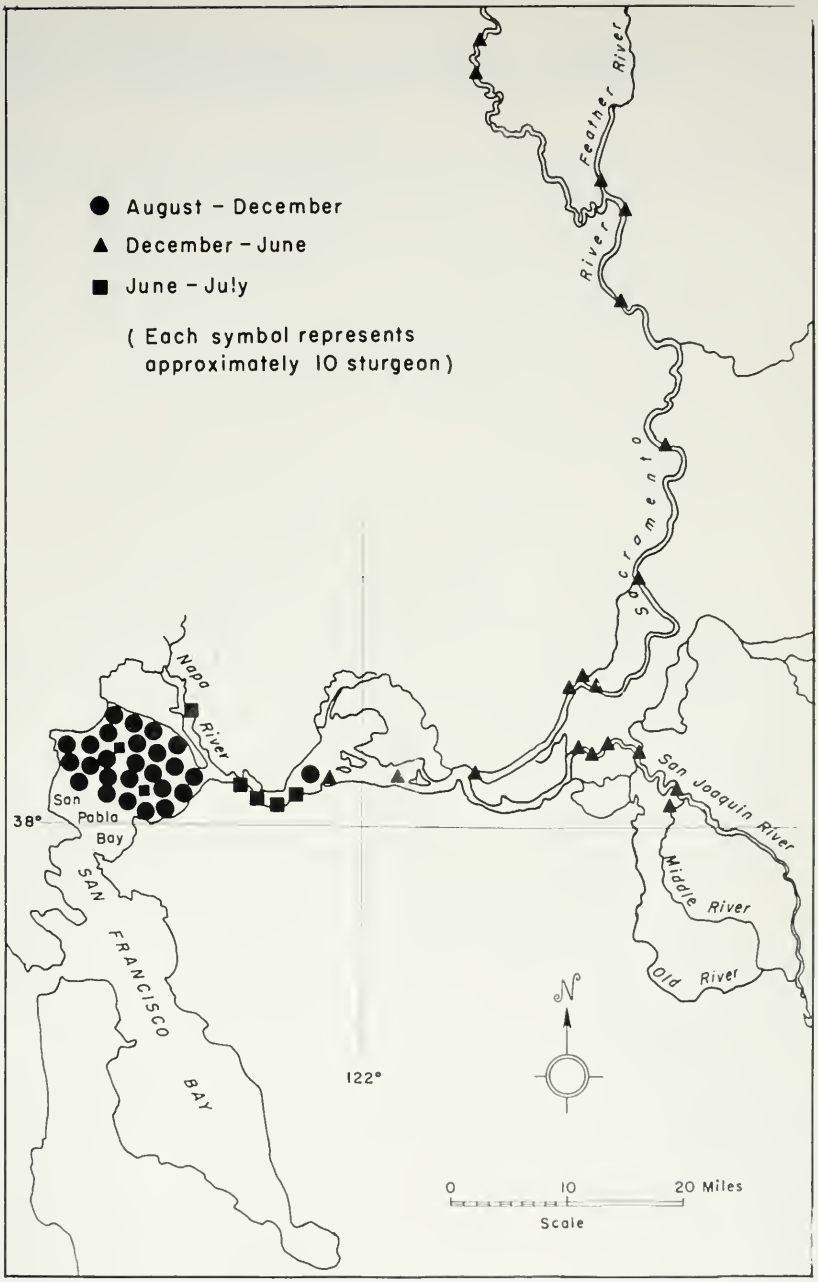

FIGURE 3. Locations where anglers caught sturgeon during the period April 1, 1954, to April 1, 1955. (Data from newspaper reports, Fish and Game warden reports, personal interviews, and communications.)

TABLE 3

Frequency Distribution of Various Age Groups, Mean Lengths of Various Age Groups, Corresponding Values on "Faired-in" Growth Curve, and Annual Increments of White Sturgeon

Length in inches	Age group														
	0	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV
0- 2.9															
3.0- 5.9															
6.0- 8.9	1														
9.0-11.9	29														
12.0-14.9															
15.0-17.9		1													
18.0-20.9		1	2												
21.0-23.9			1												
24.0-26.9						1									
27.0-29.9															
30.0-32.9						2									
33.0-35.9							5								
36.0-38.9						1	16	2	1						
39.0-41.9							21	4	4	2	1				
42.0-44.9							10	1	7	1	1				
45.0-47.9							2	4	4	1	3			1	2
48.0-50.9								1	3		1		1		2
51.0-53.9									1				1		3
54.0-56.9												1			5
57.0-59.9														1	5
60.0-62.9															
63.0-65.9															1
66.0-68.9															
69.0-71.9															
72.0-74.9															
75.0-77.9															
78.0-80.9															
81.0-83.9															
84.0-86.9															
87.0-89.9															
90.0-92.9															
93.0-95.9															
No. fish	30	2	6			4	54	12	20	4	6	1	2	2	18
$\bar{x}$ Length	10.4	18.0	21.2			31.5	39.8	43.0	44.6	42.8	45.5	55.5	51.0	52.5	54.7
"Faired-in" value	10.5	18.0	23.0	28.0	32.0	35.3	38.5	41.0	43.6	45.8	47.9	50.0	52.2	54.5	56.8
Increment	10.5	7.5	5.0	5.0	4.0	3.3	3.2	2.5	2.5	2.2	2.1	2.1	2.2	2.3	2.3

TABLE 3—Continued

Frequency Distribution of Various Age Groups, Mean Lengths of Various Age Groups, Corresponding Values on "Faired-in" Growth Curve, and Annual Increments of White Sturgeon

XV	XVI	XVII	XVIII	XIX	XX	XXI	XXII	XXIII	XXIV	XXV	XXVI	XXVII	XXVIII	XXIX	XXX	
																1
																29
																1
																3
																4
																1
																2
																5
																20
																32
																20
																17
6																14
3	7	3														18
8	19	5														38
11	36	9	4													66
4	35	5	2	1		1										48
3	19	5	3	2	1											34
	6	7	3	1	1											18
	2	5	3		1											11
	1			1	2											4
		1				1	1									3
				1						1						2
							1				1					2
														1	1	2
35	125	40	15	6	5	2	2			1	1			1	1	395
56.6	60.2	62.3	64.3	68.5	69.9	69.0	79.5			79.5	82.5			94.5	94.5	
59.0	61.2	63.6	66.0	68.3	70.7	73.1	75.5	78.0	80.4	82.8	85.2	87.7	90.2	92.8	95.3	
2.2	2.2	2.4	2.4	2.3	2.4	2.4	2.4	2.5	2.4	2.4	2.4	2.5	2.5	2.6	2.5	

gave no evidence of a systematic migration through the bay, so this is probably not a serious source of error.

Fin ray sections gave no evidence of growth during the brief tagging period, and mortality is believed to have been negligible. Aside from one fish caught by the Petersen disk tag, no evidence of differences in behavior of tagged and untagged fish was noted. This fish was not included in the recaptures. The Petersen disk tags had caused irritation on some fish, but all other types had healed well. Loss of tags during the period involved is therefore believed to have been negligible.

MIGRATION OF WHITE STURGEON

By April 1, 1955, only six tags had been returned by anglers: four from San Pablo Bay, and two from the Sacramento River. One had migrated approximately 60 miles upstream. The upstream migrants were taken during the winter of 1954-1955.

Tags were removed from five other fish by commercial salmon fishermen who caught them while salmon fishing, and several others have been reported caught, but the tags have not been returned.

The frequency of sturgeon catches in the Sacramento and San Joaquin rivers in the spring, and in San Pablo Bay in the fall (Figure 3), suggests an annual winter or spring upstream migration and summer downstream migration of large fish. Small fish less than 40 inches long seem to be present throughout the Delta area all year.

Columbia River sturgeon are known to enter the ocean (Bajkov, 1951). Knowledge of the extent to which Californian fish enter the ocean is incomplete. Occasional catches by commercial fishermen off the central California coast have been reported, but the origin of these fish was not known. Tagging data are expected to further clarify this phase of the life history.[3]

VALIDITY OF THE FIN RAY AGE DETERMINATIONS

The fin ray method of age determination has been well validated for other sturgeons, but not for this species. Final validation is impossible with only a single year's collection. However, indications are that the method is valid.

The number of "annular" rings per section increases progressively in the expected manner with the size of the fish (Table 3). Age group modes correspond reasonably well with length-frequency modes for at least the first six years. Moreover, large numbers of six- and sixteen-year-old fish correspond almost exactly with the two modes of the length-frequency distribution, suggesting a typical dominant year class type of age distribution.

If there are strong seven- and seventeen-year-old groups in a large 1955 sample, the method will be well validated.

[3] A sturgeon tagged November 5, 1954, in San Pablo Bay, California, was recovered in the Columbia River near Astoria, Oregon, on October 26, 1955.

AGE COMPOSITION OF THE STURGEON POPULATION

It is apparent from the age class distribution (Table 3) that spawning success of sturgeon has fluctuated greatly. Age groups VI and XVI comprised 50 percent of all the fish over four years old. Age groups IX through XIII contained only 15 fish, and all age groups older than XX were also poorly represented. Most large fish that hit the nets could be seen, and few are believed to have escaped. If the year classes before 1936 (age group XVIII) had been very abundant, more should have been caught.

Since sturgeon weighing several hundred pounds were once common, it seems safe to assume that natural mortality is very low and could not account for the present scarcity of fish older than 20 years. The bulk of the stock now available to anglers came from the 1937 through 1940 year classes, with the 1938 year class providing most of the fish.

From all indications another sizable year class (1948) is just entering the fishery. Its relative size is uncertain, because many of the fish were probably too small to catch in the nets used. Many of the small fish observed going through the nets may have been slow-growing members of the 1948 year class.

GROWTH IN LENGTH

The first fin ray was commonly fused with the second ray and grown around it, making back calculations of growth impractical. Moreover, growth of most fish appeared to be relatively constant from year to year, making back calculations of little use in validating age determination. Lengths at capture of the various age groups have therefore been used to express growth.

Mean total lengths for each age group were calculated (Table 3) and plotted against age (Figure 4). One year was added to each age

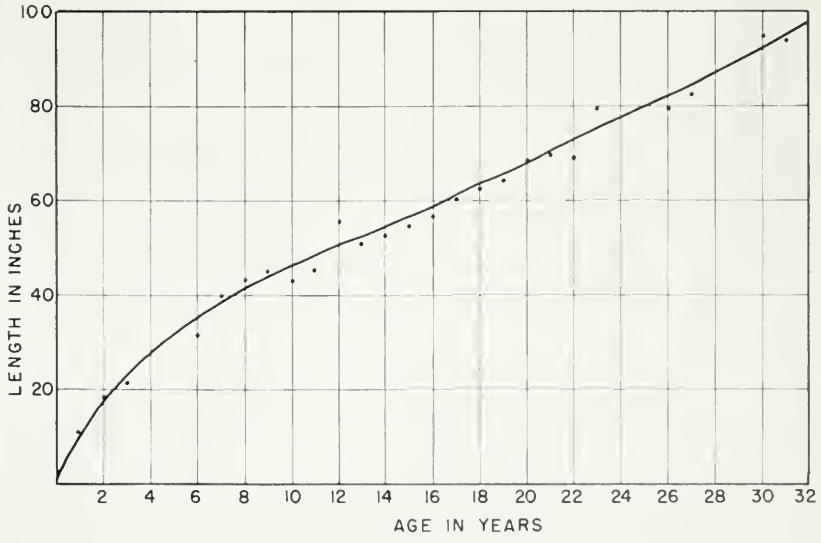

FIGURE 4. Growth in length of white sturgeon.

group because one growth season was presumably completed after the last annulus. An approximate growth curve was then "faired-in" (Table 3).

Annual length increments are large for the first four years, but decline to a nearly constant increment of 2.1 to 2.6 inches after the eighth year (Table 3). Although some differences in growth rate between the sexes might be expected, data were insufficient to clarify this point.

Sturgeon begin to reach the 40-inch minimum legal length in the seventh growing season, and almost all of them do so by the ninth growing season.

If growth in length continues at a similar rate after the thirtieth year, the 14- to 16-foot specimens reported in the early days of the fishery must have been 60 to 75 years old.

GROWTH IN WEIGHT

The total lengths and weights of 163 sturgeon caught by anglers, and of several small fish taken at the Tracy Pumping Plant screens, were plotted to determine the length-weight relationship (Figure 5). The regression line did not appear to be a simple curve, so an approximate line was "faired-in."

Weight increases slowly until the fish are about 35 inches, after which it speeds up. It slackens again between 50 and 60 inches, increasing again beyond that length.

The unusual change in slope of the regression curve between 40 and 55 inches should be noted. Most fish in the 50- to 53-inch range weighed between 35 and 50 pounds, while those in the 40- to 43-inch range weighed only 12 to 20 pounds.

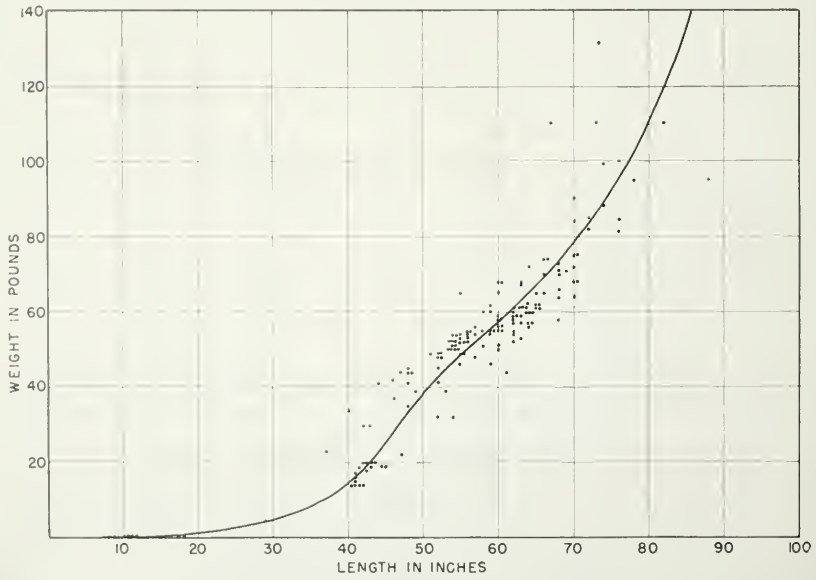

FIGURE 5. Length-weight relationship of white sturgeon.

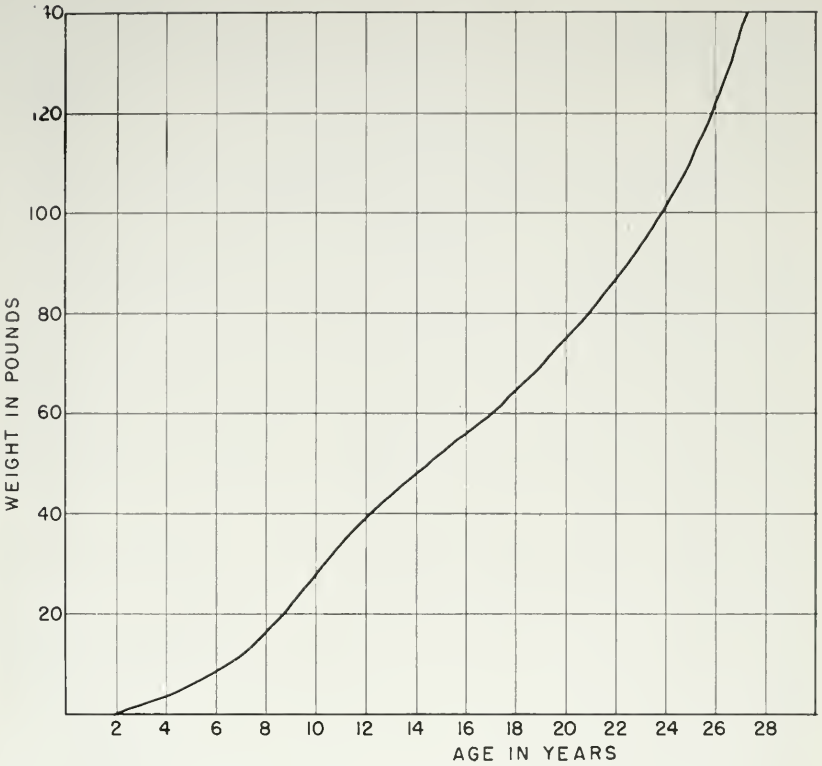

FIGURE 6. Growth in weight of white sturgeon.

A commercial sturgeon fisherman on the Columbia River informed the author that the smallest female sturgeon with ripe eggs he had seen weighed about 35 pounds. It is therefore possible that the inflection in the length-weight regression is connected in some way with sexual maturation.

By combining the data on growth in length and the length-weight relationship, a general curve of growth in weight is obtained (Figure 6). Weight increases slowly during the first 6 years, increases rapidly between 6 and about 12 years, increases more slowly from 12 to about 20 years, and increases very rapidly again past 20 years.

The largest sturgeon weighed in 1954 was 102 inches long and weighed 277 pounds.

MANAGEMENT IMPLICATIONS OF THE STUDY

The tagging done in San Pablo Bay indicates that the sturgeon population is large enough to support a small, carefully regulated sport fishery.

The angling catch is still small, but increasing. The large size, gameness, and excellent table qualities of sturgeon have created much interest among sportsmen, and a few individuals have learned how to catch them in some numbers. The commercial gill net fisheries also

kill an undetermined number of sturgeon each year while fishing for salmon and shad.

The general depletion of most sturgeon fisheries in the western hemisphere is a warning that careful management of these fish is necessary.

The angling regulations established in 1954 were based on the best information available at that time. Results of this present study indicate that they were too liberal in some respects.

Fish of the present 40-inch minimum legal length are about eight years old and weigh only about 15 pounds. A 50-inch fish weighs 38 pounds or more, and is only four or five years older. Moreover, the game qualities of sturgeon are mediocre until they reach 50 inches. A 60-inch fish is a real challenge to the angler.

The sturgeon fishery should be managed so as to maintain a sizable reservoir of large fish both as a spawning stock and a buffer supply for periods of low recruitment. This should also provide maximum recreational benefits. It is particularly important to protect the broodstock of a species such as this which does not begin to spawn until a fairly advanced age, and which appears to produce a strong year class only about every 10 years.

While age at sexual maturity has not yet been determined in California, the available evidence from Columbia River fish suggests that the females are probably not mature before 11 to 12 years.

Since several fish over 100 pounds and one weighing 277 pounds were taken in 1954, and since anglers on the Columbia River take sturgeon weighing well over 300 pounds, it appears that large sturgeon can be harvested by angling.

The present sturgeon sport fishery appears to be supported principally by the 1937 through 1940 year classes, with the 1938 year class making up the greater part of the production. The next strong year class was spawned in 1948 and is just entering the fishery. The fishery is therefore dependent upon a very few widely spaced year classes. Under heavy exploitation, wide fluctuations in abundance of legal-sized fish could be expected. Heavy exploitation is possible, as demonstrated by the taking of 194 sturgeon in San Pablo Bay by one party boat between September 23 and November 28, 1954. An even greater number was taken prior to this period by trolling with snagging gear. Trolling has since been made illegal.

The size of the spawning stock necessary to maintain the California sturgeon fishery is not known. The 40-inch size limit could possibly lead to reduction below the optimal level.

It is therefore recommended that the minimum size limit be raised to 50 inches. The fishery depends, at present, primarily on fish larger than 50 inches, so little immediate reduction in total catch is to be expected. However, the large existing crop of fish under about 45 inches would be protected and allowed to grow to a size worth catching.

In order to fully utilize the growth potentialities of the species, the average size of the catch should be maintained well above 50 inches. A decrease in average size to a point near 50 inches will indicate overexploitation. The angling catch should therefore be sampled regularly in the future to follow trends in average size.

Under proper management, the California sturgeon population should provide recreation for considerable numbers of fishermen, along with the rare opportunity of catching a really large fish in inland waters.

ACKNOWLEDGMENT

The invaluable assistance of Vincent Catania, Net Man and Boatswain, in carrying out the field work is gratefully acknowledged.

SUMMARY

After 35 years of complete closure, a sport fishery for sturgeon (*Acipenser transmontanus* and *A. medirostris*) was established in California in 1954. A life history study of the former was begun to evaluate the one-fish-per-day-bag limit, 40-inch size limit, and the no closed season regulations.

A total of 1,003 sturgeon ranging in size from 31 to 94 inches was captured with trammel nets in San Pablo Bay, tagged, and released. Pectoral spine sections were collected from the fish tagged and from fish taken by anglers for age studies.

The recapture of 45 fish while tagging gave a total population estimate of 11,154 fish in San Pablo Bay. In the first five months after tagging, only six tags were turned in by anglers and five by commercial fishermen. Only two fish were recaptured upstream in the Sacramento River. The frequency of angler catches suggests a winter or spring upstream migration and summer downstream migration of large fish. Small fish appear to be nonmigratory.

The fin ray method of age determination appears to be valid. Fish from 0 to 30 years old were aged, with age groups VI and XVI comprising about half of all fish taken. Recruitment was very poor prior to 1936 and from 1940 to 1947. Another large group of young fish is just entering the fishery.

Sturgeon attain a length of 40 inches in the eighth year, 50 inches in the 13th year, and 94 inches in the 30th year. Weight increases slowly with length up to 35 inches, increases rapidly between 35 and 45 inches, slackens somewhat between 50 and 60 inches, and increases rapidly beyond that length.

Exploitation of sturgeon is still at a low level, but is increasing. Because of the great increase in weight between 40 and 50 inches, and because of the wide year class fluctuations, a 50-inch size limit is recommended to provide a buffer stock of large fish for anglers and to insure maintenance of an adequate spawning stock.

REFERENCES

Bajkov, A. D.
1951. Migration of white sturgeon (*Acipenser transmontanus*) in the Columbia River. Fish Comm. Oregon, Fish Comm. Res. Briefs, vol. 3, no. 2, p. 8-21.

Cuerrier, Jean-Paul
1951. The use of pectoral fin rays for determining age of sturgeon and other species of fish. Canadian Fish Culturist, no. 11, p. 10-18.

Pycha, Richard L.
1955. A quick method for preparing permanent fin-ray and spine sections. Prog. Fish-Culturist, vol. 17, no. 4, p. 192.

Schnabel, Zoe E.
1938. The estimation of total fish population of a lake. Amer. Math. Monthly, vol. 45, no. 6, p. 348-352.

FURTHER OBSERVATIONS ON STREAM SURVIVAL OF KING SALMON SPAWN[1]

HAROLD A. GANGMARK and ROBERT D. BROAD
United States Fish and Wildlife Service
Seattle, Washington

INTRODUCTION

An experimental hatching study of king salmon (*Oncorhynchus tshawytscha*) eggs in Mill Creek, a tributary of the Sacramento River, California, in the fall of 1952 suggested a direct relationship between floods and egg mortalities (Gangmark and Broad, 1955). This study was a part of a general investigation of the reasons for widely fluctuating survival rates of salmon from year to year. Further information on the influence of floods being desirable, additional investigations were carried out during the 1953-1954 season as a part of the more general investigation at Mill Creek.

In the experiments at Mill Creek incubating king salmon eggs were observed in their natural environment in order to determine the effect of various influences on survival of eggs near the southernmost limit of the spawning range of the species. Fertilized eggs from native king salmon were placed in containers which were buried in spawning riffles and covered with gravel to simulate natural conditions as closely as possible. One-fifth of the containers were removed from the stream bed at equal intervals during the incubation period. Laboratory examination of the contents of each container was then made. The results were tabulated and related to various ecological conditions that may have occurred during incubation. During the later stages of the experiment some eggs could not be accounted for, even though the eggs were in plastic sacks. An accurate record of survival rates was kept by using samples of known size.

THE EXPERIMENTAL AREA

Several requirements for a suitable area for the tests were met by a site near Woodward's Gate (Figure 1). It would be accessible under heavy flows, since the stream at this point could spread laterally 150 feet before it would become much deeper. The area was well supplied with gravel of the size which Burner (1951) terms as medium and small (less than six inches at its greatest breadth). Finally, spawning salmon actually had used the riffle in the past.

A controlled flow stream was also desired, to compare survival in the absence of stream fluctuation. Approximately two miles from the mouth of Mill Creek, an old channel which had become isolated from the main stream by silting and brush growth leads to the Sacramento

[1] Submitted for publication June, 1955.

FIGURE 1. Spawning riffle area used for Mill Creek hatching experiments at Woodward's Gate in 1953-1954, exposed at low water.

River. This channel was dry except during high water, although some sections were fed by an underground spring.

Permission was obtained to divert a controlled flow into this channel, and to prevent flooding an earth fill dam was built across the entrance over a 30-inch culvert connecting the channel with Mill Creek. A headgate was installed to control water flow through the culvert.

RESULTS OF THE FIRST WOODWARD'S GATE EXPERIMENT

On November 6, 1953, two female and four male king salmon were obtained from Mill Creek and were artifically spawned, using the hatchery dry method described by Cameron (1940). The eggs were then placed in a hatchery type egg basket in the current of the stream. After water-hardening for 1½ hours, 100 eggs were placed in each of the numbered sacks, together with small amounts of gravel. The sacks were gently set into the depressions prepared for them in the stream bed at Woodward's Gate and were covered to the level of the surrounding gravel. The planting scheme was such that each removal group would represent as much of the whole planting area as possible. Each nest was protected from spawning salmon by a piece of wire netting 2 feet square anchored over it.

The first 50 sacks contained eggs from one female, and the second 50 sacks contained eggs from the second female plus some from the first. Knowledge of the time interval required for hatching was needed in order to divide the entire trial into equal periods. Past temperature records for Mill Creek indicated that approximately 1,000 heat units would be required for hatching.

When the sacks of eggs had been buried for three days, the first group was removed to obtain information on the handling loss. The next group was removed when the accumulated heat units approximated 20 percent or 250 heat units. Other lots were removed on a similar schedule of approximately 500, 750, and 1,000 heat units. The daily temperatures and heat units during the experimental period are shown in Table 1.

After the sacks had been removed from the stream bed, the eggs were separated from the gravel and placed in bottles containing a

TABLE 1

Mill Creek Stream Hatching Experiment Heat Unit Accumulation During Winter of 1953-54

Date	Mean daily stream temp., °F.	Heat units	Sub-totals		Date	Mean daily stream temp., °F.	Heat units	Sub-totals	
			Expt. 1	Expt. 2				Expt. 1	Expt. 2
Nov. 6		11	x		Dec. 21	47	15		
7	53	21			22	44	12		
8	51	19			23	43	11		
9	51	19			24	42	10	755	519
10	51	19			25	43	11		
11	52	20			26	44	12		
12	53	21			27	45	13		
13	53	21			28	44	12		
14	53	21			29	43	11		
15	52	20			30	42	10		
16	51	19			31	42	10		
17	49	17			Jan. 1	42	10		
18	44	12		x	2	42	10		
19	44	12			3	44	12		
20	44	12	257		4	45	13		
21	44	12			5	44	12		
22	47	15			6	44	12		
23	50	18			7	45	13		
24	50	18			8	44	12		
25	51	19			9	42	10		
26	50	18			10	43	11		
27	50	18			11	45	13		
28	49	17			12	44	12		
29	48	16			13	42	10	983	748
30	48	16			14	43	11		
Dec. 1	48	16			15	44	12		
2	47	15			16	46	14		
3	47	15			17	46	14		
4	47	15			18	44	12		
5	45	13	498	265	19	44	12		
6	45	13			20	43	11		
7	45	13			21	44	12		
8	45	13			22	45	13		
9	45	13			23	46	14		
10	45	13			24	44	12		
11	44	12			25	42	10		
12	43	11			26	42	10		
13	43	11			27	43	11		
14	45	13			28	44	12		
15	46	14			29	46	14		
16	46	14			30	46	14		
17	47	15			31	46	14		
18	48	16			Feb. 1	48	16		
19	49	17			2	48	16		
20	50	18			3	47	15		
					4	47	15		1031

x—day planted

TABLE 2

Egg Survival of First Main Stream Plant at Woodward's Gate With Average Eggs per Sack and Standard Deviations

Removal group and date	Original number of eggs	Moldy and/or ruptured	Opaque	Clear unfertilized	Partial development	Alevins	Number alive	Remarks
1A	1,000	0	0	851	0	0	149	Sacks 1-50 eliminated because of low fertility demonstrated in this sample.
11/ 9/53								
x	100	0.0	0.0	85.1	0.0	0.0	14.9	
s.d.							5.9	
1B	864	1	0	477	0	0	376	Eggs from salmon of low fertility eliminated.
11/ 9/53								
x	86.4	0.1	0.0	47.7	0.0	0.0	37.6	
s.d.							11.7	
2	893	314	15	318	0	0	344	Three sacks moved from original positions in stream bed.
11/20/53								
x	89.3	31.4	1.5	34.8	0.0	0.0	34.4	
s.d.							28.0	
3	913	231	8	81	36	0	129	Seven sacks moved from original positions.
12/ 5/53								
x	91.3	28.1	0.8	8.4	3.6	0.0	12.9	
s.d.							17.4	
4	667	394	6	56	11	0	16	One sack moved from original position. Worms present in one sack.
12/24/53								
x	95.3	56.3	0.9	8.0	1.6	0.0	2.3	
s.d.							2.9	
5	788	137	7	10	12	16	41	Six sacks moved from original positions. One apparently normal alevin hatching from moldy shell. Worms in one sack.
1/13/54								
x	98.5	17.1	0.9	1.2	1.5	2.0	5.1	
s.d.							5.8	

clearing solution of 1 part formalin, 1 part glacial acetic acid, and 14 parts water. Microscopic examination was required to detect early cell stages in those eggs removed shortly after planting. All other eggs showed the embryonic fish very clearly.

Ten of the first 50 sacks, with eggs from the first female, had an egg survival rate of only 14.9 percent (Table 2). The low initial rate left such a small sample for measuring future mortalities that this sample was discarded from the experiment.

Since the eggs from the second female were much smaller, it was easy to distinguish them from the few larger eggs of the first female that were mixed with them in the remaining 50 sacks. The survival rate for the second female's eggs after 3 days was 57.6 percent. Carl (1939), in planting silver salmon (*Oncorhynchus kisutch*) eggs in gravel in a hatchery trough, experienced losses of 46.4 percent. He offers the opinion that high mortalities are the result of extra handling involved in counting the eggs.

Thirteen days later, on November 20, the second group was removed. During this time, the mean temperature of Mill Creek dropped from 55° F. to 44° F. On November 14, during a freshet, the mean stream flow increased to 491 c.f.s.,[2] 7 times the mean recorded at time of planting. This group survived at a rate of 34.4 percent, which is a drop of 23.2 percent from the first removal (Table 2).

A third group was removed on December 5, after 29 days in the gravel. Laboratory examination showed a survival of 12.9 percent. This group had again been exposed to a stream freshet. Mean daily flow for November 24 reached 515 c.f.s.; an increase of over 7 times that recorded when the eggs were planted. Temperature during this time rose from 44° F. to 51° F. and dropped again to 45° F. when the group was removed. The fourth group was collected after 48 days. In the period between the third and fourth removals, flows remained relatively stable. Temperatures fluctuated somewhat, reaching 50° F. and dropping to a low for the season of 42° F. Two and three-tenths percent of the embryos per cartridge were alive. On January 13, the fifth group was removed, after a total of 68 days or 983 heat units. Flows and temperatures remained stable between the fourth and fifth removals. A survival of 5.1 percent was recorded. The eggs were in the process of hatching when removed. Better indicated survival of the last group than the fourth group is a result of sampling error. The daily mean temperatures and stream flows are plotted in Figure 2, along with the various survival rates. Here it can be seen that early freshets were accompanied by rapid declines in survival, while stable flows that followed produced less mortality. A relation between the occurrence of freshets and survival rate was thus suggested.

Freshets the year before (1952-1953) (Gangmark and Broad, 1955) occurred late in the incubation period, in contrast with their early occurrence in the experiment just described. The time of major egg mortality corresponded with the freshets. In 1952-1953 average losses of 4.1 and 7.7 eggs per sack were recorded between the first to second and second to third removals, respectively, when the stream fluctuation

[2] Water flow records were obtained from the State of California Division of Water Resources. Their stream flow gauge is located one-half mile downstream from Woodward's Gate.

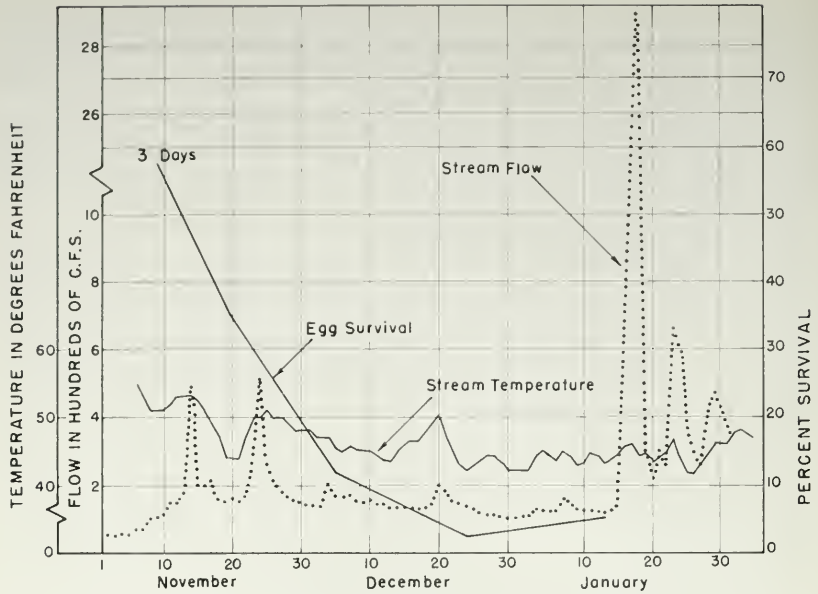

FIGURE 2. The fluctuations in stream flow and temperature of Mill Creek and percentages of survival of egg samples during the first study in 1953-1954.

was moderate. A loss of 18 eggs per sack was experienced between the removal of the third and fourth groups, when the mean flow for one day reached 1,250 c.f.s.

RESULTS OF THE CONTROLLED FLOW CHANNEL EXPERIMENT

There appeared to be a correlation between occurrence of marked stream fluctuation and survival. Therefore, a controlled flow channel experiment was carried out for purposes of comparison. On November 18, 1953, spawn was taken from two female and three male king salmon. Standard hatchery procedure was followed for obtaining the spawn as before. The eggs were then allowed to water harden for 1½ hours before being placed in the cartridges with some small gravel. Thirty of the containers were destined for Woodward's Gate, as an open channel control, and 31 for the controlled flow area. They were selected alternately for each area and buried in the respective areas simultaneously. Again there were five colors of tags in each group. They were planted by a staggered distribution or by rotating the colored tags. The temperature of the water at this time was colder (44° F.) than during the first plant.

After two days, the first groups were removed. In the main stream, 63.6 percent of the eggs survived the handling operation (Table 3), and in the control channel, 52 percent (Table 4). Between this time and the removal of the second group, flows had increased to a mean of 515 c.f.s. from 152 c.f.s. at planting on November 24. At the end of this period, the cartridges in Mill Creek proper revealed a 37.2 percent survival in the second group, or a drop of 26.4 percent. This is

TABLE 3

Egg Survival of Second Main Stream Plant at Woodward's Gate With Average Eggs per Sack and Standard Deviations

Removal group and date	Number of eggs found	Moldy and/or ruptured	Opaque	Clear unfertilized	Partial development	Alevins	Number alive	Remarks
1	496	0	1	177	0	0	318	One sack removed from stream by a fisherman; eggs destroyed, not counted.
11/20/53								
x	99.2	0.0	0.2	35.4	0.0	0.0	63.6	
s.d.							11.4	
2	591	137	0	231	0	0	223	Two sacks moved from original position.
12/ 5/53								
x	98.5	22.8	0.0	38.5	0.0	0.0	37.2	
s.d.							26.3	
3	589	291	8	69	61	0	160	
12/24/53								
x	98.2	48.5	1.3	11.5	10.2	0.0	26.7	
s.d.							9.6	
4	379	85	9	120	29	0	136	
1/13/54								
x	63.2	14.2	1.5	20.0	4.8	0.0	22.7	
s.d.							14.1	
5								No eggs recovered.

the same time interval as between the second and third groups in the first experiment, in which a 21.5 percent loss occurred. The rates of loss in the two experiments for the same period were somewhat similar. In the controlled flow area 53.8 percent of the eggs were alive after this period, indicating that sampling error was responsible for a lower survival of the first sample. However, there is a clear difference in survival rates between the two areas. Eggs in the main stream suffered a substantial loss as compared to an apparently good survival rate in the control area (Figure 3).

In the period that followed until the third group was removed, when the salmon embryos were 36 days old, the temperatures and stream flows remained relatively stable. The survival rates in the two areas were quite similar. The main stream survival was 26.7 percent, a drop of 10.5 percent since the previous sampling. Embryos in the controlled flow area survived at a rate of 44.4 percent, a drop of 9.4 percent.

At the end of 56 days, the eggs were sampled for the fourth time in the two areas. In the main stream, 22.7 percent were alive, an average of 4 less per cartridge than in the previous sample. In the control area, 37.8 percent were alive, for an average of 6.6 embryos per container less than in the previous group. Again the temperature and stream flow factors remained stable for this period.

After the fourth group had been removed, stream flow suddenly rose to a high for the year. The water gauge at Mill Creek recorded a mean of 2,740 c.f.s. for the 17th of January. This represented a flow of 18 times the mean recorded on the day the eggs were planted. It will be recalled that the experimental area at Woodward's Gate was specifically chosen for its ability to carry large volumes of water. How-

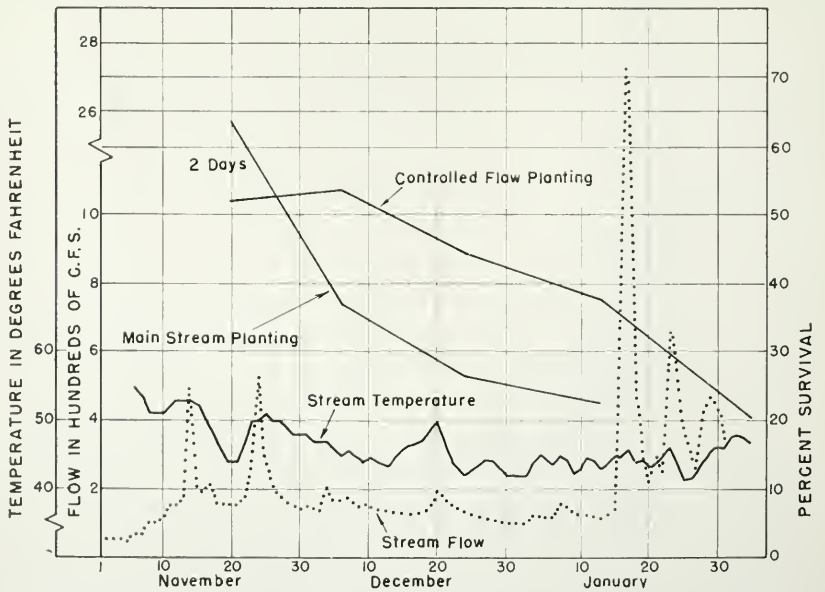

FIGURE 3. The fluctuations in stream flow and temperature at Mill Creek and percentages of survival of egg samples during the controlled flow and second main stream study in 1953-1954.

TABLE 4

Egg Survival of Controlled Flow Area Plant With Average Eggs per Sack and Standard Deviations

Removal group and date	Number of eggs found	Moldy and/or ruptured	Opaque	Clear unfertilized	Partial develpment	Alevins	Number alive	Remarks
1	599	1	0	286	0	0	312	
11/20/53								
x	99.8	0.2	0.0	47.7	0.0	0.0	52.0	
s.d.							18.3	
2	556	181	0	52	0	0	323	
12/ 5/53								
x	92.7	30.2	0.0	8.7	0.0	0.0	53.8	
s.d.							7.5	
3	673	301	16	20	25	0	311	
12/24/53								
x	96.1	43.0	2.3	2.9	3.6	0.0	44.4	
s.d.							14.8	
4	268	30	0	0	11	0	227	Six eggs with mold on shells classified as alive.
1/13/54								
x	44.7	5.0	0.0	0.0	1.8	0.0	37.8	
s.d.							14.0	
5	240	52	17	7	41	45	123	Alevin count included in "alive."
2/ 4/54								
x	10.0	8.7	2.8	1.2	6.8	7.5	20.5	
s.d.							5.5	

ever, the force of the current was sufficient to change the profile of the riffle and to dislodge the salmon embryos in the gravel.

No evidence remained of the cartridges which were to be removed on February 4, after 78 days. The final tally was 20.5 percent alive for the controlled flow area, a decline of 17.3 salmon embryos per cartridge since the last removal. The stream temperature and flow records are shown in Figure 3 in connection with survival rates in the two areas.

RESULTS OF THE JANUARY 17, 1954, FRESHET

The high velocity flows which occurred January 17 thoroughly flushed and changed the riffle area at Woodward's Gate. Stones of varying size which had been painted white, numbered in black, and placed individually on each redd were no longer in position over the nests. Thirteen of the stones were found downstream at distances varying from 8 feet for a 9-pound stone to 525 feet for a 1.6-pound stone. The distances were measured from the downstream end of the planting area because most of the numbers had been worn from the stones.

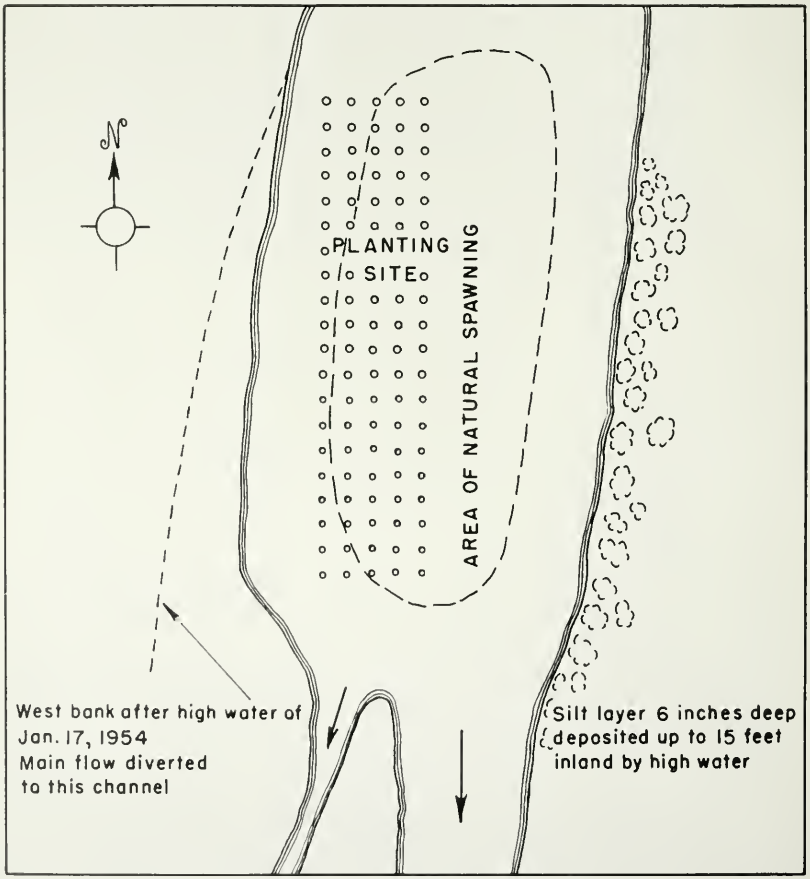

FIGURE 4. Sketch of Mill Creek planting site at Woodward's Gate.

The profile of the riffle at Woodward's Gate was changed markedly. A channel 18 inches deep was gouged through the area where 30 pairs of king salmon had spawned. The main stream was diverted from the east to the west side of a little island shown in Figure 4 and 6 inches of silt was left on the east bank up to 15 feet from the water's edge. A check was made to determine to what extent the natural spawn was affected. Nests were explored with a hoe, and a hand net was used to catch any embryos which might be dislodged. From other samples of eggs, we estimated that the majority of the natural spawn would be in the early alevin stage, when the young fish require gravel to protect them from the pull of the current and from predators. Persistent digging produced no eyed eggs or alevins.

In an attempt to evaluate roughly the extent of main stream damage, other areas were excavated in a similar manner. Below Ward Dam the stream is divided into three channels. In the two smaller channels, each of which contains less than 25 percent of the total flow of Mill Creek, eyed eggs and alevins were discovered in the gravel. Such small channels appear to be of considerable value in maintaining salmon runs, since the effect of flooding is less violent.

Evidence of loss of spawn was found at the mouth of Mill Creek, where water from the Sacramento River temporarily backed into Mill Creek. Several thousand dead eyed eggs were seen floating on the surface after the January 17th freshet. Also, 51 eyed eggs were found in the stomach of a 12-inch rainbow trout caught by a local sportsman after the flood.

DISCUSSION

Of the various factors that might have affected egg survival in our experiments, flooding is the most apparent. This influence has been so overwhelming that it has overshadowed other factors. More data are always desirable, but the effect of freshets in both the 1952-53 and 1953-54 work cannot be overlooked. This conclusion is based on the following: (1) the close correlation existing between egg losses and freshets in which stream flow increased by seven or more times; (2) the opposite survival trends for the two years in which heavy losses and extreme flows occurred late in 1952-53, compared with early losses accompanying freshets in 1953-54; and (3) the heavy egg losses experienced during an early period in the main stream in two experimental plants, in comparison with little or no egg loss during the same period in the control flow channel in 1953-54.

The influence of freshets should not be confused with that of substantial stream flows. Adequate flows are especially important in the Sacramento Valley in California. First of all, the upstream migrants must have sufficient water to swim in and there must be enough water to maintain suitable temperatures and oxygen supply. Second, stream flows must provide adequate area for adults to spawn without crowding. Third, there must be sufficient water flow throughout the incubation period to keep the eggs alive. Fourth, strong flows during downstream migration increase turbidity and protection from predators, lessen the chance of the small fish being swept into irrigation intakes, dilute pollutants, and stabilize temperatures and oxygen conditions in the streams.

As in the case of the analyses made on the data of 1952-53 (Gangmark and Broad, 1955), no significant difference in survival related to position of the cartridges in the stream was found. The analyses covering the two seasons indicate that with the exception of the flow control area, position of the cartridges in the stream has not significantly affected survival in these experiments.

ACKNOWLEDGMENTS

Grateful acknowledgment is extended to Robert Azevedo of the Branch of Game-Fish and Hatcheries and to several members of the California Department of Fish and Game, for their assistance in conducting the experiments described herein. We wish also to express sincere thanks to Scott Bair, Hydraulic Engineer, Fish and Wildlife Service Regional Office in Portland, Oregon, for surveying and providing plans for construction of the flow control dam which was built.

SUMMARY

Because of the correlation of king salmon egg mortality between the stages of fertilization and hatching in Mill Creek, California, with stream freshets in 1952-53, a controlled flow area was established to further investigate the problem in 1953-54.

The technique for conducting the experiment involved enclosing fertilized eggs with gravel in plastic screen sacks and burying them in the streambed. The sacks were removed at five different stages and various influences that may have affected survival were noted.

In one experiment involving 50 such sacks planted at Woodward's Gate, early losses were noted in the first two periods, in each of which a freshet occurred. The mortality rate was comparatively light during the last two periods, when stream flows remained stable.

Early mortalities during 1953-54 accompanied early freshets. In 1952-53 mortalities were at first small, while stream flows were stable. Mortalities increased with the occurrence of the first freshet, with complete loss following a subsequent flood.

A second experiment in 1953-54 involved placing eggs in the Woodward's Gate section and planting a similar group in the controlled flow channel. Main stream losses were heavy and in sharp contrast to a good survival rate in the control channel.

In the two periods which followed this, stream flows remained moderate and survival rates were comparable in the creek and controlled flow area until January 17, 1954, when a freshet occurred.

Results of this freshet on the Woodward's Gate area were: (1) complete erosion of the streambed; (2) loss of experimental cartridges and natural spawn from the riffle; and (3) a change of the channel and a heavy deposit of silt on the banks. Eggs in the controlled flow area suffered mortalities from silt deposition only. After the freshet only areas in which the rate of flow was reduced by the stream dividing and subdividing produced eggs and alevins.

Further indication of spawn losses after the flood were numerous floating eyed eggs which were seen at the mouth of Mill Creek. A rainbow trout caught after the freshet was found to contain many king salmon eggs that had been eroded from the gravel.

Severe freshets or violent stream fluctuations should be distinguished from substantial stream flows, which are beneficial to virtually all phases of the freshwater life history of salmonids.

An analysis of variance revealed that position in the stream had not significantly affected survival in these experiments.

LITERATURE CITED

Burner, Clifford J.
1951. Characteristics of spawning nests of Columbia River salmon. U. S. Fish and Wildl. Serv., Fish. Bull., vol. 52, no. 61, p. 97-110.

Cameron, M. W.
1940. The efficiency of fertilization in the natural spawning of Pacific salmon. Fish. Res. Bd. Can., Prog. Repts. Pac. Coast Sta., no. 45, p. 23-24.

Carl, G. Clifford
1940. Comparison of coho salmon fry from eggs incubated in gravel and in hatchery baskets. Amer. Fish. Soc., Trans., 1939, vol. 69, p. 132-134.

Gangmark, Harold A., and Robert D. Broad
1955. Experimental hatching of king salmon in Mill Creek, a tributary of the Sacramento River. Calif. Fish and Game, vol. 41, no. 3, p. 233-242.

AN ECOLOGICAL STUDY OF LOWER SAN GABRIEL RIVER, CALIFORNIA, WITH SPECIAL REFERENCE TO POLLUTION[1, 2]

DONALD J. REISH
Allan Hancock Foundation and Department of Biology
University of Southern California, Los Angeles[3]

INTRODUCTION

An ecological study of Lower San Gabriel River was carried out by the California Department of Fish and Game in 1952, in connection with its program of studying the fish and other aquatic life resources of California's bays and harbors. This area was found to be very polluted in 1952, as will be discussed below. In the fall of 1952, a section of the sampled area was diked and excavated under contract with the Los Angeles County Flood Control District as a flood control measure. In 1954 Lower San Gabriel River was resampled to determine what effect this excavation had had upon bottom conditions. If pollutants were again accumulating on the river bottom, some indication of the length of time required to reach the conditions evident in 1952 could be obtained. The term Lower San Gabriel River is used to denote that portion of the river which has marine or brackish waters.

It is important to distinguish between dictionary and California Legislative definitions of the word "pollution". A dictionary definition is "the act of making or rendering unclean", whereas in Division 7 of the Water Code of the State of California, under which the State and Regional Water Pollution Control Boards operate, pollution means "an impairment of the quality of the waters of the State by sewage or industrial waste to a degree which does not create an actual hazard to the public health but which does adversely and unreasonably affect such waters for domestic, agricultural, navigational, recreational or other beneficial use." In this study the author employed the dictionary definition of pollution.

A summary of marine pollution studies in California was given by Reish and Winter (1954). Later, Filice (1954) described the ecology

[1] Submitted for publication March, 1955. Contribution number 165 from the Allan Hancock Foundation, University of Southern California, Los Angeles.

[2] The hazards of pollution of California's coastal areas, including both marine waters and outlets of streams, are increasing as the population and industrial development of the State increase. To meet and solve this problem, detailed investigations must be made of many areas and indicators to measure the magnitude of such pollution must be established. This report is a facet of the over-all pollution studies being undertaken by various agencies in the State.—*Editor.*

[3] This work was sponsored in 1952 by the California Department of Fish and Game, which served as a technical consultant to Regional Water Pollution Control Boards Numbers 4 and 8.

The 1952 study was initiated and requested by the Los Angeles Regional Water Pollution Control Board and pursuant to this request, the Department of Fish and Game submitted a report to the board entitled, "Lower San Gabriel River Survey —July, 1952—Special Investigation Project No. 52-4-11."

The work was supported in 1954 by a research grant (E-556) from the National Microbiological Institute of the National Institutes of Health, United States Public Health Service.

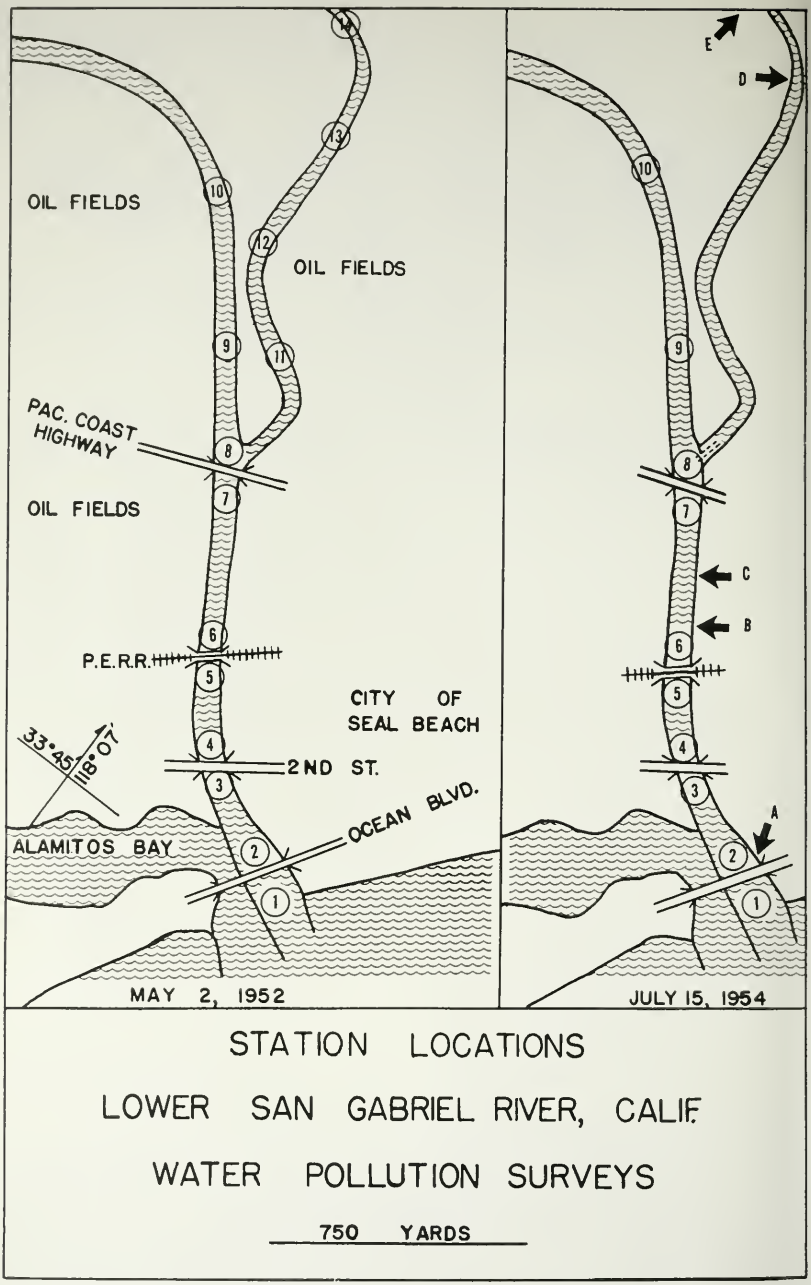

FIGURE 1. Station locations and major sources of pollution, Lower San Gabriel River water pollution surveys of May 2, 1952, and July 15, 1954. *A*, outfall from the Los Angeles Bureau of Water and Power Steam Plant. *B*, outfall from the sewage treatment plant of the City of Seal Beach. *C*, outfall from the Dow Chemical Company. *D*, outfall (east shore) from the sewage treatment plant of the Los Alamitos Naval Air Station. *E*, outfall from the Santa Fe Springs Waste Disposal Company located northeast of Station 14.

TABLE 1

Lower San Gabriel River Station Locations

Station number	Descriptive location
1	Middle of river near mouth of San Gabriel River.
2	Middle of river, 200 feet northeast of Ocean Blvd. Bridge, near Los Angeles Bureau of Water and Power Steam Plant.
3	Middle of river, 150 feet southwest of Second Street Bridge.
4	Middle of river, 150 feet northeast of Second Street Bridge.
5	Middle of river, 150 feet southwest of Pacific Electric Bridge.
6	Middle of river, 150 feet northwest of Pacific Electric Bridge, near City of Seal Beach outfall sewer.
7	Middle of river, 200 feet southwest of Pacific Coast Highway (U.S. Alternate 101).
8	Middle of river, 300 feet northeast of Pacific Coast Highway (U.S. Alternate 101).
9	Middle of river, 1,100 feet northeast of Pacific Coast Highway (U.S. Alternate 101).
10*	Middle of river, 2,300 feet northeast of Pacific Coast Highway (U.S. Alternate 101).
11†	Middle of tributary, 1,100 feet east of Pacific Coast Highway (U.S. Alternate 101).
12†	Middle of tributary, 2,000 feet northeast of Pacific Coast Highway (U.S. Alternate 101).
13†	Middle of tributary, 2,500 feet northeast of Pacific Coast Highway (U.S. Alternate 101).
14†	Middle of tributary, 4,200 feet northeast of Pacific Coast Highway (U.S. Alternate 101).

* Not sampled May 2, 1952.
† Not sampled July 15, 1954.

of the Castro Creek area in San Pablo Bay, an arm of San Francisco Bay, with particular reference to pollution. Filice divided the invertebrate bottom fauna into three zones: (1) a healthy zone unaffected by waste discharges, (2) a marginal zone characterized by a few tolerant species, notably the polychaetes *Neanthes succinea* (Frey and Leuckart), *Capitella capitata* (Fabricius), and *Streblospio benedicti* Webster, and the molluses *Mya arenaria* Linnaeus and *Macoma inconspicua* (Broderip and Sowerby), and (3) a zone, over which concentrated wastes flowed, essentially barren of animals.

DESCRIPTION OF LOWER SAN GABRIEL RIVER

San Gabriel River (Figure 1; Table 1) flows into the Pacific Ocean at the northern boundary of the City of Seal Beach, Orange County, California. The history of Lower San Gabriel River and its relationship to Alamitos Bay have been described previously (Reish and Winter, 1954). The depth of the river within the tidal range varies during the year, depending upon the amount of freshwater runoff. The greatest depth recorded during the course of the study was four feet, on July 15, 1954, at Stations 8 to 10, northeast of the Pacific Coast Highway (Alternate 101), within the area dredged in 1952 (Figure 2). However, the depth was probably greater during the winter runoff.

In 1952, the Los Angeles County Flood Control District awarded a contract for dredging and enlarging the river between the Pacific Coast Highway (Figure 2) and Spring Street (not shown in Figure 1) in the City of Long Beach, a distance of about four miles. Excavation was started on August 1, 1952, and completed on December 15, 1952. During this time the river was diked between Stations 7 and 8 at the Pacific Coast Highway bridge. Water remained in the right branch of the river (Figure 1) until some time between October 3, 1952, and November 20, 1952, when the river bed was observed to be dry.

FIGURE 2. Lower San Gabriel River from a small bridge midway between Stations 9 and 10, looking southwest. The area between the place where the photograph was taken and the Pacific Coast Highwoy (Alt. 101) bridge was dredged in 1952. *Photograph by the author, July 7, 1954.*

FIGURE 3. Lower San Gabriel River from the Pacific Electric Railroad bridge, looking southwest towards Station 4. Second Street Bridge is in the foreground. *Photograph by the author, July 7, 1954.*

A total of 864,937 cubic yards of material was excavated, making the river bed deeper by an average of four to five feet. Figures 3 and 4 show portions of the river that were not excavated.

MATERIALS AND METHODS

Lower San Gabriel River was sampled May 2, 1952, and July 15, 1954, from a small skiff furnished by the California Department of Fish and Game. The temperature, dissolved oxygen, chlorinity, and pH of the water were measured. A sample of the substrate was taken for pH and preserved for the animals it contained. Measurements and analyses of these data were carried out as described for Alamitos Bay (Reish and Winter, 1954). Stations 11 to 14, located on a tributary of San Gabriel River, were not sampled July 15, 1954, since this area was no longer accessible by boat (Figure 1). Additional trips were made to collect the high tide horizon animals (July 2, 1952) and measure the pH and temperature of the water and substrate from shore (October 3, 1952, and November 20, 1952).

SOURCES OF WASTE DISCHARGES INTO LOWER SAN GABRIEL RIVER

The primary sources of waste discharge into Lower San Gabriel River during the 1952-54 period were: Dow Chemical Company (Figure 1, C; Figure 4), Santa Fe Springs Waste Disposal Company (Figure 1, E), two domestic sewage disposal plants (Figure 1, B and

FIGURE 4. Lower San Gabriel River from the Pacific Coast Highway (Alt. 101) bridge, looking southwest towards Station 6. Dow Chemical Company located in left center. The large smoke stack is a portion of the Los Angeles Bureau of Water and Power Steam Plant. The Pacific Electric Railroad bridge crosses the river downstream from the Dow Chemical Company. *Photograph by the author, July 7, 1954.*

D), and Los Angeles Bureau of Water and Power Steam Plant (Figure 1, A). The former two were the principal contributors of wastes discharged into the river during 1952 (California Department of Public Health, 1952).

The outfall sewer of Dow Chemical Company consists of a single pipe which empties the liquid waste into the river on the east shore midway between Stations 6 and 7, just southwest of the Pacific Coast Highway. This waste discharge was investigated on May 2, 1952, October 3, 1952, November 20, 1952, and July 15, 1954. The temperature of the discharge varied; it was twice observed as high as 40.0 degrees C. (May 2, 1952, and July 15, 1954) and once as low as 23.5 degrees C. (October 3, 1952). The water temperature of the river in the immediate vicinity of this outfall was affected by this warm discharge, but temperatures 150 feet downstream were observed to be normal. The pH of the liquid wastes ranged from 2.2 to 2.5. Normal seawater pH was not found as close to the discharge as was normal temperature. At 150 feet downstream the pH of the water ranged from 4.3 to 5.8. Normal pH of the water and substratum was noted at Station 6, a distance of about 700 feet. A strong acrid odor, noted at the outfall, was still pronounced 150 feet downwind. No living animals were observed in the vicinity of the Dow Chemical Company outfall sewer.

Waste discharges from the Santa Fe Springs Waste Disposal Company, which is located northeast of Station 14, northeast of the Pacific Coast Highway, consisted of brine from oil well drilling operations. No special investigation was made of this outfall.

The two sewage treatment plants which have outfalls into Lower San Gabriel River are those of the City of Seal Beach and the Los Alamitos Naval Air Station. Both of these plants provide complete treatment with effluent chlorination of the discharge. The outfall of the City of Seal Beach is located on the southeast shore near Station 6, just northeast of the Pacific Electric Railroad bridge. The Los Alamitos Naval Air Station outfall is situated between Stations 13 and 14 on the east shore, northeast of the Pacific Coast Highway. The cooling waters from the Los Angeles Bureau of Water and Power Steam Plant are emptied into the river near Station 2, close to the mouth of San Gabriel River.

CHEMICAL AND PHYSICAL DATA

Chemical and physical data are included in Tables 2 and 3. The dissolved oxygen was over 5.0 p.p.m. at all stations except 9 to 14 on May 2, 1952, and 8, 9, and 10 on July 15, 1954. All of these low dissolved oxygen stations are located above the Pacific Coast Highway bridge. The substratum at all of the stations on May 2, 1952, was a fine black mud with a petroleum odor. Stations 8, 9, and 10 on July 15, 1954, had a fine black mud layer overlying gray mud, but only at Station 8 was any odor detected, this being sulfide.

Subsurface water temperatures ranged from 18.5 to 28.0 degrees C. on May 2, 1952, and 21.0 to 28.5 degrees C. on July 15, 1954, with the warmer temperatures occurring progressively upstream. As discussed above, the highest water temperatures, not included in the tables, were encountered at the Dow Chemical Company outfall sewer, where temperatures as high as 40.0 degrees C. were measured.

TABLE 2

Chemical and Physical Data—May 2, 1952

Station Number	Time	Temperature in °C.	Dissolved oxygen in p.p.m.	Chlorinity in 0/00	pH	
					Water	Substratum
1	1515	18.5	7.0	18.9	8.3	7.85
2	1535	19.5	7.95	18.8	8.0	7.6
3	1550	19.0	8.6	18.9	7.75	7.5
4	1620	19.5	8.9	18.7	7.8	7.9
5	1635	20.0	9.1	18.8	7.5	7.2
6	1650	20.0	7.3	19.9	8.1	7.3
7	1705	22.0	7.6	18.1	6.8	7.7
8	1735	24.5	6.95	17.8	6.2	6.8
9	1755	28.0	0.5	12.9	6.65	6.9
11	1815	27.0	trace	15.8	7.95	9.5
12	1845	28.0	0.0	11.1	10.0	11.2
13	1900	28.0	0.0	8.1	12.3	12.4
14	1930	26.5	trace	7.0	5.9	3.6

TABLE 3

Chemical and Physical Data—July 15, 1954

Station number	Time	Temperature in °C.	Dissolved oxygen in p.p.m.	Chlorinity in 0/00	pH	
					Water	Substratum
1	0945	22.0	7.6	19.3	8.1	--
2	1010	28.0	7.4	19.3	8.1	7.6
3	1020	21.0	6.8	19.3	8.1	7.7
4	1030	27.5	6.8	19.5	8.1	7.5
5	1045	27.0	7.2	19.4	8.0	7.6
6	1115	27.5	7.3	19.0	8.05	7.1
7	1200	27.0	5.8	19.6	7.5	7.1
8	1305	28.0	4.4	19.5	7.3	6.9
9	1250	28.0	3.0	19.3	7.4	6.8
10	1230	28.5	0.0	18.3	7.25	6.7

Chlorinity was slightly below that of normal seawater (19.4 0/00) on May 2, 1952, at Stations 1 to 8, and the water was brackish at Stations 11 to 14, in the tributary. Only at Station 10, some 750 yards upstream from the Pacific Coast Highway, on July 15, 1954, was the chlorinity much below that of normal seawater.

The pH of the water and substratum varied considerably from station to station on May 2, 1952. Both water mass and substratum were slightly alkaline at Stations 1 to 6 and 11, and highly alkaline at Stations 12 and 13. The pH was slightly acid at Stations 8 and 9, but highly acidic at Station 14. In general, the pH of the substratum follows that of the water mass. However, exceptions were observed at Stations 7 and 14 on May 2, 1954. At Station 7 the water was slightly acid (6.8) and the substratum slightly alkaline (7.7). At Station 14 the pH of the water was acid (5.9), while that of the substratum was highly acidic (3.6). The pH of the water mass and substratum were alkaline at all stations on July 15, 1954, except for the substratum at Stations 8 to 10, which was slightly acidic.

NATURE OF THE SUBSTRATUM

The bottom on May 2, 1952, was coarse black sand at Stations 1 to 7, seaward of the Pacific Coast Highway, and black mud at Stations 8, 9, and 11 to 14, upstream from the Pacific Coast Highway bridge. The substratum possessed a sulfide odor at Stations 3 to 8 and a petroleum odor at Stations 9 and 11 to 14. No odors were detected at Stations 1 and 2, near the mouth of San Gabriel River.

The substratum at Stations 2 to 7 was of the same consistency on July 15, 1954, as on May 2, 1952. At Station 8 the bottom was black mud and sand, with a slight sulfide odor. Stations 9 and 10 had a black mud upper layer, with gray mud beneath. No sample had been taken at Station 10 on May 2, 1952. No odors were detected at Stations 2 to 7, 9, and 10 on July 15, 1954. No sample was obtained at Station 1 on July 15, 1954, despite repeated efforts.

BOTTOM FAUNA

No living bottom animals were taken on May 2, 1952, but fragments of clam and snail shells were obtained in the samples from Stations 1, 12, 13, and 14. (Stations 1 to 9 and 11 were revisited two months later, on July 2, 1952, in an attempt to determine whether or not pollution had affected the high tide horizon. At this time the intertidal surfaces of all but Station 1, located near the mouth of San Gabriel River, were covered with fine black mud having a sulfide or petroleum odor. Occasionally a thin layer of tan-colored sand overlaid the black mud. Barnacles, *Balanus* sp., were found attached to rocks of the jetty at Stations 1 to 4, and the shore-crab, *Pachygrapsus crassipes* Randall, was found

TABLE 4

Species and Number of Animals Found in the Bottom Samples Taken on July 15, 1954

Species	Station numbers										Totals
	1	2	3	4	5	6	7	8	9	10	
Sea Anemone								1			1
Turbellarian								1			1
Nemertean			1	1		3	16	16			37
Polychaetes											
*Neanthes succinea**								2			2
Polydora nuchalis							41	108	2		151
Prionospio cirrifera								5		1	6
*Capitella capitata**					2	2		231	34		269
Capitita ambiscta								105			105
Crustaceans											
Epicbalia sp.		1									1
Callianassa californiensis								1			1
Pelecypods											
Macoma nasuta								1			1
Tagelus californianus								3			3
Totals		1	1	1	2	5	57	474	36	1	578

No sample

* Indicator organisms, marginal zone (Filice, 1954).

at these same stations between the rocks. The tube-dwelling polychaete *Boccardia proboscidea* Hartman formed beds at Stations 3 and 4. Insect larvae were observed in the mud at Stations 5 to 9 and 11. Oligochaetes were associated with the insect larvae at Stations 4 and 8.)

Whereas no living animals had been found in the bottom on May 2, 1952, a total of 578 animals representing 12 species were taken during the survey on July 15, 1954 (Table 4). These included: a sea anemone, a turbellarian, a nemertean, five polychaetes, two crustaceans, and two pelecypods. Four hundred and seventy-four of the 578 specimens were taken at Station 8. The crustacean *Epinebalia* sp. was the only species of the 12 not found at Station 8, just upstream from the Pacific Coast Highway and within the area excavated by the Los Angeles Flood Control District in 1952. All except *Prionospio cirrifera* Wiren, *Epinebalia* sp., and the sea anemone have been reported from nearby Alamitos Bay (Reish and Winter, 1954). The polychaete *Capitella capitata* was found at four stations (5, 6, 8, and 9) and was the most abundant animal taken (269 specimens). Several individuals of this species were incubating eggs at the time of collection. *Capitella capitata* and *Neanthes succinea* were two of the forms used by Filice (1954) as indicators of marginal zones of pollution.

FIGURE 5. Lower San Gabriel River, looking southwest towards the Pacific Coast Highway (Alt. 101) bridge, the site of the dike during the dredging operations in the fall of 1952. Station 8 is located in the center foreground. Conduit in the left foreground connects with the tributary of the river (Figure 1, right branch). *Photograph by the author, July 7, 1954.*

DISCUSSION

The substratum of Lower San Gabriel River was completely devoid of animals at all stations sampled on May 2, 1952. At this time it was black in color, with either a sulfide or petroleum odor. Five animal species were present in the high tide horizon at some of the stations two months later (July 2, 1952).

Two years later (July 15, 1954) the substratum between the mouth and the Pacific Coast Highway was essentially the same as observed in 1952. A few animals were present within this area in 1954, but only in small numbers. At Station 8, just beyond the Pacific Coast Highway, 474 individuals representing 11 species were taken in 1954. A polychaete worm, *Capitella capitata,* was the most common species at this station. Several *C. capitata* were incubating eggs, and many young metamorphosed worms were present in the mud. This, the only species definitely established to be reproducing in the substratum of Lower San Gabriel River, was listed by Filice (1954) as an indicator species of a marginal zone of pollution. The substratum at Station 8 on July 15, 1954, was black and possessed a sulfide odor, indicating that once again pollutants were accumulating on the bottom. This accummulation was particularly noticeable in the main river channel upstream from the Pacific Coast Highway, where a fine black mud layer overlaid gray mud, which is the characteristic soil for this area.

Since none of the 12 species collected on July 15, 1954, was present in 1952, it is reasonable to assume that these animals migrated into Lower San Gabriel River. These animals are known to be typically estuarine forms. Nine of the 12 species had previously been reported from Alamitos Bay (Reish and Winter, 1954). All have planktonic stages during their early development, indicating that they could have migrated or drifted into San Gabriel River as larvae, possibly from Alamitos Bay.

ACKNOWLEDGMENTS

The field work on May 2, 1952, was done by Dr. John L. Mohr, Mr. Charles Horvath, and Mr. Howard A. Winter, University of Southern California. Mr. Parke Young, California Department of Fish and Game, assisted the author with the field work on July 15, 1954. The special surveys from shore, the laboratory analyses, and the identifications of the animals (with the exception of *Polydora nuchalis* Woodwick, which was identified by Dr. Keith H. Woodwick) were carried out by the author. The Los Angeles County Flood Control District Office supplied the data on the excavation of Lower San Gabriel River. The author wishes to express his thanks to Mr. Robert M. Paul, California Department of Fish and Game, for his assistance during the course of this study. The author is indebted to the administration of the Allan Hancock Foundation for the use of laboratory facilities. The specimens have been deposited in the Allan Hancock Foundation.

SUMMARY

1. Physical, chemical, and biological studies of the water mass and bottom of Lower San Gabriel River, California, were made on May 2, 1952, and July 15, 1954. Special surveys of the pH and temperature were made from shore on October 3, 1952, and November 20, 1952, and collections of the high tide horizon animals of part of the shore were made on July 2, 1952.

2. The substratum at Stations 3 to 9 and 11 to 14 on May 2, 1952, was black and possessed either a sulfide or petroleum odor. On July 15, 1954, the accummulation of pollutants on the bottom was particularly observable at Stations 9 and 10, but odors were noted only at Station 8.

3. No living animals were observed in the bottom of Lower San Gabriel River on May 2, 1952, although several species were found in the high tide horizon on July 2, 1952. Twelve species of marine invertebrates were collected from the bottom on July 15, 1954. The majority of these were found at Station 8, an area which was excavated in the fall of 1952 under a contract with the Los Angeles County Flood Control District. There was evidence of new deposits of pollutants forming within the area of excavation.

4. Five major sources of waste discharge into Lower San Gabriel River are discussed. The liquid wastes from the Dow Chemical Company outfall sewer were the subject of a study which showed the discharge to be warm and highly acidic. Recovery of the river water to normal levels of temperature and pH took place between 150 and 700 feet downstream from this outfall.

REFERENCES

California Department of Public Health
1952. Lower San Gabriel River pollution survey, September 1951 to May 1952. Calif. Dept. Pub. Health, Bur. Sanitary Eng. 26 p. (Hectographed.)

Filice, Francis P.
1954. An ecological survey of the Castro Creek area in San Pablo Bay. Wasmann Jour. Biol., vol. 12, no. 1, p. 1-24.

Reish, Donald J., and Howard A. Winter
1954. The ecology of Alamitos Bay, California, with special reference to pollution. Calif. Fish and Game, vol. 40, no. 2, p. 105-121.

A NEW METHOD OF ATTACHING PETERSEN DISK TAGS WITH MONOFILAMENT NYLON[1]

JOHN E. RANDALL
Department of Zoology
University of Hawaii

Several methods of tagging and marking have been attempted in the course of a life-history study of the convict surgeon fish or manini (*Acanthurus triostegus sandvicensis* Streets) in the Hawaiian Islands.[2]

The first tag tried was the Atkins tag (Rounsefell and Kask, 1945), which was fastened by tying with light nylon leader beneath the base of the posterior part of the dorsal fin. At the end of one month all captive fish tagged in this manner had lost their tags.

Next similar tags were threaded through the bony area above the urostyle at the upper base of the caudal fin. These were retained for longer periods; however, all disappeared within six months. Disappointing results with such tags were reported by Fraser (1955) for smallmouth bass.

Petersen disk tags, hand-made from cellulose nitrate, were then tried. Since, among metals commonly used to attach Petersen disk tags, stainless steel seemed most promising from a corrosion standpoint (Calhoun, Fry, and Hughes, 1951), this material was chosen for initial trials. Considerable difficulty was experienced, however, in bending the free ends of the wire on a struggling fish, a disadvantage clearly pointed out by these authors.

An attempt was next made to devise a means of using nylon without resorting to tying knots. Four important disadvantages to the use of this synthetic for tagging when knots must be tied are: knots of nylon are prone to slip; thickness of nylon must be sacrificed to obtain tight knots; a considerable length of nylon is needed for each tying, much of which must be discarded; knot tying is very time consuming in an operation that demands dispatch.

The idea came to mind to melt each free end of the nylon into a little ball. This method proved successful, although there has not been sufficient time to permit any claims of exceptionally long periods of tag retention.

A flame is necessary to obtain sufficient heat to melt the nylon. Heat from a very hot or even glowing object (such as a soldering iron, punk, or cigarette) does not melt the nylon rapidly enough unless the heat-producing object contacts the material. Contact often results in the sticking of the molten nylon to the object.

[1] Submitted for publication March, 1955. Contribution No. 68 from the Hawaii Marine Laboratory in cooperation with the Department of Zoology and Entomology, University of Hawaii.

[2] This species does not occur in Californian waters. However, methods used on one species are often applicable to others, which may be far removed both geographically and by relationship. The findings contained in this article may therefore be expected to be of significance to fisheries workers both in California and elsewhere. —*Editor.*

The best flame-producing device found to date for tagging is the Ronson Windlite cigarette lighter. The perforated collar at the top of this lighter is more restricted than that of other windproof lighters, and the flame does not flicker as badly in the wind. Jet pipe lighters were tried, but these blew out too readily. A small acetylene torch has been used with success, but is not as convenient as a lighter.

The diameter of the monofilament nylon used measures 0.035 inches. This is sufficiently heavy to avoid the necessity of threading the strand through the back of the fish with a needle. One end of the nylon is melted into a ball and the first disk threaded in place. A dissecting needle is run through the back of the fish below the center of the dorsal fin just above the vertebral column. The dissecting needle should be drawn back and forth several times to clear the hole. The remaining free end of the nylon, which is cut on an angle to form a point, is inserted through the hole, and the second disk put in place. The flame is first used to cut off any excess length of nylon (thus eliminating the need for some cutting instrument such as scissors) and then to melt the end into a knob. The second disk serves as a natural shield against burning the epidermis of the fish during the melting process. The molten nylon requires about 10 seconds to set hard in air. If a fish is released before the nylon sets, the tags may be lost due to sudden flexure of the body of the fish. Setting may be hastened by immersing the newly-tagged fish in a bucket of sea-water while holding the second disk against the side of the body; however, this causes a further loss of tensile strength of the nylon (see below). It is important that a good-sized knob be formed, preferably two to three times the diameter of the nylon filament. If only slightly larger than the hole in the disk, the knob may be forced through the hole. Also, allowance should be made for possible attrition of the knob against rocks or coral. In order to provide for growth, space is left between each knob and adjacent disk. Approximately 3 mm. is needed on each side for growth of small adult manini (which are about 100 to 110 mm. in standard length). Surgeon fishes have compressed bodies (maximum width contained about 1.7 times in head length) and lend themselves well to Petersen disk tagging.

A concrete tank at the Hawaii Marine Laboratory, which measures 34.7 feet by 10.8 feet and is an average 3.9 feet in depth, was made available for testing this method of attaching disk tags to manini. This fish grazes constantly during the day on filamentous algae. In view of the limited amount of substrate for algal growth, only 10 fish were placed in the tank. These ranged from 70 to 96 mm. in standard length. On August 6, 1953, four were tagged, three by using a monofilament nylon and one by stainless steel wire. Seven weeks later all of the fish were caught and measured. The six untagged fish, which had a mean standard length of 86.3 mm., had grown an average of 6.6 mm. The three tagged with nylon (mean standard length 84.4 mm.) grew an average of 7.7 mm. The 93 mm. fish whose disks were attached with stainless steel wire added a smaller increment of growth than any of the other fish, only 2.5 mm. Although these data are insufficient for definite conclusions, it seems apparent that surgeon fish tagged with Petersen disk tags fastened with monofilament nylon are capable of normal growth.

Heavy mortality of captive fish ensued during winter months, possibly because of turbid water following storms or lack of algae in the tank. One of the fish which survived 11 months, until July, when the tank was needed for other purposes, still retained its nylon fastened disks. It was noted that the flesh around the hole pierced by the nylon strand was almost in contact with the nylon. There was no evidence of deterioration of the nylon.

Before the Ronson Windlite lighter was used for tagging, working with a flame was troublesome in waters off Oahu exposed to the strong winds of the Kaiwi Channel (Molokai Channel). Personnel of the Division of Fish and Game, Territory of Hawaii, upon the suggestion of Mr. Kenji Ego, resorted to crimping brass (bronze would probably be superior to brass) or stainless steel leader sleeve on the free ends. Such tags have held on field-tagged fish as long as six months. It would seem that corrosion of the metal would not be as serious at the ends of the nylon as it would be if it passed through the back of the fish, since the metal is not subject to stresses of bending or twisting at the former location. Nevertheless, given enough time, corrosion may result in a loosening of the metal tab from the nylon.

Tests were run to compare the strength of monofilament nylon when knotted, when a metal sleeve was crimped at the ends, and when the ends were melted into knobs. Nylon of 0.035-inch diameter (rated 60-pound test) was used. When knotted with two half hitches, the nylon broke at the knot under the stress of 24 to 26 pounds dead weight. When a one-eighth-inch length of brass leader sleeve, one-sixteenth inch in outside diameter, was strongly crimped at the ends, the nylon pulled out of the metal sleeves at forces of from 16.60 to 21.58 pounds dead weight (five trials). When the ends of a nylon filament were melted to 2-mm. knobs which were allowed to set in air, 9.08 to 11.23 pounds of dead weight caused breakage at the base of a knob (five trials). When tests of tensile strength were made on nylon with knobs which had been cooled in water immediately upon being formed by melting, the breaking occurred under a strain of about half this weight.

Although it is evident that a considerable loss of strength occurs from heating, it should be emphasized that the strength of the nylon which passes through the body of the fish and the holes in the disks is unimpaired. As long as growth pressure is not brought to bear against the disks, it is unlikely that a force of 10 pounds could be experienced against a knob on a fish which does not exceed a half pound in weight. Also, the nylon would probably tear through the flesh of a surgeon fish before such a force could be exerted. However, should greater strength be desired, heavier nylon could be used. Heavier plastic disks would then become necessary as well. A force of 17.6 pounds was sufficient to cause cracking at the hole in the center of a 0.036-inch thick cellulose acetate disk when it was supported from the peripheral one-sixteenth inch of its one-half-inch diameter surface.

Since the experimental work demonstrated no obvious fault in the method, field tagging was begun. Vernon E. Brock, Yoshio Yamaguchi, and Carl M. Nemoto of the Division of Fish and Game, Territory of Hawaii, provided valuable assistance in tagging operations.

FIGURE 1. Petersen disk tag used in tagging surgeon fish in the Hawaiian Islands. The ends of the monofilament nylon connecting the two disks have been melted into knobs. The heating caused a blackening of the one knob which is visible.

The disks (Figure 1) are laminated cellulose acetate (the manufacturer much preferred to work with this material rather than cellulose nitrate because of the fire hazard associated with the latter), 0.036 inches in thickness at the center and 0.045 inches at the edge, and one-half inch in diameter. The 0.035-inch monofilament nylon fits snugly in the hole in the center of each disk. As may be noted, the tag number appears on the inside of the disks. This is advantageous, since in Hawaiian waters algae cover the outside of the tag after immersion of a month or more, but do not accumulate on the inside. Some of the algae are calcareous and difficult to remove.

Most of the fish have been tagged from commercial trapfishing vessels operating from Kewalo Basin, Honolulu. Since July 6, 1954, when extensive tagging began, a total of 1,202 manini have been tagged, and to date there have been 265 recoveries. Some fish have been recovered which had been at liberty for six and one-half months. Most of the tagged fish have been taken in traps and are brought to port alive in wells on the vessels. This has afforded an opportunity for re-release. Twenty-three tagged fish have been caught a second time, and three of these have been taken a third time.

The tagging wounds of most of the recovered fish are small, rarely exceeding 2 mm. in diameter. When the wounds are larger, the fish generally show evidence of long sojourn in traps: bacterial and fungus infections which cause eroding of the fins, and raw, abraded areas on the snout and forehead. No tags were seen in the process of migrating up through the back of the fish.

It is believed that monofilament nylon, when used without knotting, will prove to be superior to metal pins or wire for attaching Petersen disk tags to fish. Nylon appears to have the following distinct advantages over metal in general: no obvious deterioration due to corrosion or galvanic action, nontoxicity, and greater flexibility and softness.

REFERENCES

Calhoun, A. J.
1953. Aquarium tests of tags on striped bass. Calif. Fish and Game, vol. 39, no. 2, p. 209-218.

Calhoun, A. J., D. H. Fry, Jr., and E. P. Hughes
1951. Plastic deterioration and metal corrosion in Petersen disk fish tags. Calif. Fish and Game, vol. 37, no. 3, p. 301-314.

Forrester, C. R., and K. S. Ketchen
1955. The resistance to salt water corrosion of various types of metal wire used in the tagging of flatfish. Fish. Res. Bd. Canada, Jour., vol. 12, no. 1, p. 134-142.

Fraser, J. M.
1955. The smallmouth bass fishery of South Bay, Lake Huron. Fish. Res. Bd. Canada, Jour., vol. 12, no. 1, p. 147-177.

Rounsefell, G. A., and J. L. Kask
1945. How to mark fish. Amer. Fish. Soc., Trans., vol. 73, p. 320-363.

Skinner, J. E., and A. J. Calhoun
1954. Field tests of stainless steel and tantalum wire with disk tags on striped bass. Calif. Fish and Game, vol. 40, no. 3, p. 323-328.

Young, P. H., J. W. Schott, and R. D. Collyer
1953. The use of monofilament nylon for attaching Petersen disk fish tags. Calif. Fish and Game, vol. 39, no. 4, p. 445-462.

REARING LARVAL SCOMBRID FISHES IN SHIPBOARD AQUARIA[1]

HAROLD B. CLEMENS
Marine Fisheries Branch
California Department of Fish and Game

INTRODUCTION

The scombrid group of fishes includes many species which are of considerable economic importance and several others which have an untapped economic potential. The Eastern Pacific fishery for yellowfin tuna, *Neothunnus macropterus*, and oceanic skipjack, *Katsuwonus pelamis*, for example, represents one of the most valuable marine resources of modern times. Each year this fishery brings new wealth to the State of California and provides gainful employment for many thousands of individuals.

This fishery and the fish supporting it are being studied by several governmental agencies in an effort to develop methods and techniques to maintain the fishery so as to provide the highest possible economic yield. Such studies require detailed information about the biology of the fishes throughout their entire lives. Extremely little is known about the distribution, growth, and behavior of larval and postlarval scombrids, and methods to obtain this much needed information are still in developmental stages.

Since 1950, the author has had an opportunity to gain information on the young stages of scombrid life history. On various cruises off Central and South America and the Galapagos Islands, several months of each year have been devoted to studies of tunas and their close relatives. During each cruise an attempt has been made to estimate the magnitude of spawning areas by obtaining larval specimens.

Extensive collections of recently hatched scombrids from the waters of Central America resulted in plans for an attempt to rear them in aquaria during a scheduled cruise of the N. B. Scofield in January and February, 1955, in the belief that a successful effort would offer an opportunity to observe the behavior of the postlarval fish and to learn something about their growth rates.

This paper presents the results of the initial attempt to rear young tuna-like fishes in aquaria and describes the techniques developed. It is hoped that these preliminary experiments will furnish a basis for further experiments by fisheries biologists and eventually will enable them to raise these fast-swimming fishes to considerable size and age.

[1] Submitted for publication August, 1955.

EQUIPMENT USED

The two aquaria used in this experiment measured $36\frac{3}{4} \times 24 \times 17$ inches and were solidly constructed, on three sides and the bottom, of two-inch by eight-inch redwood slabs. One side was enclosed with one-half-inch plate glass to serve as an observation window. A piece of one-quarter-inch marine plywood was secured across the top to prevent water and fish from splashing out in rough weather. Specimens were put in the tank through a nine-inch-square hole cut in the plywood top. Each aquarium was supplied with constantly circulating sea water, which entered at the bottom through a one-quarter-inch hose and drained from an overflow pipe near the top. A 100-watt bulb was suspended above the opening in each tank and left burning at night, enabling the fish to see and thus avoid the aquarium sides. Other equipment included: a small glass aquarium $20 \times 10 \times 14$ inches; a standard, long-handled dipnet with three-millimeter mesh in the bag; an eight-inch, square, short-handled dipnet with three-millimeter mesh; and a night light consisting of a 1,500-watt bulb, plus reflector.

COLLECTING METHOD

At night, when the vessel was drifting or anchored in an area known to have produced postlarval scombrids, the night light was suspended over the stern approximately three feet above the water. Various small fishes attracted to the surface by this light were easily captured with the long-handled dipnet. The net contents were then carefully emptied into the small glass aquarium, which had been half filled with fresh sea water and conveniently located on the stern of the N. B. Scofield. All of the fish captured in each dipnet sweep could then be clearly observed with the aid of a 150-watt bulb located on the opposite side of the aquarium.

The larval scombrids of paramount interest, yellowfin tuna and oceanic skipjack, are difficult to distinguish, by such gross observation, from several closely related species. The delicate nature of larval scombrids precludes a careful microscopic examination; however, separation of yellowfin tuna and black skipjack (*Euthynnus*) from other scombrid larvae can be accomplished with little chance for error. According to Schaefer and Marr (1947) and Mead (1951) only the larvae of yellowfin tuna and black skipjack have a solidly pigmented spinous dorsal fin. Although it has been found that larval bonito (*Sarda*) also have a solidly pigmented first doral fin, they can be distinguished from both *Euthynnus* and *Neothunnus* by their black ventral fins. For the purpose of this experiment it was felt that either black skipjack or yellowfin tuna would serve equally satisfactorily. As a result, one had only to look for a tuna-like larva with a black first dorsal and clear ventrals. When such a fish was recognized it was recaptured with a small dipnet, immediately placed in a wide-mouth gallon jar filled with fresh sea water, and then quickly transferred into one of the large aquaria. The remaining fish were removed from the glass aquarium, and either preserved or placed in the other large aquarium. The gallon jar was refilled and the process repeated.

Several precautions were necessary: only one sweep of the dipnet could be made at a time, since the pressure of too many fish in the net

resulted in fatal injuries. The cupped palm of one hand was placed on the bottom of the bag when depositing each dipnet full of fish into the small aquarium. The bag could then be deftly flipped wrong side out and the specimens gently washed into the water, thus insuring that the opercular spines on small scombrids were not entangled in the mesh —a fatal mishap. Other unrelated species were not placed in the same tank, for very little is known concerning the predaceous habits of immature fishes. In all operations maximum speed and care were used, and a minimum of handling employed. Even though extreme caution was exercised, only one-third of the larvae captured survived longer than 24 hours.

FIRST FIELD TRIAL

During the evening of January 20th, at latitude 12° 34′ N., longitude 89° 50′ W., between 6 p.m. and 12.30 a.m. approximately 280 separate dipnet sweeps produced eight scombrid larvae with black first dorsals and clear ventrals averaging one inch in total length. After having been gently washed from the net into the glass aquarium, two of these "tuna" swam about at great speed in a very erratic manner, repeatedly bumping their noses on the sides and bottom of the tank. Death resulted in a very short time (similar behavior has been noted in adult tuna; some lie quietly after being caught while others maintain a powerful frantic vibration until their gills hemorrhage, with death resulting). The remaining six small "tuna" showed no unusual behavior and were placed in the large aquarium. Unfortunately, three died within 24 hours, probably as a result of injuries received during capture.

The three remaining fish swam aimlessly about the large aquarium, making no effort to school, and refused various kinds of food offered throughout the day and night. The food offered included: living planktonic organisms, ground flesh of anchovetas (*Cetengraulis mysticetus*), yellowfin tuna, oceanic skipjack, and dolphinfish (*Coryphaena hippurus*), particles of coagulated fish blood, and dolphinfish eggs. These "tuna" showed only mild interest in each type of nonliving food offered, but paid particular attention to several of the fast-swimming planktonic organisms. It is thought that they were unable to recognize the particles offered as being edible.

A heavy sea during the following two days caused water to splash around in the aquarium and the three larvae had a difficult time avoiding the sides. By the morning of January 23d it was obvious that they were starving: their bodies had become shriveled and emaciated, causing their heads to appear greatly enlarged. That afternoon at 2 p.m. all three specimens were dead. The battering they received in the aquarium, as a result of the rough weather, probably hastened death by 24 hours.

In contrast, the postlarvae of several other species, captured at the same time as the "tuna" and placed in the other large aquarium, were doing nicely. This group, including dolphinfish (*Coryphaena*), jacks (*Caranx*), frigate mackerel (*Auxis*), pompano (*Trachinotus*), threadfins (*Polydactylus*), and pomacentrids (*Chromis*), readily consumed dolphinfish eggs and all kinds of ground fish flesh. The jacks, pompano, and threadfins voraciously devoured not only the larger pieces of food,

but also a number of smaller fish that were in the way during the feeding excitement.

After observing the other fishes feeding for several minutes, the pomacentrids "got the idea" and started feeding heavily on bite-sized dolphinfish eggs and smaller pieces of flesh. Frigate mackerel and dolphinfish, however, refused food until the second day, at which time they started to compete with the other fishes for choice bits, thus suggesting they they had learned to eat this unnatural food by watching the others.

Competition appeared to be of fundamental importance. In a tank with a large number of fish that splashed about at a high rate of speed and voraciously struck at everything in sight, frigate mackerel commenced to feed. On the other hand, the three larval "tuna", close relatives of the frigate mackerel, in an aquarium lacking both numbers of fish and excited feeding activities, could not be induced to feed.

The assorted larvae were fed every six or seven hours and all excess food was regularly siphoned off the bottom to prevent spoilage.

SECOND FIELD TRIAL

During the morning of January 24th at latitude 08° 43′ N., longitude 84° 11′ W., between midnight and 3 a.m. 95 dipnet sweeps produced 34 postlarval "tuna" of approximately the same lengths as those previously captured. Thirteen of these died immediately, after frenzied, erratic behavior, and 10 more died within 24 hours, presumably as a result of injuries received in handling. The remaining 11 swam around the aquarium counterclockwise in a compact school.

Feeding experiments were started immediately, but as in the first experiment the various types of food offered were refused. When several particles of a mixture of ground fish flesh and dolphinfish eggs were dropped into the aquarium, four or five fish would leave the school and dart up to investigate, only to regroup almost immediately. All would then ignore the food as it settled to the bottom.

An attempt to excite them into striking at offered food by splashing the surface of the water with one hand, while dropping in food with the other, almost succeeded. The entire school broke up and each individual investigated food particles. However, within several seconds all regrouped without having fed. They were unquestionably hungry and easily excited but appeared unable to recognize the small particles as food.

When living zooplanktonic organisms were dropped into the aquarium the school again broke up and individuals darted to the surface and struck at the wildly swimming plankton. Each "tuna", after taking one of these tiny creatures into its mouth, would immediately spit it out. Removal and examination with a microscope of some of these planktonic organisms revealed the presence of many tiny, hook-like appendages on their bodies. These hooks apparently effectively discouraged predators. The "tuna" remained curious, however, and did not reschool until all the plankton had been removed. These feeding attempts indicated that actively swimming food organisms of a suitable size were preferred.

After failing to entice the fish to eat during the first day and most of the night, a new approach was tried. This entailed transferring one specimen into the other aquarium, where it could watch the feeding of other species of postlarval fishes. It was thought that as a result it would learn to eat ground fish flesh, as appeared to be the case with frigate mackerel. After one "tuna" had learned to feed it could be returned and others removed for training. If four or five could thus be conditioned to a new diet, the remaining school would soon learn from their trained companions.

This experiment was doomed to failure a split second after transfer of the largest and healthiest of the precious "tuna". With one gulp a two and one-half inch long dolphinfish swallowed all but the tail of the "tuna". All efforts to retrieve the "tuna" were of no avail. The well-trained dolphinfish hung on tenaciously and eventually even the tail disappeared. It had not been anticipated that a one-inch "tuna" would be swallowed by a two and one-half inch dolphinfish.

At 9 p.m. the evening of January 25th many larval blennies approximately one-half inch long were captured under the night light. After splashing the water in the aquarium to excite the "tuna" a few live blennies were poured in. The "tuna" immediately struck at this fast-swimming bait and in a matter of seconds none was left. Each fish consumed approximately 12 blennies before being satisfied. Their stomachs, visible through transparent body walls, were so distended that the circumference of the fish was doubled. An increase in stomach length comprising one-half the total fish length was also apparent. Each "tuna" visibly increased in length and girth while feeding, apparently a result of stretching at vertebral joints and other nonossified spots.

The next day, January 26th, some adult oceanic skipjack were caught on trolling lines. One was a ripe female and an attempt was made to feed eggs from the ovaries of this fish to the young "tuna". Small egg clusters were dropped into the aquarium, along with several blennies which had been kept alive in a gallon jar. The larvae, excited by the splashing water and fast-swimming blennies, struck skipjack eggs as readily as living bait. When no more blennies remained, splashing the water surface with the hands while dropping in small egg clusters thoroughly excited the "tuna" and they struck voraciously at the eggs, gorging themselves on this food.

Several feeding periods later, when the young "tuna" were well conditioned to an egg diet, ground fish flesh was added. Both kinds of food were indiscriminately consumed, so the egg portion of the diet was slowly decreased. By the morning of January 27th, all "tuna" were eating ground flesh exclusively. Next, the time interval between feeding periods was adjusted by observing stomach size. As soon as the greatly enlarged, just-fed stomachs took on a more normal shape, the fish were fed again. Thus, feeding took place every five or six hours on the average.

All excess food was immediately siphoned off the aquarium bottom. "Tuna" were never observed feeding on the bottom; they preferred to dart to the surface and strike as soon as food was introduced. When feeding was finished, they schooled and continued circling the aquarium at speeds up to 10 inches per second.

FIGURE 1. Aquarium-reared *Euthynnus lineatus*, illustrating growth. Standard lengths (top to bottom) are 25.5, 48.0, 55.0, and 65.0 mm., respectively. Hours of growth for these fish were 0, 173, 197, and 246. *Photograph by Jack Schott.*

Experiments conducted during the next few days revealed that small pieces of fish larvae were preferred. Various species of larvae were present in abundance at night light stations and were easily collected for freezing. At feeding time several food items were thawed, cut vertically into one-eighth-inch wide strips with a pair of scissors, and fed to the fast-biting school.

Although growth in an aquarium is probably different from that in nature, the growth increment of these juveniles was nevertheless of special interest. An increase in swimming speed was correlated with rapid size increase, and after 170 hours of growth they were swimming at speeds up to 20 inches per second. At this point it was obvious that

if size and swimming speed continued to increase at such a rapid rate, the aquarium would soon be inadequate. Subsequent events proved this to be the case, for on February 1st they started dying and by February 5th, 12 days after their capture, all were dead.

The amount of dissolved oxygen present in the water at the beginning of the experiment was apparently adequate, even though food intake was high. With an increase in size and food consumption, however, oxygen demand undoubtedly became greater, as reflected by the increase in swimming speed. During the last two days of the experiment, food consumption dropped off and swimming speed increased to an estimated 25 inches per second. A slightly larger aquarium with a constant artificial oxygen supply and greater water volume circulation would have provided better conditions.

SPECIES IDENTIFICATION

Subsequent laboratory analysis revealed that the "tuna" used in the second field trial belong to the genus *Euthynnus* (Figure 1). Since the locality of capture was off Central America, these specimens are most probably *E. lineatus*. According to Godsil (1954), the species definition must be based on positive skeletal differences. One of the larger specimens was cleared and stained and the presence of 37 vertebrae further substantiated this identification. A second of the larger specimens, 59.0 mm. in standard length, was dissected to expose a ventral view of the viscera. This dissection revealed the position of the liver, caecal mass, intestine, and stomach to be almost identical to that found by Godsil (1954) in adult *E. lineatus*.

GROWTH OBSERVATIONS

Information on time of death for each fish was recorded to the nearest hour and all specimens were immediately preserved in formalin. Subsequent analysis described the increases in length and weight (Tables 1 and 2). Because all food offered was refused until 42 hours after capture, the total hours during which growth occurred was computed from the time feeding started. The measurement commonly used for adults is fork length, so this measurement was also taken on the postlarvae; however, difficulties were encountered because of imperfectly developed caudal fins. As a result, standard length measurements are probably more accurate and have been used in all calculations.

TABLE 1

Growth of Postlarval Euthynnus lineatus, Second Field Trial

Number of fish	Hours*		Standard length, mm.		Fork length, mm.		Weight, gms.	
	Range	Average	Range	Average	Range	Average	Range	Average
23	0	0	17.0–37.5	26.8	18.5–40.0	28.3	0.10–0.57	0.29
3	171–175	173	48.0–52.0	49.3	51.0–55.0	52.0	1.51–1.91	1.70
3	194–200	197	54.0–55.0	54.3	58.0	58.0	1.91–2.37	2.11
4	244–248	246	59.0–71.5	63.6	63.0–75.0	67.5	2.61–4.72	3.46

* Hours of growth computed from time fish started feeding, 42 hours after capture

TABLE 2

Measurements and Weights of Postlarval Scombrids

Euthynnus lineatus (Second field trial)			*Scomberomorus sierra*
Standard length, mm.	Fork length, mm.	Total weight, gms.	Standard length, mm.
Fish that died soon (within 24 hrs.) after capture			
17.0	18.5	0.10	12.0
17.5	19.0	0.10	12.5
20.0	21.0	0.12	12.5
20.5	22.0	0.13	13.0
21.5	22.5	0.15	13.5
23.0	24.0	0.21	13.5
24.5	26.0	0.15	14.0
24.5	26.5	0.22	14.0
25.0	26.5	0.22	15.5
25.0	26.5	0.24	†16.5
*25.5	27.0	0.18	17.5
25.5	27.0	0.25	22.0
26.5	28.0	0.25	
27.0	28.0	0.26	
28.0	29.5	0.31	
28.0	30.0	0.30	
30.0	31.0	0.44	
31.0	32.0	0.38	
32.0	33.0	0.42	
34.5	36.0	0.56	
35.0	37.0	0.57	
37.0	39.0	0.60	
37.5	40.0	0.57	
173 hours of growth			
*48.0	51.0	1.51	
48.0	50.0	1.67	
52.0	55.0	1.91	
197 hours of growth			
54.0	58.0	2.37	
54.0	58.0	2.10	
*55.0	58.0	1.94	
246 hours of growth			
59.0	63.0	2.61	
59.0	63.0	2.74	
*65.0	69.0	3.75	
71.5	75.0	4.72	
319 hours of growth			
			†54.0
			47.5

* Photograph (Figure 1).
† Photograph (Figure 2).

Twenty-three of 34 fish captured for the second trial died within 24 hours, 10 from handling injuries and 13 because of their erratic natures. One specimen, not included in Table 1, mysteriously broke its upper jaw a day after capture. It was unable to feed actively, but survived in a stunted condition for 133 hours, at which time its standard length was 34.0 mm. and its weight 0.44 grams. Three fish survived an average of 173 hours. Their average standard length was 49.3 mm. and their weight 1.70 grams. Weight had increased approximately five times in seven days. Three of the remaining seven survived for 197 hours. These had an average standard length of 54.3 mm. and a weight of 2.14 grams. Weight had increased six times in eight days. The four fish which grew for a total of 246 hours averaged 63.6 mm. in standard length and 3.46 grams in weight. Weight had increased 11 times in 10 days. During the entire 10-day period, length had increased approximately 1.4 times.

The growth data in Tables 1 and 2 probably more nearly represent a minimum in nature. More than half the total observed weight increase occurred during the last three days, during two of which the fish apparently suffered from lack of oxygen and food consumption dropped off.

SCHOOLING AND SWIMMING OBSERVATIONS

Specimens of *Euthynnus*, of the size captured, have never been observed by the author schooled in the ocean under a night light, but as soon as four or more were placed in an aquarium under a light, they formed a tight, orderly school. Apparently, if sufficient numbers congregate and are strong enough to remain grouped, a school will be formed. In the confines of an aquarium, in which strong water movements and large areas are not involved, it is relatively easy for these juveniles to school. Bullis (1955) reported schooling behavior of *E. alletteratus* under a night light in the offshore waters of the Gulf of Mexico. He noted two separate schools of approximately 200 fish each, ranging in size from 20 to 31 mm., fork length. *Euthynnus* larger than 45 mm. in standard length do not appear near the surface under a night light but are sometimes found in stomachs of larger predators, such as yellowfin tuna and rainbow runners, *Elagatis bipinnulatus*, captured on hook and line during daylight hours.

Swimming was accomplished by a quivering of the body between the insertion of the first dorsal fin and the tip of the caudal fin. One might best describe these motions by saying that the entire body behind the operele is a single, quivering, locomotive appendage which serves to push the head through the water. By comparison, young dolphinfish swam with an undulating motion of the trunk and tail. *Euthynnus* larvae swam constantly during both day and night—never resting. Periodically one fish would leave the school, examine a small particle, and rejoin immediately to continue on a tireless circuit. The first dorsal fin lay in a groove in the back while swimming, resulting in a streamlined appearance. When a fish became excited or slowed down to examine food particles, the first dorsal fin was erected. There was no evidence of a school leader; all fish changed position by frequent regrouping. There was, however, a slight tendency for larger fish to stay at the head of the school.

OBSERVATIONS ON *AUXIS* AND *SCOMBEROMORUS* LARVAE

The larval scombrids most frequently captured under a night light in the tropical eastern Pacific are frigate mackerel. These fish, sometimes called "bullets" by tuna fishermen, are more numerous and widely distributed than *Euthynnus* larvae. In areas where larvae of both frigate mackerel and *Euthynnus* occur, in the samples taken under the light the former outnumber the latter by an estimated 300 to 1.

During the evening of January 20th, five postlarval *Auxis* were placed in the aquarium for observation. Three died several hours later from injuries received in handling. Two, 20 and 30 mm. in total length, survived for six days. The larger of the two leaped out of the aquarium one evening and was badly decomposed when discovered the next day. It had grown an estimated 46 mm. during the six days. The remaining specimen was fatally wounded by a 35-mm., transparent, larval blenny that darted up from the bottom of the tank and bit out a chunk of flesh immediately posterior to the second dorsal fin. This frigate mackerel had grown approximately 40 mm. during its six days in captivity. These measurements indicate a more rapid rate of growth for *Auxis* than for *Euthynnus*.

During the evening of February 5th, at latitude 08° 06′ N., longitude 79° 06′ W., 14 postlarval sierra mackerel, *Scomberomorus sierra*, ranging from 12 to 22 mm. (average 15 mm.) in standard length, were placed in the aquarium. Five died several hours later from handling injuries, and seven starved to death within a few days. Two, however, survived for 13 days, during which they grew approximately 36 mm. (Table 2 and Figure 2).

FIGURE 2. Postlarval *Scomberomorus sierra*, illustrating growth during 13 days of captivity. These fish are, respectively, 16.5 and 54.0 mm. in standard length. *Photograph by Jack Schott.*

ACKNOWLEDGMENTS

Many individuals cooperated wholeheartedly in making this experiment possible. I would like to extend my thanks and appreciation to Messrs. Kenneth Norris and Jack Schott for the loan of aquaria; to the captain and hardworking crew of the N. B. Scofield for assisting with night light collecting, and especially to the engineers, who also maintained the aquaria in good working order; to Mr. Lee Tebo, who assisted me and shouldered the lion's share of the work during the last half of the cruise; and to Mr. Michael Angot, a visiting biologist from France, who was always willing to lend a hand in all operations.

REFERENCES

Bullis, Harvey R., Jr.
1955. Observation on schooling juvenile tuna, *Euthynnus alletteratus*, in the Gulf of Mexico. Copeia, no. 2, p. 153.

Godsil, H. C.
1954. A descriptive study of certain tuna-like fishes. Calif. Dept. Fish and Game, Fish Bull. 97, 185 p.

Mead, Giles W.
1951. Postlarval *Neothunnus macropterus*, *Auxis thazard* and *Euthynnus lineatus* from the Pacific coast of Central America. U. S. Fish and Wildl. Serv., Fish Bull., vol. 52, no. 63, p. 121-127.

Schaefer, Milner B., and John C. Marr
1948. Contributions to the biology of the Pacific tunas. U. S. Fish and Wildl. Serv., Fish Bull., vol. 51, no. 44, p. 187-206.

NOTE

BLUE-WINGED TEAL IN DEL NORTE COUNTY, CALIFORNIA

In reviewing the literature, we find no record of blue-winged teal (*Anas discors*) in the extreme northwestern corner of California. The northwesternmost observation of this species in California is one reported two and one-half miles north of Arcata, Humboldt County (Clay, 1939).

Wooten, while conducting a survey of nesting waterfowl in the vicinity of lakes Earl and Talawa, Del Norte County, on May 14, 1953, observed a female teal with a brood of at least five young on a small pond on the Talawa Gun Club approximately one mile north of the channel connecting the two lakes. In the same pond a male blue-winged teal in breeding plumage was flushed; the bird circled the area and refused to leave. Wooten assumed that the female teal was the mate to the male, and therefore represented a breeding record for blue-winged teal in this coastal area.

On June 10, 1954, the authors visited the same area, and a blue-winged teal male in breeding plumage was flushed from the small 2-acre pond on which Wooten had seen blue-winged teal the year before. This male demonstrated behaviorism similar to blue-winged teal flushed by the senior author from breeding areas in the small ponds of the channeled scablands of eastern Washington. We were unable to flush a female, but the male continued to return to this pond after being flushed. Another male blue-winged teal (or possibly the same bird) was seen on Lake Talawa the same day.

The pond on which the birds were seen is very shallow, but permanent. American three-square bulrush (*Scirpus americanus*) and rush (*Juncus*) were the dominant plants that extended to the open water. Rush, sedge (*Carex* sp.), and forbs constituted the major plants in the zone that extends to higher ground, where grasses dominated. Small willow trees bordered the pond on the east side and yellow water lily (*Nymphaea polysepala*) grew in the deeper water. Sand dunes stabilized with grasses extend westward to the ocean. Cattle utilize this grassland.

In many respects this area is similar to those used by nesting blue-winged teal observed in eastern Washington.

On June 7, 1955, the area was visited again, but no blue-winged teal were seen. There are several potholes in this area, however, so we could have missed flushing the birds. Water levels were very low this spring, in contrast with the other two years.

REFERENCE

Clay, C. I.
1939. White-throated sparrow coincidence and other notes. Condor, vol. 41, no. 3, p. 121.

Charles F. Yocom, Humboldt State College, Arcata, and William A. Wooten, formerly Game Management Agent, Eureka, California, September, 1955.

REVIEWS

Conserving Naturol Resources: Principles and Practice in a Democracy

By Shirley W. Allen; McGraw-Hill Book Company, Inc., New York, 1955; ix + 347 p., 169 figs. $5.50.

The title of this book implies that there is a difference between a democracy and other forms of government in the methods used in the conservation of natural resources. The democratic way is described as being somewhere between the cutout and get out policy of the old lumber barons and the Tennessee Valley Authority. The general tone of the book is, however, conservative and indicates that the preferable approach is that of private exploitation.

This is a text book—a good one, but not any better than many others. It is written by a distinguished individual, which gives it some additional weight. If you are a teacher, then you will be quite interested in reading it and possibly, depending upon your approach, using it as a text. If you are a student using it as a text, you will probably sell it when the course is over.

The whole field of natural resources is covered in a rather unimaginative but certainly adequate fashion. A total of 169 illustrations is used, most of them being photographs. Again, they are adequate, but not imaginative. The problem appears to be one of format. Here is a great teacher writing from years of experience but somehow missing the idea that a book, particularly an introduction to a field as important as this, should inspire, not bore, students.

There are seven chapters, including an excellent Introduction and a thought-provoking chapter on Human Powers as Natural Resources. The others cover the fields of Soil Conservation; Water; Forests, Grazing and Recreation; Wild-animal Resources (including fish); and Mineral Resources.

The quality of this book is of the highest in physical materials, such as binding and paper, as well as in intellectual materials. The feeling persists, however, that as an introductory text it would be very ably resisted by students.—*J. Bruce Kimsey, California Department of Fish and Game.*

Soil

By G. V. Jacks; Philosophical Library, New York, 1954; ix + 221 p.; 10 pls. $5.

The preface of this little book states its purpose as being that of giving interested persons an insight into the new science of soil management. This it proceeds to do in a most informal, brief, and interesting manner. For instance, such an extensive subject as soil chemistry is disposed of in about 22 well written, straightforward, pages. The only prerequisite to understanding is relaxed interest and perhaps high school chemistry.

It is written and printed in Great Britain. Because of this, many examples will be rather obscure to American readers, since they are largely drawn from European sources. The principles, however, are the same and, in a few instances, North American situations are used for illustration. A pertinent bibliography of 60 citations is included. Many of the references are not readily available to American readers, however.

In the chapter on soil erosion the interesting idea is offered that soil erosion may be regarded by posterity as one of the greatest blessings European civilization has given the world. Out of context this appears ridiculous, but the reason for the remark is quite sensible. Agricultural revolutions tend to be long, drawn out affairs and they need powerful stimuli to set them in motion. Soil erosion has been such a stimulus.

This reviewer recommends this book to anyone with an interest in soil conservation, providing they understand that it is an erudite introduction to the science written for the educated layman—and not a technical handbook.

In comparison with books of a similar material quality, the cost of this volume appears to be somewhat high.—*J. Bruce Kimsey, California Department of Fish and Game.*

Aspects of Deep Sea Biology

By N. B. Marshall; Philosophical Library, Inc., New York, 1954; 380 p., 103 figs. + 5 col. plates; illustrated by Olga Marshall. $10.

Here is a book that is interesting and very worthwhile for both the student and the practicing fisheries worker. Those of us engaged in marine research know only too well the inadequacy of man's current knowledge of the physical and biological aspects of the ocean depths. However, each day brings new discoveries, and if we consider the relatively short time which has elapsed since the first studies of deep sea biology were made and realize the great technical problems involved, it is obvious that we have come a long way in our understanding of the deep sea and its inhabitants.

The author, a British worker, has compiled in fairly orderly fashion what is essentially an inventory of knowledge on certain aspects of deep sea biology. There is particular emphasis on those subjects (adaptations of deep sea fishes and deep scattering layer organisms) on which he has done original research. Approximately the first third of the book is devoted to an historical account of the growth of deep sea biology, the methods and techniques of studying the sea and collecting data and specimens, and a rather brief description of the physical environment of the depths. The remaining chapters deal with the organisms themselves, their structures and modes of life, and the patterns of adaptations which make them uniquely suited to their environment.

Obviously, in a single volume covering a subject as broad as this a great many details will be slighted and many topics, of vital importance, will not be mentioned. However, the information presented and the extensive bibliographies following each chapter expose the reader to a wealth of material and afford him the opportunity to delve more deeply into those facets of the field in which he may be particularly interested.

The book is generally well written and easily understood and is amply illustrated in black and white and color. The five color plates which have obviously contributed to the rather high cost of the book are indeed beautiful.—*David C. Joseph, California Department of Fish and Game.*

Modern Spearfishing

By Vane Ivanović; A. S. Barnes and Co., New York, 1955; ix + 203 p., 19 photos and 69 line drawings. $3.75.

This is one of the better books on diving which the reviewer has read. The main subject is spearfishing, but there is good coverage of diving in general. It should make interesting reading for both the novice and the expert.

The author makes one common mistake. In singling out a few divers and naming them the best in a given area, he assumes that the best are always those who attain the most publicity. There are many in this sport, as in any other, who go about their favorite diversion quietly, sans publicity. Many of these are equal or superior to those whose names and pictures make the magazines. In fact, the reviewer knows many divers who are as reticent above water as they are below.

The technical chapters of the book on "Breathing underwater", "The human body and pressure", etc., are generally accurate and complete. In the chapter on fishes the author does show a lack of knowledge, but as he makes no claims to being a biologist, his mistakes in terminology, spelling, and handling of nomenclature can easily be forgiven.

All in all the book can be recommended for both the vicarious and the active diver. Its style and light vein make it good reading.—*John G. Carlisle, Jr., California Department of Fish and Game.*

The Underwater Naturalist

By Pierre de Latil (translated from the French by Edward Fitzgerald); Houghton Mifflin Company, Boston, 1955; 275 p., illus. with photos and line drawings by Hubert Williams. $3.50.

One of the first impressions received from this book was of its complete provincialism; the author apparently has no knowledge of early diving developments outside of France. In the early and mid-1930's there was also a band of pioneers in Southern California, who first used Japanese pearl diving goggles, then made their own face plates, and later were able to buy Japanese face plates. They dove for abalones and lobsters and speared fish with Hawaiian-type spear guns—and they dove for the sheer joy of diving, without publicity. The reviewer was one of this group and can vouch for the dates.

The reviewer experimented as a boy during a two-year stay in Europe, diving with swimming goggles as early as 1928-1930 near Cannes, on the French Mediterranean coast; there must have been others. The author could have said that diving became widely popular from the impetus it received from this area in France in the late 1930's.

It is good that the author does not call himself a biologist, but even for a naturalist he shows a singular lack of knowledge of biology and scientific nomenclature. For example, he is amazed that systematists have made some changes in classification and fiish nomenclature after 40 years. I doubt if the fisheries biologist will care to wade through the chapters on fishes which take up most of the book.—*John G. Carlisle, Jr., California Department of Fish and Game.*

Pacific Salmons, Trouts, and Fresh Water Fishes

By C. E. "Quill" Gordon, Manuscript Press, Portland, Oregon, 1954; 70 p. $1.50.

This booklet of 70 closely printed pages consists of a series of accounts of the individual species of both introduced and native freshwater and anadromous fishes of the Pacific Coast.

According to the author, the information was compiled not so much for the benefit of the ichthyologist or to "delight the haughty" as to enrich "the fishing pleasures of the humble" through increased general knowledge and to extend "a welcome * * * to the uninitiated."

It is not an easy task to sift and comb data scattered throughout numerous bulletins and technical papers and present them in popular yet accurate form. The author has succeeded in considerable measure, although the professional worker will no doubt raise an eyebrow now and then. The choice of some adjectives—such as "restless"—to describe the qualities of the various species might be questioned, and occasional omissions and inaccuracies occur.

For example, the author states (page 7) that "Columbia spawned chinook not only provide the bulk of the multimillion harvest of the offshore fisheries of Alaska and British Columbia, but these fish also range south to support the California salmon fisheries as well." Thus, the enormous contribution made by the runs of the Sacramento-San Joaquin river system is ignored.

One page 28, in saying that "The golden trout are found in the high mountain waters of the 10,000 foot elevations in the Sierra Nevada of California", the author perpetuates a rather widespread fallacy. Actually, in their native habitat golden trout are found at elevations down to 6,300 feet or less.

Although on page 49 he states that "All the spiny-ray fishes except the yellow perch are nest builders that defend their eggs and young during the most critical period of the life cycle," he later (page 60) correctly notes that the Sacramento perch constitutes another exception.

On the latter page he says that "The Sacramento perch is a spirited game fish that takes the hook readily * * *." Californian fisheries managers, who have attempted to further the Sacramento perch as a game fish, have been distressed by its reluctance to take a hook during most of the year.

Throughout his accounts, the author interweaves commentary on the effects of man's activities on the various species. He also comments on their management, and calls attention to the possibilities of greater utilization for food of some of the so-called "roughfish".

No references are included, but the author directs the reader to the state fish and game departments for more detailed and localized information, and notes that usually literature is available from them on request. He also wisely advises the angler to familiarize himself with the policies and programs of these agencies.—*Leo Shapovalov, California Department of Fish and Game.*

A Manual of the Dragonflies of North America (Anisoptera)

By James G. Needham and Minter J. Westfall, Jr., University of California Press, Berkeley, 1955; xii + 615 p., illus. $12.50.

Every once in a while a book appears that has been heralded for a long time by persistent rumors of its preparation. This is such a book and it was certainly worth waiting for. The authors have produced what will undoubtedly prove to be a classic. This reviewer, not being an authority on the taxonomy of the Anisoptera, cannot critically evaluate that phase of the work. However, as a fisheries biologist with an interest in aquatic entomology he must give this book his wholehearted recommendation.

The manual is divided into two parts. The first consists of an introduction to the natural history of dragonflies, a description of methods of study and collection, and a brief section on procedure, in which the reader will find material designed to make the use of part two easier.

The important anatomical characters used in keying out adults and nymphs are clearly illustrated in the introductory section by photographs, and in the instance of wing venation by line drawings. Careful study of this section should make the use of the keys pleasurable.

Part two (about 88 percent of the book) covers systematic classification and contains keys to families, genera, and, where possible, to species. Both adults and nymphs are treated. The keys to nymphs are of particular value to fisheries biologists.

The biology of each family, genus, and species is usually discussed when such information is available. This includes environmental notes, information on reproduction and transformation, and other pertinent material.

Tables summarize taxonomic characters of families and subfamilies, genera, and species. In the case of each group these characters are given for both adults and nymphs. The complete treatment of the nymphs is unusually valuable and is a phase long neglected. Keys to nymphs are not unique, but this is the first volume to be seen by this reviewer that treats the subject completely.

The quality of this book is excellent. The photographs are clear and demonstrate beautifully what they are meant to demonstrate. The line drawings are precise and without the superfluity of unnecessary applique stippling or shading. The illustrations of wing venation, a most important key character for the adults, are as beautifully simple as the original wing. The publisher is to be complimented upon a fine job of printing and binding.

This volume is recommended without reservation to anyone interested in dragonflies.—*J. Bruce Kimsey, California Department of Fish and Game.*

Mammals

By Herbert S. Zim and Donald Hoffmeister; Simon and Schuster, New York, 1955; 160 p.; illustrated by James Gordon Irving. $1 paperbound, $1.95 clothbound.

This addition to the Golden Nature Guide series is a good source of information for both adult and youthful outdoorsmen who are interested in identifying the mammals which may be encountered on their trips into the field.

In a simple and direct style the authors have classified, described, and illustrated 218 of the 350 species of mammals found in the United States and Canada. The illustrated key to mammals in the forepart of the book groups the mammals handily for locating the descriptions and illustrations and the index of scientific names on page 155 completes the identification. For more rapid use, an index of common names is included in the back of the book.

The illustrations are clear and the color is good on the bats and smaller mammals, rodents, etc. The illustrator did become rather bold in the use of his brush, which gives a coarse look to many of the paintings. However, if one does not criticize by comparisons and accepts the key features, the illustrations serve their purpose—that of identification.

Due to the reduction in size, the distributional maps are rather weak, but if one keeps in mind the general use to which this book will be made, they are satisfactory.

This reader found only one glaring fault, and that was the confusing illustration and description of the mule and black-tailed deer.—*George D. Seymour, California Department of Fish and Game.*

Bird Navigation

By G. V. L. Matthews; Cambridge University Press, New York, 1955; vi + 141 p. $2.50.

This little volume of 123 pages of pertinent text and 15 pages of bibliography is a remarkable job of condensing the important facts from the major works dealing with this field.

One has the feeling, after reading a few pages, that here is the meat of bird navigation and migration minus the long involved dissertations of most other works on the subject.

In the first two chapters the author takes us through the contributions to the knowledge of bird navigation and migration made by the taxonomists and field collectors. Field observation and systematic specimen collecting have played a major part in the mapping of birds' movements, and some of the other more involved problems relative to age, independence, high and low level flying, channelling of migrants, and other related phases.

From the above chapters he brings out the experimental evidence of bearing and distance navigation. As an example, young storks were used. In this species, the old and young migrate independently. The young were removed far outside their regular range for release. The cases studied gave, in general, the same conclusion that the young birds continued to migrate from the release point in the same direction that their congeners follow from the trapping site. This was a parallel course and took them far outside their normal winter range.

In Chapter 3 the author leads into a discussion of various homing experiments, from which very interesting observations and conclusions were obtained. In the next chapter the reality of a complete form of navigation in birds is discussed, and many instances are demonstrated of rapid return to their original home by banded birds.

The development of the theories brought forth in the earlier chapters is well covered in Chapter 5 and shows what physical features of environment are concerned in this navigation, as well as the sensory equipment needed to react to such stimuli. Various theories, such as magnetism, coriolis force, and pressure patterns, are discussed and rejected. The author then discusses the extensive work done with the sun acting as a point of reference. Most of the many experiments point toward this theory conclusively in one directional navigation.

Complete navigation through maintenance of sensory contact with home is discussed in various phases. Birds have acute vision, but it is doubtful that they can see any farther than we can and they are, of course, limited by the earth's curvature. Even at 3,000 feet the horizon is never more than 73 miles away.

Chemical and physical constitutents of the atmosphere and radiation are discarded. Succession of visual landmarks, sense of smell, memory of outward route, and other theories are discussed and discarded.

This leads into a discussion of complete navigation by means of a "grid" derived from the earth's rotation and magnetism, which is rejected as nearly impossible.

The meat of the book follows in Chapters 8 and 9, in which the theory of complete navigation by means of a grid derived from the sun's co-ordinates is developed. It has been so thoroughly demonstrated by a series of experiments with controlled light, that it seems to leave little doubt as to the reality of the theory. The essential feature of the theory is the sun-arc.

The structure of the bird's eye is known to be exceptionally well developed. It is then demonstrated how the function of the eye makes use of the sun-arc hypothesis. The fixed reference point is always due south. Bearings are apparently fixed from that point by use of the bird's chronometer in whatever form this occurs.

In conclusion, the primary stimuli for the onset of migration appear to be changes in the sun-arc and day-length.

No theory of the physical basis of bird migration remains in the field except that involving the sun.—*Donald D. McLean, California Department of Fish and Game.*

o

printed in CALIFORNIA STATE PRINTING OFFICE

25467 10-55 5300

FISH AND GAME COMMISSION
STATE OF CALIFORNIA

Notice is hereby given, in accordance with Section 14.2 of the Fish and Game Code, that the Fish and Game Commission shall meet on February 24, 1956, in the California State Building, Los Angeles, to hear and consider any objections to its determinations and proposed orders in relation to fish, amphibia and reptiles for the 1956 angling season, such determinations and orders resuting from hearing held on January 6, 1956.

FISH AND GAME COMMISSION
MONICA O'BRIEN
Secretary to the Commission