A REVIEW OF INVERTEBRATE SPECIES

OF MANAGEMENT CONCERN ON FIVE NORTHERN ARIZONA FORESTS:

FINAL REPORT

Prepared for:

Apache-Sitgreaves National Forest
Coconino National Forest
Kaibab National Forest
Prescott National Forest
Tonto National Forest
USDA Forest Service Southwestern Region

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EXECUTIVE SUMMARY

To assist with the development of species-of-concern (SOC) and potential species-of interest (SOI) lists for the revision of Forest Plans, the Museum of Northern Arizona conducted a preliminary review of the distribution and status of 284 invertebrate taxa considered by the U.S. Forest Service as being of potential management concern or interest in 5 forests in central and northern Arizona: Apache-Sitgreaves, Coconino, Kaibab, Prescott, and Tonto National Forests. This desert-mountain region is topographically extremely diverse, with more than 3000 m of elevational range, numerous complex drainage basins, highly isolated mountain ranges, and the highest density of springs of any large region in North America. Paleontologically, it encompasses much of the Lowe-Davis biogeographic boundary between southerly Madrean-Tertiary and boreal Rocky Mountain-Great Basin biotic assemblages. As a consequently, the region is remarkably rich in rare, relictual, and endemic taxa, particularly plants and invertebrates.

Much uncertainty exists on the distribution and status of most all of the SOC and SOI invertebrate taxa, and additional information over time may alter the conclusions drawn here. We eliminated 159 taxa from the original list because background literature, museum specimen checks, discussion with experts, and/or database searches did not support their existence in these forests. We could not find sufficient information to make informed judgments about 26 taxa. Existing literature supported the potential designation of 79 taxa as species of concern (SOC) and 20 as species of interest (SOI). Apache-Sitgreaves NF has the most SOC + SOI (63 taxa), while Kaibab NF had the fewest (47 taxa). An additional 18 species not considered on the original list may be of potential interest in forest management. Data for SOC, SOI and additional species for consideration are unwieldy and are provided as electronic appendices only. We describe the caveats surrounding these data, and discuss overall habitat requirements for several groups of taxa, as well as non-native species threats. Protection of aquatic habitats (particularly springs and riparian zones), grasslands above 4000 ft elevation, coniferous forest meadows, deciduous woodlands and forests, and alpine habitats may help protect many of the SOC and SOI identified in this analysis; however, the uncertainties surrounding distribution and population status of these taxa, as well as regional resource management issues like groundwater aquifer protection, does not guarantee that habitat protection will translate into population protection. We suggest several approaches for improving the quality of information on these invertebrate taxa.

INTRODUCTION

Apache-Sitgreaves, Coconino, Kaibab, Prescott, and Tonto National Forests in northern Arizona are in the process of revising their forest management plans, and are evaluating the distribution, status, and habitat requirements of selected invertebrate species of potential management concern. The Forest Service recognizes invertebrate species of concern (SOC) as those that may have rare, unique, or declining habitat or populations, as well as species of interest (SOI), which may be rare or restricted to specific habitats, but about which more data are needed to inform management. In this report, we provide data from literature, museum collection searches, discussions with experts, and available database that provide insight on the distribution, status, and habitats of invertebrate species that may warrant management attention in these five forests.

METHODS

Study Area: Biogeographic Context

The five forests considered here cover much of the southern margins, uplands, and mountainous portions of the southern Colorado Plateau and the transition zone of the Plateau with the Basin and Range geologic province. This region encompasses much of the biogeographic boundary known as the Lowe-Davis line (LDL; Lomolino et al. 2006), which roughly separates the dry-tropical Madrean-Tertiary floristic zone of northern Mexico from the boreal Rocky Mountain and cold-desert Great Basin biomes (Axelrod 1950, 1983; Axelrod and Raven 1985). The latitude of the LDL has fluctuated over Quaternary time, shifting northward during interglacial warming periods, and southward during glacial advances. These climate and associated biological fluctuations also have extended into Grand Canyon (Phillips et al. 1987), altering the extent of barrier/filter and corridor effects there, and consequently differences in biota on the two rims (e.g., Stevens and Huber 2004). As a result of biological surges in response to Quaternary climate changes, and the great topographic diversity of central and northern Arizona, the five forests region holds many isolated, refugial, and endemic species, particularly of plants and invertebrates. It is a naturally highly fragmented landscape, with an enormous array of complex drainage networks, high mountain peaks, and the highest density of springs in North America (Stevens and Meretsky in press). The region has little state and private land, and thus the task of managing these diverse habitats and species falls primarily to the Forest Service, as well as other federal agencies and tribal governments.

Data Sources: Collections and Databases

We examined four major Arizona invertebrate collections and numerous databases to determine where species of concern or interest had been collected or reported. We examined invertebrate collections at: the Museum of Northern Arizona and Northern Arizona University (Flagstaff), the University of Arizona (UA, Tucson), and Arizona State University (Tempe). We examined databases from MNA, UA, Colorado State University (Ft. Collins), as well as Natureserve and other databases listed in References Cited (below). While important for assessing stream habitat quality, monitoring survey results that did not take identification to the taxonomic level of species were of limited use or misleading for this analysis (e.g., Mangum 1987, Dinger and Marks 2002).

Data for SOC, SOI, and additional species for consideration were compiled electronically, and are unwieldy, so they are provided as electronic appendices only (A-C).

Discussions with Experts

We discussed the status of Arizona Mollusca with Dr. James I Mead (Department of Geology, Northern Arizona University, Flagstaff on 19 Jan 2007), and Arizona invertebrates with Mr. Carl E. Olson (Entomology Department, University of Arizona, Tucson, 17-19 Jan 2007) and Dr. Anthony Gill (Curator of Biological Collections, Arizona State University, Tempe, 18 Jan 2007). We discussed Plecoptera distribution with Dr. Richard Baumann (Monte L. Bean Life Sciences Museum, Brigham Young University, Provo, UT, on 24 January 2007). We electronically communicated with Mr. Richard A. Bailowitz (Tucson) on the distribution of some Odonata, and with Dr. Dean W. Blinn (NAU emeritus, 24 Jan 2007) and Dr. David Ruiter (Colorado State University, Ft. Collins, 24 Jan 2007) about Trichoptera distribution on the forests.

Caveats: Uncertainty

The species targeted in this inquiry are generally extremely poorly known in terms of life history information, range, and population trends. Many are known from a single or a very few collections, and many have not been detected in recent decades. Just as it is impossible to demonstrate extinction, it is impossible to definitively say that these invertebrate species do not occur in one or another of the forests. This study is useful in that it presents in one database which documents what is presently known about the distribution of these species. In addition, the database may be useful as a baseline through which to assess improving quality of information and changing population status.

In our tabulation of these species' distribution among the forests, we indicate the extent of our uncertainty through the use of several designations in Appendices A-C: an "0" in a forest's column indicates a very low probability of detection exists for that species in that forest; "U" indicates a minor possibility of the species' occurrence in a forest; a "P" indicates at least a 50% probability of the species occurring on a forest, but the species has not been detected there; and a "1" indicates that the species has either been detected on the forest or information about its range is entirely consistent with its occurrence there. In relation to our original charge, any non"0" designation should be considered as deserving the attention of forest managers, with the "U" and "P" species worthy of consideration as SOI, and species given scores of "1" having SOI or potential SOC status.

RESULTS

This preliminary examination considered 284 Arizona invertebrate taxa under consideration by the Forest Service (Table 1; Appendices, A, B). We examined the information available on those species to ascertain whether and to what extent management attention was warranted. We found that 159 taxa were considered unlikely to occur on any of the 5 forests. Most excluded taxa were endemic to southeastern or western Arizona in Cochise, La Paz, Pima, Pinal, Santa Cruz, or Yuma Counties, particularly among the Chiricahua, Huachuca, Santa Catalina, and Santa Rita Mountain

ranges (Coronado National Forest was not one of the targeted forests). Insufficient data were available to assess the status of 25 taxa.

Existing literature supported the potential designation of 79 taxa as SOC and 20 taxa as SOI (Table 1; Appendices A, B). We could not find sufficient information to make informed judgments about 24 SOC and 2 SOI taxa. Apache-Sitgreaves NF has the most SOC + SOI (63 taxa), while Kaibab NF had the fewest (47 taxa). Thus the total potential SOC and SOI list includes 125 taxa. An additional 18 species not considered on the original list may be of potential interest in forest management (Table 1; Appendix C). In most cases these are taxa that are poorly known relictual, endemic, or isolated species with highly disjunct ranges. This brings the grand total to 142 invertebrate taxa. Data for SOC, SOI and additional species for consideration are unwieldy and are provided as electronic appendices only.

Table 1: Forest invertebrate group, status, and number of species in 5 forests in Arizona.

Group	Status	Number of Species					
		ASNF	CNF	KNF	PNF	TNF	Total
SOC	Likely to Occur	50	36	28	35	31	79
SOC	Insufficient Info	24	24	24	24	24	24
SOC	Potential SOC Subtotal	74	60	52	59	55	103
SOI	Likely to Occur	13	11	11	12	15	20
SOI	Insufficient Info	2	2	2	2	2	2
SOI	Potential SOI Subtotal	15	13	13	14	17	22
Addn'l	Potential for consideration	8	4	7	7	6	17 (18)
All	Total SOC, SOI, Addn'l.	97	77	72	80	78	142

DISCUSSION

A Focus on Habitat Management

Sensitive invertebrate species' distributions and life histories often require considerable additional study before management options can be prioritized; however, habitat management options are often clearer and more readily accomplished. In general, managing habitat according to desired criteria often translates into achieving desired species responses, and protecting other species associated with that habitat whose population status or even existence may be known. Habitat management is as important as direct species management, for sensitive invertebrate species are often highly adapted to specific habitats and cannot exist away those habitats. Also, habitat maintenance is an important proximal consideration for management, particularly while additional data are being acquired.

Seven habitat types emerge as supporting many of the sensitive invertebrate species listed in Appendices A-C, and are described below:

1) Stream-riparian habitats across elevation (tiger beetles, aquatic beetles, caddisflies, mayflies, stoneflies, true bugs, aquatic mollusks). Habitat characteristics and processes include those elements reported in Stevens et al. (2005), particularly: geomorphically appropriate hydrographic and water chemistry, channel and riparian bank or terrace geomorphology, diversity of microhabitats (pools, runs, riffles, over- and under-bank cover, riparian vegetation diversity, stand structure, and demography, and where appropriate with the management objectives for the site, limited impact of undesirable human impacts, including the introduction of non-native species.
2) Springs, particularly desert to intermediate elevation pool-forming, slow-rheocrene (lotic), and contact springs on cliff faces, as well as wet meadow low-gradient cienegas throughout the region (particularly for aquatic beetles, true bugs, stoneflies, and other aquatic and riparian taxa). Springs habitat characteristics and processes include those elements reported in Springer et al (2005), particularly: geomorphically appropriate flow and water chemistry, channel and adjacent habitat geomorphology, microhabitat array (e.g., wet backwalls, pools, channels, colluvial slopes, adjacent bedrock, wetland and riparian vegetation diversity and stand structure and, where appropriate for the management objectives for the springs, freedom from ecologically undesirable human impacts, including non-native species introductions.
3) An important habitat for a surprisingly rich assemblage of large-shelled landsnails (e.g., *Sonorella, Oreohelix, Ashmunella*) are mostly-barren piles of scree or boulders, often at the foot of cliffs, often with only a small amount of cover of lichens or moss. These habitats are generally quite stable, and the associated snails may be remarkably difficult to detect alive, or monitor. Nonetheless, such barren habitat is what they require, and among the nearly 100 *Sonorella* species in Arizona, many appear to be restricted to individual, isolated boulder or talus slopes. Inventory would appear to be a necessary precursor to management of such habitats. Other little-known invertebrate taxa are likely to exist in such settings as well.
4) Grasslands above approximately 4000 ft elevation, and particularly those above 6000 ft elevation (tiger beetles and many other invertebrates). Given the limitations of our knowledge of actual habitat requirements for most sensitive invertebrates, having a good matrix of different successional stages and associations, that are arrayed with good connectivity and patch sizes is appropriate. Some species, such as Horn's Tiger Beetle (Cicindelidae: *Cicindela h. hornii*), which may exist in Tonto National Forest grasslands, generally prefers geomorphically appropriate sparse grasslands (Pearson et al. 2006). Infestation of non-native grasses that create too dense a cover may preclude the presence of this species. Healthy soils are essential for the maintenance of these habitats.
5) Coniferous forest meadows above 6000 ft elevation support numerous invertebrate species, including Riding's Satyr (Nymphalidae: *Neominois ridingsii*) and other butterfly and tiger beetle species. Such habitats appear to vary in proportion of native grasses, herbs and forbs over the growing season across elevation, and achieving as nearly natural assemblages while at the

same time achieving management goals for these habitats is likely to best maintain associated invertebrate species.

6) Deciduous woodlands and forests, such as Gambel's oak and quaking aspen stands, are habitats in which landsnails and other terrestrial and fossorial (burrowing) invertebrates exist. There appears to be more to learn about the role of fire in the management of southwestern deciduous forest stands, and how taxa such as land snails respond to changes in such habitats; however, landsnails appear to be highly sensitive to deciduous litter quality.
7) Southwestern mountaintop alpine habitats are widely recognized as supporting isolated and endemic plants, but numerous poorly understood invertebrate populations exist there as well. For example, some landsnail species exist up to nearly 12,000 ft elevation on the San Franciso Peaks in Coconno National Forest (Colton collection, MNA). There has been little exploration of the alpine biota in northern Arizona, but a large array of rare and potentially undescribed invertebrate taxa exist there, including springtails, centipedes, and spiders.

A caveat bears consideration with regard to the focus on habitat as the primary vehicle for the management of poorly known, and particularly highly localized endemic species: inventory and occasional monitoring data are generally needed to determine whether and how a selected sensitive taxon or population is responding to management activities over time. A population may not respond as expected to intuitively appropriate management actions. Newly introduced diseases, other non-native species, unrecognized stressors, natural or anthropogenic disturbances, may be simultaneously affecting target population responses, and populations may not respond to habitat-supportive maintenance or restoration activities. For example, 1) the Bureau of Land Management fenced off several desert springs in Grand Wash, Mohave Co. Arizona, to protect them from grazing impacts. After more than a decades of management treatment, the riparian vegetation had expanded, apparently consuming all surface water and threatening the existence of an endemic aquatic snail (Grand Canyon Wildlands Council 2002). Apparently some level of disturbance is needed to maintain surface water at that site. 2) More than $20 million of riparian habitat improvement in the lower Colorado River basin has not resulted in larger or healthier southwestern willow flycatcher (Tyrannidae: *Empidonax traillii extimus*) or Yellow-billed Cuckoo (Cuculidae: *Coccyzus americanus*) populations there. 3) There are many examples around the world of splendid, well-managed forests that could, but no longer do, support extirpated species (Schwartzman et al. 2000). Therefore, ensuring an apparently high quality habitat does not necessarily mean that the target sensitive species will respond positively, nor does simple habitat monitoring guarantee the persistence of a population in that habitat.

Comments on Individual Taxa

Mollusca: The Arizona landsnail fauna is primarily known from Bequwert and Miller (1973), and is strongly dominated by the helmintoglyptid genus *Sonorella*. *Sonorella* species are typically large snails with flattened shells, and are commonly narrowly (highly localized) endemic in rock piles, scree slopes, and at the base of cliffs. Thus, their habitats are commonly unvegetated habitats, some of which are difficult to map because

they are on steep slopes. *Sonorella* are often apparently rare, and are difficult to collect, and even more difficult to distinguish as the only reliable morphological differences are reproductive tract characters. While their habitats may be small, their habitats may be relatively well protected from incidental anthropogenic impacts, and are likely only to be threatened by major actions, such as road construction, large-scale development, and mining. There appears to have been little advance in scientific understanding of most species in the past three decades, and much additional inventory, basic life history and taxonomic analysis, and monitoring remains to be done.

As a genus, *Sonorella* is widely distributed occurs throughout the southern half of Arizona, with the Mogollon Rim (or perhaps the Lowe-Davis line) as the general, but poorly understood, boundary; however, Mogollon Rim forests may have both *Sonorella* and *Oreohelix*. In northern Arizona and New Mexico, *Sonorella* is replaced by the oreohelicid genus *Oreohelix* and the polygyrid genus *Ashmunella*. These taxa often occupy forest habitats, but like *Sonorella*, some *Oreohelix* exist as endemics in (sometimes) individual rock piles. Other landsnails in Arizona are usually small, inconspicuous, and tend to occur in deciduous leaf litter. Springs and some riparian settings may provide undisturbed deciduous leaf litter and various small landsnail taxa at low elevations, and oak and aspen stands provide suitable habitat at middle and upper elevations (apparently from roughly 4000 up to more than 9000 ft elevation). Several species occur above treeline on the San Francisco Peaks and elsewhere.

Insecta – Odonata: The Odonata are increasingly well known in Arizona (Bailowitz et al. 2003), and relatively few of those on the preliminary list are likely to occur among the 5 forests. Among the few that do occur, the larger-bodied forms (e.g., *Cordulegaster diadema*) apparently wander widely in mid-late summer, and may occur far from their natal habitat. Therefore, aquatic inventory is needed to determine where the actual population sources occur, and monitoring and protection of those habitats is needed to protect the species. As with some of the Lepidoptera (below) apparent rarity may be related to the difficulty of capturing or even observing these very agile, fast-flying organisms.

Insecta – Cicindelidae: Several tiger beetles (Cicindelidae) of interest or concern to Forest Service management are represented on Forest planning lists; however, few tiger beetle taxa are known in sufficient detail to provide substantive land management guidance. Fortunately, the habitats occupied by tiger beetles are distinctive in Arizona and are subject to relatively discrete anthropogenic threats. Below an elevation of approximately 4000' in Arizona, tiger beetles typically occupy open patches in riparian wetlands corridors or near playas. From that elevation up to approximately 10,500 ft, tiger beetles are found in grasslands and sparse shrublands, including those with sand-gravel substrata and little-used roads (Stevens and Huber 2004).

Insecta – Trichoptera: Larval Trichoptera are aquatic (many different kinds of habitat), and adults occur in wetland-riparian habitats. While many species are included on the list as likely to occur on the forests, only a few are well enough known as to actual distribution. Blinn and Ruiter (2006) claim their data provide a useful baseline for future monitoring, but unfortunately journal space did not permit them to include specific

localities for the 103 species they collected (a subsequent manuscript is promised). Those data would be most useful to the Forest Service in evaluating Trichoptera distributions across these 5 forests. Dinger and Marks reported the genus *Cheumatopschye*, *Nectopsyche*, and *Wormaldia* in Fossil Creek at the Verde River confluence, but without species-level determinations, we are uncertain whether these represent species of management concern in PNF. Also, Moulton et al. (1994) reported *Oecetis avare* from Oak Creek and the Verde River (Coconino and Yavapai Counties), but we cannot determine whether this is the sensitive species described in one Forest Service list as "*Oecetis* sp. G."

Insecta – Lepidoptera: Arizona habitats support a large array of butterflies and skippers, and the ranges of many species are becoming better understood. Cochise County supports numerous Mexican taxa of invertebrates and birds, and thus many unique taxa are reported from the Chiricahua and Huachuca and Santa Rita mountains (Bailowitz and Brock 1991). Rarity is difficult to establish for many species, because of prescriptive flight behaviors. For example, *Agathymus alliae* (various subspecies) are reported to be in imperiled condition; however, these are large-bodied, diurnal skippers that emerge in late summer when daytime temperature limit collecting. They are difficult to capture and, being very fast-flying, are relatively rarely seen, even though they may be fairly common. Their larvae feed inside *Agave* leaves, and many *Agathymus* species appear to be host plant-specific, or even *Agave* variety-specific. If the host plant population is in good health, simply monitoring the leaves for emergence holes in early winter may be a suitable monitoring approach. If *Agave* populations are threatened, the associated *Agathymus* population will be as well.

Few, if any, moth taxon ranges have been very thoroughly determined. Noctuidae and Notodontidae are extremely species-rich families, and much further inventory and research is needed before the status of species in those families can be realistically evaluated.

OTHER SPECIES OF POTENTIAL MANAGEMENT CONSIDERATION

A daunting, but little understood, number of endemic and rare invertebrates occupy the forests of central and northern Arizona, including insects, scorpions, spiders, centipedes, millipedes, and many other taxa. Here, we present information on 15 additional species not presently included on Northern Arizona forest planning lists, but which may occur on one or more of those forests, and may be of interest from conservation and management standpoints (Appendix C). Additional information on their distribution, status, and habitats should be compiled before these taxa are recommended for incorporation into forest planning efforts.

Mollusca

Helminthoglyptidae: *Sonorella c. coloradoensis* ("Colorado River Talussnail"). This taxon is known to occur up to 5300 ft elevation in Grand Canyon National Park, and has been reported 5 mi NW of Seligman in Coconino County. Therefore, it may occur in Coconino, South Kaibab, and/or Prescott National Forests. Desert rock-pile habitats at the base of escarpments are the normal kinds of habitat this genus occupies.

Helminthoglyptidae: *Sonorella r. rooseveltiana and r. fragilis* ("Roosevelt Talussnails"). These two taxa are apparently endemic to the vicinity of Roosevelt Lake, and therefore may occur on Tonto National Forest lands. Desert rock-pile habitats at the base of escarpments are the normal kinds of habitat this genus occupies.

Plecoptera

Nemouridae: *Amphinemura mogollonica.* This species appears to be endemic to Christopher Creek in TNF.

Odonata

Coenagrionidae: *Coenagrion resolutum*. This diminutive damselfly occurs in Arizona apparently only at natural ponds on the North Kaibab, including Crane, Deer, and Bear Lakes. These ponds are largely perennial, and several are leech-dominated.

Libellulidae: *Sympetrum danae.* This small dragonfly "…has only one known colony in Arizona and that (is) in the highest White Mtns in Apache County. It is a high altitude species of willow bogs…" (R.A. Bailowitz, written communication, 14 Feb 2007). While common throughout the northern US and Europe, this population represents the most southerly extent of its range.

Aquatic Hemiptera

Veliidae - *Platyvelia summersi*. This species is known from AZ: Coconino Co., Sedona; PNF – W. Fork Clear Cr. Also reported from Gila, Graham, Maricopa, and Yavapai counties; 26 Mar-18 Nov; 975-1370 m (Stevens and Polhemus in press).

Veliidae: *Microvelia glabrosulcata.* This species is only reported from W. Clear Cr. in PNF in the US (whether it occurs in CNF is not yet known), but it occurs into Mexico (Stevens and Polhemus in press).. *Microvelia* are micro-predators and scavengers that occur around the margins and on the surfaces of generally relatively warm, slow-lotic or lentic water bodies

Hebridae: *Hebrus longivillus*. This species is only known in Arizona from Forestdale on the Mogollon Rim, ASNF. It has not been collected in the past 25 years, and its status warrants confirmation in the near future (Stevens and Polhemus in press). The hebrids are often found on or in shoreline vegetation, such as algal mats, in relatively warm, slow-lotic or lentic water bodies.

Naucoridae: *Ambrysus arizonus.* Yavapai Co. near Camp Verde (near PNF); also in Bonito Creek, 24 km NE Safford (La Rivers 1951, Stevens and Polhemus in press. Naucorids occupy the bottoms of shallow, gravel and cobble-floored streams.

Naucoridae: *Ambrysus thermarum*. Endemic to White Mountains of Arizona (La Rivers 1951, Stevens and Polhemus in press). Naucorids occupy the bottoms of shallow, gravel and cobble-floored streams, and sometimes warm springs..

Coleoptera

Cicindelidae: *Cicindela terricola kaibabensis* (Kaibab Variable Tiger Beetle). This species is only known from meadows near the top of the North Canyon Trail on the East Rim Rd., and possible in DeMotte Park, on the North Kaibab National Forest. It flies in late May and June. LES last reported it there in 2003.

Cicindelidae: *Cicindela hirticollis coloradula* (Little Colorado River Hairy-necked Tiger Beetle). Known only from the lower Little Colorado River upstream from

the confluence with the mainstream Colorado River, as reported by Pearson et al. (2006). Although not on National Forest lands, this taxon is yet another case of a highly localized endemic tiger beetle.

Lepidoptera

Papilionidae: *Papilio indra kaibabensis* (Kaibab Indra Swallowtail). This taxon is endemic to the North Rim of Grand Canyon, and may be found on the adjacent NKNF. It commonly flies in mixed conifer drainages in mid summer.

Lycaenidae: *Glochopsyche lygdamus* (Silvery Blue). This species is represented in Arizona in three apparently isolated populations, one each in the North Kaibab Forest, San Francisco Peaks, and White Mountains. This species flies from mid-May into August, in meadows and into open coniferous-deciduous (aspen) stands, and is sufficiently regular, conspicuous and numerous in all habitats to serve in monitoring.

Nymphalidae: *Speyeria atlantis schellbachi* (Schellbach's Fritillary). This taxon is endemic to the North Rim of Grand Canyon, and is locally abundant in the upper elevations of the North Canyon Wilderness Area, NKNF. It commonly flies in mixed conifer drainages in mid summer.

Nymphalidae: *Coenonympha tullia furcae* (Grand Canyon Ringlet). This taxon is endemic to the eastern South Rim of Grand Canyon, and regularly strays into SKNF immediately to the south. It flies in late May-early July in meadows and pine-oak woodlands.

Nymphalidae: *Coenonympha tullia subfusca* (White Mountains Ringlet). This taxon is endemic to the White Mountains, where we have encountered it most often in meadows and into open coniferous-deciduous (aspen) stands,

Nymphalidae: *Neominois ridingsii* (Ridings' Satyr). This species exists in an isolated population at the southernmost edge of its range on the south side of the San Francisco Peaks. Apparently this species only flies every other year (last seen in 2006), and exists solely in grassland-herb meadows at about 7000' elevation. While common in western states to the north, this population appears to be distinctive, and highly isolated from other populations.

MANAGEMENT CONSIDERATIONS

Non-native Species

Arizona faces major threats to its ecosystems from introduced species. Aquatic habitats throughout the state have been colonized by exotic crayfish, bullfrogs, introduced fish, other taxa, and at the time of this report, quagga mussels (Dreissenidae: *Dreissena bugensis* Andrusov). Of these, crayfish and quagga mussels are or soon will be, the most difficult invaders to manage. Crayfish are presently exacting the greatest toll on native aquatic biota. We recommend that the forests collaborate with other wildlife and habitat managing agencies and entities to develop a statewide monitoring plan to determine crayfish distribution and impacts, and promote research into crayfish pathology. That control method is likely to be the only form of biological control that is likely to be fruitful against crayfish. As there are no native crayfish in Arizona, a crayfish-specific pathogen would not be likely to harm the native taxa.

Quagga mussels recently have been identified in Lake Mead, and constitute a new and extreme threat to Arizona's waters. Unlike its congener, the zebra mussel, this highly

tolerant invader can colonize both soft-bottom and firm substrata, choking waterways and clogging waterworks. Widespread establishment in the Colorado River will almost certainly result in the spread of quagga mussels eventually moving into all flowing waters in the state. Such an invasion will be disastrous for the states aquatic biota, and considerable interagency effort should be devoted to slowing and stopping that invasion.

Inventory and Monitoring

This analysis raises numerous questions about the distribution, habitat requirements, population status, and threats to the known and perhaps undiscovered native invertebrate taxa on the 5 forests. Answering those questions in a manner sufficient to inform forest management is likely to be expensive and time-consuming. Consequently, the Forest Service may wish to participate in a multi-agency team to adopt a programmatic approach to develop a biodiversity over the duration of the forest plans. We suggest that such a process start by convening a panel of experts to discuss in detail candidate taxa, their habitat requirements, and inventory and monitoring protocols needed to protect at-risk invertebrates on the forests. Out of that process, at a pace and expenditure appropriate to the participating agencies, improved planning of the acquisition of immediate and longer-term inventory data and monitoring strategies can be developed.

Several kinds of habitat appear to be prime candidates for inventory, including: springs, riparian areas, deciduous woodland and forests, desert grasslands (if any exist), and montane meadows. We consider the inventory of springs and riparian zones to be a top priority because of the large number of unique taxa that occur in those settings, and because non-native crayfish and quagga mussel introductions and water developments pose immediate and significant threats to those habitats. Inventories on the Arizona Strip, in Grand Canyon, and in Grand Staircase-Escalante National Monument (southern Utah) that were coordinated by L.E. Stevens have demonstrated that springs are hotspots of biodiversity, often functioning as “keystone ecosystems” (Perla and Stevens in press). Riparian zones are similarly important, and new approaches to inventory and evaluation of such habitats provide useful management and monitoring data (Stevens et al. 2005). Deciduous woodlands and forests are likely to support numerous landsnail taxa and butterflies, making them candidates for inventory and monitoring. Likewise, montane meadows are likewise species-rich habitats that support tiger beetles, numerous butterflies, and other taxa, and are relatively easily inventories and monitored. A habitat-based inventory approach, with standardized methods for sampling adjacent uplands, will likely be the most efficient means of improving understanding of the taxa of concern to the Forest Service.

L.E. Stevens and his colleagues have developed protocols for both riparian and springs inventory and ecological assessment, and we recommend those sampling strategies to streamline the inventory process as efficient as possible (Stevens et al. 2005, Springer et al. 2006).

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REFERENCES CITED

Arizona Game and Fish Department. 2002. *Megathymus ursus deserti.* http://www.google.com/search?sourceid=navclient&ie=UTF-8&rls=GGLD,GGLD:2004-45,GGLD:en&q=Megathymus+ursus+deserti. Accessed 21 Jan 2007.

Arizona Game and Fish Department. 2002. *Agathymus baueri freemani*. http://www.gf.state.az.us/w_c/edits/documents/Agatbafr.d.pdf.. Accessed 21 Jan 2007.

Arizona Game and Fish Department. 2004. *Acrolophitus nevadensis*: Nevada Point-Headed Grasshopper. http://72.14.253.104/search?q=cache:vOvurKD37wIJ: www.gf.state.az.us/w_c/edits/documents/Acroneva.d.pdf+%27Acrolophitus+nevadensis&hl=en&gl=us&ct=clnk&cd=5. Accessed 26 Jan 2007.

Arizona Game and Fish Department. 2004. *Cymbiodyta arizonica*.. www.gf.state.az.us/w_c/edits/documents/Cymbariz.d_000.pdf Accessed 21 Jan 2007.

Arizona Game and Fish Department. 2004. *Anacroneuria wipukupa*. http://www.gf.state.az.us/w_c/edits/documents/Anacwipu.d.pdf. Accessed 21 Jan 2007.

Arizona Game and Fish Department. 2004. *Microdynerus arenicolus.* http://www.gf.state.az.us/w_c/edits/documents/Micraren_000.pdf. Accessed 21 Jan 2007.

Arizona Game and Fish Department. 2004. *Stygobromus arizonensis*. http://72.14.253.104/search?q=cache: UYLzXr6M0fgJ:www.gf.state.az.us/wc/edits/documents/Stygariz.d.pdf+Stygobromus+arizonensis&hl=en&gl=us&ct=clnk&cd=2. Accessed 21 Jan 2007.

Arizona Game and Fish Department. 2005. *Taenionema jacobii.* http://www.gf.state.az.us/w_c/edits/documents/Taenjaco.d.pdf. Accessed 22 Jan 2007.

Austin, G. T. 1998. New Subspecies of Lycaenidae (Lepidoptera from Nevada and Arizona). Pp. 539-572 *in*: Emmel, T. C. editor. Systematics of western North American butterflies. Mariposa Press, Gainesville.

Bailowitz, R.A. and J.P. Brock. 1991. Butterflies of Southeastern Arizona. Sonoran Arthropod Studies, Inc., Tucson, AZ. 342 pp.

Bailowitz, R., D. Danforth, and S. Upson. 2003. Arizona Odonates. www.azodes.com. Accessed 21 January 2007.

Ball, E.D., E.R. Tinkham, R. Flock, C.T. Vorhies. 1942. The grasshoppers and other Orthoptera of Arizona. Technical Bulletin No. 93. University of Arizona, Tucson, AZ.

Banks, N. 1909. A new genus and species of Neuroptera. Entomological News 19:203-204.

Bequaert, J.C. and W.B. Miller. 1973. The Mollusks of the arid southwest, with an Arizona checklist. University of Arizona Press, Tucson, AZ.

Blinn, D.W. and D. E. Ruiter. 2006. Tolerance values of stream caddisflies (Trichoptera) in the lower Colorado River Basin, USA. The Southwestern Naturalist 51(3): 326-337.

Brock, J.P. and K. Kaufman. 2003. Butterflies of North America. Houghflin-Mifflin, New York.

Brown, H.P. 1981. *Huleechius*, a new genus of riffle beetles from Mexico and Arizona (Coleoptera: Dryopoidea, Elmidae). Pan-Pacific Entomologist 57:228-244.

Burch, J.B. 1988. North American freshwater snails: introduction, systematics, nomenclature, identification, morphology, habitats, distribution. Walkerana 2:1-80.

Center for Biodiversity. 2004. Stephan's riffle beetle. http://www.biologicaldiversity.org/swcbd/species/rifflebeetle/index.html. Accessed 21 Jan 2007.

Christensen, C.C. and R.L. Reeder. 1981. New records of *Sonorella* (Pulmonata: Helminthoglyptidae) from the Table Top Mountains, Pinal County, Arizona, with a description of *Sonorella milleri*, new species. The Southwestern Naturalist 26(4):341-344.

Dinger, E.C. and J.C. Marks. 2002. Aquatic macroinvertebrate survey of Fossil Creek, Arizona: final report. USDA Coconino National Forest and Northern Arizona University, Flagstaff.

Eades, D.C., D. Otte, and P. Naskrecki. Orthoptera species file online. Version 2.7. Available from: http://osf2.orthoptera.org. (accessed 21 January 2007).

Fairbanks, H.L. and R.L. Reeder. 1980. Two new species of *Sonorella* (Gastropoda: Pulmonata: Helminthoglyptidae) from the Pinaleno Mountains, Arizona. Proceedings of the Biological Society of Washington 93:395-404.

Garth, J.S. 1950. Grand Canyon butterflies. Grand Canyon Natural History Association, Grand Canyon.

Grand Canyon Wildlands Council, Inc. 2002. Inventory of 100 Arizona Strip springs, seeps and natural ponds: Final Project Report. Arizona Water Protection Fund, Phoenix.

Hershler, R. and J.J. Landye. 1988. Arizona Hydrobiidae (Prosobranchia: Rissoacea). Smithsonian Contributions to Zoology No. 459.

Hoekstra, Jon D. & R. Garrison. 1999. Range extension of *Palaemnema domina* Calvert (Odonata: Platystictidae) to southeastern Arizona, U.S.A.: a new odonate family for the United States. Proceedings of the Entomology Society Washington 101:756-759.

Holsinger, J.R. 1974. Systematics of the subterranean amphipod genus *Stygobromus* (Gammaridae), Part I: species of the western United States. Smithsonian Institution Press, Washington.

Houghton, D.C. 2001. Caddisfly (Trichoptera) records from the Apache National Forest, Eastern Arizona. Entomological News 112:85-93.

Hovingh, P. 2004. Intermountain freshwater mollusks, USA (*Magaritifera*, *Anodonta*, *Gonidea*, *Valavata*, *Ferrissia*): geography, conservation, and fish management implications. Monographs of the Western North American Naturalist 2: 109-135.

Jacobi, G.Z. and S.J. Cary. 1996. Winter stoneflies (Plecoptera) in seasonal habitats in New Mexico, USA. Journal of the North American Benthological Society 15:690-699.

La Rivers, I. 1951. A revision of the genus *Ambrysus* in the United States (Hemiptera: Naucoridae). University of California Publications in Entomology 8:277-338.

Lomolino, M.V., B.R. Riddle, and J.H. Brown. 2006. Biogeography, 3rd edition. Sinauer Associates Inc., Sunderland.

Kondratieff, B. C., editor. 2003. Dragonflies and damselflies (Odonata) of the United States. Jamestown, ND: Northern Prairie Wildlife Research Center Online. http://www.npwrc.usgs.gov/resource/distr/insects/dfly/index.htm (accessed 21 January 2007).

Mangum, F.A. 1987. Aquatic ecosystem inventory: macroinvertebrate analysis. USDA Intermountain Region Aquatic Ecosystem Analysis Laboratory, BYU, Provo.

Mattox, N.T. 1954. Description of *Eocyzicus concavus* (Mackin) with a review of other North American species of the genus (Crustacea: Conchostraca). Journal of the Washington Academy of Sciences 44:46-49.

McCafferty, W.P., M.D. Meyer, and G.T. Lester. 2002. Significant range extensions for southwestern Nearctic mayflies (Ephemeroptera: Baetidae). Entomological News 113: 211-214.

Moulton, S.R. II, K.W. Stewart, and K.L. Young. 1994. New records, distribution and taxonomic status of some northern Arizona caddisflies (Trichoptera). Entomological News 105:164-174.

NatureServe. 2006. Downloadable animal datasets. NatureServe Central Databases. Available from: www.natureserve.org/getData/dataSets/watershedHucs/index.jsp. Accessed 21 January 2007.

Needham, J.G., M.J. Westfall, Jr., and M.L. May. 2000. Dragonflies of North America, revised edition. Scientific Publishers, Gainesville.

Opler, P.A., H. Pavulaan, R. E. Stanford, and M. Pogue, coordinators. 2006. Butterflies and moths of North America. Bozeman, MT: Mountain Prairie Information Node. http://www.butterfliesandmoths.org/ (Version 22012007).

Pearson, D.L., C.B. Knisley, and C.J. Kazilek. 2006. Tiger beetles of the United States and Canada. Oxford University Press, Oxford.

Peck, S.B. 1973. A Systematic revision and the evolutionary biology of the *Ptomaphagus* (*Adelops*) beetles of North America (Coleoptera; Leiodidae, Catopinae), with emphasis on cave-inhabiting species. Museum Comparative Zoology Bulletin 145:29-162.

Phillips, B.G., A.M. Phillips III, and M.A. Schmidt Bernzott. 1987. Annotated checklist of vascular plants of Grand Canyon National Park. Grand Canyon Natural History Association, Grand Canyon.

Pool, R.W. 2007. Nearctica.com: the natural history of North America. http://www.nearctica.com/butter/plate33/Aalliae.htm. Accessed 21 Jan 2007.

Ross, H.H., 1941**.** Descriptions and Records of North American Trichoptera. Transactions of the American Entomological Society 67:91.

Sanderson, M.W. 1953. New species and a new genus of New World Elmidae with supplemental keys. The Coleopterists' Bulletin 7:33-40.

Stephan Schwartzman, S., A. Moreira, and D. Nepstad. 2000. Rethinking Tropical Forest Conservation: Perils in Parks. Conservation Biology 14:1351–1357.

Scott, J.A. 1986. The butterflies of North America. Stanford University Press, Stanford, CA. 583 pp.

Smetana, A. 1974. Revision of the *Cymbiodyta* (Coleoptera: Hydrophilidae). Memoirs of the Entomological Society of Canada No. 93.

Stevens, L.E. and R.L. Huber. 2004. Biogeography of tiger beetles (Cicindelidae) in the Grand Canyon Ecoregion, Arizona and Utah. *Cicindela* 35:41-64.

Stevens, L.E. and V. J. Meretsky, editors. Every Last Drop: the Ecology and Conservation of North American Aridlands Springs. University of Arizona Press, Tucson. *In press.*

Stevens, L.E. and A.E. Springer. 2004. A conceptual model of springs ecosystem ecology. National Park Service, Flagstaff, AZ, published online at http://www1.nature.nps.gov/im/ units/scpn/phase2.htm.

Stevens, L.E., T.J. Ayers, J.B. Bennett, K.Christensen, M.J.C. Kearsley, V.J. Meretsky, A.M. Phillips III, R.A. Parnell, J.Spence, M.K. Sogge, A.E. Springer, and D.L. Wegner. 2001. Planned flooding and Colorado River riparian trade-offs downstream from Glen Canyon Dam, Arizona. Ecological Applications 11:701-710.

Stevens, L.E., P.B. Stacey, A. Jones, D. Duff, C. Gourley, and J.C. Caitlin. 2005. A protocol for rapid assessment of southwestern stream-riparian ecosystems. Pp. 397-420 *in* van Riper, C. III and D.J. Mattson, editors. Fifth Conference on Research on the Colorado Plateau, University of Arizona Press., Tucson.

Taylor, D.W. 1987. Fresh-water mollusks from New Mexico and vicinity. New Mexico Bureau of Mines & Mineral Resources Bulletin 116:34-36.

U.S. Fish and Wildlife Service. SW Region USFS Sensitive Species List (Corrected 02/23/00). http://roadless.fs.fed.us/documents/feis/data/sheets/ summspd/tes_supp/r3 sensitive_list.PDF. Accessed 21 Jan 2007.

U.S. Geological Survey Non-indigenous Aquatic Species. 2005. *Orconectes causeyi*. http://nas.er.usgs.gov/ queries/collectioninfo.asp?SpeciesID=209. Accessed 21 Jan 2007.

U.S. Geological Survey Northern Prairie Wildlife Research Center. 2006. Mayflies of the United States, Mayflies of Arizona: No Common Name (*Ameletus falsus*). http://www. npwrc. usgs.gov/resource/distr/insects/mfly/az/13.htm.

U.S. Geological Survey Northern Prairie Wildlife Research Center. 2006. Stoneflies of the United States, Stoneflies of Arizona: Apache Forestfly (*Amphinemura apache*). http://www.npwrc.usgs.gov/resource/distr/insects/sfly/az/557.htm. Accessed 21 Jan 2007.

Wahlberg, N., Oliveira, R., and Scott, J. A. 2003. Phylogenetic relationships of *Phyciodes* butterfly species (Lepidoptera: Nymphalidae): complex mtDNA variation and species delimitations. Systematic Entomology 28:257-273.

Wang, D. and J.R. Holsinger. 2001. Systematics of the subterranean amphipod genus *Stygodromus* (Crangonyctidae) in western North America, with emphasis on species of the *hubbsi*-group. Amphipacifica 3:39-147.

Warrick, G. 1986. Field survey for the riffle beetle Cylloepus parkeri Sanderson. Unpublished report prepared for Prescott National Forest.

Whaley, W.H. 2000. An Illustrated Guide to Geographic Variation in the Indra Swallowtail Butterfly and its Larval Host Plants: a composite of two papers presented at the Annual Meeting of the Lepidopterists' Society, Sierra Vista, Arizona, Aug. 6-8, 1999
& the Annual Meeting of the Pacific Slope Section of the Lepidopterists' Society, Grants Pass, Oregon, June 23-25, 2000. On-line at http://research.uvsc.edu/whaley/print.html. Accessed 23 Jan 2007.

Wielgus, R., Wielgus, and Wielgus.1972.A new subspecies of *Megathymus ursus* Poling from Arizona with observations and notes on its distribution and life history. Ally Museum Bulletin 9: 1-11.

APPENDICES A-C AND ASSOCIATED DATA FILES

These files are provided in electronic Microsoft Excel format only.