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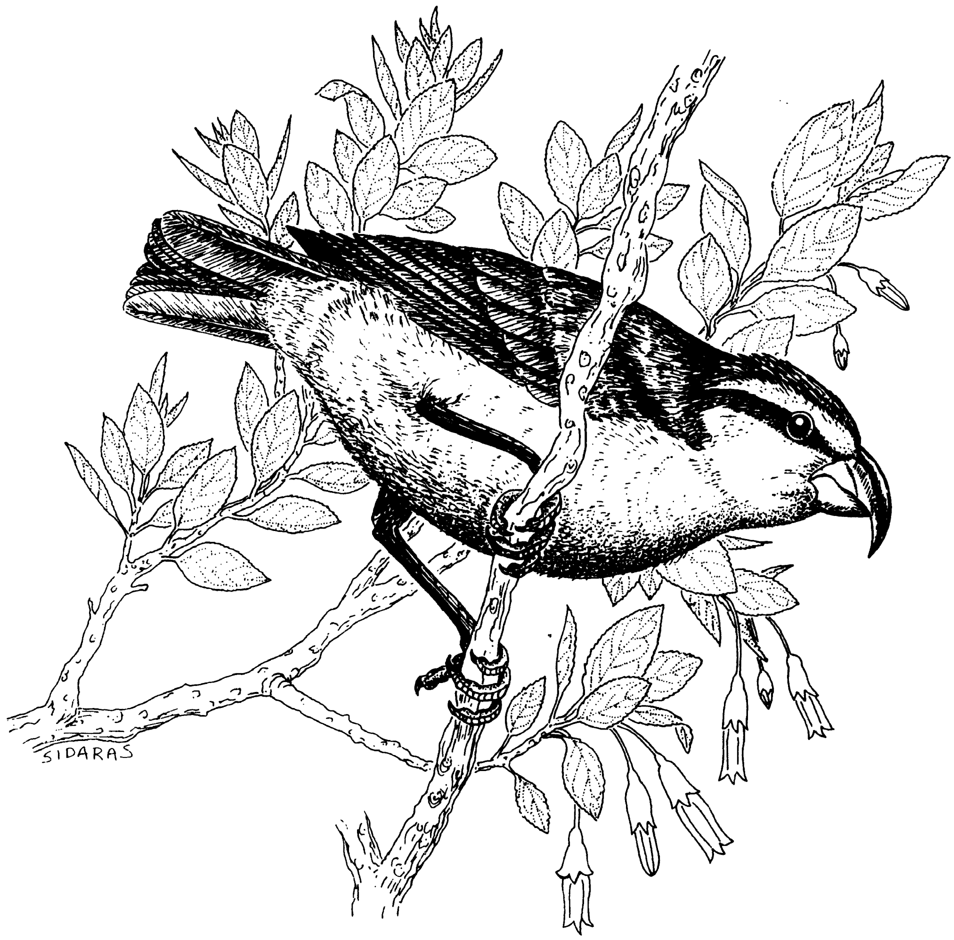

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Strategies for Long-Term Protection of Biological Diversity in Rainforests of Haleakala National Park and East Maui, Hawaii

by

Lloyd L. Loope and
Arthur C. Medeiros

Rainforests of northeastern Haleakala volcano are among the biologically richest and most intact in Hawaii. Hawaii's surviving natural heritage, the product of millions of years of evolution in isolation, is a unique national treasure (Howarth et al. 1988). As a result of habitat destruction and human introduction of invasive non-native species to a vulnerable island environment, this natural heritage is in serious jeopardy.

Much has been written about the loss and decline of much of the Hawaiian biota (e.g. Gagne 1988; Cuddihy and Stone 1990). The extent of biodiversity loss (e.g. 70% of endemic land birds and land snail species) is unequalled in any other region of the United States. Hawaii is well known as the extinction capital of the United States, with roughly one-third of the endangered species in the entire country. What is not generally appreciated, however, is that much of Hawaii's unique biological heritage remains and can be protected with achievable levels of management. Large tracts of near pristine ecosystems remain at high elevation on several islands, with some of the most promising opportunities occurring on Maui.

The Maui Greensword, *Argyroxiphium grayanum*, grows primarily in montane bogs in the upper elevation rainforest that have been heavily impacted by feral pigs and invasive plants. Fencing of areas to keep pigs out has proven successful in the recovery of this and other native plants. Illustration by Nanci Sidaras.

Decline of Hawaii's ecosystems has been going on since the first arrival of Polynesians in the 4th century A.D. In modern times the movement, establishment, and spread of non-native species to new geographic areas have created such havoc worldwide that these biological invasions are now considered a major component of global environmental change (D'Antonio and Vitousek 1992). Few areas in the world have suffered as many negative effects of biological invasions as Hawaii. However, much can be saved if the political will exists to implement needed management.

Most of the intact upper elevation rainforests on Maui and other islands are dominated by the myrtaceous tree ʻohiʻa (*Metrosideros polymorpha*). These forests have a closed canopy with a well-developed subcanopy of mixed native tree species and tree ferns and an understory of shrubs and ferns. Another tree, koa (*Acacia koa*), is locally dominant or codominant with ʻohiʻa. These high-elevation rainforests are overwhelmingly dominated by native species, including about 240 native species of flowering plants (with ca. 90% endemic to Hawaii and 20% endemic to Maui), 100 species of ferns (ca. 50% endemic to Hawaii), 600-1,000 species of native invertebrates (ca. 90% endemic to Maui), one endemic mammal taxon (a federally endangered subspecies of hoary bat), and nine endemic forest bird species in the family

Fringillidae, subfamily Drepanidinae (Hawaiian honeycreepers). The 200 km^2 area provides habitat for five federally endangered bird species (Table 1), nine federally endangered plant species and 21 recommended or candidate plant taxa (Table 2), and numerous very rare endemic invertebrate species.

The Feral Pig and Invasive Plant Species

Pigs were brought to the Hawaiian Islands by Polynesians as early as the 4th century A.D. However, the currently severe environmental damage done by pigs largely began after 1900 and seems to have resulted entirely from release of domestic, non-Polynesian genotypes (Diong 1982). Pig raising was an important agricultural activity in the early 1900s (through the 1950s) in coastal settlements of East Maui. Some pigs were raised through free-farming (Diong 1982), and some of these domestic breeds escaped or were released and worked their way to higher elevations, where they were first seen in the 1930's.

Aided by a seasonally abundant and expanding carbohydrate source from non-native strawberry guava and by an enhanced protein source from abundant non-native earthworms, feral pig populations developed and spread into upland pristine native forest. By 1945, pigs had moved into Haleakala National Park's upper Kipahulu Valley, though an expedition (by F. Hjort and G. Fagerlund) in that year found the middle valley pig-free between 610 and 1375 m (2000-4500 ft) elevation. By 1967, pig damage was found for the first time throughout Kipahulu Valley—although damage at that time was still moderate (Warner 1968). By 1979-81, pig densities had greatly increased, ranging in Kipahulu Valley from 5 to 31 per km^2 (13-80 per mi^2) (Diong 1982). A similar pattern appears to have occurred across the entire north and northeastern slopes of East Maui during the past 30 years (R.W. Hobdy, Hawaii Division of Forestry and Wildlife, pers. comm.).

Chronic degradation of rainforests by pigs has become increasingly common in the past several decades as they have spread into formerly pristine areas and facilitated the establishment of invasive plants and invertebrates. Feral pigs degrade rainforest environments by turning up ("rototilling") the forest floor and consuming lobelias, tree ferns, and other understory species. Seeds of non-native plants are carried on pigs' coats or in their digestive tracts and thrive upon germination on the forest floor where pig-digging has exposed mineral soil. Once aggressive plant invaders have obtained a new foothold in the forest, they spread opportunistically, aided by pigs and non-native birds (without which little or no spread of most species would take place). The synergistic interaction of selective herbivory and ground disturbance (sometimes at dramatic levels) by pigs with the progressively increasing invasion of non-native plant species can eventually lead to complete loss of a rainforest ecosystem, with native plants being replaced by such invasives as Koster's curse (*Clidemia hirta*), strawberry guava (*Psidium cattleianum*), Australian tree fern (*Cyathea cooperi*), kahili ginger (Hedychium gardnerianum), and Hilo grass (*Paspalum conjugatum*) (Anderson et al. 1992; Loope et al. 1992; Medeiros et al. 1992).

Impacts on Native Birds

The prognosis for long-term survival of many endangered forest bird species is not favorable. Once occupying extensive ranges, many surviving species are now extirpated from lower elevations and leeward exposures and are now confined to small tracts of high-elevation rainforest. Habitat alteration by pigs and invasive plants contribute to the endangerment of native forest birds, but other less manageable factors such as rat and mongoose predation, competition with introduced birds, and reduction in abundance of arthropod food items are also involved. An apparently overwhelming factor contributing to native forest bird endangerment is susceptibility to avian disease, especially viral pox and protozoan-caused avian malaria, both carried by an introduced mosquito, *Plasmodium relictum*. Mosquito reproduction is enhanced by

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Cover: Maui Parrotbill (*Psuedonestor xanthophrys*). Illustration by Nanci Sidaras.

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Table 1: Endangered Birds of East Maui Rainforests - All are in the Family Fringillidae, Subfamily Drepanidinae (Hawaiian Honeycreepers).

Hawiian name (common name)	Latin name
'akohekohe (crested honeycreeper)	*Palmeria dolei*
Maui parrotbill	*Pseudonestor xanthophrys*
po'o-uli	*Melamprosops phaeosoma*
nukupuu	*Hemignathus lucidus*
akepa	*Loxops coccineus*

existence of standing water in pig wallows and tree-fern cavities (Scott et al. 1988; Jacobi and Atkinson 1995). Many native Hawaiian passerine birds are extinct as a result of these human-caused environmental changes (James and Olson 1991), and despite recent habitat management by fencing and animal removal, numbers of rare forest birds have continued to decline (e.g. Scott et al. 1988; Jacobi and Atkinson 1995).

Management of Rainforest in Haleakala National Park

National Park Service (NPS) jurisdiction over extensive rainforests dates back only to 1969, when additions to Haleakala National Park were made with the hope of protecting some of the most pristine remaining rainforest tracts in the state. The NPS initially hoped to maintain this rainforest ecosystem in a pristine state by keeping people out. However, addition of the area to the national park in 1969 coincided with a rapid ingress and expansion of pig populations (Diong 1982) and consequent weed invasion (Lamoureux and Stemmermann 1976; Anderson et al. 1992).

Removal of pigs through snaring within fenced management units, beginning in the late 1980s (Anderson and Stone 1993), has led to partial recovery of forest understory and a marked slowing of plant invasions. New plant invasions, formerly occurring throughout extensive pig-disturbed areas, are now largely confined to areas of frequent natural disturbance (e.g. trailsides, stream courses, landslides). Removal of selected invasive plants by park managers has promise for nearly full restoration of the ecosystem.

Diversity on Adjacent Lands Important for Conservation

About 25% of the rainforest above 1000 m elevation on East Maui are in Haleakala National Park. Areas outside the park provide outstanding opportunities for conservation of a much larger area; for example, The Nature Conservancy's Waikamoi Preserve (2,117 ha) and Hanawi (State) Natural Area Reserve (3,035 ha), are important existing high-elevation rainforest refuges. Both are protected through active management including pig control. The cooperative state-private-federal East Maui Watershed Partnership has the objective of managing the shared watershed "to protect this area from non-native pest animals, weeds and other threats." The Partnership is currently mounting an effort, aided by matched funding from the State of Hawaii, to protect an additional 4,000 ha of rainforest between Waikamoi and Hanawi through fencing and pig control for watershed and biodiversity protection. The partnership is additionally committed to containment and eradication of the invasive non-native tree *Miconia calvescens*, which appears to pose an especially severe threat.

***Platanthera holochila*, one of three native Hawaiian Orchids. Their decline may be due to feral pigs, herbivory by introduced mollusks, or an unknown introduced orchid pathogen. Illustration by Nanci Sidaras.**

Addressing Long-term Threats

An important element of protection of biological diversity in Hawaiian rainforests is the need to devise strategies not only to address the immediate threats, but also predictable threats on a time scale of at least 30-100 years into the future. Unless non-native species are managed with ingenuity and commitment, invasive species can be expected to proliferate and eventually pose intractable threats perhaps even to managed areas in East Maui's high-elevation rainforests. Conservation authorities in Hawaii are beginning to address the continuing alien pest invasion (The Nature Conservancy of Hawaii and Natural Resources Defense Council 1992; Loope 1992).

The most dramatic example of management of a long-term threat on Maui involves the invasive tree *Miconia calvescens* (Melastomataceae), which is native to neotropical forests at 300-1800 m (1000-6000 ft) elevation, and is now known to be an unusually aggressive invader of moist island habitats. Introduced to Tahiti in 1937, dense thickets of *M. calvescens* had by the 1980s replaced the native forest over most of the island, with dramatic reduction of biological diversity (Meyer in press). After the late F.R. Fosberg saw this species in Tahiti in 1971, he reported that "it is the one plant that could really destroy the native Hawaiian forest." Because of its attractive purple and green foliage, it was nevertheless inadvertently introduced to Hawaii as an ornamental in the 1970s. After its detection on Maui by conservation agencies in 1990, an alarm was raised. Nearly 20,000 individuals of *M. calvescens* were removed from private lands by agency staff and volunteers in 1991-93, and control appeared feasible. However, in September 1993, an aerial vegetation survey discovered a previously undetected *Miconia* population on state land—far larger (over ca. 100 ha) than all previously known populations on Maui (R.W. Hobdy, personal communication 1993). An interagency working group, the Melastome Action Committee, developed and began (January 1994) implementation of a containment strategy, initially involving helicopter herbicide (Garlon 4) spraying of individual emergent *Miconia* trees and monitoring of results. Efforts to mobilize a control effort commensurate with the task are still underway.

Table 2: Endangered (E), Recommended (C1), and Candidate (C2) Plant Taxa of the East Maui Rainforest

Taxon	Family	Life form	Status
Asplenium schizophyllum	*Aspleniaceae*	fern	C2
Bidens campylotheca pentamera	*Asteraceae*	herb	C2
Bidens campylotheca waihoiensis	*Asteraceae*	herb	C2
Calamagrostis expansa	*Poaceae*	herb	C2
Christella boydiae	*Thelypteridaceae*	fern	C2
Ctenitis squamigera	*Aspidiaceae*	fern	E
Cyanea copelandii haleakalaensis	*Campanulaceae*	shrub	C1
Cyanea glabra	*Campanulaceae*	shrub	C1
Cyanea hamatiflora hamatiflora	*Campanulaceae*	shrub	C1
Cyanea grimesiana grimesiana	*Campanulaceae*	shrub	C1
Cyanea kunthiana	*Campanulaceae*	shrub	C2
Cyanea mceldowneyi	*Campanulaceae*	shrub	E
Gardenia remyi	*Rubiaceae*	tree	C2
Geranium arboreum	*Geraniaceae*	shrub	E
Geranium multiflorum	*Geraniaceae*	shrub	E
Huperzia mannii	*Lycopodiaceae*	clubmoss	E
Joinvillea ascendens ascendens	*Joinvilleacae*	herb	C2
Melicope balloui	*Rutaceae*	tree	E
Melicope haleakalae	*Rutaceae*	tree	C2
Melicope ovalis	*Rutaceae*	tree	E
Peperomia subpetiolata	*Piperaceae*	herb	C2
Phyllostegia bracteata	*Lamiaceae*	herb	C2
Planyago princeps laxiflora	*Plantaginaceae*	shrub	E
Platanthera holochila	*Orchidaceae*	herb	C1
Ranunculus hawaiiensis	*Ranunculaceae*	herb	C2
Ranunculus mauiensis	*Ranunculaceae*	herb	C2
Rubus macraei	*Rosaceae*	shrub	C2
Sicyos cucumerinus	*Cucurbitaceae*	vine	C2
Solanum incompletum	*Solanaceae*	shrub	E
Wikstroemia villosa	*Thymelaeaceae*	shrub	C2

Miconia is not the only example of an incipient long-term threat which must be confronted by the East Maui Watershed Partnership. The axis deer (*Axis axis*), a forest deer from India, was introduced to the Hawaiian Islands on Molokai in the 1860s. Within 30 years, they had become extremely numerous and were doing severe damage to the Molokai forest (including rainforest). They continue to damage forest on that island, as well as on neighboring Lanai, where they were introduced in 1920 (Cuddihy and Stone 1990; Hobdy 1993). Pressure was strong for increased hunting opportunities in the 1950s; based on the assessment that deer would not penetrate the native forest and numbers would be kept under control by hunting, a territorial/ state legislative mandate led to introduction of axis deer to Maui in 1960 (Tomich 1986). The axis deer on Maui originally occupied a small area of private land in dry, coastal lowlands of East Maui, but they have spread in a period of 35 years to the point that sightings are common on West Maui and in the uplands of East Maui as high as 2135 m (7000 ft) elevation. Without management, it seems only a matter of time until the deer invade native forest on Maui, as they have on Molokai and Lanai, and with similar consequences. The East Maui Watershed Partnership is in the process of addressing this important issue.

A flock of 10-12 Red-crowned Amazon parrots (*Amazona viridigenalis*) has recently been illegally released on East Maui. This species has been present for a few years on Oahu and is suspected of breeding there (Hawaii Audubon Society 1993). If these birds are allowed to become established, spread of alien plant species such as *Miconia* and strawberry guava may be substantially aided. Concerted and carefully planned interagency action is needed in the near future to eliminate this threat.

Conclusion

Exclusion of feral pigs is the single most important management action for protection of the biological diversity of East Maui's rainforests. After feral pigs are removed, recovery of native plant species can be rapid and extensive, especially at elevations above 1500 m. At 1000-1500 m elevation (and increasingly so at lower elevations), invasive plant monitoring and control may be necessary to prevent gradually increasing infiltration by non-native plant species and elimination of very rare plant species. Based on preliminary experience, the level of active management necessary, including surveillance for new threats, is achievable.

Some conservation biologists in Hawaii argue that too much emphasis in the total conservation effort is placed upon research and management of individual rare species. Ultimately almost nothing will be safe in the long run without active ecosystem management, given the progressive pervasiveness of feral pigs into the forest and the continuing associated onslaught of non-native plants. Research and management of rare species is crucial, but much more must be done to protect large ecosystem tracts from pigs and weeds if a substantial part of Hawaii's biological diversity is to be preserved in the long run.

Continuing research is needed 1) to understand the biology and impacts of invasive species; 2) to provide the tools needed to manage the most destructive invasive species; and 3) to provide the tools for ecological restoration.

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Alien Species and the Extinction Crisis of Hawaii's Invertebrates

by

Adam Asquith

In 1962, Rachel Carson eloquently and convincingly argued that the intensive and widespread use of pesticides was resulting in the pollution of ecosystems, declines in wildlife, and human health problems. These poisons were primarily insecticides used against what she called "an avalanche" of resistant insects. Most people share this concept of insects and other invertebrates as a natural disaster (Kellert 1993), and concerns for invertebrate conservation seem almost oxymoronic. Even the Endangered Species Act withholds protection for any insect viewed as a significant pest. There has never been a documented invertebrate extinction from pesticides (Howarth 1991), but, as is often the case, where our technology fails our bumbling and perseverance succeed. Like mud tracked across a living room floor, as humans perambulate, roll, sail, and fly across the face of the earth, we scatter other organisms into areas they don't belong. For example, over 2500 alien arthropods are now established in Hawaii (Howarth 1990, Howarth et al. 1995, Nishida 1992), with a continuing establishment rate of an appalling 10-20 new species per year (Beardsley 1962, 1979). Unlike chemicals, established alien organisms are permanent, they propagate, and they disperse. The visual result is a homogenization of the biological landscape. The often unseen result is the disappearance of native species, including invertebrates, due to predation, competition and associated diseases of the alien organisms. In this article, I describe how the introduction of alien species into the Hawaiian Islands has resulted in an almost unimaginable decline and extinction of invertebrates, and repercussions on the ecosystems.

Unique Fauna Susceptible to Invasions

Continents typically have large, diverse faunas and comparatively low establishment rates of alien species, therefore ecological consequences of introductions are often small (Simberloff 1995), although there are many significant exceptions (OTA 1993). In contrast, island faunas are characterized by low species richness with the entire absence of certain groups, and many island species have lost competitive or antipredation adaptations (Howarth & Ramsay 1991, Paulay 1994). These features seem to allow alien species to colonize islands more successfully and have major environmental impacts (Carlquist 1965, Simberloff 1995).

In general, more isolated islands have more disharmonic faunas and species with unusual characteristics (Howarth & Ramsay 1991).

Hawaii, over 3500 kilometers from any major land mass, is the most isolated island group on earth, and has a correspondingly unusual invertebrate fauna derived from relatively few successful colonists (Simon et al. 1984). For example, only 15% of insect and snail families are represented in Hawaii (Howarth 1990, Solem 1990); one hears no cicadas, sees no lightning bugs, nor originally would have felt the bite of any mosquito, or lost garden plants to slugs. Successful colonizing groups frequently lose characters common in their continental ancestors, and move into ecological niches normally occupied by other groups, thus,

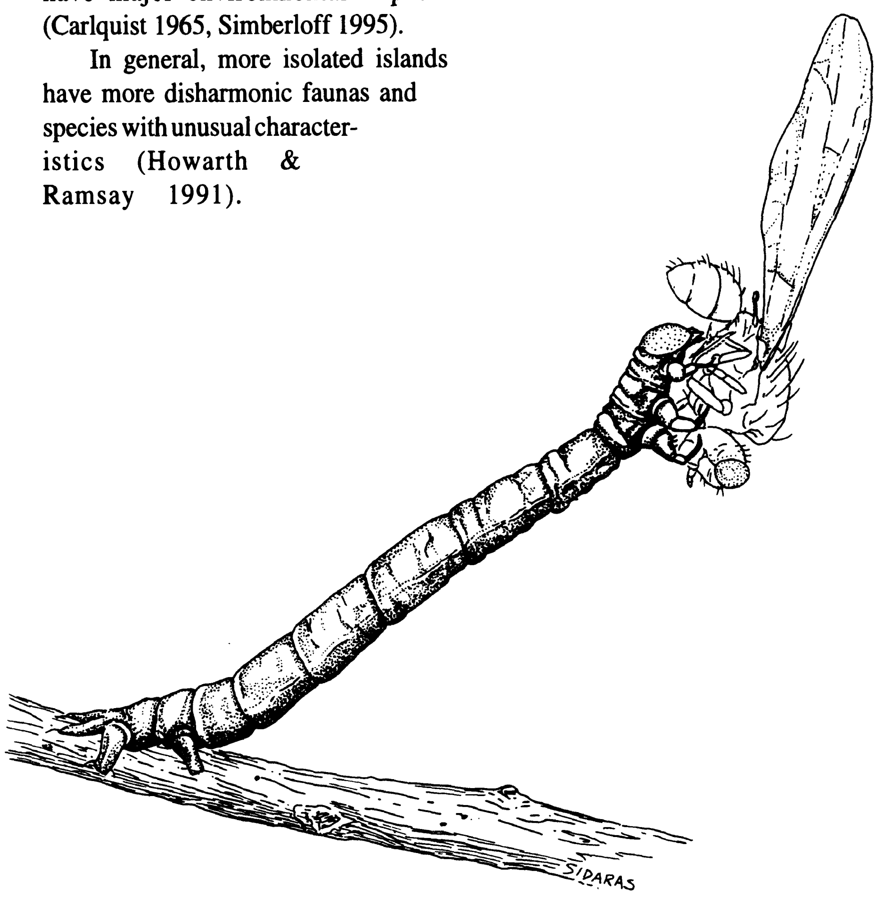

Figure 1. The Hawaiian carnivorous inchworm, *Eupithecia scoriodes*, one of several fly-eating caterpillars in Hawaii. Illustration by Nanci Sidaras.

Hawaii has flies with no wings, stink bugs with no stink, snails with no shells, and caterpillars that eat flies (Figure 1).

Rather than receiving species from elsewhere, Hawaii's fauna tends to be home grown, with *in situ* speciation occurring rapidly (Carson 1983) and over very small geographic distances (Otte 1994). It has also allowed spectacular radiations in some lineages, with over 500 species of *Drosophila* flies and *Hyposmocoma* moths, and at least 9 other genera that contain over 100 species (Howarth 1990). Hawaii's snail fauna is considered to be the most diverse and unique on earth, with over 1000 endemic species (Solem 1990). With the end of Hawaii's isolation, however, a process of mass extinction began that is rapidly dismantling this archipelago's invertebrate showcase of insular evolution (Zimmerman 1970, Howarth and Ramsay 1991).

Human Impacts on Native Fauna

Human occupation of the Hawaiian islands began with the arrival of the Polynesians about A.D. 400. Largely through agricultural activities, Polynesians extensively altered Hawaii's dry forests, shrublands, and mesic valleys, severely impacting its vegetation, birds, land snails, and probably arthropods (Kirch 1982, Olson & James 1982, Cuddihy & Stone 1990). But Polynesians introduced fewer than 60 plants and animals, and only the Polynesian rat (*Rattus exulans*) likely had much of an effect on flightless arthropods and land snails. After the arrival of Captain James Cook in 1778, Hawaii's invertebrates continued to suffer from direct habitat loss in low elevations due to humans, and also from the direct and indirect effects of a burgeoning assemblage of alien species. Goats, cattle, horses, sheep, deer, and pigs were introduced in the 1800's and established large feral populations. These animals destroy vegetation by browsing and trampling root systems, and facilitating the dispersal of alien weeds (Stone 1985) such as strawberry guava (*Psidium cattleianum*), Koster's curse (*Clidemia hirta*), blackberry (*Rubus* species), lantana (*Lantana camara*), and fountain grass (*Pennisetum setaceum*). These species invade disturbed areas and compete with native species or increase the frequency of fires (Smith 1989, Stone et al. 1992). The impacts of large mammals and alien plants on Hawaiian ecosystems are well documented (Stone & Scott 1985, Cuddihy & Stone 1990) and native invertebrates disappear as their habitats are lost (Foote & Carson 1995).

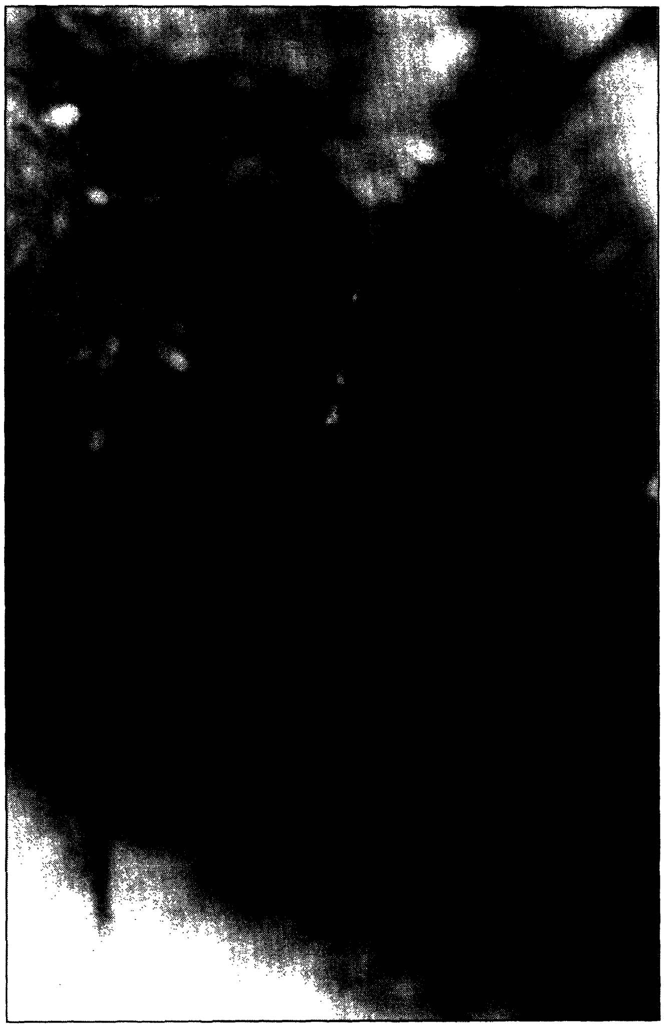

Figure 2. Three endemic Hawaiian species of the plant bug *Engytatus* are each restricted to a different species of endangered plant. Photo by William P. Mull.

The best documented decline of a Hawaiian invertebrate is among snails due to the preservation of their shells and their popularity among early naturalists. The genus *Carelia* was endemic to the island of Kauai and contained Hawaii's largest land snails, some with shells over 85 mm long. The last living specimen was seen in 1950 and all 12 or more species are now believed extinct (Solem 1990). In fact, all the 300+ species of Amastridae, a family of predominately ground dwelling snails endemic to Hawaii, may now be extinct (S. Miller, USFWS, Pacific Islands Office, pers. comm. 1995). This loss of higher level taxa is comparable to other mass extinctions in earth's history (Jablonski 1991) only this one is occurring in a geological blink of an eye.

The extinction of Hawaiian arthropods from alien species-induced habitat loss has undoubtedly been even greater, but most have left no trace of their existence. A mass arthropod extinction that was at least partly documented occurred on the small (ca. 5 km sq.) island of Laysan in the northwestern part of the Hawaiian archipelago. Rabbits were introduced to Laysan about 1903 and were not exterminated until 1923 (Ely & Clapp 1973). In that time, the rabbits almost completely devegetated the island. While much of the vegetation subsequently recovered at least 10 endemic phytophagous insects went extinct. Many Hawaiian arthropods may be more susceptible to extinction than other species because they are more provincial and more ecologically specialized. For example, the extinct weevil, *Rhyncogonus bryani* was restricted to Laysan and fed exclusively on *Chenopodium oahuense*. While the plant was decimated, it is now recovering on Laysan and also occurs on numerous other Hawaiian islands. The weevil, however, did not survive the severe reduction of its host plant.

While more difficult to document, the main Hawaiian Islands have also suffered innumerable extinctions of phytophagous insects. Over 100 species of Hawaiian plants are known to be extinct (USFWS 1994) and over 100 more plant extinctions probably went undocumented (L. Mehrhoff, USFWS, Pacific Islands Ecoregion, pers. comm., 1995), along with their compliment of host specific insects. In 1917, a new species of *Proterhinus* weevil was collected from the last remaining tree of *Hibiscadelphus giffardianus* on the island of Hawaii. While the tree has been given a reprieve from extinction by propagation of individuals from seed, the weevil, which breeds in senescent branches, was doomed with the death of the last wild tree. Members of the plant bug genus *Engytatus* typically live on sticky or hairy plants (Figure 2). In Hawaii, three undescribed species are each restricted to a different species of endangered plant. While these plants may recover in the wild, or at least be artificially propagated, it is unlikely that their associated insects will survive such a severe decline in their specialized habitat.

Going Quietly Into That Good Night

Other alien species have a more direct, yet less visible effect on Hawaiian invertebrates (Howarth & Medeiros 1989). Any tropical biologist will tell you that while the lion may be the king of the jungle, the ant is most certainly the queen. Ants and other social insects frequently dominate the ecologies of tropical ecosystems and strongly influence the evolution of certain plants and animals. The Hawaiian invertebrate fauna evolved without the influence of ants or social wasps, and their arrival has been devastating.

Ants can be particularly destructive predators because of their high densities, recruitment behavior, aggressiveness, and broad range of diet (Reimer 1993). These attributes allow some ants to affect prey populations independent of prey density, and ants can therefore locate and destroy isolated populations and individuals (Nafus 1993). At least 36 species of ants are known to be established in the Hawaiian Islands, and particularly aggressive species have had severe effects on the native insect fauna (Zimmerman 1948). By the late 1870's, the big-headed ant (*Pheidole megacephala*) was present in Hawaii and its predation on native insects was noted by the early Hawaiian naturalist R.C.L. Perkins (1913) "It may be said that no native Hawaiian Coleoptera insect can resist this predator, and it is practically useless to attempt to collect where it is well established. Just on the limits of its range one may occasionally meet with a few native beetles, e.g.—species of *Plagithmysus*, often with these ants attached to their legs and bodies, but sooner or later they are quite exterminated from these localities." With few exceptions, native insects have been eliminated from areas where the big-headed ant is present (Perkins 1913, Gagne 1979, Gillespie & Reimer 1993), and it has been documented to completely exterminate populations of native insects. It has also been implicated in the extinction of the endodontid land snail fauna in Hawaii and on other Pacific islands (Solem 1990).

The Argentine ant (*Iridomyrmex humilis*) was discovered on the island of Oahu in 1940 and is now established on all the main islands. Unlike the big-headed ant, the Argentine ant is primarily confined to higher elevations (Reimer et al. 1990). This species has been demonstrated to reduce populations or even eliminate native arthropods at high elevations in Haleakala National Park on Maui (Cole et al. 1992). While this species does not disperse by flight, colonies are moved about with soil and construction material, and a colony was recently discovered on an isolated peak on the island of Oahu under a radio tower. Numerous other ant species are recognized as threats to native invertebrates (Figure 3), and additional species become established yearly, including one new ant which was discovered in Hawaii while this article was being written (N. Reimer, Hawaii Dept. of Agriculture, pers. comm., 1995).

Another group of social insects that are voracious predators and were originally absent from Hawaii are yellowjacket wasps (Hymenoptera: Vespidae). In 1977, an aggressive race of the western yellowjacket (*Paravespula pennsylvanica*) became established in Hawaii and is now abundant at most higher elevations (Gambino et al. 1990). In Haleakala National Park on Maui, yellowjackets were found to forage predominantly on native arthropods (Gambino et al. 1987, Gambino & Loope 1992). Overwintering yellowjacket colonies in Hawaii can produce over half a million foragers that consume tens of millions of arthropods, and there is evidence for localized reduction in native arthropod abundance (Gambino & Loope 1992). The establishment of this species on the island of Hawaii corresponded

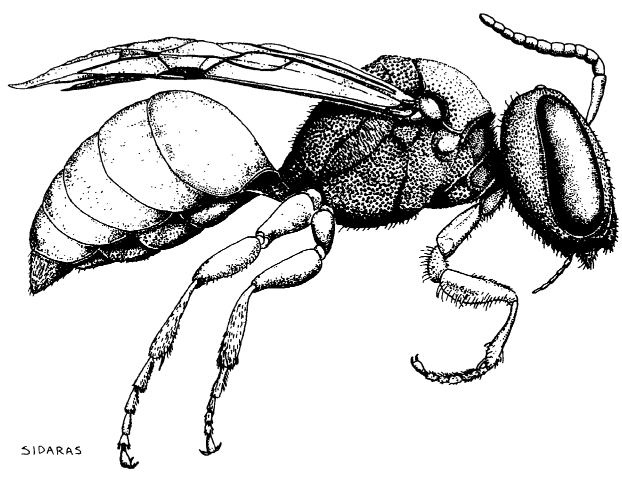

Figure 3. The Hawaiian yellow-faced bee, *Nesoprosopis volcanicus*, currently threatened by non-native ants, including the Argentine ant. Illustration by Nanci Sidaras.

with a significant decline in some species of endemic *Drosophila* flies (Carson 1986).

Hawaii has only a handful of freshwater fishes, and all but one are predominantly herbivorous. The aquatic stages of Hawaii's endemic *Megalagrion* damselflies, therefore, evolved largely in the absence of fish predation. Particularly on the populous island of Oahu, native damselflies which could be found in the city of Honolulu only 10 years ago (Figure 4) have now virtually disappeared. Most populations now occur only in remote stream drainages or at high elevations. This decline in native damselflies was associated with a proliferation of the aquarium fish trade in Hawaii (Devick 1991), because fish hobbyists sometimes release these pets into the wild where they become established. Freshwater aquatic habitats on Oahu are now choked with 45 varieties of alien fish, from guppies and swordtails to armored catfish, needlefish and even piranha (Devick 1991). Hawaii's damselflies have succumbed to this onslaught and six species are now candidates for Federal listing.

I Know an Old Lady who Swallowed a Spider

Classical biological control involves the purposeful release of a predator or parasite into a novel area to control a pest species. Hawaii has long been active in classical biological control, and between 1890 and 1985, 243 alien species were introduced, sometimes with the specific intent of reducing populations of native Hawaiian organisms (Funasaki et al. 1988, Lai 1988). The endangered Oahu tree snails in the genus *Achatinella* (Figure 5) were experiencing declines and extinctions due to habitat loss and overcollecting since the arrival of the Polynesians (Hadfield 1986), but the *coup de grace* was delivered from a biological control agent. In 1956, the predatory snail, *Euglandina rosea*, was introduced from Florida to Hawaii as a biological control agent for the giant African snail, *Achatina fulica*. While it has not been demonstrated to control the target pest, it has been documented to completely exterminate populations of endangered *Achatinella* (Hadfield et al. 1993). This predator is slowly reaching the last, isolated populations of *Achatinella* high in the Koolau Moutains of Oahu, and is now even foraging in streams, threatening Hawaii's endemic freshwater snails (Kinsey 1992).

Hawaii's insects have also suffered extensively from biological control. For example, the Koa bug (*Coleotichus blackburniae*) is Hawaii's largest and most spectacular native true bug. Historically, the koa bug was known from all the major Hawaiian islands and was easy to observe because hundreds of individuals could sometimes be seen on a single tree. Until the 1960's, the Koa bug was a very common insect and could frequently be found on koa trees within the city of Honolulu. In 1962, several parasites were released in Hawaii to control a pest stink bug (*Nezara viridula*), despite the fact that laboratory tests demonstrated that they would also attack the native koa bug (Davis 1964). Subsequent field observations confirmed that some of these parasites were attacking koa bugs in the wild (Howarth 1983). The koa bug is now extremely rare (Howarth et al. 1995) and the spectacular aggregations of this insect may never be enjoyed by future generations.

Hawaii's forest are also polluted with parasites introduced for control of pest Lepidoptera (Howarth et al. 1995). The effects of these parasites may not be limited to direct impacts on the native Lepidoptera fauna (Gagne & Howarth 1985), but may have also contributed to the degradation of an entire ecosystem. Prior to the purposeful introduction of these parasites, almost every year the koa forests on at least Hawaii and Maui islands experienced partial defoliation from the native koa moth caterpillars (*Scotorythra paludicola*) (R.C.L. Perkins, in Swezey 1926). During these periods the caterpillars were an important food source for birds, as observed by Perkins (1913) "Native birds attracted in thousands by the abundance of this [caterpillars], one of their favorite foods, were gorged to repletion, and the starving caterpillars formed in writhing masses on the ground beneath the tall koa trees. The dropping of excrement from the trees on the dead leaves made a rattling noise as of a hailstorm." Protein provided by insect prey can be the limiting factor in the breeding success of birds (Martin 1987, Boutin 1990), and Rodenhouse and Holmes (1992) demonstrated a reduction in the reproductive success of warblers resulting from a decline in the caterpillar prey base. Now

Figure 4. Hawaiian *Megalagrion* damselfly. Several species are now rare due to predation by alien aquatic species such as aquarium fish. Photo by William P. Mull.

only rarely (1926, 1953, 1977, and 1982) do Hawaiian koa forests experience any defoliation because the koa moth is under "complete biological control" from alien parasites (Lai 1988). The increased parasite pressure on this species has apparently restricted these normal, seasonal population increases. The elimination of this important food source may be a contributing factor to the decline of Hawaii's forest birds (Banko 1978, Gagne 1981), and the ecological functions they served as pollinators and seed dispersers (Carlquist 1980, Cox 1983, Lammers & Freeman 1986).

Saving The Little Things that Run the World

Even when convinced of the mass extinctions occurring among Hawaii's invertebrates, resource managers frequently point out that limited conservation resources need to be allocated to higher priority species. But it is ecologically indefensible and shortsighted to attempt to manage for the conservation and recovery of species without considering the other organisms which constitute the biological components of the ecosystem (USFWS 1994). For example, both species in the endemic Hawaiian plant genus *Brighamia* are listed as endangered. While these taxa are easily propagated, wild plants must be hand pollinated because the natural pollinator, a moth, is extinct. Thus, we can win battles by fencing a natural area, pulling weeds, and shooting pigs, but unless the conservation needs of **all** the organisms are addressed, we will still lose the war for the forest. Invertebrates are the glue that hold Hawaii's ecosystems together.

What can we do? First we must recognize that management of natural areas and ecosystems will require inclusion of organisms in addition to plants and birds. We need to develop sophisticated chemical and pheromone controls for predatory snails, yellowjacket wasps and other alien invertebrate species. We must cooperate with the appropriate Federal and State agencies to slow or stop the influx of additional alien species. Finally, we must recognize that the purposeful introduction of alien organisms is one of our most powerful technologies, and mistakes are irreversible and sometimes devastating (Howarth 1983, 1991). Present Federal laws regulating the release of invertebrate biocontrol agents are ambiguous and insufficient (Miller & Aplet 1993). The State of Hawaii review process presently excludes most Federal and private agencies charged with management of natural resources in Hawaii. In 1995, Hawaii's silent spring is occurring not because increasing chemical usage can't kill invertebrates, but because poorly regulated transportation and biological technologies can.

Figure 5. The *Achatinella* tree snail. All the remaining species of this genus are now endangered and further threatened due to an intentional introduction for biological control purposes. Photo by Stephan Miller.

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Ten Ways to Fix the Endangered Species Act

By Edward C. Beedy

In 15 years as a professional wildlife biologist, I have worked on a large number of projects where the Endangered Species Act (ESA) played a central role, including cases involving the California gnatcatcher, San Joaquin kit fox, California spotted owl, and a variety of other special-status species. In my professional work and in local conservation activities I have heard many of the concerns and conflicts that private developers, loggers, farmers, and oil companies commonly express regarding the ESA.

I have asked my clients and professional biologists working at our and other private consulting firms, universities, and in state and federal agencies to list the primary problems they have encountered with the ESA. Based on my informal surveys, the most persistent problems with the ESA occur during its implementation. Most of these problems could be corrected administratively and with clear direction from Congress. Make no mistake: we need a strong ESA to prevent the extinction of many declining species of native plants and animals. During the past 25 years, the ESA has prevented the extinction of many species and has promoted the recovery of many others such as bald eagles, American peregrine falcons, brown pelicans, and California gray whales. In my view, proposals to severely weaken the ESA will create more, not fewer, conflicts over endangered species.

The ESA requires careful revision to ensure that it protects our biological heritage that Americans still strongly value, while treating all citizens in a fair, reasonable, and respectful manner. Following are ten suggestions for revising the ESA to provide more certainty about its implications for landowners while preserving the act's essential function of preventing the extinction of threatened and endangered species.

1) Facilitate Landowner Participation in Recovery Efforts

Landowners should be encouraged to create and maintain habitat for listed and candidate species through tax credits, hold harmless agreements, and other incentives. If society values the preservation of habitat for declining species on private lands, it should be willing to reward landowners for protecting these resources. Currently, landowners are penalized for harming endangered species and their habitats, but the ESA offers no direct incentives for preserving or enhancing these habitats on private lands.

Most landowners enjoy wildlife and plants and want to maintain them on their property. Examples of financial incentives that could be offered to landowners willing to preserve sensitive habitats include conservation easements, mitigation credits, tax deductions, and reduced inheritance taxes. A system of financial rewards would encourage willing landowners to protect and enhance sensitive habitats, and they would facilitate collaboration between landowners, biologists, and regional planners to ensure that the best available scientific data are incorporated into the planning process. By reducing the level of conflict, an incentive based system may also reduce demands for compensation for decreased land values resulting from implementation of the ESA.

2) Eliminate Critical Habitat Designations

The ESA defines "critical habitat" as specific areas that are essential to the conservation of the species and lands that may require special management consideration or protection. For most listed species, however, critical habitat has not been formally designated. Such designations require significant U.S. Fish and Wildlife Service (USFWS) staff time to prepare and defend, and they provide no substantial benefits after the initial listing has occurred. The USFWS regulations that define "take" include significant habitat modification or degradation, without regard to whether the habitat has been designated as critical habitat. Therefore, for all practical purposes, the ESA's critical habitat provisions add nothing to the protection of listed species and are redundant.

For rare, but widespread species, such as the desert tortoise, southwestern willow flycatcher, and least Bell's vireo, designated critical habitats may include some unoccupied habitat areas. In contrast, other undesignated, but occupied, areas offer equivalent habitat values and may be just as worthy of protection.

Critical habitat designations on private property have the potential to restrict land uses and to reduce property values. For these reasons, most landowners usually oppose such designations, often through litigation. Eliminating this provision of the ESA would not jeopardize the future existence of any species, and it would reduce unnecessary conflicts and concerns for private landowners. Many USFWS personnel agree that critical habitat designations have done little to protect the target species and that they have generated a large amount of unnecessary litigation.

If endangered species were only protected on critical habitats, and not on other lands, substantial losses of existing habitat could occur without adequate scientific review. Further, there would be no incentives for biologists to search for undiscovered populations of endangered species outside critical habitat areas. Discovery of new populations could provide a scientific basis for delisting species that may not qualify for future listed status.

3) Refine the Definition of Potential Habitat

The term "potential habitat" is not rigorously defined under the ESA, but the term is used frequently by USFWS personnel to require mitigation. Definitions of this term should accurately reflect the importance of a specific habitat for a target species. For example, a recently occupied peregrine falcon eyrie or bald eagle nest is potential habitat, while an isolated, unoccupied patch of coastal sage scrub may not meet the habitat requirements of California gnatcatchers.

The term potential habitat should only apply to habitat that is considered suitable in its current state, and is within reasonable proximity of occupied habitat to promote the recovery of the species. As described in the professional literature, suitable habitats are those that would be commonly used by the species for foraging, resting, or breeding. The term reasonable proximity is defined as the known dispersal capability of the species, based on scientific studies.

4) Establish Specific Criteria for Listing and Delisting Species

USFWS should publish specific criteria in the Federal Register defining what endangerment means for the proposed species before, or as part of, the listing decision. For example, such criteria could identify the percentage of the historical range that is currently occupied by the species, or it could specify the number of populations or individuals below which a species would meet the definition of either threatened or endangered. Such criteria could include specific thresholds, or a range of published values, depending on the reproductive potential and dispersal capabilities of the proposed species. Most important, definitions of threatened or endangered status identified during the listing process should also provide guidance for the appropriate population levels for recovery and delisting of the target species.

5) Develop Recovery Plans within One Year of Listing

The recovery plans for individual listed species should be funded and prepared on a fixed time schedule to ensure that clear goals for recovery are defined at an early stage. This could be accomplished by specifically earmarking funds and assigning specific USFWS personnel to recovery planning and implementation. The goal would be to prepare recovery plans within one year of the listing decision; if this deadline is not met, USFWS should be directed to prepare a report describing the status of the recovery effort and what additional funding would be required to complete the plan.

Current staffing at USFWS is inadequate to prepare recovery plans for more than a small fraction of the listed species that they are assigned to monitor. Preparation of good recovery plans requires extensive time, energy, and cooperation; therefore, without a significant increase in funding, the plans simply will not be prepared for most species. Lack of adequate recovery plans will increase the public's frustration over endangered species management because clear goals will not be identified and recovery will rarely be achieved. These conflicts could be resolved if USFWS was provided with sufficient funding to prepare recovery plans.

6) Assess Take at a Population Level

The definition of "take" under Section 9 of the ESA includes any loss of individuals of listed species. This provision of the ESA needs to be made more flexible to ensure that it recognizes that species with different reproductive strategies vary in their sensitivity to disturbance and population losses. The definition of take should be revised so it does not focus on individuals, but rather includes demonstrable adverse effects on populations.

For many species, such as bald eagles, California condors, and Florida panthers, loss of a single individual or breeding pair could have significant effects on their local, regional, or global populations. Many other listed vertebrates and some invertebrates are similarly vulnerable to extinction, and current incidental take requirements appropriately reflect the need to protect individuals and local populations.

At the other end of the spectrum, many plants, invertebrates, and some fish species are not vulnerable to the losses of individuals from their populations. Unlike most vertebrates, these organisms may produce thousands of progeny per reproductive pair or individual. Thus, for these species, the loss of a single individual would have no population effects as long as their habitats are intact. For example, a taking of one or several fairy shrimp would not jeopardize the continued existence of the species, as long as its vernal pool habitat remains intact.

7) Develop an Administrative Appeals Process within USFWS

The ESA needs to provide clearly defined mechanisms and deadlines for the public to appeal USFWS decisions, similar to the process that currently exists in the U.S. Forest Service. Such an administrative process would enable the public to appeal important decisions made by USFWS staff to higher authority personnel at regional and national levels within USFWS. Much current litigation regarding USFWS actions could be avoided by providing scientifically based administrative solutions to conflicts over listing recommendations, biological opinions, and mitigation requirements.

8) Streamline the Process for Obtaining Scientific Permits

Specific deadlines should be required to ensure that all scientific permits for endangered species are issued on a timely schedule. The current shortage of USFWS personnel often results in needless and lengthy delays in obtaining permits to conduct surveys for certain listed species. Project delays of up to a year are not uncommon due to USFWS processing survey permits; such delays often translate into increased costs for project proponents. Possible ways to facilitate the permitting process include increased staffing and funding of more positions at USFWS to handle the heavy work load, and giving the regional and local offices the authority to issue permits.

9) Streamline the Section 10(a) Process to Parallel the Section 7 Process Available to Federal Agencies

USFWS has recently developed guidelines to streamline the Section 10(a) process, which legally authorizes the incidental taking of listed species on private land through preparation of a Habitat Conservation Plan (HCP).

Some of the concepts in the recent draft USFWS guidelines include less detailed planning and environmental documentation to streamline the HCP process for "low effect" projects. This streamlining, however, has been limited by existing administrative regulations and agency interpretations of ESA requirements. The HCP process, therefore, is usually lengthy and expensive. In addition to detailed biological studies, it typically requires extensive negotiations among landowners, local governments, and resource agencies. Several years of negotiation may be required to complete the process, and many important HCPs languish for lack of direction or consensus.

Compared to the HCP process, Section 7 consultations are far easier and less costly to implement. Section 7 of the ESA permits the incidental take of listed species for projects with federal funding, on federal land, or with other federal involvement. These consultations require the project proponent to prepare a biological assessment for review by USFWS. Within a specified time, USFWS must issue a biological opinion that reviews the project and determines whether it will be likely to jeopardize the continued existence of any listed species. The biological opinion also identifies the incidental take of listed species that is permitted by the project. For many projects, the entire process can be completed within a few months.

Because such Section 7 consultations are faster and less expensive, many project proponents design their projects to include federal land so that their ESA requirements can be met under Section 7, rather than under Section 10(a). Long delays and increased costs are fundamentally unfair to private landowners because the ESA mandates stricter requirements for private land than those that exist for federal land. Section 10(a) of the act should be streamlined to create parallel processes for ESA consultations on both private and public lands. The streamlined process in the current guidelines should be codified and expanded in the ESA to limit delays for projects with low effects. These revisions should be built into legislation, with adequate funding and mandated response times for agencies.

10) Encourage Multispecies Planning Efforts

Despite the unnecessarily strict requirements of the Section 10(a) process, preparation of large, multispecies protection plans, such as HCPs, offers the greatest opportunities to recover populations of declining species and to promote biodiversity. The objective of multispecies plans is also consistent with the stated goals of the ESA: ". . . to provide a means whereby the ecosystems upon which endangered species and threatened species depend may be preserved . . .". Such efforts should include broadly based citizen groups to evaluate the proposed plans; the task of making environmental policy should not be the exclusive province of taxonomists and other biologists.

Initial HCP efforts were limited to a single listed species and were project specific. Most recently proposed HCPs, however, have the objective of comprehensive regional protection of several species, both listed and unlisted. Overall, project-specific, single-species HCPs tend to be less successful at preserving endangered species habitat because they often result in piecemeal, fragmented mitigation parcels.

In contrast, regional, multispecies HCPs enable long-range planning efforts that have the potential to preserve a high diversity of declining species simultaneously. Coordinated multispecies planning efforts also provide landowners with more predictability in land use planning and more incentives to participate in preserving endangered species and their habitats for future generations.

Dr. Beedy is a professional wildlife biologist for Jones & Stokes Associates, an environmental consulting firm based in Sacramento, CA. He has taught at the University of California at Davis and California State University in Sacramento and has published several works on the distribution of birds in the Central Valley and Sierra Nevada.

Bulletin Board

UPDATE and Other Endangered Species Information Online

EE-Link, a source of information for K-12 environmental educators on the Internet providing instructional materials, curriculum directories, organizational contacts, and grant information, has created and compiled substantial information resources dealing with endangered species. The resources created include a directory about endangered species factsheets, a clickable map linking states to the listed species there, two small image databases of endangered species, and a hypertext version of a curriculum plan for middle school students called "Birds: Our Environmental Indicators." Resources compiled include information on endangered species legislation, contact information for congressional representatives, and directories for lesson plans and projects.

Find EE-Link's Endangered Species on WWW at: <http://www.nceet.snre.umich.edu/EndSpp/Endangered.html>. The site containing information from the UPDATE can be found at <http://www.nceet.snre.umich.edu/ESupdate/ESupdate/about.html>.

EE-Link is a project of the National Consortium for Environmental Education and Training. For more information, call (313) 998-6727, or email <eelink@nceet.snre.umich.edu>.

New Southeast Wetlands Report

The U.S. Fish and Wildlife Service, in conjunction with the U.S. EPA, has published *Southeast Wetlands: Status and Trends, Mid-1970's to Mid 1980's.* This 33 page document examines the loss of wetlands on a regional and state-by-state basis, and looks at causes and effects of the losses. It can be purchased from the U.S. Government Printing Office by writing to Superintendent of Documents, Mail Stop: SSOP, Washington, DC 20402-9328.

Call for Proposals

The Center for Field Research (CFR) invites proposals for 1996 field grants awarded by its affiliate Earthwatch. Field grants, which average $20,000, cover the cost of maintaining volunteers and principal investigators in the field and possibly other field expenses. Preliminary proposals should be submitted 13 months in advance of the field dates; full proposals are invited upon review of preliminary proposals.

For more information contact Dee Robbins, Life Science Program Director, The Center for Field Research, 680 Mt. Auburn Street, Watertown, MA 02172; phone (617) 926-8200.

Mailing List Exchange

The Endangered Species UPDATE may occasionally exchange mailing lists with other organizations whose values and goals we feel are compatible with our own. Readers may have their names removed from the exchange list at any time, at their request. Please call or write the UPDATE office if you would like to have your name withheld.

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Eric Lane has left the UDPATE to take a summer position with The Nature Conservancy in Boulder, CO. His talents and efforts, which are largely responsible for much of this and other issues, will be greatly missed. We wish him well in his work with TNC.

Announcements for the Bulletin Board are welcomed. Some items from the Bulletin Board have been provided by Jane Villa-Lobos, Smithsonian Institution.

Endangered Species UPDATE

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