CENTER FOR BIOLOGICAL DIVERSITY

Protecting endangered species and wild places through science, policy, education, and environmental law.

Candidate Petition Project

INSECTS

PETITIONS TO LIST AS FEDERALLY ENDANGERED SPECIES

The following document contains the individual petitions for the 27 insect species and 1 arachnid species to be listed as federally endangered species under the federal Endangered Species Act.

Holsinger's cave beetle	***Pseudanophthalmus holsingeri***
Warm spring zaitzevian riffle beetle	***Zaitzevia thermae***
Wekiu bug	***Nysius wekiuicola***
Mariana eight-spot butterfly	***Hypolimnas octucula mariannensis***
Mariana wandering butterfly	***Vagrans egestina***
Sequatchie caddisfly	***Glyphopsyche sequatchie***
Clifton cave beetle	***Pseudanophthalmus caecus***
Lesser Adams cave beetle	***Pseudanophthalmus cataryctos***
Icebox Cave beetle	***Pseudanophthalmus frigidus***
Surprising cave beetle	***Pseudanophthalmus inexpectatus***
Inquirer cave beetle	***Pseudanophthalmus inquisitor***
Beaver Cave beetle	***Pseudanophthalmus major***
Greater Adam's cave beetle	***Pseudanophthalmus pholeter***
Tatum cave beetle	***Pseudanophthalmus parvus***
Louisville cave beetle	***Pseudanophthalmus troglodytes***
Blackline megalagrion damselfly	***Megalagrion nigrohamatum nigrolineatum***
Crimson Hawaiian damselfly	***Megalagrion leptodemas***
Flying earwig Hawaiian damselfly	***Megalagrion nesiotes***
Oceanic Hawaiian damselfly	***Megalagrion oceanicum***
Orangeblack Hawaiian megalagrion damselfly	***Megalagrion xanthomelas***
Pacific Hawaiian megalagrion damselfly	***Megalagrion pacificum***
Po'olanui gall fly	***Phaeogramma sp.***
Pomace fly	***Drosophila attigua***
Pomace fly	***Drosophila digressa***
Highlands tiger beetle	***Cicindela highlandensis***
Warton cave meshweaver	***Circurina wartoni***
Stephan's riffle beetle	***Heterelmis stephani***

Main Office: PO Box 710 • Tucson, AZ • 85702-0710
PHONE: (520) 623-5252 • FAX: (520) 623-9797 • WEB: www.biologicaldiversity.org

PETITION TO LIST

Holsinger's cave beetle
(*Pseudanophthalmus holsingeri*)

AS A FEDERALLY ENDANGERED SPECIES

CANDIDATE HISTORY

CNOR 1/6/89
CNOR 11/21/91
CNOR 11/15/94
CNOR 2/28/96: C
CNOR 9/19/97: C
CNOR 10/25/99: C
CNOR 10/30/01: C
CNOR 6/13/02: C

TAXONOMY

The status of *Pseudanophthalmus holsinger* (Carabidae) as a taxonomically valid species is uncontroversial (e.g., Erwin 2002).

NATURAL HISTORY

P. holsingeri is a small, copper colored, eyeless cave-dwelling beetle, up to 4 millimeters long. It is known from just a single cave in southwestern Virginia. It is found on damp mud banks along the shallow cave stream and feeds on rotting wood, leaves, and other organic matter that naturally washes into the cave.

POPULATION STATUS

Reports concerning the populations of this beetle are inconsistent. Barr (1965) reported being unable to find any in November 1962 where eight had been collected in August. Later (Barr, 1981) he referred to the species as "relatively abundant".

The Virginia Natural Heritage Program ranks Holsinger's cave beetle as Critically Imperiled.

The U.S. Fish and Wildlife Service classifies Holsinger's cave beetle as a candidate for Endangered Species Act protection with a listing priority number of 5.

LISTING CRITERIA

A. ***The present or threatened destruction, modification, or curtailment of its habitat or range.***

Historical range:	Fugates Cave, Virginia.
Current range:	Fugates Cave, Virginia.
Land ownership:	100% privately owned. However, a linear park is planned near the species habitat, which could aid in its protection.

Two previous threats have been eliminated through conservation activities:
1) a highway widening project proposed to be constructed near the only cave occupied by this beetle, such that runoff would enter the sink at the cave entrance; and
2) a gas station located over the cave with a leaking underground fuel tank.

The U.S. Fish and Wildlife Service asserts that a third problem, raw sewage observed entering the cave from a house or houses located over the cave, is being worked on (U.S. Fish and Wildlife Service candidate assessment form). Other threats to the species include potential non-point source pollution of the cave stream by animal manure, storm water runoff, and petroleum spills from a commercial petroleum storage facility.

B. ***Overutilization for commercial, recreational, scientific, or educational purposes.***

None known.

C. ***Disease or predation.***

None known.

D. ***The inadequacy of existing regulatory mechanisms.***

Existing laws to protect caves in Virginia and groundwater and surface water quality are not adequate to protect the species.

Current Conservation Efforts: The Virginia Department of Transportation modified a highway project to avoid impacting the beetle. A leaking gas tank located over the cave was removed, and dye tracing studies were conducted to identify the source of the sewage pollution.

E. ***Other natural or manmade factors affecting its continued existence.***

None known.

REFERENCES

Barr, Thomas B. and Stewart B. Peck. 1965. Occurrence of a troglobitic *Pseudanophthalmus* outside of a cave (Coleoptera:Carabidae). Amer. Midland Naturalist 73:73-74.

Barr, Thomas C. 1965. The *Pseudanophthalmus* of the Appalachian Valley (Coleoptera: Carabidae). Amer. Midland Naturalist 73:41-72.

Barr, Thomas C., Jr. 1981. *Pseudanophthalmus* from Appalachian caves (Coleoptera: Carabidae): the engelhardti complex. Brimleyana 5:37-94.

Erwin, T. 2002. Western Hemisphere Carabids Checklist (http://entomology.si.edu/Entomology/WstrnCarabids/search.lasso). Dept. of Systematic Biology (Entomology), Smithsonian Institution, Washington, D.C.

Holsinger, John. Unpublished data (species expert).

Hubbard, D.A. and W.M. Balfour. 1993. An investigation of engineering and environmental concerns relating to proposed highway construction in Karst terrane. Environmental Geology, 22:326-329.

PETITION TO LIST

Warm Springs zaitzevian riffle beetle
(*Zaitzevia thermae*)

AS A FEDERALLY ENDANGERED SPECIES

CANDIDATE HISTORY

CNOR 5/22/84	
CNOR 1/6/89	
CNOR 11/21/91	
CNOR 11/15/94	
CNOR 2/28/96:	C
CNOR 9/19/97:	C
CNOR 10/25/99:	C
CNOR 10/30/01:	C
CNOR 6/13/02:	C

TAXONOMY

Zaitzevia thermae is an extremely locally distributed riffle beetle (Elmidae).

NATURAL HISTORY

The small Warm Springs zaitzevian riffle beetle is flightless and wingless. It feeds on algae on the gravel bottom and among the vegetation and requires flowing water to breathe. It is endemic to the Bridger Creek Warm Springs near Bozeman, Montana. Warm Springs is on U.S. Fish and Wildlife Service property (Fish Technology Center). The surface area of the springs is approximately 35 square meters. Water temperature is likely the most influential factor in the species' biology. It requires surface flowing warm water 60-84° F; it attaches under rocks or clings to watercress (Hooten 1991).

POPULATION STATUS

The species is presumed to have occupied most of the available habitat in the warm springs. However, the available habitat has now been reduced to less than five square meters (see factor A below). Habitat destruction in 1993 may have severely impacted the population. The population must be monitored to determine its status. Recently, habitat that had been accidently buried was completely restored and the riffle beetles were doing well (U.S. Fish and Wildlife Service candidate assessment form).

The Montana Natural Heritage Program ranks the Warm Springs zaitzevian riffle beetle as Critically Imperiled.

The U.S. Fish and Wildlife Service classifies the Warm Springs zaitzevian riffle beetle as a candidate for Endangered Species Act protection with a listing priority number of 11.

LISTING CRITERIA:

A. *The present or threatened destruction, modification, or curtailment of its habitat or range.*

Historical range: Montana (Bridger Creek Warm Springs near Bozeman).

Current range: Montana (Bridger Creek Warm Springs near Bozeman).

Land ownership: 100 percent Federal ownership, under jurisdiction of U.S. Fish and Wildlife Service.

Early in the 1900s, a large cement water collection box was built around much of the springs. The species was still found within the box. In the 1970s a solid metal roof was put on the box, preventing all light from entering the box. Without light, the species' food, algae, did not grow, thereby eliminating the interior of the box as available habitat. The beetles were found only at the outside edge of the box and in a small portion of the spring nearby.

In1993, fill was placed outside the box and over the remaining spring, covering almost all of the remaining habitat. However, this fill has since been removed in an attempt to salvage *Z. thermae* habitat. Following the expansion and restoration of the habitat, the riffle beetle population was at an all time high (U.S. Fish and Wildlife Service candidate assessment form). The area is protected by a chain-link fence and posted "Government Property." In 1994, the U.S. Fish and Wildlife Service completed a Conservation Management Plan for this species and reduced the listing priority to 11 (i.e., moderate to low, non-imminent threat), a decision that should now be reassessed nearly a decade later. Improvements are planned (to be undertaken in Fall, 2002) to better protect this beetle’s habitat from silt, and the Conservation Management Plan will be updated (Greg Kindschi, USFWS Bozeman Fish Technology Center, *in litt.* August 2002).

B. *Overutilization for commercial, recreational, scientific, or educational purposes.*

Unknown.

C. *Disease or predation.*

Unknown.

D. ***The inadequacy of existing regulatory mechanism***

The Clean Water Act provides some measure of protection with regard to water quality, but accidental contamination of the spring is a threat.

Current Conservation Efforts: The U.S. Fish and Wildlife Service (Bozeman Fish Technology Center) completed a management plan for *Z. thermae* in 1994.

E. ***Other natural or manmade factors affecting its continued existence.***

Because of the extremely restricted habitat of *Z. therma*e, any contamination or hazardous substances running into the creek could impact the springs and therefore the beetle. For example, a well-used road runs along the creek on the shore opposite the springs. The potential exists for contamination of the spring if a vehicle crashed in the creek or if there was an accident on the road.

REFERENCES:

Hooten, M.M. 1991. Biological systematics of *Zaitzevia thermae* (Hatch). M.S. Thesis. Montana State University, Bozeman.

PETITION TO LIST

wekiu bug
(*Nysius wekiuicola*)

AS A FEDERALLY ENDANGERED SPECIES

CANDIDATE HISTORY

CNOR 10/25/99: C
CNOR 10/30/01: C
CNOR 6/13/02: C

TAXONOMY

The taxonomic status of *Nysius wekiuicola* (Lygaeidae) as a valid species is uncontroversial (e.g., Bishop Museum 2002).

NATURAL HISTORY

Morphology
Adult wekiu bugs are about 3.4 to 4.9 mm (0.13 to 0.19 in) in total length and 1.0 to 1.8 mm (0.039 to 0.07 in) in total width. The head is black, with pale reddish-brown median bars from the base of head to just short of the anterior eye margins. The pronotum is black, grayish-brown. The abdomen is black with pale lateral margins, and black legs (Ashlock and Gagne 1983). The wekiu bug is a unique component of the Mauna Kea aeolian ecosystem due to the evolution of its predatory habits. Excluding its close relative and Mauna Loa counterpart, *Nysius a'a* , the wekiu bug differs from all the world's *Nysius* species in its predatorial habits and unusual physical characteristics (Polhemus 1998). Furthermore, the bug is micropterous (possessing nearly microscopically small wings), has by far the longest, thinnest appendages in relation to body length of any lygaeid in the world, and the most elongate head as well. The wekiu bug may be the most unusual of the 106 worldwide species of *Nysius* (Ashlock and Gagne 1983).

In Hawaii, the genus *Nysius* is characterized by the following physical attributes: conspicuous pubescence and erect setae (hairs) which clothe the greater part of the dorsal surfaces; the breadth of the head across the eyes is less than the narrowest breadth of the pronotum (the plate covering the thorax); and the hind margins of the metapleura (side of thorax) are concave with the postero-lateral angle rounded off (Zimmerman 1948). Hawaiian *Nysius* also exhibit a wider range of characters than is exhibited.worldwide by *Nysius*. For example, the form of the bucculae (mouth), length of the beak, and shape of the costal margins are unreliable clues to identification

(Zimmerman 1948). In Hawaii, *Nysius* has radiated into over 26 endemic species that feed on the seed heads of native plants (Polhemus 1998).

Behavior

Most lygaeids are primarily seed feeders, earning the family nickname “seed bugs.” Although the order Hemiptera contains many predators, including entire families of predators, (e.g., Reduviidae), there are few carnivorous lygaeids (Borror et al. 1992).

The wekiu bug occupies a predator-scavenger niche on the top of Mauna Kea. It is most often found under rocks and cinders where it is active during the day, preying upon moribund and dead insects and even birds blown up from lower elevations. The presence of high altitude arthropods on Mauna Kea has been known since the 1920s (Bryan 1923, 1926, Swezey and Williams 1932, Wentworth et al. 1935, Usinger 1936, Gagne 1971), but it wasn’t until 1980 that *N. wekiuicola* and some other arthropods were identified as being resident predator-scavengers. In the field, the wekiu bug has been observed feeding upon adult lady beetles, upon recently dead adult syrphid flies, and as mentioned above, even dead birds. The wekiu bug has not been observed feeding upon other resident arthropods (Ashlock and Gagne 1983, Howarth 1997a).

Wekiu bugs, both larvae and adults, apparently remain active during winter months, and even exhibit activity at ambient air temperatures of minus 7 degrees Celsius (19 degrees Fahrenheit) (personal communication 1998 cited in U.S. Fish and Wildlife Service candidate assessment form). They use snow to their advantage by feeding on insects that are either kept fresh or immobilized by the cold when they are escorted by winds to the summit. Although difficult to establish, it is widely believed the wekiu bug has some obligatory association with snow and/or permafrost, the former for food, and the latter especially for year-round moisture. This would at least partly explain its restriction to higher elevations on Mauna Kea. Wekiu bugs are fairly susceptible to dehydration, which is probably related to their abdominal physogastricity (extreme swelling) exhibited after feeding (Ashlock and Gagne 1983).

Wekiu bugs will emerge from beneath the tephra where they live, to feed and mate when the sun has warmed the rock surfaces, particularly at the margins of snow fields. Apparently, they will remain along the narrow melting, outer perimeter of a snowfield to take advantage of any frozen insects which drop from the receding snowfield perimeter (Howarth 1997a). Should a shadow cross the sun when wekiu bugs are foraging in this warm, moist, food-rich habitat, they will quickly retreat deep into the tephra. Although not established with complete certainty, it is believed the distribution and biology of these bugs is strongly linked with the tephra cinder cones present on Mauna Kea’s summit (Ashlock and Gagne 1983). During most surveys up to now, tephra habitats have yielded the highest capture rates for these bugs. It is believed it utilizes the tephra to its benefit by migrating vertically through the interstitial spaces according to day and night or seasonal temperatures. Most likely, the bugs also safely follow shifting snowfield edges by means of these spaces between the lightweight tephra (Howarth 1997b).

Habitat

Aeolian ecosystems are characterized by a near lack of natural producers, a windborne supply of nutrient material, a few plants such as algae, mosses, and lichens, and by a community of mostly arthropod predators and scavengers evolved to feed on the windborne food supply. On Mauna

Kea's summit, the major faunal components include a flightless moth whose caterpillars feed on the lichens, a *Lycosa* wolf spider, a centipede that preys on moribund insects blown to the summit, and the unique, flightless wekiu bug (Howarth and Stone 1982).

At least six major habitat types can be recognized within this alpine ecosystem, and not all are suitable for each of the species (Howarth and Stone 1982): 1) Snow patches provide a moisture and food resource for all of the summit arthropods but are not directly utilized by any of the species, 2) tephra ridges and slopes on cinder cones are important habitat for the spider, the wekiu bug, and smaller arthropods such as springtails, 3) loose, steep tephra slopes with smaller cinders are not suitable habitat for the wekiu bug, 4) lava flows with large outcrops of andesitic rock are the primary habitat for the moth, the spider, and the centipede, but the wekiu bug is rare in this habitat due to the lack of suitable microclimate, 5) talus slopes and fractured rock outcrops are typically smaller areas that occur within areas of andesitic lava flows and are suitable habitat for the wekiu bug and, 6) compacted ash, silt, and mud along roadsides and in depressions. Because the interstitial voids among the cinders are filled, the aeolian arthropods cannot utilize this habitat (Howarth and Stone 1982).

The wekiu bug (*Nysius wekiuicola*) was first discovered in 1979 by F.G. Howarth, S.L. Montgomery, and W.P. Mull on Pu'u Wekiu, the summit cinder cone of Mauna Kea on the island of Hawaii. Wekiu is a Hawaiian word meaning tip, top , or summit, and the common name "wekiu bug" was selected in reference to the insect's habitat (Ashlock and Gagne 1983).

Distribution

The island of Hawaii today consists of five volcanic mountains. All are very young and three have been active in recent history (MacDonald et al. 1983). Mauna Kea is the highest of these volcanoes, rising 4,206 meters (m) (13,796 feet (ft)) above sea level. The surface lavas of this volcano are all younger than middle Pleistocene, and it has probably not been active during the last 2,000 years. During the Pleistocene epoch an ice cap existed on the summit of Mauna Kea, with at least four distinct glacial episodes during the last 300,000 years (Porter 1979). The most recent glacial event (the Makanapa ice cap) disappeared from Mauna Kea about 9,000 years ago, but permanent ice still exists in the cinder of the summit cones just a few feet below the surface (Woodcock 1974).

Presently, the summit of Mauna Kea above 3,000 m (9,843 ft) is an alpine lava community sparsely vegetated with growths of foliose lichens and the moss, *Racometrium lanuginosum* (Gagne and Cuddihy 1990). Prior to the 1980s, due to an apparent lack of vegetation, it was popularly believed the Mauna Kea summit was a lifeless alpine desert. One well-known astronomer was even quoted as saying "(the summit) is a lifeless, red-black jumble of lava blocks" (Waldrop 1981).

However, in 1979 with the discovery of the wekiu bug and subsequently into the early1980s, a whole aeolian community of arthropods was discovered at the summit (Mull and Mull 1980, Papp 1981, Gagne and Howarth 1982).

POPULATION STATUS

Since 1968, approximately 25 hectares (ha) (62 acres (ac)) of potential wekiu bug and other Mauna Kea arthropod habitat has been lost to astronomy development on the summit. Since 1963, when the first modern road was bulldozed to the summit of Mauna Kea, an estimated 25 percent of the potential wekiu bug habitat has been destroyed or degraded by astronomical development (personal communication 1998 cited in U.S. Fish and Wildlife Service candidate assessment form).

The U.S. Fish and Wildlife Service classifies the wekiu bug as a candidate for Endangered Species Act protection with a listing priority number of 2.

LISTING CRITERIA

A. *The present or threatened destruction, modification, or curtailment of its habitat or range.*

Historical range:	Hawaii, island of Hawaii only, on the upper Mauna Kea summit.
Current range:	Hawaii, island of Hawaii only, on the upper Mauna Kea summit.
Land ownership:	This species occurs only on the upper Mauna Kea summit, which is owned by the State of Hawaii and managed by the Institute for Astronomy.

Due to certain ideal atmospheric qualities and ideal weather conditions at the summit of Mauna Kea, the University of Hawaii has developed the summit area as the Mauna Kea Science Reserve for astronomical study (Research Corporation of the University of Hawaii (RCUH) 1983). Since 1968, approximately 25 hectares (ha) (62 acres (ac)) of potential wekiu bug and other Mauna Kea arthropod habitat has been lost to astronomy development on the summit. There are 4,536 ha (11,200 ac) in the Institute for Astronomy (IfA) Reserve. The Reserve's lower elevational boundary ranges from 3,569 m (11,700 ft) to 3,691 m (12,100 ft). Above 3,660 m (12,000 ft), there are approximately 1,539 ha (3,800 ac) contained within the protected state-owned natural area reserves (NARS) (RCUH 1983). The absolute lower elevational range boundary of the wekiu bugs is believed to be at approximately 3,660 m (12,000 ft) (Ashlock and Gagne 1983). More than two thirds of its potential range is unprotected from astronomical development.

To date, fourteen telescopes (including one removed in 1994) and several buildings and associated structures have been constructed on the summit. The 1985 Summit Management Plan authorized a total of 13 telescopes (State Auditor 1998). Resultant impacts have included road construction, parking areas, tourist facilities, temporary storage areas, substrate removal, and oil spills, and constant traffic to the summit with the concomitant human dispersal of trash and debris. The suspected preferred habitat of the wekiu bug, tephra cinders, is easily crushed to dust-sized particles, and vehicular traffic can quickly and permanently change a rocky tephra habitat to one of compacted silt and mud. Furthermore, the silt and mud has the potential to degrade nearby tephra habitat by filling the interstitial spaces between cinders that are used by this bug and other arthropods (Ashlock and Gagne 1983).

Since 1963, when the first modern road was bulldozed to the summit of Mauna Kea, an estimated 25 percent of the potential wekiu bug habitat has been destroyed or degraded by astronomical development (personal communication 1998 cited in U.S. Fish and Wildlife Service candidate assessment form). The IfA receives and entertains new inquiries/proposals for telescope construction on an on-going basis (State Auditor 1998). While few groups have the money to invest in Mauna Kea due to the cost of operating the facilities and the shared maintenance, it remains one of the most desirable locations worldwide for astronomical observation. In addition to the possibility of new facility construction, many of the existing facilities and structures are nearly 25 years old and will probably soon require rebuilding and updating (State Auditor 1998). This would likely include new construction and expansion.

B. *Over-utilization for commercial, recreational, scientific, or educational purposes.*

Not applicable.

C. *Disease or predation.*

Since the wekiu bug and other Mauna Kea arthropods rely on the mechanics of an aeolian system for obtaining prey, the amounts and type of prey upon which they depend may be affected by introductions of alien arthropods and parasites (personal communication 1998 cited in U.S. Fish and Wildlife Service candidate assessment form). For example, the wekiu bug now competes with at least one introduced species of linyphiidae (small sheetweb) spider which has become established on the summit (Howarth and Stone 1982).

D. *The inadequacy of existing regulatory mechanisms.*

The summit area lies within a State conservation district and any construction in the area requires a permit from the State Department of Land and Natural Resources (DLNR) (State Auditor 1998). Prior to development of the Mauna Kea Science Reserve, a development plan for the summit area was written that addressed the sensitivity of the wekiu bug and its habitat. Despite the fact that important wekiu bug habitat was identified as sensitive in the 1983 plan and was to be avoided in the development of the facilities, a lack of communication and monitoring of construction activities at the summit during construction of the Subaru telescope facility resulted in the loss of most wekiu bug habitat in Puu Hau Oki (*in litt*. 1996 cited in U.S. Fish and Wildlife Service candidate assessment form, State Auditor 1998).

A 1997 report on the State of Hawaii’s audit of the management of Mauna Kea and the Mauna Kea Science Reserve stated, “Management of Mauna Kea fails to adequately ensure protection of our natural resources” (State Auditor 1998). In addition, unapproved construction activities on the summit area, unauthorized cinder cone and crater “reshaping” activities, and large spills of motor oil have been reported (*in litt*. 1996 cited in U.S. Fish and Wildlife Service candidate assessment form, State Auditor 1998).

In response to the State Auditor’s 1998 report, the IfA, the University of Hawaii, and DLNR have agreed to better manage the Mauna Kea Science Reserve and its natural resources. Currently, the

IfA is developing a new Mauna Kea Science Reserve master plan and is funding a series of surveys to determine how the impact of future development might impact the flora and fauna (particularly.the wekiu bug) of the summit area (State Auditor 1998). Under the current management plan, telescope number is limited to 13 telescopes. However, old facilities could be torn down and replaced with submillimeter arrays which can have up to twenty times the surface impact of construction of a standard telescope and still count as one telescope (State Auditor 1998). Furthermore, development of interferometers on Mauna Kea may continue under the current management plan since they do not count as “telescopes.” Interferometers are specialized antennae for observing astronomical occurrences, and the resulting structure impacts at least as much surface area as a large telescope (State Auditor 1998).

Current Conservation Efforts: Several local community members and members of the scientific community are interested in and have taken active steps to help protect the arthropod fauna of the Mauna Kea summit. In 1982, two biological surveys above the 13,000 foot level were completed as part of the environmental impact studies for planned construction of astronomy facilities. A second, more inclusive environmental impact study was conducted in 1985, which developed into the (first) Mauna Kea Master Plan (a summit management plan).

The Bishop Museum has been contracted by the IfA to conduct research necessary for development of an arthropod conservation plan for the Mauna Kea summit. The Bishop Museum’s goal is to develop and include adequate protection for the wekiu bug in the Mauna Kea Science Reserve Master Plan. However, federal listing of the wekiu bug as an endangered species could provide additional legal protection critical to the preservation of this unique insect and its habitat.

E. *Other natural or manmade factors affecting its continued existence.*

Shifts in global climate (toward warmer winters with less snowfall on the Mauna Kea summit) may potentially threaten the Mauna Kea arthropods, including the wekiu bug. The summit area has been warmer and has had less snowfall since 1982 (Howarth 1997a). The capture rates for wekiu bugs in a 1997 study were significantly lower than the rates obtained in the 1982 study (Howarth 1997c). It is possible that as the summit area becomes warmer over time, alien predators and parasites could more easily establish themselves or have indirect effects on the wekiu bug’s food supply. In addition, if available habitat is seriously reduced by summit development, the wekiu bug will likely be less capable of responding and surviving during climatic changes (personal communication 1998 cited in U.S. Fish and Wildlife Service candidate assessment form).

REFERENCES

Ashlock, P.D. and W.C. Gagne. 1983. A remarkable new micropterous *Nysius* species from the aeolian zone of Mauna Kea, Hawai’i Island (Hemiptera: Heteroptera: Lygaeidae). International Journal of Entomology 25(1): 47- 55.

Auditor, State of Hawaii. (Prepared by Marion H. Higa, State Auditor). February 1998. Audit of the management of Mauna Kea and the Mauna Kea Science Reserve (Report No. 98-6). pp. 1-54.

Bishop Museum of Honolulu. Hawaiian Terrestrial Arthropod Checklist, March 2002 version. http://www2.bishopmuseum.org/HBS/checklist/query.asp?grp=Arthropod

Borror, D.J., Triplehorn, C.A., & Johnson, N.F. 1992. An introduction to the study of insects. Harcourt Brace College Publishers. Fort Worth, TX.

Bryan, E.H. 1923. Insects from the summit of Mauna Kea. Proc. Hawaii. Entomol. Soc. 5: 287-88.

Bryan, E.H. 1926. Additional notes on the insects occurring on.Mauna Kea and Mauna Loa. Proc. Hawaii. Entomol. Soc. 6: 280- 282.

Gagne, W.C. 1971. Note and exhibitions: *Psylla uncatoides* (Ferris & Klyver). Proc. Hawaii. Entomol. Soc. 21(1): 25.

Gagne, W.C. and L.W. Cuddihy. 1990. Vegetation: in Wagner, W.L., D.R. Herbst, and S.H. Sohmer (eds), Manual of the flowering plants of Hawai'i. University of Hawaii Press and Bishop Museum Press, Honolulu. Bishop Mus. Spec. Publ. 83: 45-114.

Gagne, W.C. and F.G. Howarth. 1982. On Mauna Kea A desert: entomologists discover new life. Ka`Elele, Bishop Museum Newsletter 9(2): 1,6.

Howarth, F.G. 1997. Arthropod assessment habitat survey report. (submitted to IfA).

Howarth, F.G. 1997. Arthropod assessment preliminary report. (submitted to IfA).

Howarth, F.G. 1997. Arthropod assessment proposal. (submitted to IfA).

Howarth, F.G. and F.D. Stone. 1982. An assessment of the arthropod fauna and aeolian ecosystem near the summit of Mauna Kea, Hawaii. Report submitted to Group 70, Honolulu, Hawaii.

MacDonald, G.A., A.T. Abbott, and F.L. Peterson. 1983. Volcanoes in the sea. University of Hawaii Press. 517 pp.

Mull, M.E. and W.P. Mull. 1980. Perspective: the marvelous mountain. Hawaii Tribune-Herald. Sunday, Jan. 27, 1980; Sect. B5.

Papp, R.P. 1981. High altitude aeolian ecosystems in the Hawaiian Islands. Proc. 3rd Conf. Nat. Sci. Hawaii Volcanoes National Cooperative National Park Resources Studies Unit, University of Hawaii, Manoa. Pp 259-264.

Polhemus, D.A. 1998. *Nysius aa* (Heteroptera: Lygaeidae), a new species of micropterous wekiu bug from the summit of Mauna.Loa Volcano, Hawaii. Proc. Entomol. Soc. Wash. 100(1): 25- 31.

Porter, S.C. 1979. Hawaiian glacial ages. Quaternary Research 12:161-187. Research Corporation of the University of Hawaii. 1983. Mauna Kea Science Reserve Complex Development Plan.

Swezey, O.H. and F.X. Williams. 1932. Insects from the summit of Mauna Kea. Proc. Hawaii. Entomol. Soc. 8: 191-192.

Usinger, R.L. 1936. The genus *Geocoris* in the Hawaiian Islands (Hemiptera, Lygaeidae). Proc. Hawaii. Entomol. Soc. 9: 214- 15.

Waldrop, M.M. 1981. Research news. Mauna Kea (I): halfway to space. Science 214:1010-1013.

Wentworth, C.K., J.W. Coulter & C.E. Hartt. 1935. The Mauna Kea Expedition of 1935: Hawaii Academy of Science. 95p. Manuscript located at B.P. Bishop Museum Library.

Woodcock, A.H. 1976. Permafrost and climatology of a Hawaii volcano crater. Arctic and Alpine Research 6: 49-62.

Zimmerman, E.C. 1948. Insects of Hawaii: Volume 3-Heteroptera. University of Hawaii Press. Honolulu, HI. p. 93.

PETITION TO LIST

Mariana eight-spot butterfly
(*Hypolimnas octucula mariannensis*)

AS A FEDERALLY ENDANGERED SPECIES

CANDIDATE HISTORY

CNOR 9/19/97:	C
CNOR 10/25/99:	C
CNOR 10/30/01:	C
CNOR 6/13/02:	C

TAXONOMY

The Mariana eight-spot butterfly (*Hypolimnas octucula mariannensis*) is an endangered butterfly in the family Nymphalidae.

NATURAL HISTORY

This subspecies is endemic to the islands of Guam and Saipan in the Mariana archipelago, where it is limited to remaining native forests. The larvae of this butterfly feed on two native plants, *Procris pedunculata* and *Elatostema calcareum* (both Urticaceae). Both of these forest herbs grow only on karst limestone, thus limiting the breeding habitat of this butterfly.

POPULATION STATUS

The Mariana eight-spot butterfly was apparently always uncommon on Guam but is currently in decline due to a recent drought and browsing of the host plants by alien deer (Schreiner and Nafus 1996).

Recent surveys of the remote northern Mariana islands failed to locate this species (Miyano 1994). During a recent survey of Saipan several areas were found that supported good populations of the host plants, but no individuals of *Hypolimnas octucula mariannensis* were seen (Schreiner and Nafus 1996); the species is considered to be extinct on that island. Although the island of Rota has no records of the Mariana eight spot butterfly, this island was also surveyed but no butterflies were found (Schreiner and Nafus 1996).

Recent surveys on the island of Guam located ten populations of *Hypolimnas octucula mariannensis* (Schreiner and Nafus 1996). The major threats to these remaining populations are browsing of the host plants by alien deer, development of lands in or near areas that currently support populations, wildfires in the southern mountains where two populations remain, and extremely high mortality (99+percent) of eggs and larvae due to predation by alien ants and parasitoid wasps.

The U.S. Fish and Wildlife Service classifies the Mariana eight-spot butterfly as a candidate for Endangered Species Act protection with a listing priority number of 3.

LISTING CRITERIA

A. *The present or threatened destruction, modification, or curtailment of its habitat or range.*

Historical range:	Guam; Commonwealth of the Northern Mariana Islands (Saipan).
Current range:	Guam.
Land ownership:	The lands that support populations of this butterfly are owned by private landowners (three populations), the Government of Guam (one population), and the U.S. Government (six populations).

The host plant of this butterfly is still present on Guam, but has severely declined as result of development, browsing by feral deer, and displacement by alien species. Loss of habitat combined with predation by alien parasitoids have probably been the major factors in the decline and extinction of this butterfly.

The Mariana Islands are believed to have been mostly forested prior to the arrival of humans (Fosberg 1960, 1971). The intact structure of native Mariana forests has four general levels: the high trees; the shrubs and *Pandanus*; the cycads and taller ferns; and the succulent herbs (Crampton 1925, Fosberg 1960, 1971). With the arrival and population growth of the aboriginal Chamorro people 4,000 years ago (Carano and Sanchez 1964), native forests began to be cleared and savanna grasslands began to develop (Mueller-Dumbois 1981). During the Spanish occupation of the Mariana Islands (1521- 1899), alien goats, pigs, cattle, and deer were introduced. Extensive herds of cattle were noted on the main islands, with some herds numbering in excess of 10,000 head. Large numbers of pigs, goats and deer were also present (Engbring et al. 1986, Carano and Sanchez 1964). In 1742, the forested areas on the island of Tinian were described as park-like and open (Engbring et al. 1986 citing Anson’s journal as cited by Walter 1928). These animals, along with extensive logging, further contributed to the expansion of savanna grasslands and directly altered the understory plant community and overall forest microclimate. All of these changes resulted in a continuing decline in area and quality of butterfly habitat.

The German occupation of the Mariana Islands (1899-1914) resulted in few ecological changes, although there was a recorded increase in the populations of Chamorros and Carolinians that settled on Saipan and actively developed coconut orchards (Engbring et al. 1986).

Sweeping ecological changes took place during the Japanese occupation from 1914-1944 (Kanehira 1936, Fosberg 1960, 1971, Engbring et al . 1986). Extensive removal of native forests for the development of sugar cane was pursued on all of the main islands. These fields covered almost all of Tinian and much of Guam, Saipan, Rota, and Aguijan. In 1920, Crampton (1925) stated that much deforestation had occurred in the southern half of Guam and that the savanna grassland.habitat (which is unsuitable for this butterfly) had greatly expanded during recent centuries.. He also noted that extensive wood cutting had reduced the forest canopy.

During and after World War II dramatic reductions in butterfly forest habitat occurred on the islands of Guam, Tinian, Rota, and Saipan where major military operations, bombing, and landings were conducted. Following the War, open agricultural fields and other areas prone to erosion were seeded with tangantangan (*Leucaena leucocephala*) by the U.S. Military (Fosberg 1960). Tangantangan grows as a single species stand with no substantial understory. The microclimatic conditions are dry, with little accumulation of leaf litter humus (Hopper and Smith 1992), and it is particularly unsuitable as butterfly habitat. In addition, native forest cannot reinvade and grow where this alien weed has become established (Hopper and Smith 1992). The post-War establishment and operation of large military bases has similarly prevented the return of native forest that could support partulid tree snails. Today on the island of Guam, the U.S. military occupies approximately 17,500 hectares or 30 percent of the island, most (90+ percent) of which once was forested habitat that supported this endemic butterfly.

The native butterfly habitat on the main islands of the Commonwealth of the Northern Mariana Islands has been greatly reduced by development and agricultural activities (Engbring et al. 1986). For instance, most of the island of Rota was forested in 1932, but by 1935 almost all level areas has been cleared of forest to support sugar cane production and phosphate mining (Kanehira 1936). The only areas left undisturbed were too steep for agriculture, generally along the base of cliffs, which are an extensive geological feature of the island. These areas still support native limestone forests (Fosberg 1960). During World War II, Rota was heavily bombed (Farrell 1991) and aerial photos from this period show that most of the island was riddled with bomb craters and denuded of vegetation. Following the War, much of this area was given over to cattle grazing, urban growth, and airport development.

In some areas, native forest has reestablished (Engbring et al. 1986, Falanruw et al. 1989). In 1988, supertyphoon Roy hit Rota with winds in excess of 150 miles per hour (240 kilometers per hour), defoliating almost all of the forested areas and downing.trees, especially along the southeast and northern cliff slopes of the central Sabana (Fancy and Snetsinger 1996). Vegetation changes associated with this storm have opened up forested areas to desiccation and invasion by alien weeds, making them unsuitable as butterfly habitat.

Events and changes similar to those described for Rota also apply to the island of Saipan, where most of the native forest is gone. Falanruw et al. (1989) reported that only 4 percent of the native forest that could support habitat for this butterfly is left on Saipan. The remaining area has been replaced by mixed second growth forests, savanna grasslands, dense thickets of tangantangan (due to military aerial seeding), agroforests, and urban areas. None of these vegetation types provide suitable habitat for the Mariana eight-spot butterfly.

B. ***Overutilization for commercial, recreational, scientific, or educational purposes.***

Rare butterflies and moths are highly prized by collectors (Morris et al. 1991), who often take all individuals obtainable (*in litt* . 1993 cited in U.S. Fish and Wildlife Service candidate assessment form). For instance, there has been a standing reward for specimens of the extremely rare fabulous green sphinx moth (*Tinostoma smargditis*) of Hawaii (Zimmerman 1958), and specimens of the rare Blackburn's sphinx moth (*Manduca blackburni*) have already been secured and traded by collectors (personal communication 1994 cited in U.S. Fish and Wildlife Service candidate assessment form). The listing of a butterfly species as federally endangered may increase its attractiveness to collectors of rare species (*in litt.* 1993 cited in U.S. Fish and Wildlife Service candidate assessment form), although in most cases the benefits of listing are likely to greatly outweigh the risks. Unrestricted collecting and handling are known to impact populations of other species of rare Lepidoptera (Murphy 1988) and are considered significant threats to the Mariana eight-spot butterfly.

C. ***Disease or predation.***

Numerous alien predators and parasitoids of Lepidoptera have become established, purposefully or adventively, in the Mariana Islands and these have been documented to attack and significantly impact other species of native butterflies (Nafus 1989, 1992, 1993 a,b,c, Peterson 1957, Schreiner and.Nafus 1986). These alien predators and parasitoids undoubtedly contribute to the decline of this butterfly. In addition, on average, two new alien species of arthropods become established each year in the Marianas, and the possibility of the establishment of additional predators and parasitoid that will attack this species is a significant threat.

Ants can be particularly destructive predators because of their high densities, recruitment behavior, aggressiveness, and broad range of diet (Reimer 1993). This last attribute allows some ants to affect prey populations independent of prey density, and ants can therefore locate and destroy isolated individuals and populations (Nafus 1993a). Ants prey on all immature stages of Lepidoptera and can completely exterminate populations (Illingworth 1915; Zimmerman 1958). During some times of the year, alien ants destroyed virtually all the eggs of the related butterfly *Hypolimnas bolina* in Guam (Nafus 1992) and predation by alien ants is the primary cause of mortality (>90%) in *H. octocula marianensis* (Schreiner and Nafus 1996).

Small wasps in the family Trichogrammatidae parasitize insect eggs, with numerous adults sometimes developing within a single host egg. The taxonomy of this group is confusing, but at least two native species attack the eggs of butterflies in the Mariana islands, including *H. octocula marianensis* (Schreiner and Nafus 1996). Several alien species are established in the Mariana islands, including, *Trichogramma chilonis* which effectively limits populations of the sweetpotato hornworm in Guam (Nafus and Schreiner 1986) and is a potential threat to the eight-spot butterfly.

The introduced biological control agent *Brachymeria lasus* parasitizes up to 20 percent of the pupae of the related butterfly *H. bolina* in Guam (Nafus 1992). While this wasp has not been observed to attack *H. octocula marianensis,* only 16 pupae have been studied in the field, and this wasp is a potential threat to this rare butterfly (Drost and Carde 1992).

D. ***The inadequacy of existing regulatory mechanisms.***

Listing of this species would provide critical legal protection and should eventually lead to recovery efforts. Alien predatory and parasitic insects are one of the primary cause of the reduction in range and abundance of this butterfly. Some of these alien species have been purposefully introduced by the Territorial agricultural agencies (Nafus and Schreiner 1989) and importations and augmentations of parasitoids of lepidopterans continues. Federal regulations for the introductions of biocontrol agents are inadequate (Howarth 1991, Lockwood 1993). Presently, there are no Federal statutes that require biocontrol agents to be reviewed before they are introduced, and the limited Federal review process requires consideration of potential harm only to economically important species (Miller and Aplet 1993). Existing regulations do not require post-release impacts on non-target organisms, and host range cannot be predicted from laboratory studies (Gonzalez and Gilstrap 1992; Roderick 1992). The purposeful release or augmentation of any lepidopteran predator or parasitoid is a potential threat to this butterfly (Simberloff 1992).

Current Conservation Efforts: None.

E. ***Other natural or manmade factors affecting its continued existence.***

The fact that only ten populations of the Mariana eight spot butterfly remain increases the potential for extinction from stochastic events. These butterflies are good fliers and in an undisturbed setting probably existed as a series of metapopulations (Harrison et al. 1988), with considerable movement between demes and continued colonizations and extinctions in disparate localities. Alien predators and parasitoids and the loss of its host plant have extirpated all populations of this butterfly on Saipan and have greatly reduced its numbers on Guam. If the Guam populations are severely reduced or eliminated, there will be less potential for recolonization or rescue (Brown and Kodric-Brown 1977) of the remaining population by immigrants (Arnold 1983). The current distances between populations represents a severe threat to gene flow and the maintenance of genetically healthy populations.

New purposeful introductions or augmentative releases of existing parasitoids for control of pest Lepidoptera pose a great threat to this species. The small geographic areas where this species still exists puts it at risk of stochastic extinction from natural events (typhoons) and normal population fluctuations.

REFERENCES

Arnold, R.A. 1983. Ecological studies of six endangered butterflies (Lepidoptera, Lycaenidae): Island biogeography, patch dynamics, and design of habitat preserves. Univ. Calif. Pub. Entomol. 99:1-161.

Brown, J.H. and A. Kodric-Brown. 1977. Turnover rates in insular biogeography: effect of immigration on extinction. Ecology 58:445-449.

Carano, P. And P.C. Sanchez. 1964. A complete history of Guam. Charles E. Tuttle, Inc., Rutland, Vermont. 452pp.

Crampton, H.E. 1925. Studies on the variation, distribution, and.evolution of the genus *Partula* . The species of the Mariana Islands, Guam and Saipan. Carnegie Institute of Washington Publication 228A. vii + 116 p., 14 pl.

Drost, Y.C., and R.T. Carde. 1992. Host switching in *Brachymeria intermedia* (Hymenoptera: Chalcididae), a pupal endoparasitoid of *Lymantria dispar* (Lepidoptera: Lymantriidae). Environ. Entomol. 21: 760-766.

Engbring, J., F.L. Ramsey, and V.J. Wildman. 1986. Micronesian forest bird survey, 1982: Saipan, Tinian, Agiguan, and Rota. U.S. Fish Wildl. Serv., Region 1, Portland, Oregon.

Falanruw, M.C., T.G. Cole, and A.H. Ambacher. 1989. Vegetation survey of Rota, Tinian, and Saipan, Commonwealth of the Northern Mariana Islands. Resour. Bull. PSW-27. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture. 11pp +13 maps.

Fancy, S.G. and T.J. Snetsinger. 1996. Potential reasons for the decline of the bridled white-eye population on Rota, Mariana Islands. Unpublished report, U.S. Geological Survey, Biological Resources Division, Pacific Islands Ecosystems Research Center, Hawaii National Park, Hawaii.

Farrell, D.A. 1991. History of the Northern Mariana Islands. Public School system, Commonwealth of the Northern Mariana Islands.

Fosberg, F.R. 1960. The vegetation of Micronesia. Bull. Am. Mus. Nat. Hist. 119:1-75.

Fosberg, F.R. 1971. On present conditions and conservation of forests in Micronesia. In: Pacific Science Association Standing committee on Pacific Botany. Symposium: Planned utilization of the lowland tropical forests. Bogor, Indonesia.

Gonzalez, D. and F.E. Gilstrap. 1992. Foreign Exploration: Assessing and prioritizing natural enemies and consequences of preintroduction studies: in Kauffman, W.C. and J.E. Nechols (eds), Selection Criteria and Ecological Consequences of Importing Natural Enemies. Thomas Say.Publications in Entomology: Proceedings. Entomol. Soc. Am., Lanham, Maryland. pp. 53-70.

Harrison, S., D.D. Murphy, and P.R. Ehrlich. 1988. Distribution of the Bay checkerspot butterfly, *Euphydryas editha bayensis*: Evidence for a metapopulation model. Am. Nat. 132:360-382.

Hopper, D.R., and B.D. Smith. 1992. The status of tree snails (Gastropoda: Partulidae) on Guam, with a resurvey of sites studied by H. E. Crampton in 1920. Pacific Science 46:77-85.
Howarth, F.G. 1991. Environmental impacts of classical biological control. Ann. Rev. Entomol. 36:485-509.

Illingworth 1915. [cited in U.S. Fish and Wildlife Service candidate assesssment form, but full citation omitted from References]

Kanehira, R. 1936. Forests of Rota. Bot. Zool. 4:63-70.

Lockwood, J.A. 1993. Environmental issues involved in biological control of rangeland grasshoppers (Orthoptera: Acrididae) with exotic agents. Environ. Entomol. 22:503-518.

Miller, M. and G. Aplet. 1993. Biological control: A little knowledge is a dangerous thing. Rutgers Law Rev. 45:285-334.

Miyano, S. 1994. Insects of the northern Mariana Islands, Micronesia, collected during the expedition. Nat. Hist. Res. Spec. Iss. No. 1:199-215.

Morris, M.G., N.M. Collins, R.I. Vane-Wright, and J. Waage. 1991. The utilization and value of non-domesticated insects: in Collins, N.M. and J.A. Thomas (eds), The Conservation of Insects and Their Habitats , Academic Press, London. pp. 319- 347.

Mueller-Dombois. D. 1981. Fire in tropical ecosystems, In: Fire regimes and ecosystem properties. U.S. For. Serv. Tech. Rep. WO-26.

Murphy, D.D. 1988. Are we studying our endangered butterflies to death? J. Research Lep. 26:236-239.

Nafus, D.M. 1989. Biological control activities in the Mariana.Islands form 1911 to 1988. Micronesica 22:65-106.

Nafus, D.M. 1992. Impact of intentionally and accidentally introduced biological control agents on unitended hosts, *Hypolimnas anomala* and *H. Bolina* (Lepidoptera: Nymphalidae) on Guam. Pac. Sci. 46:394 (abstract)

Nafus, D.M. 1993a. Movement of introduced biological control agents onto nontarget butterflies, *Hypolimnas* spp. (Lepidoptera: Nymphalidae). Environ. Entomol. 22:265-272.

Nafus, D.M. 1993b. Biological control agents and native parasitoids in the population system of the butterfly *Hypolimnas bolina* (L.) (Lepidopetera: Nymphalidae). Micronesica, Suppl. 4:17-23.

Nafus, D.M. 1993c. Extinction, biological control, and insect conservation on islands. In: Gaston, K.J., T.R. New, and M.J. Samways (eds.) Perspectives on Insect Conservation. Intercept Ltd. Andover, U.K.

Nafus, D.M. and I. Schreiner. 1986. Intercropping maize and sweet potatoes. Effects on parasitization of *Ostrina furnicalis* eggs by *Trichogramma chilonis*. Agric. Ecosyst. Environ. 15:189-200.

Nafus, D.M. and I. Schreiner. 1989. [cited in U.S. Fish and Wildlife Service candidate assesssment form, but full citation omitted from References]

Peterson, Jr., G.D. 1957. An annotated checklist of parasites and predators introduced into Guam during the years 1950-1955. Hawaiian Entomol. Soc. 16:199-202.

Pollard, E. and T.J. Yates. 1992. The extinction and foundation of local butterfly populations in relation to population variability and other factors. Ecol. Entomol. 17:249-254.

Reimer, N.J. 1993. Distribution and impact of alien ants in vulnerable Hawaiian ecosystems: in D.F.Williams (ed), Exotic Ants: Biology, Impact, and Control of Introduced Species. Westview Press, Boulder, Colorado. Pp. 11-22.

Roderick, G.K. 1992. Postcolonization evolution of natural enemies: in: Kauffman, W.C. and J.E. Nechols (eds), Selection Criteria and Ecological Consequences of Importing.Natural Enemies. Thomas Say Publications in Entomology: Proceedings. Entomological Society of America, Lanham, Maryland. pp. 53-70.

Schreiner, I.H. and D.M. Nafus. 1986. Accidental introductions of insect pests to Guam, 1945-1985. Proc. Hawaii. Entomol. Soc. 27:45-52.

Schreiner, I.H. and D.M. Nafus. 1996. Survey of rare butterflies in the Mariana Islands. Preliminary report. U.S. Fish Wildlife Service unpublished report. 10pp.

Simberloff, D. 1992. Conservation of pristine habitats and unintended effects of biological control: in Kauffman, W.C. and J.E. Nechols (eds), Selection Criteria and Ecological Consequences of Importing Natural Enemies. Thomas Say Publications in Entomology: Proceedings. Entomol. Soc. Am., Lanham, Maryland. pp. 103-117.

United States Department of Justice. 1993. Press release, San Jose, California, December 14, 1993. Announcing indictments for poaching of federally protected butterflies.

Zimmerman, E.C. 1958. Macrolepidoptera. Insects of Hawaii, Vol. 7. Univ. Hawaii Press, Honolulu..

PETITION TO LIST

Mariana wandering butterfly
(*Vagrans egestina*)

AS A FEDERALLY ENDANGERED SPECIES

CANDIDATE HISTORY

CNOR 9/19/97:	C
CNOR 10/25/99:	C
CNOR 10/30/01:	C
CNOR 6/13/02:	C

TAXONOMY

The Mariana wandering butterfly (*Vagrans egestina*) is an endangered butterfly in the family Nymphalidae.

NATURAL HISTORY

This species is endemic to the islands of Guam and Rota in the Mariana archipelago. The larvae of this butterfly feed on a single plant species, *Maytenus thompsonii* (Celastraceae), which is endemic to the Mariana Islands. *Maytenus thompsonii* is a forest herb and is the breeding habitat of this butterfly.

POPULATION STATUS

The Mariana wandering butterfly was considered to be common on Guam in the 1930's, but has not been seen on this island since 1979 and is currently (Schreiner and Nafus 1996) extirpated from Guam.

During a recent survey of Rota, the host plant of *Vagrans egestina* was abundant but only one butterfly population of seven individuals could be located. No eggs or larvae could be found (Schreiner and Nafus 1996). This species was also not seen during recent surveys of the remote northern Mariana islands (Miyano 1994).

The U.S. Fish and Wildlife Service classifies the Mariana wandering butterfly as a candidate for Endangered Species Act protection with a listing priority number of 2.

LISTING CRITERIA

A. ***The present or threatened destruction, modification, or curtailment of its habitat or range.***

Historical range:	Guam, Commonwealth of the Northern Mariana Islands (Rota).
Current range:	Commonwealth of the Northern Mariana Islands (Rota).
Land ownership:	The Commonwealth of the Northern Mariana Islands owns the land that supports the last known population of this butterfly.

The major threats to these remaining populations are browsing of the host plants by alien ungulates, development of lands in or near areas that currently support the last know population, wildfires, and predation of eggs and larvae by alien ants and parasitoid wasps.

The host plant of this butterfly is still present on Guam, but has severely declined along with the native vegetation of these islands as result of development, grazing by alien ungulates, and displacement by alien weed species. Loss of habitat combined with the impacts of alien parasitoids have probably been the major factors in the decline and extinction of this butterfly.

The Mariana Islands are believed to have been mostly forested prior to the arrival of humans (Fosberg 1960, 1971). The intact structure of native Mariana forests has four general levels: the high trees; the shrubs and *Pandanus*; the cycads and taller ferns; and the succulent herbs (Crampton 1925, Fosberg 1960, 1971). With the arrival and population growth of the aboriginal Chamorro people 4,000 years ago (Carano and Sanchez 1964), native forests began to be cleared and savanna grasslands began to develop (Mueller-Dumbois 1981). During the Spanish occupation of the Mariana Islands (1521- 1899), alien goats, pigs, cattle, and deer were introduced. Extensive herds of cattle were noted on the main islands, with some herds numbering in excess of 10,000 head. Large numbers of pigs, goats and deer were also present (Engbring et al. 1986, Carano and Sanchez 1964). In 1742, the forested areas on the island of Tinian were described as park-like and open (Engbring et al. 1986 citing Anson's journal as cited by Walter 1928). These animals, along with extensive logging, further contributed to the expansion of savanna grasslands and directly altered the understory plant community and overall forest microclimate. All of these changes resulted in a continuing decline in area and quality of butterfly habitat.

Sweeping ecological changes took place during the Japanese occupation from 1914-1944 (Kanehira 1936, Fosberg 1960, 1971, Engbring et al. 1986). Extensive removal of native forests for the development of sugar cane was pursued on all of the main islands. These fields covered almost all of Tinian and much of Guam, Saipan, Rota, and Aguijan. In 1920, Crampton (1925) stated that much deforestation had occurred in the southern half of Guam and that the savanna grassland habitat (which is unsuitable for this butterfly) had greatly expanded during Arecent centuries. He also noted that extensive wood cutting had reduced the forest canopy.

During and after World War II dramatic reductions in butterfly forest habitat occurred on the islands of Guam, Tinian, Rota, and Saipan where major military operations, bombing, and landings were conducted. Following the War, open agricultural fields and other areas prone to erosion were seeded with tangantangan (*Leucaena leucocephala*) by the.U.S. Military (Fosberg 1960). Tangantangan grows as a single species stand with no substantial understory. The micoclimatic conditions are dry, with little accumulation of leaf litter humus (Hopper and Smith 1992), and is particularly unsuitable as butterfly habitat. In addition, native forest cannot re-invade and grow where this alien weed has become established (Hopper and Smith 1992). Today on the island of Guam, the U.S. military occupies approximately 17,500 hectares or 30 percent of the island, most (>90 percent) of which once was forested habitat that supported this endemic butterfly.

The native butterfly habitat on the main islands of the Commonwealth of the Northern Mariana Islands has been greatly reduced by development and agricultural activities (Engbring et al. 1986). Most of the island of Rota was forested in 1932, but by 1935 almost all level areas has been cleared of forest to support sugar cane production and phosphate mining (Kanehira 1936). The only areas left undisturbed were too steep for agriculture, generally along the base of cliffs, which are an extensive geological feature of the island. These areas still support native limestone forests (Fosberg 1960). During World War II, Rota was heavily bombed (Farrell 1991) and aerial photos from this period show that most of the island was riddled with bomb craters and denuded of vegetation.

Following the War, much of this area was given over to cattle grazing, urban growth, and airport development. In some areas, native forest has reestablished (Engbring et al. 1986, Falanruw 1989). In 1988, supertyphoon Roy hit Rota with winds in excess of 150 miles per hour (240 kilometers per hour), defoliating almost all of the forested areas and downing trees, especially along the southeast and northern cliff slopes of the central Sabana (Fancy and Snetsinger 1996). Vegetation changes associated with this storm have opened up forested areas to desiccation and invasion by alien weeds, making them unsuitable as butterfly habitat.

B. ***Overutilization for commercial, recreational, scientific, or educational purposes.***

Rare butterflies and moths are highly prized by collectors (Morris et al. 1991), who often take all individuals obtainable (*in litt* . 1993 cited in U.S. Fish and Wildlife Service candidate assessment form). For instance, there has been a standing reward for specimens of the extremely rare fabulous green sphinx moth (*Tinostoma smargditis*) of Hawaii (Zimmerman 1958), and specimens of the rare Blackburn's sphinx moth (*Manduca blackburni*) have already been secured and traded by collectors (personal communication 1994 cited in U.S. Fish and Wildlife Service candidate assessment form). The listing of a butterfly species as federally endangered may increase its attractiveness to collectors of rare species (*in litt.* 1993 cited in U.S. Fish and Wildlife Service candidate assessment form), although in most cases the benefits of listing are likely to greatly outweigh the risks. Unrestricted collecting and handling are known to impact populations of other species of rare Lepidoptera (Murphy 1988) and are considered significant threats to the Mariana wandering butterfly.

C. *Disease or predation.*

Numerous alien predators and parasitoids of Lepidoptera have become established, purposefully or adventively, in the Mariana Islands and these have been documented to attack and significantly impact other species of native butterflies (Nafus 1989, 1992, 1993 a,b,c, Peterson 1957, Schreiner and Nafus 1986). These alien predators and parasitoids undoubtedly contribute to the decline of this butterfly. In addition, on average, two new alien species of arthropods become established each year in the Marianas, and the possibility of the establishment of additional predators and parasitoid that will attack this species is a significant threat.

Ants can be particularly destructive predators because of their high densities, recruitment behavior, aggressiveness, and broad range of diet (Reimer 1993). This last attribute allows some ants to affect prey populations independent of prey density, and ants can therefore locate and destroy isolated individuals and populations (Nafus 1993a).

Ants prey on all immature stages of Lepidoptera and can completely exterminate populations (Illingworth 1915; Zimmerman 1958). During some times of the year, alien ants destroyed virtually all the eggs of the related butterfly *Hypolimnas bolina* in Guam (Nafus 1992) and predation by alien ants is the primary cause of mortality (>90 percent) in *H. octocula marianensis* (Schreiner and Nafus 1996). Small wasps in the family Trichogrammatidae parasitize insect eggs, with numerous adults sometimes developing within a single host egg. The taxonomy of this group is confusing but at least two native species attack the eggs of butterflies in the Mariana islands, including *H. octocula marianensis* (Schreiner and Nafus 1996). Several alien species are established in the Mariana islands, including, *Trichogramma chilonis* which effectively limits populations of the sweetpotato hornworm in Guam (Nafus and Schreiner 1986) and is a potential threat to the *Vagrans egestina* .

The introduced biological control agent *Brachymeria lasus* parasitizes up to 20 percent of the pupae of the related butterfly *H. bolina* in Guam (Nafus 1992). While this wasp as not been observed to attack *Vagrans egestina*, because no larvae or pupae have been found in the field, this wasp is a potential threat to this rare butterfly (Drost and Carde 1992).

D. *The inadequacy of existing regulatory mechanisms.*

Listing of this butterfly species will provide critical legal protection and should eventually lead to recovery efforts. Alien predatory and parasitic insects are most likely one of the primary cause of the reduction in range and abundance of this butterfly. Some of these alien species have been purposefully introduced by the State agricultural agencies (Nafus and Schreiner 1989) and importations and augmentations of lepidopteran parasitoids continues. Federal regulations for the introductions of biocontrol agents are inadequate (Howarth 1991, Lockwood 1993). Presently, there are no Federal statutes that require biocontrol agents to be reviewed before they are introduced, and the limited Federal review process requires consideration of potential harm only to economically important species (Miller and Aplet 1993). Existing regulations do not require post-release impacts on non-target organisms, and host range cannot be predicted from laboratory studies (Gonzalez and Gilstrap 1992; Roderick 1992). The purposeful release or augmentation of any lepidopteran predator or parasitoid is a potential threat to this butterfly (Simberloff 1992).

Current Conservation Efforts: None.

E. *Other natural or manmade factors affecting its continued existence.*

The fact that there is just a single extant population of the Mariana wandering butterfly increases the potential for extinction from stochastic events. These butterflies are good fliers and in an undisturbed setting probably existed as a series of metapopulations (Harrison et al. 1988), with considerable movement between demes and continued colonizations and extinctions in disparate localities. Alien predators and parasitoids and the loss of its host plant have extirpated all populations of this butterfly on Guam and have greatly reduced its numbers on Rota. If the Rota population is severely reduced in size there is now no potential for recolonization or rescue (Brown and Kodric-Brown 1977) of the remaining population by immigrants (Arnold 1983).

New purposeful introductions or augmentative releases of existing parasitoids for control of pest Lepidoptera pose a great threat to this species. The small geographic area where this species still exists puts it at risk of stochastic extinction from natural events (typhoons) and normal population fluctuations.

REFERENCES

Arnold, R.A. 1983. Ecological studies of six endangered butterflies (Lepidoptera, Lycaenidae): Island biogeography, patch dynamics, and design of habitat preserves. Univ. Calif. Pub. Entomol. 99:1-161.

Brown, J.H. and A. Kodric-Brown. 1977. Turnover rates in insular biogeography: effect of immigration on extinction. Ecology 58:445-449.

Carano, P., and P.C. Sanchez. 1964. A complete history of Guam. Charles E. Tuttle, Inc., Rutland, Vermont. 452 pp.

Crampton, H.E. 1925. Studies on the variation, distribution, and evolution of the genus *Partula* . The species of the Mariana Islands, Guam and Saipan. Carnegie Institute of Washington Publication 228A. vii + 116 p., 14 pl.

Drost, Y.C., and R.T. Carde. 1992. Host switching in *Brachymeria intermdia* (*Hymenoptera: Chalcididae*), a pupal endoparasitoid of *Lymantria dispar* (Lepidoptera: Lymantriidae). Environ. Entomol. 21: 760-766.

Engbring, J., F.L. Ramsey, and V.J. Wildman. 1986. Micronesian forest bird survey, 1982: Saipan, Tinian, Agijuan, and Rota. U.S. Fish and Wildlife Service, Region 1, Portland, Oregon.

Falanruw, M.C., T.G. Cole, and A.H. Ambacher. 1989. Vegetation survey of Rota, Tinian, and Saipan, Commonwealth of the Northern Mariana Islands. Resour. Bull. PSW-27. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture. 11p +13 maps.

Fancy, S.G. and T.J. Snetsinger. 1996. Potential reasons for the decline of the bridled white-eye population on Rota, Mariana Islands. Unpublished report, U.S. Geological Survey, Biological Resources Division, Pacific Islands Ecosystems Research Center, Hawaii National Park, Hawaii.

Farrell, D.A. 1991. History of the Northern Mariana Islands. Public School system, Commonwealth of the Northern Mariana.Islands.

Fosberg, F.R. 1960. The vegetation of Micronesia. Bull. Am. Mus. Nat. Hist. 119:1-75.

Fosberg, F.R. 1971. On present conditions and conservation of forests in Micronesia. In: Pacific Science Association Standing committee on Pacific Botany. Symposium: Planned utilization of the lowland tropical forests. Bogor, Indonesia.

Gonzalez, D. and F.E. Gilstrap. 1992. Foreign Exploration: Assessing and prioritizing natural enemies and consequences of preintroduction studies: in Kauffman, W.C. and J.E. Nechols (eds), Selection Criteria and Ecological Consequences of Importing Natural Enemies. Thomas Say Publications in Entomology: Proceedings. Entomological Society of America, Lanham, Maryland. pp. 53-70.

Harrison, S., D.D. Murphy, and P.R. Ehrlich. 1988. Distribution of the Bay checkerspot butterfly, *Euphydryas editha bayensis*: Evidence for a metapopulation model. Am. Nat. 132:360-382.

Hopper, D.R., and B.D. Smith. 1992. The status of tree snails (Gastropoda: Partulidae) on Guam, with a resurvey of sites studied by H. E. Crampton in 1920. Pacific Science 46:77-85. Howarth, F.G. 1991. Environmental impacts of classical biological control. Ann. Rev. Entomol. 36:485-509.

Illingworth 1915. [cited in U.S. Fish and Wildlife Service candidate assesssment form, but full citation omitted from References]

Kanehira, R. 1936. Forests of Rota. Botany and Zoology 4:63-70.

Lockwood, J.A. 1993. Environmental issues involved in biological control of rangeland grasshoppers (Orthoptera: Acrididae) with exotic agents. Environ. Entomol. 22:503-518.

Miller, M. and G. Aplet. 1993. Biological control: A little knowledge is a dangerous thing. Rutgers law Review 45:285- 334.

Miyano, S. 1994. Insects of the northern Mariana Islands, Micronesia, collected during the expedition. Natural History Research Special Issue No. 1:199-215..Morris, M.G., N.M. Collins, R.I. Vane-Wright, and J. Waage. 1991. The utilization and value of non-domesticated insects: in Collins, N.M. and J.A. Thomas (eds), The Conservation of Insects and Their Habitats , Academic Press, London. pp. 319- 347.

Mueller-Dombois, D. 1981. Fire in tropical ecosystems. In: Fire regimes and ecosystem properties. U.S. Forest Service Technical Report WO-26.

Murphy, D.D. 1988. Are we studying our endangered butterflies to death? J. Research Lep. 26:236-239.

Nafus, D.M. 1989. Biological control activities in the Mariana Islands form 1911 to 1988. Micornesica 22:65-106.

Nafus, D.M. 1992. Impact of intentionally and accidentally introduced biological control agents on unitended hosts, *Hypolimnas anomala* and *H. Bolina* (Lepidoptera: Nymphalidae) on Guam. Pac. Sci. 46:394 (abstract)

Nafus, D.M. 1993a. Movement of introduced biological control agents onto nontarget butterflies, *Hypolimnas* spp. (Lepidoptera: Nymphalidae). Environ. Entomol. 22:265-272.

Nafus, D.M. 1993b. Biological control agents and native parasitoids in the population system of the butterfly *Hypolimnas bolina* (L.) (Lepidopetera: Nymphalidae). Micronesica Suppl. 4:17-23.

Nafus, D.M. 1993c. Extinction, biological control, and insect conservation on islands. In: Gaston, K.J., T.R. New, and M.J. Samways (eds.) Perspectives on Insect Conservation. Intercept Ltd. Andover, U.K.

Nafus, D.M. and I. Schreiner. 1986. Intercropping maize and sweet potatoes. Effects on parasitization of *Ostrina furnicalis* eggs by *Trichogramma chilonis*. Agric. Ecosyst. Environ. 15:189-200.

Peterson, Jr., G.D. 1957. An annotated checklist of parasites and predators introduced into Guam during the years 1950-1955. Hawaiian Entomol. Soc. 16:199-202..Pollard, E. and T.J. Yates. 1992. The extinction and foundation of local butterfly populations in relation to population variability and other factors. Ecol. Entomol. 17:249-254.

Reimer, N.J. 1993. Distribution and impact of alien ants in vulnerable Hawaiian ecosystems: in D.F.Williams (ed), Exotic Ants: Biology, Impact, and Control of Introduced Species. Westview Press, Boulder, Colorado. pp. 11-22.

Roderick, G.K. 1992. Postcolonization evolution of natural enemies: in: Kauffman, W.C. and J.E. Nechols (eds), Selection Criteria and Ecological Consequences of Importing Natural Enemies. Thomas Say Publications in Entomology: Proceedings. Entomological Society of America, Lanham, Maryland. pp. 53-70.

Schreiner, I.H. and D.M. Nafus. 1986. Accidental introductions of insect pests to Guam, 1945-1985. Proc. Hawaii. Entomol. Soc. 27:45-52.

Schreiner, I.H. and D.M. Nafus. 1996. Survey of rare butterflies in the Mariana Islands. Preliminary report. U.S. Fish and Wildlife Service unpublished report. 10 pp.

Simberloff, D. 1992. Conservation of pristine habitats and unintended effects of biological control: in Kauffman, W.C. and J.E. Nechols (eds), Selection Criteria and Ecological Consequences of Importing Natural Enemies. Thomas Say Publications in Entomology: Proceedings. Entomological Society of America, Lanham, Maryland. pp. 103-117.

Swezey, O.H. 1942. Insects of Guam I. Lepidoptera. Butterflies of Guam. B.P. Bishop Museum Bull. 172.

United States Department of Justice. 1993. Press release, San Jose, California, December 14, 1993. Announcing indictments for poaching of federally protected butterflies.

Zimmerman, E.C. 1958. Macrolepidoptera. Insects of Hawaii, Vol. 7. University of Hawaii Press, Honolulu..

PETITION TO LIST

Whulge checkerspot
(*Euphydryas editha taylori*)

AS A FEDERALLY ENDANGERED SPECIES

CANDIDATE HISTORY

CNOR 10/30/01: C
CNOR 06/13/02: C

TAXONOMY

The status of *Euphydryas editha taylori* (Nymphalidae), the Whulge checkerspot, as a recognized subspecies is uncontroversial. “Whulge” is a Salish Indian name referring to Puget Sound. This subspecies is also known as the Taylor’s checkerspot.

NATURAL HISTORY

The Whulge checkerspot is a small, colorfully checkered butterfly. It is orange with black and yellowish spot bands, giving a checkered appearance. The Whulge checkerspot is known from open habitat dominated by grassland vegetation throughout its range of distribution. In the southern Puget Sound region of western Washington it inhabits glacial outwash prairie habitat. In British Columbia it is known from coastal grassland formed on bluffs, while the single population from Oregon is known from a grassland opening (bald) in an otherwise forested ecosystem in MacDonald Forest, north of Corvallis, Oregon. Host plants include members of the figwort or snapdragon family (Scrophulariaceae) such as paintbrushes (*Castilleja*) and owl’s clover (*Orthocarpu*s), as well as native and non-native plantains (*Plantag*o). One brood per year is produced.

POPULATION STATUS

Historically, the Whulge checkerspot was known from more than 50 locations in British Columbia, Washington, and Oregon. In 1989, Pyle reported there were less than 15 populations remaining. As of the fall of 2000, just nine populations were known.

During 1999 and 2000, surveys were conducted at all the known and historic locations in Thurston and Pierce Counties, Washington, by the Washington Department of Fish and Wildlife (personal communication 2000 cited in U.S. Fish and Wildlife Service candidate assessment form). No more than 20 adults were observed at any location. One location in Thurston County (Glacial Heritage) that had 131 adults in 1997 had no Whulge checkerspots counted in 1999 or 2000.

The Whulge checkerspot was designated a candidate species by Washington State in 1991.

The Natural Heritage Programs of Oregon, Washington, and British Columbia all rank the Whulge checkerspot butterfly as Critically Imperiled.

The U.S. Fish and Wildlife Service classifies the Whulge checkerspot butterfly as a candidate for Endangered Species Act protection with a listing priority number of 6.

LISTING CRITERIA

A. *The present or threatened destruction, modification, or curtailment of its habitat or range.*

Historical range: Historically this subspecies was known from more than 50 locations in Oregon, Washington, and British Columbia.

Current range: Oregon, Washington, and British Columbia. The current range is similar to the historic range, except in the southern Willamette Valley, where the species is now extirpated. One population in Oregon has been observed at MacDonald Forest, a state experimental forest administered by Oregon State University College of Forestry. Three locations within close proximity to one another are known from Hornby Island, British Columbia. The current locations in Washington that harbor the species are found in San Juan (one population), Pierce (two), and Thurston Counties (three, although one is likely extirpated).

Land ownership: The estimated proportion of habitat found on Federal, State, county, and private ownership is 55 percent, 30 percent, five percent, and 10 percent, respectively.

Whulge checkerspots are threatened by changes in the vegetation structure and composition of native-grassland-dominated plant communities. Native grassland communities have been lost to conversion for agriculture and development for residential and commercial purposes. Grassland vegetation is threatened; therefore habitat for the Whulge checkerspot has been degraded and encroached by nonnative, woody shrubs including Scotch broom (*Cytisus scoparius*), and several Washington state listed noxious weeds, such as leafy spurge (*Euphorbia esula*) and knapweed (*Centaurium*).

Prairies in the southern Puget Sound of Washington have been lost at an average rate of approximately 100 acres per year since the 1850s due to the rapid change of conversion from grassland to Douglas-fir forest (Kruckeberg 1991). Less than three percent of the original estimated 150,000 acres of pre-European settlement grasslands remains (Crawford and Hall1997).

In pre-settlement times, prairies were maintained by periodic fires that reduced the rate of conversion to forest by restricting the establishment of Douglas-fir along forested edges with grasslands. Fires also maintained the native grass (Idaho fescue)-and forb-dominated plant communities that had formed on the glacial outwash soils of southern Puget Sound. In the Straits of San Juan, Washington, and the Georgia Straits of British Columbia the coastal grassland communities are being encroached by Douglas-fir, rose, and snowberry. In addition to the loss of grasslands to conversion and plant succession, these communities are faced with decline and degradation of the grassland habitat that remains. As grasslands have been converted, the availability of host plants for feeding and nectaring by larvae and adults has declined.

B. ***Overutilization for commercial, recreational, scientific, or educational purposes.***

Populations of Whulge checkerspot have declined dramatically during the past decade. No known overutilization for commercial, recreational, or educational purposes exist; however, scientific studies may have negatively affected Whulge checkerspot populations at one known location. At a location on Fort Lewis Military Reservation in Pierce County, Washington, where over 1000 individuals were observed as recently as 1997, only 6 adults were observed during field year 2000 surveys. In the early and mid-90s, mark-recapture studies were conducted at this location, 13th Division Prairie (Char and Boersma 1995). It is difficult to know whether this factor caused the sharp decline in the population; however, mark-recapture studies of the bay Edith’s checkerspot (*Euphydryas editha bayensi*s) was considered a.contributing factor in the extirpation of a population from a Stanford Preserve (McGarrahan 1997).

C. ***Disease or predation.***

Currently, there are no known disease or predation factors affecting the species.

D. ***The inadequacy of existing regulatory mechanisms.***

The Whulge checkerspot was designated a candidate species by Washington State in 1991 (personal communication 2000 cited in U.S. Fish and Wildlife Service candidate assessment form). State candidate species are under review for listing as a Washington State Endangered, Threatened, or Sensitive species. No protection or restrictions on direct take is provided to these butterflies on any lands administered by any city, county, State or Federal agencies.

Current Conservation Efforts: No Conservation Agreements have been developed for the Whulge checkerspot. Restoration of some grasslands in the southern Puget Sound region of Washington has resulted in control of Scotch broom and other invasive woody plants through the use of herbicides, mowing, grazing, and fire. The Nature Conservancy, with funding from the U.S. Fish and Wildlife Service has conducted restoration projects on grassland habitat at Fort Lewis Military Reservation, Glacial Heritage, Scatter Creek Wildlife Area, Mima Mounds, and Rocky Prairie Natural Area Preserve.

E. ***Other natural or manmade factors affecting its continued existence.***

The application of *Bacillus thuringiensis* var. *kurstaki* (Btk) for control of the Asian gypsy moth likely contributed to the extirpation of three historic locales for the species in Pierce County. Spraying of Btk is known to have adverse affects to nontarget Lepidoptera species (butterflies and moths). Species that have a single brood per year, such as the Whulge checkerspot, are active in the spring and have caterpillars that are active during the spray application period. It has been documented that most lepidopterans are more susceptible to Btk than the target species (Haas and Scriber 1998), in this case Asian gypsy moth. Non-target lepidopterans may remain susceptible for up to 30 days after spraying has ceased (Wagner and Miller 1995).

REFERENCES

Char, P and P.D. Boersma. 1995. The Effects of Prairie Fragmentation on Butterfly Species in Western Washington. Final Report Submitted to the Nature Conservancy, Washington Field Office and The U.S. Army, Fort Lewis, WA.

Crawford, R. and H. Hall. 1997. Changes in the South Puget Prairie Landscape. Ecology and Conservation of the South Puget Sound Prairie Landscape. The Nature Conservancy, Seattle, Washington. 289pp.

Fleckenstein, J, and A. Potter. 1999. 1997, 1998 Project Summary, Puget Prairie Butterfly Surveys. Washington Department of Natural Resources and Washington Department of Fish and Wildlife.

Haas, L and J.M Scriber. 1998. Phyllopane sterilization with bleach does not reduce Btk toxicity for *Papilio glaucus* larvae (Lepidoptera: Papilionidae). Great Lakes Entomologist. 31(1):49-57.

Hays, D. W., A.E. Potter, C.W. Thompson, and P.V. Dunn. 2000. Critical Habitat Components for Four Rare South Puget Sound Butterflies. Final Report. McGarrahan, E. 1997. Much-studied butterfly winks out on Stanford Preserve. Science. Vol. 275. pp 470-480.

Pyle, R.M. 1989. Washington Butterfly Conservation Status Report and Plan. Report submitted to the nongame program of the Washington Department of.Wildlife.

Pyle, R.M. 1981. National Audubon Society Field Guide to North American Butterflies. Alfred A. Knopf, New York, New York. 924 pp.

Wagner, D. and J.C. Miller. 1995. Must butterflies die for the Gypsy Moth's sins? American Butterflies. 3(3):19-23.

PETITION TO LIST

Sequatchie caddisfly
(*Glyphopsyche sequatchie*)

AS A FEDERALLY ENDANGERED SPECIES

CANDIDATE HISTORY

CNOR 10/25/99: C
CNOR 10/30/01: C
CNOR6/13/02: C

TAXONOMY

Glyphopsyche sequatchie is a recently described caddisfly in the family Limnephilidae.

NATURAL HISTORY

Morphology
Adult male *Glyphopsyche sequatchie* differ from *G. irrorata* and *G. missouri* (the other two U.S. species in this genus, the former being boreal and the latter only known from one spring in Missouri) in having far more elaborate genitalia and in having two rather than three patches of black spines on the dorsum of segment 8. Adult females, pupae, and larvae are also easily separable from these species.

Behavior
Larvae are large enough to be easily identified by early June and are in the final instar in early September. Etnier and Hix (1999) found final instar larvae in pools and gently flowing runs on dead limbs 5-10 cm in diameter with bark still attached. Other larvae were found on larger logs, with and without bark, and in wads of root hairs. Larvae were not found on rocks in the stream. In laboratory conditions, emergence dates extended from October 31 to February 4 and similar dates are expected in the wild (Etnier and Hix 1999).

Habitat
This species is known from only two sites, both in Marion County, Tennessee. Owen Spring's run averages about 12 meters (m) wide and 0.5 m deep and flows over a substrate of chert gravel, with silt and organic matter in the pool areas. The spring and spring run are within a small county park that extends to Old Highway 28, about 200 m below the cave mouth. About 15 m above the highway, a tributary of the Little Sequatchie River joins the spring run to form Owen Spring Branch. Another first order stream joins Owen Spring branch before entering the Sequatchie River

about 1.3 kilometers (km) below Owen Spring. The species occurs in the spring run from about 30 m below the mouth of the cave downstream to about 150 m below the highway - a reach of about 300 m. At this point a lumber processing plant has dumped sawdust into the creek and larvae are difficult to find. No specimens were found in the noticeably warmer Little Sequatchie tributary.

Distribution
The Sequatchie caddisfly (*Glyphopsyche sequatchie*) is only known from two spring runs--Owen Spring (the type locality) and Martin Spring--in Marion County, Tennessee. Both springs emerge from caves.

POPULATION STATUS

The Martin Spring site was discovered in May 1998 and is about 12 air miles west-northwest from the type locality. This spring also emerges from a cave and has about twice the width and discharge of Owen Spring. However, though there appears to be twice as much suitable habitat, *Glyphopsyche* are more difficult to find at this site. Etnier and Hix (1999) estimated population sizes at 500 to 5000 individuals for Owen Spring and two to 10 times higher at Martin Spring. For a caddisfly these populations are considered small.

The Tennessee Natural Heritage Program ranks the Sequatchie caddisfly as Critically Imperiled.

The U.S. Fish and Wildlife Service classifies the Sequatchie caddisfly as a candidate for Endangered Species Act protection with a listing priority number of 5.

LISTING CRITERIA

A. *The present or threatened destruction, modification, or curtailment of its habitat or range.*

Historical range:	Owen Spring (the type locality) and Martin Spring, both in Marion County, Tennessee.
Current range:	Owen Spring and Martin Spring, both in Marion County, Tennessee.
Land ownership:	One population is located on county-owned property and one population is on private property.

The Sequatchie caddisfly is known from only two spring runs in Marion County, Tennessee, and has never been found outside these areas. This extremely limited distribution, small population size, the limited amount of occupied habitat, the ease of accessibility, and the species' annual life cycle make the Sequatchie caddisfly extremely vulnerable to extirpation. Threats to the species include siltation; road construction; agricultural, municipal, industrial, and mining runoff (both direct and from subsurface flows); vandalism; and pollution from trash thrown into the springs. The Owen Spring population is currently receiving some incidental legal protection because the federally endangered royal snail (*Pyrgulopsis ogmorhaphe*) occupies this spring.

B. ***Overutilization for commercial, recreational, scientific, or educational purposes.***

There is no indication that overutilization has been a problem for the Sequatchie caddisfly. Etnier and Hix (1999) in their description of the species urge the scientific community to treat this species as endangered because of it apparent vulnerability to extirpation. With details about the specific areas inhabited by this species, it would be extremely easy for vandals to seriously impact or eliminate this species.

C. ***Disease or predation.***

Although various predators undoubtedly consume the Sequatchie caddisfly, predation by naturally occurring predators is a normal aspect of the population dynamics of a species and is not considered a threat to this species. No diseases are known to be affecting the species.

D. ***The inadequacy of existing regulatory mechanisms.***

While the Sequatchie caddisfly receives incidental protection within the part of its range that is also occupied by the endangered royal snail, the State of Tennessee does not prohibit the taking of insects for scientific or other purposes. Federal listing will provide additional protection for this species from collectors by requiring Federal endangered species permits to take this species and by requiring Federal agencies to consult with the U.S. Fish and Wildlife Service when projects they fund, authorize, or carry out may adversely affect the species.

Current Conservation Efforts: No written agreements are in place.

E. ***Other natural or manmade factors affecting its continued existence.***

Because the Sequatchie caddisfly is presently restricted to two small spring runs, it is extremely vulnerable to extirpation from intentional or accidental toxic chemical spills. Because the populations are physically isolated from each other, recolonization of any extirpated population would not be possible without human intervention.

REFERENCES

Etnier, D. A. 1997. Status of *Ceratopsyche etnieri*, *Glyphopsyche missouri*, *Hydroptila decia*, and *Lepidostoma etnieri* (Insecta: *Trichoptera*). Report submitted to the U. S. Fish and Wildlife Service Office of Endangered Species, Asheville, North Carolina and the Tennessee Wildlife Resources Agency, Nashville. 7 pp.

Etnier, D. A., and R. L. Hix. 1999. A new *Glyphopsyche* Banks (Trichoptera: Limnephilidae) from southeastern Tennessee. Proc. Ent. Soc. Washington 101:624-630.

Gordon, M. 1991. Survey of the aquatic mollusca of the Sequatchie River and battle Creek drainages. Report submitted to the U. S. Fish and Wildlife Service Office of Endangered Species, Asheville, North Carolina and the Tennessee Wildlife Resources Agency, Nashville. 21 pp.

PETITION TO LIST

Clifton Cave beetle
(*Pseudanophthalmus horni caecus*)

lesser Adams Cave beetle
(*Pseudanophthalmus catoryctos*)

Icebox Cave beetle
(*Pseudanophthalmus frigidus*)

surprising cave beetle
(*Pseudanophthalmus inexpectatus*)

inquirer cave beetle
(*Pseudanophthalmus inquisitor*)

Beaver Cave beetle
(*Pseudanophthalmus desertus major*)

greater Adams Cave beetle
(*Pseudanophthalmus pholeter*)

Tatum Cave beetle
(*Pseudanophthalmus parvus*)

Louisville cave beetle
(*Pseudanophthalmus troglodytes*)

AS FEDERALLY ENDANGERED SPECIES

CANDIDATE HISTORY

Clifton Cave beetle, lesser Adams Cave beetle, Beaver Cave beetle, greater Adams Cave beetle
Tatum Cave beetle, Louisville cave beetle
CNOR 11/15/94:
CNOR 10/30/01: C
CNOR 6/13/02: C

Icebox Cave beetle, inquirer cave beetle
CNOR 1/6/89:
CNOR 11/21/91:
CNOR 11/15/94:
CNOR 10/30/01: C
CNOR 6/13/02: C

surprising cave beetle
CNOR 10/30/01: C
CNOR 6/13/02: C

TAXONOMY

The taxonomic status of the carabid beetles *Pseudanophthalmus horni caecus*, *P. catoryctos*, *P. frigidus*, *P. inexpectatus*, *P. inquisitor*, *P. desertus major*, *P. pholeter*, *P. parvus*, and *P. troglodytes* is uncontroversial (e.g., Erwin 2002). In the most recent list of candidate species published by the U.S. Fish and Wildlife Service (13 June 2002) the subspecies *P. horni caecus* and *P. desertus major* were both listed as distinct species (*P. caecus* and *P. major*, respectively) with no explanation, although they were both originally described as subspecies (Krekeler 1973) and are still listed as such by Erwin (2002). Although this change in taxonomic rank may possibly be justified, it is not clear on what basis the change was made. In addition, in the candidate species list the specific epithet for *P. catoryctos* is incorrectly spelled as "*cataryctos*".

NATURAL HISTORY

Morphology
Cave beetles in the genus *Pseudanophthalmus* are fairly small, eyeless, reddish-brown insects. Like most other insects, they have six legs and a body that consists of a head, thorax, and abdomen. Body length is generally from 3.0 to 8.0 millimeters (mm) (0.12 to 0.32 inches), depending upon the species. The different species within the genus are differentiated by differences in the shape and size of the various body parts, especially the shape of the male appendages used during reproduction.

Behavior
All are predatory and feed upon small cave invertebrates such as spiders, mites, millipedes, and diplurans, while the larger *Pseudanophthalmus* species also feed on cave cricket eggs (Barr 1996). Members of this genus vary in rarity from fairly common, widespread species that are found in many caves to species that are extremely rare and restricted to only one cave or, at most, two caves.

Little detailed life history information is available for the rarest of the cave beetles that are considered here, but the generalized summary that follows is accurate for the more common and more easily studied species and likely applies to the rarer species as well (Barr 1998). Cave beetles copulate in the fall, and the eggs are deposited in the cave soil during late fall. The eggs hatch and larvae appear in late fall through early winter. Pupation occurs in late winter to early summer, with the adult beetles emerging in early summer (Barr 1996).

Habitat
Most members of this genus are cave-dependent (troglobites) and are not found outside the cave environment**.** The limestone caves in which these cave beetles are found provide a unique and fragile environment that supports a variety of species that have evolved to survive and reproduce under the demanding conditions found in cave ecosystems. No photosynthesis takes place within the dark zone of a cave. Therefore, all organisms that are adapted to life within a cave are dependent upon energy from the surface. This energy can be in the form of leaf litter, woody debris or small bits of organic matter that is washed or falls into the cave, or guano deposited by cave-dependent bats that feed on the surface and return to the cave to roost (Barr 1996). This dependence upon the surface makes caves and the life that is found within them vulnerable to actions that take place well outside and away from the cave. Protection of caves and cave dependent species must include both the physical environment in which the species are found and the surface components that provide the energy and clean water needed for survival.

POPULATION STATUS

Pseudanophthalmus horni caecus, the Clifton Cave beetle, was described by Krekeler (1973) based upon material collected by T. C. Barr in 1963. Clifton Cave, the cave from which this species was first collected, is near Versailles, Woodford County, Kentucky. Soon after the species was first collected, the entrance to the cave was enclosed due to road construction. Other caves in the vicinity of Clifton Cave were surveyed for the species during a 1995-1996 survey for the species. Most contained other species of *Pseudanophthalmu*s, but only one additional site was found for *P. horni caecu*s. Four specimens were found in a very small, 30 foot (9 meters) long cave about 1 mile (1.61 kilometers) from Clifton Cave. It can not be determined at this time if the species still occurs in Clifton Cave or if the species has been extirpated from its type locality by the closure of the cave entrance.

*Pseudanophthalmus catoryct*os, the lesser Adams Cave beetle, was described by Krekeler (1973) based upon material collected by T. C. Barr and S. B. Peck in 1964 from Adams Cave in Madison County, Kentucky. This cave also supports *Pseudanophthalmus pholeter*, the greater Adams Cave beetle, which was also described by Krekeler (1973) from additional collections made by T. C.

Barr and S. B. Beck in 1964 (Barr 1996). During a 1995 visit to the cave, Barr (1996) observed one specimen of *P. pholeter* but *P. catoryctos* was not observed. During this same visit, Barr reported that Adams Cave has now become [one of] the most outrageously vandalized caves in the eastern United States. He observed large amounts of trash, batteries, discarded clothing and other debris throughout the cave. Although *P. catoryctos* was not observed during the 1995 visit to the cave, Barr speculated that the species may still exist at the site. There are no other caves in the vicinity of Adams Cave and these two species have not been found at any other locations.

Pseudanophthalmus frigidus, the Icebox Cave beetle, was described by Barr (1981) based upon two specimens he collected from Icebox Cave, Bell County, Kentucky. Despite searches of caves in the vicinity of this cave and several later visits to Icebox Cave, no additional specimens of *P. frigidus* have been found. Icebox Cave is within the city limits of Pineville and is frequently visited, heavily vandalized, and contains a lot of trash.

Pseudanophthalmus inexpectatus, the surprising cave beetle, was described by Barr (1959) from specimens collected in the historic section of Mammoth Cave and White Cave, Mammoth Cave National Park (MCNP), Edmonston County, Kentucky. Subsequent to these original discoveries, the species was also found in MCNP's Great Onyx Cave (Barr 1996). Despite extensive collecting within MCNP by Barr and others, no additional sites for the species have been found. It appears that the basis of the food chain at the site within the historic section of Mammoth Cave that once supported *P. inexpectatus* was discarded wood. About 40 years ago, this wooden debris was removed from the cave and the species has not been observed there since then. Wood is also the basis of the food chain in Whites Cave and the wood at this site is slowly decaying. Barr (1996) has observed a gradual decrease in the number of *P. inexpectatus* in White Cave as the quantity of wood available has decreased.

Pseudanophthalmus inquisitor, the inquirer cave beetle, was described by Barr (1980) from specimens collected in Sheals's Cave, Clay County, Tennessee. The species is not known from any other caves. During a 1997 survey of the cave, Barr (1998) observed 3 specimens of *P. inquisitor*. This cave is currently protected by the landowner from any physical alterations that could adversely affect the species. However, the site is in a rapidly expanding urban area and indirect impacts, such as chemical or other pollution, could significantly impact both the cave and the species the cave supports. A sinkhole that drains into the cave system is located away from the protected entrance and is near a highway (Barr 1998). Chemical and other spills could easily enter the cave system through this sinkhole entrance. Alterations in the landscape associated with an expanding urban area are expected and could negatively affect the cave system that contains the inquirer cave beetle.

Pseudanophthalmus desertus major, the Beaver Cave beetle, was described by Krekeler (1973) from three specimens collected by T.C. Barr and J. R. Holsinger in 1966, from Beaver Cave, Harrison County, Kentucky. No additional caves that could provide habitat for *P. desertus major* were found during a 1996 survey of Beaver Cave and the surrounding area. One specimen of the species was observed in Beaver Cave during this survey (Barr 1996). Beaver Cave is well known in the local area and is frequently visited. Vandalism and the accumulation of trash in the cave has increased in recent years. Barr (1996) states that this has probably resulted in a decrease in the habitat available to *P. desertus major*.

Pseudanophthalmus parvus, the Tatum Cave beetle, was described by Krekeler (1973) from material collected from Tatum Cave, Marion County, Kentucky. Despite searches in 1980 and in 1996, the species has not been observed in Tatum Cave since 1965. There are no other known caves in the vicinity of Tatum Cave that could support the species. This cave has three natural entrances and an additional entrance has been created in order to use the cave as a water supply (Barr 1996). This additional entrance has modified air flow within the cave and may have seriously impacted *P. parvu*s.

*Pseudanophthalmus troglodyte*s, the Louisville cave beetle, was described by Krekeler (1973) from specimens collected from Oxmoor Cave, Jefferson County, Kentucky. During 1994, surveys of other caves that could potentially support the species were conducted by J. Lewis (Barr 1996). Ten caves were surveyed and the species was found in only one additional cave (Eleven Jones Cave). Oxmoor and Eleven Jones Caves are both within the Louisville metropolitan area. Urban expansion has resulted in the loss of Oxmoor Cave. In about 1990, the entrance to the cave was bulldozed shut and a residential subdivision was built over the area. Eleven Jones Cave is a small cave that sometimes has high levels of carbon dioxide (Barr 1996). These elevated carbon dioxide levels may be related to high levels of pollution in the water entering the cave.

The Kentucky Natural Heritage Program ranks the Clifton Cave beetle, lesser Adams Cave beetle, Icebox Cave beetle, Beaver Cave beetle, greater Adams Cave beetle, and Tatum Cave beetle as Critically Imperiled, and ranks the surprising cave beetle and Louisville cave beetle as imperiled.

The Tennessee Natural Heritage Program ranks the inquirer cave beetle as Critically Imperiled.

The U.S. Fish and Wildlife Service classifies the Clifton Cave beetle, lesser Adams Cave beetle, Icebox Cave beetle, surprising cave beetle, inquirer cave beetle, Beaver Cave beetle, greater Adams Cave beetle, Tatum Cave beetle, and Louisville cave beetle as candidates for Endangered Species Act protection with a listing priority number of 5.

LISTING CRITERIA

A. *The present or threatened destruction, modification, or curtailment of its habitat or range.*

Historical range: *Pseudanophthalmus horni caecus* (Clifton Cave beetle): Kentucky.

*Pseudanophthalmus catorycto*s (lesser Adams Cave beetle): Kentucky.

Pseudanophthalmus frigidus (Icebox Cave beetle): Kentucky.

Pseudanophthalmus inexpectatus (surprising cave beetle): Kentucky.

Pseudanophthalmus inquisitor (inquirer cave beetle): Tennessee.

Pseudanophthalmus desertus major (Beaver Cave beetle): Kentucky.

Pseudanophthalmus parvus (Tatum Cave beetle): Kentucky.

Pseudanophthalmus pholeter (greater Adams Cave beetle): Kentucky.

Pseudanophthalmus troglodytes, Louisville cave beetle - Kentucky.

Current range: *Pseudanophthalmus horni caecus* (Clifton Cave beetle): Small cave near Clifton Cave, Woodford County, Kentucky.

Pseudanophthalmus catoryctos (lesser Adams Cave beetle): Adams Cave, Madison County, Kentucky.

Pseudanophthalmus frigidus (Icebox Cave beetle): Icebox Cave, Bell County, Kentucky.

Pseudanophthalmus inexpectatus (surprising cave beetle): Mammoth Cave, White Cave, and Great Onyx Cave, Mammoth Cave National Park (MCNP), Edmonston County, Kentucky.

Pseudanophthalmus inquisitor (inquirer cave beetle): Sheals's Cave, Clay County, Tennessee.

Pseudanophthalmus desertus major (Beaver Cave beetle): Beaver Cave, Harrison County, Kentucky.

Pseudanophthalmus parvus (Tatum Cave beetle): Tatum Cave, Marion County, Kentucky.

Pseudanophthalmus pholeter (greater Adams Cave beetle): Adams Cave, Madison County, Kentucky.

Pseudanophthalmus troglodytes (Louisville cave beetle): Oxmoor Cave, Jefferson County, Kentucky.

Land ownership: All but three of the caves supporting these species are privately owned. The entrance to the cave supporting *Pseudanophthalmus horni caecus* is within a State-owned highway right of way (Kentucky Department of Transportation) and the two caves still supporting *P. inexpectatus* are within lands managed by the National Park Service (NPS).

Eight of these nine cave beetles (*P. horni caecus, P. catoryctos, P. frigidus, P. inquistor, P. desertus major, P. parvus, P. pholeter*, and *P. troglodytes*) are currently known from just a single cave. Only one, *P. inexpectatus*, is known to occur in more than one cave. Historically, *P. inexpectatus* occurred in three caves within MCNP. It apparently has now has been extirpated from one of these caves and is declining in numbers in one of the two sites that still support it.

Their limited distributions make these species vulnerable to isolated events that would only have a minimal effect on the more wide-ranging members of the genus. Events such as toxic chemical spills, discharges of large amounts of polluted water, closure of entrances, alteration of entrances, or the creation of new entrances can have serious adverse impacts on these cave beetles and could result in their extinction. Caves and the species that are completely dependent upon them (troglobites) receive the energy that forms the basis of the cave food chain from outside the cave. This energy can be in the form of bat guano deposited by cave-dependent bats, large or small woody debris washed or blown into the cave, or tiny bits of organic matter that is carried into the cave by water through small cracks in the rocks overlaying the cave.

Activities such as industrial, residential, commercial, or highway construction can, if not planned in a manner to protect caves, directly destroy caves or result in severe modification of the natural processes that maintain the sensitive biological systems they support. Examples of these types of threats can be seen with *P. horni caecus*, the Clifton Cave beetle, and *P. troglodytes*, the Louisville cave beetle, which have both had one of their two known caves destroyed due to construction-related activities. Pollution and chemical contamination can, under certain circumstances, result in the complete destruction of the unique life found within a cave impacted by these factors. Vandalism and trash dumping have affected some of the sites and all but the caves within MCNP are vulnerable to these activities. Loss or reduction of the supply of energy, such as occurred to *P. inexpectatus* in Mammoth Cave and White Cave (MCNP) can result in the loss or severe reduction of cave beetle populations.

B. *Overutilization for commercial, recreational, scientific, or educational purposes.*

All of these cave beetles occur at only one or two locations. Most populations are extremely small and careless collecting, whether for scientific or other purposes, could adversely affect them. These species have no known commercial value, however, the caves in which these species occur maybe used for recreational purposes by spelunkers and by passive recreationists.

C. *Disease or predation.*

Disease or predation is not known to be a significant problem for any of these species. However, since each species appears to exist with low numbers of individuals, mortality via either of these two factors may have a significant, negative impact on recruitment and long-term survival.

D. *The inadequacy of existing regulatory mechanisms.*

The only sites that receive any official State or Federal protection are those that are found within MCNP. MCNP requires a park scientific collecting permit before any collecting or scientific study is initiated. Otherwise, these species are not protected under Kentucky or Tennessee state law.

Current Conservation Efforts: None.

E. *Other natural or manmade factors affecting its continued existence.*

None are known at this time.

REFERENCES

Barr, Thomas C. 1959. New cave beetles (*Carabidae,* Trechini) from Tennessee and Kentucky. Journal Tennessee Academy of Science 34:5-30.

Barr, Thomas C. 1995. Kentucky Cave Beetles: Progress Report II. Unpublished Report to Kentucky Department of Fish and Wildlife Resources. Frankfort, Kentucky. 20 pp.

Barr, Thomas C., 1996. Cave Beetle Status Survey and Prelisting Recovery Project. Unpublished Report to Kentucky Department of Fish and Wildlife Resources, Frankfort, Kentucky, and the U.S. Fish and Wildlife Service, Asheville, North Carolina. 63 pp.

Barr, Thomas C. 1998. Study of Potentially Threatened or Endangered Species of Cave Beetles in Tennessee, Alabama and Georgia. Interim Progress Report to the Tennessee Wildlife Resources Commission. 11 pp.

Erwin, T. 2002. Western Hemisphere Carabids Checklist (http://entomology.si.edu/Entomology/WstrnCarabids/search.lasso). Dept. of Systematic Biology (Entomology), Smithsonian Institution, Washington, D.C.

Krekeler, C. H. 1973. Cave Beetles of the Genus *Pseudanophthalmus* (Coleoptera, Carabidae) from the Kentucky Bluegrass and Vicinity. Fieldiana 62(4):35-83.

PETITION TO LIST

blackline Hawaiian damselfly (*Megalagrion nigrohamatum nigrolineatum*)

AS A FEDERALLY ENDANGERED SPECIES

CANDIDATE HISTORY

CNOR 5/22/84:	
CNOR 1/6/89:	
CNOR 11/21/91:	
CNOR 11/15/94:	
CNOR 2/28/96:	C
CNOR 9/19/97:	C
CNOR 10/25/99:	C
CNOR 10/30/01:	C
CNOR 6/13/02:	C

TAXONOMY

Native Hawaiians apparently did not differentiate among the different species, but referred to the native damselflies collectively as pinaoʻula. There has been no traditional European use of a common name for species in the genus *Megalagrion* (Coenagrionidae). In a recent taxonomic review of the candidate species of insects in Hawaii, Nishida (1994b) proposed the name "Hawaiian damselflies". Because this name reflects the restricted distribution of these insects and should be readily used by nontechnical persons, the U.S. Fish and Wildlife Service has adopted this common name for the genus, with additional descriptive terms to identify each species.

The status of *Megalagrion nigrohamatum nigrolineatum* as a valid subspecies is uncontroversial (e.g., Bishop Museum 2002).

NATURAL HISTORY

Distribution

Because of the extreme geographic isolation of the Hawaiian islands and the poor dispersal capabilities of many aquatic insects, the freshwater insect fauna of Hawaii is depauperate compared to continental areas despite the diversity of aquatic habitats. Many groups of insects that typify freshwater habitats in continental areas are absent from the native fauna. Some notable examples of such groups are mayflies (Ephemeroptera), stoneflies (Plecoptera), caddisflies (Trichoptera), and alderflies and dobsonflies (Neuroptera), all of which are absent from Hawaii.

Like most of the native fish, mollusc, and crustacean faunas (Ford and Kinsey 1994), most of Hawaii's freshwater insects evolved from marine or intertidal ancestors (Hardy and Delfinado 1980) that could easily colonize the islands.

One group of insects in Hawaii that does appear to be derived from the unlikely colonization by a continental freshwater ancestor is the narrow-winged damselflies (Coenagrionidae) in the genus *Megalagrion* . The genus *Megalagrion* is endemic to the Hawaiian Islands and appears to be most closely related to species of *Pseudagrion* elsewhere in the Indo-Pacific (Zimmerman 1948b).

The Hawaiian damselflies are represented by 23 species and five subspecies, all confined to the Hawaiian Islands. Historically these were among the most common and conspicuous native Hawaiian insects. Some species inhabited water gardens in residential areas, artificial reservoirs, and watercress farms, and were abundant in the city of Honolulu (Perkins 1913, Williams 1936).

Morphology
Megalagrion nigrohamatum nigrolineatum is a medium sized Hawaiian damselfly. Males have a broad yellow, orange, or red patch on the side of the thorax not interrupted by transverse black bands. The females are similarly patterned but with sides of thorax ranging from yellow to light blue. Both sexes have a striking lime-green to turquoise coloration on the lower half of the face and eyes. More detailed descriptions and color photos are available in Polhemus and Asquith (1996).

Behavior
The general biology of Hawaiian damselflies is typical of other narrow-winged damselflies. The males of most species are territorial, guarding areas of habitat where females will lay eggs (Moore 1983a). During copulation, and often while the female lays eggs, the male grasps the female behind the head with his terminal abdominal appendages to guard her against rival males, thus males and females are frequentlyseen flying in tandem. In species with fully aquatic immature stages, females lay eggs in submerged aquatic vegetation or in mats of moss or algae on submerged rocks, and hatching occurs in about ten days (Williams 1936, Polhemus 1994b).

In most species of Hawaiian damselflies, the immature stages (naiads) are aquatic, breathing though three flattened, abdominal gills, and are predacious, feeding on small aquatic invertebrates or fish (Williams 1936). Naiads may take up to four months to mature (Williams 1936), after which they crawl out of the water onto rocks or vegetation and molt into winged adults, which typically remain very close to the aquatic habitat from which they emerged. Adults are also predacious and feed on small flying insects such as midges. In a remarkable example of adaptive radiation in Hawaii, some species of Hawaiian damselflies have foregone the aquatic lifestyle, either partly, with naiads living on wet rock faces, or completely, with terrestrial naiads living in the damp leaf litter, or others inhabiting moist leaf axils of native plants up to several meters above the ground (Zimmerman 1970, Simon et al. 1984). Adults are also unusual in that they have a highly developed behavior of feigning death when caught or attacked (Moore 1983b).

This species breeds in the slow sections or pools along the mid-reach and headwater sections of perennial upland streams, and in seepage fed pools along overflow channels bordering such streams. The naiads can swim but prefer to remain concealed, typically occurring under stones or in mats of algae (Williams 1936). Adults are relatively weak fliers, and often perch on streamside rocks and vegetation. The primary threats to the remaining populations of the blackline Hawaiian damselfly are predation by alien aquatic species such as fish and predacious insects and habitat loss through dewatering of streams.

Habitat

Freshwater streams and pools. Nymphs are found under stones or in mats of algae in running or quiet waters (Williams 1936).

POPULATION STATUS

As early as 1948, Zimmerman noted a decline of the more common *Megalagrion* species, particularly on Oahu. By the late 1970s less than six populations of the Pacific Hawaiian damselfly could be located (Harwood 1976, Gagne 1980, Moore and Gagne 1982), and the conservation of this species was identified as a priority by the International Union for Conservation of.Nature and Natural Resources (Moore 1982). A review of the status of Hawaiian damselflies in 1981 (Gagne and Howarth 1982) led to the placement of several species on the U.S. Fish and Wildlife Service's list of candidate species for Federal listing (49 FR 21664). Due to a continued decline of these damselflies, particularly on the island of Oahu, intensive surveys were initiated in 1990. The results of these surveys demonstrate that six species of Hawaiian damselflies are now threatened with extinction.

Though the populations have not been formally assessed, the number of individuals of the blackline Hawaiian damselfly is probably at least 1,000 individuals, although occupying less than 50 acres in total area (Nishida 1997 in NatureServe Explorer).

The U.S. Fish and Wildlife Service classifies the blackline Hawaiian damselfly as a candidate for Endangered Species Act protection with a listing priority number of 9.

LISTING CRITERIA

A. ***The present or threatened destruction, modification, or curtailment of its habitat or range.***

Historical range: The blackline Hawaiian damselfly (*Megalagrion nigrohamatum nigrolineatum*) is endemic to the island of Oahu, where it was historically known from the following localities-- Haleauau Stream (Williams 1936), Makaha Valley and Pahole Gulch (Polhemus 1994b) in the Waianae Mountains, the Hering Spring stream (Williams 1936), Honaunau, Honolulu, Kahamainui Gulch, Kahuku Prawn Farm, Kaluanui Valley at Sacred Falls, Kamooalii Stream on the Nuuanu Pali, Kawailoa Stream, Malamalama Stream in Kailua Manoa Stream, Pahole Stream, Pearl City, Poamoho Trail, Makiki Stream (Polhemus 1994b), Waiakekua (Cowles 1977), Waialua, Waikane Stream, Waimanalo, and Waimano (Polhemus 1994b). It is now extinct in the Waianae Mountains and is gone from all but three of the original locations in the Koolau Mountains. It is presently known from eleven streams on both the windward and leeward sides of the Koolau Mountains.

Current range: Hawaii, island of Oahu, restricted to 15 relatively remote stream reaches of the Kulau Range.

Land ownership: This species occurs in State-managed waters.

Freshwater habitats on all the main Hawaiian Islands have been severely altered and degraded because of past and present land and water management practices including agriculture, urban development, development of ground water, perched aquifer and surface water resources, and the deliberate introduction of alien animals (Harris et al. 1993, Meier et al. 1993, U.S. Fish and Wildlife Service 1985, 1995).

Extensive modification of lentic (standing water) habitats in the Hawaiian Islands began about 1100 AD with a rapid population increase among native Hawaiians (Kirch 1982). Hawaiians cultivated taro (*Colocasia esculenta*) by creating shallow, walled ponds called lo‘I, in marshes and riparian areas (Handy and Handy 1972). By 1778, virtually all valley bottoms with permanent stream flow and most basin marshes were converted to irrigated taro cultivation (Handy and Handy 1972). While this represents a significant alteration of the natural aquatic system, these extensive artificial wetlands were probably suitable habitat for many native Hawaiian species, particularly waterbirds (Olson and James 1982). Native Hawaiian dragonflies were recorded in taro lo‘I (Handy and Handy 1972) and some damselflies may also have utilized these systems (Moore and Gagne 1982), since the lo‘I remained flooded for months or years at a time (Handy and Handy 1972).

Hawaiians also modified wetlands by constructing fishponds, many of which were primarily freshwater, fed by streams or springs (Summers 1964). Despite this habitat modification by early Hawaiians, many areas of extensive marsh land remained intact. The best example of this was the Mana marsh of western Kauai. In this area, sedimentary deposits restrict the flow of ground water seaward, creating basal water spring discharge 3-4 m (8-12 ft) above sea level, and the development of an extensive marsh system (MacDonald et al. 1960). This area was famous for its mirages on open water surfaces (MacDonald et al. 1960) and Hawaiians traveled by canoe for miles between villages (Bennett 1931).

Some wetlands which had been converted to taro lo‘I were.maintained and others were utilized for rice cultivation between 1850 and 1930. In 1900, there was approximately 19,000 acres of taro and 16,000 acres of rice in production in Hawaii (U.S. Fish and Wildlife Service 1995). By 1960, taro production was reduced to only 510 acres and the rice industry had been completely abandoned. Many of these wetlands formerly used for taro or rice were drained and filled for dry-land agriculture (Stone 1989, Meier et al . 1993). The Mana marsh on Kauai is also one of the best examples of extensive freshwater habitat loss due to modern agriculture. The margins of the Mana marsh were used for rice cultivation until 1922, when the land, including several open ponds, were leased to Kekaha Sugar Company for sugarcane cultivation (Joesting 1984). By the late 1940s, the entire Mana marsh had been drained and filled and was under sugarcane cultivation (Wenkam 1969).

Most urban, residential and resort development in Hawaii has occurred in the coastal plains and as a result, many freshwater lentic habitats have been negatively affected (U.S. Fish & Wildlife Service 1985). Most of this development has occurred on Oahu, which now supports four fifths of the state's population (Dept. of Geography 1983). The Ala Moana and Waikiki areas of Honolulu were once extensive marshlands that were converted to hundreds of taro lo’I and fishponds by Hawaiians (Handy and Handy 1972). Small development projects began in Waikiki in 1910, but even as late as 1920, 85 percent of Waikiki remained under water, used as duckponds, fishponds, and for the cultivation of rice and taro (Hibbard and Franzen 1991). In 1928, the Ala Wai Canal was completed, resulting in the complete drainage and development of the Waikiki wetlands, which now on an average day hosts over 60,000 people (Hibbard and Franzen 1991).

Construction for housing and civil works projects on Oahu also resulted in the draining and filling of large fresh and brackish water marshes at Wailupe Peninsula, Hawaii Kai, Kaelepulu Pond, and Salt Lake (U.S. Fish and Wildlife Service 1995). The U.S. Fish and Wildlife Service has estimated that 30 percent of all coastal plain wetlands in Hawaii have been lost to agriculture and urban development (*in litt*. 1990 cited in U.S. Fish and Wildlife Service candidate assessment form), and if only freshwater habitat was considered the loss would be proportionately much higher, probably approaching 80 to 90 percent. While intentional.filling of freshwater wetlands with open water is rarely permitted today (personal communication 1995 cited in U.S. Fish and Wildlife Service candidate assessment form), loss of smaller areas utilized by damselflies, such as narrow strips of freshwater seeps within anchialine pool complexes, and loss of emergent vegetation still occurs. In addition, marshes are slowly filled and converted to meadow habitat due to increased sedimentation resulting from increased storm water runoff from upslope development, and blockage of downslope drainage (Wilson Okamoto & Associates, Inc. 1993).

Presently the most significant threat to natural ponds and marshes in Hawaii is the alien species California grass (*Brachiaria mutica* (Forssk.) Stapf). The area of origin of this sprawling perennial grass is unknown, but it was first noted on Oahu in 1924 and now occurs on all the major islands (O'Connor 1990). This plant forms dense, monotypic stands that can completely eliminate any open water by layering of its trailing stems (Smith 1985). The most extensive remaining marsh system on the island of Oahu, Kawainui, is now almost entirely choked with California grass, facilitating its conversion to meadowland (Wilson Okamoto & Associates, Inc. 1993).

The James Campbell and Pearl Harbor National Wildlife Refuges on Oahu, and Kakahaia National Wildlife Refuge on Molokai must be constantly managed to control this plant (personal communication 1995 cited in U.S. Fish and Wildlife Service candidate assessment form). The Pacific Hawaiian damselfly and the orangeblack Hawaiian damselfly have both sustained loss of palustrine habitat on all islands due to human activities and California grass. Presently two populations of the orangeblack damselfly along the Kona coast of Hawaii are threatened with further habitat loss from overdraw of the aquifer that feeds coastal marshes (personal communication 1995 cited in U.S. Fish and Wildlife Service candidate assessment form). The only known population of the orangeblack damselfly on Oahu is threatened with habitat degradation from a proposed construction project (Ogden Environmental 1994).

Early Hawaiians also modified stream systems by diverting water from the main channel to irrigate taro lo'I. In some cases these diversions, or 'auwai, were elaborate, such as the cut and fitted stone ditch of Kiki a Ola in Waimea Canyon on Kauai (Bennett 1932). Other diversions were.several kilometers long (Kirch 1985) and moved water between drainages (Devaney et al. 1983). However, these diversions were closely regulated and were not allowed to take more than half the stream flow, and diversions were typically periodic to flood lo'I rather than continuous (Handy and Handy 1972).

The advent of plantation sugarcane cultivation in 1835 led to more extensive stream diversions. The first irrigation system for sugar, built in 1856 on Kauai, was 16 km (10 mi) long. In 1900, the Maunawili Ditch on windward Oahu diverted all the water from Maunawili Stream into Waimanalo Valley (Takasaki et al. 1969). By 1906, the Kohala Ditch system on Maui utilized 15 km (9 mi) of tunnels, 7 km (4.5 mi) of open ditch, and 20 flumes, and now the East Maui Irrigation system may be the largest private water company in the United States (Harris et al . 1993). These systems typically tap water at upper elevations (> 300 m) by means of a concrete weir in the stream. All or most of the low or average flow of the stream is diverted into fields or reservoirs (Takasaki et al. 1969, Harris et al. 1993). By the 1930s, major water diversions had been developed on all the major islands and currently one third of Hawaii's perennial streams are diverted (Hawaii Stream Assessment 1990). Some systems are extensive, such as the Waiahole Ditch which takes water from 37 streams on the windward side of Oahu, and transports it to the leeward plains via a tunnel cut through the Koolau Mountain Range (Stearns and Vaksvik 1935).

On West Maui, as of 1978, over 49 miles of stream habitat in 12 streams have been lost due to diversions, and all of the 17 perennial streams on West Maui are diverted to some extent (Macioleck 1979). In addition to diverting water for agriculture and domestic water supply, streams have also been diverted for use in hydroelectric power. There are currently 18 active hydroelectric plants operating on Hawaiian streams, with another 10 proposed for construction, and another 28 sites identified for potential development (Hawaii Stream Assessment 1990)
In addition to diverting surface flow in the stream channels, the perched aquifers which feed the streams have also been tapped by means of tunnels (Stearns and Vaksvik 1935, Stearns 1985). For example, both the bore tunnels.and the contour tunnel of the Waiahole Ditch system pierced perched aquifers which were drained to the level of the tunnels (Stearns and Vaksvik 1935).

Many of these aquifers were also the sources of springs which contributed flow to the windward streams. The boring of the Haiku tunnel in 1940 caused a 25 percent reduction in the base flow of Kahaluu Stream, over 2.5 miles away (Takasaki et al. 1969). The draining of these aquifers caused many of the springs to dry up, including some over 0.5 km (0.3 mi) away from the bore tunnels (Stearns and Vaksvik 1935). Frequently the actual springs were tapped by driving tunnels into the rock from where the water emerged, and on the water-poor island of Lanai, almost every spring and seep was bored or captured (Stearns 1940).

Surface waters in streams have also been captured by tunnels in the alluvium of the stream channel. Historically, Maunalei Stream was the only perennial stream on Lanai, and Hawaiians constructed taro lo'I in the lower portions of this system. In 1911, a tunnel was developed at 330 m (1,100 ft) elevation which undercut the stream bed, capturing both the surface and subsurface flow and dewatering the stream from this point to the mouth (Stearns 1940).

Stream degradation has been particularly severe on the island of Oahu, where, in 1978, 57 percent of the perennial streams had been channelized (lined, partially lined or altered stream course) and 89 percent of the total length of these streams were channelized (Parrish et al. 1984). Channelization of streams has not been restricted to lower reaches, in Kalihi Stream there is extensive channelization above 300 m (1,000 ft). Channelization results in removal of riparian vegetation, increased velocity, increased illumination, and higher water temperatures. Hawaiian damselflies do not utilize channelized portions of streams.

Surface flow of streams has also been affected by vertical wells, because the basal aquifer and alluvial caprock through which the lower sections of streams flow can be hydraulically connected (*in litt*. 1995 cited in U.S. Fish and Wildlife Service candidate assessment form). Historically, for example, there was sufficient surface flow in Makaha and Nanakuli streams on Oahu to support taro lo'I in their lower.reaches, but this flow disappeared subsequent to construction of wells upstream (personal communication 1995 cited in U.S. Fish and Wildlife Service candidate assessment form). The blackline Hawaiian damselfly has sustained habitat loss due to water diversions, and stream alterations on all the island of Oahu.

B. ***Overutilization for commercial, recreational, scientific, or educational purposes.***

Healthy populations of stream-inhabiting Hawaiian damselflies are composed of large numbers of individuals. Moore (1983a) recorded 75 males per 100 m of stream edge for *Megalagrion heterogamias* on Kauai. In addition, there are often more males than suitable territorial habitat, and when males are removed from a territory they are immediately replaced by other individuals (Moore 1983a). However, populations of the these damselflies, are now extremely reduced, with fewer than 10 males per 100 m of stream edge at all localities. Publication of the rarity of these species will likely increase the interest of professional and amateur Odonata collectors. Unrestricted collecting and handling could impact these small populations and are considered significant threats to the species.

C. ***Disease or predation.***

The geographic isolation of the Hawaiian Islands has restricted the number of original successful colonizing arthropods and resulted in the development of an unusual fauna. An unusually small number (15 percent) of the known families of insects are represented by native Hawaiian species (Howarth 1990). Some groups that often dominate continental arthropod faunas, such as social *Hymenoptera* (group nesting ants, bees, and wasps), are entirely absent.

Commercial shipping and air cargo to Hawaii has now resulted in the establishment of over 2,500 species of alien arthropods (Howarth 1990, Howarth et al. 1994), with a continuing establishment rate of 10-20 new species per year (Beardsley 1962, 1979). In addition to the accidental establishment of alien species, alien predators and parasites for biological control of pests have been intentionally imported and released by individuals, Republic, Territorial, State, and Federal agencies, since 1865. Between 1890 and 1985, 243 alien species were introduced, sometimes with the specific intent of reducing populations of native Hawaiian insects (Funasaki et al. 1988, Lai 1988). Alien arthropods, whether purposefully introduced or adventive, pose a serious threat to Hawaii's native insects, through direct predation and parasitism, and competition for food or space (Howarth and Medeiros 1989; Howarth and Ramsay 1991).

Ants are not a natural component of Hawaii's arthropod fauna, and endemic species evolved in the absence of predation pressure from ants. Ants can be particularly destructive predators because of their high densities, recruitment behavior, aggressiveness, and broad range of diet (Reimer 1993). The latter attribute allows some ants to affect prey populations independent of prey density, and ants can therefore locate and destroy isolated individuals and populations (Nafus 1993).

At least 36 species of ants are known to be established in the Hawaiian Islands, and three particularly aggressive species have had severe effects on the native insect fauna (Zimmerman 1948a). By the late 1870s, the big-headed ant (*Pheidole megacephala*) was present in Hawaii and its predation on native insects was noted by 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, including most moths, have been eliminated from areas where the big-headed ant is present (Perkins 1913, Gillespie and Reimer 1993). This predator generally does not occur at elevations higher than 600 m (2,000 ft), and is also restricted by rainfall, rarely being found in particularly dry (less than ca 35-50 cm [15- 20 in] annually) or wet areas (more than ca 250 cm [100 in] annually) (Reimer et al. 1990).

The long-legged ant (*Anoplolepis longipes*) appeared in Hawaii in 1952 and now occurs on Oahu, Maui, and Hawaii.(Reimer et al. 1990). It inhabits low elevation (less than 600 m [2,000 ft]), rocky areas of moderate rainfall (less than 250 cm [100 in] annually) (Reimer et al. 1990). Direct observations indicate that Hawaiian arthropods are susceptible to predation by this species (Gillespie and Reimer 1993) and Hardy (1979) documented the disappearance of most native insects from Kipahulu Stream on Maui after the area was invaded by the long-legged ant.

At least two species of fire ants, *Solenopsis geminita* and *Solenopsis papuana*, are also important threats (Gillespie and Reimer 1993) and occur on all the major islands (Reimer et al. 1990). *Solenopsis geminita* is also known to be a significant predator on pest fruit flies in Hawaii (Wong and Wong 1988). *Solenopsis papuana* is the only abundant, aggressive ant that has invaded intact mesic forest above 600 m (2,000 ft) and is still expanding its range in Hawaii (Reimer 1993). At least some populations of all the damselfly taxa included in this proposed rule are threatened by one or more of the ant species described above.

Backswimmers are aquatic true bugs (Heteroptera) in the family Notonectidae, so called because they swim upside down. Backswimmers are voracious predators and frequently feed on prey much larger than themselves, tadpoles, small fish, and other aquatic insects including damselfly naiads (Borror et al. 1989). Backswimmers are not native to Hawaii, but several species have been introduced in recent times. *Buenoa pallipes* (Fabricus) (NCN) has been known from Hawaii since 1900 (Zimmerman 1948c) and has been recorded from all the major islands except Lanai (Nishida 1994a). This species can be abundant in lowland ponds and reservoirs and feeds on any suitably sized insect, including damselfly naiads. More recently, two additional species of backswimmers have become established in Hawaii (Polhemus 1995). *Anisops batillifrons* was first collected in 1991 and is known only from Maui. *Notonecta indica* was first collected on Oahu in the mid 1980s and is presently known from Maui and Hawaii.

Species of *Notonecta* are known to prey on damselfly naiads and the mere presence of this predator in the water can cause naiads to reduce foraging (Heads 1985) which can reduce growth, development, and survival (Heads 1986). Backswimmers pose a threat to all populations of this damselfly. Similar to the aquatic insects, Hawaii has a depauperate freshwater fish fauna with only five native species comprised of gobies (Gobiidae) and sleepers (Eleotridae), that occur on all the major islands. The ‘o’opu okuhe (*Eleotris sandwicensis*) and the ‘o’opu naniha (*Stenogobius hawaiiensis*) are coastal fishes, occurring in brackish and freshwater ponds and in lower reaches of streams below the first waterfall. While the ‘o’opu okuhe is the most predaceous of the Hawaiian freshwater fishes (*in litt.* 1995 cited in U.S. Fish and Wildlife Service candidate assessment form), it occurs infrequently with damselflies in the lower reaches of larger streams.

The ‘o’opu nakea (*Awaous stamineus*) and the ‘o’opu nopili (*Sicyopterus stimpsoni*) frequent the middle reaches of streams up to 300 m (1,000 ft) elevation. The ‘o’opu alamo (*Lentipes concolor*) usually occupies the upper sections streams above 800 m (2,600 ft) and can apparently navigate Hawaii's largest waterfalls (Devick et al. 1992). Prior to human alteration of the aquatic habitats, the ‘o’opu nakea, ‘o’opu nopili, and the ‘o’opu alamo’o would have all occurred with the naiads of some of the Hawaiian damselflies, at least occasionally. The ‘o’opu nakea has been reported to feed on Hawaiian damselfly naiads (Ego 1956), but this species is apparently primarily herbivorous and ingestion of naiads probably occurs incidental to feeding on algae (Kido et al. 1993). The ‘o’opu noplili feeds predominately on algae and ‘o’opu alamo’o, while facultatively predaceous and not known to feed on damselfly naiads (*in litt*. 1995 cited in U.S. Fish and Wildlife Service candidate assessment form). Therefore, the Hawaiian damselflies probably experienced limited natural predation pressure from the native fishes.

Fish predation has been an important factor in the evolution of behavior in damselfly naiads in continental systems (Johnson 1991). Some species of damselflies are not adapted to cohabitate with fish, and are found only in bodies of water without fish (Henrickson 1988, McPeek 1990a). The naiads of these species tend to occupy more exposed positions and engage in conspicuous foraging behavior, thereby being susceptible to fish (Macan 1977, McPeek 1990b). The evolutionary history of the Hawaiian damselflies coexisting with few, if any predatory fish, and the exposed behavior of most of the fully aquatic species, makes them particularly vulnerable to predation by alien fish introductions. Over 60 species of aquatic organisms have been introduced into Hawaiian freshwater habitats, including at least 45 species of fish (Devick 1991).

The impact of fish introductions prior to 1900 cannot be assessed because this predated the initial collection of damselflies in Hawaii (Perkins 1913). In 1905, two species, the mosquito fish (*Gambusia affinis*), and the sailfin molly (*Poecilia latipinna*), were successfully introduced for biological control of mosquitoes (Van Dine 1907). In 1922, three additional species were established for mosquito control, the green swordtail (*Xiphophorus helleri*), the Moonfish (*Xiphophorus maculatus*), and the guppy (*Poecilia reticulata*). The introduction of these species has been implicated in the extinction of the Pacific Hawaiian damselfly from most of the main islands (Moore and Gagne 1982), and by 1935 on Oahu, the orangeblack Hawaiian damselfly was found only in waters without these introduced fish (Williams 1936, Zimmerman 1948b, Polhemus 1993b). Most of the fish introduced early into Hawaii are now established on all the major islands, and are primarily pond and reservoir inhabitants.

Beginning in about 1980, a large number of new fish introductions began in Hawaii, originating primarily from the aquarium fish trade (Devick 1991). By 1990, an additional 15 species of fish were established in waters on Oahu, including catfish, cichlids, gobies, top minnows, needlefish, and piranha many which readily invaded stream systems. By early 1990, the lower to middle reaches of two widely separated streams on Oahu, Manoa on the south leeward side, and Kaukanohua on the north windward side, were choked with dense populations of armored catfish (*Hypostomus* sp. and *Pterygoplichthys multiradiatus*) (Devick 1991). This recent wave of fish introductions on Oahu corresponded with the drastic decline and range reduction of the crimson Hawaiian damselfly, the oceanic Hawaiian damselfly, and the blackline Hawaiian damselfly. Currently, these damselflies occur only in drainages or higher parts of stream systems where alien fish are not yet established (*in litt*. 1994 cited in U.S. Fish and Wildlife Service candidate assessment form). The continued introduction and establishment of new species of alien fish, and the movement of established species to new drainages (personal communication 1994 cited in U.S. Fish and Wildlife Service candidate assessment form) presents the greatest threat to this Hawaiian damselfly species.

D. *The inadequacy of existing regulatory mechanisms.*

The State of Hawaii considers all natural flowing surface water (streams, springs and seeps) as State property (Hawaii Revised Statutes 174c 1987), and the Hawaii Department of Land And Natural Resources has management responsibility for the aquatic organisms in these waters (personal communication 1995 cited in U.S. Fish and Wildlife Service candidate assessment form). Thus, damselfly populations associated with streams, seeps and springs are under the jurisdiction of the State of Hawaii, regardless of the ownership of the property across which the stream flows. This includes all populations of the crimson Hawaiian damselfly, the blackline Hawaiian damselfly, and the oceanic Hawaiian damselfly, as well as some populations of the Pacific Hawaiian damselfly and the orangeblack Hawaiian damselfly occurring in streams.

State regulatory mechanisms currently in effect do not provide adequate protection for the Hawaiian damselflies or their habitat. The State of Hawaii has not listed these damselflies as endangered or threatened and so has not afforded them any protection under the State endangered species act. Nor does the State Water Code afford adequate protect from the adverse effects of water development projects. The State of Hawaii manages the use of surface and ground water resources through the Commission on Water Resource Management (Water Commission), as mandated by the 1987 State Water Code (State Water Code, Hawaii Revised Statutes Chapter 174C-71, 174C-81-87, and 174C-9195 and Administrative Rules of the State Water Code, Title 13, Chapters 168 and 169). In the State Water Code, there are no formal requirements that project proponents or the Water Commission protect the habitats of fish and wildlife prior to issuance of a permit to modify surface or ground water resources.

The maintenance of instream flow, which is required to protect the habitat of damselflies and other aquatic wildlife, is regulated by the establishment of standards on a stream-by-stream basis (State Water Code, Hawaii Revised Statutes Chapter 174C-71 and Administrative Rules of the State Water Code, Title 13, Chapter 169). Currently, the interim instream flow standards represent the existing flow conditions in streams in the State as of 15 June 1988 for Molokai, Hawaii, Kauai and East Maui, and 19 October 1988 for West Maui and Leeward Oahu (Administrative Rules of the State Water Code, Title 13, Chapter 169-44-49). However, the State Water Code does not provide for permanent or minimal instream flow standards for the protection of aquatic wildlife. Instead, modification of instream flow standards and stream channels can be undertaken at any time by the Water Commission or via public petitions to revise flow standards or modify stream channels in a specified stream (Administrative Rules of the State Water Code, Title 13, Chapter 169-36). Additionally, the Water Commission must consider economic benefits gained from out-of-stream water uses, and is not required to balance these benefits against instream benefits to aquatic fish and wildlife. Consequently, any stabilization of stream flow for the protection of Hawaiian damselfly habitat is subject to modification at a future date.

The natural value of Hawaii's stream systems have been recognized under the State of Hawaii Instream Use Protection Program (Administrative Rules of the State Water Code, Title 13, Chapter 169-20(2)). In the Hawaii Stream Assessment Report, prepared in coordination with the National Park Service (National Park Service 1990), the State Water Commission identified high quality rivers or streams, or portions of a rivers or streams, that may be placed within a wild and scenic river system. This report recommended that streams meeting certain criteria be protected from further development. However, there is no formal or institutional mechanism within the Water Code to designate and set aside these streams, or to identify and protect stream habitat for Hawaiian damselflies.

Existing Federal regulatory mechanisms that may protect Hawaiian damselflies and their habitat are also inadequate. The Federal Energy Regulatory Commission (FERC) has very limited jurisdiction in Hawaii. Hydroelectric power projects in Hawaii are not on navigable water, public lands, or United States reservations; do not use surplus water or water power from a Federal Government Dam; and do not affect the interests of interstate or foreign commerce. Thus, licensing of hydroelectric projects do not come under the purview of FERC. However, hydropower developers in Hawaii may voluntarily seek licensing under FERC.

The U.S. Army Corps of Engineers (COE) also has some.regulatory control over modifications of freshwater streams in the United States. For modifications (i.e. discharge of fill) of streams with an average annual flow greater than five cubic feet per second (cfs), the COE can issue individual Department of the Army (DOA) permits under Section 404 of the Clean Water Act. These permits are subject to public review, and must comply with the Environmental Protection Agency's 404(b)(1) guidelines and public comment requirements. However, in issuing these permits, the COE does not establish instream flow standards as a matter of policy. The COE normally considers that the public interest for instream flow is represented by the state water allocation rights or preferences (Regulatory Guidance Letter No 85-6), and project alternatives that supersede, abrogate, or otherwise impair the state water quantity allocations are not normally addressed as alternatives during permit review.

In cases where the COE district engineer does propose to impose instream flow standard on an individual DOA permit, this flow standard must reflect a substantial national interest. Additionally, if this instream flow standard is in conflict with a State water quantity allocation, then it must be reviewed and approved by the Office of the Chief Engineer in Washington, D.C. Currently, the setting of instream flow standards sufficient to conserve Hawaiian damselflies is not a condition that would be considered or included in a DOA individual permit. If this damselfly was listed as endangered or threatened, Federal interest in its conservation would be assured through consultation under Section 7 of the Endangered Species Act.

The COE may also authorize the discharge of fill into streams with an average annual flow of less than five cfs. These discharges are covered under a nationwide permit (33 CFR 330 Appendix A, Nationwide Permit 26). This permit is designed to expedite small scale activities that the COE considers to have only minimal environmental impacts (33 CFR 330.1(b)). The U.S. Fish and Wildlife Service and the State Department of Land and Natural Resources have only 15 days to provide substantive site-specific comments following the issuance of a nationwide permit (33 CFR 330 Appendix A, Nationwide Permit Condition 13). Given the complexity of the impacts on Hawaiian damselflies from stream modifications and surface water diversions, the remoteness.of project sites, and the types of studies necessary to determine project impacts and mitigation, this limited comment period does not allow for an adequate assessment of impacts. The listing of the Hawaiian damselflies as endangered or threatened species will insure that their conservation is adequately considered during consultation, as required under Section 7 of the Endangered Species Act.

Current Conservation Efforts: None.

E. *Other natural or manmade factors affecting its continued existence.*

Not applicable.

REFERENCES

Asquith, A. 1995. Hawaiian Damselfly Survey: Population Checklist of Category 1 Candidate Species. Unpublished Document by U.S. Fish & Wildlife Service, Pacific Islands Office, Honolulu, HI.

Beardsley, J.W. 1962. On accidental immigration and establishment.of terrestrial arthropods in Hawaii during recent years. Proc. Hawaii. Entomol. Soc. 18:99-109.

Beardsley, J.W. 1979. New immigrant insects in Hawaii: 1962 through 1976. Proc. Hawaii. Entomol. Soc. 23:35-44.

Bennett, W.C. 1931. Archaeology of Kauai. B.P. Bishop Mus. Bull. 80:1-156.

Bishop Museum of Honolulu. Hawaiian Terrestrial Arthropod Checklist, March 2002 version. http://www2.bishopmuseum.org/HBS/checklist/query.asp?grp=Arthropod

Blackburn, T. 1884. Notes on Hawaiian Neuroptera, with descriptions of new species. Ann. Mag. Nat. Hist., (V) 14: 412-421. As referenced in: Zimmerman, E.C. 1948. Insects of Hawaii, Vol. 2. Apterygota -Thysanoptera. University of Hawaii Press, Honolulu.

Borror, D.J., C.A. Triplehorn and N.F. Johnson. 1989. Introduction to the Study of Insects, Sixth Edition. Saunders College Publishing, Philadelphia.

Cowles, L.E. 1977. Status of Damselflies (Odonata: Zygoptera) in Hawaii in 1977, with special reference to the endemic genus *Megalagrion* . Senior Honors Thesis, Department of Biology, University of Hawaii, Manoa.

Cuddihy, L.W., and C.P. Stone. 1990. Alteration of native Hawaiian vegetation: Effects of humans, their activities and introductions. University of Hawaii Press, Honolulu. 138 pp.

Department of Geography, University of Hawaii. 1983. Atlas of Hawaii. second edition. University of Hawaii Press. Honolulu. 238 pp.

Devaney, D.M., M. Kelly, P.J. Lee, and L.S. Motteler. 1982. Kaneohe: A History of Change. The Bess Press, Honolulu, Hawaii.

Devick, W.S. 1991. Patterns of introduction of aquatic organisms to Hawaiian freshwater habitats: in Devick, W.S., New Direction in Research, Management and Conservation of Hawaiian Freshwater Stream Ecosystems, Proceedings of the 1990 Symposium on Freshwater Stream Biology and Fisheries Management, Department of Land and Natural Resources, Honolulu, Hawaii.

Ego, K. 1956. Life history of freshwater gobies. Freshwater Game and Fish Management Research Project No. F-4-R. Honolulu, Hawaii.

Englund, R. and D.A. Polhemus. 1994. Maakua Stream biological assessment, Oahu, Hawaii. Environmental Technologies International, Honolulu, Hawaii.

Ford, J.I. and R.A. Kinzie, III. 1982. Life crawls upstream. Natural History 91:61-66.

Funasaki, G.Y., P.-L. Lai, L.M. Nakahara, J.W. Beardsley & A.K. Ota. 1988. A review of biological control introductions in Hawaii: 1890 to 1985.Proc. Hawaii. Entomol. Soc. 28:105-160.

Gagne, W.C. 1980. Insect and myriopods of Kipahulu Valley below 2,000 feet: in. Smith, C.W., Resources Base Inventory of Kipahulu Valley below 2,000 feet, Maui, Hawaii. Coop. Natl. Park. Res. S. Studies Unit. 119-175 pp.

Gagne, W.C. and F.G. Howarth. 1982. Assessment of Endangered and Threatened Status of Hawaiian Arthropods. Report to U.S. Fish and Wildlife Service, in Pacific Islands Office, Honolulu.

Giambelluca, T.W., M.A. Nullet, M.A. Rifgley, P.R. Eyre, J.E.T. Moncur, and S. Price. 1991. Drought in Hawaii. Report 87. State of Hawaii. Department of Land and Natural Resources, Commission on Water Resource Management.

Gillespie, R.G. and N. Reimer. 1993. The effect of alien predatory ants(Hymenoptera: Formicidae) on Hawaiian endemic spiders (Araneae:Tetragnathidae). Pacific Science 47:21-33.

Handy, E.S.C. and E.G. Handy. 1972. Native planters in old Hawaii. Their life, lore, and environment. B.P. Bishop Mus. Bull. 233:1-641.

Hardy, D.E. 1979. An ecological survey of Puaaluu Stream. Part III. Report on a preliminary entomological survey of Puaaluu Stream, Maui. Coop. Nat. park Resources Study Unit. University of Hawaii. Tech. Report 27:34-39.

Hardy, D.E. and M.D. Delfinado. 1980. Insect of Hawaii. Volume 13, Diptera: Cyclorrhapha III. University of Hawaii Press,.Honolulu.

Harris, S., A. Rubissow, S. Edmunds, and J.-A. Cachola. 1993. Hawaii Streams. Document prepared for Commission on Water Resource Management, State of Hawaii. 40 pp.

Harwood, P.D. 1976. Dragonflies (Odonata) observed in Hawaii in 1973 and 1974. Proc. Hawaii. Entomol. Soc. 22:251-253.

Hawaii Stream Assessment. 1990. Department of Land and Natural Resources, State of Hawaii. 300 pp.

Heads, P.A. 1985. The effect of invertebrate and vertebrate predators on the foraging movements of Ischnura elegans larvae (Odonata: Zygoptera). Freshwater Biology 15:559-571.

Heads, P.A. 1986. The costs of reduced feeding due to predator avoidance: potential effects on growth and fitness in *Ischnura elegans* larvae (Odonata: Zygoptera). Ecological Entomology 11:369-377.

Henrikson, B.-I. 1988. The absence of antipredator behavior in the larvae of *Leucorrhinia dubia* (Odonata) and the consequences for their distribution. Oikos 51:179-183.

Hibbard, D. and D. Franzen. 1991. The View from Diamond Head: Royal Residence to Urban Resort. Editions Limited, Honolulu, Hawaii. 221 pp.

Howarth, F.G. 1990. Hawaiian terrestrial arthropods: An overview. Bishop. Mus. Occas. Pap. 30:4-26.

Howarth, F.G. and W.P. Mull. 1992. Hawaiian Insects and Their Kin. University of Hawaii Press, Honolulu.

Howarth, F.G., A. Asquith, and G. Nishida. 1994. Insect of Hawaii: Status and Trends. Unpublished manuscript.

Howarth, F.G. and A.C. Medeiros. 1989. Non-native invertebrates: in Stone,C.P. and D.B. Stone (eds), Conservation Biology in Hawaii. University of Hawaii Cooperative National Park Resources Studies Unit, Honolulu. pp. 82-87.

Howarth, F.G. and G.W. Ramsay. 1991. The conservation of island insects and their habitats: in Collins, N.M. and J.A. Thomas.(eds), The Conservation of Insects and Their Habitats, Academic Press, London. pp. 71-107

Joesting, E. 1984. Kauai: The separate kingdom. University of Hawaii Press, Honolulu.

Johnson, D.M. 1991. Behavioral ecology of larval dragonflies and damselflies. Trends in Ecol. Evol. 6:8-13.

Jones, B.L., S.S.W. Chin, and J.C. Brice. 1984. Olokele rock avalanche, island of Kauai, Hawaii. Geology 12:209-211.

Kennedy, C.H. 1917. Notes on the penes of damselflies (Odonata). No. 2. The close relations inter se of the Hawaiian *Agrionines*. Entomological News. 28:9-14.

Kennedy, C.H. 1920. Forty-two hitherto unrecognized genera and subgenera of Zygoptera. Ohio J. Science. 21:83-88.

Kennedy, C.H. 1929. The origin of the Hawaiian Odonata fauna and its evolution within the islands. Proceedings of the Fourth International Congress of Entomology 2:978-981.

Kennedy, C.M. 1934. *Kilauagrion dinesiotes*, a new species of dragonfly (Odonata) from Hawaii. Annals of the Entomological Society of America. 27:343-345.

Kido, M.H., P. Ha, and R.A. Kinzie III. 1993. Insect introductions and diet changes in and endemic Hawaiian amphidromous goby, *Awaous stamineous* (Pisces: Gobiidae). Pacific Science 47:43-50.

Kirby, W. F. 1890. A synonymic catalog of Neuroptera Odonata, or Dragonflies, with an appendix of fossil species. Gurney and Jackson, London. 202 pp. As referenced in: Zimmerman, E.C. 1948. Insects of Hawaii, Vol. 2. Apterygota - Thysanoptera. University of Hawaii Press, Honolulu.

Kirch, P.V. 1982. The impact of the prehistoric Polynesians on the Hawaiian ecosystem. Pacific Science 36:1-14.

Kirch, P.V. 1985. Feathered gods and fishhooks. University of Hawaii Press, Honolulu, Hawaii. 349 pp..Lai, P.-Y. 1988. Biological control: A positive point of view. Proc. Hawaii. Entomol. Soc. 28:179-190.

McLachlan, R. 1883. Neuroptera of the Hawaiian Islands. - Part I. Pseudo-Neuroptera. Ann. Mag. Nat. Hist., (V) 12: 226-240. As referenced in: Zimmerman, E.C. 1948. Insects of Hawaii, Vol. 2. Apterygota - Thysanoptera. University of Hawaii Press, Honolulu.

McPeek, M.A. 1990a. Determination of species composition in the *Enallagma* damselfly assemblages of permanent lakes. Ecology 71:83-98.

McPeek, M.A. 1990b. Behavioral differences between *Enallagma* species (Odonata) influencing differential vulnerability to predators. Ecology 71:1714-1726.

Macan, T.T. 1977. The influence of predation on the composition of fresh-water animal communities. Biol. Rev. 52:45-70.

MacDonald, G.A., D.A. Davis, and D.C. Cox. 1960. Geology and ground-water resources of the island of Kauai, Hawaii. Hawaii Division of Hydrology, Bulletin No. 13. 212 pp.

Maciolek, J.A. 1982. Lakes and lake-like waters of the Hawaiian Archipelago. Occas. Pap. B.P. Bishop Mus. 25:1-14.

Meier, K.Z., J.P. Laurel and J.E. Maragos. 1993. State of Hawaii (USA). in Scott, D.A., A Directory of Wetlands in Oceania, The international Waterfowl and Wetlands Research Bureau, U.K., and Asia Wetland Bureau, Kuala Lumpur, Malaysia. 444 pp.

Moore, N.W. 1982. Conservation of Odonata - First steps towards a world strategy. Adv. Odontal. 1:205-211.

Moore, N. W. 1983a. Territorial behavior in the genus *Megalagrion* (McLachlan) (Zygoptera: Coenagrionidae). Odonatologica 12(1): 87-92.

Moore, N. W. 1983b. Reflex immobilisation in the Hawaiian endemic genus *Megalagrion* McLachlan (Zygoptera: Coenagrionidae). Odonatologica, 12(2): 161-165..Moore, N.W. and W.C. Gagne. 1982. *Megalagrion* pacificum (McLachlan) - A preliminary study of the conservation requirements of an endangered species. Rep. Odon. Specialist group Int. Un. Conserv. Nat. Natur. Res. No 3:1-5.

Nafus, D.M. 1993a. Biological control agents and native parasitoids in the population system of the butterfly *Hypolimnas bolinas* (L.) (Lepidoptera:Nymphalidae). Micronesica, Suppl. 4:17-23.

NatureServe Explorer: An online encyclopedia of life [web application]. 2001. Version 1.6 . Arlington, Virginia, USA: NatureServe. Available: http://www.natureserve.org/explorer.

Nishida, G.M., Ed. 1994a. Hawaiian Terrestrial Arthropod Checklist, 2nd Edition. Bishop. Mus. Technical Report No. [1]. 287 pp.

Nishida, G.M. 1994b. Taxonomic validation of Candidate species of insects (and related Arthropods) of the Hawaii Islands. Report prepared for the National Biological Survey, 61 pp.

O'Connor, P.J. 1990. Poaceae. in W.L. Wagner, D.R. Herbst and S. Sohmer, Manual of the Flowering Plants of Hawai'i. B.P. Bishop Mus. Spec. Publ. No. 83. 1853 pp.

Ogden Environmental and Energy Service. 1994. VA Medical and Regional Office Center Project Conceptual Mitigation Plan for Impacts on the Orange-black damselfly Population at Tripler Army Medical Center. pp. 16.

Olson, S.L. and H.F. James. 1982. Prodromus of the fossil avifauna of the Hawaiian Islands. Smithsonian Contrib. Zool. 1-59.

Parrish, J.D., J.A. Maciolek, A.S. Timbol, C.B. Hathaway, and S.E. Norton. 1984. Status of stream channel modification in Hawaii and its effects on native aquatic fauna. pp. 83-84. Proc. 5th Conference in Natural Sciences, Hawaii, Volcanoes National Park. Coop. Natl. Park. Res. Stud. Unit, University of Hawaii.

Perkins, R.C.L. 1899. Neuroptera. D. Sharp, ed., Vol. 2:63-77. Cambridge University Press, Cambridge.

Perkins, R.C.L. 1907. Insects at Kilauea, Hawaii. Proc. Hawaii. Entomol. Soc. 1:89-95..Perkins, R.C.L. 1913. Introduction to Fauna Hawaiiensis. D. Sharp, ed., Vol.1:xv-ccxxvii. Cambridge University Press, Cambridge.

Polhemus, D.A., J. Maciolek, and J. Ford. 1992. An ecosystem classification of inland waters for the tropical Pacific islands. Micronesica 25:155-173.

Polhemus, D.A. 1993a. Damsels in distress: a review of the conservation status of Hawaiian *Megalagrion* damselflies (Odonata: Coenagrionidae). Aquatic Conservation: Marine and Freshwater Ecosystems 3:343-349.

Polhemus, D.A. 1993b. Conservation of aquatic insects: Worldwide crisis or localized threats? Amer. Zool. 33:588-598.

Polhemus, D.A. 1993c. A preliminary assessment of the impacts of hurricane Iniki on the aquatic insect faunas of streams on the Na Pali Coast, Kaua'i, Hawai'i. in Assessments of the impact of Hurricane Iniki on stream biota and ecosystems on Kaua'i. Department of Land and Natural Resources, Division of Aquatic Resources. State of Hawai'i. pp. 59-88.

Polhemus, D.A. 1994a. Current status of *Megalagrion* populations on Oahu: 1990 - Present. Report to U.S. Fish & Wildlife Service, Pacific Islands Office.

Polhemus, D.A. 1994b. A revision of the Hawaiian damselflies in the genus *Megalagrion* (Odonata: Coenagrionidae). Unpublished report to U.S. Fish & Wildlife Service, Pacific Islands Office.

Polhemus, D.A. 1995. New Heteroptera and Odonata (Insecta) records and range extensions in the Hawaiian Islands. Bish. Mue. Occass. Pap. 42:42-43.

Polhemus, D.A., and A. Asquith. 1996. Hawaiian Damselfies: A Field Identification Guide. Hawaii Biological Survey Handbook, Bishop Museum Press, Honolulu, Hawaii. 122 pp.

Reimer, N.J. 1993. Distribution and impact of alien ants in vulnerable Hawaiian ecosystems: in D.F.Williams (ed), Exotic Ants: Biology, Impact,and Control of Introduced Species. Westview Press, Boulder, Colorado. Pp. 11-22.

Reimer, N., J.W. Beardsley and G. Jahn. 1990. Pest ants in Hawaii. in Vander Meer, R.K, K. Jaffe and A. Cedeno (eds), Applied Myrmecology: A World Perspective. Westview Press, Boulder, Colorado, pp. 40-50.

Schmidt, E. 1938. Check-list of Odonata of Oceania. Ann. Entomol. Soc. America. 31:322-344.

Selys-Longchamps, E. 1876. Synopsis des Agrionines, 5me Legion: Agrion. Bull. Acad. Royal Belgique, (II) 41 (2,3): 1-282. As referanced in: Zimmerman, E.C. 1948. Insects of Hawaii, Vol. 2. Apterygota -Thysanoptera. University of Hawaii Press, Honolulu.

Simon, C.M., W.C. Gagne, F.G. Howarth, and F.J. Radovsky. 1984. Hawaii: A natural entomological laboratory. Bull. Entomol. Soc. Am.30:8-17.

Smith, C.W. 1985. Impact of alien plants on Hawai'i's native biota. in C.P.Stone and J.M. Scott (eds), Hawai'i's Terrestrial Ecosystems: Preservation and Management. Cooperative National Park Resources Study Unit, University of Hawaii, Honolulu.

Stearns, H.T. 1940. Geology and ground-water resources of the islands of Lanai and Kahoolawe, Hawaii. Bulletin 6 of the Division of Hydrography, Territory of Hawaii.

Stearns, H.T. and K.N. Vaksvik. 1935. Geology and ground-water resources of the island of Oahu, Hawaii. Bulletin 1 of the Division of Hydrography, Territpry of Hawaii.

Stearns, H.T. 1985. Geology of the State of Hawaii. second edition. Pacific Books, Palo Alto, California.

Stone, C.P. 1985. Alien animals in Hawai'i's native ecosystems: toward controlling the adverse effects of introduced vertebrates: in Stone, C.P., and J.M. Scott (eds.), Hawai'i's terrestrial ecosystems: preservation and management. Coop. Natl. Park Resources Stud. Unit, Univ. Hawaii, Honolulu, pp. 251-297.

Stone, C.P. 1989. Hawai'i's wetlands, streams, fishponds, and pools. in C.P.Stone and D.B. Stone (eds), Conservation Biology in Hawai'i. Cooperative National Park Resources Study, pp. 125-136. Unit, University of Hawaii, Honolulu.

Summers, C.C. 1964. Hawaiian Fishponds. B.P. Bish. Mus. Spec..Publ. 52. Takasaki, K.I., G.T. Hirashima, and E.R. Lubke. 1969. Water Resources of Windward Oahu, Hawaii. U.S. Geological Survey Water Supply Paper No. 1894:1-119. U.S. Govt. Printing Office, Washington, D.C.

U.S. Fish and Wildlife Service. 1985. Recovery plan for the Hawaiian waterbirds. U.S. Fish and Wildlife Service, Portland, Oregon, 99 pp.

U.S. Fish and Wildlife Service. 1995. Pacific Islands Ecoregion Coastal Ecosystems Program Proposal. U.S. Fish and Wildife Service, Honolulu, Hawaii, 119. pp.

Van Dine, D.L. 1907. The introduction of top-minnows (natural enemies of mosquitoes) into the Hawaiian Islands. Haw. Agr. Exp. St. Press Bull. 20:1-10.

Wenkam, R. 1969. Kauai and the park county of Hawaii. Sierra Club, San Fransisco. 160 pp.

Williams, F.X. 1936. Biological studies in Hawaiian water-loving insects. Part 1. Coleoptera or beetles. Part 2. Odonata or dragonflies. Proc. Hawaii. Entomol. Soc. 9:235-345.

Wilson, Okamoto and Associates, Inc. 1993. Kawai Nui Marsh Master Plan: Development Project Report. Document prepared for Department of Land and Natural resoruces, State of Hawaii.

Wong, M.A. and T.T.Y. Wong. 1988. Predation of the Mediterranean fruit fly and oriental fruit fly (Diptera: Tephritidae) by the fire ant (Hymenoptera: Formicidae) in Hawaii. Proc. Hawaii. Entomol. Soc. 28:169-177.

Zimmerman, E.C. 1948a. Insects of Hawaii. Vol. 1. Introduction. xvii + 206 pp. University of Hawaii Press.

Zimmerman, E.C. 1948b. Insects of Hawaii, Vol. 2. Apterygota - Thysanoptera. University of Hawaii Press, Honolulu.

Zimmerman, E.C. 1948c. Insects of Hawaii, Vol. 3. Heteroptera. University of Hawaii Press, Honolulu.

Zimmerman, E.C. 1970. Adaptive radiation in Hawaii with special.reference to insects. Biotropica 2:32-38.

PETITION TO LIST

crimson Hawaiian damselfly
(*Megalagrion leptodemas*)

AS A FEDERALLY ENDANGERED SPECIES

CANDIDATE HISTORY

CNOR 5/22/84:	
CNOR 1/6/89:	
CNOR 11/21/91:	
CNOR 11/15/94:	
CNOR 2/28/96:	C
CNOR 9/19/97:	C
CNOR 10/25/99:	C
CNOR 10/30/01:	C
CNOR 6/13/02:	C

TAXONOMY

Native Hawaiians apparently did not differentiate among the different species, but referred to the native damselflies collectively as pinaoʻula. There has been no traditional European use of a common name for species in the genus *Megalagrion* (Coenagrionidae). In a recent taxonomic review of the candidate species of insects in Hawaii, Nishida (1994b) proposed the name "Hawaiian damselflies". Because this name reflects the restricted distribution of these insects and should be readily used by nontechnical persons, the U.S. Fish and Wildlife Service has adopted this common name for the genus, with additional descriptive terms to identify each species.

The status of *Megalagrion leptodemas* as a valid species is uncontroversial (e.g., Bishop Museum 2002). In the most recent list of candidate species for listing as endangered species, published in the Federal Register on 13 June 2002, the U.S. Fish and Wildlife Service has incorrectly written the specific epithet for this species as "*leptodemus*".

NATURAL HISTORY

Distribution

Because of the extreme geographic isolation of the Hawaiian islands and the poor dispersal capabilities of many aquatic insects, the freshwater insect fauna of Hawaii is depauperate compared to continental areas despite the diversity of aquatic habitats. Many groups of insects that typify freshwater habitats in continental areas are absent from the native fauna. Some notable examples of such groups are mayflies (*Ephemeroptera*), stoneflies (*Plecoptera*), caddisflies (*Trichoptera*), and alderflies and dobsonflies (*Neuroptera*), all of which are absent from Hawaii. Like most of the native fish, mollusc, and crustacean faunas (Ford and Kinsey 1994), most of Hawaii's freshwater insects evolved from marine or intertidal ancestors (Hardy and Delfinado 1980) that could easily colonize the islands.

The Hawaiian damselflies are represented by 23 species and five subspecies, all confined to the Hawaiian Islands. Historically these were among the most common and conspicuous native Hawaiian insects. Some species inhabited water gardens in residential areas, artificial reservoirs, and watercress farms, and were abundant in the city of Honolulu (Perkins 1913, Williams 1936).

Morphology
Megalagrion leptodemas is of the smaller Hawaiian damselflies. The male is slender and predominantly red in coloration with black markings on the tops of segments V to VII of the abdomen. The female is similarly colored, but with pale markings on body green rather than red and with the top of the abdomen mostly blackish. More detailed descriptions and color photo of male are available in Polhemus and Asquith (1996).

Behavior
The general biology of Hawaiian damselflies is typical of other narrow-winged damselflies. The males of most species are territorial, guarding areas of habitat where females will lay eggs (Moore 1983a). During copulation, and often while the female lays eggs, the male grasps the female behind the head with his terminal abdominal appendages to guard her against rival males, thus males and females are frequently seen flying in tandem. In species with fully aquatic immature stages, females lay eggs in submerged aquatic vegetation or in mats of moss or algae on submerged rocks, and hatching occurs in about ten days (Williams 1936, Polhemus 1994b).

In most species of Hawaiian damselflies, the immature stages (naiads) are aquatic, breathing though three flattened, abdominal gills, and are predacious, feeding on small aquatic invertebrates or fish (Williams 1936). Naiads may take up to four months to mature (Williams 1936), after which they crawl out of the water onto rocks or vegetation, molt into winged adults, which typically remain very close to the aquatic habitat from which they emerged. Adults are also predacious and feed on small flying insects such as midges. In a remarkable example of adaptive radiation in Hawaii, some species of Hawaiian damselflies have foregone the aquatic lifestyle, either partly, with naiads living on wet rock faces, or completely, with terrestrial naiads living in the damp leaf litter, or others inhabiting moist leaf axils of native plants up to several meters above the ground (Zimmerman 1970, Simon et al. 1984). Adults are also unusual in that they have a highly developed behavior of feigning death when caught or attacked (Moore 1983b).

The crimson Hawaiian damselfly breeds in the slow reaches of streams and stream pools (Williams 1936, Zimmerman 1948b, Polhemus 1994a, 1994b).

Habitat
Pools in intermittent streams and slow sections of perennial upland streams. The naiads of this species are fully aquatic and good swimmers. They frequent open water, resting horizontally on the bottom or on submerged vegetation (Williams 1936). The four remaining populations occur in

the headwater reaches of streams, with the naiads living in seepage fed pools in the basaltic bedrock.

POPULATION STATUS

This species is considered the rarest and most endangered of the native Oahu damselflies (Polhemus & Asquith 1996).

The crimson Hawaiian damselfly (*Megalagrion leptodemas*) is endemic to the island of Oahu, where it was historically known from the following areas--Haleauau Stream in the Waianae Mountains (Williams 1936), Hering Spring above Makiki (Williams 1936), Kahamainui Gulch above Laie (Polhemus 1994b), Kawailoa Gulch, Palolo Stream, Pauoa Flats on Tantalus (Polhemus 1994b), and Poamoho Trail (Perkins 1899, Polhemus 1994b). All these localities have recently been surveyed and no longer harbor populations of this species. Currently only four populations of this damselfly are known; North Halawa Valley (Polhemus 1994a), Kahana Stream tributary (personal communication 1996 cited in U.S. Fish and Wildlife Service candidate assessment form), the headwaters of Waiawa Stream (two 1996 personal communications cited in candidate assessment form), and Maakua Gulch above Hauula (Englund and Polhemus 1994).

As early as 1948, Zimmerman noted a decline of the more common species, particularly on Oahu. By the late 1970s less than six populations of the Pacific Hawaiian damselfly could be located (Harwood 1976, Gagne 1980, Moore and Gagne 1982), and the conservation of this species was identified as a priority by the International Union for Conservation of.Nature and Natural Resources (Moore 1982). A review of the status of Hawaiian damselflies in 1981 (Gagne and Howarth 1982) lead to the placement of several species on the U.S. Fish and Wildlife Service's list of candidate species for Federal listing (49 FR 21664). Due to a continued decline of these damselflies, particularly on the island of Oahu, intensive surveys were initiated in 1990, supported by both the Service and the State of Hawaii. The results of these surveys demonstrate that six species of Hawaiian damselflies are now threatened with extinction.

No quantitative estimates of population sizes are available, but adults are rare at all localities, and immatures have not been seen (Polhemus 1994a, 1994b). This contrasts sharply with historical accounts by Williams (1936) who describes it as abundant along the stream issuing from Hering Springs, and observed 21 naiads in a 1 sq m pool. The primary threats to the remaining populations of the crimson Hawaiian damselfly are predation by alien aquatic species such as fish and frogs, and habitat loss through channel alteration and dewatering of streams.

Populations of the crimson Hawaiian Damselfly are now extremely reduced, with fewer than 10 males per 100 m of stream edge at all localities.

The International Union for the Conservation of Nature (IUCN) considers the species to be endangered.

The U.S. Fish and Wildlife Service classifies the crimson Hawaiian damselfly as a candidate for Endangered Species Act protection with a listing priority number of 2.

LISTING CRITERIA

A. *The present or threatened destruction, modification, or curtailment of its habitat or range.*

Historical range: Hawaii. The crimson Hawaiian damselfly (*Megalagrion leptodemas*) is endemic to the island of Oahu, where it was historically known from the following areas--Haleauau Stream in the Waianae Mountains (Williams 1936), Hering Spring above Makiki (Williams 1936), Kahamainui Gulch above Laie (Polhemus 1994b), Kawailoa Gulch, Palolo Stream, Pauoa Flats on Tantalus (Polhemus 1994b), and Poamoho Trail (Perkins 1899, Polhemus 1994b).

Current range: Hawaii, island of Oahu. North Halawa Valley (Polhemus 1994a), Kahana Stream tributary (personal communication 1996 cited in U.S. Fish and Wildlife Service candidate assessment form), the headwaters of Waiawa Stream (personal communication 1996 cited in U.S. Fish and Wildlife Service candidate assessment form), and Maakua Gulch above Hauula (Englund and Polhemus 1994).

Land ownership: This species occurs in State-managed waters.

Freshwater habitats on all the main Hawaiian Islands have been severely altered and degraded because of past and present land and water management practices including agriculture, urban development, development of ground water, perched aquifer and surface water resources, and the deliberate introduction of alien animals (Harris et al. 1993, Meier et al. 1993, U.S. Fish and Wildlife Service 1985, 1995).

Extensive modification of lentic (standing water) habitats in the Hawaiian Islands began about 1100 AD with a rapid population increase among native Hawaiians (Kirch 1982). Hawaiians cultivated taro (*Colocasia esculenta*) by creating shallow, walled ponds called lo’I, in marshes and riparian areas (Handy and Handy 1972). By 1778, virtually all valley bottoms with permanent stream flow and most basin marshes were converted to irrigated taro cultivation (Handy and Handy 1972). While this represents a significant alteration of the natural aquatic system, these extensive artificial wetlands were probably suitable habitat for many native Hawaiian species, particularly waterbirds (Olson and James 1982). Native Hawaiian dragonflies were recorded in taro lo’I (Handy and Handy 1972) and some damselflies may also have utilized these systems (Moore and Gagne 1982), since the lo’I remained flooded for months or years at a time (Handy and Handy 1972).

Hawaiians also modified wetlands by constructing fish ponds, many of which were primarily freshwater, fed by streams or springs (Summers 1964). Despite this habitat modification by early Hawaiians, many areas of extensive marsh land remained intact. The best example of this was the Mana marsh of western Kauai. In this area, sedimentary deposits restrict the flow of ground water seaward, creating basal water.spring discharge 3-4 m (8-12 ft) above sea level, and the development of an extensive marsh system (MacDonald et al. 1960). This area was famous for its mirages on open water surfaces (MacDonald et al. 1960) and Hawaiians traveled by canoe for miles between villages (Bennett 1931).

Some wetlands which had been converted to taro lo’I were maintained and others were utilized for rice cultivation between 1850 and 1930. In 1900, there was approximately 19,000 acres of taro and 16,000 acres of rice in production in Hawaii (U.S. Fish and Wildlife Service 1995). By 1960, taro production was reduced to only 510 acres and the rice industry had been completely abandoned. Many of these wetlands formerly used for taro or rice were drained and filled for dry-land agriculture (Stone 1989, Meier et al. 1993). The Mana marsh on Kauai is also one of the best examples of extensive freshwater habitat loss due to modern agriculture. The margins of the Mana marsh were used for rice cultivation until 1922, when the land, including several open ponds, were leased to Kekaha Sugar Company for sugarcane cultivation (Joesting 1984). By the late 1940s, the entire Mana marsh had been drained and filled and was under sugarcane cultivation (Wenkam 1969).

Most urban, residential and resort development in Hawaii has occurred in the coastal plains and as a result, many freshwater lentic habitats have been negatively affected (U.S. Fish & Wildlife Service 1985). Most of this development has occurred on Oahu, which now supports four fifths of the state's population (Dept. of Geography 1983). The Ala Moana and Waikiki areas of Honolulu were once extensive marshlands that were converted to hundreds of taro lo’I and fishponds by Hawaiians (Handy and Handy 1972). Small development projects began in Waikiki in 1910, but even as late as 1920, 85 percent of Waikiki remained under water, used as duckponds, fishponds, and for the cultivation of rice and taro (Hibbard and Franzen 1991). In 1928, the Ala Wai Canal was completed, resulting in the complete drainage and development of the Waikiki wetlands, which now on an average day hosts over 60,000 people (Hibbard and Franzen 1991). Construction for housing and civil works projects on Oahu also resulted in the draining and filling of large fresh and brackish water marshes at Wailupe Peninsula, Hawaii Kai, Kaelepulu Pond, and Salt Lake (U.S. Fish and Wildlife Service 1995).

The Service now estimates that 30 percent of all coastal plain wetlands in Hawaii have been lost to agriculture and urban development (*in litt*. 1990 cited in U.S. Fish and Wildlife Service candidate assessment form), and if only freshwater habitat was considered the loss would be proportionately much higher, probably approaching 80 to 90 percent. While intentional filling of freshwater wetlands with open water is rarely permitted today (personal communication 1995 cited in U.S. Fish and Wildlife Service candidate assessment form), loss of smaller areas utilized by damselflies, such as narrow strips of freshwater seeps within anchialine pool complexes, and loss of emergent vegetation still occurs. In addition, marshes are slowly filled and converted to meadow habitat due to increased sedimentation resulting from increased storm water runoff from upslope development, and blockage of downslope drainage (Wilson Okamoto & Associates, Inc. 1993).

Presently the most significant threat to natural ponds and marshes in Hawaii is the alien species California grass (*Brachiaria mutica* (Forssk.) Stapf). The area of origin of this sprawling perennial grass is unknown, but it was first noted on Oahu in 1924 and now occurs on all the major islands (O'Connor 1990). This plant forms dense, monotypic stands that can completely eliminate any open water by layering of its trailing stems (Smith 1985). The most extensive remaining marsh system on the island of Oahu, Kawainui, is now almost entirely choked with California grass, facilitating its conversion to meadowland (Wilson Okamoto & Associates, Inc. 1993).

The James Campbell and Pearl Harbor National Wildlife Refuges on Oahu, and Kakahaia National Wildlife Refuge on Molokai must be constantly managed to control this plant (personal communication 1995 cited in U.S. Fish and Wildlife Service candidate assessment form). The Pacific Hawaiian damselfly and the orangeblack Hawaiian damselfly have both sustained loss of palustrine habitat on all islands due to human activities and California grass. Presently two populations of the orangeblack damselfly along the Kona coast of Hawaii are threatened with further habitat loss from overdraw of the aquifer that feeds coastal marshes (personal communication 1995 cited in U.S. Fish and Wildlife Service candidate assessment form). The only known population of the orangeblack damselfly on Oahu is threatened with habitat degradation from a proposed construction project (Ogden Environmental 1994).

Early Hawaiians also modified stream systems by diverting water from the main channel to irrigate taro lo'I. In some cases these diversions, or 'auwai, were elaborate, such as the cut and fitted stone ditch of Kiki a Ola in Waimea Canyon on Kauai (Bennett 1932). Other diversions were several kilometers long (Kirch 1985) and moved water between drainages (Devaney et al. 1983). However, these diversions were closely regulated and were not allowed to take more than half the stream flow, and diversions were typically periodic to flood lo'I rather than continuous (Handy and Handy 1972).

The advent of plantation sugarcane cultivation in 1835 led to more extensive stream diversions. The first irrigation system for sugar, built in 1856 on Kauai, was 16 km (10 mi) long. In 1900, the Maunawili Ditch on windward Oahu diverted all the water from Maunawili Stream into Waimanalo Valley (Takasaki et al. 1969). By 1906, the Kohala Ditch system on Maui utilized 15 km (9 mi) of tunnels, 7 km (4.5 mi) of open ditch, and 20 flumes, and now the East Maui Irrigation system may be the largest private water company in the United States (Harris et al. 1993). These systems typically tap water at upper elevations (> 300 m) by means of a concrete weir in the stream. All or most of the low or average flow of the stream is diverted into fields or reservoirs (Takasaki et al. 1969, Harris et al. 1993). By the 1930s, major water diversions had been developed on all the major islands and currently one third of Hawaii's perennial streams are diverted (Hawaii Stream Assessment 1990). Some systems are extensive, such as the Waiahole Ditch which takes water from 37 streams on the windward side of Oahu, and transports it to the leeward plains via a tunnel cut through the Koolau Mountain Range (Stearns and Vaksvik 1935).

On West Maui, as of 1978, over 49 miles of stream habitat in 12 streams have been lost due to diversions, and all of the 17 perennial streams on West Maui are diverted to some extent (Macioleck 1979). In addition to diverting water for agriculture and domestic water supply, streams have also been diverted for use in hydroelectric power. There are currently 18 active hydroelectric plants operating on Hawaiian streams, with another 10 proposed for construction, and another 28 sites identified for potential.development (Hawaii Stream Assessment 1990)
In addition to diverting surface flow in the stream channels, the perched aquifers which feed the streams have also been tapped by means of tunnels (Stearns and Vaksvik 1935, Stearns 1985). For example, both the bore tunnels and the contour tunnel of the Waiahole Ditch system pierced perched aquifers which were drained to the level of the tunnels (Stearns and Vaksvik 1935).

Many of these aquifers were also the sources of springs which contributed flow to the windward streams. The boring of the Haiku tunnel in 1940 caused a 25 percent reduction in the base flow of Kahaluu Stream, over 2.5 miles away (Takasaki et al. 1969). The draining of these aquifers caused many of the springs to dry up, including some over 0.5 km (0.3 mi) away from the bore tunnels (Stearns and Vaksvik 1935). Frequently the actual springs were tapped by driving tunnels into the rock from where the water emerged, and on the water-poor island of Lanai, almost every spring and seep was bored or captured (Stearns 1940).

Surface waters in streams have also been captured by tunnels in the alluvium of the stream channel. Historically, Maunalei Stream was the only perennial stream on Lanai, and Hawaiians constructed taro lo'I in the lower portions of this system. In 1911, a tunnel was developed at 330 m (1100 ft) elevation which undercut the stream bed, capturing both the surface and subsurface flow and dewatering the stream from this point to the mouth (Stearns 1940).

Stream degradation has been particularly severe on the island of Oahu, where, in 1978, 57 percent of the perennial streams had been channelized (lined, partially lined or altered stream course) and 89 percent of the total length of these streams were channelized (Parrish et al. 1984). Channelization of streams has not been restricted to lower reaches, in Kalihi Stream there is extensive channelization above 300 m (1000 ft). Channelization results in removal of riparian vegetation, increased velocity, increased illumination, and higher water temperatures. Hawaiian damselflies do not utilize channelized portions of streams.

Surface flow of streams has also been affected by vertical wells, because the basal aquifer and alluvial caprock.through which the lower sections of streams flow can be hydraulically connected (*in litt*. 1995 cited in U.S. Fish and Wildlife Service candidate assessment form). Historically, for example, there was sufficient surface flow in Makaha and Nanakuli streams on Oahu to support taro lo'I in their lower reaches, but this flow disappeared subsequent to construction of wells upstream (personal communication 1995 cited in U.S. Fish and Wildlife Service candidate assessment form). The crimson Hawaiian damselfly has sustained habitat loss due to water diversions, and stream alterations, on all the island of Oahu.

B. *Overutilization for commercial, recreational, scientific, or educational purposes.*

Healthy populations of stream-inhabiting Hawaiian damselflies are composed of large numbers of individuals. Moore (1983a) recorded 75 males per 100 m of stream edge for *Megalagrion heterogamias* on Kauai. In addition, there are often more males than suitable territorial habitat, and when males are removed from a territory they are immediately replaced by other individuals (Moore 1983a). However, populations of the crimson Hawaiian Damselfly, are now extremely reduced, with fewer than 10 males per 100 m of stream edge at all localities. Publication of the rarity of these species will likely increase the interest of professional and amateur Odonata collectors. Unrestricted collecting and handling could impact these small populations and are considered significant threats to the species.

C. *Disease or predation.*

The geographic isolation of the Hawaiian Islands has restricted the number of original successful colonizing arthropods and resulted in the development of an unusual fauna. An unusually small number (15 percent) of the known families of insects are represented by native Hawaiian species (Howarth 1990). Some groups that often dominate continental arthropod faunas, such as social Hymenoptera (group nesting ants, bees, and wasps), are entirely absent. Commercial shipping and air cargo to Hawaii has now resulted in the establishment of over 2,500 species of alien arthropods (Howarth 1990, Howarth et al. 1994), with a continuing establishment rate of 10-20 new species per year (Beardsley 1962; 1979). In addition to the accidental establishment of alien species, alien predators and parasites for biological control of pests have been purposefully imported and released by individuals, Republic, Territorial, State, and Federal agencies, since 1865. Between 1890 and 1985, 243 alien species were introduced, sometimes with the specific intent of reducing populations of native Hawaiian insects (Funasaki et al. 1988, Lai 1988). Alien arthropods, whether purposefully introduced or adventive, pose a serious threat to Hawaii's native insects, through direct predation and parasitism, and competition for food or space (Howarth and Medeiros 1989; Howarth and Ramsay 1991).

Ants are not a natural component of Hawaii's arthropod fauna, and endemic species evolved in the absence of predation pressure from ants. Ants can be particularly destructive predators because of their high densities, recruitment behavior, aggressiveness, and broad range of diet (Reimer 1993). The latter attribute allows some ants to affect prey populations independent of prey density, and ants can therefore locate and destroy isolated individuals and populations (Nafus 1993).

At least 36 species of ants are known to be established in the Hawaiian Islands, and three particularly aggressive species have had severe effects on the native insect fauna (Zimmerman 1948a). By the late 1870s, the big-headed ant (*Pheidole megacephala*) was present in Hawaii and its predation on native insects was noted by 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, including most moths, have been eliminated from areas where the big-headed ant is present (Perkins 1913, Gillespie and Reimer 1993). This predator generally does not occur at elevations higher than 600 m (2,000 ft), and is also restricted by rainfall, rarely being found in particularly dry (less than ca 35-50 cm [15-.20 in] annually) or wet areas (more than ca 250 cm [100 in] annually) (Reimer et al. 1990).

The long-legged ant (*Anoplolepis longipes*) appeared in Hawaii in 1952 and now occurs on Oahu, Maui, and Hawaii (Reimer et al. 1990). It inhabits low elevation (less than 600 m [2,000 ft]), rocky areas of moderate rainfall (less than 250 cm [100 in] annually) (Reimer et al. 1990). Direct observations indicate that Hawaiian arthropods are susceptible to predation by this species (Gillespie and Reimer 1993) and Hardy (1979) documented the disappearance of most native insects from Kipahulu Stream on Maui after the area was invaded by the long-legged ant.

At least two species of fire ants, *Solenopsis geminita* and *Solenopsis papuana*, are also important threats (Gillespie and Reimer 1993) and occur on all the major islands (Reimer et al. 1990).

Solenopsis geminita is also known to be a significant predator on pest fruit flies in Hawaii (Wong and Wong 1988). *Solenopsis papuana* is the only abundant, aggressive ant that has invaded intact mesic forest above 600 m (2,000 ft) and is still expanding its range in Hawaii (Reimer 1993). At least some populations of all the damselfly taxa included in this proposed rule are threatened by one or more of the ant species described above.

Backswimmers are aquatic true bugs (Heteroptera) in the family Notonectidae, so called because they swim upside down. Backswimmers are voracious predators and frequently feed on prey much larger than themselves, tadpoles, small fish, and other aquatic insects including damselfly naiads (Borror et al. 1989). Backswimmers are not native to Hawaii, but several species have been introduced in recent times. *Buenoa pallipes* (Fabricus) (NCN) has been known from Hawaii since 1900 (Zimmerman 1948c) and has been recorded from all the major islands except Lanai (Nishida 1994a). This species can be abundant in lowland ponds and reservoirs and feeds on any suitably sized insect, including damselfly naiads. More recently, two additional species of backswimmers have become established in Hawaii (Polhemus 1995). *Anisops batillifrons* was first collected in 1991 and is known only from Maui. *Notonecta indica* was first collected on Oahu in the mid 1980s and is presently known from Maui and Hawaii. Species of *Notonecta* are known to prey on damselfly naiads and the mere presence of this predator in the water can cause naiads to reduce foraging (Heads 1985) which can reduce growth, development, and survival (Heads 1986). Backswimmers pose a threat to all populations of this damselfly.

Similar to the aquatic insects, Hawaii has a depauperate freshwater fish fauna with only five native species comprised of gobies (Gobiidae) and sleepers (Eleotridae), that occur on all the major islands. The ‘o’opu okuhe (*Eleotris sandwicensis*) and the ‘o’opu naniha (*Stenogobius hawaiiensis*) are coastal fishes, occurring in brackish and freshwater ponds and in lower reaches of streams below the first waterfall. While the ‘o’opu okuhe is the most predaceous of the Hawaiian freshwater fishes (*in litt.* 1995 cited in U.S. Fish and Wildlife Service candidate assessment form), it occurs infrequently with damselflies in the lower reaches of larger streams. The ‘o’opu nakea (*Awaous stamineus*) and the ‘o’opu nopili (*Sicyopterus stimpsoni*) frequent the middle reaches of streams up to 300 m (1000 ft) elevation.

The ‘o’opu alamo’o (*Lentipes concolor*) usually occupies the upper sections streams above 800 m (2600 ft) and can apparently navigate Hawaii's largest waterfalls (Devick et al. 1992). Prior to human alteration of the aquatic habitats, the ‘o’opu nakea, ‘o’opu nopili, and the ‘o’opu alamo’o would have all occurred with the naiads of some of the Hawaiian damselflies, at least occasionally. The ‘o’opu nakea has been reported to feed on Hawaiian damselfly naiads (Ego 1956), but this species is apparently primarily herbivorous and ingestion of naiads probably occurs incidental to feeding on algae (Kido et al. 1993). The ‘o’opu noplili feeds predominately on algae and ‘o’opu alamo’o, while facultatively predaceous and not known to feed on damselfly naiads (*in litt.* 1995 cited in U.S. Fish and Wildlife Service candidate assessment form). Therefore, the Hawaiian damselflies probably experienced limited natural predation pressure from the native fishes.

Fish predation has been an important factor in the evolution of behavior in damselfly naiads in continental systems (Johnson 1991). Some species of damselflies are not adapted to cohabitat with fish, and are found only in bodies of water without fish (Henrickson 1988, McPeek 1990a). The naiads of these species tend to occupy more exposed positions and engage in conspicuous foraging behavior, thereby being susceptible to fish (Macan 1977, McPeek.1990b). The evolutionary history of the Hawaiian damselflies coexisting with few, if any predatory fish, and the exposed behavior of most of the fully aquatic species, makes them particularly vulnerable to predation by alien fish introductions.

Over 60 species of aquatic organisms have been introduced into Hawaiian freshwater habitats, including at least 45 species of fish (Devick 1991). The impact of fish introductions prior to 1900 cannot be assessed because this predated the initial collection of damselflies in Hawaii (Perkins 1913). In 1905, two species, the mosquito fish (*Gambusia affinis*), and the sailfin molly (*Poecilia latipinna*), were successfully introduced for biological control of mosquitoes (Van Dine 1907). In 1922, three additional species were established for mosquito control, the green swordtail (*Xiphophorus helleri*), the moonfish (*Xiphophorus maculatus*), and the guppy (*Poecilia reticulata*). The introduction of these species has been implicated in the extinction of the Pacific Hawaiian damselfly from most of the main islands (Moore and Gagne 1982), and by 1935 on Oahu, the orangeblack Hawaiian damselfly was found only in waters without these introduced fish (Williams 1936, Zimmerman 1948b, Polhemus 1993b). Most of the fish introduced early into Hawaii are now established on all the major islands, and are primarily pond and reservoir inhabitants.

Beginning in about 1980, a large number of new fish introductions began in Hawaii, originating primarily from the aquarium fish trade (Devick 1991). By 1990, an additional 15 species of fish were established in waters on Oahu, including catfish, cichlids, gobies, top minnows, needlefish, and piranha many which readily invaded stream systems. By early 1990, the lower to middle reaches of two widely separated streams on Oahu, Manoa on the south leeward side, and Kaukanohua on the north windward side, were choked with dense populations of armored catfish (*Hypostomus* sp. and *Pterygoplichthys multiradiatus*) (Devick 1991). This recent wave of fish introductions on Oahu corresponded with the drastic decline and range reduction of the crimson Hawaiian damselfly, the oceanic Hawaiian damselfly, and the blackline Hawaiian damselfly. Currently, these damselflies occur only in drainages or higher parts of stream systems where alien fish are not yet established (*in litt*. 1994 cited in U.S. Fish and Wildlife Service candidate assessment form). The continued introduction and establishment of new species of alien fish, and the movement of established species to new drainages (personal communication 1994 cited in U.S. Fish and Wildlife Service candidate assessment form) presents the greatest threat to this Hawaiian damselfly species.

D. *The inadequacy of existing regulatory mechanisms.*

The State of Hawaii considers all natural flowing surface water (streams, springs and seeps) as State property (Hawaii Revised Statutes 174c 1987), and the Hawaii Department of Land And Natural Resources has management responsibility for the aquatic organisms in these waters (personal communication 1995 cited in U.S. Fish and Wildlife Service candidate assessment form). Thus, damselfly populations associated with streams, seeps and springs are under the jurisdiction of the State of Hawaii, regardless of the ownership of the property across which the stream flows. This includes all populations of the crimson Hawaiian damselfly, the blackline Hawaiian damselfly, and the oceanic Hawaiian damselfly, as well as some populations of the Pacific Hawaiian damselfly and the orangeblack Hawaiian damselfly occurring in streams.

State regulatory mechanisms currently in effect do not provide adequate protection for the Hawaiian damselflies or their habitat. The State of Hawaii has not listed these damselflies as endangered or threatened and so does not afforded them any protection under the State endangered species act. Nor does the State Water Code afford adequate protect from the adverse effects of water development projects. The State of Hawaii manages the use of surface and ground water resources through the Commission on Water Resource Management (Water Commission), as mandated by the 1987 State Water Code (State Water Code, Hawaii Revised Statutes Chapter 174C-71, 174C-81-87, and 174C-9195 and Administrative Rules of the State Water Code, Title 13, Chapters 168 and 169). In the State Water Code, there are no formal requirements that project proponents or the Water Commission protect the habitats of fish and wildlife prior to issuance of a permit to modify surface or ground water resources.

The maintenance of instream flow, which is required to protect the habitat of damselflies and other aquatic wildlife, is regulated by the establishment of standards on a stream-by-stream basis (State Water Code, Hawaii Revised Statutes Chapter 174C-71 and Administrative Rules of the State Water Code, Title 13, Chapter 169). Currently, the interim instream flow standards represent the existing flow conditions in streams in the State as of 15 June 1988 for Molokai, Hawaii, Kauai and East Maui, and 19 October 1988 for West Maui and Leeward Oahu (Administrative Rules of the State Water Code, Title 13, Chapter 169-44-49).

However, the State Water Code does not provide for permanent or minimal instream flow standards for the protection of aquatic wildlife. Instead, modification of instream flow standards and stream channels can be undertaken at any time by the Water Commission or via public petitions to revise flow standards or modify stream channels in a specified stream (Administrative Rules of the State Water Code, Title 13, Chapter 169-36). Additionally, the Water Commission must consider economic benefits gained from out-of-stream water uses, and is not required to balance these benefits against instream benefits to aquatic fish and wildlife. Consequently, any stabilization of stream flow for the protection of Hawaiian damselfly habitat is subject to modification at a future date.

The natural value of Hawaii's stream systems have been recognized under the State of Hawaii Instream Use Protection Program (Administrative Rules of the State Water Code, Title 13, Chapter 169-20(2)). In the Hawaii Stream Assessment Report, prepared in coordination with the National Park Service (National Park Service 1990), the State Water Commission identified high quality rivers or streams, or portions of a rivers or streams, that may be placed within a wild and scenic river system. This report recommended that streams meeting certain criteria be protected from further development. However, there is no formal or institutional mechanism within the Water Code to designate and set aside these streams, or to identify and protect stream habitat for Hawaiian damselflies.

Existing Federal regulatory mechanisms that may protect Hawaiian damselflies and their habitat are also inadequate. The Federal Energy Regulatory Commission (FERC) has very limited jurisdiction in Hawaii. Hydroelectric power projects in Hawaii are not on navigable water, public lands, or United States reservations; do not use surplus water or water power from a Federal Government Dam; and do not affect the interests of interstate or foreign commerce. Thus, licensing of hydroelectric projects do not come under the purview of FERC. However, hydropower developers in Hawaii may voluntarily seek licensing under FERC.

The U.S. Army Corps of Engineers (COE) also has some regulatory control over modifications of freshwater streams in the United States. For modifications (i.e. discharge of fill) of streams with an average annual flow greater than 5 cubic feet per second (cfs), the COE can issue individual Department of the Army (DOA) permits under Section 404 of the Clean Water Act. These permits are subject to public review, and must comply with the Environmental Protection Agency's 404(b)(1) guidelines and public comment requirements. However, in issuing these permits, the COE does not establish instream flow standards as a matter of policy. The COE normally considers that the public interest for instream flow is represented by the state water allocation rights or preferences (Regulatory Guidance Letter No 85-6), and project alternatives that supersede, abrogate, or otherwise impair the state water quantity allocations are not normally addressed as alternatives during permit review.

In cases where the COE district engineer does propose to impose instream flow standard on an individual DOA permit, this flow standard must reflect a substantial national interest. Additionally, if this instream flow standard is in conflict with a State water quantity allocation, then it must be reviewed and approved by the Office of the Chief Engineer in Washington, D.C. Currently, the setting of instream flow standards sufficient to conserve Hawaiian damselflies is not a condition that would be considered or included in a DOA individual permit. If this damselfly was listed as endangered or threatened, Federal interest in its conservation would be assured through consultation under Section 7 of the Endangered Species Act.

The COE may also authorize the discharge of fill into streams with an average annual flow of less than 5 cfs. These discharges are covered under a nationwide permit (33 CFR 330 Appendix A, Nationwide Permit 26). This permit is designed to expedite small scale activities that the COE considers to have only minimal environmental impacts (33 CFR 330.1(b)). The U.S. Fish and Wildlife Service and the State Department of Land and Natural Resources have only 15 days to provide substantive site-specific comments following the issuance of a nationwide permit (33 CFR 330 Appendix A, Nationwide Permit Condition 13). Given the complexity of the impacts on Hawaiian damselflies from stream modifications and surface water diversions, the remoteness of project sites, and the types of studies necessary to determine project impacts and mitigation, this limited comment period does not allow for an adequate assessment of impacts. The listing of the Hawaiian damselflies as endangered or threatened species will insure that their conservation is adequately considered during consultation, as required under Section 7 of the Endangered Species Act.

Current Conservation Efforts: None.

E. *Other natural or manmade factors affecting its continued existence.* Not applicable

REFERENCES

Asquith, A. 1995. Hawaiian Damselfly Survey: Population Checklist of Category 1 Candidate Species. Unpublished Document by U.S. Fish & Wildlife Service, Pacific Islands Office, Honolulu, HI.

Beardsley, J.W. 1962. On accidental immigration and establishment of terrestrial arthropods in Hawaii during recent years. Proc. Hawaii. Entomol. Soc. 18:99-109.

Beardsley, J.W. 1979. New immigrant insects in Hawaii: 1962 through 1976. Proc. Hawaii. Entomol. Soc. 23:35-44.

Bennett, W.C. 1931. Archaeology of Kauai. B.P. Bishop Museum Bulletin 80:1-156.

Bishop Museum of Honolulu. Hawaiian Terrestrial Arthropod Checklist, March 2002 version. http://ww2.bishopmuseum.org/HBS/checklist/query.asp?grp=Arthropod

Blackburn, T. 1884. Notes on Hawaiian Neuroptera, with descriptions of new species. Ann. Mag. Nat. Hist., (V) 14: 412-421. As referenced in: Zimmerman, E.C. 1948. Insects of Hawaii, Vol. 2. Apterygota -Thysanoptera. University of Hawaii Press, Honolulu.

Borror, D.J., C.A. Triplehorn and N.F. Johnson. 1989. Introduction to the Study of Insects, Sixth Edition. Saunders College Publishing, Philadelphia.

Cowles, L.E. 1977. Status of Damselflies (Odonata: Zygoptera) in Hawaii in 1977, with special reference to the endemic genus *Megalagrion* . Senior Honors Thesis, Department of Biology, University of Hawaii, Manoa.

Cuddihy, L.W., and C.P. Stone. 1990. Alteration of native Hawaiian vegetation: Effects of humans, their activities and introductions. University of Hawaii Press, Honolulu, 138 pp.

Department of Geography, University of Hawaii. 1983. Atlas of Hawaii. second edition. University of Hawaii Press. Honolulu, 238 pp.

Devaney, D.M., M. Kelly, P.J. Lee, and L.S. Motteler. 1982. Kaneohe: A History of Change. The Bess Press, Honolulu, Hawaii.

Devick, W.S. 1991. Patterns of introduction of aquatic organisms to Hawaiian freshwater habitats: in Devick, W.S., New Direction in Research, Management and Conservation of Hawaiian Freshwater Stream Ecosystems, Proceedings of the 1990 Symposium on Freshwater Stream Biology and Fisheries Management, Department of Land and Natural Resources, Honolulu, Hawaii..Ego, K. 1956. Life history of freshwater gobies. Freshwater Game and Fish Management Research Project No. F-4-R. Honolulu, Hawaii.

Englund, R. and D.A. Polhemus. 1994. Maakua Stream biological assessment, Oahu, Hawaii. Environmental Technologies International, Honolulu, Hawaii.

Ford, J.I. and R.A. Kinzie, III. 1982. Life crawls upstream. Natural History 91:61-66.

Funasaki, G.Y., P.-L. Lai, L.M. Nakahara, J.W. Beardsley & A.K. Ota. 1988. A review of biological control introductions in Hawaii: 1890 to 1985.Proc. Hawaii. Entomol. Soc. 28:105-160.

Gagne, W.C. 1980. Insect and myriopods of Kipahulu Valley below 2,000 feet: in. Smith, C.W., Resources Base Inventory of Kipahulu Valley below 2,000 feet, Maui, Hawaii. Coop. Natl. Park. Res. Spec. Studies Unit. 119-175 pp.

Gagne, W.C. and F.G. Howarth. 1982. Assessment of Endangered and Threatened Status of Hawaiian Arthropods. Report to U.S. Fish and Wildlife Service, in Pacific Islands Office, Honolulu.

Giambelluca, T.W., M.A. Nullet, M.A. Rifgley, P.R. Eyre, J.E.T. Moncur, and S. Price. 1991. Drought in Hawaii. Report 87. State of Hawaii. Department of Land and Natural Resources, Commission on Water Resource Management.

Gillespie, R.G. and N. Reimer. 1993. The effect of alien predatory ants(Hymenoptera: Formicidae) on Hawaiian endemic spiders (Araneae: Tetragnathidae). Pacific Science 47:21-33.

Handy, E.S.C. and E.G. Handy. 1972. Native planters in old Hawaii. Their life, lore, and environment. B.P. Bishop Mus. Bull. 233:1-641.

Hardy, D.E. 1979. An ecological survey of Puaaluu Stream. Part III. Report on a preliminary entomological survey of Puaaluu Stream, Maui. Coop. Nat. Park Resour. Study Unit. University of Hawaii. Tech. Report 27:34-39.

Hardy, D.E. and M.D. Delfinado. 1980. Insect of Hawaii. Volume 13, Diptera: Cyclorrhapha III. University of Hawaii Press,.Honolulu.

Harris, S., A. Rubissow, S. Edmunds, and J.-A. Cachola. 1993. Hawaii Streams. Document prepared for Commission on Water Resource Management, State of Hawaii. 40 pp.

Harwood, P.D. 1976. Dragonflies (Odonata) observed in Hawaii in 1973 and 1974. Proc. Hawaii. Entomol. Soc. 22:251-253.

Hawaii Stream Assessment. 1990. Department of Land and Natural Resources, State of Hawaii, 300 pp.

Heads, P.A. 1985. The effect of invertebrate and vertebrate predators on the foraging movements of Ischnura elegans larvae (Odonata: Zygoptera). Freshwater Biology 15:559-571.

Heads, P.A. 1986. The costs of reduced feeding due to predator avoidance: potential effects on growth and fitness in Ischnura elegans larvae (Odonata: Zygoptera). Ecological Entomology 11:369-377.

Henrikson, B.-I. 1988. The absence of antipredator behavior in the larvae of Leucorrhinia dubia (Odonata) and the consequences for their distribution. Oikos 51:179-183.

Hibbard, D. and D. Franzen. 1991. The View from Diamond Head: Royal Residence to Urban Resort. Editions Limited, Honolulu, Hawaii. 221 pp.

Howarth, F.G. 1990. Hawaiian terrestrial arthropods: An overview. Bishop. Mus. Occas. Pap. 30:4-26.

Howarth, F.G. and W.P. Mull. 1992. Hawaiian Insects and Their Kin. University of Hawaii Press, Honolulu.

Howarth, F.G., A. Asquith, and G. Nishida. 1994. Insect of Hawaii: Status and Trends. Unpublished manuscript.

Howarth, F.G. and A.C. Medeiros. 1989. Non-native invertebrates: in Stone, C.P. and D.B. Stone (eds), Conservation Biology in Hawaii. University of Hawaii Cooperative National Park Resources Studies Unit, Honolulu. pp. 82-87.

Howarth, F.G. and G.W. Ramsay. 1991. The conservation of island insects and their habitats: in Collins, N.M. and J.A. Thomas.(eds), The Conservation of Insects and Their Habitats , Academic Press, London. pp. 71-107

Joesting, E. 1984. Kauai: The separate kingdom. University of Hawaii Press, Honolulu. Johnson, D.M. 1991. Behavioral ecology of larval dragonflies and damselflies. Trends in Ecol. Evol. 6:8-13.

Jones, B.L., S.S.W. Chin, and J.C. Brice. 1984. Olokele rock avalanche, island of Kauai, Hawaii. Geology 12:209-211.

Kennedy, C.H. 1917. Notes on the penes of damselflies (Odonata). No. 2. The close relations inter se of the Hawaiian Agrionines. Entomological News. 28:9-14.

Kennedy, C.H. 1920. Forty-two hitherto unrecognized genera and subgenera of Zygoptera. Ohio J. Science. 21:83-88.

Kennedy, C.H. 1929. The origin of the Hawaiian Odonata fauna and its evolution within the islands. Proceedings of the Fourth International Congress of Entomology 2:978-981.

Kennedy, C.M. 1934. Kilauagrion dinesiotes, a new species of dragonfly (Odonata) from Hawaii. Annals of the Entomological Society of America. 27:343-345.

Kido, M.H., P. Ha, and R.A. Kinzie III. 1993. Insect introductions and diet changes in and endemic Hawaiian amphidromous goby, Awaous stamineous (Pisces: Gobiidae). Pacific Science 47:43-50.

Kirby, W. F. 1890. A synonymic catalog of Neuroptera Odonata, or Dragonflies, with an appendix of fossil species. Gurney and Jackson, London. 202 pp. As referenced in: Zimmerman, E.C. 1948. Insects of Hawaii, Vol. 2. Apterygota - Thysanoptera. University of Hawaii Press, Honolulu.

Kirch, P.V. 1982. The impact of the prehistoric Polynesians on the Hawaiian ecosystem. Pacific Science 36:1-14.

Kirch, P.V. 1985. Feathered gods and fishhooks. University of Hawaii Press, Honolulu, Hawaii 349 pp..Lai, P.-Y. 1988. Biological control: A positive point of view. Proc. Hawaii. Entomol. Soc. 28:179-190.

McLachlan, R. 1883. Neuroptera of the Hawaiian Islands. - Part I. Pseudo-Neuroptera. Ann. Mag. Nat. Hist., (V) 12: 226-240. As referenced in: Zimmerman, E.C. 1948. Insects of Hawaii, Vol. 2. Apterygota - Thysanoptera. University of Hawaii Press, Honolulu.

McPeek, M.A. 1990a. Determination of species composition in the Enallagma damselfly assemblages of permanent lakes. Ecology 71:83-98.

McPeek, M.A. 1990b. Behavioral differences between Enallagma species (Odonata) influencing differential vulnerability to predators. Ecology 71:1714-1726.

Macan, T.T. 1977. The influence of predation on the composition of fresh-water animal communities. Biol. Rev. 52:45-70.

MacDonald, G.A., D.A. Davis, and D.C. Cox. 1960. Geology and ground-water resources of the island of Kauai, Hawaii. Hawaii Division of Hydrology, Bulletin No. 13. 212 pp.

Maciolek, J.A. 1982. Lakes and lake-like waters of the Hawaiian Archipelago. Occas. Pap. B.P. Bishop Mus. 25:1-14.

Meier, K.Z., J.P. Laurel and J.E. Maragos. 1993. State of Hawaii (USA). in Scott, D.A., A Directory of Wetlands in Oceania, The international Waterfowl and Wetlands Research Bureau, U.K., and Asia Wetland Bureau, Kuala Lumpur, Malaysia. 444 pp.

Moore, N.W. 1982. Conservation of Odonata - First steps towards a world strategy. Adv. Odontal. 1:205-211.

Moore, N. W. 1983a. Territorial behavior in the genus *Megalagrion* (McLachlan) (Zygoptera: Coenagrionidae). Odonatologica 12(1): 87-92.

Moore, N. W. 1983b. Reflex immobilisation in the Hawaiian endemic genus *Megalagrion*

McLachlan (Zygoptera: Coenagrionidae). Odonatologica, 12(2): 161-165..Moore, N.W. and W.C. Gagne. 1982. *Megalagrion pacificum*

(McLachlan) - A preliminary study of the conservation requirements of an endangered species. Rep. Odon. Specialist group Int. Un. Conserv. Nat. Natur. Res. No 3:1-5.

Nafus, D.M. 1993a. Biological control agents and native parasitoids in the population system of the butterfly *Hypolimnas bolinas* (L.) (Lepidoptera: Nymphalidae). Micronesica, Suppl. 4:17-23.

NatureServe Explorer: An online encyclopedia of life [web application]. 2001. Version 1.6 . Arlington, Virginia, USA: NatureServe. Available: http://www.natureserve.org/explorer.

Nishida, G.M., Ed. 1994a. Hawaiian Terrestrial Arthropod Checklist, 2nd Edition. Bishop. Mus. Technical Report No. [1]. 287 pp.

Nishida, G.M. 1994b. Taxonomic validation of Candidate species of insects (and related Arthropods) of the Hawaii Islands. Report prepared for the National Biological Survey. 61 pp.

O'Connor, P.J. 1990. Poaceae. in W.L. Wagner, D.R. Herbst and S.. Sohmer, Manual of the Flowering Plants of Hawai'i. B.P. Bish. Mus. Spec. Publ. No. 83. 1-1853 pp.

Ogden Environmental and Energy Service. 1994. VA Medical and Regional Office Center Project Conceptual Mitigation Plan for Impacts on the Orange-black damselfly Population at Tripler Army Medical Center. pp. 16.

Olson, S.L. and H.F. James. 1982. Prodromus of the fossil avifauna of the Hawaiian Islands. Smithsonian Contrib. Zool. 1-59.

Parrish, J.D., J.A. Maciolek, A.S. Timbol, C.B. Hathaway, and S.E. Norton. 1984. Status of stream channel modification in Hawaii and its effects on native aquatic fauna. pp. 83-84. Proc. 5th Conference in Natural Sciences, Hawaii, Volcanoes National Park. Coop. Natl. Park. Res. Stud. Unit, University of Hawaii.

Perkins, R.C.L. 1899. Neuroptera. D. Sharp, ed., Vol. 2:63-77. Cambridge University Press, Cambridge.

Perkins, R.C.L. 1907. Insects at Kilauea, Hawaii. Proc. Hawaii. Entomol. Soc. 1:89-95..Perkins, R.C.L. 1913. Introduction to Fauna Hawaiiensis. D. Sharp, ed., Vol.1:xv-ccxxvii. Cambridge University Press, Cambridge.

Polhemus, D.A., J. Maciolek, and J. Ford. 1992. An ecosystem classification of inland waters for the tropical Pacific islands. Micronesica 25:155-173.

Polhemus, D.A. 1993a. Damsels in distress: a review of the conservation status of Hawaiian *Megalagrion* damselflies (Odonata: Coenagrionidae). Aquatic Conservation: Marine and Freshwater Ecosystems 3:343-349.

Polhemus, D.A. 1993b. Conservation of aquatic insects: Worldwide crisis or localized threats? Amer. Zool. 33:588-598.

Polhemus, D.A. 1993c. A preliminary assessment of the impacts of hurricane Iniki on the aquatic insect faunas of streams on the Na Pali Coast, Kaua'i, Hawai'i. in Assessments of the impact of Hurricane Iniki on stream biota and ecosystems on Kaua'i. Department of Land and Natural Resources, Division of Aquatic Resources. State of Hawai'i. pp. 59-88.

Polhemus, D.A. 1994a. Current status of *Megalagrion* populations on Oahu: 1990 - Present. Report to U.S. Fish & Wildlife Service, Pacific Islands Office.

Polhemus, D.A. 1994b. A revision of the Hawaiian damselflies in the genus *Megalagrion* (Odonata: Coenagrionidae). Unpublished report to U.S. Fish & Wildlife Service, Pacific Islands Office.

Polhemus, D.A. 1995. New Heteroptera and Odonata (Insecta) records and range extensions in the Hawaiian Islands. Bish. Mus. Occas. Pap. 42:42-43.

Polhemus, D., and A. Asquith. 1996. Hawaiian Damselfies: A Field Identification Guide. Hawaii Biological Survey Handbook, Bishop Museum Press, Honolulu, Hawaii. 122 pp.

Reimer, N.J. 1993. Distribution and impact of alien ants in vulnerable Hawaiian ecosystems: in D.F. Williams (ed), Exotic Ants: Biology, Impact, and Control of Introduced Species. Westview Press, Boulder, Colorado. pp. 11-22.

Reimer, N., J.W. Beardsley and G. Jahn. 1990. Pest ants in Hawaii. in Vander Meer, R.K., K. Jaffe and A. Cedeno (eds), Applied Myrmecology: A World Perspective. Westview Press,.Boulder, Colorado, pp. 40-50.

Schmidt, E. 1938. Check-list of Odonata of Oceania. Ann. Entomol. Soc. America. 31:322-344.

Selys-Longchamps, E. 1876. Synopsis des Agrionines, 5me Legion: Agrion. Bull. Acad. Royal Belgique, (II) 41 (2,3): 1-282. As referenced in: Zimmerman, E.C. 1948. Insects of Hawaii, Vol. 2. Apterygota -Thysanoptera. University of Hawaii Press, Honolulu.

Simon, C.M., W.C. Gagne, F.G. Howarth, and F.J. Radovsky. 1984. Hawaii: A natural entomological laboratory. Bull. Entomol. Soc. Am.30:8-17.

Smith, C.W. 1985. Impact of alien plants on Hawai'i's native biota. in C.P. Stone and J.M. Scott (eds), Hawai'i's Terrestrial Ecosystems: Preservation and Management. Cooperative National Park Resources Study Unit, University of Hawaii, Honolulu.

Stearns, H.T. 1940. Geology and ground-water resources of the islands of Lanai and Kahoolawe, Hawaii. Bulletin 6 of the Division of Hydrography, Territory of Hawaii.

Stearns, H.T. and K.N. Vaksvik. 1935. Geology and ground-water resources of the island of Oahu, Hawaii. Bulletin 1 of the Division of Hydrography, Territory of Hawaii.

Stearns, H.T. 1985. Geology of the State of Hawaii. second edition. Pacific Books, Palo Alto, California.

Stone, C.P. 1985. Alien animals in Hawai'i's native ecosystems: toward controlling the adverse effects of introduced vertebrates: in Stone, C.P., and J.M. Scott (eds.), Hawai'i's terrestrial ecosystems: preservation and management. Coop. Natl. Park Resources Stud. Unit, Univ. Hawaii, Honolulu, pp. 251-297.

Stone, C.P. 1989. Hawai'i's wetlands, streams, fishponds, and pools. in C.P. Stone and D.B. Stone (eds), Conservation Biology in Hawai'i. Cooperative National Park Resources Study, pp. 125-136. Unit, University of Hawaii, Honolulu.

Summers, C.C. 1964. Hawaiian Fishponds. B.P. Bish. Mus. Spec..Publ. 52. Takasaki, K.I., G.T. Hirashima, and E.R. Lubke. 1969. Water Resources of Windward Oahu, Hawaii. U.S. Geological Survey Water Supply Paper No. 1894:1-119. U.S. Gov. Printing Office, Washington, D.C.

U.S. Fish and Wildlife Service. 1985. Recovery plan for the Hawaiian waterbirds. U.S. Fish and Wildlife Service, Portland, Oregon, 99 pp.

U.S. Fish and Wildlife Service. 1995. Pacific Islands Ecoregion Coastal Ecosystems Program Proposal. U.S. Fish and Wildlife Service, Honolulu, Hawaii, 119. pp.

Van Dine, D.L. 1907. The introduction of top-minnows (natural enemies of mosquitoes) into the Hawaiian Islands. Haw. Ag. Exp. St. Press Bull. 20:1-10.

Wenkam, R. 1969. Kauai and the park county of Hawaii. Sierra Club, San Francisco. 160 pp.

Williams, F.X. 1936. Biological studies in Hawaiian water-loving insects. Part 1. Coleptera or beetles. Part 2. Odonata or dragonflies. Proc. Hawaii. Entomol. Soc. 9:235-345.

Wilson, Okamoto and Associates, Inc. 1993. Kawai Nui Marsh Master Plan: Development Project Report. Document prepared for Department of Land and Natural resources, State of Hawaii.

Wong, M.A. and T.T.Y. Wong. 1988. Predation of the Mediterranean fruit fly and oriental fruit fly (Diptera: Tephritidae) by the fire ant(Hymenoptera: Formicidae) in Hawaii. Proc. Hawaii. Entomol. Soc. 28:169-177.

Zimmerman, E.C. 1948a. Insects of Hawaii. Vol. 1. Introduction. xvii + 206pp. University of Hawaii Press.

Zimmerman, E.C. 1948b. Insects of Hawaii, Vol. 2. Apterygota - Thysanoptera. University of Hawaii Press, Honolulu.

Zimmerman, E.C. 1948c. Insects of Hawaii, Vol. 3. Heteroptera. University of Hawaii Press, Honolulu.

Zimmerman, E.C. 1970. Adaptive radiation in Hawaii with special.reference to insects. Biotropica 2:32-38..

PETITION TO LIST

flying earwig Hawaiian damselfly (*Megalagrion nesiotes*)

AS A FEDERALLY ENDANGERED SPECIES

CANDIDATE HISTORY

CNOR 5/22/84:	
CNOR 1/6/89:	
CNOR 11/15/94:	
CNOR 2/28/96:	C
CNOR 9/19/97:	C
CNOR 10/25/99:	C
CNOR 10/30/01:	C
CNOR 6/13/02:	C

TAXONOMY

Native Hawaiians apparently did not differentiate among the different species, but referred to the native damselflies collectively as pinaoʻula. There has been no traditional European use of a common name for species in the genus *Megalagrion* (Coenagrionidae). In a recent taxonomic review of the candidate species of insects in Hawaii, Nishida (1994b) proposed the name "Hawaiian damselflies". Because this name reflects the restricted distribution of these insects and should be readily used by nontechnical persons, the U.S. Fish and Wildlife Service has adopted this common name for the genus, with additional descriptive terms to identify each species.

The status of *Megalagrion nesiotes* as a valid species is uncontroversial (e.g., Bishop Museum 2002).

NATURAL HISTORY

Distribution

Because of the extreme geographic isolation of the Hawaiian islands and the poor dispersal capabilities of many aquatic insects, the freshwater insect fauna of Hawaii is depauperate compared to continental areas despite the diversity of aquatic habitats. Many groups of insects that typify freshwater habitats in continental areas are absent from the native fauna. Some notable examples of such groups are mayflies (Ephemeroptera), stoneflies (Plecoptera), caddisflies (Trichoptera), and alderflies and dobsonflies (Neuroptera), all of which are absent from Hawaii. Like most of the native fish, mollusc, and crustacean faunas (Ford and Kinsey 1994), most of

Hawaii's freshwater insects evolved from marine or intertidal ancestors (Hardy and Delfinado 1980) that could easily colonize the islands.

The Hawaiian damselflies are represented by 23 species and five subspecies, all confined to the Hawaiian Islands. Historically these were among the most common and conspicuous native Hawaiian insects. Some species inhabited water gardens in residential areas, artificial reservoirs, and watercress farms, and were abundant in the city of Honolulu (Perkins 1913, Williams 1936).

Morphology

Megalagrion nesiotes is a large damselfly. Males have black abdomens with brownish rings at the base of the segments and black with blue-grey sided thoraxes. Females are mostly brownish with blackish rings at bases of abdominal segments. More detailed descriptions and color photos are available in Polhemus and Asquith (1996).

Behavior

Adults are usually seen perched on vegetation, and fly slowly and only short distances. When disturbed, the adults actually fly into the tangled vegetation rather than up and away as in the aquatic Hawaiian damselflies.

The general biology of Hawaiian damselflies is typical of other narrow-winged damselflies. The males of most species are territorial, guarding areas of habitat where females will lay eggs (Moore 1983a). During copulation, and often while the female lays eggs, the male grasps the female behind the head with his terminal abdominal appendages to guard her against rival males, thus males and females are frequently seen flying in tandem. In species with fully aquatic immature stages, females lay eggs in submerged aquatic vegetation or in mats of moss or algae on submerged rocks, and hatching occurs in about ten days (Williams 1936, Polhemus 1994b).

In most species of Hawaiian damselflies, the immature stages (naiads) are aquatic, breathing though three flattened, abdominal gills, and are predacious, feeding on small aquatic invertebrates or fish (Williams 1936). Naiads may take up to four months to mature (Williams 1936), after which they crawl out of the water onto rocks or vegetation, molt into winged adults, which typically remain very close to the aquatic habitat from which they emerged. Adults are also predacious and feed on small flying insects such as midges. In a remarkable example of adaptive radiation in Hawaii, some species of Hawaiian damselflies have foregone the aquatic lifestyle, either partly, with naiads living on wet rock faces, or completely, with terrestrial naiads living in the damp leaf litter, or others inhabiting moist leaf axils of native plants up to several meters above the ground (Zimmerman 1970, Simon et al. 1984). Adults are also unusual in that they have a highly developed behavior of feigning death when caught or attacked (Moore 1983b).

Habitat

Little known about the biology of this species, but it is not associated with standing or flowing water (Perkins 1899, Polhemus 1994b). The only known population occurs along a steep, moist, talus slope, densely covered with *Dicranopteris linearis* (uluhe) and *Rubus* sp. (blackberry).

Although immature stages have not been found, based on the habitat and the behavior of the adults, it is believed that the naiads are terrestrial or semi-terrestrial, occurring among the damp leaflitter (Kennedy 1934, Polhemus 1994b). The primary threats to this species are predation by ants and other alien arthropods, and habitat loss due to disturbance by feral ungulates (Cuddihy and Stone 1990, Stone 1985).

POPULATION STATUS

Known from only one population estimated at less than 1,000 individuals. This species has declined dramatically since the 1920's when it was considered locally common (NatureServe Explorer 2001).

Historically, the flying earwig Hawaiian damselfly was known from the following general localities, Kau (Polhemus 1994b), Kilauea (Perkins 1907), Olaa, Kau, and Kona (Perkins 1899) on the island of Hawaii, and Haipuaena, Honomanu, Kailua, and Keanae on windward East Maui (Kennedy 1934). Despite extensive surveys for damselflies recently on the island of Hawaii (Polhemus 1994b) this species has not been seen since 1906 and is probably extinct on that island. Likewise on Maui, this species has not been seen at its historical localities, and the only known population occurs along East Wailuaiki Stream (Polhemus 1994b).

As early as 1948, Zimmerman noted a decline of the more common species, particularly on Oahu. By the late 1970s less than six populations of the Pacific Hawaiian damselfly could be located (Harwood 1976, Gagne 1980, Moore and Gagne 1982), and the conservation of this species was identified as a priority by the International Union for Conservation of Nature and Natural Resources (Moore 1982). A review of the status of Hawaiian damselflies in 1981 (Gagne and Howarth 1982) lead to the placement of several species on the U.S. Fish and Wildlife Service's list of candidate species for Federal listing (49 FR 21664). Due to a continued decline of these damselflies, particularly on the island of Oahu, intensive surveys were initiated in 1990. The results of these surveys demonstrate that six species of Hawaiian damselflies are now threatened with extinction.

The U.S. Fish and Wildlife Service classifies flying earwig Hawaiian damselfly as a candidate for Endangered Species Act protection with a listing priority number of 2.

LISTING CRITERIA

A. ***The present or threatened destruction, modification, or curtailment of its habitat or range.***

Historical range: Hawaii, islands of Maui and Hawaii. The flying earwig Hawaiian damselfly (*Megalagrion nesiotes*) was known from the following general localities, Kau (Polhemus 1994b), Kilauea (Perkins 1907), Olaa, Kau, and Kona (Perkins 1899) on the island of Hawaii, and Haipuaena, Honomanu, Kailua, and Keanae on windward East Maui (Kennedy 1934).

Current range:	Hawaii, island of Maui. This species has not been seen at its historical localities, and the only known population occurs along East Wailuaiki Stream (Polhemus 1994b).
Land ownership:	This species occurs on State land.

Animals such as pigs, goats, axis deer, black-tailed deer, and cattle were introduced either by the early Hawaiians (pigs) or more recently by European settlers (all ungulate species) for food and/or commercial ranching activities. Over the 200 years following their introduction, their numbers increased and the adverse impacts of feral ungulates on native vegetation have become increasingly apparent. Beyond the direct effect of trampling and grazing native plants, feral ungulates have contributed significantly to the heavy erosion still taking place on most of the main Hawaiian islands.

Pigs (*Sus scrofa*), originally native to Europe, Africa, and Asia, were introduced to Hawaii by the Polynesian ancestors of Hawaiians, and later by western immigrants. The pigs escaped domestication and invaded primarily wet and mesic forests and grasslands of Kauai, Oahu, Molokai, Maui, and Hawaii. They presently threaten the existence of the flying earwig damselfly in mesic forest on Maui. While foraging, pigs root and trample the forest floor, encouraging the establishment of alien plants in the newly disturbed soil. In moist depressions, pigs completely remove all vegetation by wallowing, leaving nothing but mud and water (Cuddihy and Stone 1990, Stone 1985). Pigs are degrading the habitat of the flying earwig damselfly on Maui.

B. *Overutilization for commercial, recreational, scientific, or educational purposes.*

Healthy populations of stream-inhabiting Hawaiian damselflies are composed of large numbers of individuals. Moore (1983a) recorded 75 males per 100 m of stream edge for *Megalagrion heterogamias* on Kauai. In addition, there are often more males than suitable territorial habitat, and when males are removed from a territory they are immediately replaced by other individuals (Moore 1983a). However, populations of these damselflies, are now extremely reduced, typically with fewer than 10 males per 100 m of stream edge at all localities. Publication of the rarity of these species will likely increase the interest of professional and amateur Odonata collectors. Unrestricted collecting and handling could impact these small populations and are considered significant threats to the species.

C. *Disease or predation.*

The geographic isolation of the Hawaiian Islands has restricted the number of original successful colonizing arthropods and resulted in the development of an unusual fauna. An unusually small number (15 percent) of the known families of insects are represented by native Hawaiian species (Howarth 1990). Some groups that often dominate continental arthropod faunas, such as social Hymenoptera (group nesting ants, bees, and wasps), are entirely absent. Commercial shipping and air cargo to Hawaii has now resulted in the establishment of over 2,500 species of alien arthropods (Howarth 1990, Howarth et al. 1994), with a continuing establishment rate of 10-20 new species per year (Beardsley 1962; 1979). In addition to the accidental establishment of alien species, alien predators and parasites for biological control of pests have been purposefully imported and released by individuals, Republic, Territorial, State, and Federal agencies, since 1865. Between 1890 and 1985, 243 alien species were introduced, sometimes with the specific intent of reducing populations of native Hawaiian insects (Funasaki et al. 1988, Lai 1988). Alien arthropods, whether purposefully introduced or adventive, pose a serious threat to Hawaii's native insects, through direct predation and parasitism, and competition for food or space (Howarth and Medeiros 1989; Howarth and Ramsay 1991).

Ants are not a natural component of Hawaii's arthropod fauna, and endemic species evolved in the absence of predation pressure from ants. Ants can be particularly destructive predators because of their high densities, recruitment behavior, aggressiveness, and broad range of diet (Reimer 1993). The latter attribute allows some ants to affect prey populations independent of prey density, and ants can therefore locate and destroy isolated individuals and populations (Nafus 1993). At least 36 species of ants are known to be established in the Hawaiian Islands, and three particularly aggressive species have had severe effects on the native insect fauna (Zimmerman 1948a). By the late 1870s, the big-headed ant (*Pheidole megacephala*) was present in Hawaii and its predation on native insects was noted by 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, including most moths, have been eliminated from areas where the big-headed ant is present (Perkins 1913, Gillespie and Reimer 1993). This predator generally does not occur at elevations higher than 600 m (2,000 ft), and is also restricted by rainfall, rarely being found in particularly dry (less than ca 35-50 cm [15- 20 in] annually) or wet areas (more than ca 250 cm [100 in] annually) (Reimer et al. 1990). The long-legged ant (*Anoplolepis longipes*) appeared in Hawaii in 1952 and now occurs on Oahu, Maui, and Hawaii (Reimer et al. 1990). It inhabits low elevation (less than 600 m [2,000 ft]), rocky areas of moderate rainfall (less than 250 cm [100 in] annually) (Reimer et al. 1990).

Direct observations indicate that Hawaiian arthropods are susceptible to predation by this species (Gillespie and Reimer 1993) and Hardy (1979) documented the disappearance of most native insects from Kipahulu Stream on Maui after the area was invaded by the long-legged ant. At least two species of fire ants, *Solenopsis geminita* and *Solenopsis papuana*, are also important threats (Gillespie and Reimer 1993) and occur on all the major islands (Reimer et al. 1990). *Solenopsis geminita* is also known to be a significant predator on pest fruit flies in Hawaii (Wong and Wong 1988). *Solenopsis papuana* is the only abundant, aggressive ant that has invaded intact mesic forest above 600 m (2,000 ft) and is still expanding its range in Hawaii (Reimer 1993). The only known population of this damselfly taxa included in this proposed rule are threatened by one or more of the ant species described above.

D. *The inadequacy of existing regulatory mechanisms.*

This species is not currently protected by any regulatory mechanisms.

Current Conservation Efforts: None.

E. ***Other natural or manmade factors affecting its continued existence.***

Not applicable.

REFERENCES

Asquith, A. 1995. Hawaiian Damselfly Survey: Population Checklist of Category 1 Candidate Species. Unpublished Document by U.S. Fish & Wildlife Service, Pacific Islands Office, Honolulu, HI.

Beardsley, J.W. 1962. On accidental immigration and establishment of terrestrial arthropods in Hawaii during recent years. Proc. Hawaii. Entomol. Soc. 18:99-109..Beardsley, J.W. 1979. New immigrant insects in Hawaii: 1962 through 1976. Proc. Hawaii. Entomol. Soc. 23:35-44.

Bennett, W.C. 1931. Archaeology of Kauai. B.P. Bishop Mus. Bull. 80:1-156.

Bishop Museum of Honolulu. Hawaiian Terrestrial Arthropod Checklist, March 2002 version. http://ww2.bishopmuseum.org/HBS/checklist/query.asp?grp=Arthropod

Blackburn, T. 1884. Notes on Hawaiian Neuroptera, with descriptions of new species. Ann. Mag. Nat. Hist., (V) 14: 412-421. As referenced in: Zimmerman, E.C. 1948. Insects of Hawaii, Vol. 2. Apterygota -Thysanoptera. University of Hawaii Press, Honolulu.

Borror, D.J., C.A. Triplehorn and N.F. Johnson. 1989. Introduction to the Study of Insects, Sixth Edition. Saunders College Publishing, Philadelphia.

Cowles, L.E. 1977. Status of Damselflies (Odonata: Zygoptera) in Hawaii in 1977, with special reference to the endemic genus *Megalagrion* . Senior Honors Thesis, Department of Biology, University of Hawaii, Manoa.

Cuddihy, L.W., and C.P. Stone. 1990. Alteration of native Hawaiian vegetation: Effects of humans, their activities and introductions. University of Hawaii Press, Honolulu, 138 pp. Department of Geography, University of Hawaii. 1983. Atlas of Hawaii. second edition. University of Hawaii Press. Honolulu, 238 pp.

Devaney, D.M., M. Kelly, P.J. Lee, and L.S. Motteler. 1982. Kaneohe: A History of Change. The Bess Press, Honolulu, Hawaii.

Devick, W.S. 1991. Patterns of introduction of aquatic organisms to Hawaiian freshwater habitats: in Devick, W.S., New Direction in Research, Management and Conservation of Hawaiian Freshwater Stream Ecosystems, Proceedings of the 1990 Symposium on Freshwater Stream Biology and Fisheries Management, Department of Land and Natural Resources, Honolulu, Hawaii.

Ego, K. 1956. Life history of freshwater gobies. Freshwater Game and Fish Management Research Project No. F-4-R. Honolulu, Hawaii..Englund, R. and D.A. Polhemus. 1994. Maakua Stream biological assessment, Oahu, Hawaii. Environmental Technologies International, Honolulu, Hawaii.

Ford, J.I. and R.A. Kinzie, III. 1982. Life crawls upstream. Natural History 91:61-66.

Funasaki, G.Y., P.-L. Lai, L.M. Nakahara, J.W. Beardsley & A.K. Ota. 1988. A review of biological control introductions in Hawaii: 1890 to 1985.Proc. Hawaii. Entomol. Soc. 28:105-160.

Gagne, W.C. 1980. Insect and myriopods of Kipahulu Valley below 2,000 feet: in. Smith, C.W., Resources Base Inventory of Kipahulu Valley below 2,000 feet, Maui, Hawaii. Coop. Natl. Park. Res. S. Studies Unit. 119-175 pp.

Gagne, W.C. and F.G. Howarth. 1982. Assessment of Endangered and Threatened Status of Hawaiian Arthropods. Report to U.S. Fish and Wildlife Service, in Pacific Islands Office, Honolulu.

Giambelluca, T.W., M.A. Nullet, M.A. Rifgley, P.R. Eyre, J.E.T. Moncur, and S. Price. 1991. Drought in Hawaii. Report 87. State of Hawaii. Department of Land and Natural Resources, Commission on Water Resource Management.

Gillespie, R.G. and N. Reimer. 1993. The effect of alien predatory ants(Hymenoptera: Formicidae) on Hawaiian endemic spiders (Araneae:Tetragnathidae). Pacific Science 47:21-33.

Handy, E.S.C. and E.G. Handy. 1972. Native planters in old Hawaii. Their life, lore, and environment. B.P. Bishop Mus. Bull. 233:1-641.

Hardy, D.E. 1979. An ecological survey of Puaaluu Stream. Part III. Report on a preliminary entomological survey of Puaaluu Stream, Maui. Coop. Nat. park Resources Study Unit. University of Hawaii. Tech. Report 27:34-39.

Hardy, D.E. and M.D. Delfinado. 1980. Insect of Hawaii. Volume 13, Diptera: Cyclorrhapha III. University of Hawaii Press, Honolulu.

Harris, S., A. Rubissow, S. Edmunds, and J.-A. Cachola. 1993..Hawaii Streams. Document prepared for Commission on Water Resource Management, State of Hawaii. 40 pp.

Harwood, P.D. 1976. Dragonflies (Odonata) observed in Hawaii in 1973 and 1974. Proc. Hawaii. Entomol. Soc. 22:251-253.

Hawaii Stream Assessment. 1990. Department of Land and Natural Resources, State of Hawaii, 300 pp.

Heads, P.A. 1985. The effect of invertebrate and vertebrate predators on the foraging movements of *Ischnura elegans* larvae (Odonata: Zygoptera). Freshwater Biology 15:559-571.

Heads, P.A. 1986. The costs of reduced feeding due to predator avoidance: potential effects on growth and fitness in *Ischnura elegans* larvae (Odonata: Zygoptera). Ecological Entomology 11:369-377.

Henrikson, B.-I. 1988. The absence of antipredator behavior in the larvae of *Leucorrhinia dubia* (Odonata) and the consequences for their distribution. Oikos 51:179-183.

Hibbard, D. and D. Franzen. 1991. The View from Diamond Head: Royal Residence to Urban Resort. Editions Limited, Honolulu, Hawaii. 221 pp.

Howarth, F.G. 1990. Hawaiian terrestrial arthropods: An overview. Bishop. Mus. Occas. Pap. 30:4-26.

Howarth, F.G. and W.P. Mull. 1992. Hawaiian insects and their kin. University of Hawaii Press, Honolulu.

Howarth, F.G., A. Asquith, and G. Nishida. 1994. Insect of Hawaii: Status and Trends. Unpublished manuscript.

Howarth, F.G. and A.C. Medeiros. 1989. Non-native invertebrates: in Stone,C.P. and D.B. Stone (eds), Conservation Biology in Hawaii. University of Hawaii Cooperative National Park Resources Studies Unit, Honolulu. pp. 82-87.

Howarth, F.G. and G.W. Ramsay. 1991. The conservation of island insects and their habitats: in Collins, N.M. and J.A. Thomas (eds), The Conservation of Insects and Their Habitats, Academic Press, London. pp. 71-107.Joesting, E. 1984. Kauai: The separate kingdom. University of Hawaii Press, Honolulu.

Johnson, D.M. 1991. Behavioral ecology of larval dragonflies and damselflies. Trends in Ecol. Evol. 6:8-13.

Jones, B.L., S.S.W. Chin, and J.C. Brice. 1984. Olokele rock avalanche, island of Kauai, Hawaii. Geology 12:209-211.

Kennedy, C.H. 1917. Notes on the penes of damselflies (Odonata). No. 2. The close relations inter se of the Hawaiian Agrionines. Entomological News. 28:9-14.

Kennedy, C.H. 1920. Forty-two hitherto unrecognized genera and subgenera of Zygoptera. Ohio J. Science. 21:83-88.

Kennedy, C.H. 1929. The origin of the Hawaiian Odonata fauna and its evolution within the islands. Proceedings of the Fourth International Congress of Entomology 2:978-981.

Kennedy, C.M. 1934. *Kilauagrion dinesiotes*, a new species of dragonfly (Odonata) from Hawaii. Annals of the Entomological Society of America. 27:343-345.

Kido, M.H., P. Ha, and R.A. Kinzie III. 1993. Insect introductions and diet changes in and endemic Hawaiian amphidromous goby, *Awaous stamineous* (Pisces: Gobiidae). Pacific Science 47:43-50.

Kirby, W. F. 1890. A synonymic catalog of Neuroptera Odonata, or Dragonflies, with an appendix of fossil species. Gurney and Jackson, London. 202 pp. As referenced in: Zimmerman, E.C. 1948. Insects of Hawaii, Vol. 2. Apterygota - Thysanoptera. University of Hawaii Press, Honolulu.

Kirch, P.V. 1982. The impact of the prehistoric Polynesians on the Hawaiian ecosystem. Pacific Science 36:1-14.

Kirch, P.V. 1985. Feathered gods and fishhooks. University of Hawaii Press, Honolulu, Hawaii. 349 pp.

Lai, P.-Y. 1988. Biological control: A positive point of view. Proc. Hawaii. Entomol. Soc. 28:179-190.

McLachlan, R. 1883. Neuroptera of the Hawaiian Islands. - Part I..Pseudo-Neuroptera. Ann. Mag. Nat. Hist., (V) 12: 226-240. As referenced in: Zimmerman, E.C. 1948. Insects of Hawaii, Vol. 2. Apterygota - Thysanoptera. University of Hawaii Press, Honolulu.

McPeek, M.A. 1990a. Determination of species composition in the *Enallagma* damselfly assemblages of permanent lakes. Ecology 71:83-98.

McPeek, M.A. 1990b. Behavioral differences between *Enallagma* species (Odonata) influencing differential vulnerability to predators. Ecology 71:1714-1726.

Macan, T.T. 1977. The influence of predation on the composition of fresh-water animal communities. Biol. Rev. 52:45-70.

MacDonald, G.A., D.A. Davis, and D.C. Cox. 1960. Geology and ground-water resources of the island of Kauai, Hawaii. Hawaii Division of Hydrology, Bulletin No. 13. 212 pp.

Maciolek, J.A. 1982. Lakes and lake-like waters of the Hawaiian Archipelago. Occas. Pap. B.P. Bishop Mus. 25:1-14.

Meier, K.Z., J.P. Laurel and J.E. Maragos. 1993. State of Hawaii (USA). in Scott, D.A., A Directory of Wetlands in Oceania, The international Waterfowl and Wetlands Research Bureau, U.K., and Asia Wetland Bureau, Kuala Lumpur, Malaysia. 444 pp.

Moore, N.W. 1982. Conservation of Odonata - First steps towards a world strategy. Adv. Odontal. 1:205-211.

Moore, N. W. 1983a. Territorial behavior in the genus *Megalagrion* (McLachlan) (Zygoptera: Coenagrionidae). Odonatologica 12(1): 87-92.

Moore, N. W. 1983b. Reflex immobilisation in the Hawaiian endemic genus *Megalagrion* McLachlan (Zygoptera: Coenagrionidae). Odonatologica, 12(2): 161-165.

Moore, N.W. and W.C. Gagne. 1982. *Megalagrion pacificum* (McLachlan) - A preliminary study of the conservation requirements of an endangered species. Rep. Odon. Specialist group Int. Un. Conserv. Nat. Natur. Res. No 3:1-5..Nafus, D.M. 1993a. Biological control agents and native parasitoids in the population system of the butterfly *Hypolimnas bolinas* (L.) (Lepidoptera:Nymphalidae). Micronesica, Suppl. 4:17-23.

NatureServe Explorer: An online encyclopedia of life [web application]. 2001. Version 1.6 . Arlington, Virginia, USA: NatureServe. Available: http://www.natureserve.org/explorer.

Nishida, G.M., Ed. 1994a. Hawaiian Terrestrial Arthropod Checklist, 2nd Edition. Bishop. Mus. Technical Report No. [1]. 287 pp.

Nishida, G.M. 1994b. Taxonomic validation of Candidate species of insects (and related Arthropods) of the Hawaii Islands. Report prepared for the National Biological Survey, 61 pp.

O'Connor, P.J. 1990. Poaceae. in W.L. Wagner, D.R. Herbst and S. Sohmer, Manual of the Flowering Plants of Hawai'i. B.P. Bishop Mus. Spec. Publ. No. 83. 1853 pp.

Ogden Environmental and Energy Service. 1994. VA Medical and Regional Office Center Project Conceptual Mitigation Plan for Impacts on the Orange-black damselfly Population at Tripler Army Medical Center. 16 pp.

Olson, S.L. and H.F. James. 1982. Prodromus of the fossil avifauna of the Hawaiian Islands. Smithsonian Contrib. Zool. 1-59.

Parrish, J.D., J.A. Maciolek, A.S. Timbol, C.B. Hathaway, and S.E. Norton. 1984. Status of stream channel modification in Hawaii and its effects on native aquatic fauna. pp. 83-84. Proc. 5th Conference in Natural Sciences, Hawaii, Volvanoes National Park. Coop. Natl. Park. Res. Stud. Unit, University of Hawaii.

Perkins, R.C.L. 1899. Neuroptera. D. Sharp, ed., Vol. 2:63-77. Cambridge University Press, Cambridge.

Perkins, R.C.L. 1907. Insects at Kilauea, Hawaii. Proc. Hawaii. Entomol. Soc. 1:89-95.

Perkins, R.C.L. 1913. Introduction to Fauna Hawaiiensis. D. Sharp, ed., Vol.1:xv-ccxxvii. Cambridge University Press, Cambridge.

Polhemus, D.A., J. Maciolek, and J. Ford. 1992. An ecosystem classification of inland waters for the tropical Pacific.islands. Micronesica 25:155-173.

Polhemus, D.A. 1993a. Damsels in distress: a review of the conservation status of Hawaiian *Megalagrion* damselflies (Odonata: Coenagrionidae). Aquatic Conservation: Marine and Freshwater Ecosystems 3:343-349.

Polhemus, D.A. 1993b. Conservation of aquatic insects: Worldwide crisis or localized threats? Amer. Zool. 33:588-598.

Polhemus, D.A. 1993c. A preliminary assessment of the impacts of hurricane Iniki on the aquatic insect faunas of streams on the Na Pali Coast, Kaua'i, Hawai'i. in Assessments of the impact of Hurricane Iniki on stream biota and ecosystems on Kaua'i. Department of Land and Natural Resources, Division of Aquatic Resources. State of Hawai'i. pp. 59-88.

Polhemus, D.A. 1994a. Current status of *Megalagrion* populations on Oahu: 1990 - Present. Report to U.S. Fish & Wildlife Service, Pacific Islands Office.

Polhemus, D.A. 1994b. A revision of the Hawaiian damselflies in the genus *Megalagrion* (Odonata: Coenagrionidae). Unpublished report to U.S. Fish & Wildlife Service, Pacific Islands Office.

Polhemus, D.A. 1995. New Heteroptera and Odonata (Insecta) records and range extensions in the Hawaiian Islands. Bish. Mue. Occass. Pap. 42:42-43.

Polhemus, D., and A. Asquith. 1996. Hawaiian Damselfies: A Field Identification Guide. Hawaii Biological Survey Handbook, Bishop Museum Press, Honolulu, Hawaii. 122 pp.

Reimer, N.J. 1993. Distribution and impact of alien ants in vulnerable Hawaiian ecosystems: in D.F.Williams (ed), Exotic Ants: Biology, Impact,and Control of Introduced Species. Westview Press, Boulder, Colorado. Pp. 11-22.

Reimer, N., J.W. Beardsley and G. Jahn. 1990. Pest ants in Hawaii. in Vander Meer, R.K, K. Jaffe and A. Cedeno (eds), Applied Myrmecology: A World Perspective. Westview Press, Boulder, Colorado, pp. 40-50.

Schmidt, E. 1938. Check-list of Odonata of Oceania. Ann. Entomol. Soc. America. 31:322-344. Selys-Longchamps, E. 1876. Synopsis des Agrionines, 5me Legion:.Agrion. Bull. Acad. Royal Belgique, (II) 41 (2,3): 1-282. As referanced in: Zimmerman, E.C. 1948. Insects of Hawaii, Vol. 2. Apterygota -Thysanoptera. University of Hawaii Press, Honolulu.

Simon, C.M., W.C. Gagne, F.G. Howarth, and F.J. Radovsky. 1984. Hawaii: A natural entomological laboratory. Bull. Entomol. Soc. Am.30:8-17.

Smith, C.W. 1985. Impact of alien plants on Hawai'i's native biota. in C.P.Stone and J.M. Scott (eds), Hawai'i's Terrestrial Ecosystems: Preservation and Management. Cooperative National Park Resources Study Unit, University of Hawaii, Honolulu.

Stearns, H.T. 1940. Geology and ground-water resources of the islands of Lanai and Kahoolawe, Hawaii. Bulletin 6 of the Division of Hydrography, Territory of Hawaii.

Stearns, H.T. and K.N. Vaksvik. 1935. Geology and ground-water resources of the island of Oahu, Hawaii. Bulletin 1 of the Division of Hydrography, Territory of Hawaii.

Stearns, H.T. 1985. Geology of the State of Hawaii. second edition. Pacific Books, Palo Alto, California.

Stone, C.P. 1985. Alien animals in Hawai'i's native ecosystems: toward controlling the adverse effects of introduced vertebrates: in Stone, C.P., and J.M. Scott (eds.), Hawai'i's terrestrial ecosystems: preservation and management. Coop. Natl. Park Resources Stud. Unit, Univ. Hawaii, Honolulu, pp. 251-297.

Stone, C.P. 1989. Hawai'i's wetlands, streams, fishponds, and pools. in C.P.Stone and D.B. Stone (eds), Conservation Biology in Hawai'i. Cooperative National Park Resources Study, pp. 125-136. Unit, University of Hawaii, Honolulu.

Summers, C.C. 1964. Hawaiian Fishponds. B.P. Bish. Mus. Spec. Publ. 52.

Takasaki, K.I., G.T. Hirashima, and E.R. Lubke. 1969. Water Resources of Windward Oahu, Hawaii. U.S. Geological Survey Water Supply Paper No. 1894:1-119. U.S. Govt. Printing Office, Washington, D.C..U.S. Fish and Wildlife Service. 1985. Recovery plan for the Hawaiian waterbirds. U.S. Fish and Wildlife Service, Portland, Oregon, 99 pp.

U.S. Fish and Wildlife Service. 1995. Pacific Islands Ecoregion Coastal Ecosystems Program Proposal. U.S. Fish and Wildlife Service, Honolulu, Hawaii, 119 pp.

Van Dine, D.L. 1907. The introduction of top-minnows (natural enemies of mosquitoes) into the Hawaiian Islands. Haw. Agr. Exp. St. Press Bull. 20:1-10.

Wenkam, R. 1969. Kauai and the park county of Hawaii. Sierra Club, San Fransisco, 160 pp.

Williams, F.X. 1936. Biological studies in Hawaiian water-loving insects. Part 1. Coleptera or beetles. Part 2. Odonata or dragonflies. Proc. Hawaii. Entomol. Soc. 9:235-345.

Wilson, Okamoto and Associates, Inc. 1993. Kawai Nui Marsh Master Plan: Development Project Report. Document prepared for Department of Land and Natural resources, State of Hawaii.

Wong, M.A. and T.T.Y. Wong. 1988. Predation of the Mediterranean fruit fly and oriental fruit fly (Diptera: Tephritidae) by the fire ant(Hymenoptera: Formicidae) in Hawaii. Proc. Hawaii. Entomol. Soc. 28:169-177.

Zimmerman, E.C. 1948a. Insects of Hawaii. Vol. 1. Introduction. xvii + 206 pp. University of Hawaii Press.

Zimmerman, E.C. 1948b. Insects of Hawaii, Vol. 2. Apterygota - Thysanoptera. University of Hawaii Press, Honolulu.

Zimmerman, E.C. 1948c. Insects of Hawaii, Vol. 3. Heteroptera. University of Hawaii Press, Honolulu.

Zimmerman, E.C. 1970. Adaptive radiation in Hawaii with special reference to insects. Biotropica 2:32-38.

PETITION TO LIST

oceanic Hawaiian damselfly
(*Megalagrion oceanicum*)

AS A FEDERALLY ENDANGERED SPECIES

CANDIDATE HISTORY

CNOR 5/22/84:	
CNOR 1/6/89:	
CNOR 11/21/91:	
CNOR 11/15/94:	
CNOR 2/28/96:	C
CNOR 9/19/97:	C
CNOR 10/25/99:	C
CNOR 10/30/01:	C
CNOR 6/13/02:	C

TAXONOMY

Native Hawaiians apparently did not differentiate among the different species, but referred to the native damselflies collectively as pinaoʻula. There has been no traditional European use of a common name for species in the genus *Megalagrion* (Coenagrionidae). In a recent taxonomic review of the candidate species of insects in Hawaii, Nishida (1994b) proposed the name "Hawaiian damselflies". Because this name reflects the restricted distribution of these insects and should be readily used by nontechnical persons, the U.S. Fish and Wildlife Service has adopted this common name for the genus, with additional descriptive terms to identify each species.

The status of *Megalagrion oceanicum* as a valid species is uncontroversial (e.g., Bishop Museum 2002).

NATURAL HISTORY

Distribution

Because of the extreme geographic isolation of the Hawaiian islands and the poor dispersal capabilities of many aquatic insects, the freshwater insect fauna of Hawaii is depauperate compared to continental areas despite the diversity of aquatic habitats. Many groups of insects that typify freshwater habitats in continental areas are absent from the native fauna. Some notable examples of such groups are mayflies (Ephemeroptera), stoneflies (Plecoptera), caddisflies (Trichoptera), and alderflies and dobsonflies (Neuroptera), all of which are absent from Hawaii.

Like most of the native fish, mollusc, and crustacean faunas (Ford and Kinsey 1994), most of Hawaii's freshwater insects evolved from marine or intertidal ancestors (Hardy and Delfinado 1980) that could easily colonize the islands.

The Hawaiian damselflies are represented by 23 species and five subspecies, all confined to the Hawaiian Islands. Historically these were among the most common and conspicuous native Hawaiian insects. Some species inhabited water gardens in residential areas, artificial reservoirs, and watercress farms, and were abundant in the city of Honolulu (Perkins 1913, Williams 1936).

Morphology

Megalagrion oceanicum is a large Hawaiian damselfly. Males are bright red with black markings on the tops of abdominal segments VI-IX. Females are similarly patterned but with green markings rather than red and with abdomen darker above. More detailed descriptions are available in Polhemus and Asquith (1996).

Behavior

Immature of this species are found in swiftly flowing sections of streams, usually amid rocks and gravel in the tailraces of riffles and small cascades. While capable of swimming, the naiads usually crawl among gravel or submerged vegetation. Older naiads frequently forage out of the actual stream channel and have been observed among wet moss on rocks, and wet rock walls and seeps (Williams 1936). Adults are very bold and strong flyers, and when disturbed frequently fly upward into the forest canopy overhanging the stream (Williams 1936, Polhemus 1994b). The primary threats to the remaining populations of the oceanic Hawaiian damselfly are predation by alien aquatic species such as fish and predacious insects and habitat loss through dewatering of streams.

The males of most species are territorial, guarding areas of habitat where females will lay eggs (Moore 1983a). During copulation, and often while the female lays eggs, the male grasps the female behind the head with his terminal abdominal appendages to guard her against rival males, thus males and females are frequently seen flying in tandem. In species with fully aquatic immature stages, females lay eggs in submerged aquatic vegetation or in mats of moss or algae on submerged rocks, and hatching occurs in about ten days (Williams 1936, Polhemus 1994b). In most species of Hawaiian damselflies, the immature stages (naiads) are aquatic, breathing though three flattened, abdominal gills, and are predacious, feeding on small aquatic invertebrates or fish (Williams 1936).

Naiads may take up to four months to mature (Williams 1936), after which they crawl out of the water onto rocks or vegetation, molt into winged adults, which typically remain very close to the aquatic habitat from which they emerged. Adults are also predacious and feed on small flying insects such as midges. In a remarkable example of adaptive radiation in Hawaii, some species of Hawaiian damselflies have foregone the aquatic lifestyle, either partly, with naiads living on wet rock faces, or completely, with terrestrial naiads living in the damp leaf litter, or others inhabiting moist leaf axils of native plants up to several meters above the ground (Zimmerman 1970, Simon et al. 1984). Adults are also unusual in that they have a highly developed behavior of feigning death when caught or attacked (Moore 1983b).

Habitat

This species is found in fresh running water. Immatures of this species are found amid gravel and moss pads in the swift water sections of perennial streams (Polhemus and Asquith 1996). The younger nymphs are often found among algae and diatoms in shallow running water (Williams, 1936).

POPULATION STATUS

This species occurs at seven locations within one of two formerly occupied mountain ranges on Oahu. Individuals probably number less than 1,000 total. Decline seems to be continuing at a relatively gradual pace (NatureServe Explorer 2001).

The oceanic Hawaiian damselfly is endemic to the island of Oahu. Historically it occurred in both the Koolau and Waianae mountain ranges, and was known from the following localities--Haleauau Stream (Williams 1936), Waianae Mountains (Polhemus 1994b), Hering Spring stream (Williams 1936), Honolulu, Kahamainui Gulch, Kalihi Valley, Kawailoa Stream, Manoa Stream, Moanalua Valley, Palolo Stream, Poamoho Trail, Punaluu, Pupukea, Waiahole Stream, Waianae, and Waimanalo (Polhemus 1994b). This species appears to be extirpated from the Waianae Mountains and all leeward drainages of the Koolau Mountains. It is presently known only from the windward Koolau Mountains at the following localities--Kahamainui (Polhemus 1994a), Kaipapau (*in litt*. 1994 cited in U.S. Fish and Wildlife Service candidate assessment form), Kaluanui above Sacred Falls (Polhemus 1994a), Koloa Gulch (Asquith 1995), Maakua Gulch (Englund and Polhemus 1994, Polhemus 1994a), Makaua Stream (*in litt*. cited in U.S. Fish and Wildlife Service candidate assessment form), and Waihee Stream (Polhemus 1994a).

As early as 1948, Zimmerman noted a decline of the more common species, particularly on Oahu. By the late 1970s less than six populations of the Pacific Hawaiian damselfly could be located (Harwood 1976, Gagne 1980, Moore and Gagne 1982), and the conservation of this species was identified as a priority by the International Union for Conservation of Nature and Natural Resources (Moore 1982). A review of the status of Hawaiian damselflies in 1981 (Gagne and Howarth 1982) lead to the placement of several species on the U.S. Fish and Wildlife Service's list of candidate species for Federal listing (49 FR 21664). Due to a continued decline of these damselflies, particularly on the island of Oahu, intensive surveys were initiated in 1990, supported by both the Service and the State of Hawaii. The results of these surveys demonstrate that six species of Hawaiian damselflies are now threatened with extinction.

The International Union for the Conservation of Nature (IUCN) considers the species to be vulnerable.

The U.S. Fish and Wildlife Service classifies the oceanic Hawaiian damselfly as a candidate for Endangered Species Act protection with a listing priority number of 2.

LISTING CRITERIA

A. *The present or threatened destruction, modification, or curtailment of its habitat or range.*

Historical range: Hawaii, island of Oahu. It occurred in both the Koolau and Waianae mountain ranges, and was known from the following localities--Haleauau Stream (Williams 1936), Waianae Mountains (Polhemus 1994b), Hering Spring stream (Williams 1936), Honolulu, Kahamainui Gulch, Kalihi Valley, Kawailoa Stream, Manoa Stream, Moanalua Valley, Palolo Stream, Poamoho Trail, Punaluu, Pupukea, Waiahole Stream, Waianae, and Waimanalo (Polhemus 1994b).

Current range: Hawaii, island of Oahu. This species appears to be extirpated from the Waianae Mountains and all leeward drainages of the Koolau Mountains. It is presently known only from the windward Koolau Mountains at the following localities--Kahamainui (Polhemus 1994a), Kaipapau (*in litt*. 1994 cited in U.S. Fish and Wildlife Service candidate assessment form), Kaluanui above Sacred Falls (Polhemus 1994a), Koloa Gulch (Asquith 1995), Maakua Gulch (Englund and Polhemus 1994, Polhemus 1994a), Makaua Stream (*in litt*. 1994 cited in U.S. Fish and Wildlife Service candidate assessment form), and Waihee Stream (Polhemus 1994a).

Land ownership: This species occurs in State-managed waters.

Freshwater habitats on all the main Hawaiian Islands have been severely altered and degraded because of past and present land and water management practices including agriculture, urban development, development of ground water, perched aquifer and surface water resources, and the deliberate introduction of alien animals (Harris et al. 1993, Meier et al. 1993, U.S. Fish and Wildlife Service 1985; 1995).

Extensive modification of lentic (standing water) habitats in the Hawaiian Islands began about 1100 AD with a rapid population increase among native Hawaiians (Kirch 1982). Hawaiians cultivated taro (*Colocasia esculenta*) by creating shallow, walled ponds called lo’I, in marshes and riparian areas (Handy and Handy 1972). By 1778, virtually all valley bottoms with permanent stream flow and most basin marshes were converted to irrigated taro cultivation (Handy and Handy 1972). While this represents a significant alteration of the natural aquatic system, these extensive artificial wetlands were probably suitable habitat for many native Hawaiian species, particularly waterbirds (Olson and James 1982). Native Hawaiian dragonflies were recorded in taro lo’I (Handy and Handy 1972) and some damselflies may also have utilized these systems (Moore and Gagne 1982), since the lo’I remained flooded for months or years at a time (Handy and Handy 1972).

Hawaiians also modified wetlands by constructing fishponds, many of which were primarily freshwater, fed by streams or springs (Summers 1964). Despite this habitat modification by early Hawaiians, many areas of extensive marsh land remained intact. The best example of this was the Mana marsh of western Kauai. In this area, sedimentary deposits restrict the flow of ground water seaward, creating basal water spring discharge 3-4 m (8-12 ft) above sea level, and the development of an extensive marsh system (MacDonald et al. 1960). This area was famous for its mirages on open water surfaces (MacDonald et al. 1960) and Hawaiians traveled by canoe for miles between villages (Bennett 1931).

Some wetlands which had been converted to taro lo’I were maintained and others were utilized for rice cultivation between 1850 and 1930. In 1900, there was approximately 19,000 acres of taro and 16,000 acres of rice in production in Hawaii (U.S. Fish and Wildlife Service 1995). By 1960, taro production was reduced to only 510 acres and the rice industry had been completely abandoned. Many of these wetlands formerly used for taro or rice were drained and filled for dry-land agriculture (Stone 1989, Meier et al. 1993). The Mana marsh on Kauai is also one of the best examples of extensive freshwater habitat loss due to modern agriculture. The margins of the Mana marsh were used for rice cultivation until 1922, when the land, including several open ponds, were leased to Kekaha Sugar Company for sugarcane cultivation (Joesting 1984). By the late 1940s, the entire Mana marsh had been drained and filled and was under sugarcane cultivation (Wenkam 1969).

Most urban, residential and resort development in Hawaii has occurred in the coastal plains and as a result, many freshwater lentic habitats have been negatively affected (U.S. Fish & Wildlife Service 1985). Most of this development has occurred on Oahu, which now supports four fifths of the state's population (Dept. of Geography 1983). The Ala Moana and Waikiki areas of Honolulu were once extensive marshlands that were converted to hundreds of taro lo’I and fishponds by Hawaiians (Handy and Handy 1972). Small development projects began in Waikiki in 1910, but even as late as 1920, 85 percent of Waikiki remained under water, used as duckponds, fishponds, and for the cultivation of rice and taro (Hibbard and Franzen 1991). In 1928, the Ala Wai Canal was completed, resulting in the complete drainage and development of the Waikiki wetlands, which now on an average day hosts over 60,000 people (Hibbard and Franzen 1991). Construction for housing and civil works projects on Oahu also resulted in the draining and filling of large fresh and brackish water marshes at Wailupe Peninsula, Hawaii Kai, Kaelepulu Pond, and Salt Lake (U.S..Fish and Wildlife Service 1995).

Thirty percent of all coastal plain wetlands in Hawaii have been lost to agriculture and urban development (*in litt*. 1990 cited in U.S. Fish and Wildlife Service candidate assessment form), and if only freshwater habitat was considered the loss would be proportionately much higher, probably approaching 80 to 90 percent. While intentional filling of freshwater wetlands with open water is rarely permitted today (personal communication 1995 cited in U.S. Fish and Wildlife Service candidate assessment form), loss of smaller areas utilized by damselflies, such as narrow strips of freshwater seeps within anchialine pool complexes, and loss of emergent vegetation still occurs. In addition, marshes are slowly filled and converted to meadow habitat due to increased sedimentation resulting from increased storm water runoff from upslope development, and blockage of downslope drainage (Wilson Okamoto & Associates, Inc. 1993).

Presently the most significant threat to natural ponds and marshes in Hawaii is the alien species, California grass (*Brachiaria mutica* (Forssk.) Stapf). The area of origin of this sprawling perennial grass is unknown, but it was first noted on Oahu in 1924 and now occurs on all the major islands (O'Connor 1990). This plant forms dense, monotypic stands that can completely eliminate any open water by layering of its trailing stems (Smith 1985). The most extensive remaining marsh system on the island of Oahu, Kawainui, is now almost entirely choked with California grass, facilitating its conversion to meadowland (Wilson Okamoto & Associates, Inc. 1993).

The James Campbell and Pearl Harbor National Wildlife Refuges on Oahu, and Kakahaia National Wildlife Refuge on Molokai must be constantly managed to control this plant (personal communication 1995 cited in U.S. Fish and Wildlife Service candidate assessment form). The Pacific Hawaiian damselfly and the orangeblack Hawaiian damselfly have both sustained loss of palustrine habitat on all islands due to human activities and California grass. Presently two populations of the orangeblack damselfly along the Kona coast of Hawaii are threatened with further habitat loss from overdraw of the aquifer that feeds coastal marshes (personal communication 1995 cited in U.S. Fish and Wildlife Service candidate assessment form). The only known population of the orangeblack damselfly on Oahu is threatened with habitat degradation from a proposed construction project (Ogden Environmental 1994).

Early Hawaiians also modified stream systems by diverting water from the main channel to irrigate taro lo’I. In some cases these diversions, or ‘auwai, were elaborate, such as the cut and fitted stone ditch of Kiki a Ola in Waimea Canyon on Kauai (Bennett 1932). Other diversions were several kilometers long (Kirch 1985) and moved water between drainages (Devaney et al. 1983). However, these diversions were closely regulated and were not allowed to take more than half the stream flow, and diversions were typically periodic to flood lo’I rather than continuous (Handy and Handy 1972).

The advent of plantation sugarcane cultivation in 1835 led to more extensive stream diversions. The first irrigation system for sugar, built in 1856 on Kauai, was 16 km (10 mi) long. In 1900, the Maunawili Ditch on windward Oahu diverted all the water from Maunawili Stream into Waimanalo Valley (Takasaki et al. 1969). By 1906, the Kohala Ditch system on Maui utilized 15 km (9 mi) of tunnels, 7 km (4.5 mi) of open ditch, and 20 flumes, and now the East Maui Irrigation system may be the largest private water company in the United States (Harris et al. 1993). These systems typically tap water at upper elevations (> 300 m) by means of a concrete weir in the stream. All or most of the low or average flow of the stream is diverted into fields or reservoirs (Takasaki et al. 1969, Harris et al. 1993). By the 1930s, major water diversions had been developed on all the major islands and currently one third of Hawaii's perennial streams are diverted (Hawaii Stream Assessment 1990). Some systems are extensive, such as the Waiahole Ditch which takes water from 37 streams on the windward side of Oahu, and transports it to the leeward plains via a tunnel cut through the Koolau Mountain Range (Stearns and Vaksvik 1935).

On West Maui, as of 1978, over 49 miles of stream habitat in 12 streams have been lost due to diversions, and all of the 17 perennial streams on West Maui are diverted to some extent (Macioleck 1979). In addition to diverting water for agriculture and domestic water supply, streams have also been diverted for use in hydroelectric power. There are currently 18 active hydroelectric plants operating on Hawaiian streams, with another 10 proposed for construction, and another 28 sites identified for potential development (Hawaii Stream Assessment 1990)

In addition to diverting surface flow in the stream channels, the perched aquifers which feed the streams have also been tapped by means of tunnels (Stearns and Vaksvik 1935, Stearns 1985)). For example, both the bore tunnels and the contour tunnel of the Waiahole Ditch system pierced perched aquifers which were drained to the level of the tunnels (Stearns and Vaksvik 1935). Many of these aquifers were also the sources of springs which contributed flow to the windward streams. The boring of the Haiku tunnel in 1940 caused a 25 percent reduction in the base flow of Kahaluu Stream, over 2.5 miles away (Takasaki et al. 1969). The draining of these aquifers caused many of the springs to dry up, including some over 0.5 km (0.3 mi) away from the bore tunnels (Stearns and Vaksvik 1935). Frequently the actual springs were tapped by driving tunnels into the rock from where the water emerged, and on the water-poor island of Lanai, almost every spring and seep was bored or captured (Stearns 1940).

Surface waters in streams have also been captured by tunnels in the alluvium of the stream channel. Historically, Maunalei Stream was the only perennial stream on Lanai, and Hawaiians constructed taro lo'I in the lower portions of this system. In 1911, a tunnel was developed at 330 m (1,100 ft) elevation which undercut the stream bed, capturing both the surface and subsurface flow and dewatering the stream from this point to the mouth (Stearns 1940).

Stream degradation has been particularly severe on the island of Oahu, where, in 1978, 57 percent of the perennial streams had been channelized (lined, partially lined or altered stream course) and 89 percent of the total length of these streams were channelized (Parrish et al. 1984). Channelization of streams has not been restricted to lower reaches, in Kalihi Stream there is extensive channelization above 300 m (1,000 ft). Channelization results in removal of riparian vegetation, increased velocity, increased illumination, and higher water temperatures. Hawaiian damselflies do not utilize channelized portions of streams.

Surface flow of streams has also been affected by vertical wells, because the basal aquifer and alluvial caprock through which the lower sections of streams flow can be hydraulically connected (*in litt*. 1995 cited in U.S. Fish and Wildlife Service candidate assessment form). Historically, for example, there was sufficient surface flow in Makaha and Nanakuli streams on Oahu to support taro lo'I in their lower reaches, but this flow disappeared subsequent to construction of wells upstream (personal communication 1995 cited in U.S. Fish and Wildlife Service candidate assessment form). This damselfly has sustained habitat loss due to water diversions, and stream alterations, on the island of Oahu.

B. *Overutilization for commercial, recreational, scientific, or educational purposes.*

Healthy populations of stream-inhabiting Hawaiian damselflies are composed of large numbers of individuals. Moore (1983a) recorded 75 males per 100 m of stream edge for *Megalagrion heterogamias* on Kauai. In addition, there are often more males than suitable territorial habitat, and when males are removed from a territory they are immediately replaced by other individuals (Moore 1983a). However, populations of these damselflies are now extremely reduced, with fewer than 10 males per 100 m of stream edge at most localities. Publication of the rarity of these species will likely increase the interest of professional and amateur Odonata collectors. Unrestricted collecting and handling could impact these small populations and are considered significant threats to the species.

C. *Disease or predation.*

The geographic isolation of the Hawaiian Islands has restricted the number of original successful colonizing arthropods and resulted in the development of an unusual fauna. An unusually small number (15 percent) of the known families of insects are represented by native Hawaiian species (Howarth 1990). Some groups that often dominate continental arthropod faunas, such as social Hymenoptera (group nesting ants, bees, and wasps), are entirely absent. Commercial shipping and air cargo to Hawaii has now resulted in the establishment of over 2,500 species of alien arthropods (Howarth 1990, Howarth et al. 1994), with a continuing establishment rate of 10-20 new species per year.(Beardsley 1962; 1979).

In addition to the accidental establishment of alien species, alien predators and parasites for biological control of pests have been purposefully imported and released by individuals, Republic, Territorial, State, and Federal agencies, since 1865. Between 1890 and 1985, 243 alien species were introduced, sometimes with the specific intent of reducing populations of native Hawaiian insects (Funasaki et al. 1988, Lai 1988). Alien arthropods, whether purposefully introduced or adventive, pose a serious threat to Hawaii's native insects, through direct predation and parasitism, and competition for food or space (Howarth and Medeiros 1989; Howarth and Ramsay 1991).

Ants are not a natural component of Hawaii's arthropod fauna, and endemic species evolved in the absence of predation pressure from ants. Ants can be particularly destructive predators because of their high densities, recruitment behavior, aggressiveness, and broad range of diet (Reimer 1993). The latter attribute allows some ants to affect prey populations independent of prey density, and ants can therefore locate and destroy isolated individuals and populations (Nafus 1993).

At least 36 species of ants are known to be established in the Hawaiian Islands, and three particularly aggressive species have had severe effects on the native insect fauna (Zimmerman 1948a). By the late 1870s, the big-headed ant (*Pheidole megacephala*) was present in Hawaii and its predation on native insects was noted by 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, including most moths, have been eliminated from areas where the big-headed ant is present (Perkins 1913, Gillespie and Reimer 1993). This predator generally does not occur at elevations higher than 600 m (2,000 ft), and is also restricted by rainfall, rarely being found in particularly dry (less than ca 35-50 cm [15- 20 in] annually) or wet areas (more than ca 250 cm [100 in].annually) (Reimer et al. 1990).

The long-legged ant (*Anoplolepis longipes*) appeared in Hawaii in 1952 and now occurs on Oahu, Maui, and Hawaii (Reimer et al. 1990). It inhabits low elevation (less than 600 m [2,000 ft]), rocky areas of moderate rainfall (less than 250 cm [100 in] annually) (Reimer et al. 1990). Direct observations indicate that Hawaiian arthropods are susceptible to predation by this species (Gillespie and Reimer 1993) and Hardy (1979) documented the disappearance of most native insects from Kipahulu Stream on Maui after the area was invaded by the long-legged ant. At least two species of fire ants, *Solenopsis geminita* and *Solenopsis papuana* , are also important threats (Gillespie and Reimer 1993) and occur on all the major islands (Reimer et al. 1990). *Solenopsis* *geminita* is also known to be a significant predator on pest fruit flies in Hawaii (Wong and Wong 1988). *Solenopsis papuana* is the only abundant, aggressive ant that has invaded intact mesic forest above 600 m (2,000 ft) and is still expanding its range in Hawaii (Reimer 1993). At least some populations of all the damselfly taxa included in this proposed rule are threatened by one or more of the ant species described above.

Backswimmers are aquatic true bugs (Heteroptera) in the family Notonectidae, so called because they swim upside down. Backswimmers are voracious predators and frequently feed on prey much larger than themselves, tadpoles, small fish, and other aquatic insects including damselfly naiads (Borror et al. 1989). Backswimmers are not native to Hawaii, but several species have been introduced in recent times. *Buenoa pallipes* (Fabricus) (NCN) has been known from Hawaii since 1900 (Zimmerman 1948c) and has been recorded from all the major islands except Lanai (Nishida 1994a). This species can be abundant in lowland ponds and reservoirs and feeds on any suitably sized insect, including damselfly naiads. More recently, two additional species of backswimmers have become established in Hawaii (Polhemus 1995). *Anisops batillifrons* was first collected in 1991 and is known only from Maui. *Notonecta indica* was first collected on Oahu in the mid 1980s and is presently known from Maui and Hawaii. Species of *Notonecta* are known to prey on damselfly naiads and the mere presence of this predator in the water can cause naiads.to reduce foraging (Heads 1985) which can reduce growth, development, and survival (Heads 1986). Backswimmers pose a threat to all populations of this damselfly.

Similar to the aquatic insects, Hawaii has a depauperate freshwater fish fauna with only five native species comprised of gobies (Gobiidae) and sleepers (Eleotridae), that occur on all the major islands. The ‘o’opu okuhe (*Eleotris sandwicensis*) and the ‘o’opu naniha (*Stenogobius hawaiiensis*) are coastal fishes, occurring in brackish and freshwater ponds and in lower reaches of streams below the first waterfall. While the ‘o’opu okuhe is the most predaceous of the Hawaiian freshwater fishes (*in litt.* 1995 cited in U.S. Fish and Wildlife Service candidate assessment form), it occurs infrequently with damselflies in the lower reaches of larger streams. The ‘o’opu nakea (*Awaous stamineus*) and the ‘o’opu nopili (*Sicyopterus stimpsoni*) frequent the middle reaches of streams up to 300 m (1,000 ft) elevation.

The ‘o’opu alamo’o (*Lentipes concolor*) usually occupies the upper sections streams above 800 m (2600 ft) and can apparently navigate Hawaii's largest waterfalls (Devick et al. 1992). Prior to human alteration of the aquatic habitats, the ‘o’opu nakea, ‘o’opu nopili, and the ‘o’opu alamo’o would have all occurred with the naiads of some of the Hawaiian damselflies, at least occasionally. The ‘o’opu nakea has been reported to feed on Hawaiian damselfly naiads (Ego 1956), but this species is apparently primarily herbivorous and ingestion of naiads probably occurs incidental to feeding on algae (Kido et al. 1993). The ‘o’opu noplili feeds predominately on algae and ‘o’opu alamo’o, while facultatively predaceous and not known to feed on damselfly naiads (*in litt*. 1995 cited in U.S. Fish and Wildlife Service candidate assessment form). Therefore, the Hawaiian damselflies probably experienced limited natural predation pressure from the native fishes.

Fish predation has been an important factor in the evolution of behavior in damselfly naiads in continental systems (Johnson 1991). Some species of damselflies are not adapted to cohabitat with fish, and are found only in bodies of water without fish (Henrickson 1988, McPeek 1990a). The naiads of these species tend to occupy more exposed positions and engage in conspicuous foraging behavior, thereby being susceptible to fish (Macan 1977, McPeek 1990b). The evolutionary history of the Hawaiian damselflies coexisting with few, if any predatory fish, and the exposed behavior of most of the fully aquatic species, makes them particularly vulnerable to predation by alien fish introductions.

Over 60 species of aquatic organisms have been introduced into Hawaiian freshwater habitats, including at least 45 species of fish (Devick 1991). The impact of fish introductions prior to 1900 cannot be assessed because this predated the initial collection of damselflies in Hawaii (Perkins 1913). In 1905, two species, the mosquito fish (*Gambusia affinis*), and the sailfin molly (*Poecilia latipinna*), were successfully introduced for biological control of mosquitoes (Van Dine 1907). In 1922, three additional species were established for mosquito control, the Green swordtail (*Xiphophorus helleri*), the moonfish (*Xiphophorus maculatus*), and the guppy (*Poecilia reticulata*). The introduction of these species has been implicated in the extinction of the Pacific Hawaiian damselfly from most of the main islands (Moore and Gagne 1982), and by 1935 on Oahu, the orangeblack Hawaiian damselfly was found only in waters without these introduced fish (Williams 1936, Zimmerman 1948b, Polhemus 1993b). Most of the fish introduced early into Hawaii are now established on all the major islands, and are primarily pond and reservoir inhabitants.

Beginning in about 1980, a large number of new fish introductions began in Hawaii, originating primarily from the aquarium fish trade (Devick 1991). By 1990, an additional 15 species of fish were established in waters on Oahu, including catfish, cichlids, gobies, top minnows, needlefish, and piranha many which readily invaded stream systems. By early 1990, the lower to middle reaches of two widely separated streams on Oahu, Manoa on the south leeward side, and Kaukanohua on the north windward side, were choked with dense populations of armored catfish (*Hypostomus* sp. and *Pterygoplichthys multiradiatus*) (Devick 1991). This recent wave of fish introductions on Oahu corresponded with the drastic decline and range reduction of the crimson Hawaiian damselfly, the oceanic Hawaiian damselfly, and the blackline Hawaiian damselfly. Currently, these damselflies occur only in drainages or higher parts of stream systems where alien fish are not yet established (*in litt*. 1994 cited in U.S. Fish and Wildlife Service candidate assessment form). The continued introduction and establishment of new species of alien fish, and the movement of established species to new drainages (personal communication 1994 cited in U.S. Fish and Wildlife Service candidate assessment form) presents the greatest threat to this Hawaiian damselfly species.

D. ***The inadequacy of existing regulatory mechanisms.***

The State of Hawaii considers all natural flowing surface water (streams, springs and seeps) as State property (Hawaii Revised Statutes 174c 1987), and the Hawaii Department of Land And Natural Resources has management responsibility for the aquatic organisms in these waters (personal communication 1995 cited in U.S. Fish and Wildlife Service candidate assessment form). Thus, damselfly populations associated with streams, seeps and springs are under the jurisdiction of the State of Hawaii, regardless of the ownership of the property across which the stream flows. This includes all populations of the crimson Hawaiian damselfly, the blackline Hawaiian damselfly, and the oceanic Hawaiian damselfly, as well as some populations of the Pacific Hawaiian damselfly and the orangeblack Hawaiian damselfly occurring in streams.

State regulatory mechanisms currently in effect do not provide adequate protection for the Hawaiian damselflies or their habitat. The State of Hawaii has not listed these damselflies as endangered or threatened and so does not afforded them any protection under the State endangered species act. Nor does the State Water Code afford adequate protect from the adverse effects of water development projects. The State of Hawaii manages the use of surface and ground water resources through the Commission on Water Resource Management (Water Commission), as mandated by the 1987 State Water Code (State Water Code, Hawaii Revised Statutes Chapter 174C-71, 174C-81-87, and 174C-9195 and Administrative Rules of the State Water Code, Title 13, Chapters 168 and 169). In the State Water Code, there are no formal requirements that project proponents or the Water Commission protect the habitats of fish and wildlife prior to issuance of a permit to modify surface or ground water resources.

The maintenance of instream flow, which is required to protect the habitat of damselflies and other aquatic wildlife, is regulated by the establishment of standards on.a stream-by-stream basis (State Water Code, Hawaii Revised Statutes Chapter 174C-71 and Administrative Rules of the State Water Code, Title 13, Chapter 169). Currently, the interim instream flow standards represent the existing flow conditions in streams in the State as of 15 June 1988 for Molokai, Hawaii, Kauai and East Maui, and 19 October 1988 for West Maui and Leeward Oahu (Administrative Rules of the State Water Code, Title 13, Chapter 169-44-49). However, the State Water Code does not provide for permanent or minimal instream flow standards for the protection of aquatic wildlife. Instead, modification of instream flow standards and stream channels can be undertaken at any time by the Water Commission or via public petitions to revise flow standards or modify stream channels in a specified stream (Administrative Rules of the State Water Code, Title 13, Chapter 169-36). Additionally, the Water Commission must consider economic benefits gained from out-of-stream water uses, and is not required to balance these benefits against instream benefits to aquatic fish and wildlife. Consequently, any stabilization of stream flow for the protection of Hawaiian damselfly habitat is subject to modification at a future date.

The natural value of Hawaii's stream systems have been recognized under the State of Hawaii Instream Use Protection Program (Administrative Rules of the State Water Code, Title 13, Chapter 169-20(2)). In the Hawaii Stream Assessment Report, prepared in coordination with the National Park Service (National Park Service 1990), the State Water Commission identified high quality rivers or streams, or portions of a rivers or streams, that may be placed within a wild and scenic river system. This report recommended that streams meeting certain criteria be protected from further development. However, there is no formal or institutional mechanism within the Water Code to designate and set aside these streams, or to identify and protect stream habitat for Hawaiian damselflies.

Existing Federal regulatory mechanisms that may protect Hawaiian damselflies and their habitat are also inadequate. The Federal Energy Regulatory Commission (FERC) has very limited jurisdiction in Hawaii. Hydroelectric power projects in Hawaii are not on navigable water, public lands, or United States reservations; do not use surplus water or water power from a Federal Government Dam; and do not affect the interests of interstate or foreign commerce. Thus, licensing of hydroelectric projects do not come under the purview of FERC. However, hydropower developers in Hawaii may voluntarily seek licensing under FERC.

The U.S. Army Corps of Engineers (COE) also has some regulatory control over modifications of freshwater streams in the United States. For modifications (i.e. discharge of fill) of streams with an average annual flow greater than 5 cubic feet per second (cfs), the COE can issue individual Department of the Army (DOA) permits under Section 404 of the Clean Water Act. These permits are subject to public review, and must comply with the Environmental Protection Agency's 404(b)(1) guidelines and public comment requirements. However, in issuing these permits, the COE does not establish instream flow standards as a matter of policy. The COE normally considers that the public interest for instream flow is represented by the state water allocation rights or preferences (Regulatory Guidance Letter No 85-6), and project alternatives that supersede, abrogate, or otherwise impair the state water quantity allocations are not normally addressed as alternatives during permit review.

In cases where the COE district engineer does propose to impose instream flow standard on an individual DOA permit, this flow standard must reflect a substantial national interest. Additionally, if this instream flow standard is in conflict with a State water quantity allocation, then it must be reviewed and approved by the Office of the Chief Engineer in Washington, D.C. Currently, the setting of instream flow standards sufficient to conserve Hawaiian damselflies is not a condition that would be considered or included in a DOA individual permit. If this damselfly was listed as endangered or threatened, Federal interest in its conservation would be assured through consultation under Section 7 of the Endangered Species Act.

The COE may also authorize the discharge of fill into streams with an average annual flow of less than 5 cfs. These discharges are covered under a nationwide permit (33 CFR 330 Appendix A, Nationwide Permit 26). This permit is designed to expedite small scale activities that the COE considers to have only minimal environmental impacts (33CFR 330.1(b)). The U.S. Fish and Wildlife Service and the State Department of Land and Natural Resources have only 15 days to provide substantive site-specific comments following the issuance of a nationwide permit (33 CFR 330 Appendix A, Nationwide Permit Condition 13). Given the complexity of the impacts on Hawaiian damselflies from stream modifications and surface water diversions, the remoteness of project sites, and the types of studies necessary to determine project impacts and mitigation, this limited comment period does not allow for an adequate assessment of impacts. The listing of the Hawaiian damselflies as endangered or threatened species will insure that their conservation is adequately considered during consultation, as required under Section 7 of the Endangered Species Act.

Current Conservation Efforts: None.

E. ***Other natural or manmade factors affecting its continued existence.***

Not applicable.

REFERENCES

Asquith, A. 1995. Hawaiian Damselfly Survey: Population Checklist.of Category 1 Candidate Species. Unpublished Document by U.S. Fish & Wildlife Service, Pacific Islands Office, Honolulu, HI.

Beardsley, J.W. 1962. On accidental immigration and establishment of terrestrial arthropods in Hawaii during recent years. Proc. Hawaii. Entomol. Soc. 18:99-109.

Beardsley, J.W. 1979. New immigrant insects in Hawaii: 1962 through 1976. Proc. Hawaii. Entomol. Soc. 23:35-44.

Bishop Museum of Honolulu. Hawaiian Terrestrial Arthropod Checklist, March 2002 version. http://ww2.bishopmuseum.org/HBS/checklist/query.asp?grp=Arthropod

Bennett, W.C. 1931. Archaeology of Kauai. B.P. Bishop Mus. Bull. 80:1-156

Blackburn, T. 1884. Notes on Hawaiian Neuroptera, with descriptions of new species. Ann. Mag. Nat. Hist., (V) 14: 412-421. As referenced in: Zimmerman, E.C. 1948. Insects of Hawaii, Vol. 2. Apterygota -Thysanoptera. University of Hawaii Press, Honolulu.

Borror, D.J., C.A. Triplehorn and N.F. Johnson. 1989. Introduction to the Study of Insects, Sixth Edition. Saunders College Publishing, Philadelphia.

Cowles, L.E. 1977. Status of Damselflies (Odonata: Zygoptera) in Hawaii in 1977, with special reference to the endemic genus *Megalagrion* . Senior Honors Thesis, Department of Biology, University of Hawaii, Manoa.

Cuddihy, L.W., and C.P. Stone. 1990. Alteration of native Hawaiian vegetation: Effects of humans, their activities and introductions. University of Hawaii Press, Honolulu. 138 pp.

Department of Geography, University of Hawaii. 1983. Atlas of Hawaii. second edition. University of Hawaii Press. Honolulu, 238 pp.

Devaney, D.M., M. Kelly, P.J. Lee, and L.S. Motteler. 1982. Kaneohe: A History of Change. The Bess Press, Honolulu, Hawaii.

Devick, W.S. 1991. Patterns of introduction of aquatic organisms to Hawaiian freshwater habitats: in Devick, W.S., New Direction in Research, Management and Conservation of Hawaiian Freshwater Stream Ecosystems, Proceedings of the 1990 Symposium on Freshwater Stream Biology and Fisheries Management, Department of Land and Natural Resources, Honolulu, Hawaii.

Ego, K. 1956. Life history of freshwater gobies. Freshwater Game and Fish Management Research Project No. F-4-R. Honolulu, Hawaii.

Englund, R. and D.A. Polhemus. 1994. Maakua Stream biological assessment, Oahu, Hawaii. Environmental Technologies International, Honolulu, Hawaii.

Ford, J.I. and R.A. Kinzie, III. 1982. Life crawls upstream. Natural History 91:61-66.

Funasaki, G.Y., P.-L. Lai, L.M. Nakahara, J.W. Beardsley & A.K. Ota. 1988. A review of biological control introductions in Hawaii: 1890 to 1985.Proc. Hawaii. Entomol. Soc. 28:105-160.

Gagne, W.C. 1980. Insect and myriopods of Kipahulu Valley below 2,000 feet: in. Smith, C.W., Resources Base Inventory of Kipahulu Valley below 2,000 feet, Maui, Hawaii. Coop. Natl. Park. Res. S. Studies Unit. 119-175 pp.

Gagne, W.C. and F.G. Howarth. 1982. Assessment of Endangered and Threatened Status of Hawaiian Arthropods. Report to U.S. Fish and Wildlife Service, in Pacific Islands Office, Honolulu.

Giambelluca, T.W., M.A. Nullet, M.A. Rifgley, P.R. Eyre, J.E.T. Moncur, and S. Price. 1991. Drought in Hawaii. Report 87. State of Hawaii. Department of Land and Natural Resources, Commission on Water Resource Management.

Gillespie, R.G. and N. Reimer. 1993. The effect of alien predatory ants (Hymenoptera: Formicidae) on Hawaiian endemic spiders (Araneae: Tetragnathidae). Pacific Science 47:21-33.

Handy, E.S.C. and E.G. Handy. 1972. Native planters in old Hawaii. Their life, lore, and environment. B.P. Bishop Mus. Bull. 233:1-641.

Hardy, D.E. 1979. An ecological survey of Puaaluu Stream. Part III. Report on a preliminary entomological survey of Puaaluu Stream, Maui. Coop. Nat. park Resources Study Unit. University of Hawaii. Tech. Report 27:34-39.

Hardy, D.E. and M.D. Delfinado. 1980. Insect of Hawaii. Volume 13, Diptera: Cyclorrhapha III. University of Hawaii Press, Honolulu.

Harris, S., A. Rubissow, S. Edmunds, and J.-A. Cachola. 1993. Hawaii Streams. Document prepared for Commission on Water Resource Management, State of Hawaii. 40 pp.

Harwood, P.D. 1976. Dragonflies (Odonata) observed in Hawaii in 1973 and 1974. Proc. Hawaii. Entomol. Soc. 22:251-253.

Hawaii Stream Assessment. 1990. Department of Land and Natural Resources, State of Hawaii. 300 pp.

Heads, P.A. 1985. The effect of invertebrate and vertebrate predators on the foraging movements of Ischnura elegans larvae (Odonata: Zygoptera). Freshwater Biology 15:559-571.

Heads, P.A. 1986. The costs of reduced feeding due to predator avoidance: potential effects on growth and fitness in *Ischnura elegans* larvae (Odonata: Zygoptera). Ecological Entomology 11:369-377.

Henrikson, B.-I. 1988. The absence of antipredator behavior in the larvae of Leucorrhinia dubia (Odonata) and the consequences for their distribution. Oikos 51:179-183.

Hibbard, D. and D. Franzen. 1991. The View from Diamond Head: Royal Residence to Urban Resort. Editions Limited, Honolulu, Hawaii. 221 pp.

Howarth, F.G. 1990. Hawaiian terrestrial arthropods: An overview. Bishop. Mus. Occas. Pap. 30:4-26.

Howarth, F.G. and W.P. Mull. 1992. Hawaiian Insects and Their Kin. University of Hawaii Press, Honolulu.

Howarth, F.G., A. Asquith, and G. Nishida. 1994. Insect of Hawaii: Status and Trends. Unpublished manuscript.

Howarth, F.G. and A.C. Medeiros. 1989. Non-native invertebrates: in Stone, C.P. and D.B. Stone (eds), Conservation Biology in.Hawaii. University of Hawaii Cooperative National Park Resources Studies Unit, Honolulu. pp. 82-87.

Howarth, F.G. and G.W. Ramsay. 1991. The conservation of island insects and their habitats: in Collins, N.M. and J.A. Thomas (eds), The Conservation of Insects and Their Habitats , Academic Press, London. pp. 71-107

Joesting, E. 1984. Kauai: The separate kingdom. University of Hawaii Press, Honolulu. Johnson, D.M. 1991. Behavioral ecology of larval dragonflies and damselflies. Trends in Ecol. Evol. 6:8-13.

Jones, B.L., S.S.W. Chin, and J.C. Brice. 1984. Olokele rock avalanche, island of Kauai, Hawaii. Geology 12:209-211.

Kennedy, C.H. 1917. Notes on the penes of damselflies (Odonata). No. 2. The close relations inter se of the Hawaiian Agrionines. Entomological News. 28:9-14.

Kennedy, C.H. 1920. Forty-two hitherto unrecognized genera and subgenera of Zygoptera. Ohio J. Science. 21:83-88.

Kennedy, C.H. 1929. The origin of the Hawaiian Odonata fauna and its evolution within the islands. Proceedings of the Fourth International Congress of Entomology 2:978-981.

Kennedy, C.M. 1934. *Kilauagrion dinesiotes*, a new species of dragonfly (Odonata) from Hawaii. Annals of the Entomological Society of America. 27:343-345.

Kido, M.H., P. Ha, and R.A. Kinzie III. 1993. Insect introductions and diet changes in and endemic Hawaiian amphidromous goby, *Awaous stamineous* (Pisces: Gobiidae). Pacific Science 47:43-50.

Kirby, W. F. 1890. A synonymic catalog of Neuroptera Odonata, or Dragonflies, with an appendix of fossil species. Gurney and Jackson, London. 202 pp. As referenced in: Zimmerman, E.C. 1948. Insects of Hawaii, Vol. 2. Apterygota - Thysanoptera. University of Hawaii Press, Honolulu.

Kirch, P.V. 1982. The impact of the prehistoric Polynesians on the Hawaiian ecosystem. Pacific Science 36:1-14.

Kirch, P.V. 1985. Feathered gods and fishhooks. University of Hawaii Press, Honolulu, Hawaii. 349 pp.

Lai, P.-Y. 1988. Biological control: A positive point of view. Proc. Hawaii. Entomol. Soc. 28:179-190.

McLachlan, R. 1883. Neuroptera of the Hawaiian Islands. - Part I. Pseudo-Neuroptera. Ann. Mag. Nat. Hist., (V) 12: 226-240. As referenced in: Zimmerman, E.C. 1948. Insects of Hawaii, Vol. 2. Apterygota - Thysanoptera. University of Hawaii Press, Honolulu.

McPeek, M.A. 1990a. Determination of species composition in the *Enallagma* damselfly assemblages of permanent lakes. Ecology 71:83-98.

McPeek, M.A. 1990b. Behavioral differences between *Enallagma* species (Odonata) influencing differential vulnerability to predators. Ecology 71:1714-1726.

Macan, T.T. 1977. The influence of predation on the composition of fresh-water animal communities. Biol. Rev. 52:45-70.

MacDonald, G.A., D.A. Davis, and D.C. Cox. 1960. Geology and ground-water resources of the island of Kauai, Hawaii. Hawaii Division of Hydrology, Bulletin No. 13. 212 pp.

Maciolek, J.A. 1982. Lakes and lake-like waters of the Hawaiian Archipelago. Occas. Pap. B.P. Bishop Mus. 25:1-14.

Meier, K.Z., J.P. Laurel and J.E. Maragos. 1993. State of Hawaii (USA). in Scott, D.A., A Directory of Wetlands in Oceania, The international Waterfowl and Wetlands Research Bureau, U.K., and Asia Wetland Bureau, Kuala Lumpur, Malaysia. 444 pp.

Moore, N.W. 1982. Conservation of Odonata - First steps towards a world strategy. Adv. Odontal. 1:205-211.

Moore, N. W. 1983a. Territorial behavior in the genus *Megalagrion* (McLachlan) (Zygoptera: Coenagrionidae). Odonatologica 12(1): 87-92..Moore, N. W. 1983b. Reflex immobilisation in the Hawaiian endemic genus *Megalagrion* McLachlan (Zygoptera: Coenagrionidae). Odonatologica, 12(2): 161-165.

Moore, N.W. and W.C. Gagne. 1982. *Megalagrion* pacificum (McLachlan) - A preliminary study of the conservation requirements of an endangered species. Rep. Odon. Specialist group Int. Un. Conserv. Nat. Natur. Res. No 3:1-5.

Nafus, D.M. 1993a. Biological control agents and native parasitoids in the population system of the butterfly *Hypolimnas bolinas* (L.) (Lepidoptera: Nymphalidae). Micronesica, Suppl. 4:17-23.

NatureServe Explorer: An online encyclopedia of life [web application]. 2001. Version 1.6 . Arlington, Virginia, USA: NatureServe. Available: http://www.natureserve.org/explorer.

Nishida, G.M., Ed. 1994a. Hawaiian Terrestrial Arthropod Checklist, 2nd Ed. Bishop. Mus. Tech. Rep. No. 1. 287 pp.

Nishida, G.M. 1994b. Taxonomic validation of Candidate species of insects (and related Arthropods) of the Hawaii Islands. Report prepared for the National Biological Survey, 61pp.

O'Connor, P.J. 1990. Poaceae. in W.L. Wagner, D.R. Herbst and S. Sohmer, Manual of the Flowering Plants of Hawai'i. B.P. Bishop Mus. Spec. Publ. No. 83. 1853 pp.

Ogden Environmental and Energy Service. 1994. VA Medical and Regional Office Center Project Conceptual Mitigation Plan for Impacts on the Orange-black damselfly Population at Tripler Army Medical Center. 16 pp.

Olson, S.L. and H.F. James. 1982. Prodromus of the fossil avifauna of the Hawaiian Islands. Smithsonian Contrib. Zool. 1-59.

Parrish, J.D., J.A. Maciolek, A.S. Timbol, C.B. Hathaway, and S.E. Norton. 1984. Status of stream channel modification in Hawaii and its effects on native aquatic fauna. pp. 83-84. Proc. 5th Conference in Natural Sciences, Hawaii, Volcanoes National Park. Coop. Natl. Park. Res. Stud. Unit, University of Hawaii.

Perkins, R.C.L. 1899. Neuroptera. D. Sharp, ed., Vol. 2:63-77. Cambridge University Press, Cambridge. Perkins, R.C.L. 1907. Insects at Kilauea, Hawaii. Proc. Hawaii. Entomol. Soc. 1:89-95.

Perkins, R.C.L. 1913. Introduction to Fauna Hawaiiensis. D. Sharp, ed., Vol.1:xv-ccxxvii. Cambridge University Press, Cambridge.

Polhemus, D.A., J. Maciolek, and J. Ford. 1992. An ecosystem classification of inland waters for the tropical Pacific islands. Micronesica 25:155-173.

Polhemus, D.A. 1993a. Damsels in distress: a review of the conservation status of Hawaiian *Megalagrion* damselflies (Odonata: Coenagrionidae). Aquatic Conservation: Marine and Freshwater Ecosystems 3:343-349.

Polhemus, D.A. 1993b. Conservation of aquatic insects: Worldwide crisis or localized threats? Amer. Zool. 33:588-598.

Polhemus, D.A. 1993c. A preliminary assessment of the impacts of hurricane Iniki on the aquatic insect faunas of streams on the Na Pali Coast, Kaua'i, Hawai'i. in Assessments of the impact of Hurricane Iniki on stream biota and ecosystems on Kaua'i. Department of Land and Natural Resources, Division of Aquatic Resources. State of Hawai'i. pp. 59-88.

Polhemus, D.A. 1994a. Current status of *Megalagrion* populations on Oahu: 1990 - Present. Report to U.S. Fish & Wildlife Service, Pacific Islands Office.

Polhemus, D.A. 1994b. A revision of the Hawaiian damselflies in the genus *Megalagrion* (Odonata: Coenagrionidae). Unpublished report to U.S. Fish & Wildlife Service, Pacific Islands Office.

Polhemus, D.A. 1995. New Heteroptera and Odonata (Insecta) records and range extensions in the Hawaiian Islands. Bish. Mue. Occass. Pap. 42:42-43.

Polhemus, D., and A. Asquith. 1996. Hawaiian Damselfies: A Field Identification Guide. Hawaii Biological Survey Handbook, Bishop Museum Press, Honolulu, Hawaii. 122 pp.

Reimer, N.J. 1993. Distribution and impact of alien ants in vulnerable Hawaiian ecosystems: in D.F.Williams (ed), Exotic Ants: Biology, Impact,and Control of Introduced Species. Westview Press, Boulder, Colorado. Pp. 11-22..Reimer, N., J.W. Beardsley and G. Jahn. 1990. Pest ants in Hawaii. in Vander Meer, R.K, K. Jaffe and A. Cedeno (eds), Applied Myrmecology: A World Perspective. Westview Press, Boulder, Colorado, pp. 40-50.

Schmidt, E. 1938. Check-list of Odonata of Oceania. Ann. Entomol. Soc. America. 31:322-344.

Selys-Longchamps, E. 1876. Synopsis des Agrionines, 5me Legion: Agrion. Bull. Acad. Royal Belgique, (II) 41 (2,3): 1-282. As referanced in: Zimmerman, E.C. 1948. Insects of Hawaii, Vol. 2. Apterygota -Thysanoptera. University of Hawaii Press, Honolulu.

Simon, C.M., W.C. Gagne, F.G. Howarth, and F.J. Radovsky. 1984. Hawaii: A natural entomological laboratory. Bull. Entomol. Soc. Am.30:8-17.

Smith, C.W. 1985. Impact of alien plants on Hawai'i's native biota. in C.P.Stone and J.M. Scott (eds), Hawai'i's Terrestrial Ecosystems: Preservation and Management. Cooperative National Park Resources Study Unit, University of Hawaii, Honolulu.

Stearns, H.T. 1940. Geology and ground-water resources of the islands of Lanai and Kahoolawe, Hawaii. Bulletin 6 of the Division of Hydrography, Territory of Hawaii.

Stearns, H.T. and K.N. Vaksvik. 1935. Geology and ground-water resources of the island of Oahu, Hawaii. Bulletin 1 of the Division of Hydrography, Territpry of Hawaii.

Stearns, H.T. 1985. Geology of the State of Hawaii. second edition. Pacific Books, Palo Alto, California.

Stone, C.P. 1985. Alien animals in Hawai'i's native ecosystems: toward controlling the adverse effects of introduced vertebrates: in Stone, C.P., and J.M. Scott (eds.), Hawai'i's terrestrial ecosystems: preservation and management. Coop. Natl. Park Resources Stud. Unit, Univ. Hawaii, Honolulu, pp. 251-297.

Stone, C.P. 1989. Hawai'i's wetlands, streams, fishponds, and pools. in C.P.Stone and D.B. Stone (eds), Conservation Biology in Hawai'i. Cooperative National Park Resources.Study, pp. 125-136. Unit, University of Hawaii, Honolulu.

Summers, C.C. 1964. Hawaiian Fishponds. B.P. Bish. Mus. Spec. Publ. 52.

Takasaki, K.I., G.T. Hirashima, and E.R. Lubke. 1969. Water Resources of Windward Oahu, Hawaii. U.S. Geological Survey Water Supply Paper No. 1894:1-119. U.S. Govt. Printing Office, Washington, D.C.

U.S. Fish and Wildlife Service. 1985. Recovery plan for the Hawaiian waterbirds. U.S. Fish and Wildlife Service, Portland, Oregon, 99 pp.

U.S. Fish and Wildlife Service. 1995. Pacific Islands Ecoregion Coastal Ecosystems Program Proposal. U.S. Fish and Wildife Service, Honolulu, Hawaii, 119 pp.

Van Dine, D.L. 1907. The introduction of top-minnows (natural enemies of mosquitoes) into the Hawaiian Islands. Haw. Agr. Exp. St. Press Bull. 20:1-10.

Wenkam, R. 1969. Kauai and the park county of Hawaii. Sierra Club, San Fransisco, 160 pp.Williams, F.X. 1936. Biological studies in Hawaiian water-loving insects. Part 1. Coleptera or beetles. Part 2. Odonata or dragonflies. Proc. Hawaii. Entomol. Soc. 9:235-345.

Williams, F.X. 1936. Biological studies in Hawaiian water-loving insects. Part II Order Odonata. Proc. Hawaiian Ent. Soc. 9(2):273-349.

Wilson, Okamoto and Associates, Inc. 1993. Kawai Nui Marsh Master Plan: Development Project Report. Document prepared for Department of Land and Natural resoruces, State of Hawaii.

Wong, M.A. and T.T.Y. Wong. 1988. Predation of the Mediterranean fruit fly and oriental fruit fly (Diptera: Tephritidae) by the fire ant (Hymenoptera: Formicidae) in Hawaii. Proc. Hawaii. Entomol. Soc. 28:169-177.

Zimmerman, E.C. 1948a. Insects of Hawaii. Vol. 1. Introduction. xvii + 206 pp. University of Hawaii Press.

Zimmerman, E.C. 1948b. Insects of Hawaii, Vol. 2. Apterygota - Thysanoptera. University of Hawaii Press, Honolulu.

Zimmerman, E.C. 1948c. Insects of Hawaii, Vol. 3. Heteroptera..University of Hawaii Press, Honolulu.

Zimmerman, E.C. 1970. Adaptive radiation in Hawaii with special reference to insects. Biotropica 2:32-38..

PETITION TO LIST

orangeblack Hawaiian damselfly
(*Megalagrion xanthomelas*)

AS A FEDERALLY ENDANGERED SPECIES

CANDIDATE HISTORY

CNOR 5/22/84:	
CNOR 1/6/89:	
CNOR 11/21/91:	
CNOR 11/15/94:	
CNOR 2/28/96:	C
CNOR 9/19/97:	C
CNOR 10/25/99:	C
CNOR 10/30/01:	C
CNOR 6/13/02:	C

TAXONOMY

Native Hawaiians apparently did not differentiate among the different species, but referred to the native damselflies collectively as pinaoʻula. There has been no traditional European use of a common name for species in the genus *Megalagrion* (Coenagrionidae). In a recent taxonomic review of the candidate species of insects in Hawaii, Nishida (1994b) proposed the name "Hawaiian damselflies". Because this name reflects the restricted distribution of these insects and should be readily used by nontechnical persons, the U.S. Fish and Wildlife Service has adopted this common name for the genus, with additional descriptive terms to identify each species.

The status of *Megalagrion xanthomelas* as a valid species is uncontroversial (e.g., Bishop Museum 2002).

NATURAL HISTORY

Distribution
Because of the extreme geographic isolation of the Hawaiian islands and the poor dispersal capabilities of many aquatic insects, the freshwater insect fauna of Hawaii is depauperate compared to continental areas despite the diversity of aquatic habitats. Many groups of insects that typify freshwater habitats in continental areas are absent from the native fauna. Some notable examples of such groups are mayflies (Ephemeroptera), stoneflies (Plecoptera), caddisflies (Trichoptera), and alderflies and dobsonflies (Neuroptera), all of which are absent from Hawaii.

Like most of the native fish, mollusc, and crustacean faunas (Ford and Kinsey 1994), most of Hawaii's freshwater insects evolved from marine or intertidal ancestors (Hardy and Delfinado 1980) that could easily colonize the islands.

The Hawaiian damselflies are represented by 23 species and five subspecies, all confined to the Hawaiian Islands. Historically these were among the most common and conspicuous native Hawaiian insects. Some species inhabited water gardens in residential areas, artificial reservoirs, and watercress farms, and were abundant in the city of Honolulu (Perkins 1913, Williams 1936).

Morphology

Megalagrion xanthomelas is a small Hawaiian damselfly. The males are black with red markings on the thorax, the first three, and last three segments of the abdomen. The females have similar color patterning, but with tan rather than red coloration. More detailed descriptions and color photos are available in Polhemus and Asquith (1996).

Behavior

The general biology of Hawaiian damselflies is typical of other narrow-winged damselflies. The males of most species are territorial, guarding areas of habitat where females will lay eggs (Moore 1983a). During copulation, and often while the female lays eggs, the male grasps the female behind the head with his terminal abdominal appendages to guard her against rival males, thus males and females are frequently seen flying in tandem. In species with fully aquatic immature stages, females lay eggs in submerged aquatic vegetation or in mats of moss or algae on submerged rocks, and hatching occurs in about ten days (Williams 1936, Polhemus 1994b).

In most species of Hawaiian damselflies, the immature stages (naiads) are aquatic, breathing though three flattened, abdominal gills, and are predacious, feeding on small aquatic invertebrates or fish (Williams 1936). Naiads may take up to four months to mature (Williams 1936), after which they crawl out of the water onto rocks or vegetation, molt into winged adults, which typically remain very close to the aquatic habitat from which they emerged. Adults are also predacious and feed on small flying insects such as midges. In a remarkable example of adaptive radiation in Hawaii, some species of Hawaiian damselflies have foregone the aquatic lifestyle, either partly, with naiads living on wet rock faces, or completely, with terrestrial naiads living in the damp leaf litter, or others inhabiting moist leaf axils of native plants up to several meters above the ground (Zimmerman 1970, Simon et al. 1984). Adults are also unusual in that they have a highly developed behavior of feigning death when caught or attacked (Moore 1983b).

Similar to the crimson Hawaiian damselfly, the naiads of this species are active swimmers and rest on exposed areas of the bottom on submerged vegetation (Williams 1936). They prefer standing or very slow moving bodies of water, and have been observed breeding in garden pools, large reservoirs, pools of an intermittent stream, a pond formed behind a cobble bar at the seaward terminus of a large stream, and coastal springs, fishponds and freshwater marshes (Polhemus 1994b).

Habitat

Historically, the orangeblack Hawaiian damselfly was Hawaii's most abundant species of damselfly and it utilized a variety of aquatic habitats for breeding sites. In 1913, Perkins describes it as “A common insect in Honolulu gardens and in lowland districts generally, not usually partial to the mountains, though in the Kona district of Hawaii it is common about stagnant pools up to an elevation of about 3,000 feet. It is very numerous in individuals under conditions totally changed from natural.” Standing or very slow moving bodies of water, garden pools, large reservoirs, pools of an intermittent stream, a pond formed behind a cobble bar at the seaward terminus of a large stream, and coastal springs, fishponds and freshwater marshes.

POPULATION STATUS

Historically, this species probably occurred on all the major islands except Kahoolawe (Perkins 1913, Kennedy 1917, Zimmerman 1948b, Polhemus 1994b). On Oahu, it was recorded from Honolulu, Kaimuki, Koko Head, Pearl City, Waialua, the Waianae Mountains (Polhemus 1994b), and Waianae (Williams 1936). On Molokai, it was known from the following localities: Kainalu, Meyer's Lake on the Kalaupapa peninsula, Kaunakakai, Mapulehu, and Palaau (Polhemus 1994b). On Maui, it was recorded from an unspecified locality in the West Maui Mountains (Polhemus 1994b). On Hawaii, it was known from Hilo, Kona, Naalehu, and Panaewa Forest Reserve (Polhemus 1994b). If this species did occur on Kauai it is now extirpated. Until recently, the last report of the orangeblack Hawaiian damselfly on Oahu was in 1935 (Williams 1936) and it was believed extinct on this island (Polhemus 1993a).

In 1993, a very small population was discovered existing in pools of an intermittent stream at the Tripler Army Medical Facility (*in litt*. 1993 cited in U.S. Fish and Wildlife Service candidate assessment form). This is the only known population of this species on Oahu. The remaining population on Oahu is threatened by ongoing construction projects (*in litt*. 1994 cited in U.S. Fish and Wildlife Service candidate assessment form). Populations on other islands are threatened primarily by predation by alien fish and habitat degradation from water development projects and urban development..

Populations are known from Molokai at the mouths of Pelekunu and Waikolu streams, and at the Palaau wetlands on the south coast (Polhemus 1994b). On Lanai, a large population occurs in an artificial pond at Koele (Polhemus 1994b), and a few individuals have been seen at the mouth of Maunalei Stream (personal communication 1995 cited in U.S. Fish and Wildlife Service candidate assessment form), and around a fishpond at Loko Lopa (personal communication 1995 cited in U.S. Fish and Wildlife Service candidate assessment form). While this species is apparently extinct on Maui (Polhemus 1993a), several large populations exist in coastal wetlands on Hawaii in the following localities: Anaehoomalu Bay, Hawa Bay, Hilea Stream, Hilo, Honokohau, Kiholo Bay, Ninole Springs (Polhemus 1994b), Onomea Bay (*in litt*. cited in U.S. Fish and Wildlife Service candidate assessment form), and Whittington Beach (Polhemus 1994b).

As early as 1948, Zimmerman noted a decline of the more common species, particularly on Oahu. By the late 1970s less than six populations of the Pacific Hawaiian damselfly could be located (Harwood 1976, Gagne 1980, Moore and Gagne 1982), and the conservation of this species was identified as a priority and “vulnerable” by the International Union for Conservation of Nature and

Natural Resources (Moore 1982). A review of the status of Hawaiian damselflies in 1981 (Gagne and Howarth 1982) lead to the placement of several species on the U.S. Fish and Wildlife Service's list of candidate species for Federal listing (49 FR 21664). Due to a continued decline of these damselflies, particularly on the island of Oahu, intensive surveys were initiated in 1990. The results of these surveys demonstrate that six species of Hawaiian damselflies are now threatened with extinction.

The U.S. Fish and Wildlife Service classifies the orangeblack Hawaiian damselfly as a candidate for Endangered Species Act protection with a listing priority number of 8.

LISTING CRITERIA

A. *The present or threatened destruction, modification, or curtailment of its habitat or range.*

Historical range: Hawaii, islands of Kauai, Oahu, Molokai, Maui, Lanai, and Hawaii. This species probably occurred on all the major islands except Kahoolawe (Perkins 1913, Kennedy 1917, Zimmerman 1948b, Polhemus 1994b). On Oahu, it was recorded from Honolulu, Kaimuki, Koko Head, Pearl City, Waialua, the Waianae Mountains (Polhemus 1994b), and Waianae (Williams 1936). On Molokai, it was known from the following localities: Kainalu, Meyer's Lake on the Kalaupapa peninsula, Kaunakakai, Mapulehu, and Palaau (Polhemus 1994b). On Maui, it was recorded from an unspecified locality in the West Maui Mountains (Polhemus 1994b). On Hawaii, it was known from Hilo, Kona, Naalehu, and Panaewa Forest Reserve (Polhemus 1994b). If this species did occur on Kauai it is now extirpated. Until recently, the last report of the orangeblack Hawaiian damselfly on Oahu was in 1935 (Williams 1936) and it was believed extinct on this island (Polhemus 1993a).

Current range: Hawaii, islands of Oahu, Molokai, Lanai, and Hawaii. In 1993, a very small population was discovered existing in pools of an intermittent stream at the Tripler Army Medical Facility (*in litt*. 1993 cited in U.S. Fish and Wildlife Service candidate assessment form). This is the only known population of this species on Oahu. Populations are known from Molokai at the mouths of Pelekunu and Waikolu streams, and at the Palaau wetlands on the south coast (Polhemus 1994b). On Lanai, a large population occurs in an artificial pond at Koele (Polhemus 1994b), and a few individuals have been seen at the mouth of Maunalei Stream (personal communication 1995 cited in U.S. Fish and Wildlife Service candidate assessment form), and around a fishpond at Loko Lopa (personal communication 1995 cited in U.S. Fish and Wildlife Service candidate assessment form). While this species is apparently extinct on Maui (Polhemus 1993a), several large populations exist in coastal wetlands on Hawaii in the following localities:.Anaehoomalu Bay, Hawa Bay, Hilea Stream, Hilo, Honokohau, Kiholo Bay, Ninole Springs (Polhemus 1994b), Onomea Bay (*in litt*. cited in U.S. Fish and Wildlife Service candidate assessment form), and Whittington Beach (Polhemus 1994b).

Land ownership: This species occurs in State-managed waters, and on Federal and private lands.

Freshwater habitats on all the main Hawaiian Islands have been severely altered and degraded because of past and present land and water management practices including agriculture, urban development, development of ground water, perched aquifer and surface water resources, and the deliberate introduction of alien animals (Harris et al. 1993, Meier et al. 1993, U.S. Fish and Wildlife Service 1985, 1995).

Extensive modification of lentic (standing water) habitats in the Hawaiian Islands began about 1100 AD with a rapid population increase among native Hawaiians (Kirch 1982). Hawaiians cultivated taro (*Colocasia esculenta*) by creating shallow, walled ponds called lo'I, in marshes and riparian areas (Handy and Handy 1972). By 1778, virtually all valley bottoms with permanent stream flow and most basin marshes were converted to irrigated taro cultivation (Handy and Handy 1972). While this represents a significant alteration of the natural aquatic system, these extensive artificial wetlands were probably suitable habitat for many native Hawaiian species, particularly waterbirds (Olson and James 1982). Native Hawaiian dragonflies were recorded in taro lo'I (Handy and Handy 1972) and some damselflies may also have utilized these systems (Moore and Gagne 1982), since the lo'I remained flooded for months or years at a time (Handy and Handy 1972).

Hawaiians also modified wetlands by constructing fishponds, many of which were primarily freshwater, fed by streams or springs (Summers 1964). Despite this habitat modification by early Hawaiians, many areas of extensive marsh land remained intact. The best example of this was the Mana marsh of western Kauai. In this area, sedimentary deposits restrict the flow of ground water seaward, creating basal water spring discharge 3-4 m (8-12 ft) above sea level, and the development of an extensive marsh system (MacDonald et al. 1960). This area was famous for its mirages on open water surfaces (MacDonald et al. 1960) and Hawaiians traveled by canoe for miles between villages (Bennett 1931).

Some wetlands which had been converted to taro lo'I were maintained and others were utilized for rice cultivation between 1850 and 1930. In 1900, there was approximately 19,000 acres of taro and 16,000 acres of rice in production in Hawaii (U.S. Fish and Wildlife Service 1995). By 1960, taro production was reduced to only 510 acres and the rice industry had been completely abandoned. Many of these wetlands formerly used for taro or rice were drained and filled for dry-land agriculture (Stone 1989, Meier et al. 1993). The Mana marsh on Kauai is also one of the best examples of extensive freshwater habitat loss due to modern agriculture. The margins of the Mana marsh were used for rice cultivation until 1922, when the land, including several open ponds, were leased to Kekaha Sugar Company for sugarcane cultivation (Joesting 1984). By the late 1940s, the entire Mana marsh had been drained and filled and was under sugarcane cultivation (Wenkam 1969).

Most urban, residential and resort development in Hawaii has occurred in the coastal plains and as a result, many freshwater lentic habitats have been negatively affected (U.S. Fish & Wildlife Service 1985). Most of this development has occurred on Oahu, which now supports four fifths of the state's population (Dept. of Geography 1983). The Ala Moana and Waikiki areas of Honolulu were once extensive marshlands that were converted to hundreds of taro lo'I and fishponds by Hawaiians (Handy and Handy 1972). Small development projects began in Waikiki in 1910, but even as late as 1920, 85 percent of Waikiki remained under water, used as duckponds, fishponds, and for the cultivation of rice and taro (Hibbard and Franzen 1991). In 1928, the Ala Wai Canal was completed, resulting in the complete drainage and development of the Waikiki wetlands, which now on an average day hosts over 60,000 people (Hibbard and Franzen 1991). Construction for housing and civil works projects on Oahu also resulted in the draining and filling of large fresh and brackish water marshes at Wailupe Peninsula, Hawaii Kai, Kaelepulu Pond, and Salt Lake (U.S. Fish and Wildlife Service 1995).

The Service now estimates that 30 percent of all coastal plain wetlands in Hawaii have.been lost to agriculture and urban development (*in litt*. 1990 cited in U.S. Fish and Wildlife Service candidate assessment form), and if only freshwater habitat was considered the loss would be proportionately much higher, probably approaching 80 to 90 percent. While intentional filling of freshwater wetlands with open water is rarely permitted today (personal communication 1995 cited in U.S. Fish and Wildlife Service candidate assessment form), loss of smaller areas utilized by damselflies, such as narrow strips of freshwater seeps within anchialine pool complexes, and loss of emergent vegetation still occurs. In addition, marshes are slowly filled and converted to meadow habitat due to increased sedimentation resulting from increased storm water runoff from upslope development, and blockage of downslope drainage (Wilson Okamoto & Associates, Inc. 1993).

Presently the most significant threat to natural ponds and marshes in Hawaii is the alien species, California grass (*Brachiaria mutica* (Forssk.) Stapf). The area of origin of this sprawling perennial grass is unknown, but it was first noted on Oahu in 1924 and now occurs on all the major islands (O'Connor 1990). This plant forms dense, monotypic stands that can completely eliminate any open water by layering of its trailing stems (Smith 1985). The most extensive remaining marsh system on the island of Oahu, Kawainui, is now almost entirely choked with California grass, facilitating its conversion to meadowland (Wilson Okamoto & Associates, Inc. 1993). The James Campbell and Pearl Harbor National Wildlife Refuges on Oahu, and Kakahaia National Wildlife Refuge on Molokai must be constantly managed to control this plant (personal communication 1995 cited in U.S. Fish and Wildlife Service candidate assessment form).

The Pacific Hawaiian damselfly and the orangeblack Hawaiian damselfly have both sustained loss of palustrine habitat on all islands due to human activities and California grass. Presently two populations of the orangeblack damselfly along the Kona coast of Hawaii are threatened with further habitat loss from overdraw of the aquifer that feeds coastal marshes (personal communication 1995 cited in U.S. Fish and Wildlife Service candidate assessment form). The only known population of the orangeblack damselfly on Oahu is threatened with habitat degradation from a proposed construction project (Ogden Environmental 1994). Early Hawaiians also modified stream systems by diverting water from the main channel to irrigate taro lo'I. In some cases these diversions, or ‘auwai, were elaborate, such as the cut and fitted stone ditch of Kiki a Ola in

Waimea Canyon on Kauai (Bennett 1932). Other diversions were several kilometers long (Kirch 1985) and moved water between drainages (Devaney et al. 1983). However, these diversions were closely regulated and were not allowed to take more than half the stream flow, and diversions were typically periodic to flood lo'I rather than continuous (Handy and Handy 1972).

The advent of plantation sugarcane cultivation in 1835 led to more extensive stream diversions. The first irrigation system for sugar, built in 1856 on Kauai, was 16 km (10 mi) long. In 1900, the Maunawili Ditch on windward Oahu diverted all the water from Maunawili Stream into Waimanalo Valley (Takasaki et al. 1969).

By 1906, the Kohala Ditch system on Maui utilized 15 km (9 mi) of tunnels, 7 km (4.5 mi) of open ditch, and 20 flumes, and now the East Maui Irrigation system may be the largest private water company in the United States (Harris et al. 1993). These systems typically tap water at upper elevations (> 300 m) by means of a concrete weir in the stream. All or most of the low or average flow of the stream is diverted into fields or reservoirs (Takasaki et al. 1969, Harris et al. 1993). By the 1930s, major water diversions had been developed on all the major islands and currently one third of Hawaii's perennial streams are diverted (Hawaii Stream Assessment 1990). Some systems are extensive, such as the Waiahole Ditch which takes water from 37 streams on the windward side of Oahu, and transports it to the leeward plains via a tunnel cut through the Koolau Mountain Range (Stearns and Vaksvik 1935). On West Maui, as of 1978, over 49 miles of stream habitat in 12 streams have been lost due to diversions, and all of the 17 perennial streams on West Maui are diverted to some extent (Macioleck 1979).

In addition to diverting water for agriculture and domestic water supply, streams have also been diverted for use in hydroelectric power. There are currently 18 active hydroelectric plants operating on Hawaiian streams, with another 10 proposed for construction, and another 28 sites identified for potential development (Hawaii Stream Assessment 1990). In addition to diverting surface flow in the stream channels, the perched aquifers which feed the streams have also been tapped by means of tunnels (Stearns and Vaksvik 1935, Stearns 1985)). For example, both the bore tunnels and the contour tunnel of the Waiahole Ditch system pierced perched aquifers which were drained to the level of the tunnels (Stearns and Vaksvik 1935). Many of these aquifers were also the sources of springs which contributed flow to the windward streams. The boring of the Haiku tunnel in 1940 caused a 25 percent reduction in the base flow of Kahaluu Stream, over 2.5 miles away (Takasaki et al. 1969). The draining of these aquifers caused many of the springs to dry up, including some over 0.5 km (0.3 mi) away from the bore tunnels (Stearns and Vaksvik 1935). Frequently the actual springs were tapped by driving tunnels into the rock from where the water emerged, and on the water-poor island of Lanai, almost every spring and seep was bored or captured (Stearns 1940).

Surface waters in streams have also been captured by tunnels in the alluvium of the stream channel. Historically, Maunalei Stream was the only perennial stream on Lanai, and Hawaiians constructed taro lo'I in the lower portions of this system. In 1911, a tunnel was developed at 330 m (1100 ft) elevation which undercut the stream bed, capturing both the surface and subsurface flow and dewatering the stream from this point to the mouth (Stearns 1940).

Stream degradation has been particularly severe on the island of Oahu, where, in 1978, 57 percent of the perennial streams had been channelized (lined, partially lined or altered stream course) and 89 percent of the total length of these streams were channelized (Parrish et al. 1984). Channelization of streams has not been restricted to lower reaches, in Kalihi Stream there is extensive channelization above 300 m (1,000 ft). Channelization results in removal of riparian vegetation, increased velocity, increased illumination, and higher water temperatures. Hawaiian damselflies do not utilize channelized portions of streams.

Surface flow of streams has also been affected by vertical wells, because the basal aquifer and alluvial caprock through which the lower sections of streams flow can be hydraulically connected (*in litt*. 1995 cited in U.S. Fish and Wildlife Service candidate assessment form). Historically, for example, there was sufficient surface flow in Makaha and Nanakuli streams on Oahu to support taro lo'I in their lower reaches, but this flow disappeared subsequent to construction of wells upstream (personal communication 1995 cited in U.S. Fish and Wildlife Service candidate assessment form). This damselfly has sustained habitat loss due to water diversions, and stream alterations, on all the islands.

B. *Overutilization for commercial, recreational, scientific, or educational purposes.*

Not applicable.

C. *Disease or predation.*

The geographic isolation of the Hawaiian Islands has restricted the number of original successful colonizing arthropods and resulted in the development of an unusual fauna. An unusually small number (15 percent) of the known families of insects are represented by native Hawaiian species (Howarth 1990). Some groups that often dominate continental arthropod faunas, such as social Hymenoptera (group nesting ants, bees, and wasps), are entirely absent. Commercial shipping and air cargo to Hawaii has now resulted in the establishment of over 2,500 species of alien arthropods (Howarth 1990, Howarth et al. 1994), with a continuing establishment rate of 10-20 new species per year (Beardsley 1962, 1979).

In addition to the accidental establishment of alien species, alien predators and parasites for biological control of pests have been purposefully imported and released by individuals, Republic, Territorial, State, and Federal agencies, since 1865. Between 1890 and 1985, 243 alien species were introduced, sometimes with the specific intent of reducing populations of native Hawaiian insects (Funasaki et al. 1988, Lai 1988). Alien arthropods, whether purposefully introduced or adventive, pose a serious threat to Hawaii's native insects, through direct predation and parasitism, and competition for food or space (Howarth and Medeiros 1989, Howarth and Ramsay 1991).

Ants are not a natural component of Hawaii's arthropod.fauna, and endemic species evolved in the absence of predation pressure from ants. Ants can be particularly destructive predators because of their high densities, recruitment behavior, aggressiveness, and broad range of diet (Reimer 1993). The latter attribute allows some ants to affect prey populations independent of prey density, and ants can therefore locate and destroy isolated individuals and populations (Nafus 1993). At least 36 species of ants are known to be established in the Hawaiian Islands, and three particularly aggressive species have had severe effects on the native insect fauna (Zimmerman 1948a). By the late 1870s, the big-headed ant (*Pheidole megacephala*) was present in Hawaii and its predation on native insects was noted by 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, including most moths, have been eliminated from areas where the big-headed ant is present (Perkins 1913, Gillespie and Reimer 1993). This predator generally does not occur at elevations higher than 600 m (2,000 ft), and is also restricted by rainfall, rarely being found in particularly dry (less than ca 35-50 cm [15- 20 in] annually) or wet areas (more than ca 250 cm [100 in] annually) (Reimer et al. 1990).

The long-legged ant (*Anoplolepis longipes*) appeared in Hawaii in 1952 and now occurs on Oahu, Maui, and Hawaii (Reimer et al. 1990). It inhabits low elevation (less than 600 m [2,000 ft]), rocky areas of moderate rainfall (less than 250 cm [100 in] annually) (Reimer et al. 1990). Direct observations indicate that Hawaiian arthropods are susceptible to predation by this species (Gillespie and Reimer 1993) and Hardy (1979) documented the disappearance of most native insects from Kipahulu Stream on Maui after the area was invaded by the long-legged ant.

At least two species of fire ants, *Solenopsis geminita* and *Solenopsis papuana*, are also important threats (Gillespie.and Reimer 1993) and occur on all the major islands (Reimer et al. 1990). *Solenopsis geminita* is also known to be a significant predator on pest fruit flies in Hawaii (Wong and Wong 1988). *Solenopsis papuana* is the only abundant, aggressive ant that has invaded intact mesic forest above 600 m (2,000 ft) and is still expanding its range in Hawaii (Reimer 1993). At least some populations of all the damselfly taxa included in this proposed rule are threatened by one or more of the ant species described above.

Backswimmers are aquatic true bugs (Heteroptera) in the family Notonectidae, so called because they swim upside down. Backswimmers are voracious predators and frequently feed on prey much larger than themselves, tadpoles, small fish, and other aquatic insects including damselfly naiads (Borror et al. 1989). Backswimmers are not native to Hawaii, but several species have been introduced in recent times. *Buenoa pallipes* (Fabricus) (NCN) has been known from Hawaii since 1900 (Zimmerman 1948c) and has been recorded from all the major islands except Lanai (Nishida 1994a).

This species can be abundant in lowland ponds and reservoirs and feeds on any suitably sized insect, including damselfly naiads. More recently, two additional species of backswimmers have become established in Hawaii (Polhemus 1995). *Anisops batillifrons* was first collected in 1991 and is known only from Maui. *Notonecta indica* was first collected on Oahu in the mid 1980s and is presently known from Maui and Hawaii. Species of *Notonecta* are known to prey on damselfly naiads and the mere presence of this predator in the water can cause naiads to reduce foraging (Heads 1985) which can reduce growth, development, and survival (Heads 1986). Backswimmers pose a threat to all populations of this damselfly.

Similar to the aquatic insects, Hawaii has a depauperate freshwater fish fauna with only five native species comprised of gobies (Gobiidae) and sleepers (Eleotridae), that occur on all the major islands. The ‘o’opu okuhe (*Eleotris sandwicensis*) and the ‘o’opu naniha (*Stenogobius hawaiiensis*) are coastal fishes, occurring in brackish and freshwater ponds and in lower reaches of streams below the first waterfall. While the ‘o’opu okuhe is the most predaceous of the Hawaiian freshwater fishes (*in litt*. 1995 cited in U.S. Fish and Wildlife Service candidate assessment form), it occurs infrequently with damselflies in the lower reaches of larger streams. The ‘o’opu nakea (*Awaous.stamineus*) and the ‘o’opu nopili (*Sicyopterus stimpsoni*) frequent the middle reaches of streams up to 300 m (1,000 ft) elevation. The ‘o’opu alamo’o (*Lentipes concolor*) usually occupies the upper sections streams above 800 m (2600 ft) and can apparently navigate Hawaii's largest waterfalls (Devick et al. 1992).

Prior to human alteration of the aquatic habitats, the ‘o’opu nakea, ‘o’opu nopili, and the ‘o’opu alamo’o would have all occurred with the naiads of some of the Hawaiian damselflies, at least occasionally. The ‘o’opu nakea has been reported to feed on Hawaiian damselfly naiads (Ego 1956), but this species is apparently primarily herbivorous and ingestion of naiads probably occurs incidental to feeding on algae (Kido et al. 1993). The ‘o’opu noplili feeds predominately on algae and ‘o’opu alamo’o, while facultatively predaceous and not known to feed on damselfly naiads (*in litt*. 1995 cited in U.S. Fish and Wildlife Service candidate assessment form). Therefore, the Hawaiian damselflies probably experienced limited natural predation pressure from the native fishes.

Fish predation has been an important factor in the evolution of behavior in damselfly naiads in continental systems (Johnson 1991). Some species of damselflies are not adapted to cohabitat with fish, and are found only in bodies of water without fish (Henrickson 1988, McPeek 1990a). The naiads of these species tend to occupy more exposed positions and engage in conspicuous foraging behavior, thereby being susceptible to fish (Macan 1977, McPeek 1990b). The evolutionary history of the Hawaiian damselflies coexisting with few, if any predatory fish, and the exposed behavior of most of the fully aquatic species, makes them particularly vulnerable to predation by alien fish introductions.

Over 60 species of aquatic organisms have been introduced into Hawaiian freshwater habitats, including at least 45 species of fish (Devick 1991). The impact of fish introductions prior to 1900 cannot be assessed because this predated the initial collection of damselflies in Hawaii (Perkins 1913). In 1905, two species, the mosquito fish (*Gambusia affinis*), and the sailfin molly (*Poecilia latipinna*), were successfully introduced for biological control of mosquitoes (Van Dine 1907). In 1922, three additional species were established for mosquito control, the green swordtail (*Xiphophorus helleri*), the moonfish (*Xiphophorus maculatus*), and the guppy (*Poecilia reticulata*). The introduction of these species has been implicated in the extinction of the Pacific Hawaiian damselfly from most of the main islands (Moore and Gagne 1982), and by 1935 on Oahu, the orangeblack Hawaiian damselfly was found only in waters without these introduced fish (Williams 1936, Zimmerman 1948b, Polhemus 1993b). Most of the fish introduced early into Hawaii are now established on all the major islands, and are primarily pond and reservoir inhabitants.

Beginning in about 1980, a large number of new fish introductions began in Hawaii, originating primarily from the aquarium fish trade (Devick 1991). By 1990, an additional 15 species of fish were established in waters on Oahu, including catfish, cichlids, gobies, top minnows, needlefish, and piranah many which readily invaded stream systems. By early 1990, the lower to middle reaches of two widely separated streams on Oahu, Manoa on the south leeward side, and Kaukanohua on the north windward side, were choked with dense populations of armored catfish (*Hypostomus* sp. and *Pterygoplichthys multiradiatus*) (Devick 1991).

This recent wave of fish introductions on Oahu corresponded with the drastic decline and range reduction of the crimson Hawaiian damselfly, the oceanic Hawaiian damselfly, and the blackline Hawaiian damselfly. Currently, these damselflies occur only in drainages or higher parts of stream systems where alien fish are not yet established (*in litt*. 1994 cited in U.S. Fish and Wildlife Service candidate assessment form). The continued introduction and establishment of new species of alien fish, and the movement of established species to new drainages (personal communication 1994 cited in U.S. Fish and Wildlife Service candidate assessment form) presents the greatest threat to this Hawaiian damselfly species.

D. *The inadequacy of existing regulatory mechanisms.*

The State of Hawaii considers all natural flowing surface water (streams, springs and seeps) as State property (Hawaii Revised Statutes 174c 1987), and the Hawaii Department of Land And Natural Resources has management responsibility for the aquatic organisms in these waters (personal communication 1995 cited in U.S. Fish and Wildlife Service candidate assessment form). Thus, damselfly populations associated with streams, seeps and springs are under the jurisdiction of the State of Hawaii, regardless of the ownership of the property across which the stream flows. This includes all populations of the crimson Hawaiian damselfly, the blackline Hawaiian damselfly, and the oceanic Hawaiian damselfly, as well as some populations of the Pacific Hawaiian damselfly and the orangeblack Hawaiian damselfly occurring in streams.

State regulatory mechanisms currently in effect do not provide adequate protection for the Hawaiian damselflies or their habitat. The State of Hawaii has not listed these damselflies as endangered or threatened and so does not afforded them any protection under the State endangered species act. Nor does the State Water Code afford adequate protect from the adverse effects of water development projects. The State of Hawaii manages the use of surface and ground water resources through the Commission on Water Resource Management (Water Commission), as mandated by the 1987 State Water Code (State Water Code, Hawaii Revised Statutes Chapter 174C-71, 174C-81-87, and 174C-9195 and Administrative Rules of the State Water Code, Title 13, Chapters 168 and 169). In the State Water Code, there are no formal requirements that project proponents or the Water Commission protect the habitats of fish and wildlife prior to issuance of a permit to modify surface or ground water resources.

The maintenance of instream flow, which is required to protect the habitat of damselflies and other aquatic wildlife, is regulated by the establishment of standards on a stream-by-stream basis (State Water Code, Hawaii Revised Statutes Chapter 174C-71 and Administrative Rules of the State Water Code, Title 13, Chapter 169). Currently, the interim instream flow standards represent the existing flow conditions in streams in the State as of 15 June 1988 for Molokai, Hawaii, Kauai and

East Maui, and 19 October 1988 for West Maui and Leeward Oahu (Administrative Rules of the State Water Code, Title 13, Chapter 169-44-49). However, the State Water Code does not provide for permanent or minimal instream flow standards for the protection of aquatic wildlife. Instead, modification of instream flow standards and stream channels can be undertaken at any time by the Water Commission or via public petitions to revise flow standards or modify stream channels in a specified stream (Administrative Rules of the State Water Code, Title 13,.Chapter 169-36). Additionally, the Water Commission must consider economic benefits gained from out-of-stream water uses, and is not required to balance these benefits against instream benefits to aquatic fish and wildlife. Consequently, any stabilization of stream flow for the protection of Hawaiian damselfly habitat is subject to modification at a future date.

The natural value of Hawaii's stream systems have been recognized under the State of Hawaii Instream Use Protection Program (Administrative Rules of the State Water Code, Title 13, Chapter 169-20(2)). In the Hawaii Stream Assessment Report, prepared in coordination with the National Park Service (National Park Service 1990), the State Water Commission identified high quality rivers or streams, or portions of rivers or streams, that may be placed within a wild and scenic river system. This report recommended that streams meeting certain criteria be protected from further development. However, there is no formal or institutional mechanism within the Water Code to designate and set aside these streams, or to identify and protect stream habitat for Hawaiian damselflies.

Existing Federal regulatory mechanisms that may protect Hawaiian damselflies and their habitat are also inadequate. The Federal Energy Regulatory Commission (FERC) has very limited jurisdiction in Hawaii. Hydroelectric power projects in Hawaii are not on navigable water, public lands, or United States reservations; do not use surplus water or water power from a Federal Government Dam; and do not affect the interests of interstate or foreign commerce. Thus, licensing of hydroelectric projects do not come under the purview of FERC. However, hydropower developers in Hawaii may voluntarily seek licensing under FERC.

The U.S. Army Corps of Engineers (COE) also has some regulatory control over modifications of freshwater streams in the United States. For modifications (i.e., discharge of fill) of streams with an average annual flow greater than 5 cubic feet per second (cfs), the COE can issue individual Department of the Army (DOA) permits under Section 404 of the Clean Water Act. These permits are subject to public review, and must comply with the Environmental Protection Agency's 404(b)(1) guidelines and public comment requirements. However, in issuing these permits, the COE.does not establish instream flow standards as a matter of policy. The COE normally considers that the public interest for instream flow is represented by the state water allocation rights or preferences (Regulatory Guidance Letter No 85-6), and project alternatives that supersede, abrogate, or otherwise impair the state water quantity allocations are not normally addressed as alternatives during permit review.

In cases where the COE district engineer does propose to impose instream flow standard on an individual DOA permit, this flow standard must reflect a substantial national interest. Additionally, if this instream flow standard is in conflict with a State water quantity allocation, then it must be reviewed and approved by the Office of the Chief Engineer in Washington, D.C. Currently, the setting of instream flow standards sufficient to conserve Hawaiian damselflies is not a condition that would be considered or included in a DOA individual permit. If this damselfly was listed as endangered or threatened, Federal interest in its conservation would be assured through consultation under Section 7 of the Endangered Species Act.

The COE may also authorize the discharge of fill into streams with an average annual flow of less than 5 cfs. These discharges are covered under a nationwide permit (33 CFR 330 Appendix A, Nationwide Permit 26). This permit is designed to expedite small scale activities that the COE considers to have only minimal environmental impacts (33CFR 330.1(b)). The U.S. Fish and Wildlife Service and the State Department of Land and Natural Resources have only 15 days to provide substantive site-specific comments following the issuance of a nationwide permit (33 CFR 330 Appendix A, Nationwide Permit Condition 13). The listing of the Hawaiian damselflies as endangered or threatened species will insure that their conservation is adequately considered during consultation, as required under Section 7 of the Endangered Species Act.

Current Conservation Efforts: None

E. *Other natural or manmade factors affecting its continued existence.*

Not applicable.

REFERENCES

Asquith, A. 1995. Hawaiian Damselfly Survey: Population Checklist of Category 1 Candidate Species. Unpublished Document by U.S. Fish & Wildlife Service, Pacific Islands Office, Honolulu, HI.

Beardsley, J.W. 1962. On accidental immigration and establishment of terrestrial arthropods in Hawaii during recent years. Proc.Hawaii. Entomol. Soc. 18:99-109.

Beardsley, J.W. 1979. New immigrant insects in Hawaii: 1962 through 1976. Proc. Hawaii. Entomol. Soc. 23:35-44..Bennett, W.C. 1931. Archaeology of Kauai. B.P. Bishop Museum Bulletin 80:1-156.

Bishop Museum of Honolulu. Hawaiian Terrestrial Arthropod Checklist, March 2002 version. http://ww2.bishopmuseum.org/HBS/checklist/query.asp?grp=Arthropod

Blackburn, T. 1884. Notes on Hawaiian Neuroptera, with descriptions of new species. Ann. Mag. Nat. Hist., (V) 14: 412-421. As referanced in: Zimmerman, E.C. 1948. Insects of Hawaii, Vol. 2. Apterygota -Thysanoptera. Univ. Hawaii Press, Honolulu.

Borror, D.J., C.A. Triplehorn and N.F. Johnson. 1989. Introduction to the Study of Insects, Sixth Edition. Saunders College Publishing, Philadelphia.

Cowles, L.E. 1977. Status of Damselflies (Odonata: Zygoptera) in Hawaii in 1977, with special reference to the endemic genus *Megalagrion* . Senior Honors Thesis, Department of Biology, Univ. Hawaii, Manoa.

Cuddihy, L.W., and C.P. Stone. 1990. Alteration of native Hawaiian vegetation: Effects of humans, their activities and introductions. Univ. Hawaii Press, Honolulu, 138 pp.

Department of Geography, Univ. Hawaii. 1983. Atlas of Hawaii. second edition. Univ. Hawaii Press. Honolulu, 238 pp.

Devaney, D.M., M. Kelly, P.J. Lee, and L.S. Motteler. 1982. Kaneohe: A History of Change. The Bess Press, Honolulu, Hawaii.

Devick, W.S. 1991. Patterns of introduction of aquatic organisms to Hawaiian freshwater habitats: in Devick, W.S., New Direction in Research, Management and Conservation of Hawaiian Freshwater Stream Ecosystems, Proceedings of the 1990 Symposium on Freshwater Stream Biology and Fisheries Management, Department of Land and Natural Resources, Honolulu, Hawaii.

Ego, K. 1956. Life history of freshwater gobies. Freshwater Game and Fish Management Research Project No. F-4-R. Honolulu, Hawaii.

Englund, R. and D.A. Polhemus. 1994. Maakua Stream biological assessment, Oahu, Hawaii. Environmental Technologies.International, Honolulu, Hawaii.

Ford, J.I. and R.A. Kinzie, III. 1982. Life crawls upstream. Natural History 91:61-66. Funasaki, G.Y., P.-L. Lai, L.M. Nakahara, J.W. Beardsley & A.K. Ota. 1988. Areview of biological control introductions in Hawaii: 1890 to 1985.Proc. Hawaii. Entomol. Soc. 28:105-160.

Gagne, W.C. 1980. Insect and myriopods of Kipahulu Valley below 2,000 feet: in. Smith, C.W., Resources Base Inventory of Kipahulu Valley below 2,000 feet, Maui, Hawaii. Coop. Natl. Park. Resc. S. Studies Unit. Pp. 119-175.

Gagne, W.C. and F.G. Howarth. 1982. Assessment of Endangered and Threatened Status of Hawaiian Arthropods. Report to U.S. Fish Wildl. Serv., in Pacific Islands Office, Honolulu.

Giambelluca, T.W., M.A. Nullet, M.A. Rifgley, P.R. Eyre, J.E.T. Moncur, and S. Price. 1991. Drought in Hawaii. Report 87. State of Hawaii. Department of Land and Natural Resources, Commission on Water Resource Management.

Gillespie, R.G. and N. Reimer. 1993. The effect of alien predatory ants (Hymenoptera: Formicidae) on Hawaiian endemic spiders (Araneae:Tetragnathidae). Pacific Science 47:21-33.

Handy, E.S.C. and E.G. Handy. 1972. Native planters in old Hawaii. Their life, lore, and environment. B.P. Bishop Mus. Bull. 233:1-641.

Hardy, D.E. 1979. An ecological survey of Puaaluu Stream. Part III. Reporton a preliminary entomological survey of Puaaluu Stream, Maui. Coop.Nat. Park Resources Study Unit. Univ. Hawaii. Tech. Report 27:34-39.

Hardy, D.E. and M.D. Delfinado. 1980. Insect of Hawaii. Volume 13, Diptera: Cyclorrhapha III. Univ. Hawaii Press, Honolulu.

Harris, S., A. Rubissow, S. Edmunds, and J.-A. Cachola. 1993. Hawaii Streams. Document prepared for Commission on Water Resource Management, State of Hawaii. 40 pp.

Harwood, P.D. 1976. Dragonflies (Odonata) observed in Hawaii in 1973 and 1974. Proc. Hawaii. Entomol. Soc. 22:251-253..Hawaii Stream Assessment. 1990. Department of Land and Natural Resources, State of Hawaii, 300 pp.

Heads, P.A. 1985. The effect of invertebrate and vertebrate predators on the foraging movements of *Ischnura elegans* larvae (Odonata: Zygoptera). Freshwater Biology 15:559-571.

Heads, P.A. 1986. The costs of reduced feeding dur to predator avaoidance: potential effects on growth and fitness in *Ischnura elegans* larvae (Odonata: Zygoptera). Ecological Entomology 11:369-377.

Henrikson, B.-I. 1988. The absence of antipredator behavior in the larvae of *Leucorrhinia dubia* (Odonata) and the consequences for their distribution. Oikos 51:179-183.

Hibbard, D. and D. Franzen. 1991. The View from Diamond Head: Royal Residence to Urban Resort. Editions Limited, Honolulu, Hawaii. 221 pp.

Howarth, F.G. 1990. Hawaiian terrestrial arthropods: An overview. Bishop.Mus. Occas. Pap. 30:4-26.

Howarth, F.G. and W.P. Mull. 1992. Hawaiian Insects and Their Kin.Univ. Hawaii Press, Honolulu.

Howarth, F.G., A. Asquith, and G. Nishida. 1994. Insect of Hawaii: Status and Trends. Unpublished manuscript.

Howarth, F.G. and A.C. Medeiros. 1989. Non-native invertebrates: in Stone,C.P. and D.B. Stone (eds), Conservation Biology in Hawaii. University of Hawaii Cooperative National Park Resources Studies Unit, Honolulu. Pp. 82-87.

Howarth, F.G. and G.W. Ramsay. 1991. The conservation of island insects and their habitats: in Collins, N.M. and J.A. Thomas (eds), The Conservation of Insects and Their Habitats , Academic Press, London. Pp. 71-107

Joesting, E. 1984. Kauai: The separate kingdom. Univ. Hawaii Press, Honolulu.

Johnson, D.M. 1991. Behavioral ecology of larval dragonflies and damseflies. Trends in Ecol. Evol. 6:8-13..Jones, B.L., S.S.W. Chin, and J.C. Brice. 1984. Olokele rock avalanche, island of Kauai, Hawaii. Geology 12:209-211.

Kennedy, C.H. 1917. Notes on the penes of damselflies (Odonata). No. 2. The close relations inter se of the Hawaiian Agrionines. Entomological News. 28:9-14.

Kennedy, C.H. 1920. Forty-two hitherto unrecognized genera and subgenera of Zygoptera. Ohio J. Science. 21:83-88.

Kennedy, C.H. 1929. The origin of the Hawaiian Odonata fauna and its evolution within the islands. Proceedings of the Fourth International Congress of Entomology 2:978-981.

Kennedy, C.M. 1934. *Kilauagrion dinesiotes*, a new species of dragonfly (Odonata) from Hawaii. Annals of the Entomological Society of America. 27:343-345.

Kido, M.H., P. Ha, and R.A. Kinzie III. 1993. Insect introductions and diet changes in and endemic Hawaiian amphidromous goby, *Awaous stamineous* (Pisces: Gobiidae). Pacific Science 47:43-50.

Kirby, W. F. 1890. A synonymic catalog of Neuroptera Odonata, or Dragonflies, with an appendix of fossil species. Gurney and Jackson, London. 202pp. As referaned in: Zimmerman, E.C. 1948. Insects of Hawaii, Vol. 2. Apterygota - Thysanoptera. Univ. Hawaii Press, Honolulu.

Kirch, P.V. 1982. The impact of the prehistoric polynesians on the Hawaiian ecosystem. Pacific Science 36:1-14.

Kirch, P.V. 1985. Feathered gods and fishhooks. Univ. Hawaii Press, Honolulu, Hawaii 349 pp.

Lai, P.-Y. 1988. Biological control: A positive point of view. Proc. Hawaii.Entomol. Soc. 28:179-190.

McLachlan, R. 1883. Neuroptera of the Hawaiian Islands. - Part I. Pseudo-Neuroptera. Ann. Mag. Nat. Hist., (V) 12: 226-240. As referanced in: Zimmerman, E.C. 1948. Insects of Hawaii, Vol. 2. Apterygota - Thysanoptera. Univ. Hawaii Press, Honolulu.

McPeek, M.A. 1990a. Determination of species composition in the *Enallagma* damselfly assemblages of permanent laeks. Ecology.71:83-98.

McPeek, M.A. 1990b. Behavioral differences between *Enallagma* species (Odonata) influencing differential vulnerability to predators. Ecology 71:1714-1726.

Macan, T.T. 1977. The influence of predation on the composition of fresh-water animal communities. Biol. Rev. 52:45-70.

MacDonald, G.A., D.A. Davis, and D.C. Cox. 1960. Geology and ground-water resources of the island of Kauai, Hawaii. Hawaii Division of Hydrology, Bulletin No. 13. 212 pp.

Maciolek, J.A. 1982. Lakes and lake-like waters of the Hawaiian Archipelago. Occass. Pap. B.P. Bishop Mus. 25:1-14.

Meier, K.Z., J.P. Laurel and J.E. Maragos. 1993. State of Hawaii (USA). in Scott, D.A., A Directory of Wetlands in Oceania, The international Waterfowl and Wetlands Research Bureau, U.K., and Asia Wetland Bureau, Kuala Lumpur, Malaysia. 444pp.

Moore, N.W. 1982. Conservation of Odonata - First steps towards a world strategy. Adv. Odontal. 1:205-211.

Moore, N. W. 1983a. Territorial behavior in the genus *Megalagrion* (McLachlan) (Zygoptera: Coenagrionidae). Odonatologica,12(1): 87-92.

Moore, N. W. 1983b. Reflex immobilisation in the Hawaiian endemic genus *Megalagrion* McLachlan (Zygoptera: Coenagrionidae). Odonatologica, 12(2): 161-165.

Moore, N.W. and W.C. Gagne. 1982. *Megalagrion* pacificum (McLachlan) - A preliminary study of the conservation requirements of an endangered species. Rep. Odon. Specialist group Int. Un. Conserv. Nat. Natur. Res. No 3:1-5.

Nafus, D.M. 1993a. Biological control agents and native parasitoids in thepopulation system of the butterfly *Hypolimnas bolinas* (L.) (Lepidoptera:Nymphalidae). Micronesica, Suppl. 4:17-23.

Nishida, G.M., Ed. 1994a. Hawaiian Terrestrial Arthropod.Checklist, 2ndEdition. Bishop. Mus. Tech. Rep. No. [1]. 287pp.

Nishida, G.M. 1994b. Taxonomic validation of Candidate species of insects (and related Arthropods) of the Hawaii Islands. Report prepared for the National Biological Survey, 61 pp.

O'Connor, P.J. 1990. Poaceae. in W.L. Wagner, D.R. Herbst and S.. Sohmer, Manual of the Flowering Plants of Hawai'i. B.P. Bish. Msu. Spec. Publ. No. 83. 1853 pp.

Ogden Environmental and Energy Service. 1994. VA Medical and Regional OfficeCenter Project Conceptual Mitigation Plan for Impacts on the Orange-black damselfly Population at Tripler Army Medical Center. 16pp.

Olson, S.L. and H.F. James. 1982. Prodromus of the fossil avifauna of the Hawaiian Islands. Smithsonian Contrib. Zool. 1-59.

Parrish, J.D., J.A. Maciolek, A.S. Timbol, C.B. Hathaway, and S.E. Norton. 1984. Status of stream channel modification in Hawaii and its effects on native aquatic fauna. Pp. 83-84. Proc. 5th Conference in Natural Sciences, Hawaii, Volcanoes National Park. Coop. Natl. Park. Res. Stud. Unit, Univ. Hawaii.

Perkins, R.C.L. 1899. Neuroptera. D. Sharp, ed., Vol. 2:63-77. Cambridge University Press, Cambridge.

Perkins, R.C.L. 1907. Insects at Kilauea, Hawaii. Proc. Hawaii. Entomol. Soc. 1:89-95.

Perkins, R.C.L. 1913. Introduction to Fauna Hawaiiensis. D. Sharp, ed., Vol.1:xv-ccxxvii. Cambridge University Press, Cambridge.

Polhemus, D.A., J. Maciolek, and J. Ford. 1992. An ecosystem classification of inland waters for the tropical Pacific islands. Micronesica 25:155-173.

Polhemus, D.A. 1993a. Damsels in distress: a review of the conservation status of Hawaiian *Megalagrion* damselflies (Odonata: Coenagrionidae). Aquatic Conservation: Marine and Freshwater Ecosystems 3:343-349.

Polhemus, D.A. 1993b. Conservation of aquatic insects: Worldwide crisis or localized threats? Amer. Zool. 33:588-598.

Polhemus, D.A. 1993c. A preliminary assessment of the impacts of hurricane Iniki on the aquatic insect faunas of streams on the Na Pali Coast, Kaua'i, Hawai'i. in Assessments of the impact of Hurricane Iniki on stream biota and ecosystems on Kaua'i. Department of Land and Natural Resources, Division of Aquatic Resources. State of Hawai'i. Pp. 59-88.

Polhemus, D.A. 1994a. Current status of *Megalagrion* populations on Oahu: 1990 - Present. Report to U.S. Fish & Wildlife Service, Pacific Islands Office.

Polhemus, D.A. 1994b. A revision of the Hawaiian damselflies in the genus *Megalagrion* (Odonata: Coenagrionidae). Unpublished report to U.S. Fish & Wildlife Service, Pacific Islands Office.

Polhemus, D.A. 1995. New Heteroptera and Odonata (Insecta) records and range extensions in the Hawaiian Islands. Bish. Mue. Occass. Pap. 42:42-43.

Polhemus, D., and A. Asquith. 1996. Hawaiian Damselfies: A Field Identification Guide. Hawaii Biological Survey Handbook, Bishop Museum Press, Honolulu, Hawaii. 122 pp.

Reimer, N.J. 1993. Distribution and impact of alien ants in vulnerable Hawaiian ecosystems: in D.F.Williams (ed), Exotic Ants: Biology, Impact,and Control of Introduced Species. Westview Press, Boulder, Colorado.pp. 11-22.

Reimer, N., J.W. Beardsley and G. Jahn. 1990. Pest ants in Hawaii. in Vander Meer, R.K, K. Jaffe and A. Cedeno (eds), Applied Myrmecology: A World Perspective. Westview Press, Boulder, Colorado, Pp. 40-50.

Schmidt, E. 1938. Check-list of Odonata of Oceania. Ann. Entomol. Soc. America. 31:322-344.

Selys-Longchamps, E. 1876. Synopsis des Agrionines, 5me Legion: Agrion. Bull. Acad. Royal Belgique, (II) 41 (2,3): 1-282. As referanced in: Zimmerman, E.C. 1948. Insects of Hawaii, Vol. 2. Apterygota -Thysanoptera. Univ. Hawaii Press, Honolulu.

Simon, C.M., W.C. Gagne, F.G. Howarth, and F.J. Radovsky. 1984..Hawaii: A natural entomological laboratory. Bull. Entomol. Soc. Am.30:8-17.

Smith, C.W. 1985. Impact of alien plants on Hawai'i's native biota. in C.P.Stone and J.M. Scott (eds), Hawai'i's Terrestrial Ecosystems: Preservation and Management. Cooperative National Park Resources Study Unit, Univ. Hawaii, Honolulu.

Stearns, H.T. 1940. Geology and ground-water resources of the islands of Lanai and Kahoolawe, Hawaii. Bulletin 6 of the Division of Hydrography, Territory of Hawaii.

Stearns, H.T. and K.N. Vaksvik. 1935. Geology and ground-water resources of the island of Oahu, Hawaii. Bulletin 1 of the Division of Hydrography, Territory of Hawaii.

Stearns, H.T. 1985. Geology of the State of Hawaii. second edition. Pacific Books, Palo Alto, California.

Stone, C.P. 1985. Alien animals in Hawai'i's native ecosystems: toward controlling the adverse effects of introduced vertebrates: in Stone, C.P., and J.M. Scott (eds.), Hawai'i's terrestrial ecosystems: preservation and management. Coop. Natl. Park Resources Stud. Unit, Univ. Hawaii, Honolulu, Pp. 251-297.

Stone, C.P. 1989. Hawai'i's wetlands, streams, fishponds, and pools. in C.P.Stone and D.B. Stone (eds), Conservation Biology in Hawai'i. Cooperative National Park Resources Study Unit, Univ. Hawaii, Honolulu. Pp. 125-136.

Summers, C.C. 1964. Hawaiian Fishponds. B.P. Bishop Mus. Spec. Publ. 52.

Takasaki, K.I., G.T. Hirashima, and E.R. Lubke. 1969. Water Resources of Windward Oahu, Hawaii. U.S. Geological Survey Water Supply Paper No. 1894:1-119. U.S. Govt. Printing Office, Washington, D.C.

U.S. Fish and Wildlife Service. 1985. Recovery plan for the Hawaiian waterbirds. U.S. Fish Wildl. Serv., Portland, Oregon, 99pp.

U.S. Fish and Wildlife Service. 1995. Pacific Islands Ecoregion.Coastal Ecosystems Program Proposal. U.S. Fish and Wildife Service, Honolulu, Hawaii, 119pp.

Van Dine, D.L. 1907. The introduction of top-minnows (natural enemies of mosquitoes) into the Hawaiian Islands. Haw. Agr. Exp. St. Press Bull. 20:1-10.

Wenkam, R. 1969. Kauai and the park county of Hawaii. Sierra Club, San Fransisco, 160pp. Williams, F.X. 1936. Biological studies in Hawaiian water-loving insects. Part 1. Coleptera or beetles. Part 2. Odonata or dragonflies. Proc. Hawaii. Entomol. Soc. 9:235-345.

Wilson, Okamoto and Associates, Inc. 1993. Kawai Nui Marsh Master Plan: Development Project Report. Document prepared for Department of Land and Natural resoruces, State of Hawaii.

Wong, M.A. and T.T.Y. Wong. 1988. Predation of the Mediterranean fruit flyand oriental fruit fly (Diptera: Tephritidae) by the fire ant(Hymenoptera: Formicidae) in Hawaii. Proc. Hawaii. Entomol. Soc. 28:169-177.

Zimmerman, E.C. 1948a. Insects of Hawaii. Vol. 1. Introduction. xvii + 206pp. Univ. Hawaii Press, Honolulu.

Zimmerman, E.C. 1948b. Insects of Hawaii, Vol. 2. Apterygota - Thysanoptera. Univ. Hawaii Press, Honolulu.

Zimmerman, E.C. 1948c. Insects of Hawaii, Vol. 3. Heteroptera. Univ. Hawaii Press, Honolulu.

Zimmerman, E.C. 1970. Adaptive radiation in Hawaii with special reference to insects. Biotropica 2:32-38..

PETITION TO LIST

Pacific Hawaiian damselfly
(*Megalagrion pacificum*)

AS A FEDERALLY ENDANGERED SPECIES

CANDIDATE HISTORY

CNOR 5/22/84:	
CNOR 1/6/89:	
CNOR 11/21/91:	
CNOR 11/15/94:	
CNOR 2/28/96:	C
CNOR 9/19/97:	C
CNOR 10/25/99:	C
CNOR 10/30/01:	C
CNOR 6/13/02:	C

TAXONOMY

Native Hawaiians apparently did not differentiate among the different species, but referred to the native damselflies collectively as pinaoʻula. There has been no traditional European use of a common name for species in the genus *Megalagrion* (Coenagrionidae). In a recent taxonomic review of the candidate species of insects in Hawaii, Nishida (1994b) proposed the name "Hawaiian damselflies". Because this name reflects the restricted distribution of these insects and should be readily used by nontechnical persons, the U.S. Fish and Wildlife Service has adopted this common name for the genus, with additional descriptive terms to identify each species.

The status of *Megalagrion pacificum* as a valid species is uncontroversial (e.g., Bishop Museum 2002).

NATURAL HISTORY

Distribution

Because of the extreme geographic isolation of the Hawaiian islands and the poor dispersal capabilities of many aquatic insects, the freshwater insect fauna of Hawaii is depauperate compared to continental areas despite the diversity of aquatic habitats. Many groups of insects that typify freshwater habitats in continental areas are absent from the native fauna. Some notable examples of such groups are mayflies (Ephemeroptera), stoneflies (Plecoptera), caddisflies (Trichoptera), and alderflies and dobsonflies (Neuroptera), all of which are absent from Hawaii.

Like most of the native fish, mollusc, and crustacean faunas (Ford and Kinsey 1994), most of Hawaii's freshwater insects evolved from marine or intertidal ancestors (Hardy and Delfinado 1980) that could easily colonize the islands.

The Hawaiian damselflies are represented by 23 species and five subspecies, all confined to the Hawaiian Islands. Historically these were among the most common and conspicuous native Hawaiian insects. Some species inhabited water gardens in residential areas, artificial reservoirs, and watercress farms, and were abundant in the city of Honolulu (Perkins 1913, Williams 1936).

Morphology
Megalagrion pacificum is a small Hawaiian damselfly. The male has red markings on the thorax and red rings around the last few segments of the abdomen. The female is similar to the male except with green rather than red markings. More detailed descriptions and color photos are available in Polhemus and Asquith (1996).

Behavior
The general biology of Hawaiian damselflies is typical of other narrow-winged damselflies. The males of most species are territorial, guarding areas of habitat where females will lay eggs (Moore 1983a). During copulation, and often while the female lays eggs, the male grasps the female behind the head with his terminal abdominal appendages to guard her against rival males, thus males and females are frequently seen flying in tandem. In species with fully aquatic immature stages, females lay eggs in submerged aquatic vegetation or in mats of moss or algae on submerged rocks, and hatching occurs in about ten days (Williams 1936, Polhemus 1994b).

Adults usually do not stray far from the vicinity of the breeding pools, perching on bordering vegetation and flying only short distances if disturbed. They are rarely seen along the main stream corridors.

In most species of Hawaiian damselflies, the immature stages (naiads) are aquatic, breathing though three flattened, abdominal gills, and are predacious, feeding on small aquatic invertebrates or fish (Williams 1936). Naiads may take up to four months to mature (Williams 1936), after which they crawl out of the water onto rocks or vegetation, molt into winged adults, which typically remain very close to the aquatic habitat from which they emerged. Adults are also predacious and feed on small flying insects such as midges. In a remarkable example of adaptive radiation in Hawaii, some species of Hawaiian damselflies have foregone the aquatic lifestyle, either partly, with naiads living on wet rock faces, or completely, with terrestrial naiads living in the damp leaf litter, or others inhabiting moist leaf axils of native plants up to several meters above the ground (Zimmerman 1970, Simon et al. 1984). Adults are also unusual in that they have a highly developed behavior of feigning death when caught or attacked (Moore 1983b).

Habitat
Historically this species was most common at low elevations, and Perkins (1913) described it as breeding in stagnant water, large ponds at higher elevations, and small, quiet pools in gulches that have been cut off from the main channel of the stream. It can no longer utilize most lentic habitats in Hawaii such as ponds and taro fields due to predation by alien fish (Moore and Gagne 1982). Recent observations have confirmed that the species is now restricted almost exclusively to

seepage fed pools along overflow channels in the terminal reaches of perennial streams, usually in areas with thick, surrounding vegetation (Moore and Gagne 1982, Polhemus 1994b).

POPULATION STATUS

The primary threats to the remaining populations of the Pacific Hawaiian damselfly are predation by alien aquatic species such as fish and aquatic insects and habitat loss through channel alteration and dewatering of streams.

Historically the pacific Hawaiian damselfly (*Megalagrion pacificum*) was found on all the major islands except Niihau and Kahoolawe. It was recorded from the following general localities--Lihue and Waimea on Kauai (Polhemus 1994b); Honolulu and Kawailoa Stream on Oahu, Kalae (Polhemus 1994b) and Waialua Stream (Harwood 1976) on Molokai; Hahalawe (Polhemus 1994b), Haipuaena (Harwood 1976), Iao, Palikea (Polhemus 1994b), Puaaluu (Moore and Gagne 1982), Puohokamoa, and Waikamoi Streams (Harwood 1976) on Maui; Lanai (Polhemus 1994b); and Hilo (Perkins 1907) on Hawaii. It is now apparently extirpated on the islands of Kauai, Oahu, Lanai and Hawaii. Extant populations are known from Pelekunu and Waikolu streams on Molokai, and Haipuaena, Hanawi, Keanae, Palikea and Kuhiwa Streams on Maui (Polhemus 1994b). Damselflies do not occur along the entire reaches of these streams, but rather have very small populations in restricted locations.

As early as 1948, Zimmerman noted a decline of the more common species, particularly on Oahu. By the late 1970s less than six populations of the Pacific Hawaiian damselfly could be located (Harwood 1976, Gagne 1980, Moore and Gagne 1982), and the conservation of this species was identified as a priority by the International Union for Conservation of Nature and Natural Resources (Moore 1982). A review of the status of Hawaiian damselflies in 1981 (Gagne and Howarth 1982) lead to the placement of several species on the U.S. Fish and Wildlife Service's list of candidate species for Federal listing (49 FR 21664). Due to a continued decline of these damselflies, particularly on the island of Oahu, intensive surveys were initiated in 1990. The results of these surveys demonstrate that six species of Hawaiian damselflies are now threatened with extinction.

The U.S. Fish and Wildlife Service classifies the Pacific Hawaiian damselfly as a candidate for Endangered Species Act protection with a listing priority number of 2.

LISTING CRITERIA

A. *The present or threatened destruction, modification, or curtailment of its habitat or range.*

Historical range: Hawaii: islands of Kauai, Oahu, Molokai, Maui, Lanai, and Hawaii. It was recorded from the following general localities--Lihue and Waimea on Kauai (Polhemus 1994b); Honolulu and Kawailoa Stream on Oahu, Kalae

(Polhemus 1994b) and Waialua Stream (Harwood 1976) on Molokai; Hahalawe (Polhemus 1994b), Haipuaena (Harwood 1976), Iao, Palikea (Polhemus 1994b), Puaaluu (Moore and Gagne 1982), Puohokamoa, and Waikamoi Streams (Harwood 1976) on Maui; Lanai (Polhemus 1994b); and Hilo (Perkins 1907) on Hawaii. It is now apparently extirpated on the islands of Kauai, Oahu, Lanai and Hawaii. Extant populations are known from Pelekunu and Waikolu streams on Molokai, and Haipuaena, Hanawi, Keanae, Palikea and Kuhiwa Streams on Maui (Polhemus 1994b). Damselflies do not occur along the entire reaches of these streams, but rather have very small populations in restricted locations.

Current range: Hawaii: islands of Molokai, Maui. Extirpated from Oahu, Kauai, and Lanai. Presently known from six remnant populations, on East Maui and Molokai, each probably numbering fewer than 1,000 individuals (Nishida, 1994a).

Land ownership: This species occurs in State-managed waters.

Freshwater habitats on all the main Hawaiian Islands have been severely altered and degraded because of past and present land and water management practices including agriculture, urban development, development of ground water, perched aquifer and surface water resources, and the deliberate introduction of alien animals (Harris et al. 1993, Meier et al. 1993, U.S. Fish and Wildlife Service 1985, 1995).

Extensive modification of lentic (standing water) habitats in the Hawaiian Islands began about 1100 AD with a rapid population increase among native Hawaiians (Kirch 1982). Hawaiians cultivated taro (*Colocasia esculenta*) by creating shallow, walled ponds called lo'I, in marshes and riparian areas (Handy and Handy 1972). By 1778, virtually all valley bottoms with permanent stream flow and most basin marshes were converted to irrigated taro cultivation (Handy and Handy 1972). While this represents a significant alteration of the natural aquatic system, these extensive artificial wetlands were probably suitable habitat for many native Hawaiian species, particularly waterbirds (Olson and James 1982). Native Hawaiian dragonflies were recorded in taro lo'I (Handy and Handy 1972) and some damselflies may also have utilized these systems (Moore and Gagne 1982), since the lo'I remained flooded for months or years at a time (Handy and Handy 1972).

Hawaiians also modified wetlands by constructing fishponds, many of which were primarily freshwater, fed by streams or springs (Summers 1964). Despite this habitat modification by early Hawaiians, many areas of extensive marsh land remained intact. The best example of this was the Mana marsh of western Kauai. In this area, sedimentary deposits restrict the flow of ground water seaward, creating basal water spring discharge 3-4 m (8-12 ft) above sea level, and the development of an extensive marsh system (MacDonald et al. 1960). This area was famous for its mirages on open water surfaces (MacDonald et al. 1960) and Hawaiians traveled by canoe for miles between villages (Bennett 1931).

Some wetlands which had been converted to taro lo'I were maintained and others were utilized for rice cultivation between 1850 and 1930. In 1900, there was approximately 19,000 acres of taro and

16,000 acres of rice in production in Hawaii (U.S. Fish and Wildlife Service 1995). By 1960, taro production was reduced to only 510 acres and the rice industry had been completely abandoned. Many of these wetlands formerly used for taro or rice were drained and filled for dry-land agriculture (Stone 1989, Meier et al. 1993). The Mana marsh on Kauai is also one of the best examples of extensive freshwater habitat loss due to modern agriculture. The margins of the Mana marsh were used for rice cultivation until 1922, when the land, including several open ponds, were leased to Kekaha Sugar Company for sugarcane cultivation (Joesting 1984). By the late 1940s, the entire Mana marsh had been drained and filled and was under sugarcane cultivation (Wenkam 1969).

Most urban, residential and resort development in Hawaii has occurred in the coastal plains and as a result, many freshwater lentic habitats have been negatively affected (U.S. Fish & Wildlife Service 1985). Most of this development has occurred on Oahu, which now supports four fifths of the state's population (Dept. of Geography 1983). The Ala Moana and Waikiki areas of Honolulu were once extensive marshlands that were converted to hundreds of taro lo’I and fishponds by Hawaiians (Handy and Handy 1972). Small development projects began in Waikiki in 1910, but even as late as 1920, 85 percent of Waikiki remained under water, used as duckponds, fishponds, and for the cultivation of rice and taro (Hibbard and Franzen 1991). In 1928, the Ala Wai Canal was completed, resulting in the complete.drainage and development of the Waikiki wetlands, which now on an average day hosts over 60,000 people (Hibbard and Franzen 1991). Construction for housing and civil works projects on Oahu also resulted in the draining and filling of large fresh and brackish water marshes at Wailupe Peninsula, Hawaii Kai, Kaelepulu Pond, and Salt Lake (U.S. Fish and Wildlife Service 1995).

The Service now estimates that 30 percent of all coastal plain wetlands in Hawaii have been lost to agriculture and urban development (*in litt*. 1990 cited in U.S. Fish and Wildlife Service candidate assessment form), and if only freshwater habitat was considered the loss would be proportionately much higher, probably approaching 80 to 90 percent. While intentional filling of freshwater wetlands with open water is rarely permitted today (personal communication 1995 cited in U.S. Fish and Wildlife Service candidate assessment form), loss of smaller areas utilized by damselflies, such as narrow strips of freshwater seeps within anchialine pool complexes, and loss of emergent vegetation still occurs. In addition, marshes are slowly filled and converted to meadow habitat due to increased sedimentation resulting from increased storm water runoff from upslope development, and blockage of downslope drainage (Wilson Okamoto & Associates, Inc. 1993).

Presently the most significant threat to natural ponds and marshes in Hawaii is the alien species California grass (*Brachiaria mutica* (Forssk.) Stapf). The area of origin of this sprawling perennial grass is unknown, but it was first noted on Oahu in 1924 and now occurs on all the major islands (O'Connor 1990). This plant forms dense, monotypic stands that can completely eliminate any open water by layering of its trailing stems (Smith 1985). The most extensive remaining marsh system on the island of Oahu, Kawainui, is now almost entirely choked with California grass, facilitating its conversion to meadowland (Wilson Okamoto & Associates, Inc. 1993).

The James Campbell and Pearl Harbor National Wildlife Refuges on Oahu, and Kakahaia National Wildlife Refuge on Molokai must be constantly managed to control this plant (personal communication 1995 cited in U.S. Fish and Wildlife Service candidate assessment form). The Pacific Hawaiian damselfly and the orangeblack Hawaiian damselfly have both sustained loss of palustrine habitat on all islands due to human activities and California grass. Presently two populations of the orangeblack damselfly along the Kona coast of Hawaii are threatened with further habitat loss from overdraw of the aquifer that feeds coastal marshes (personal communication 1995 cited in U.S. Fish and Wildlife Service candidate assessment form). The only known population of the orangeblack damselfly on Oahu is threatened with habitat degradation from a proposed construction project (Ogden Environmental 1994).

Early Hawaiians also modified stream systems by diverting water from the main channel to irrigate taro lo'I. In some cases these diversions, or ‘auwai, were elaborate, such as the cut and fitted stone ditch of Kiki a Ola in Waimea Canyon on Kauai (Bennett 1932). Other diversions were several kilometers long (Kirch 1985) and moved water between drainages (Devaney et al. 1983). However, these diversions were closely regulated and were not allowed to take more than half the stream flow, and diversions were typically periodic to flood lo'I rather than continuous (Handy and Handy 1972).

The advent of plantation sugarcane cultivation in 1835 led to more extensive stream diversions. The first irrigation system for sugar, built in 1856 on Kauai, was 16 km (10 mi) long. In 1900, the Maunawili Ditch on windward Oahu diverted all the water from Maunawili Stream into Waimanalo Valley (Takasaki et al. 1969). By 1906, the Kohala Ditch system on Maui utilized 15 km (9 mi) of tunnels, 7 km (4.5 mi) of open ditch, and 20 flumes, and now the East Maui Irrigation system may be the largest private water company in the United States (Harris et al. 1993). These systems typically tap water at upper elevations (> 300 m) by means of a concrete weir in the stream. All or most of the low or average flow of the stream is diverted into fields or reservoirs (Takasaki et al. 1969, Harris et al. 1993).

By the 1930s, major water diversions had been developed on all the major islands and currently one third of Hawaii's perennial streams are diverted (Hawaii Stream Assessment 1990). Some systems are extensive, such as the Waiahole Ditch which takes water from 37 streams on the windward side of Oahu, and transports it to the leeward plains via a tunnel cut through the Koolau Mountain Range (Stearns and Vaksvik 1935). On West Maui, as of 1978, over 49 miles of stream habitat in 12 streams have been lost due to diversions, and all of the 17 perennial streams on West Maui are diverted to some extent (Macioleck 1979). In addition to diverting water for agriculture and domestic water supply, streams have also been diverted for use in hydroelectric power. There are currently 18 active hydroelectric plants operating on Hawaiian streams, with another 10 proposed for construction, and another 28 sites identified for potential development (Hawaii Stream Assessment 1990).

In addition to diverting surface flow in the stream channels, the perched aquifers which feed the streams have also been tapped by means of tunnels (Stearns and Vaksvik 1935, Stearns 1985). For example, both the bore tunnels and the contour tunnel of the Waiahole Ditch system pierced perched aquifers that were drained to the level of the tunnels (Stearns and Vaksvik 1935). Many of these aquifers were also the sources of springs which contributed flow to the windward streams. The boring of the Haiku tunnel in 1940 caused a 25 percent reduction in the base flow of Kahaluu Stream, over 2.5 miles away (Takasaki et al. 1969). The draining of these aquifers caused many of the springs to dry up, including some over 0.5 km (0.3 mi) away from the bore tunnels (Stearns and Vaksvik 1935). Frequently the actual springs were tapped by driving tunnels into the rock from where the water emerged, and on the water-poor island of Lanai, almost every spring and seep was bored or captured (Stearns 1940).

Surface waters in streams have also been captured by tunnels in the alluvium of the stream channel. Historically, Maunalei Stream was the only perennial stream on Lanai, and Hawaiians constructed taro lo'i in the lower portions of this system. In 1911, a tunnel was developed at 330 m (1,100 ft) elevation which undercut the stream bed, capturing both the surface and subsurface flow and dewatering the stream from this point to the mouth (Stearns 1940).

Stream degradation has been particularly severe on the island of Oahu, where, in 1978, 57 percent of the perennial streams had been channelized (lined, partially lined or altered stream course) and 89 percent of the total length of these streams were channelized (Parrish et al. 1984). Channelization of streams has not been restricted to lower reaches, in Kalihi Stream there is extensive channelization above 300 m (1,000 ft). Channelization results in removal of riparian vegetation, increased velocity, increased illumination, and higher water temperatures. Hawaiian damselflies do not utilize channelized portions of streams.

Surface flow of streams has also been affected by vertical wells, because the basal aquifer and alluvial caprock through which the lower sections of streams flow can be hydraulically connected (*in litt*. 1995 cited in U.S. Fish and Wildlife Service candidate assessment form). Historically, for example, there was sufficient surface flow in Makaha and Nanakuli streams on Oahu to support taro lo'i in their lower reaches, but this flow disappeared subsequent to construction of wells upstream (personal communication 1995 cited in U.S. Fish and Wildlife Service candidate assessment form). This damselfly has sustained habitat loss due to water diversions and stream alterations on all the islands.

B. *Overutilization for commercial, recreational, scientific, or educational purposes.*

Healthy populations of stream-inhabiting Hawaiian damselflies are composed of large numbers of individuals. Moore (1983a) recorded 75 males per 100 m of stream edge for *Megalagrion heterogamias* on Kauai. In addition, there are often more males than suitable territorial habitat, and when males are removed from a territory they are immediately replaced by other individuals (Moore 1983a). However, populations of these damselflies are now extremely reduced, with fewer than 10 males per 100 m of stream edge at all localities. Publication of the rarity of these species will likely increase the interest of professional and amateur Odonata collectors. Unrestricted collecting and handling could impact these small populations and are considered significant threats to the species.

C. *Disease or predation.*

The geographic isolation of the Hawaiian Islands has restricted the number of original successful colonizing arthropods and resulted in the development of an unusual fauna. An unusually small number (15 percent) of the known families of insects are represented by native Hawaiian species (Howarth 1990). Some groups that often dominate continental arthropod faunas, such as social

Hymenoptera (group nesting ants, bees, and wasps), are entirely absent. Commercial shipping and air cargo to Hawaii has now resulted in the establishment of over 2,500 species of alien arthropods (Howarth 1990, Howarth et al. 1994), with a continuing establishment rate of 10-20 new species per year (Beardsley 1962; 1979). In addition to the accidental establishment of alien species, alien predators and parasites for biological control of pests have been purposefully imported and released by individuals, Republic, Territorial, State, and Federal agencies, since 1865. Between 1890 and 1985, 243 alien species were introduced, sometimes with the specific intent of reducing populations of native Hawaiian insects (Funasaki et al. 1988, Lai 1988). Alien arthropods, whether purposefully introduced or adventive, pose a serious threat to Hawaii's native insects, through direct predation and parasitism, and competition for food or space (Howarth and Medeiros 1989; Howarth and Ramsay 1991).

Ants are not a natural component of Hawaii's arthropod fauna, and endemic species evolved in the absence of predation pressure from ants. Ants can be particularly destructive predators because of their high densities, recruitment behavior, aggressiveness, and broad range of diet (Reimer 1993). The latter attribute allows some ants to affect prey populations independent of prey density, and ants can therefore locate and destroy isolated individuals and populations (Nafus 1993). At least 36 species of ants are known to be established in the Hawaiian Islands, and three particularly aggressive species have had severe effects on the native insect fauna (Zimmerman 1948a).

By the late 1870s, the big-headed ant (*Pheidole megacephala*) was present in Hawaii and its predation on native insects was noted by 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, including most moths, have been eliminated from areas where the big-headed ant is present (Perkins 1913, Gillespie and Reimer 1993). This predator generally does not occur at elevations higher than 600 m (2,000 ft), and is also restricted by rainfall, rarely being found in particularly dry (less than ca 35-50 cm [15- 20 in] annually) or wet areas (more than ca 250 cm [100 in] annually) (Reimer et al. 1990).

The long-legged ant (*Anoplolepis longipes*) appeared in Hawaii in 1952 and now occurs on Oahu, Maui, and Hawaii (Reimer et al. 1990). It inhabits low elevation (less than 600 m [2,000 ft]), rocky areas of moderate rainfall (less than 250 cm [100 in] annually) (Reimer et al. 1990). Direct observations indicate that Hawaiian arthropods are susceptible to predation by this species (Gillespie and Reimer 1993) and Hardy (1979) documented the disappearance of most native insects from Kipahulu Stream on Maui after the area was invaded by the long-legged ant.

At least two species of fire ants, *Solenopsis geminita* and *Solenopsis papuana*, are also important threats (Gillespie and Reimer 1993) and occur on all the major islands (Reimer et al. 1990). *Solenopsis geminita* is also known to be a significant predator on pest fruit flies in Hawaii (Wong and Wong 1988). *Solenopsis papuana* is the only abundant, aggressive ant that has invaded intact mesic forest above 600 m (2,000 ft) and is still expanding its range in Hawaii (Reimer 1993). At least some populations of all the damselfly taxa included in this proposed rule are threatened by one or more of the ant species described above.

Backswimmers are aquatic true bugs (Heteroptera) in the family Notonectidae, so called because they swim upside down. Backswimmers are voracious predators and frequently feed on prey much larger than themselves, tadpoles, small fish, and other aquatic insects including damselfly naiads (Borror et al. 1989). Backswimmers are not native to Hawaii, but several species have been introduced in recent times. *Buenoa pallipes* (Fabricus) (NCN) has been known from Hawaii since 1900 (Zimmerman 1948c) and has been recorded from all the major islands except Lanai (Nishida 1994a). This species can be abundant in lowland ponds and reservoirs and feeds on any suitably sized insect, including damselfly naiads. More recently, two additional species of backswimmers have become established in Hawaii (Polhemus 1995). *Anisops batillifrons* was first collected in 1991 and is known only from Maui. *Notonecta indica* was first collected on Oahu in the mid 1980's and is presently known from Maui and Hawaii. Species of *Notonecta* are known to prey on damselfly naiads and the mere presence of this predator in the water can cause naiads to reduce foraging (Heads 1985) which can reduce growth, development, and survival (Heads 1986). Backswimmers pose a threat to all populations of this damselfly.

Similar to the aquatic insects, Hawaii has a depauperate freshwater fish fauna with only five native species comprised of gobies (Gobiidae) and sleepers (Eleotridae), that occur on all the major islands. The ‘o’opu okuhe (*Eleotris sandwicensis*) and the ‘o’opu naniha (*Stenogobius hawaiiensis*) are coastal fishes, occurring in brackish and freshwater ponds and in lower reaches of streams below the first waterfall. While the ‘o’opu okuhe is the most predaceous of the Hawaiian freshwater fishes (*in litt.*1995 cited in U.S. Fish and Wildlife Service candidate assessment form), it occurs infrequently with damselflies in the lower reaches of larger streams. The ‘o’opu nakea (*Awaous stamineus*) and the ‘o’opu nopili (*Sicyopterus stimpsoni*) frequent the middle reaches of streams up to 300 m (1,000 ft) elevation.

The ‘o’opu alamo’o (*Lentipes concolor*) usually occupies the upper sections streams above 800 m (2600 ft) and can apparently navigate Hawaii's largest waterfalls (Devick et al. 1992). Prior to human alteration of the aquatic habitats, the ‘o’opu nakea, ‘o’opu nopili, and the ‘o’opu alamo’o would have all occurred with the naiads of some of the Hawaiian damselflies, at least occasionally. The ‘o’opu nakea has been reported to feed on Hawaiian damselfly naiads (Ego 1956), but this species is apparently primarily herbivorous and ingestion of naiads probably occurs incidental to feeding on algae (Kido et al. 1993). The ‘o’opu noplili feeds predominately on algae and ‘o’opu alamo’o, while facultatively predaceous and not known to feed on damselfly naiads (*in litt*. 1995 cited in U.S. Fish and Wildlife Service candidate assessment form). Therefore, the Hawaiian damselflies probably experienced limited natural predation pressure from the native fishes.

Fish predation has been an important factor in the evolution of behavior in damselfly naiads in continental systems (Johnson 1991). Some species of damselflies are not adapted to cohabitate with fish, and are found only in bodies of water without fish (Henrickson 1988, McPeek 1990a). The naiads of these species tend to occupy more exposed positions and engage in conspicuous foraging behavior, thereby being susceptible to fish (Macan 1977, McPeek 1990b). The evolutionary history of the Hawaiian damselflies coexisting with few, if any predatory fish, and the exposed behavior of most of the fully aquatic species, makes them particularly vulnerable to predation by alien fish introductions.

Over 60 species of aquatic organisms have been introduced into Hawaiian freshwater habitats, including at least 45 species of fish (Devick 1991). The impact of fish introductions prior to 1900 cannot be assessed because this predated the initial collection of damselflies in Hawaii (Perkins 1913). In 1905, two species, the mosquito fish (*Gambusia affinis*), and the sailfin molly (*Poecilia latipinna*), were successfully introduced for biological control of mosquitoes (Van Dine 1907). In 1922, three additional species were established for mosquito control, the Green swordtail (*Xiphophorus helleri*), the moonfish (*Xiphophorus maculatus*), and the guppy (*Poecilia reticulata*). The introduction of these species has been implicated in the extinction of the Pacific Hawaiian damselfly from most of the main islands (Moore and Gagne 1982), and by 1935 on Oahu, the orangeblack Hawaiian damselfly was found only in waters without these introduced fish (Williams 1936, Zimmerman 1948b, Polhemus 1993b). Most of the fish introduced early into Hawaii are now established on all the major islands, and are primarily pond and reservoir inhabitants.

Beginning in about 1980, a large number of new fish introductions began in Hawaii, originating primarily from the aquarium fish trade (Devick 1991). By 1990, an additional 15 species of fish were established in waters on Oahu, including catfish, cichlids, gobies, top minnows, needlefish, and piranha many which readily invaded stream systems. By early 1990, the lower to middle reaches of two widely separated streams on Oahu, Manoa on the south leeward side, and Kaukanohua on the north windward side, were choked with dense populations of armored catfish (*Hypostomus* sp. and *Pterygoplichthys multiradiatus*) (Devick 1991).

This recent wave of fish introductions on Oahu corresponded with the drastic decline and range reduction of the crimson Hawaiian damselfly, the oceanic Hawaiian damselfly, and the blackline Hawaiian damselfly. Currently, these damselflies occur only in drainages or higher parts of stream systems where alien fish are not yet established (*in litt*., 1994 cited in U.S. Fish and Wildlife Service candidate assessment form). The continued introduction and establishment of new species of alien fish, and the movement of established species to new drainages (personal communication 1994 cited in U.S. Fish and Wildlife Service candidate assessment form) presents the greatest threat to this Hawaiian damselfly species.

D. *The inadequacy of existing regulatory mechanisms.*

The State of Hawaii considers all natural flowing surface water (streams, springs and seeps) as State property (Hawaii Revised Statutes 174c 1987), and the Hawaii Department of Land And Natural Resources has management responsibility for the aquatic organisms in these waters (personal communication 1995 cited in U.S. Fish and Wildlife Service candidate assessment form). Thus, damselfly populations associated with streams, seeps and springs are under the jurisdiction of the State of Hawaii, regardless of the ownership of the property across which the stream flows. This includes all populations of the crimson Hawaiian damselfly, the blackline Hawaiian damselfly, and the oceanic Hawaiian damselfly, as well as some populations of the Pacific Hawaiian damselfly and the orangeblack Hawaiian damselfly occurring in streams.

State regulatory mechanisms currently in effect do not provide adequate protection for the Hawaiian damselflies or their habitat. The State of Hawaii has not listed these damselflies as endangered or threatened and so does not afforded them any protection under the State endangered species act. Nor does the State Water Code afford adequate protect from the adverse effects of water development projects. The State of Hawaii manages the use of surface and ground water resources through the Commission on Water Resource Management (Water Commission), as mandated by the 1987 State Water Code (State Water Code, Hawaii Revised Statutes Chapter 174C-71, 174C-81-87, and 174C-9195 and Administrative Rules of the State Water Code, Title 13, Chapters 168 and 169). In the State Water Code, there are no formal requirements that project proponents or the Water Commission protect the habitats of fish and wildlife prior to issuance of a permit to modify surface or ground water resources.

The maintenance of instream flow, which is required to protect the habitat of damselflies and other aquatic wildlife, is regulated by the establishment of standards on a stream-by-stream basis (State Water Code, Hawaii Revised Statutes Chapter 174C-71 and Administrative Rules of the State Water Code, Title 13, Chapter 169). Currently, the interim instream flow standards represent the existing flow conditions in streams in the State as of 15 June 1988 for Molokai, Hawaii, Kauai and East Maui, and 19 October 1988 for West Maui and Leeward Oahu (Administrative Rules of the State Water Code, Title 13, Chapter 169-44-49).

However, the State Water Code does not provide for permanent or minimal instream flow standards for the protection of aquatic wildlife. Instead, modification of instream flow standards and stream channels can be undertaken at any time by the Water Commission or via public petitions to revise flow standards or modify stream channels in a specified stream (Administrative Rules of the State Water Code, Title 13, Chapter 169-36). Additionally, the Water Commission must consider economic benefits gained from out-of-stream water uses, and is not required to balance these benefits against instream benefits to aquatic fish and wildlife. Consequently, any stabilization of stream flow for the protection of Hawaiian damselfly habitat is subject to modification at a future date.

The natural value of Hawaii's stream systems have been recognized under the State of Hawaii Instream Use Protection Program (Administrative Rules of the State Water Code, Title 13, Chapter 169-20(2)). In the Hawaii Stream Assessment Report, prepared in coordination with the National Park Service (National Park Service 1990), the State Water Commission identified high quality rivers or streams, or portions of a rivers or streams, that may be placed within a wild and scenic river system. This report recommended that streams meeting certain criteria be protected from further development. However, there is no formal or institutional mechanism within the Water Code to designate and set aside these streams, or to identify and protect stream habitat for Hawaiian damselflies.

Existing Federal regulatory mechanisms that may protect Hawaiian damselflies and their habitat are also inadequate. The Federal Energy Regulatory Commission (FERC) has very limited jurisdiction in Hawaii. Hydroelectric power projects in Hawaii are not on navigable water, public lands, or United States reservations; do not use surplus water or water power from a Federal Government Dam; and do not affect the interests of interstate or foreign commerce. Thus, licensing of hydroelectric projects do not come under the purview of FERC.

However, hydropower developers in Hawaii may voluntarily seek licensing under FERC.

The U.S. Army Corps of Engineers (COE) also has some regulatory control over modifications of freshwater streams in the United States. For modifications (i.e. discharge of fill) of streams with an average annual flow greater than five cubic feet per second (cfs), the COE can issue individual Department of the Army (DOA) permits under Section 404 of the Clean Water Act. These permits are subject to public review, and must comply with the Environmental Protection Agency's 404(b)(1) guidelines and public comment requirements. However, in issuing these permits, the COE does not establish instream flow standards as a matter of policy. The COE normally considers that the public interest for instream flow is represented by the state water allocation rights or preferences (Regulatory Guidance Letter No 85-6), and project alternatives that supersede, abrogate, or otherwise impair the state water quantity allocations are not normally addressed as alternatives during permit review.

In cases where the COE district engineer does propose to impose instream flow standard on an individual DOA permit, this flow standard must reflect a substantial national interest. Additionally, if this instream flow standard is in conflict with a State water quantity allocation, then it must be reviewed and approved by the Office of the Chief Engineer in Washington, D.C. Currently, the setting of instream flow standards sufficient to conserve Hawaiian damselflies is not a condition that would be considered or included in a DOA individual permit. If this damselfly was listed as endangered or threatened, Federal interest in its conservation would be assured through consultation under Section 7 of the Endangered Species Act.

The COE may also authorize the discharge of fill into streams with an average annual flow of less than five cfs. These discharges are covered under a nationwide permit (33 CFR 330 Appendix A, Nationwide Permit 26). This permit is designed to expedite small scale activities that the COE considers to have only minimal environmental impacts (33CFR 330.1(b)). The U.S. Fish and Wildlife Service and the State Department of Land and Natural Resources have only 15 days to provide substantive site-specific comments following the issuance of a nationwide permit (33 CFR 330 Appendix A, Nationwide Permit Condition 13). Given the complexity of the impacts on Hawaiian damselflies from stream modifications and surface water diversions, the remoteness of project sites, and the types of studies necessary to determine project impacts and mitigation, this limited comment period does not allow for an adequate assessment of impacts. The listing of the Hawaiian damselflies as endangered or threatened species will insure that their conservation is adequately considered during consultation, as required under Section 7 of the Endangered Species Act.

Current Conservation Efforts: None.

E. ***Other natural or manmade factors affecting its continued existence.***

Not applicable.

REFERENCES

Asquith, A. 1995. Hawaiian Damselfly Survey: Population Checklist of Category 1 Candidate Species. Unpublished Document by U.S. Fish Wildl. Serv., Pacific Islands Office, Honolulu, HI.

Beardsley, J.W. 1962. On accidental immigration and establishment of terrestrial arthropods in Hawaii during recent years. Proc.Hawaii. Entomol. Soc. 18:99-109.

Beardsley, J.W. 1979. New immigrant insects in Hawaii: 1962 through 1976. Proc. Hawaii. Entomol. Soc. 23:35-44.

Bennett, W.C. 1931. Archaeology of Kauai. B.P. Bishop Mus. Bull. 80:1-156.

Bishop Museum of Honolulu. Hawaiian Terrestrial Arthropod Checklist, March 2002 version. http://ww2.bishopmuseum.org/HBS/checklist/query.asp?grp=Arthropod

Blackburn, T. 1884. Notes on Hawaiian Neuroptera, with descriptions of new species. Ann. Mag. Nat. Hist., (V) 14: 412-421. As referenced in: Zimmerman, E.C. 1948. Insects of Hawaii, Vol. 2. Apterygota -Thysanoptera. Univ. Hawaii Press, Honolulu.

Borror, D.J., C.A. Triplehorn and N.F. Johnson. 1989. Introduction to the Study of Insects, Sixth Ed. Saunders College Publishing, Philadelphia.

Cowles, L.E. 1977. Status of Damselflies (Odonata: Zygoptera) in Hawaii in 1977, with special reference to the endemic genus *Megalagrion* . Senior Honors Thesis, Dep. Biol., Univ. Hawaii, Manoa.

Cuddihy, L.W., and C.P. Stone. 1990. Alteration of native Hawaiian vegetation: Effects of humans, their activities and introductions. Univ. Hawaii Press, Honolulu. 138 pp.

Department of Geography, University of Hawaii. 1983. Atlas of Hawaii. Second edition. Univ. Hawaii Press, Honolulu. 238 pp..Devaney, D.M., M. Kelly, P.J. Lee, and L.S. Motteler. 1982. Kaneohe: A History of Change. The Bess Press, Honolulu, Hawaii.

Devick, W.S. 1991. Patterns of introduction of aquatic organisms to Hawaiian freshwater habitats: in Devick, W.S., New Direction in Research, Management and Conservation of Hawaiian Freshwater Stream Ecosystems, Proceedings of the 1990 Symposium on Freshwater Stream Biology and Fisheries Management, Dep. Land Nat. Resour., Honolulu, Hawaii.

Ego, K. 1956. Life history of freshwater gobies. Freshw. Game Fish Manage. Res. Proj. No. F-4-R. Honolulu, Hawaii.

Englund, R. and D.A. Polhemus. 1994. Maakua Stream biological assessment, Oahu, Hawaii. Environmental Technologies International, Honolulu, Hawaii.

Ford, J.I. and R.A. Kinzie, III. 1982. Life crawls upstream. Nat. Hist. 91:61-66.

Funasaki, G.Y., P.-L. Lai, L.M. Nakahara, J.W. Beardsley & A.K. Ota. 1988. A review of biological control introductions in Hawaii: 1890 to 1985. Proc. Hawaii. Entomol. Soc. 28:105- 160.

Gagne, W.C. 1980. Insect and myriopods of Kipahulu Valley below 2,000 feet: In Smith, C.W., Resources Base Inventory of Kipahulu Valley below 2,000 feet, Maui, Hawaii. Coop. Natl. Park. Res. Spec. Stud. Unit. Pp. 119-175.

Gagne, W.C. and F.G. Howarth. 1982. Assessment of Endangered and Threatened Status of Hawaiian Arthropods. Report to U.S. Fish and Wildlife Service, in Pacific Islands Office, Honolulu.

Giambelluca, T.W., M.A. Nullet, M.A. Rifgley, P.R. Eyre, J.E.T. Moncur, and S. Price. 1991. Drought in Hawaii. Report 87. State of Hawaii. Department of Land and Natural Resources, Commission on Water Resource Management.

Gillespie, R.G. and N. Reimer. 1993. The effect of alien predatory ants (Hymenoptera: Formicidae) on Hawaiian endemic spiders (Araneae: Tetragnathidae). Pacific Sci. 47:21-33.

Handy, E.S.C. and E.G. Handy. 1972. Native planters in old Hawaii. Their life, lore, and environment. B.P. Bishop Mus. Bull. 233:1-641.

Hardy, D.E. 1979. An ecological survey of Puaaluu Stream. Part III. Report on a preliminary entomological survey of Puaaluu Stream, Maui. Coop. Nat. Park Resour. Study Unit. Univ. Hawaii. Tech. Rep. 27:34-39.

Hardy, D.E. and M.D. Delfinado. 1980. Insect of Hawaii. Volume 13, Diptera: Cyclorrhapha III. Univ. Hawaii Press, Honolulu.

Harris, S., A. Rubissow, S. Edmunds, and J.-A. Cachola. 1993. Hawaii Streams. Document prepared for Commission on Water Resource Management, State of Hawaii. 40 pp.

Harwood, P.D. 1976. Dragonflies (Odonata) observed in Hawaii in 1973 and 1974. Proc. Hawaii. Entomol. Soc. 22:251-253.

Hawaii Stream Assessment. 1990. Department of Land and Natural Resources, State of Hawaii. 300 pp.

Heads, P.A. 1985. The effect of invertebrate and vertebrate predators on the foraging movements of Ischnura elegans larvae (Odonata: Zygoptera). Freshw. Biol. 15:559-571.

Heads, P.A. 1986. The costs of reduced feeding due to predator avoidance: potential effects on growth and fitness in Ischnura elegans larvae (Odonata: Zygoptera). Ecol. Entomol. 11:369-377.

Henrikson, B.-I. 1988. The absence of antipredator behavior in the larvae of Leucorrhinia dubia (Odonata) and the consequences for their distribution. Oikos 51:179-183.

Hibbard, D. and D. Franzen. 1991. The View from Diamond Head: Royal Residence to Urban Resort. Editions Limited, Honolulu, Hawaii. 221 pp.

Howarth, F.G. 1990. Hawaiian terrestrial arthropods: An overview. Bishop. Mus. Occas. Pap. 30:4-26.

Howarth, F.G. and W.P. Mull. 1992. Hawaiian Insects and Their Kin. Univ. Hawaii Press, Honolulu..Howarth, F.G., A. Asquith, and G. Nishida. 1994. Insect of Hawaii: Status and Trends. Unpublished manuscript.

Howarth, F.G. and A.C. Medeiros. 1989. Non-native invertebrates: in Stone, C.P. and D.B. Stone (eds), Conservation Biology in Hawaii. Univ. Hawaii Coop. Natl. Park Resour. Stud. Unit, Honolulu. Pp. 82-87.

Howarth, F.G. and G.W. Ramsay. 1991. The conservation of island insects and their habitats: in Collins, N.M. and J.A. Thomas (eds), The Conservation of Insects and Their Habitats, Academic Press, London. Pp. 71-107

Joesting, E. 1984. Kauai: The separate kingdom. Univ. Hawaii Press, Honolulu. Johnson, D.M. 1991. Behavioral ecology of larval dragonflies and damselflies. Trends Ecol. Evol. 6:8-13.

Jones, B.L., S.S.W. Chin, and J.C. Brice. 1984. Olokele rock avalanche, island of Kauai, Hawaii. Geol. 12:209-211.

Kennedy, C.H. 1917. Notes on the penes of damselflies (Odonata). No. 2. The close relations inter se of the Hawaiian Agrionines. Entomol. News 28:9-14.

Kennedy, C.H. 1920. Forty-two hitherto unrecognized genera and subgenera of Zygoptera. Ohio J. Sci. 21:83-88.

Kennedy, C.H. 1929. The origin of the Hawaiian Odonata fauna and its evolution within the islands. Proc. Fourth Int. Congr. Entomol. 2:978-981.

Kennedy, C.M. 1934. Kilauagrion dinesiotes, a new species of dragonfly (Odonata) from Hawaii. Annals Entomol. Soc. Am. 27:343-345.

Kido, M.H., P. Ha, and R.A. Kinzie III. 1993. Insect introductions and diet changes in and endemic Hawaiian amphidromous goby, Awaous stamineous (Pisces: Gobiidae). Pacific Sci. 47:43-50.

Kirby, W. F. 1890. A synonymic catalog of Neuroptera Odonata, or Dragonflies, with an appendix of fossil species. Gurney and.Jackson, London. 202pp. As referenced in: Zimmerman, E.C. 1948. Insects of Hawaii, Vol. 2. Apterygota - Thysanoptera. Univ. Hawaii Press, Honolulu.

Kirch, P.V. 1982. The impact of the prehistoric Polynesians on the Hawaiian ecosystem. Pacific Sci. 36:1-14.

Kirch, P.V. 1985. Feathered gods and fishhooks. Univ. Hawaii Press, Honolulu, Hawaii. 349 pp.

Lai, P.-Y. 1988. Biological control: A positive point of view. Proc. Hawaii. Entomol. Soc. 28:179-190.

McLachlan, R. 1883. Neuroptera of the Hawaiian Islands. - Part I. Pseudo-Neuroptera. Ann. Mag. Nat. Hist., (V) 12: 226-240. As referenced in: Zimmerman, E.C. 1948. Insects of Hawaii, Vol. 2. Apterygota - Thysanoptera. Univ. Hawaii Press, Honolulu.

McPeek, M.A. 1990a. Determination of species composition in the Enallagma damselfly assemblages of permanent lakes. Ecol. 71:83-98.

McPeek, M.A. 1990b. Behavioral differences between Enallagma species (Odonata) influencing differential vulnerability to predators. Ecol. 71:1714-1726.

Macan, T.T. 1977. The influence of predation on the composition of freshwater animal communities. Biol. Rev. 52:45-70.

MacDonald, G.A., D.A. Davis, and D.C. Cox. 1960. Geology and ground-water resources of the island of Kauai, Hawaii. Hawaii Division of Hydrology, Bull. No. 13. 212 pp.

Maciolek, J.A. 1982. Lakes and lake-like waters of the Hawaiian Archipelago. Occas. Pap. B.P. Bishop Mus. 25:1-14.

Meier, K.Z., J.P. Laurel and J.E. Maragos. 1993. State of Hawaii (USA). in Scott, D.A., A Directory of Wetlands in Oceania, The International Waterfowl and Wetlands Research Bureau, U.K., and Asia Wetland Bureau, Kuala Lumpur, Malaysia. 444 pp.

Moore, N.W. 1982. Conservation of Odonata - First steps towards a world strategy. Adv. Odontal. 1:205-211..Moore, N. W. 1983a. Territorial behavior in the genus *Megalagrion* (McLachlan) (Zygoptera: Coenagrionidae). Odonatologica 12(1): 87-92.

Moore, N. W. 1983b. Reflex immobilisation in the Hawaiian endemic genus *Megalagrion*

McLachlan (Zygoptera: Coenagrionidae). Odonatologica, 12(2): 161-165.

Moore, N.W. and W.C. Gagne. 1982. *Megalagrion* pacificum (McLachlan) - A preliminary study of the conservation requirements of an endangered species. Rep. Odon. Specialist group Int. Un. Conserv. Nat. Natur. Res. No 3:1-5.

Nafus, D.M. 1993a. Biological control agents and native parasitoids in the population system of the butterfly Hypolimnas bolinas (L.) (Lepidoptera: Nymphalidae). Micronesica, Suppl. 4:17-23.

NatureServe Explorer: An online encyclopedia of life [web application]. 2001. Version 1.6 . Arlington, Virginia, USA: NatureServe. Available: http://www.natureserve.org/explorer.

Nishida, G.M., Ed. 1994a. Hawaiian Terrestrial Arthropod Checklist, 2nd Ed. Bishop. Mus. Tech. Rep. No. [1]. 287 pp.

Nishida, G.M. 1994b. Taxonomic validation of Candidate species of insects (and related Arthropods) of the Hawaii Islands. Report prepared for the Nat. Biol. Surv., 61 pp.

O'Connor, P.J. 1990. Poaceae. in W.L. Wagner, D.R. Herbst and S. Sohmer, Manual of the Flowering Plants of Hawai'i. B.P. Bishop Mus. Spec. Publ. No. 83. 1853 pp.

Ogden Environmental and Energy Service. 1994. VA Medical and Regional Office Center Project Conceptual Mitigation Plan for Impacts on the Orange-black damselfly Population at Tripler Army Medical Center. 16 pp.

Olson, S.L. and H.F. James. 1982. Prodromus of the fossil avifauna of the Hawaiian Islands. Smithsonian Contrib. Zool. 1-59.

Parrish, J.D., J.A. Maciolek, A.S. Timbol, C.B. Hathaway, and S.E. Norton. 1984. Status of stream channel modification in Hawaii and its effects on native aquatic fauna. Pp. 83-84. Proc. 5th Conference in Natural Sciences, Hawaii, Volcanoes National Park. Coop. Natl. Park. Res. Stud. Unit, Univ. Hawaii.

Perkins, R.C.L. 1899. Neuroptera. D. Sharp, ed., Vol. 2:63-77. Cambridge Univ. Press, Cambridge.

Perkins, R.C.L. 1907. Insects at Kilauea, Hawaii. Proc. Hawaii. Entomol. Soc. 1:89-95.

Perkins, R.C.L. 1913. Introduction to Fauna Hawaiiensis. D. Sharp, ed., Vol. 1:xv-ccxxvii. Cambridge Univ. Press, Cambridge.

Polhemus, D.A., J. Maciolek, and J. Ford. 1992. An ecosystem classification of inland waters for the tropical Pacific islands. Micronesica 25:155-173.

Polhemus, D.A. 1993a. Damsels in distress: a review of the conservation status of Hawaiian *Megalagrion* damselflies (Odonata: Coenagrionidae). Aquatic Conservation: Marine and Freshwater Ecosystems 3:343-349.

Polhemus, D.A. 1993b. Conservation of aquatic insects: Worldwide crisis or localized threats? Amer. Zool. 33:588-598.

Polhemus, D.A. 1993c. A preliminary assessment of the impacts of hurricane Iniki on the aquatic insect faunas of streams on the Na Pali Coast, Kaua'i, Hawai'i. in Assessments of the impact of Hurricane Iniki on stream biota and ecosystems on Kaua'i. Department of Land and Natural Resources, Division of Aquatic Resources. State of Hawai'i. Pp. 59-88.

Polhemus, D.A. 1994a. Current status of *Megalagrion* populations on Oahu: 1990 - Present. Report to U.S. Fish & Wildlife Service, Pacific Islands Office.

Polhemus, D.A. 1994b. A revision of the Hawaiian damselflies in the genus *Megalagrion* (Odonata: Coenagrionidae). Unpublished report to U.S. Fish & Wildlife Service, Pacific Islands Office.

Polhemus, D.A. 1995. New Heteroptera and Odonata (Insecta) records and range extensions in the Hawaiian Islands. Bishop Mus. Occas. Pap. 42:42-43.

Polhemus, D.A., and A. Asquith. 1996. Hawaiian Damselfies: A Field Identification Guide. Hawaii Biological Survey Handbook, Bishop Museum Press, Honolulu, Hawaii. 122 pp.

Reimer, N.J. 1993. Distribution and impact of alien ants in vulnerable Hawaiian ecosystems: in D.F.Williams (ed), Exotic.Ants: Biology, Impact, and Control of Introduced Species. Westview Press, Boulder, Colorado. Pp. 11-22.

Reimer, N., J.W. Beardsley and G. Jahn. 1990. Pest ants in Hawaii. in Vander Meer, R.K, K. Jaffe and A. Cedeno (eds), Applied Myrmecology: A World Perspective. Westview Press, Boulder, Colorado, Pp. 40-50.

Schmidt, E. 1938. Check-list of Odonata of Oceania. Ann. Entomol. Soc. Am. 31:322-344.

Selys-Longchamps, E. 1876. Synopsis des Agrionines, 5me Legion: Agrion. Bull. Acad. Royal Belgique, (II) 41 (2,3): 1-282. As referanced in: Zimmerman, E.C. 1948. Insects of Hawaii, Vol. 2. Apterygota -Thysanoptera. Univ. Hawaii Press, Honolulu.

Simon, C.M., W.C. Gagne, F.G. Howarth, and F.J. Radovsky. 1984. Hawaii: A natural entomological laboratory. Bull. Entomol. Soc. Am.30:8-17.

Smith, C.W. 1985. Impact of alien plants on Hawai'i's native biota. in C.P.Stone and J.M. Scott (eds), Hawai'i's Terrestrial Ecosystems: Preservation and Management. Coop. National Park Resour. Study Unit, Univ. Hawaii, Honolulu.

Stearns, H.T. 1940. Geology and ground-water resources of the islands of Lanai and Kahoolawe, Hawaii. Bulletin 6 of the Division of Hydrography, Territory of Hawaii.

Stearns, H.T. and K.N. Vaksvik. 1935. Geology and ground-water resources of the island of Oahu, Hawaii. Bulletin 1 of the Division of Hydrography, Territory of Hawaii.

Stearns, H.T. 1985. Geology of the State of Hawaii. second edition. Pacific Books, Palo Alto, California.

Stone, C.P. 1985. Alien animals in Hawai'i's native ecosystems: toward controlling the adverse effects of introduced vertebrates: in Stone, C.P., and J.M. Scott (eds.), Hawai'i's terrestrial ecosystems: preservation and management. Coop. Natl. Park Resour. Stud. Unit, Univ. Hawaii, Honolulu. Pp. 251-297.

Stone, C.P. 1989. Hawai'i's wetlands, streams, fishponds, and pools. in C.P.Stone and D.B. Stone (eds), Conservation.Biology in Hawai'i. Coop. Natl. Park Resour. Study Unit, Univ. Hawaii, Honolulu. Pp. 125-136.

Summers, C.C. 1964. Hawaiian Fishponds. B.P. Bish. Mus. Spec. Publ. 52.

Takasaki, K.I., G.T. Hirashima, and E.R. Lubke. 1969. Water Resources of Windward Oahu, Hawaii. U.S. Geological Survey Water Supply Paper No. 1894:1-119. U.S. Gov. Printing Office, Washington, D.C.

U.S. Fish and Wildlife Service. 1985. Recovery plan for the Hawaiian waterbirds. U.S. Fish Wildl. Serv., Portland, Oregon. 99 pp.

U.S. Fish and Wildlife Service. 1995. Pacific Islands Ecoregion Coastal Ecosystems Program Proposal. U.S. Fish Wildl. Serv., Honolulu, Hawaii, 119 pp.

Van Dine, D.L. 1907. The introduction of top-minnows (natural enemies of mosquitoes) into the Hawaiian Islands. Haw. Agr. Exp. St. Press Bull. 20:1-10.

Wenkam, R. 1969. Kauai and the park county of Hawaii. Sierra Club, San Francisco. 160 pp.

Williams, F.X. 1936. Biological studies in Hawaiian water-loving insects. Part 1. Coleptera or beetles. Part 2. Odonata or dragonflies. Proc. Hawaii. Entomol. Soc. 9:235-345.

Wilson, Okamoto and Associates, Inc. 1993. Kawai Nui Marsh Master Plan: Development Project Report. Document prepared for Dep. Land and Natural Resour., State of Hawaii.

Wong, M.A. and T.T.Y. Wong. 1988. Predation of the Mediterranean fruit fly and oriental fruit fly (Diptera: Tephritidae) by the fire ant (Hymenoptera: Formicidae) in Hawaii. Proc. Hawaii. Entomol. Soc. 28:169-177.

Zimmerman, E.C. 1948a. Insects of Hawaii. Vol. 1. Introduction. xvii + 206pp. Univ. Hawaii Press, Honolulu.

Zimmerman, E.C. 1948b. Insects of Hawaii, Vol. 2. Apterygota - Thysanoptera. Univ. Hawaii Press, Honolulu..Zimmerman, E.C. 1948c. Insects of Hawaii, Vol. 3. Heteroptera. Univ. Hawaii Press, Honolulu.

Zimmerman, E.C. 1970. Adaptive radiation in Hawaii with special reference to insects. Biotropica 2:32-38.

PETITION TO LIST

Po‘olanui gall fly
(*Phaeogramma* sp.)

AS A FEDERALLY ENDANGERED SPECIES

CANDIDATE HISTORY

CNOR 11/15/94:	
CNOR 2/28/96:	C
CNOR 9/19/97:	C
CNOR 10/25/99:	C
CNOR 10/30/01:	C
CNOR 6/13/02:	C

TAXONOMY

Although flies in the family Tephritidae are most commonly thought of as agricultural pests (fruit flies), the Hawaiian Islands have at least 26 endemic tephritid species, which are found on native plants. Most of the endemic tephritids are placed in the genus *Trupanea* Schrank, but the endemic Hawaiian genus *Phaeogramma* Grimshaw (Tephritidae) was erected to contain species with unusual striped wing markings (Grimshaw 1901) (some authorities, however, view the erection of this genus to be unwarranted and consider species placed in *Phaeogramma* to belong in *Trupanea*). *Phaeogramma* species form stem galls on Hawaiian species of *Bidens* (Asteraceae). To date, two species of *Phaeogramma* have been described, *P. hispida* Hardy from Maui, and *P. vittipennis* Grimshaw from Moloka’i. Hardy and Delfinado (1980) tentatively included a series of specimens from Oahu's Waianae Mountains as *P. hispida*, and Swezey (1954) reported pupae that may have represented this species from Kauai. In 1991, Asquith et al. (1995) confirmed the presence of an additional, undescribed species of *Phaeogramma* on Kauai currently referred to as the po‘olanui gall fly (voucher specimens are deposited in the Bishop Museum in Honolulu, but this new species has not yet been formally described as of August 2002).

NATURAL HISTORY

The larvae of species in the genus *Trupanea*, which includes most of the endemic tephritids of Hawaii, typically develop in the flower heads of native Asteraceae such as *Dubautia*, *Argyroxyphium*, *Artemisia* and *Bidens* (Hardy & Delfinado 1980). However, at least one species of Hawaiian *Trupanea*, *T . celaenoptera* Hardy, forms stems galls on *Dubautia* at Pohakuloa on Hawai’i island, and a closely related species from Hualalai, *T. nigripennis* Hardy, may also be a gall-former.

The galls of the stem-galling poʻolanui gall fly develop in the internodes along the distal 0.5 m of stems and occasionally branches of its host plant. Gall development has not been examined, but only a single larva or pupa are found in each mature gall. Mature, third instar larva develop in an elongate oval feeding chamber only slightly larger than the larva itself. The longitudinal axis of the larva is oriented with the long axis of the stem or branch. Prior to pupation, the larva extends the feeding chamber for a short distance apically and then laterally to form an exit tunnel. A thin cuticular window is left at the end of the exit tunnel and the larva returns to the base of the feeding chamber to pupate.

The general structure of these galls and behavior of the larvae (Asquith et al. 1995) are similar to that described for other gallicolous Tephritidae (Goeden 1990a, b, Goeden & Headrick 1991). Phenology of adult emergence in the field has not been determined. Despite the fact the malaise traps were positioned in stands with galls, only two flies were caught in an entire two year period (Asquith et al. 1995). One individual was trapped in April and the other in August. This low incidence of capture underscores the rarity of this fly. For example, *Trupanea bidensicola* Hardy is also endemic to Kauai and develops only in the flower heads of *Bidens cosmoides* . During the same trapping period, however, over 300 individuals of *T. bidensicola* were captured in the malaise traps.

With one exception, galls of this species have been found only in plants of *Bidens cosmoides*. In the Wahiawa Mountains, galls were found in both *B. cosmoides* and a plant that was either *B. forbesii* or a *B. cosmoides* x *B. forbesii* hybrid (personal communication cited in U.S. Fish and Wildlife Service candidate assessment form). *Bidens cosmoides* is a mesic forest species, and is usually found under a canopy of *Metrosideros polymorpha* or *Acacia koa*, with an understory of *Melicope* spp. or *Coprosma* sp. The ground cover in this habitat is typically *Rubus* sp., or ferns. Herbarium specimen data indicate that *B. cosmoides* will also grow in wetter habitat, such as Kilohana Lookout on the edge of Wainiha Valley, but plants are extremely rare in these areas and appear never to support galls.

Thirty different stands of the host plant *Bidens cosmoides* have been surveyed. Over 4,400 plants have been examined and 740 galls observed. Galls occur in 20, or two thirds of the stands surveyed. The absolute number of galls in a stand is not related to number of plants in the stand, the amount of shade, or the slope. The poʻolanui gall fly does not appear to be strictly limited by the number of available plants, thus the average number of galls per plant rather than total number of galls is used as a measure of stand suitability. The average number of galls per plant in a stand ranges from 6 galls / 1000 plants to 4.5 galls / plant. In only three stands is the average greater than one gall per plant. There is a slight negative correlation between the percent shade and number of galls per plant, suggesting that flies select or do better in stands with more sunlight. There is also a slight negative correlation between the number of plants in a stand and the number of galls per plant, again indicating that females do not utilize all available plants in a stand, and plants can and frequently do support more than one gall.

Strong evidence for the effect of stand/plant condition on gall formation comes from the pre- and post hurricane (1992) surveys. A total of 72 galls were observed in a stand before the hurricane. In the survey after the hurricane, 438 galls were counted. Seventy-six of these were old galls, which corresponded closely with the total number observed before the hurricane. Over 360 galls developed the year following the hurricane. This explosion in gall development corresponded to an obvious flush in growth of the *Bidens* plants. This growth flush probably resulted from the increased sunlight reaching the understory from the canopy that had been opened by the hurricane. This suggests that galls develop more successfully in plants undergoing rapid growth. Three stands have experienced extinctions (only old galls were evident) and at least two stands are recently colonized (only new galls). While the data are limited, it appears that extinction in stands is roughly equal to colonization of stands, so that the total number of occupied stands is probably stable. Total emergence from old galls (77) was similar to the total emergence from new galls (80), again suggesting a stable population (flies had not yet emerged from post-hurricane survey stand).

Old galls show 50 percent successful emergence, with 25 percent parasitized, and another 25 percent with unexplained mortality (no emergence). This is a minimum estimate of parasitization because it is based on successful emergence of the parasitoid. Significant mortality can result without parasitoid emergence (personal communication 1996 cited in U.S. Fish and Wildlife Service candidate assessment form), thus a large part of the unexplained mortality may also be due to parasitoids. Of new galls, 20 percent are parasitized and 13 percent emerged. If new galls eventually have the same emergence success of old galls, there would be an emergence of approximately 150 adults from new galls surveyed (Post hurricane survey data from stand #7 were excluded from this estimate, approximately 150 adults would have emerged from that stand alone following the hurricane).

Successful emergence is positively related to stand size (number of plants in stand). Stands with more than 40 plants have significantly higher emergence success (% emergence) from old galls than stands with less than 40 plants. Successful emergence is also positively related to population size (number of galls in stand). Stands with six or more old galls have significantly greater emergence success from those galls than stands with less than six old galls, and there was no successful emergence from any stands with less than five galls. A similar disparity in emergence success is evident when all galls are used to assess population size.

While available surveys provide relative rather than absolute data on the total population size of the poʻolanui gall fly, given the small numbers discovered, it is instructive to roughly estimate the total population size of this fly. Although it is not known for how long galls persist on the plant, flies successfully emerged from 80 old galls (50 percent emergence). Assuming the same success emergence, approximately 150 adult flies would emerge from new galls surveyed (again, eliminating the unusual post-hurricane survey of stand #7). Assuming these numbers represent annual productions, then roughly between 100 and 200 adult flies emerge annually from the stands that have been surveyed.

Galls are found most abundantly in the narrow strip of mesic forest at the head and eastern ridges of Waimea Canyon between 1060-1160 m elevation. Galls are also found on Kumuwela Ridge, Kohua Ridge, Nawaimaka Ridge, Kapukapaia Ridge and the heads of some valleys between these ridges. A small, single patch of galls were also found at 1250 m in Kaahuamaa Flats, but galls are not found on *B. cosmoides* on the west slopes of Kokee or along the west rim of Waimea Canyon. The occurrence of galls in the Wahiawa Mountians, suggests that the fly probably also occurs on the ridges between Kapukapaia and Wahiawa such as Kalaukea Ridge, Nakanukalolo Ridge, Ohulelua Ridge, and the ridges of the Olokele and Hanapepe river drainages. This land is privately owned and has not been surveyed.

POPULATION STATUS

The U.S. Fish and Wildlife Service has located at least half the stands in the areas surveyed, and approximately half of the potential range of the poʻolanui gall fly has been surveyed. Thus, a liberal estimate of the annual emergence of adult poʻolanui gall flies on Kauai is between 500 and 1,000 flies. This would be an extraordinarily small total population for an insect, and especially for a fly. Even if the estimate is off by an order of magnitude, which seems unlikely, an entire fly species comprised of fewer than 10,000 individuals would still be remarkable. Tscharntke (1992) documented the local extinction of a stem boring moth despite an original population of 180,000 adults. Tscharntke (1992) also estimated that for the gall midge *Giraudiella inclusa* avoiding local extinction would require 11,000 adults or 84,000 larvae in galls.

The Hawaii Natural Heritage Program ranks the poʻolanui gall fly as Imperiled.

The U.S. Fish and Wildlife Service classifies the poʻolanui gall fly as a candidate for Endangered Species Act protection with a listing priority number of 5.

LISTING CRITERIA

A. *The present or threatened destruction, modification, or curtailment of its habitat or range.*

Historical range:	Hawaii (island of Kauai).
Current range:	Hawaii (island of Kauai), currently known from six populations. Wahiawa Mountains, ridges between Kapukapaia and Wahiawa such as Kalaukea Ridge, Nakanukalolo Ridge, Ohulelua Ridge, and the ridges of the Olokele and Hanapepe river drainages. Waimea Canyon, Kumuwela Ridge, Kohua Ridge, Nawaimaka Ridge, Kapukapaia Ridge and the heads of some valleys between these ridges. A small, single patch of galls was also found at 1250 m in Kaahuamaa Flats.
Land ownership:	This species occurs on State and private lands.

Native vegetation on all the main Hawaiian islands has undergone extreme alteration because of past and present land management practices including ranching, deliberate introduction of alien plants and animals, and agricultural development (Cuddihy and Stone 1990). Some of the primary threats facing this species are ongoing and threatened destruction and adverse modification of habitat be feral animals and alien plants.

Animals such as pigs, goats, axis deer, black-tailed deer, and cattle were introduced either by the early Hawaiians (pigs) or more recently by European settlers (all ungulate species) for food and/or commercial ranching activities. Over the 200 years following their introduction, their numbers increased and the adverse impacts of feral ungulates on native vegetation have become increasingly apparent. Beyond the direct effect of trampling and grazing native plants, feral ungulates have contributed significantly to the heavy erosion still taking place on most of the main Hawaiian islands.

The habitat of this fly, a narrow strip of mesic forest around Waimea Canyon and southern ridges, was heavily impacted by feral cattle in the last century (Wenkam 1969), decimating understory growth and probably severely reducing the numbers of its host plant, *Bidens cosmoides*. While feral cattle have been removed from the Kokee area, goats are extremely abundant on the drier slopes. Most stands on exposed ridges had plants with stems that had been severely grazed by goats. Because galls develop in the terminal part of the stem or branches, these plants could not support flies.

Capra hircus (goats), native to the Middle East and India, were first successfully introduced to the Hawaiian Islands in 1792. Feral goats now occupy a wide variety of habitats from lowland dry forests to montane grasslands on Kauai, Oahu, Molokai, Maui, and Hawaii, where they consume native vegetation, trample roots and seedlings, accelerate erosion, and promote the invasion of alien plants (Stone 1985, van Riper and van Riper 1982). Goats are significantly degrading the habitat of the Poʻolanui gall fly on dry slopes around Waimea Canyon. Most plants on open sunny slopes are continually cropped by goats and do not support galls (personal communication 1996 cited in U.S. Fish and Wildlife Service candidate assessment form).

Sus scrofa (pigs), originally native to Europe, Africa, and Asia, were introduced to Hawaii by the Polynesian ancestors of Hawaiians, and later by western immigrants. The pigs escaped domestication and invaded primarily wet and mesic forests and grasslands of Kauai, Oahu, Molokai, Maui, and Hawaii. While foraging, pigs root and trample the forest floor, encouraging the establishment of alien plants in the newly disturbed soil. Pigs also disseminate alien plant seeds through their feces and on their bodies, accelerating the spread of alien plants through native forest (Cuddihy and Stone 1990, Stone 1985). Foote and Carson (1995) experimentally demonstrated the detrimental affects of feral pigs in wet forest habitat on the island of Hawaii on Hawaiian picture-wings which, like the poʻolanui gall fly, are dependent on native host plants. Feral pigs are abundant throughout the range of the poʻolanui gall fly on Kauai. While pigs do not appear to directly eat the host plant *Bidens*, they have been observed to trample the trailing stems and introduce weeds such as blackberry (personal communication 1996 cited in U.S. Fish and Wildlife Service candidate assessment form).

Because *Bidens cosmoides*, and most populations of the poʻolanui gall fly, occur most abundantly in the mesic forests around Waimaea Canyon, they have suffered heavily from human impact due to the accessibility of this area. Much of the mesic forest in Kokee has been planted in exotic trees such as *Grevillea robusta*, *Eucalyptus* spp., *Macaranga tanarius*, *Cryptomeria* sp. and *Sequoia* sp. With few exceptions, *Bidens cosmoides* is absent in the understory of these exotic plantings. In addition, many of the roads and hiking trails in Kokee are built along the 3600-3800' contour where the plant and fly occur. These factors have resulted in the *B. cosmoides* being broken into an archipelago of smaller and increasingly isolated stands. The plant that serves as breeding sites for the gall fly occurs as understory vegetation beneath the canopy of the *Metrosideros polymorpha* (‘ohi’a) and koa trees, and is affected by competition with alien weeds. The po‘olanui gall fly is threatened by loss of its host plants due to competition with one or more alien plant species. The most significant of these appear to be *Psidium cattleianum* (strawberry guava), *Clidemia hirta* (Koster's curse), *Lantana camara* (lantana), *Rubus argutus* (prickly Florida blackberry), *Passiflora mollissima* (banana poka).

Strawberry guava, an invasive shrub or small tree native to tropical America, has become naturalized on all of the main Hawaiian islands. Strawberry guava is capable of forming dense stands that exclude other plant species (Cuddihy and Stone 1990). This alien plant grows primarily in mesic and wet habitats and provides food for several alien animal species, including feral pigs and game birds, which disperse the plant's seeds through the forest (Smith 1985, Wagner et al. 1985). Strawberry guava is considered one of the greatest alien plant threats to Hawaii's rain forests and is known to pose a direct threat to the habitat of the po‘olanui gall fly on the island of Kauai. Strawberry guava is a major invader of forests in the Kokee and Wahiawa area where it often forms single-species stands.

Koster's curse, a noxious shrub native to tropical America, was first reported on Oahu in 1941. It had spread through much of the Koolau Mountains by the early 1960s, and spread to the Waianae Mountains by 1970 (Cuddihy and Stone 1990). It poses a serious threat to the po‘olanui gall fly in the Wahiawa Mountains by displacing the host plants.

Prickly Florida blackberry was introduced to the Hawaiian Islands in the late 1800s (Haselwood and Motter 1976). The fruit are easily spread by birds to open areas where this plant can form dense, impenetrable thickets (Smith 1985). On Kauai, the habitat of the po‘olanui gall fly is seriously threatened by this noxious weed (Asquith et al. 1995). Like *Bidens cosmoides*, *Rubus* also responds to an open canopy, but grows much faster and clearly competes with *B. cosmoides* for space and light. For example, after the hurricane, an attempt was made to resurvey a large stand with many galls. The area had suffered a large blow-down, opening up most of the stand to direct sunlight. Before the hurricane, *Rubus* had been present in the stand but localized;.after the hurricane, *Rubus* had almost completely taken over the stand, covering all the *B. cosmoides* except those at the shaded periphery. In 19 of the 30 stands surveyed, *Rubus* was the dominant or co-dominant ground cover. Thus, *Rubus* and its facilitation by pigs, is clearly the most serious present threat to the maintenance of healthy *B. cosmoides* stands (Asquith et al. 1995).

Lantana, a native of the West Indies, became naturalized in dry to mesic forests and shrublands of the Hawaiian Islands before 1871 (Cuddihy and Stone 1990). This shrub often forms thick cover and produces chemicals that inhibit the growth of other plant species (Smith 1985). On Kauai, lantana is a major component of the vegetation around the east and west rims of Waimea Canyon and the southern ridges, and threatens the habitat and host plant of the po‘olanui gall fly (personal communication 1996 cited in U.S. Fish and Wildlife Service candidate assessment form). It also hosts an alien gall fly with in turn serves as a reservoir for alien parasitoid wasps.

A vine in the passionflower family, banana poka, was introduced to the islands in the 1920s, probably as an ornamental. This vine is extremely detrimental to certain wet forest habitats of Kauai, Maui, and Hawaii. Heavy growth of this vine can cause damage or death to the native trees by overloading branches, causing breakage, or by forming a dense canopy cover, intercepting sunlight and shading out native plants below. This weed is particularly threatening to the poʻolanui gall fly on Kauai because the fly requires flushing growth of its host plant which normally occurs in sunny areas, also favored by banana poka (Asquith et al. 1995).

B. *Overutilization for commercial, recreational, scientific, or educational purposes.*

Not applicable.

C. *Disease or predation.*

Over 2,500 alien arthropods are now established in Hawaii (Howarth 1990, Howarth et al. 1995, Nishida 1994), with a continuing establishment rate of 10-20 new species per year (Beardsley 1962, 1979). Many of these alien species have severe affects on the native Hawaiian insect fauna (Asquith 1995). Species of alien parasitic wasps pose the greatest threat to the poʻolanui gall fly. Hawaii has a limited number of native parasitic Hymenoptera (wasps), with none known to utilize Hawaiian Tephritidae as hosts. The alien parasitic eulphid wasp, *Euderus metallicus* causes 25 percent to 50 percent mortality of the poʻolanui gall fly (Asquith et al. 1995).

It is the combination of habitat (host plant) loss and isolation and parasitization by the wasp *Euderus metallicus* that is threatening the viability of the poʻolanui gall fly. Smaller stands sustain higher levels of parasitization and have lower emergence success, and stands with small numbers of galls (< 6) never have successful emergence of flies. Because newly colonized stands will have small numbers of galls, these will rarely, if ever produce adult flies. Parasitization by *Euderus metallicus* largely prohibits establishment of new colonies of the poʻolanui gall fly and restricts viable (reproducing) colonies to large, healthy stands of *B. cosmoides*.

Most phytophagous insects and all continental gall-forming tephritid species that have been examined are attacked by multiple species of parasitoids. In contrast, the poʻolanui gall fly appears to have evolved without pressures from parasitoid predation, and is probably particularly susceptible to parasitoids (Howarth 1990, Howarth & Ramsay 1991). It is important to note that *Euderus metallicus* exerts inverse density-dependent mortality on the poʻolanui gall fly (Asquith et al. 1995), which is not uncommon among insects (Morrison & Strong 1980 , Hassell 1982). *Euderus metallicus* is a generalist parasitoid, attacking a variety of Diptera, Lepidoptera, and Coleoptera larvae (Yoshimoto 1965). It probably has no trouble finding other suitable hosts in the mesic forest habitat around Waimea Canyon, which may explain why high densities of galls are not exploited once they are discovered. Thus, while *E. metallicus* restricts the establishment of new populations of the poʻolanui gall fly, large established populations may be able to survive this predation pressure. The threat to large populations would be a parasitoid that selectively searches for gall forming insects and/or exhibits a density-dependent mortality.

For example, one of the techniques that is currently being developed for pest fruit fly control in Hawaii, is the importation and mass release of parasitoids (USDA-APHIS 1992). Although these parasitoids are generally host specific, some are known to attack tephritid flies that form galls, such as *Procecidochares utilis* Stone on *Eupatorium adenophorum* (Maui Pamakani), and *Eutreta xanthochaeta* Aldrich on *Lantana camara*.(Hardy and Delfinado 1980). One species of braconid, *Diachasmimorpha longicaudata* (Ashmead) attacks galls on lantana within a few meters of *Bidens* *cosmoides* in Kokee. Species of tephritid that can support parasitoid development, such as *Eutreta xanthochaeta*, serve as a reservoir for parasitoids, and allow for selection among parasitoids for ovipositing in galls. *Diachasmimorpha longicaudata* now parasitizes more than 30 percent of lantana galls in the Kokee area and appears to have evolved a gall-adapted race since being released for control of pest fruit flies (personal communication 1996 cited in U.S. Fish and Wildlife Service candidate assessment form).

If these or other introduced parasitoids with limited host ranges remain in and exploit stands with many galls, then even the large, healthy populations of the po‘olanui gall fly will be jeopardized. It is important to note that a parasitoid does not have to successfully develop in a fly larva to cause mortality. Even probing and oviposition by the adult female wasp can result in death to the fly larva (personal communication 1996 cited in U.S. Fish and Wildlife Service candidate assessment form). In recent field trials, caged *D. longicaudata* wasps were observed to probe into po‘olanui gall fly galls (personal communication 1996 cited in U.S. Fish and Wildlife Service candidate assessment form). Thus, inundative releases of these wasps or introductions of new species pose potential threats to the po‘olanui gall fly.

D. *The inadequacy of existing regulatory mechanisms.*

No current protection.

Current Conservation Efforts: None.

E. *Other natural or manmade factors affecting its continued existence.*

Alien parasitic wasps pose a threat to the gall flies, and some alien species are purposefully introduced by Federal and State agencies for biological control of pests flies. Federal regulations for controlling the introduction of biocontrol agents are inadequate (Lockwood 1993). The U.S. Environmental Protection Agency (EPA) under the authority of the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA), regulates biological control agents as pesticides. However, EPA only regulates microorganisms (bacteria, fungi, protozoa and viruses). EPA has exempted all other organisms from requirements of FIFRA because it has determined that they are adequately regulated by the U.S. Department of Agriculture’s Animal and Plant Health Inspection Service (USDA-APHIS).

Although the State of Hawaii requires that new introductions be reviewed by special committees before release (HRS Chapt. 150A), post-release biology and host range cannot be predicted from laboratory studies (Gonzalez and Gilstrap 1992, Roderick 1992) and the purposeful release or augmentation of any dipteran predator or parasitoid is a potential threat to gall flies.

REFERENCES

Asquith, A. 1995. Alien species and the extinction crisis of Hawaii’s invertebrates. Endangered Species Update 12:6-11.

Asquith, A., S. Seiler, and E. Miramontes. 1995. Taxonomy and conservation status of the Poʻolanui gall fly (Diptera: Tephritidae: *Phaeogramma*). Report to U.S. Fish & Wildlife Service, Pacific Islands Ecosystem.

Beardsley, J.W. 1962. On accidental immigration and establishment of terrestrial arthropods in Hawaii during recent years. Proc. Hawaii. Entomol. Soc. 18:99-109.

Beardsley, J.W. 1979. New immigrant insects in Hawaii: 1962 through 1976. Proc. Hawaii. Entomol. Soc. 23:35-44..Cuddihy, L.W. and C.P. Stone. 1990. Alteration of the native Hawaiian vegetation; effects of humans, their activities and introductions. Coop. Natl. Park Resources Stud. unit, Hawaii.

Foote, D. and H.L. Carson. 1995. *Drosophila* as monitors of change in Hawaiian ecosystems. In E.T. LaRoe, G.S. Farris, C.E. Puckett, P.D. Doran, and M.J. Mac, editors, Our Living Resources: A Report to the Nation on the Distribution, Abundance, and Health of U.S. Plants, Animals, and Ecosystems. U.S. Department of Interior, National Biological Service, Washington D.C.

Funasaki, G.Y., P.-L. Lai, L.M. Nakahara, J.W. Beardsley & A.K. Ota. 1988. A review of biological control introductions in Hawaii: 1890 to 1985. Proc. Hawaii. Entomol. Soc. 28:105- 160.

Gagne, W.C. 1979. Canopy-associated arthropods in Acacia koa and Metrosideros tree communities along an altitudinal transect on Hawaii Island. Pac. Insects 21:56-82.

Goeden, R.D. 1990a. Life history of *Eutreta diana* (Osten Sacken) on *Artemisia tridentata* Nuttall in Southern California (Diptera: Tephritidae). Pan-Pacific Entomologist 66:24-32.

Goeden, R.D. 1990b. Life history of *Eutreta simplex* Thomas on *Artemisia ludoviciana* Nuttall in Southern California (Diptera: Tephritidae). Pan-Pacific Entomologist 66:33-38.

Goeden, R.D. & D.H. Headrick. 1991. Life history of descriptions of immature stages of *Tephritis baccharis* (Coquillet) on *Baccharis salicifolia* (Ruiz & Pavon) Persoon in Southern California (Diptera: Tephritidae) Pan-Pacific Entomologist 67:86-98.

Grimshaw. P.H. 1901. Diptera. D. Sharp, ed., Vol.3:1-77. Cambridge University Press,

Cambridge..Hassell, M.P. 1982. Patterns of parasitism by insect parasitoids in patchy environments. Ecol. Entomol. 7:365-377.

Hardy, D.E. & M.D. Delfinado. 1980. Insects of Hawaii. Vol. 13. Diptera: Cyclorrhapha III.University of Hawaii Press, Honolulu.

Howarth, F.G. 1990. Hawaiian terrestrial arthropods: An overview. Bishop. Mus. Occas. Pap. 30:4-26.

Howarth, F.G. & G.W. Ramsay. 1991. The conservation of island insects and their habitats. pp. 71-107. In: *The Conservation of Insects and Their Habitats* . (N.M. Collins & J.A.Thomas, eds.). Academic Press, London.

Howarth, F.G., G. Nishida, and A. Asquith. 1995. Insects of Hawaii: Status and Trends. In E.T. LaRoe, G.S. Farris, C.E. Puckett, P.D. Doran, and M.J. Mac, editors, Our Living Resources: A Report to the Nation on the Distribution, Abundance, and Health of U.S. Plants, Animals, and Ecosystems. U.S. Department of Interior, National Biological Service, Washington D.C.

Lockwood, J.A. 1993. Environmental issues involved in biological control of rangeland grasshoppers (Orthoptera: Acrididae) with exotic agents. Environ. Entomol. 22:503-518.

Morrison, G. & D.R. Strong, Jr. 1980. Spatial variations in host density and the intensity of parasitism: some empirical examples. Environ. Entomol. 9:149-152.

Nafus, D.M. 1993. Biological control agents and native parasitoids in the population system of the butterfly *Hypolimnas bolinas* (L.) (Lepidoptera: Nymphalidae). Micronesica, Suppl. 4:17-23.

NatureServe Explorer: An online encyclopedia of life [web application]. 2001. Version 1.6 . Arlington, Virginia, USA: NatureServe. Available: http://www.natureserve.org/explorer.

Nishida, G.M., Ed. 1994. Hawaiian Terrestrial Arthropod Checklist, 2nd Edition. Bishop. Mus. Technical Report No. [1]. 287 pp..Smith, C.W. 1985. Impact of alien plants on Hawai'i's native biota: in Stone, C.P., and J.M. Scott (eds.), Hawai'i's terrestrial ecosystems: preservation and management. Coop. Natl. Park Resources Stud. Unit, Univ. Hawaii, Honolulu, pp. 180-250.

Stone, C.P. 1985. Alien animals in Hawai'i's native ecosystems: toward controlling the adverse effects of introduced vertebrates: in Stone, C.P., and J.M. Scott (eds.), Hawai'i's terrestrial ecosystems: preservation and management. Coop. Natl. Park Resources Stud. Unit, Univ. Hawaii, Honolulu, pp. 251-297.

Swezey, O.H. 1954. Forest Entomology in Hawaii. B.P. Bishop Museum Special Publication 44. 266 pp.

Tomich, P.Q. 1986. Mammals in Hawai'i; a synopsis and notational bibliography. 2nd ed. Bishop Museum Press, Honolulu. 375 pp.

Tscharntke, T. 1992. Fragmentation of *Phragmites* habitats, minimum viable population size, habitat suitability, and local extinction of moths, midges, flies, aphids and birds. Conserv. Biol. 6:530-536.

USDA-APHIS. 1993. The Hawaiian Tephritid Fruit Fly Eradication Research Action Plan. Makaha, HI.

van Riper, S.G., and C. van Riper III. 1982. A field guide to the mammals in Hawaii. The Oriental Publishing Company, Honolulu. 68 pp.

Wenkam, R. 1969. Kauai and the park county of Hawaii. Sierra Club, San Fransisco. 160 pp.

Yoshimoto, C.M. 1965. Synopsis of Hawaiian Eulophidae including Aphelininae (Hym.: Chalcidoidea). Pacific Insects 7:665-669.

Zimmerman, E.C. 1948. Insects of Hawaii. Vol.1. Introduction. xvii+206 pp. University of Hawaii Press..

PETITION TO LIST

pomace fly
(*Drosophila attigua*)

AS A FEDERALLY ENDANGERED SPECIES

CANDIDATE HISTORY

CNOR 2/28/96:	C
CNOR 9/19/97:	C
CNOR 10/25/99:	C
CNOR 10/30/01:	C
CNOR 6/13/02:	C

TAXONOMY

Among the most remarkable and best studied group of Hawaiian insects are the drosophilid flies (Williamson 1981). To date, 511 species of Hawaiian Drosophilidae have been formally described. An additional 250-300 species are already in the collection at the University of Hawaii and await taxonomic treatment, and new species are still being discovered from localities not previously sampled. It is estimated that as many as 1,000 species may be present in native Hawaiian ecosystems (Kaneshiro 1993). This family in Hawaii represents one of the most remarkable cases of adaptive radiation of any group of animals known (Hardy and Kaneshiro 1981).

The taxonomic status of *Drosophila attigua* as a valid species is uncontroversial (e.g., Bishop Museum 2002).

NATURAL HISTORY

Unlike most Hawaiian insects which remain obscure, often known only from their original taxonomic descriptions, every aspect of Hawaiian Drosophilidae biology has been researched, including their internal and external morphology, behavior, ecology, physiology, biochemistry, the banding sequence of giant chromosomes, and detailed analyses of the structure of the DNA molecules. More than 80 research scientists and over 350 undergraduates, graduate students, and post-doctoral fellows have participated in research on the Hawaiian Drosophilidae, resulting in over 600 scientific publications on the biology of these flies. The Hawaiian Drosophilidae is arguably the most intensively studied group of all terrestrial Hawaiian organisms.

Research on Hawaiian Drosophilidae has resulted in the development and testing of new theories of evolutionary biology (Bradley et al. 1991, Carson 1971, 1982a, Kaneshiro 1976, 1980, 1987, 1989). Ideas on speciation and island evolution developed from studies on Hawaiian Drosophilidae are now referenced in most modern text books of biology and evolution (e.g. Ridley 1993).

The Hawaiian *Drosophila* Project at the University of Hawaii has coordinated and cooperated in most of the research on the Hawaiian Drosophilidae. It has also maintained extensive collection records of these species. These records form the basis for much of the data used to develop this proposed rulemaking. Three decades of collection work are maintained in permanent files of the Hawaiian Drosophila Project within the University of Hawaii's Center for Conservation Research and Training. Also, collection notes of the individual researchers on the project contain extensive records of host plant associations of most of these species.

Behavior

The general life cycle of Hawaiian Drosophilidae is typical of that of many flies: after mating, females lay eggs from which larvae (immature stage) hatch; as larvae grow they molt (shed their skin) through several successive stages (instars); when fully grown the larvae pupate, metamorphosing and emerging as adults. The courtship and mating behaviors of some species (Hawaiian picture-wings) are extremely elaborate, with exaggerated visual cues displayed by the males. These flies have been referred to as the "birds of paradise" of the insect world because of their spectacular courtship displays and territorial defense. Males occupy territories which serve as mating arenas to which receptive females are attracted for mating. The males fight among themselves for the best territories and establish a dominance hierarchy like some birds and mammals.

Habitat

The Hawaiian Drosophilidae have radiated and adapted ecologically to a tremendous diversity of ecosystems ranging from desert-like habitats where the soil is powdery dry, to rain forests with lush, tree-fern jungles, and swampland perpetually shadowed by rain clouds and with vegetation that is burdened with dripping, moss-laden branches. While the larval stages of most species are saprophytic, feeding on decaying vegetation such rotting leaves, bark, flowers, and fruits, some have become highly specialized, e.g., being carnivorous on egg masses of spiders, or feeding on green algae growing underwater on boulders in streams. As a group, the Hawaiian Drosophilidae appear to be ubiquitous and can be found in most of the natural communities in Hawaii.

Distribution

Hawaiian drosophilids are distributed throughout the high islands of the archipelago, displaying not only a highly characteristic single island endemism, but also extraordinary morphological diversity along with adaptations which show their intimate ecological relationship to the native flora (Carson and Yoon 1982).

Drosophila attigua is endemic to the island of Kauai, where it apparently breeds in the stems and branches of *Cheirodendron*.

POPULATION STATUS

Biologists have observed a general decline of the Hawaiian Drosophilidae along with other components of the native ecosystem. As noted by Spieth (1980), during the early part of the century, the Tantalus area behind the city of Honolulu was the major spot for collecting *Drosophila*. By 1963 the majority of the native *Drosophila* species in this area had been exterminated, apparently due to intrusion of exotic vegetation and predation by ants. Quantitative sampling since 1971 has demonstrated dramatic declines in the abundance of some species and in other cases local extirpations (Carson 1986, Foote and Carson 1995). A review of the data collected by the Hawaii *Drosophila* Project and assessment of the threats to remaining populations suggests that at least 14 species of these flies are presently threatened with extinction.

It is believed that for many of the Hawaiian *Drosophila* species, populations are extremely small and patchy. *Drosophila attigua* may be stable at small population levels. Any threat to its host plant could be catastrophic to this species (Kaneshiro in NatureServe Explorer 1997).

The U.S. Fish and Wildlife Service classifies *Drosophila attigua* as a candidate for Endangered Species Act protection with a listing priority number of 2.

LISTING CRITERIA

A. *The present or threatened destruction, modification, or curtailment of its habitat or range.*

Historical range:	Hawaii (island of Kauai).
Current range:	Hawaii (island of Kauai). This species is known from two populations, Pihea on the western end of the Alakai Swamp, and Mt. Kahili east of the Alakai massif.
Land ownership:	This species occurs on State and private lands.

Native vegetation on all the main Hawaiian islands has undergone extreme alteration because of past and present land management practices including ranching, deliberate introduction of alien plants and animals, and agricultural development (Cuddihy and Stone 1990). Some of the primary threats facing this species are ongoing and threatened destruction and adverse modification of habitat by feral animals and alien plants.

Animals such as pigs, goats, axis deer, black-tailed deer, and cattle were introduced either by the early Hawaiians (pigs) or more recently by European settlers (all ungulate species) for food and/or commercial ranching activities. Over the 200 years following their introduction, their numbers increased and the adverse impacts of feral ungulates on native vegetation have become increasingly apparent. Beyond the direct effect of trampling and grazing native plants, feral ungulates have contributed significantly to the heavy erosion still taking place on most of the main Hawaiian islands.

Sus scrofa (pigs), originally native to Europe, Africa, and Asia, were introduced to Hawaii by the Polynesian ancestors of Hawaiians, and later by western immigrants. The pigs escaped domestication and invaded primarily wet and mesic forests and grasslands of Kauai, Oahu, Molokai, Maui, and Hawaii. While foraging, pigs root and trample the forest floor, encouraging the establishment of alien plants in the newly disturbed soil. Pigs also disseminate alien plant seeds through their feces and on their bodies, accelerating the spread of alien plants through native forest (Cuddihy and Stone 1990, Stone 1985). Foote and Carson (1995) experimentally demonstrated the detrimental affects of feral pigs on Hawaiian picture-wings in wet forest habitat on the island of Hawaii.

Capra hircus (goats), native to the Middle East and India, were first successfully introduced to the Hawaiian Islands in 1792. Feral goats now occupy a wide variety of habitats from lowland dry forests to montane grasslands on Kauai, Oahu, Molokai, Maui, and Hawaii, where they consume native vegetation, trample roots and seedlings, accelerate erosion, and promote the invasion of alien plants (Stone 1985, van Riper and van Riper 1982). Goats are significantly degrading the habitat of *Drosophila attigua* on Mt. Kahili.

Most of the plants which serve as breeding sites for Hawaiian picture-wings occur as understory vegetation beneath the canopy of the *Metrosideros polymorpha* (‘ohi’a) and koa trees, and are affected by competition with alien weeds. Hawaiian picture-wing species are threatened by loss of host plants due to competition with one or more alien plant species. The most significant of these appear to be *Schinus terebinthifolius* (Christmasberry), *Psidium cattleianum* (strawberry guava), *Melinus minutiflora* (molasses grass), *Pennisetum setaceum* (fountain grass), *Clidemia hirta* (Koster's curse), *Lantana camara* (lantana), *Rubus argutus* (prickly Florida blackberry), *Passiflora mollissima* (banana poka), and *Rubus ellipticus* (Himalayan raspberry). Strawberry guava, an invasive shrub or small tree native to tropical America, has become naturalized on all of the main Hawaiian islands. Like Christmasberry, strawberry guava is capable of forming dense stands that exclude other plant species (Cuddihy and Stone 1990). This alien plant grows primarily in mesic and wet habitats and provides food for several alien animal species, including feral pigs and game birds, which disperse the plant's seeds through the forest (Smith 1985, Wagner et al. 1985). Strawberry guava is considered one of the greatest alien plant threats to Hawaii's rain forests and is known to pose a direct threat to *Drosophila attigua* on the island of Kauai. Strawberry guava is a major invader of forests in the Kahili area where it often forms single-species stands.

Koster's curse, a noxious shrub native to tropical America, was first reported on Oahu in 1941. It had spread through much of the Koolau Mountains by the early 1960s, and spread to the Waianae Mountains by 1970 (Cuddihy and Stone 1990). It poses a serious threat to *Drosophila attigua* by displacing native plants used by this Hawaiian picture-wings as breeding sites. Prickly Florida blackberry was introduced to the Hawaiian Islands in the late 1800s (Haselwood and Motter 1976). The fruit are easily spread by birds to open areas where this plant can form dense, impenetrable thickets (Smith 1985). On Kauai, the habitat of *Drosophila attigua* is threatened by this noxious weed.

A vine in the passionflower family, banana poka was introduced to the islands in the 1920s, probably as an ornamental. This vine is extremely detrimental to certain wet forest habitats of Kauai, Maui, and Hawaii. Heavy growth of this vine can cause damage or death to the native trees by overloading branches, causing breakage, or by forming a dense canopy cover, intercepting sunlight and shading out native plants below. This weed threatens *Drosophila attigua* on Kauai.

B. ***Overutilization for commercial, recreational, scientific, or educational purposes.***

Not applicable.

C. ***Disease or predation.***

Over 2500 alien arthropods are now established in Hawaii (Howarth 1990, Howarth *et al.* 1995, Nishida 1994), with a continuing establishment rate of 10-20 new species per year (Beardsley 1962, 1979). Many of these alien species have severe affects on the native Hawaiian insect fauna (Asquith 1995). Species of social Hymenoptera (ants and some wasps) and parasitic wasps pose the greatest threat to the Hawaiian picture-wings. Ants and other social insects frequently dominate the ecologies of tropical ecosystems and strongly influence the evolution of certain plants and animals. All of the native Hawaiian arthropods, including the Hawaiian picture-wings, evolved without the predation influence of ants or social wasps, and the arrival of these new groups 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 1870s, 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 and Reimer 1993), and it has been documented to completely exterminate populations of native insects.

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.

The long-legged ant (*Anoplolepis longipes*) appeared in Hawaii in 1952 and now occurs on Oahu, Maui, and Hawaii (Reimer et al. 1990). It inhabits low elevation (less than 600 m [2,000 ft]), rocky areas of moderate rainfall (less than 250 cm [100 in] annually) (Reimer et al. 1990). Direct observations indicate that Hawaiian arthropods are susceptible to predation by this species (Gillespie and Reimer 1993) and Hardy (1979) documented the disappearance of most native insects from Kipahulu Stream on Maui after the area was invaded by the long-legged ant.

At least two species of fire ants, *Solenopsis geminita* and *Solenopsis papuana*, are also important threats (Reagan 1986; Gillespie and Reimer 1993) and occur on all the major islands (Reimer et al. 1990). *Solenopsis geminita* is known to be a significant predator on pest fruit flies in Hawaii (Wong and Wong 1988). *Solenopsis papuana* is the only abundant, aggressive ant that has invaded intact mesic forest above 600 m (2,000 ft) and is still expanding its range in Hawaii (Reimer 1993).

Numerous other ant species are recognized as threats to native invertebrates, and additional species become established almost yearly. While the larvae of most of the Hawaiian picture-wings feed deep in the substrate of the host plant, they emerge and move away to pupate in the ground, thus exposing themselves to predation by ants. Upon newly emerging as adults, these flies are particularly susceptible to predation and adult picture-wings have been observed with a ants attached to their legs (Kaneshiro and Kaneshiro 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, 1990, Gambino and 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 and Loope 1992). Yellowjackets have been observed preying on Hawaiian picture-wings Kaneshiro and Kaneshiro 1995), and the establishment of this species on the island of Hawaii corresponded with a significant decline in several species of Hawaiian picture-wings.(Carson 1982b, 1986, Foote and Carson 1995). Yellowjackets pose a serious threat to all Hawaiian picture-wing species in this proposed rulemaking.

Hawaii also has a limited number of native parasitic Hymenoptera (wasps), with only species of Eucoiliidae recorded to utilize Hawaiian picture-wings as hosts. Several species of alien braconid wasps, *Diaschasmimorpha tryoni, D. longicaudatus, Opius vandenboschi*, and *Biosteres arisanus*, were purposefully introduced into Hawaii to control several species of pest tephritid fruit flies (Funasaki et al. 1988). However, none of these wasps are specific to the pest flies, but are known to attack other species of flies, including native Hawaiian Tephritidae. While these wasps have not been recorded from Hawaiian picture-wings, and may not successfully develop in Drosophilidae, females will sting any fly larva available and can cause significant mortality (personal communication 1995 cited in U.S. Fish and Wildlife Service candidate assessment form). Inundative releases of these wasps or introductions of new species pose potential threats to Hawaiian picture-wings.

D. ***The inadequacy of existing regulatory mechanisms.***

No current protection exists.

Current Conservation Efforts: None.

E. ***Other natural or manmade factors affecting its continued existence.***

Alien parasitic wasps pose a threat to the Hawaiian picture- wings, and some alien species are purposefully introduced by Federal and State agencies for biological control of pests flies. Federal regulations for controlling the introduction of biocontrol agents are inadequate (Lockwood 1993). The U.S. Environmental Protection Agency (EPA) under the authority of the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA), regulates biological control agents as pesticides. However, EPA only regulates microorganisms (bacteria, fungi, protozoa and viruses). EPA has exempted all other organisms from requirements of FIFRA becuase it has determined that they are adequately regulated by the U.S. Department of Agriculture's Animal and Plant Health Inspection Service (USDA-APHIS).

Although the State of Hawaii requires that new introductions be reviewed by special committees before release (HRS Chapt..150A), post-release biology and host range cannot be predicted from laboratory studies (Gonzalez and Gilstrap 1992, Roderick 1992) and the purposeful release or augmentation of any dipteran predator or parasitoid is a potential threat to Hawaiian picture-wings.

REFERENCES

Asquith, A. 1995. Alien species and the extinction crisis of Hawaii's invertebrates. Endangered Species Update 12:6-11.

Beardsley, J.W. 1962. On accidental immigration and establishment of terrestrial arthropods in Hawaii during recent years. Proc. Hawaii. Entomol. Soc. 18:99-109.

Beardsley, J.W. 1979. New immigrant insects in Hawaii: 1962 through 1976. Proc. Hawaii. Entomol. Soc. 23:35-44.

Bishop Museum of Honolulu. Hawaiian Terrestrial Arthropod Checklist, March 2002 version. http://ww2.bishopmuseum.org/HBS/checklist/query.asp?grp=Arthropod

Bradley, R.D., S.K. Davis, and R.J. Baker. 1991. Genetic Control of Premating-Isolating Behavior: Kaneshiro's Hypothesis and Asymmetrical Sexual Selection in Pocket Gophers. J. Heredity. 82:192-196.

Carson, H.L. 1971. Speciation and the Founder Principle. Stadler Symposia. Vol. 3:51-70. University of Missouri..Carson, H.L. 1982a. Speciation as a Major Reorganization of Polygenic Balances, in Mechanisms of Speciation. pp. 411-433.

Carson, H.L. 1982b. Fluctuations in size of certain *Drosophila* populations in the Olaa Tract Hawaii Volcanoes National Park, in Proc. Fourth Conf. in Natural Sciences, Hawaii Volcanoes National Park, p. 40. [abstract]. Cooperative National Park Resources Unit, Department of Botany, Univ. of Hawaii.

Carson, H.L. 1986. Drosophila populations in the Olaa Tract, Hawaii Volcanoes National Park, 1971-1986. in Proc. Sixth Conf. in Natural Sciences, Hawaii Volcanoes National Park. [abstract]. Cooperative National Park Resources Unit, Department of Botany, Univ. of Hawaii.

Carson, H.L. and J.S. Yoon. 1982. Genetics and Evolution of Hawaiian *Drosophila*, in Genetics and Biology of Drosophila. J. Thompson, H.L. Carson, and M. Ashburner eds., Acad. Press, New York.

Cole, F.R., A.C. Medeiros, L.L. Loope, and W.W. Zuehlke. 1992. Effects of the Argentine ant on arthropod fauna of Hawaiian high-elevation shrubland. Ecology 73:1313- 1322.

Cuddihy, L.W. and C.P. Stone. 1990. Alteration of the native Hawaiian vegetation; effects of humans, their activities and introductions. Coop. Natl. Park Resources Stud. unit, Hawaii.

Foote, D. and H.L. Carson. 1995. Drosophila as monitors of change in Hawaiian ecosystems. In E.T. LaRoe, G.S. Farris, C.E. Puckett, P.D. Doran, and M.J. Mac, editors, Our Living Resources: A Report to the Nation on the Distribution, Abundance, and Health of U.S. Plants, Animals, and Ecosystems. U.S. Department of Interior, National Biological Service, Washington D.C.

Funasaki, G.Y., P.-L. Lai, L.M. Nakahara, J.W. Beardsley & A.K. Ota. 1988. A review of biological control introductions in Hawaii: 1890 to 1985. Proc. Hawaii. Entomol. Soc. 28:105- 160.

Gagne, W.C. 1979. Canopy-associated arthropods in *Acacia koa* and *Metrosideros* tree communities along an altitudinal transect on Hawaii Island. Pac. Insects 21:56-82.

Gambino, P., A.C. Medeiros, and L.L. Loope. 1987. Introduced vespids *Paravespula pensylvanica* prey on Maui's endemic arthropod fauna. J. Trop. Ecol. Vol. 3:169-170.

Gambino, P., A.C. Medeiros, and L.L. Loope. 1990. Invasion and colonization of upper elevations on East Maui (Hawaii) by *Paravespula pennsylvanica* (Hymenoptera: Vespidae). Annals of the Entomological Society of America 83**:**1088-1095.

Gambino, P. and L.L. Loope. 1992. Yellowjacket *Vespula pennsylvanica* biology and abatement in the National Parks of Hawaii. Cooperative National Park Resources Studies Unit, Hawaii, Technical Report 86**:**1-41.

Gillespie, R.G. and N. Reimer. 1993. The effect of alien predatory ants (Hymenoptera: Formicidae) on Hawaiian endemic spiders (Araneae: Tetragnathidae). Pacific Science 47:21-33.

Gonzalez, D. and F.E. Gilstrap. 1992. Foreign exploration: Assessing and prioritizing natural enemies and consequences of preintroduction studies, pp. 53-70. In: W.C. Kauffman and

J.R. Nichols (eds.), Selection criteria and ecological consequences of importing natural enemies. Thomas Say Publications in Entomology. Entomological Society of America.

Hardy, D.E. 1979. An ecological survey of Puaaluu Stream. Part III. Report on a preliminary entomological survey of Puaaluu Stream, Maui. Coop. Nat. park Resources Study Unit. University of Hawaii. Tech. Report 27:34-39.

Hardy, D.E. and K.Y. Kaneshiro. 1981. Drosophilidae of Pacific Oceania, in Genetics and Biology of Drosophila. J. Thompson, H.L. Carson, and M. Ashburner eds., Acad. Press, New York.

Howarth, F.G. 1990. Hawaiian terrestrial arthropods: An.overview. Bishop. Mus. Occas. Pap. 30:4-26.

Howarth, F.G., G. Nishida, and A. Asquith. 1995. Insects of Hawaii: Status and Trends. In E.T. LaRoe, G.S. Farris, C.E. Puckett, P.D. Doran, and M.J. Mac, editors, Our Living Resources: A Report to the Nation on the Distribution, Abundance, and Health of U.S. Plants, Animals, and Ecosystems. U.S. Department of Interior, National Biological Service, Washington D.C.

Kaneshiro, K.Y. 1976. Ethological isolation and phylogeny in the *planitibia* subgroup of Hawaiian Drosophila. Evolution 30:740-745.

Kaneshiro, K.Y. 1980. Sexual selection, speciation, and the direction of evolution. Evolution 34(3):437-444.

Kaneshiro, K.Y. 1987. The Dynamics of sexual selection and its pleiotropic effects. Behav. Genetics 17:559-569.

Kaneshiro, K.Y. 1989. The dynamics of sexual selection and founder effects in species formation. In Genetics, Speciation and the Founder Principle, L.V. Giddings, K.Y. Kaneshiro, and W.W. Anderson, Eds. Oxford Press. pp. 279-296.

Kaneshiro, K.Y. 1993. Habitat-related variation and evolution by sexual selection, in Evolution of Insect Pests. K.C. Kim and B.A. McPheron, eds., pp 89-101, John Wiley Sons, Inc. Publ.

Kaneshiro, K.Y. and K. Kaneshiro. 1995. Draft listing proposal for 18 species of Hawaiian picture-wing *Drosophila*. Document submitted to the Pacific Islands Office, U.S. Fish and Wildlife Service, Honolulu, Hawaii.

Lockwood, J.A. 1993. Environmental issues involved in biological control of rangeland grasshoppers (Orthoptera: Acrididae) with exotic agents. Environ. Entomol. 22:503-518.

Nafus, D.M. 1993. Biological control agents and native parasitoids in the population system of the butterfly *Hypolimnas bolinas* (L.) (Lepidoptera: Nymphalidae). Micronesica, Suppl. 4:17-23.

NatureServe Explorer: An online encyclopedia of life [web application]. 2001. Version 1.6 . Arlington, Virginia, USA: NatureServe. Available: http://www.natureserve.org/explorer.

Nishida, G.M., Ed. 1994. Hawaiian Terrestrial Arthropod Checklist, 2 nd Edition. Bishop. Mus. Technical Report No. [1]. 287 pp.

Perkins, R.C.L. 1913. Introduction to Fauna Hawaiiensis. D. Sharp, ed., Vol. 1:xv-ccxxvii. Cambridge University Press, Cambridge.

Reagan, T.E. 1986. Beneficial aspects of the imported fire ant: A field ecology approach: in Fire Ants and Leaf-Cutting Ants, (C.S. Lofgren and R.K. Vander Meer, eds.). Westview Press, Boulder Colorado. pp. 58-71.

Reimer, N.J. 1993. Distribution and impact of alien ants in vulnerable Hawaiian ecosystems: in D.F.Williams (ed), Exotic Ants: Biology, Impact, and Control of Introduced Species. Westview Press, Boulder, Colorado. pp. 11-22.

Reimer, N., J.W. Beardsley and G. Jahn. 1990. Pest ants in Hawaii. in Vander Meer, R.K, K. Jaffe and A. Cedeno (eds), Applied Myrmecology: A World Perspective. Westview Press, Boulder, Colorado, pp. 40-50.

Ridley, M. 1993. Evolution. Blackwell Scientific Publications. pp.420-421. Roderick, G. 1992. Postcolonization evolution of natural enemies. In: W.C. Kauffman and J.R. Nichols (eds.). Selection criteria and ecological consequences of importing natural enemies. Thomas Say Publications in Entomology. Entomological Society of America.

Smith, C.W. 1985. Impact of alien plants on Hawai'i's native biota: in Stone, C.P., and J.M. Scott (eds.), Hawai'i's terrestrial ecosystems: preservation and management. Coop. Natl. Park Resources Stud. Unit, Univ. Hawaii, Honolulu, pp. 180-250.

Spieth, H.T. 1980. Hawaiian Drosophila Project. Proceedings of the Hawaiian Entomological Society 23:275-291.

Stone, C.P. 1985. Alien animals in Hawai'i's native ecosystems: toward controlling the adverse effects of introduced vertebrates: in Stone, C.P., and J.M. Scott (eds.), Hawai'i's terrestrial ecosystems: preservation and.management. Coop. Natl. Park Resources Stud. Unit, Univ. Hawaii, Honolulu, pp. 251-297.

Tomich, P.Q. 1986. Mammals in Hawai'i; a synopsis and notational bibliography. 2nd ed. Bishop Museum Press, Honolulu, 375 pp.

van Riper, S.G., and C. van Riper III. 1982. A field guide to the mammals in Hawaii. The Oriental Publishing Company, Honolulu, 68 pp.

Williamson, Mark. 1981. Hawaiian Drosophilidae in Island populations. Oxford University Press.

Wong, M.A. and T.T.Y. Wong. 1988. Predation of the Mediterranean fruit fly and oriental fruit fly (Diptera: Tephritidae) by the fire ant (Hymenoptera: Formicidae) in Hawaii. Proc. Hawaii. Entomol. Soc. 28:169-177.

Zimmerman, E.C. 1941. Argentine ant in Hawaii. Proc. Hawaii. Entomo. Soc. 11:108

Zimmerman, E.C. 1948. Insects of Hawaii. Vol.1. Introduction. xvii+206 pp. University of Hawaii Press.

PETITION TO LIST

pomace fly
(*Drosophila digressa*)

AS A FEDERALLY ENDANGERED SPECIES

CANDIDATE HISTORY

CNOR 2/28/96:	C
CNOR 9/19/97:	C
CNOR 10/25/99:	C
CNOR 10/30/01:	C
CNOR 6/13/02:	C

TAXONOMY

Among the most remarkable and best studied group of Hawaiian insects are the drosophilid flies (Williamson 1981). To date, 511 species of Hawaiian Drosophilidae have been formally described. An additional 250-300 species are already in the collection at the University of Hawaii and await taxonomic treatment, and new species are still being discovered from localities not previously sampled. It is estimated that as many as 1,000 species may be present in native Hawaiian ecosystems (Kaneshiro 1993). This family in Hawaii represents one of the most remarkable cases of adaptive radiation of any group of animals known (Hardy and Kaneshiro 1981).

The taxonomic status of *Drosophila digressa* as a valid species is uncontroversial (e.g., Bishop Museum 2002).

NATURAL HISTORY

Unlike most Hawaiian insects which remain obscure, often known only from their original taxonomic descriptions, every aspect of Hawaiian Drosophilidae biology has been researched, including their internal and external morphology, behavior, ecology, physiology, biochemistry, the banding sequence of giant chromosomes, as well as detailed analyses of the structure of the DNA molecules. More than 80 research scientists and over 350 undergraduates, graduate students, and post-doctoral fellows have participated in research on the Hawaiian Drosophilidae, resulting in over 600 scientific publications on the biology of these flies. The Hawaiian Drosophilidae are arguably the most intensively studied group of all terrestrial Hawaiian organisms.

Research on Hawaiian Drosophilidae has resulted in the development and testing of new theories of evolutionary biology (Bradley et al. 1991, Carson 1971, 1982a, Kaneshiro 1976, 1980, 1987, 1989). Ideas on speciation and island evolution developed from studies on Hawaiian Drosophilidae are now referenced in most modern text books of biology and evolution (e.g. Ridley 1993).

The Hawaiian *Drosophila* Project at the University of Hawaii has coordinated and cooperated in most of the research on the Hawaiian Drosophilidae. It has also maintained extensive collection records of these species. These records form the basis for much of the data used to develop this proposed rulemaking. Three decades of collection work are maintained in permanent files of the Hawaiian Drosophila Project within the University of Hawaii's Center for Conservation Research and Training. Also, collection notes of the individual researchers on the project contain extensive records of host plant associations of most of these species.

Behavior

The general life cycle of Hawaiian Drosophilidae is typical of that of many flies: after mating, females lay eggs from which larvae (immature stage) hatch; as larvae grow they molt (shed their skin) through several successive stages (instars); when fully grown the larvae pupate, metamorphosing and emerging as adults. The courtship and mating behaviors of some species (Hawaiian picture-wings) are extremely elaborate, with exaggerated visual cues displayed by the males. These flies have been referred to as the “birds of paradise” of the insect world because of their spectacular courtship displays and territorial defense. Males occupy territories which serve as mating arenas to which receptive females are attracted for mating. The males fight among themselves for the best territories and establish a dominance hierarchy like some birds and mammals.

Habitat

The Hawaiian Drosophilidae have radiated and adapted ecologically to a tremendous diversity of ecosystems ranging from desert-like habitats where the soil is powdery dry, to rain forests with lush, tree-fern jungles, and swampland perpetually shadowed by rain clouds and with vegetation that is burdened with dripping, moss-laden branches. While the larval stages of most species are saprophytic, feeding on decaying vegetation such rotting leaves, bark, flowers, and fruits, some have become highly specialized, e.g., being carnivorous on egg masses of spiders, or feeding on green algae growing underwater on boulders in streams. As a group, the Hawaiian Drosophilidae appear to be ubiquitous and can be found in most of the natural communities in Hawaii.

Distribution

Hawaiian drosophilids are distributed throughout the high islands of the archipelago, displaying not only a highly characteristic single island endemism, but also extraordinary morphological diversity along with adaptations which show their intimate ecological relationship to the native flora (Carson and Yoon 1982).

Drosophila digressa is restricted to the island of Hawaii, where it breeds only in the bark of *Charpentiera* trees.

POPULATION STATUS

Biologists have observed a general decline of the Hawaiian Drosophilidae along with other components of the native ecosystem. As noted by Spieth (1980), during the early part of the century, the Tantalus area behind the city of Honolulu was the major spot for collecting *Drosophila*. By 1963 the majority of the native *Drosophila* species in this area had been exterminated, apparently due to intrusion of exotic vegetation, and predation by ants. Quantitative sampling since 1971 has demonstrated dramatic declines in the abundance of some species and in other cases local extirpations (Carson 1986, Foote and Carson 1995). A review of the data collected by the Hawaii *Drosophila* Project and assessment of the threats to remaining populations suggests that at least 14 species of these flies are presently threatened with extinction.

Drosophila digressa is restricted to the island of Hawaii. This species is known from three populations. The sizes of these populations have not been determined, but numbers are not large and have significantly declined. Threats to this Hawaiian picture-wing include habitat degradation from ungulates, alien weeds, and predation by ants and alien wasps.

The Hawaii Natural Heritage Program ranks *Drosophila digressa* as Critically Imperiled.

The U.S. Fish and Wildlife Service classifies *Drosophila digressa* as a candidate for Endangered Species Act protection with a listing priority number of 2.

LISTING CRITERIA

A. *The present or threatened destruction, modification, or curtailment of its habitat or range.*

Historical range: Hawaii (island of Hawaii).

Current range: Three populations on the island of Hawaii.

Land ownership: This species presently occurs on State and Federal lands.

Native vegetation on all the main Hawaiian islands has undergone extreme alteration because of past and present land management practices including ranching, deliberate introduction of alien plants and animals, and agricultural development (Cuddihy and Stone 1990). Some of the primary threats facing this species are ongoing and threatened destruction and adverse modification of habitat be feral animals and alien plants.

Animals such as pigs, goats, axis deer, black-tailed deer, and cattle were introduced either by the early Hawaiians (pigs) or more recently by European settlers (all ungulate species) for food and/or commercial ranching activities. Over the 200 years following their introduction, their numbers increased and the adverse impacts of feral ungulates on native vegetation have become increasingly apparent. Beyond the direct effect of trampling and grazing native plants, feral ungulates have contributed significantly to the heavy erosion still taking place on most of the main Hawaiian islands.

Sus scrofa (pigs), originally native to Europe, Africa, and Asia, were introduced to Hawaii by the Polynesian ancestors of Hawaiians, and later by western immigrants. The pigs escaped domestication and invaded primarily wet and mesic forests and grasslands of Kauai, Oahu, Molokai, Maui, and Hawaii. While foraging, pigs root and trample the forest floor, encouraging the establishment of alien plants in the newly disturbed soil. Pigs also disseminate alien plant seeds through their feces and on their bodies, accelerating the spread of alien plants through native forest (Cuddihy and Stone 1990, Stone 1985). Foote and Carson (1995) experimentally demonstrated the detrimental affects of feral pigs on Hawaiian picture-wings in wet forest habitat on the island of Hawaii.

Most of the plants which serve as breeding sites for Hawaiian picture-wings occur as understory vegetation beneath the canopy of the *Metrosideros polymorpha* (‘ohi’a) and koa trees, and are affected by competition with alien weeds. Hawaiian picture- wing species are threatened by loss of host plants due to competition with one or more alien plant species. The most significant of these appear to be *Schinus terebinthifolius* (Christmasberry), *Psidium cattleianum* (strawberry guava), *Melinus minutiflora* (molasses grass), *Pennisetum setaceum* (fountain grass), *Clidemia hirta* (Koster's curse), *Lantana camara* (lantana), *Rubus argutus* (prickly Florida blackberry), *Passiflora mollissima* (banana poka), and *Rubus ellipticus* (Himalayan raspberry).

Strawberry guava, an invasive shrub or small tree native to tropical America, has become naturalized on all of the main Hawaiian islands. Like Christmasberry, strawberry guava is capable of forming dense stands that exclude other plant species (Cuddihy and Stone 1990). This alien plant grows primarily in mesic and wet habitats and provides food for several alien animal species, including feral pigs and game birds, which disperse the plant's seeds through the forest (Smith 1985, Wagner et al. 1985). Strawberry guava is considered one of the greatest alien plant threats to Hawaii's rain forests and is known to pose a direct threat to *Drosophila digressa*. Strawberry guava is a.major invader of forests in windward Hawaii where it often forms single-species stands.

Prickly Florida blackberry was introduced to the Hawaiian Islands in the late 1800s (Haselwood and Motter 1976). The fruit are easily spread by birds to open areas where this plant can form dense, impenetrable thickets (Smith 1985). The habitat of *Drosophila digressa* is threatened by this noxious weed.

A recent introduction to the Hawaiian Islands, yellow Himalayan raspberry is rapidly becoming a major weed pest in wet forests, pastures, and other open areas on the island of Hawaii. It forms large thorny thickets and displaces native plants. Its ability to invade the understory of wet forests enables it to fill a niche presently unoccupied by any other major wet forest weed in Hawaii. This has resulted in an extremely rapid population expansion of this alien plant in recent years. Yellow Himalayan blackberry threatens the habitat of *Drosophila digressa*.

A vine in the passionflower family, banana poka was introduced to the islands in the 1920s, probably as an ornamental. This vine is extremely detrimental to certain wet forest habitats of Kauai, Maui, and Hawaii. Heavy growth of this vine can cause damage or death to the native trees by overloading branches, causing breakage, or by forming a dense canopy cover, intercepting sunlight and shading out native plants below. This weed threatens *Drosophila digressa.*

B. ***Overutilization for commercial, recreational, scientific, or educational purposes.***

Not applicable.

C. ***Disease or predation.***

Over 2500 alien arthropods are now established in Hawaii (Howarth 1990, Howarth et al. 1995, Nishida 1994), with a continuing establishment rate of 10-20 new species per year (Beardsley 1962, 1979). Many of these alien species have severe affects on the native Hawaiian insect fauna (Asquith 1995). Species of social Hymenoptera (ants and some wasps) and parasitic wasps pose the greatest threat to the Hawaiian picture-wings. Ants and other social insects frequently dominate the ecologies of tropical ecosystems and strongly influence the evolution of certain plants and animals. All of the native Hawaiian arthropods, including the Hawaiian picture-wings, evolved without the predation influence of ants or social wasps, and the arrival of these new groups 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 1870s, 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 and Reimer 1993), and it has been documented to completely exterminate populations of native insects.

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.

The long-legged ant (*Anoplolepis longipes*) appeared in Hawaii in 1952 and now occurs on Oahu, Maui, and Hawaii (Reimer et al. 1990). It inhabits low elevation (less than 600 m [2,000 ft]), rocky areas of moderate rainfall (less than 250 cm [100 in] annually) (Reimer et al. 1990). Direct observations indicate that Hawaiian arthropods are susceptible to predation by this species (Gillespie and Reimer 1993) and Hardy (1979) documented the disappearance of most native insects from Kipahulu Stream on Maui after the area was invaded by the long-legged ant.

At least two species of fire ants, Solenopsis geminita and Solenopsis papuana, are also important threats (Reagan 1986; Gillespie and Reimer 1993) and occur on all the major islands (Reimer et al. 1990). Solenopsis geminita is known to be a significant predator on pest fruit flies in Hawaii (Wong and Wong 1988). *Solenopsis papuana* is the only abundant, aggressive ant that has invaded intact mesic forest above 600 m (2,000 ft) and is still expanding its range in Hawaii (Reimer 1993).

Numerous other ant species are recognized as threats to native invertebrates, and additional species become established almost yearly. While the larvae of most of the Hawaiian picture-wings feed deep in the substrate of the host plant, they emerge and move away to pupate in the ground, thus exposing themselves to predation by ants. Upon newly emerging as adults, these flies are particularly susceptible to predation and adult picture-wings have been observed with a ants attached to their legs (Kaneshiro and Kaneshiro 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, 1990, Gambino and 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 and Loope 1992). Yellowjackets have been observed preying on Hawaiian picture-wings Kaneshiro and Kaneshiro 1995), and the establishment of this species on the island of Hawaii corresponded with a significant decline in several species of Hawaiian picture-wings (Carson 1982b, 1986, Foote and Carson 1995).

Yellowjackets pose a serious threat to all Hawaiian picture-wing species in this proposed rulemaking. Hawaii also has a limited number of native parasitic Hymenoptera (wasps), with only species of Eucoiliidae recorded to utilize Hawaiian picture-wings as hosts. Several species of alien braconid wasps, *Diaschasmimorpha tryoni*, *D. longicaudatus*, *Opius vandenboschi*, and *Biosteres arisanus*, were purposefully introduced into Hawaii to control several species of pest tephritid fruit flies (Funasaki et al. 1988). However, none of these wasps are specific to the pest flies, but are known to attack other species of flies, including native Hawaiian Tephritidae. While these wasps have not been recorded from Hawaiian picture-wings, and may not successfully develop in Drosophilidae, females will sting any fly larva available and can cause significant mortality (personal communication 1995 cited in U.S. Fish and Wildlife Service candidate assessment form). Inundative releases of these wasps or introductions of new species pose potential threats to Hawaiian picture-wings.

D. *The inadequacy of existing regulatory mechanisms.*

No current protection exists.

Current Conservation Efforts: None.

E. ***Other natural or manmade factors affecting its continued existence.***

Alien parasitic wasps pose a threat to the Hawaiian picture- wings, and some alien species are purposefully introduced by Federal and State agencies for biological control of pests flies. Federal regulations for controlling the introduction of biocontrol agents are inadequate (Lockwood 1993). The U.S. Environmental Protection Agency (EPA) under the authority of the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA), regulates biological control agents as pesticides. However, EPA only regulates microorganisms (bacteria, fungi, protozoa and viruses). EPA has exempted all other organisms from requirements of FIFRA becuase it has determined that they are adequately regulated by the U.S. Department of Agriculture’s Animal and Plant Health Inspection Service (USDA-APHIS).

Although the State of Hawaii requires that new introductions be reviewed by special committees before release (HRS Chapt. 150A), post-release biology and host range cannot be predicted from laboratory studies (Gonzalez and Gilstrap 1992, Roderick 1992) and the purposeful release or augmentation of any dipteran predator or parasitoid is a potential threat to Hawaiian picture-wings.

REFERENCES

Asquith, A. 1995. Alien species and the extinction crisis of Hawaii’s invertebrates. Endangered Species Update 12:6-11

Beardsley, J.W. 1962. On accidental immigration and establishment of terrestrial arthropods in Hawaii during recent years. Proc. Hawaii. Entomol. Soc. 18:99-109.

Beardsley, J.W. 1979. New immigrant insects in Hawaii: 1962 through 1976. Proc. Hawaii. Entomol. Soc. 23:35-44.

Bishop Museum of Honolulu. Hawaiian Terrestrial Arthropod Checklist, March 2002 version. http://ww2.bishopmuseum.org/HBS/checklist/query.asp?grp=Arthropod

Bradley, R.D., S.K. Davis, and R.J. Baker. 1991. Genetic Control of Premating-Isolating Behavior: Kaneshiro's Hypothesis and Asymmetrical Sexual Selection in Pocket Gophers. J. Heredity. 82:192-196.

Carson, H.L. 1971. Speciation and the Founder Principle. Stadler Symposia. Vol. 3:51-70. University of Missouri.

Carson, H.L. 1982a. Speciation as a Major Reorganization of Polygenic Balances, in Mechanisms of Speciation. pp. 411-433.

Carson, H.L. 1982b. Fluctuations in size of certain *Drosophila* populations in the Olaa Tract Hawaii Volcanoes National Park, in Proc. Fourth Conf. in Natural Sciences, Hawaii

Volcanoes National Park, p. 40. [abstract]. Cooperative National Park Resources Unit, Department of Botany, Univ. of Hawaii.

Carson, H.L. 1986. Drosophila populations in the Olaa Tract, Hawaii Volcanoes National Park, 1971-1986. in Proc. Sixth Conf. in Natural Sciences, Hawaii Volcanoes National Park. [abstract]. Cooperative National Park Resources Unit, Department of Botany, Univ. of Hawaii.

Carson, H.L. and J.S. Yoon. 1982. Genetics and Evolution of Hawaiian Drosophila, in Genetics and Biology of Drosophila. J. Thompson, H.L. Carson, and M. Ashburner eds., Acad. Press, New York.

Cole, F.R., A.C. Medeiros, L.L. Loope, and W.W. Zuehlke. 1992. Effects of the Argentine ant on arthropod fauna of Hawaiian high-elevation shrubland. Ecology 73:1313- 1322.

Cuddihy, L.W. and C.P. Stone. 1990. Alteration of the native Hawaiian vegetation; effects of humans, their activities and introductions. Coop. Natl. Park Resources Stud. unit, Hawaii.

Foote, D. and H.L. Carson. 1995. *Drosophila* as monitors of change in Hawaiian ecosystems. In E.T. LaRoe, G.S. Farris, C.E. Puckett, P.D. Doran, and M.J. Mac, editors, Our Living Resources: A Report to the Nation on the Distribution, Abundance, and Health of U.S. Plants, Animals, and Ecosystems. U.S. Department of Interior, National Biological Service, Washington D.C.

Funasaki, G.Y., P.-L. Lai, L.M. Nakahara, J.W. Beardsley & A.K. Ota. 1988. A review of biological control introductions in Hawaii: 1890 to 1985. Proc. Hawaii. Entomol. Soc. 28:105- 160.

Gagne, W.C. 1979. Canopy-associated arthropods in *Acacia koa* and *Metrosideros* tree communities along an altitudinal transect on Hawaii Island. Pac. Insects 21:56- 82..Gambino, P., A.C. Medeiros, and L.L. Loope. 1987. Introduced vespids *Paravespula pensylvanica* prey on Maui's endemic arthropod fauna. J. Trop. Ecol. Vol. 3:169-170.

Gambino, P., A.C. Medeiros, and L.L. Loope. 1990. Invasion and colonization of upper elevations on East Maui (Hawaii) by *Paravespula pennsylvanica* (Hymenoptera: Vespidae). Annals of the Entomological Society of America 8**3:**1088-1095.

Gambino, P. and L.L. Loope. 1992. Yellowjacket Vespula pennsylvanica biology and abatement in the National Parks of Hawaii. Cooperative National Park Resources Studies Unit, Hawaii, Technical Report 8**6:**1-41.

Gillespie, R.G. and N. Reimer. 1993. The effect of alien predatory ants (Hymenoptera: Formicidae) on Hawaiian endemic spiders (Araneae: Tetragnathidae). Pacific Science 47:21-33.

Gonzalez, D. and F.E. Gilstrap. 1992. Foreign exploration: Assessing and prioritizing natural enemies and consequences of preintroduction studies, pp. 53-70. In: W.C. Kauffman and J.R. Nichols (eds.), Selection criteria and ecological consequences of importing natural enemies. Thomas Say Publications in Entomology. Entomological Society of America.

Hardy, D.E. 1979. An ecological survey of Puaaluu Stream. Part III. Report on a preliminary entomological survey of Puaaluu Stream, Maui. Coop. Nat. park Resources Study Unit. University of Hawaii. Tech. Report 27:34-39.

Hardy, D.E. and K.Y. Kaneshiro. 1981. Drosophilidae of Pacific Oceania, in Genetics and Biology of *Drosophila*. J. Thompson, H.L. Carson, and M. Ashburner eds., Acad. Press, New York.

Howarth, F.G. 1990. Hawaiian terrestrial arthropods: An overview. Bishop. Mus. Occas. Pap. 30:4-26.

Howarth, F.G., G. Nishida, and A. Asquith. 1995. Insects of Hawaii: Status and Trends. In E.T. LaRoe, G.S. Farris, C.E..Puckett, P.D. Doran, and M.J. Mac, editors, Our Living Resources: A Report to the Nation on the Distribution, Abundance, and Health of U.S. Plants, Animals, and Ecosystems. U.S. Department of Interior, National Biological Service, Washington D.C.

Kaneshiro, K.Y. 1976. Ethological isolation and phylogeny in the *planitibia* subgroup of Hawaiian Drosophila. Evolution 30:740-745.

Kaneshiro, K.Y. 1980. Sexual selection, speciation, and the direction of evolution. Evolution 34(3):437-444.

Kaneshiro, K.Y. 1987. The Dynamics of sexual selection and its pleiotropic effects. Behav. Genetics 17:559-569.

Kaneshiro, K.Y. 1989. The dynamics of sexual selection and founder effects in species formation. In Genetics, Speciation and the Founder Principle, L.V. Giddings, K.Y. Kaneshiro, and W.W. Anderson, Eds. Oxford Press. pp. 279-296.

Kaneshiro, K.Y. 1993. Habitat-related variation and evolution by sexual selection, in Evolution of Insect Pests. K.C. Kim and B.A. McPheron, eds., pp 89-101, John Wiley Sons, Inc. Publ.

Kaneshiro, K.Y. and K. Kaneshiro. 1995. Draft listing proposal for 18 species of Hawaiian picture-wing Drosophila. Document submitted to the Pacific Islands Office, U.S. Fish and Wildlife Service, Honolulu, Hawaii.

Lockwood, J.A. 1993. Environmental issues involved in biological control of rangeland grasshoppers (Orthoptera: Acrididae) with exotic agents. Environ. Entomol. 22:503-518.

Nafus, D.M. 1993. Biological control agents and native parasitoids in the population system of the butterfly *Hypolimnas bolinas* (L.) (Lepidoptera: Nymphalidae). Micronesica, Suppl. 4:17-23.

Nishida, G.M., Ed. 1994. Hawaiian Terrestrial Arthropod Checklist, 2 nd Edition. Bishop. Mus. Technical Report No. [1]. 287 pp..Perkins, R.C.L. 1913. Introduction to Fauna Hawaiiensis. D. Sharp, ed., Vol. 1:xv-ccxxvii. Cambridge University Press, Cambridge.

Reagan, T.E. 1986. Beneficial aspects of the imported fire ant: A field ecology approach: in Fire Ants and Leaf-Cutting Ants, (C.S. Lofgren and R.K. Vander Meer, eds.). Westview Press, Boulder Colorado. pp. 58-71.

Reimer, N.J. 1993. Distribution and impact of alien ants in vulnerable Hawaiian ecosystems: in D.F.Williams (ed), Exotic Ants: Biology, Impact, and Control of Introduced Species. Westview Press, Boulder, Colorado. pp. 11-22.

Reimer, N., J.W. Beardsley and G. Jahn. 1990. Pest ants in Hawaii. in Vander Meer, R.K, K. Jaffe and A. Cedeno (eds), Applied Myrmecology: A World Perspective. Westview Press, Boulder, Colorado, pp. 40-50.

Ridley, M. 1993. Evolution. Blackwell Scientific Publications. pp.420-421.

Roderick, G. 1992. Postcolonization evolution of natural enemies. In: W.C. Kauffman and J.R. Nichols (eds.). Selection criteria and ecological consequences of importing natural enemies. Thomas Say Publications in Entomology. Entomological Society of America.

Smith, C.W. 1985. Impact of alien plants on Hawai'i's native biota: in Stone, C.P., and J.M. Scott (eds.), Hawai'i's terrestrial ecosystems: preservation and management. Coop. Natl. Park Resources Stud. Unit, Univ. Hawaii, Honolulu, pp. 180-250.

Spieth, H.T. 1980. Hawaiian *Drosophila* Project. Proceedings of the Hawaiian Entomological Society 23:275-291.

Stone, C.P. 1985. Alien animals in Hawai'i's native ecosystems: toward controlling the adverse effects of introduced vertebrates: in Stone, C.P., and J.M. Scott (eds.), Hawai'i's terrestrial ecosystems: preservation and management. Coop. Natl. Park Resources Stud. Unit, Univ. Hawaii, Honolulu, pp. 251-297.

Tomich, P.Q. 1986. Mammals in Hawai'i; a synopsis and.notational bibliography. 2nd ed. Bishop Museum Press, Honolulu, 375 pp.

van Riper, S.G., and C. van Riper III. 1982. A field guide to the mammals in Hawaii. The Oriental Publishing Company, Honolulu, 68 pp.

Williamson, Mark. 1981. Hawaiian Drosophilidae, in Island populations. Oxford University Press.

Wong, M.A. and T.T.Y. Wong. 1988. Predation of the Mediterranean fruit fly and oriental fruit fly (Diptera: Tephritidae) by the fire ant (Hymenoptera: Formicidae) in Hawaii. Proc. Hawaii. Entomol. Soc. 28:169-177.

Zimmerman, E.C. 1941. Argentine ant in Hawaii. Proc. Hawaii. Entomo. Soc. 11:108

Zimmerman, E.C. 1948. Insects of Hawaii. Vol.1. Introduction. xvii+206 pp. University of Hawaii Press..

PETITION TO LIST

Mardon skipper
(*Polites mardon*)

AS A FEDERALLY ENDANGERED SPECIES

CNOR 1/16/89:	
CNOR 11/21/91:	
CNOR 11/15/94:	
CNOR 10/25/99:	C
CNOR 10/30/01:	C
CNOR 6/13/02:	C

TAXONOMY

The status of *Polites mardon* (Hesperiidae), the Mardon skipper, as a taxonomically valid species is uncontroversial. Recently, Mattoon et al. (1998) recognized the Washington Mardon skippers and those in Oregon and California as two distinct subspecies, *P. m. mardon* and *P. m. klamathensis*, respectively.

NATURAL HISTORY

The Mardon skipper is a rare, northwestern butterfly with a remarkably disjunct distribution. It is currently known from four widely separated locations. Two populations are known from south Puget Sound sites in Washington. About 160 kilometers (km) (100 miles (mi)) to the southeast, six sites are known in the southern Washington Cascades, primarily on Federal lands. Three or four populations are known from the southern Oregon, Siskiyou Mountains, about 400 km (250 mi) to the south. A single population is known from coastal, northern California, approximately 129 km (75 mi) southwest of the Oregon sites.

The Mardon skipper (*Polites mardon*) is a small, sedentary butterfly. Larvae feed on grass (*Festuca idahoensis* and probably other caespitose species, e.g., *Festuca rubra*). Adults feed on a variety of nectar sources depending upon locale, and hibernation occurs in the pupal stage, likely in a loose cocoon in the grass (Newcomer 1966). Adult nectaring has been studied at one Puget Sound site by Potter and Hays (1998), and *Viola adunca* was the preferred source. Within the southern Washington Cascade physiographic province, nectaring has been observed on *Vicia* spp., *Penstemon* spp., and *Calochortus* spp. (Pyle 1978, personal observations 2000 cited in U.S. Fish and Wildlife Service candidate assessment form), as well as on *Erysimum capitatum* (Newcomer 1966). Nectar species observations are not available for California and Oregon.

In Puget Sound, the Mardon skipper is found in open *Festuca idahoensis*-dominated grassland sites on glacial outwash prairies. In pre-European settlement southern Puget Sound, prairies covered hundreds of thousands of acres (Crawford and Hall 1997). Today, less than three percent of the original prairie landscape remains and much of this has competing human uses (Crawford and Hall 1997).

In the southern Washington Cascades, the Mardon skipper is found in small (less than 0.25 to 4 hectare (ha) (0.5 to 10 acre (ac)) open grassland sites within *Pinus ponderosa* savanna/woodland, near Mount Adams. Washington Cascade locales range in elevation from 580 to 1,555 meters (m) (1,900 to 5,100 feet (ft)), and site conditions from dry, open ridgetops to areas associated with wetlands or riparian habitats. The number of Mardon skippers found in this region ranged from 1 to 50, but only three had more than 50 individuals.

Oregon populations are on small (less than 0.25 to 4 ha (0.5 to 10 ac)), high elevation (1,372 to 1,555 m (4,500-5,100 ft) grassy meadows within mixed conifer forests. The California population is located on a serpentine bald dominated by *Festuca* spp. In each of these areas, frequent low intensity fires have historically played an important role in maintaining the grassland plant communities.

POPULATION STATUS

Twelve sites are currently known. Seven historical populations have apparently been extirpated. Despite intensive surveys in recent years, Mardon skippers have not been found at four historic locales in Puget Sound, two southern Washington Cascades sites, and one southern Oregon site.

Sites in Washington State have been recently visited and extensive surveys for additional sites have been done around the Puget Sound populations. The southern Washington Cascades has been searched, although not thoroughly, and limited additional populations may exist there. One Oregon population has been recently surveyed (personal communication 1998 cited in U.S. Fish and Wildlife Service candidate assessment form); while other sites have not been visited since 1991. Some searching has been done for new populations in northwest California and southwest Oregon (personal communication 1998 cited in U.S. Fish and Wildlife Service candidate assessment form), and extensive searching for this species has been carried out in the northern Oregon Cascades (Pyle 1989).

Puget Sound (2 populations)
In 1998, 17 individuals were counted over about 80 ha (200 ac) on one site, located in Pierce County (personal observation 2000 cited in U.S. Fish and Wildlife Service candidate assessment form). Approximately 400 ha (1,000 ac) of potential habitat were not surveyed. The second site, 32 km (20 mi) away in Thurston County, is comprised of two populations: one on 2-4 ha (5-10 ac) of habitat with an estimate of 5-10 individuals (high count of 3 in 1997, 2 in 1998); the second, estimated at 50-80 individuals (high count of 50 in 1997, 30 in 1998), on 6-8 ha (15-20 ac) (personal observation 2000 cited in U.S. Fish and Wildlife Service candidate assessment form).

Southern Washington Cascades (6 populations)

Based on 1997 and 1998 surveys, populations in the Mt. Adams area are estimated to consist of 5-10 individuals (2 sites), 20-30 individuals (3 sites) and over 100 individuals (1 site) (personal observation 2000 cited in U.S. Fish and Wildlife Service candidate assessment form).

Southern Oregon, Siskiyous Mountains (3-4 populations)
Known populations are in southeastern Jackson County, within a 16 km (10 mi) radius. It was estimated in 1991 that one site had 200 individuals, but that count has not been duplicated in subsequent years (personal communication 1998 cited in U.S. Fish and Wildlife Service candidate assessment form). Other sites, most recently visited in 1991, hosted a few individuals.

Northern California (1 population)
Information on the Del Norte County site was provided by Sterling Mattoon and Ken Hanson (personal communication 1998 cited in U.S. Fish and Wildlife Service candidate assessment form). No surveys were done in 1998, but Mardon skippers were present in 1997. The core area of 0.4 to 1 ha (1 to 2 ac) hosts more than 10 individuals each year. In good years, dozens of individuals are found here, and along a ridge for 3 to 5 km (2 to 3 mi).

The Washington Natural Heritage Program ranks the Mardon skipper as Critically Imperiled.

The Oregon Natural Heritage Program ranks the Mardon skipper as Imperiled.

The U.S. Fish and Wildlife Service classifies the Mardon skipper as a candidate for Endangered Species Act protection with a listing priority number of 5.

LISTING CRITERIA:

A. ***The present or threatened destruction, modification, or curtailment of its habitat or range.***

Historical range:	South Puget Sound and southern Washington Cascades (Mt. Adams), Washington. Siskiyou Mountains, Oregon. Coastal, northern California, Del Norte County. Seven historical populations have apparently been extirpated.
Current range:	Washington, Oregon, California. Twelve sites are currently known.
Land ownership:	Washington: 1 site Department of Defense (DOD); 1 site Washington Department of Fish and Wildlife; 3 sites Yakama Indian Reservation; 2 sites private landowners; 1 site U.S. Forest Service. Oregon: 1 site U.S. Forest Service; all other sites in the area of checkerboard Bureau of Land Management and private ownership. California: 1 site of unknown ownership.

The Mardon skipper is threatened directly and indirectly by a number of factors. Pyle (1989) identifies the threats to this species as any factor that degrades its obligate grassland habitats, including: development, overgrazing, herbicides, the encroachment of invasion of non-native and native vegetation, and succession from grassland to forest. Invasion and dominance of non-native plants into native grasslands is common, and has occurred rapidly at several current and historic Mardon skipper sites. Introduced plants threaten the Mardon skipper in several ways. In addition to directly competing with larval food plants, many invasive woody shrubs, forbs, and grasses also prevent or obscure access to nectar plants. Not all Mardon skipper sites have been evaluated for the presence of aggressive, non-native plants. However, the problem is increasingly common, and most sites are particularly vulnerable because of their highly accessible locations.

Invasive, non-native, sod-forming grasses (such as *Holcus* spp. and *Arrhenatherum elatius*), and weedy forbs, including *Hypochaeris* spp., threaten native bunchgrass (*Festuca* spp.) which Mardon skippers depend on for egg depositing, larval food, and hibernaculum structures. The short character of a *Festuca* stand allows access for the adult butterfly to its similarly short, native, nectar sources. Changes in plant community structure, including the invasion and dominance of non-native grasses and forbs have occurred at several Washington sites.

The invasive shrub Scotch broom (*Cytisus scoparius*) poses a particular threat to prairies at Puget Sound sites because of its ability to form dense stands which exclude native grassland species. Parker et al. (1997) found a nearly exclusive relationship between *Cytisus* spp. and *Festuca idahoensis*. Further, due to its highly flammable nature, areas of Scotch broom increase the vulnerability of nearby native plants and butterflies to high intensity fire. Intensive management appears to be controlling Scotch broom at the two known Puget Sound prairie sites, but must be continued for the foreseeable future. Unfortunately, Scotch broom control methods, either hand pulling, tractor mowing, or burning, also likely destroy, through trampling or heat, some Mardon skipper eggs, larvae, and or pupae, which are immobile and on ground-level vegetation.

Small, roadside meadows are vulnerable to native species removal and non-native grass introduction when reseeding occurs after road work. Currently, this threat applies to most southern Oregon, and several southern Washington Cascade sites. At least one Washington Cascades historic locale, and a large portion of a remaining site, have been destroyed by this practice.

Human structures, including roads and trails, logging landings, helicopter pads, buildings, towers, livestock corrals, trail destinations, and campgrounds, are often built in forest openings. Construction in these areas results in direct habitat loss and degradation of remaining habitat. This threat has not been evaluated for all Mardon skipper populations. However, on extant Washington sites, roads, trails, and buildings, have destroyed habitat at one Puget Sound site; helicopter landing pads have removed habitat at two Cascade locales, a lookout tower, roads, trails, and buildings are also present at one of these sites; buildings at two additional Cascade locales have significantly reduced site size; roads, trails, and camping areas have destroyed habitat at another. Oregon Siskiyou sites are located adjacent to roads in a highly managed landscape. It is likely, therefore, that these structures and associated human activities threaten Oregon populations as well.

Small, isolated populations of sedentary insects, such the Mardon skipper, are likely vulnerable to fire. Their grassland habitat persisted in part because of repeated, patchy, low intensity fires. However, large-scale, intense fires will be detrimental through direct mortality of individuals and damage to habitat because of the continuous, rather than patchy, coverage of the burn.

Recreational activities including walking, horseback and off-road vehicle (ORV) use probably kill some Mardon skippers directly. These activities also degrade habitat, damaging native plants and opening ground cover for invasion by weeds. One Puget Sound site and the California population are currently threatened by these activities.

Livestock grazing impacts populations through several mechanisms: direct trampling of eggs, larvae, pupae, and adults; destruction of larval and adult food sources from consumption and trampling; and soil disturbance which allows invasion by weeds. Grazing occurs on occupied habitat in the Washington Cascades and Oregon Siskiyous.

Insecticide application poses a threat to populations in the Puget Sound and Washington Cascades. *Bacillus thurengensis* (Bt) is applied in large-scale, aerial applications in Puget Sound against Asian gypsy moth (*Lymantria dispar*), and in the Washington Cascades to control spruce budworm (*Choristoneura occidentali*s). Unless applied with care beyond that required by standard procedures and label directions, Bt is lethal to the Mardon skipper. Herbicide use could damage a population by harming larval or adult food sources. Herbicide application may pose a threat to any population but one Puget Sound and one Oregon population are especially vulnerable due to the fact that electrical utility corridors that are frequently sprayed cross the sites.

B. ***Overutilization for commercial, recreational, scientific, or educational purposes.***

Insect collecting is a valuable component of research, including systematic work, and is often necessary for documenting the existence of populations. It is also, however, potentially a threat to populations. Rare butterflies such as the Mardon skipper are desirable to collectors. Populations which are small and easily accessible (such as most Mardon populations), are especially threatened.

C. ***Disease or predation.***

Disease and predation may be a threat to populations which are suppressed by other factors, but no examples are known for this species.

D. ***The inadequacy of existing regulatory mechanisms.***

The Mardon skipper is currently a candidate for listing in Washington. However, candidate status within Washington State has no protective measures associated with it. Species listing in Washington also has no associated habitat protection regulation.

Current Conservation Efforts: Within the Puget Sound prairie ecosystem, the removal of woody shrubs (mainly Scotch broom) using herbicides, mechanical methods and prescribed burning (DOD lands) has been undertaken to improve habitat conditions for the Mardon skipper.

E. ***Other natural or manmade factors affecting its continued existence.***

Most Mardon skipper populations are small enough in numbers and area that activities of researchers may pose a threat. Trampling can cause direct mortality and damage to the habitat which may lead to additional mortality.

Most insect populations experience large fluctuations in size. Weather, predation, and disease may cause annual changes in butterfly numbers of an order of magnitude or more. Small population are acutely vulnerable to extirpation from any one of the threats presented above. Sites from which Mardon skippers are extirpated are unlikely to be recolonized because surviving populations are widely separated and very small. Almost all remaining Mardon Skipper populations are small and therefore vulnerable to this process.

REFERENCES:

Crawford, R. C., and H. Hall. 1997. Changes in the south Puget prairie landscape. Pages 11-16 in P. V. Dunn, and K. Ewing (eds.). Ecology and conservation of the south Puget Sound prairie landscape. The Nature Conservancy, Seattle, Washington. 289 pp. Edwards, W. H. 1881. Description of new species of butterflies. Papilio. 1(4):43-48.

Mattoon, S.O., J.F. Emmel, and T.C. Emmel. 1998. The distribution of *Polites mardon* (Lepidoptera: Hesperiidae) in North America, and description of a new subspecies from southern Oregon. Pp. 767-774 *in* T.C. Emmer (ed.), Systematics of Western North American Butterflies. Mariposa Press, Gainesville, Florida.

NatureServe Explorer: An online encyclopedia of life [web application]. 2001. Version 1.6 . Arlington, Virginia, USA: NatureServe. Available: http://www.natureserve.org/explorer.

Newcomer, E. J. 1966. Life histories of three western species of *Polites*. J. Res. Lepid. 5:243- 247.

Parker, I., W. Harpole, and D. Dionne. 1997. Changes in the south Puget prairie landscape. Pages 149-161 in P. V. Dunn, and K. Ewing(eds.). Ecology and conservation of the south Puget Sound prairie landscape. The Nature Conservancy, Seattle, Washington. 289 pp.

Potter, A. E., and D. W. Hays. 1998. Fieldwork conducted by Washington Department of Fish and Wildlife for the critical habitat components of candidate south Puget Sound prairie butterflies - Interim 1998 Field Season. Unpublished report. Washington Department of Fish and Wildlife. Olympia.

Pyle, R. M. 1989. Washington butterfly conservation status report and plan. Unpublished report. Washington Department of Wildlife, Nongame Program, Olympia. 217 pp.

Pyle, R. M. 1978. Observation record from Evergreen Aurelians' northwest Lepidoptera survey database. Gray's River, Washington. Unpublished report.

PETITION TO LIST

Highlands tiger beetle
(*Cicindela highlandensis*)

AS A FEDERALLY ENDANGERED SPECIES

CANDIDATE HISTORY

CNOR 11/21/91:	
CNOR 11/15/94:	
CNOR 10/25/99:	C
CNOR 10/30/01:	C
CNOR 6/13/02:	C

TAXONOMY

The taxonomic status of the Highlands tiger beetle, *Cicindela highlandensis* (Cicindelidae), as a valid species is uncontroversial (e.g., Knisley and Schultz 1997; Pearson and Vogler 2001).

NATURAL HISTORY

Behavior

Highlands tiger beetle adults are fast running predators, conspicuous, showing orange on the abdomen in flight, and are weak fliers with limited dispersal capability (Knisley and Hill 1992). Among tiger beetles there is a general trend of decreasing flight distance with decreasing body size (personal communication cited in U.S. Fish and Wildlife Service candidate assessment form). The Highlands tiger beetle is one of the smallest tiger beetles and an extremely weak flier (usual flight distance is only five to ten meters).

Species in woodland, scrub or dune habitats seem to disperse less than water edge species, and this could further explain the apparent limited dispersal of the Highlands tiger beetle (Knisley and Hill 1996). The thermal requirements of the Highlands tiger beetle may also limit its dispersal. Adults may overheat in full sun, preferring partially shaded habitats. Larval burrows tend to be near vegetation, where they are shaded for part of the day. *Cicindela hirtilabris*, a much more widely-distributed scrub species, inhabits larger and more open patches of bare sand, farther from the bases of trees and shrubs than the Highlands tiger beetle. The difference in habitat preference may have to do with *C. hirtilabris* adults being better able to tolerate heat, since they are larger and white in color. The larval burrows of *C. hirtilabris* are deeper than those of the Highlands tiger beetle and, therefore, may remain cooler (Knisley and Hill 1996).

Habitat
The Highlands tiger beetle is restricted to open, sandy, well-drained Florida scrub habitat on Lake Wales Ridge in central Florida (Knisley and Hill 1992, 1994, 1996; Deyrup 1994). Within this habitat, it is restricted to open scrub with bare sand, but is found in only a fraction of suitable sites.

Since the Highlands tiger beetle has been known only since it was described in1984, there are no records of its past distribution and abundance in Florida. It seems quite likely that it was common, widespread, and well established throughout the natural scrub and possibly high pine communities of the Lake Wales Ridge in Highlands and Polk counties prior to the widespread destruction of its habitat during the past 50 years (Knisley and Hill 1992). Most of the Highlands tiger beetle suitable scrub habitat has already been eradicated.

Knisley and Hill (1996) view high quality habitat as primarily scrub or pine woodland with a high percent of open sand (greater than 50 percent) and with many natural openings which are continuous or connected to adjacent open patches, or connected by lightly disturbed trails or paths. Adult Highlands tiger beetles were never found in areas of dense scrub (except along the edges of trails) nor in areas of low shrubs. The Highlands tiger beetle was regularly found on trails with evidence of at least moderate off-road vehicle traffic and where there was evidence of past vegetation clearing or other ground disturbance (Knisley and Hill 1992a, 1996). This suggests that fire suppression has caused the vegetation to become artificially dense, harming the beetle and other species. This also suggests the need for prescribed burning (Knisley and Hill 1996).

Distribution
Knisley and Hill (1991, 1992, 1994, 1996) found the Highlands tiger beetle at 40 sites, 25 in Polk County and 15 in Highlands County. The sites are all on the Lake Wales Ridge, including the hilly uplands along U.S. Highway 27. The range of the Highlands tiger beetle does not extend to the south end of the Lake Wales Ridge, but does extend northward to the north side of Lake Marion, east of Haines City. A number of tiger beetle collectors have sought but not found this species in other areas in this vicinity in recent years.

Most of the remaining sites that contain beetles are small, privately owned, and are subject to development activities that could negatively affect the species or its habitat. This species' narrow distribution may be in part due to its lack of dispersal.

POPULATION STATUS

Knisley and Hill (1992) recorded fewer than 500 total adults at 40 known sites, with only two sites harboring more than 50 individuals. Number of adults at any site varies seasonally. Populations may have been larger at one time; collectors took an estimated 500-1000 adults from the type locality during a several-year period after its discovery.

The Florida Natural Heritage Program ranks the Highlands tiger beetle as Critically Imperiled.

The U.S. Fish and Wildlife Service classifies the Highlands tiger beetle as a candidate for Endangered Species Act protection with a listing priority number of 5.

LISTING CRITERIA

A. ***The present or threatened destruction, modification, or curtailment of its habitat or range.***

Historical range: Florida.

Current range: Florida. The Highlands tiger beetle is present in some protected areas, including the Allen David Broussard Catfish Creek Preserve northeast of Lake Wales, The Nature Conservancy's Tiger Creek Preserve, Lake Wales Ridge State Forest, Lake Arbuckle State Park, Carter Creek (partly in the Lake Wales Ridge National Wildlife Refuge), the Jack Creek tract managed by the Southwest Florida Water Management District, and an adjoining tract of the Lake Wales Ridge Wildlife and Environmental Area.

Land ownership: Knisley and Hill (1996) graded sites with Highlands tiger beetles based on numbers of tiger beetles and extent of suitable habitat. They graded the following as AB or better: Catfish Creek (a state preserve operated by Florida Department of Environmental Protection), Flaming Arrow Boy Scout Camp (a private tract within the Hesperides acquisition project of Florida's Conservation and Recreation Lands program [CARL]), another site in the Hesperides CARL area, Livingston Creek (Lake Arbuckle State Forest/State Park), Tiger Creek Preserve (The Nature Conservancy), Tiger Creek South, Hesperides, Tiger Creek South (Hesperides CARL project), Moon Ranch road (Carter Creek CARL project vicinity), and Flamingo Villas (Lake Wales Ridge National Wildlife Refuge). The State of Florida is actively acquiring land on the Lake Wales Ridge.

The Highlands tiger beetle depends on open, sandy areas within the Lake Wales Ridge's upland vegetation. This vegetation has largely been converted to citrus groves and residential areas. Peroni and Abrahamson (1985) used aerial photography to determine that in Highlands County, 64.2 percent of the xeric vegetation (scrub, scrubby flatwoods, and high pinelands) present before European settlement had been destroyed by 1981. Thus, by the time the Highlands tiger beetle was described as a new species in 1984, much of its potential habitat had already been destroyed. However, land acquisition efforts by the State of Florida, the U.S. Fish and Wildlife Service, and others are ongoing in the Lake Wales Ridge such that most good examples of Highlands tiger beetle habitat are now under public or conservation ownership. Approximately 50 percent of the remaining available habitat for the species that has been targeted for acquisition has been purchased or is currently being purchased.

Lack of management of the remaining scrub and high pineland vegetation may constitute a threat as serious as habitat loss (Knisley and Hill 1992, 1996). The vegetation in which Highlands tiger beetle occurs is subject to fire, ranging from relatively frequent and low-intensity in high pineland to infrequent and high intensity in some scrub (Myers and Ewel 1990). Years of fire suppression in most upland habitats of the Lake Wales Ridge led to the vegetation becoming much thicker, with few patches of bare ground. One indicator of ecological problems caused by fire suppression is that small scrub plants (herbs and smaller shrubs) are now typically most abundant in artificially disturbed areas such as firebreaks.

According to the most recent U.S. Fish and Wildlife Service candidate assessment form, managers in the area have begun to implement fire management plans and programs to manage scrub vegetation that will benefit the Highlands tiger beetle. For instance, the Florida Division of Forestry has received strong State support for implementing fire management on State lands in the Lake Wales Ridge, and across the State, in the wake of several disastrous wildfire seasons. In addition, the research and other programs of Archbold Biological Station emphasize fire management and development of alternatives to fire (Lohrer 1999) that will restore and enhance scrub habitats in the area.

B. ***Overutilization for commercial, recreational, scientific, or educational purposes.***

Tiger beetles of the genus *Cicindela* may be the subject of more intense collecting and study than any other single insect genus. Knisley and Hill (1992) stated that over-collecting of the Highlands tiger beetle may be of "some importance" and suggest that over-collecting may have been partly responsible for the apparent extirpation of the species from the site where Choate had first collected it (i.e., the type locality). They estimated that well over 1,000 adults had been collected at this site (Knisley and Hill 1996). Concerns about collection of the Ohlone tiger beetle of coastal California, recently proposed for listing as an endangered species, are probably relevant to the Highlands tiger beetle. The proposal, citing a personal communication in the candidate assessment form, noted that the original petitioner for listing the Ohlone tiger beetle was contacted by several people from such places as France, Wisconsin, and California, looking for Ohlone tiger beetle specimens to add to their private collections, as well as others asking where tiger beetle colonies are located so they could collect the species at those locations.

C. ***Disease or predation.***

The major natural enemies of adult tiger beetles are robber flies (Asilidae) and birds. Parasitoid wasps (Family Tiphiidae, genus *Methocha*) and bombyliid flies (genus *Anthrax*) are the major predators of larvae (Knisley and Hill 1989, Hill and Knisley 1990). Ants may sometimes affect larvae, especially during the first instar (Knisley 1987). Most tiger beetles species that have been intensely studied experienced relatively high levels of larval parasitism (10 to over 40 percent) (Knisley and Hill 1992). It is likely that the Highlands tiger beetle experiences the limiting effects from natural enemies and generally low survivorship that are seen for other tiger beetle species.

D. ***The inadequacy of existing regulatory mechanisms.***

Cicindela highlandensis is not currently listed by the State of Florida and therefore is not afforded any regulatory protection. Furthermore, there is very little protection of its habitat since the species occurs on only a few protected sites.

Current Conservation Efforts: The State of Florida is acquiring and has acquired a number of lands that are occupied by the Highlands tiger beetle. These sites include the Lake Wales Ridge Ecosystem project, Hesperides, and Walk-in-the-Water areas within Polk and Highland counties

(Knisley and Hill 1992). The U.S. Fish and Wildlife Service is acquiring smaller areas that may harbor this species for the Lake Wales Ridge National Wildlife Refuge. Land managers in the Lake Wales Ridge area have begun to conduct more prescribed burning in recent years to enhance or restore scrub habitat. Under these efforts, it is possible that prescribed burning on State, Refuge, and private conservation lands has improved habitat for the species and may provide better habitat conditions for this species in the future.

E. *Other natural or manmade factors affecting its continued existence.*

The larvae of the Highlands tiger beetle live in burrows near the ground surface (The Nature Conservancy 1999). Although the species may benefit from the clearing activities that accompany trail construction, the off-road vehicle traffic that often follows will harm the species by crushing the individual or its burrow. An additional threat is fire suppression, which changes the nature and composition of the scrub communities. Much of the present scrub is unsuitable for the species as a result of fire suppression (Knisley and Hill 1992). Such modified scrub is much more densely vegetated and often lacks the natural open, bare patches that the Highlands tiger beetle occupies (Knisley and Hill 1992). Recently, Knisley and Hill (1992) documented how ecological succession can change habitat and cause the decline and local extirpation of tiger beetle species. An example of this was documented for *Cicindela abdominalis* (the species to which the Highlands tiger beetle is most closely related) at a Virginia pine barrens site. Encroaching vegetation and fire suppression caused the species to be extirpated from the site during the 1930s (Knisley and Hill 1992).

Little is known about the dispersal of the Highlands tiger beetle, but its small size and weak flight suggest it probably has a limited dispersal (Knisley and Hill 1992). This limited dispersal characteristic could cause the species to be extirpated from isolated sites since much of this beetle's habitat has been highly fragmented throughout its range.

REFERENCES

Deyrup, Mark. 1994. Rare and Endangered Biota of Florida. Volume IV. Invertebrates. University Presses of Florida.

Hill, J.M. and C.B. Knisley. 1990. Current status and biological studies of *C. dorsalis* and *C. puritana* in Maryland. Unpublished report to Maryland Heritage Program. 69 pp.

Knisley, C.B. 1987. Habitats, food resources, and natural enemies of a community of larval *Cicindela* in Arizona. Can. J. Zool. 65:1191-1200.

Knisley, C.B. and J.M. Hill. 1989. Human impact on *Cicindela dorsalis* at Flag Ponds, Maryland. Final report.

Knisley, C.B. and J.M. Hill. 1991. An inventory of rare tiger beetles in Florida scrub habitats. Unpublished report.

Knisley, C.B. and J.M. Hill. 1992. Status survey of the rare Florida scrub tiger beetle, *Cicindela highlandensis*. Report to U.S. Fish and Wildlife Service, Jacksonville Field Office, Jacksonville, Florida.

Knisley, C. B. and J. M. Hill. 1994. Studies of the rare Florida scrub tiger beetle, *Cicindela highlandensis*: Distribution, abundance, habitat characteristics and biology. Report prepared for U. S. Fish and Wildlife Service, Jacksonville, Florida. 33 pages, 1 table, 7 figures.

Knisley, C. B. and J. M. Hill. 1996. The Florida Highlands tiger beetle, *Cicindela highlandensis*: habitat requirements, remaining range, life history, and management. Final report, Florida nongame wildlife program grant (NG91-012). Submitted to Florida Game and Fresh Water Fish Commission, Bureau of Nongame Wildlife.

Knisley, C.B. and T.D. Schultz. 1997. The Biology of Tiger Beetles. Virginia Museum of Natural History, Special Publication Number 5. , Martinsville, VA.

Pearson, D.L. and A.P. Vogler. 2001. The Evolution, Ecology, and Diversity of the Cicindelids. Cornell University Press, Ithaca, New York.

Peroni, P. A. and W. G. Abrahamson. 1985. A rapid method for determining losses of native vegetation.

Richardson, D.R. 1989. The sand pine scrub community: an annotated bibliography. Florida Scientist 52: 65-93.

The Nature Conservancy, Conservation Science Division, in cooperation with The Association for Biodiversity Information, and the International Network of Natural Heritage Programs and Conservation Data Centers. 1999. Biodiversity Conservation Data Source (BioSource). Arlington, Virginia.

PETITION TO LIST

Warton cave meshweaver
(*Cicurina wartoni*)

AS A FEDERALLY ENDANGERED SPECIES

CANDIDATE HISTORY

CNOR 11/15/94:	
CNOR 2/28/96:	C
CNOR 9/19/97:	C
CNOR 10/25/99:	C
CNOR 10/30/01:	C
CNOR 6/13/02:	C

TAXONOMY

The spider *Cicurina wartoni* (Dictynidae), the Warton Cave meshweaver, was first collected in 1990 by James Reddell, Marcelino Reyes, and Lee Sherrod and described by Gertsch in 1992. Its taxonomic status as a valid species is uncontroversial (e.g., Platnick 2002).

NATURAL HISTORY

This small (0.25 inches long) eyeless spider is known only from female specimens. It is sedentary and spins a small web in and under detritus and small rocks, preying on other small invertebrates. It is known only from a single small, shallow cave in Texas**,** characteristically moist and extremely humid with stable air temperatures. The majority of the eyeless *Cicurina* species are known only from the Edwards Plateau region in central Texas and are obligate cave-dwellers.

POPULATION STATUS

Fewer than 1,000 individuals exist. The only known site for this species, Pickle Pit Cave in Travis County, Texas, is susceptible to fire ant invasions, vandalism, chemical contaminations and land development.

The Texas Natural Heritage Program ranks the Warton cave meshweaver as Critically Imperiled.

The U.S. Fish and Wildlife Service classifies the Warton cave meshweaver as a candidate for Endangered Species Act protection with a listing priority number of 2.

LISTING CRITERIA

A. ***The present or threatened destruction, modification, or curtailment of its habitat or range.***

Historical range:	A small, shallow cave (Pickle Pit Cave) in Travis County, Texas, is the only known location of this species.
Current range:	A small, shallow cave (Pickle Pit Cave) in Travis County, Texas, is the only known location of this species.
Land ownership:	The only known population of this spider is located on private land.

This species is known from just a single small cave in northwest Travis County. The species and its habitat are subject to threats from fire ants and possible habitat degradation due to construction of a subdivision. Site plans for development of the property were approved by the City of Austin in 1987. The U.S. Fish and Wildlife Service issued a biological opinion on this project to the Corps of Engineers on December 30, 1994. The project description was modified from the 1987 plan so that development is set back 402.5-805 kilometers (km) (250-500 feet (ft)) from the northern side of the cave, while the area to the south will remain undeveloped. This cave preserve is contiguous with the Balcones Canyonlands Preserve. The cave has been gated to prevent human access, while allowing continued air flow and nutrient input. At this time, however, there is inadequate fencing around the Balcones Canyonlands Preserve for the bird habitat and there are entryways in the cave preserve area that allow access to the cave entrance.

B. ***Overutilization for commercial, recreational, scientific, or educational purposes.***

None known.

C. ***Disease or predation.***

Imported red fire ants (*Solenopsis invicta*) are known to exist on the tract where the cave is located and pose a significant threat to karst invertebrates, including this spider. Fire ants are voracious predators, and there is evidence that overall arthropod diversity drops in their presence (Vinson and Sorensen 1986; Porter and Savignano 1990). Elliott (1990) notes that fire ant activity has increased dramatically in Central Texas since 1989. A site visit to the cave containing this spider, by U.S Fish and Wildlife Service employees, consultants to the landowner, and Army Corps of Engineers personnel in summer, 1993, revealed an active fire ant mound 48.8 km (30 ft) east of the cave entrance in a small clearing.

D. ***The inadequacy of existing regulatory mechanisms.***

Currently, no State laws protect this spider or directly address protection of its habitat. Cave protection laws of the City of Austin provide for a 100 foot buffer zone around significant aquifer recharge features and Texas Natural Resource Conservation Commission (TNRCC) rules generally affect only significant recharge features. The cave containing this species does not receive significant recharge (personal communication 1993 cited in U.S. Fish and Wildlife Service candidate assessment form) and would not likely qualify for protection under the City of Austin or TNRCC regulations. Invertebrates are not included on Texas Parks and Wildlife Department's list of threatened and endangered species. The Department regulations do not contain provisions for protecting habitat of any listed species.

According to the most recent U.S. Fish and Wildlife Service candidate assessment form, the U.S. Fish and Wildlife Service has worked with the landowner to develop a Conservation Agreement, which will incorporate additional conservation measures included in the 1994 biological opinion. These measures should include fencing, periodic (every two to three months) surveillance, revegetating man-made openings with native plants, removal of any trash dumps, pesticide and fertilizer restrictions, and fire ant control.

Current Conservation Efforts: Landowners have agreed to preserve the cave as a part of a section 7 consultation with the Corps of Engineers. A final Candidate Conservation Agreement has been expected for some time, but was still not finished as of December 2000.

E. ***Other natural or manmade factors affecting its continued existence.***

Although many caves in the Austin metropolitan area have been subject to extensive vandalism and trash dumping, the cave gate should help deter these activities. Fencing around the preserve area would further deter these activities.

REFERENCES

Barr, T.C., Jr., 1968. Cave ecology and the evolution of troglobites. Evol. Biol. 2:15-21.

Elliott, W.R. 1992 (revised 1993). Fire Ants and Endangered Cave Invertebrates: A Control and Ecological Study. Section 6 report prepared for the Texas Parks and Wildlife Department and the U.S. Fish and Wildlife Service.

Gertsch, W.J. 1992. Distribution patterns and speciation in North American cave spiders wit a list of the troglobites and revision of the cicurinas of the subgenus *Cicurell*a. Pages 75- 122 in: Texas Memorial Museum Speleological Monographs 3: Studies on the cave and endogean fauna of North America II. Edited by James Reddell. 257 pp.

Holsinger, J.R. 1988. Troglobites: The evolution of cave-dwelling organisms. Am. Scientist 76:147-153.

Howarth, F.G. 1983. Ecology of cave arthropods. Ann. Rev. Entomol. 28:365-389.

Porter, S.D., and S.A. Savignano. 1990. Invasion of polygyne fire ants decimates native ants and disrupts arthropod community. Ecology. 71(6):2095-2106.

Platnick, N.I. 2002. World Spider Catalog, version 3.0. American Museum of Natural History online at http://research.amnh.org/entomology/spiders/catalog81-97/index.html.

U.S. Fish and Wildlife Service. 1993. Draft Recovery Plan for Endangered Karst Invertebrates in Travis and Williamson Counties, TX. Albuquerque, NM. 133 pp.

Veni & Associates. 1992. Geologic controls on cave development and the distribution of cave fauna in the Austin, TX region. Section 6 report prepared for the U.S. Fish and Wildlife Service and Texas Parks and Wildlife Department. V + 77 pp.

Vinson, S.B., and A.A. Sorensen. 1986. Imported Fire Ants: Life History and Impact. Texas Department of Agriculture. 1986. 28 pp..

PETITION TO LIST

Camp Shelby burrowing crayfish (*Fallicambarus gordoni*)

AS A FEDERALLY ENDANGERED SPECIES

CANDIDATE HISTORY

CNOR 11/21/91:	
CNOR 11/15/94:	
CNOR 10/25/99:	C
CNOR 10/30/01:	C
CNOR 6/13/02:	C

TAXONOMY

The Camp Shelby burrowing crayfish, *Fallicambarus gordoni* (Cambaridae), was described in 1987 from southeast Mississippi (Fitzpatrick 1987).

NATURAL HISTORY

The Camp Shelby burrowing crayfish (CSBC) is a small burrowing crayfish less than 30 millimeters (1.5 inches) in length. It is distinguished from closely related species by a broader rostrum, characters of the chela, and characters of the male and female sexual organs.

The CSBC is a short-lived (2 to 3 years) burrowing crayfish that estivates during dry summer months, and is active during late fall, winter, and spring (Johnson and Figiel 1997). Reproductively active males (Form I) are found throughout this activity period. Females bearing eggs have only been collected during late fall and early winter. Egg numbers range from 7 to 25 per female. Juveniles are present during most of the year, but are more frequently collected in the late spring. Burrows consist of a shallow oval chamber with one to four openings. Concentrations of burrows are found only in pitcher plant bogs. Observations on the distribution of the species indicate that the CSBC is dependent on the maintenance of open-bog habitats for survival (Johnson and Figiel 1997). The species is found in association with flat woodland pitcher plant wetlands, locally referred to as pitcher plant bogs.

Extensive crayfish surveys of pitcher plant wetlands in southern Mississippi and Alabama have documented the CSBC only from a small area in central Perry County, Mississippi (Fitzpatrick 1987, 1991).

POPULATION STATUS

CSBC are locally common in the small pitcher plant bogs where they occur. To date, 18 pitcher plant wetlands in central Perry County, Mississippi have been found supporting a total of fewer than 3,000 individuals of the species (*in litt.* 1999 cited in U.S. Fish and Wildlife Service candidate assessment form).

The Mississippi Natural Heritage Program ranks the Camp Shelby burrowing crayfish as Critically Imperiled.

The U.S. Fish and Wildlife Service classifies the Camp Shelby burrowing crayfish as a candidate for Endangered Species Act protection with a listing priority number of 11.

LISTING CRITERIA

A. *The present or threatened destruction, modification, or curtailment of its habitat or range.*

Historical range:	Perry County, Mississippi.
Current range:	Perry County, Mississippi.
Land ownership:	All known habitat for the species occurs on U.S. Forest Service lands leased by the U.S. Army National Guard.

The CSBC is believed to be naturally limited in range. It is found only on pitcher plant wetlands on U.S. Forest Service (USFS) lands leased by the U.S. Army National Guard’s (NG) Camp Shelby for troop and tank training grounds. All pitcher plant wetlands combined comprise less than 500 acres of Camp Shelby’s 135,000 acres, and the crayfish has been associated with only a few of these (*in litt*. 1999 cited in U.S. Fish and Wildlife Service candidate assessment form).

The CSBC is vulnerable to activities that would directly destroy its burrows, compact the soil, or alter the hydrology of its flat pine woodland wetland habitat. The primary activities occurring in areas surrounding CSBC habitat include silvicultural activities by the USFS and tank and troop maneuvers by the NG. Silvicultural activities that could harm the species include canopy removal and dessication, soil compaction and rutting from heavy equipment operation, and toxic runoff from pesticide and herbicide applications. NG troop and tank maneuvers within crayfish habitat can kill or entomb animals, compact the soil, and/or affect hydrology through rutting.

B. *Overutilization for commercial, recreational, scientific, or educational purposes.*

CSBCs are not utilized for commercial or recreational purposes. Their cryptic habits protect them from overzealous scientific collection.

C. ***Disease or predation.***

Diseases affecting the CSBC are unknown. Although a number of vertebrate predators are known to prey on crayfish, natural predation does not appear to be a threat.

D. ***The inadequacy of existing regulatory mechanisms.***

The species is not currently protected under other environmental laws and regulations.

Current Conservation Efforts: The Forest Service and National Guard are aware of the locations inhabited by the CSBC and its vulnerability to their activities. Surveys and life history studies have been conducted. The Mississippi Natural Heritage Program and The Nature Conservancy have been monitoring the species and its habitat in cooperation with the National Guard and Forest Service. The Forest Service and National Guard have been cooperative in working with the State to avoid impacts. The National Guard has requested Mississippi Field Office assistance in developing and entering into a Candidate Conservation Agreement that will reduce or remove all known significant threats to the CSBC.

E. ***Other natural or manmade factors affecting its continued existence.***

All Terrain Vehicle (ATV) use is high in the area where the CSBC occurs. ATV trails have been observed through pitcher plant bogs inhabited by CSBC. ATV use in these areas may result in direct mortality to CSBC.

REFERENCES

Fitzpatrick, J.P. 1987. *Fallicambarus burrisi* and *F. gordoni,* two new burrowing crawfishes associated with pitcher plant bogs in Mississippi and Alabama. Proceedings of the Biological Society of Washington 100:433-446.

Fitzpatrick, J.P. 1991. Status survey report Camp Shelby crayfish. Report to U.S. Army Corps of Engineers, Champaign, Illinois. Pp. 1-14.

Johnston, C.E. and C. Figiel. 1997. Microhabitat parameters and life-history characteristics of *Fallicambarus gordoni* Fitzpatrick, a crayfish associated with pitcher-plant bogs in southern Mississippi. Journal of Crustacean Biology 17(4):687-691.

PETITION TO LIST

Stephan's riffle beetle
(*Heterelmis stephani*)

AS A FEDERALLY ENDANGERED SPECIES

CANDIDATE HISTORY

CNOR 05/22/84:
CNOR 01/06/89:
CNOR 11/21/91:
CNOR 11/15/94:
CNOR 06/13/02: C

TAXONOMY

Stephan's riffle beetle (*Heterelmis stephani*) was formally described in 1972 from 71 specimens collected near Bog Spring in Madera Canyon, Coronado National Forest, Arizona (Brown 1972a).

NATURAL HISTORY

Beetles of the family Elmidae are known as "riffle beetles" because most species are found on stones or debris in the riffles of streams. Elmid larvae are strictly aquatic and respiration occurs through rectractile cloacal tracheal gills (Brown 1983). Riffle beetles attach their eggs to the underside of submerged rocks, woody debris, or aquatic plants (Brown 1987). Elmid life histories are quite variable, but typically involve a short incubation period and a larval stage lasting from 6 to 36 months (Tavares and Williams 1990).

Upon reaching maturity, riffle beetle larvae crawl out of the aquatic environment to pupate under cover of sand, rock, bark, or other debris (Brown 1972b; Brown 1983). In temperate zones, pupation typically requires 1-2 weeks and occurs from late spring through summer (Brown 1987). After emerging, adults commonly fly and may be attracted to lights during their sole dispersal flight (Brown 1983, 1987). Adults are small, typically less than 3 mm in total length (Brown 1983). Upon reentering the aquatic environment, most elmid adults never again leave the water (Brown 1987).

Respiration for adults occurs through the use of a plastron (a semipermanent bubble of air through which respiratory gases are exchanged in some aquatic invertebrates) (Brown 1972). Riffle beetles feed on microorganisms and debris, such as diatoms and detritus, scraped from substrate surfaces (Brown 1987; Tavares and Williams 1990).

POPULATION STATUS

Stephan's riffle beetle is an endemic riffle beetle found in limited spring environments within the Santa Rita Mountains in Arizona. The beetle is known historically from only two or three sites in Madera Canyon, and based on relatively intensive surveys of the surrounding area, the entire range of the species is believed to be confined to this canyon. (in *litt.* 1991 cited in U.S. Fish and Wildlife Service candidate assessment form; Barr and Shepard 1993).

The site where this beetle was first collected no longer exists as habitat for the species (Barr and Shepard 1993). After conferring with the original collector, Barr and Shepard (1993) determined that the type locality was not Bog Spring, as reported in the original species description, but actually a site 1.5 miles away near a Forest Service campground. Apparently the original population was maintained by seepage from a pipe which was believed to be overflow seepage from a nearby tank storing water diverted from Bog Spring. Seepage from the tank ceased in 1976 and the tank was removed entirely in 1992 (Barr and Shepard 1993).

During the surveys conducted by Barr and Shepard (1993) only one adult riffle beetle was collected from Sylvester Spring, and they were unable to find the beetle in Bog Spring proper. Based on the 71 beetle specimens originally collected in 1969, Barr and Shepard (1993) believe the species was at that time very common. The subsequent loss of habitat at the type locality has eliminated what was likely a significant population of Stephan's riffle beetle.

The U.S. Fish and Wildlife Service classifies Stephan's riffle beetle as a candidate for Endangered Species Act protection with a listing priority number of 5.

LISTING CRITERIA

A. *The present or threatened destruction, modification, or curtailment of its habitat or range.*

Historical range:	Arizona.
Current range:	Madera Canyon (Coronado National Forest, Arizona).
Land ownership:	The entire range of this species is believed to be confined to Madera Canyon, Coronado National Forest.

The springs where Stephan's riffle beetle is known to have occurred historically no longer exist in their natural condition. All have been boxed, capped, or channeled into pipes (in *litt.* 1991 cited in U.S. Fish and Wildlife Service candidate assessment form). Concrete boxes were constructed around the spring heads in the 1930s by the Civilian Conservation Corps (Barr and Shepard 1993), but the most significant habitat losses occurred many decades later.

B. ***Overutilization for commercial, recreational, scientific, or educational purposes.***

Not a known threat.

C. ***Disease or predation.***

Not a known threat

D. ***The inadequacy of existing regulatory mechanisms.***

The documented loss of habitat and consequent loss of a significant population of Stephan's riffle beetle demonstrates the need to develop a conservation program in coordination with the Forest Service. No such program exists. We know of no State or local government programs structured to address the conservation of rare and imperiled insects. The Arizona Department of Fish and Game does not have any jurisdiction over invertebrates. The authority for invertebrates is with the Arizona State Department of Agriculture; however, they do not have an invertebrate conservation program. Thus, there is currently no potential for State protection.

Current Conservation Efforts: None.

E. ***Other natural or manmade factors affecting its continued existence.***

Bog Spring and Sylvester Spring are located immediately off of a recreational trail maintained by the Forest Service. Due to the relatively obscure nature of the beetle's existence, it is unlikely that recreationists are entirely aware of the sensitive nature of these spring ecosystems. In the absence of public education, recreationists may unwittingly degrade habitat by introducing chemicals or allowing pets into the springs. The unintentional killing of larvae may also occur as a result of trampling. Endemic spring-dependent organisms whose populations exhibit a high degree of geographic isolation are extremely susceptible to stochastic extinction resulting from catastrophic natural disasters such as fires, floods, or changes in spring water chemistry.

REFERENCES

Barr, C.B. and W.D. Shepard. 1993. Survey for *Heterelmis stephani* Brown (Insecta: Coleoptera: Elmidae) in Madera Canyon and other localities in the Santa Rita Mountains, Arizona. Final Report prepared for U.S. Forest Service. 48 pp. August 14, 1993.

Brown, H.P. 1972a. Synopsis of the genus *Heterelmis* Sharp in the United States, with a description of a new species from Arizona (Coleoptera, Dryopoidea, Elmidae). Entomological News. 83: 229-238.

Brown, H.P. 1972b. Biota of freshwater ecosystems. Identification Manual No. 6. Aquatic Dryopoid beetles (Coleoptera) of the United States. Prepared by H.P. Brown, University of Oklahoma, for the Environmental Protection Agency. April 1972.

Brown. H.P. 1983. A catalog of the Coleoptera of America north of Mexico. United States Department of Agriculture. Agriculture Handbook Number 529-50. Prepared by the USDA Agricultural Research Service. November 1983. 21 pp.

Brown, H.P. 1987. Biology of riffle beetles. Annual Review of Entomology 32: 253-73.

Tavares, A.F. and D.D. Williams. 1990. Life histories, diet, and niche overlap of three sympatric species of Elmidae (Coleoptera) in a temperate stream. Canadian Entomologist 122: 563-577.