SADDLE ROAD PROJECT: ASSESSMENT OF THE IMPACTS ON INVERTEBRATES (LAND SNAILS, INSECTS AND OTHER ARTHROPODS)

By

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Submitted to

Rust Environment & Infrastructure, Phoenix, Arizona

8 November 1996

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SUMMARY STATEMENT

Realignment and upgrading of Saddle Road, Hawaii Island, will impact the fauna living in the area. This report assesses these impacts on the land snails, insects, and related arthropods.

Surveys took place during August, September, and October 1996 for a total of 13 field days. A total of 80 sites were investigated for land snails and/or insects and other arthropods. These sites were located in all sections of the corridor and on all alternative routes. The focus was in Sections I and II of the corridor, especially the area within the Pohakuloa Training Area (PTA); other sections to the east of PTA were less well sampled. Based on the relatively short amount of field time to survey invertebrates during this study, the results should be considered provisional.

Land snails (including slugs) were found at 28 of the 57 sites at which they were looked for. A total of 1482 specimens were collected, representing at least 13 species. Section I, mostly in Parker Ranch, harbored low diversity, except at its upper end. Section II, mostly in the PTA, supported by far the greatest diversity of land snails, especially in the area on segment PTA-1, and in particular in the area just to the east of Mauna Kea State Recreation Area. This endemic fauna is characteristic of the dry area of the saddle and of the slopes towards Mauna Loa and Hualalai. Notable was the finding in this area of *Leptachatina lepida*, a USFWS "Species of Concern". This is one of only two localities at which this species is known to be extant. The snail fauna of Sections III and IV was dominated by introduced species and supported relatively low diversity and abundances.

Arthropods were found at 55 of the 73 sites sampled for insects and their relatives. Specimens are still being processed so the total number of specimens collected is as yet unknown, but is safely estimated to be over 3,000. As of this report, 215 arthropod taxa have been identified, 67 (31%) of which are considered endemic species.

There will clearly be direct impacts of construction, especially on sedentary species including snails and non-volant insects. Populations of individual species may be highly localized. Road construction will destroy the habitat and the animals associated with it. If the populations that are destroyed are highly localized populations of rare species, then the impact on that species will be significant. This is possibly the case for a number of insect and snail species. More generally, road construction on the new, alternative routes will generate a corridor along which introduced species, both plant and animal, will be able more readily to gain access to native habitat. This is of especial concern along PTA-1.

Two invertebrate habitats deserve special consideration and attention: *kipuka* and caves. A number of significant *kipuka* occur along EX-3 on the eastern portion of the saddle and are known to harbor many native species. Significant cave habitats are found in two areas along EX-3, but addtional caves may be broken into during construction anywhere along the proposed routes.

In general, the survey supports selection of the existing road as the alignment along which the new road should be constructed/upgraded, especially in Section II.

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1. INTRODUCTION AND BACKGROUND

The purpose of this report is to provide an evaluation of the likely impacts on invertebrates (land snails, insects, and other arthropods) of realignment and upgrading of the Saddle Road on Hawaii Island, and to offer opinions on the relative impacts associated with the various alternative routes proposed.

The primary basis of this evaluation is field work that took place in August, September, ansd October 1996 and that involved spot sampling of the fauna along the length of the Saddle Road and along the alternative new alignments. In addition, previous work in the area was reviewed by scanning the literature and the collections of Bishop Museum (Honolulu). Our participation in this project started much later than other participants and, consequently, field work was limited to 13 days comprising three separate trips (August, September, October). Following the recommendation of the client, the focus of the survey was in the section of proposed alignments through Sections I (Parker Ranch) and II (Pohakuloa Training Area) (PTA) and any caves or lava tubes that were found to exist in the Saddle Road corridor. Consequently, more limited sampling took place elsewhere. A total of 80 sample sites were investigated during this time and over 3,000 specimens of snails, insects, and related arthropods were collected.

In addition to providing a specific assessment of the various alternative routes for the realignment, more general aspects of the fauna are discussed, and particularly significant findings stressed. The issue of roads and other utility routes acting as corridors permitting access by detrimental invasive species of plants and animals is briefly discussed.

The report provides lists of all species found and their distributions within the project area, with information about them, if available.

1.1. Previous surveys in the area

1.1.1. *Snails*

In 1982, a survey of the proposed trans-island 138 kV transmission line corridor was undertaken (Wagner et al., 1983). This proposed alignment generally followed the overall corridor now proposed for the various alternative routes for realignment of the Saddle Road. The 1982 survey focused predominantly on the vegetation, but did include both entomological and malacological sampling. The focus of the malacological sampling was in *kipuka* on the Hilo side of the Saddle Road, from Kaumana to mile marker 21 (12 sites). A mixed fauna of native and non-native snails and slugs was reported from this section of the corridor. Three sites were sampled in the PTA, and were dominated by native species. A single site at low elevation (300–1000 ft.) was sampled towards Waikoloa, and harbored one species of unknown native/non-native status. More details of the 1982 survey records are provided in the discussion of the individual species of snails recorded during the present survey (section 4.1.1, below).

The only published report of a survey of land snails in the area of the saddle between Mauna Kea and Mauna Loa is that of Cowie et al. (1995), based on the unpublished report of Cowie & Nishida (1993). This intensive survey of 58 sites in the Multi-Purpose Range Complex (MPRC), an area of about 30 sq. km. in the Pohakuloa Training area (PTA), was undertaken in 1992-1993. At least 16 species were recorded by Cowie et al. (1995), all endemic to the Hawaiian Islands, and constituting a community apparently characteristic of the dry montane western side of the saddle, and including those species reported from the PTA by Wagner et al. (1983).

Other literature on the land snails of Hawaii Island deals essentially only with the taxonomy of the species. Much of this work was published in the 19th century or the early part of this century. There are few details of precise collection localities; published localities are often simply "Olaa" or "Hamakua" or "Mauna Kea", none of which allows more than very general statements to be made about former distributions. A review of the major works did not turn up any records that could be precisely located witin the area of the Saddle Road and the proposed alternative new alignments.

A brief scan of labels in the land snail collections of the Bishop Museum likewise does not allow more than a general idea to be obtained of former distributions of land snail species. There has not been a concerted effort to survey any part of the current project area in detail, other than the very limited 1982 survey of Wagner et al. (1983).

1.1.2. *Insects and other arthropods*

References to arthropods associated with Saddle Road are sparse and scattered throughout the literature. Most of the references were generated by the Hawaiian *Drosophila* project, which concentrated on the fauna of *kipuka* on the southeastern slope of Humuula Saddle primarily during the 1960s and 1970s. Surveys in the area dealing particularly with arthropods are few in number. Though not specifically related to Saddle Road, power line surveys conducted in 1982 (Wagner et al., 1983), 1991 (Nishida, 1991), and 1992 (Nishida, 1992a,b) are applicable to this report as the power line(s) parallel the existing road for much of its length. A survey of the cave invertebrate fauna (Howarth et al., 1996) of selected cave systems within the Pohakuloa Training Area (PTA) was completed in 1996. Out of 32 annotated citations of biological surveys or studies pertaining to PTA previous to the study by Howarth et al. (1996) (U.S. Army Corps of Engineers, 1995), none pertain to any specific survey of the insect fauna.

A preliminary search of Bishop Museum's collections for records of arthropods occurring along Saddle Road was conducted during this study. Databases and collections were consulted to generate a list of sensitive species historically known from the corridor (Table 1).

1.2. Endangered status of the invertebrate fauna of the project area

1.2.1. *Snails*

Four species of land snails (Table 2) are currently listed as "Species of Concern". They are *Partulina confusa, P. horneri, P. physa* (all tree snails) and *Leptachatina lepida* (ground-dwelling). *Partulina confusa* has been recorded from Waikii Paddock, which is alongside the existing Saddle Road (segment EX-1), based on a single lot in the Bishop Museum. Otherwise there are no records of *Partulina* spp. in the areas along or near the existing and proposed alternative Saddle Road alignments, nor indeed in the overall saddle area. *Leptachatina lepida*, however, was recorded in the MPRC by Cowie & Nishida (1993) and Cowie et al. (1995). Prior to the present survey, the MPRC was the only known locality at which *L. lepida* had been reported alive since the early part of the century, and it was this finding that prompts the USFWS to categorize the species as a species of concern.

Although these are the only listed land snail species, it is widely acknowledged that the majority of the native land snails of the Hawaiian Islands are severely threatened if not already extinct (e.g., Solem, 1990). Therefore, all native land snail species should be considered, at least informally, as species of special concern. This is the approach taken in this report.

Table 1. Preliminary List of Historical Records of Sensitive Species of Insects and other Arthropods from the Saddle Road Area

Scientific Name	Rarity
Archaeognatha: Machilidae *Neomachilis heteropus* Silvestris	Rarely seen
Coleoptera: Aglycyderidae *Proterhinus* spp.	Many spp. sparse or on rare host
Coleoptera: Cerambycidae *Plagithmysus montgomeryi* Gressitt & Davis	Rare, on rare host
Coleoptera: Cerambycidae *Plagithmysus mezoneuri* Swezey	Rare, on rare host
Coleoptera: Curculionidae *Rhyncogonus giffardi* Sharp	?Rare, limited distribution
Diptera: Dolichopodidae *Campsicnemus hawaiiensis* Hardy & Delfinado	?Extinct
Diptera: Drosophilidae *Drosophila heteroneura* Perkins	?Extinct (last collected in 1990)
Heteroptera: Reduviidae *Nesidiolestes ana* Gagné & Howarth	Rare, specialized habitat (cave)
Heteroptera: Reduviidae *Nesidiolestes selium* Kirkaldy	Rare
Lepidoptera: Lycaenidae *Udara blackburni* (Tuely)	Sparse
Odonata: Coenagrionidae *Megalagrion amaurodytum peles* (Perkins)	Sparse
Orthoptera: Gryllidae *Caconemobius varius* Gurney & Rentz	Rare, specialized habitat (cave)
Orthoptera: Gryllidae *Thaumatogryllus cavicola* Gurney & Rentz	Rare, specialized habitat (cave)

Table 2. Snail species from Hawaii Island Acknowledged by the USFWS as Species of Concern.

Scientific Name	Common Name
Partulina confusa (Sykes, 1900)	Hawaii tree snail
Partulina horneri (Baldwin, 1895)	Hawaii tree snail
Partulina physa (Newcomb, 1854)	Hawaii tree snail
Leptachatina lepida Cooke, 1910	no common name

1.2.2. *Insects and other arthropods*

Eleven of the 29 Hawaiian species of arthropods formally listed as candidates (C1) for endangered or threatened status by the U.S. Fish and Wildlife Service (USFWS) occur on the Big Island and are listed in Table 3 . Previously listed by USFWS as candidate (C2 & C3) species, but now considered "species of concern," are 104 species recorded from the Big Island. These species are listed in Table 4 . Though many of these species have not been recorded from Saddle Road previously and were not collected during the course of this survey, this does not eliminate the possibility that they might occur along existing and alternate proposed alignments. Owing to the length of Saddle Road and its traverse through many elevational and ecological zones, the vagility of many arthropods and their seasonality, and the presence of potential prey or host plants along the route, populations of species of concern and candidates could occur along the corridor.

Table 3. Candidate Species (C1) of Arthropods Known to Occur (or have historicall occurred) on Hawaii Island.

Scientific Name	Common Name
ODONATA: COENAGRIONIDAE	
Megalagrion nesiotes (Perkins)	Nesiotes megalagrion damselfly
Megalagrion nigrohamatum nigrolineatum (Blackburn)	Blackline megalagrion damselfly
Megalagrion pacificum (McLachlan)	Pacific megalagrion damselfly
Megalagrion xanthomelas (Selys-Longchamps)	Orangeblack megalagrion damselfly
DIPTERA: DROSOPHILIDAE	
Drosophila aglaia Hardy, 1965	pomace fly (no common name)
Drosophila alsophila Hardy & Kaneshiro, 1971	pomace fly (no common name)
Drosophila digressa Hardy & Kaneshiro, 1968	pomace fly (no common name)
Drosophila heteroneura (Perkins, 1910)	pomace fly (no common name)
Drosophila mulli Perreira & Kaneshiro, 1990	pomace fly (no common name)
Drosophila musaphilia Hardy, 1965	pomace fly (no common name)
Drosophila psilotarsalis Hardy & Kaneshiro, 1975	pomace fly (no common name)

Although 133 species are formally listed as candidates or "species of concern," a recent report to the National Biological Survey (NBS) (Nishida, 1994), urged a review of the species currently on the list and a review of the status of others not presently on the list, but with potential for listing. Therefore, a number of species are included in this report as "sensitive" species even though they are not on the list of candidates or the list of species of concern. These species are those that are known to have restricted ranges and/or restricted habitat needs or those whose populations have been observed anecdotally to have declined.

Table 4. Arthropod Species of Concern (formerly C2 & C3) Known to Occur (or Have Historically Occurred) on Hawaii Island.

Scientific Name	Common Name
ARCHAEOGNATHA: MACHILIDAE	
Neomachilis heteropus (Silvestri)	Hawaiian long-palp bristletail
COLEOPTERA: AGLYCYDERIDAE	
72 spp. (not specified)	
COLEOPTERA: CERAMBYCIDAE	
Plagithmysus claviger (Sharp)	Hawaii clubbed long-horned beetle
Plagithmysus decorus Perkins	Hawaii decorus long-horned beetle
Plagithmysus elegans Sharp	Hawaii elegant long-horned beetle
Plagithmysus greenwelli Gressitt & Davis	Greenwell's long-horned beetle
Plagithmysus kohalae Perkins	Kohala long-horned beetle
Plagithmysus kraussi Gressitt & Davis	Krauss' long-horned beetle
Plagithmysus laticollis (Sharp)	Maui wide-necked long-horned beetle
Plagithmysus mezoneuri (Swezey)	Hawaii uhiuhi long-horned beetle
Plagithmysus nihoae Perkins	Nihoa long-horned beetle
Plagithmysus platydesmae Perkins	Pilo kea long-horned beetle
Plagithmysus podagricus (Perkins)	Hawaii podagricus long-horned beetle
Plagithmysus simplicicollis Sharp	Simple-necked long-horned beetle
Plagithmysus sulphurescens Sharp	Hawaii opuhe long-horned beetle
Plagithmysus swezeyi Perkins	Swezey's long-horned beetle
Plagithmysus vicinus Sharp	Hawaii alani long-horned beetle
COLEOPTERA: CURCULIONIDAE	
Deinocossonus nesiotes Perkins	Oahu nesiotes weevil
Nesotocus giffardi Perkins	Giffard's nesotocus weevil
Nesotocus munroi Perkins	Munro's nesotocus weevil
Rhyncogonus giffardi Sharp	Giffard's rhyncogonus weevil
COLEOPTERA: ELATERIDAE	
Eopenthes cognatus Sharp	Cognatus eopenthes click beetle
Eopenthes tinctus Sharp	Tinged eopenthes click beetle
HETEROPTERA: LYGAEIDAE	
Metrarga obscura Blackburn	Mauna Loa seed bug
Nesocryptias villosa (White)	Villosan flightless seed bug
Oceanides bryani Usinger	Bryan's oceanides seed bug
HETEROPTERA: MESOVELIIDAE	
Cavaticovelia aaa (Gagné & Howarth)	Aaa water treader big
HETEROPTERA: MIRIDAE	
Kalania hawaiiensis (Kirkaldy)	Lanai kalanian leaf bug

Table 4 (continued). Arthropod Species of Concern (formerly C2 & C3) Known to Occur (or have historically occurred) on Hawaii Island

Scientific Name	Common Name
HETEROPTERA: PENTATOMIDAE	
Coleotichus blackburniae White	Koa bug
Oechalia grisea (Burmeister)	Gray oechalia stink bug
Oechalia patruelis (Stål)	Patruelis oechalia stink bug
HETEROPTERA: REDUVIIDAE	
Empicoris pulcher (Blackburn)	Pulchrus thread bug
Nesidiolestes ana Gagné & Howarth	Ana wingless thread bug
Nesidiolestes insularis Kirkaldy	Mt. Tantalus wingless thread bug
Nesidiolestes selium Kirkaldy	Robert's wingless thread bug
HETEROPTERA: RHOPALIDAE	
Ithamar annectans Van Duzee	Annectans rhopalid bug
Ithamar hawaiiensis Kirkaldy	Hawaiian rhopalid bug
HOMOPTERA: DELPHACIDAE	
Nesosydne cyrtandricola Muir	Glenwood nesosydne planthopper
HYMENOPTERA: COLLETIDAE	
Hylaeus anthracina (F. Smith)	Anthracinan yellow-faced bee
Hylaeus assimulans (Perkins)	Assimulans yellow-faced bee
Hylaeus blackburni (F. Smith)	Blackburn's yellow-faced bee
Hylaeus comes (Perkins)	Comes yellow-faced bee
Hylaeus coniceps (Blackburn)	Conehead yellow-faced bee
Hylaeus crabronoides (Perkins)	Crabronoid yellow-faced bee
Hylaeus difficilis (Perkins)	Difficult yellow-faced bee
Hylaeus dimidiata (Perkins)	Dimidiatan yellow-faced bee
Hylaeus erythrodemas (Perkins)	Erythrodeme yellow-faced bee
Hylaeus facilis (F. Smith)	Easy yellow-faced bee
Hylaeus filicum (Perkins)	Fern yellow-faced bee
Hylaeus flavipes (F. Smith)	Yellow-foot yellow-faced bee
Hylaeus homoeochroma (Perkins)	Monocolor yellow-faced bee
Hylaeus hula (Perkins)	Hulan yellow-faced bee
Hylaeus insignis (Perkins)	Insignis yellow-faced bee
Hylaeus kona (Blackburn)	Kona yellow-faced bee
Hylaeus laeta (Perkins)	Laetan yellow-faced bee
Hylaeus obscurata (Perkins)	Obscuratan yellow-faced bee
Hylaeus ombrias (Perkins)	Ombrias yellow-faced bee
Hylaeus pele (Perkins)	Pele yellow-faced bee
Hylaeus psammobia (Perkins)	Psammobian yellow-faced bee
Hylaeus pubescens (Perkins)	Furry yellow-faced bee
Hylaeus rugulosa (Perkins)	Rugulose yellow-faced bee
Hylaeus setosifrons (Perkins)	Bristlefront yellow-faced bee
Hylaeus simplex (Perkins)	Simple yellow-faced bee
Hylaeus specularis (Perkins)	Specular yellow-faced bee
Hylaeus sphecodoides (Perkins)	Sphecodoid yellow-faced bee
Hylaeus vicina (Perkins)	Vicinan yellow-faced bee
Hylaeus volatilis (F. Smith)	Volatile yellow-faced bee

Table 4 (continued). Arthropod Species of Concern (formerly C2 & C3) Known to Occur (or have historically occurred) on Hawaii Island

Scientific Name	Common Name
HYMENOPTERA: SPHECIDAE	
Deinomimesa hawaiiensis Perkins	Hawaiian deinomimesan sphecid wasp
Deinomimesa punae Perkins	Puna deinomimesan sphecid wasp
Ectemnius bidecoratus (Perkins)	Bidecoratus sphecid wasp
Ectemnius curtipes (Perkins)	Short-foot ecteminus sphecid wasp
Ectemnius fulvicrus (Perkins)	Brown cross ectemnius sphecid wasp
Ectemnius rubrocaudatus (Blackburn)	Red-tail ectemnius sphecid wasp
Ectemnius yoshimotoi Bohart	Yoshimoto's ectemnius sphecid wasp
HYMENOPTERA: VESPIDAE	
Odynerus nigripennis (Holmgren)	Black-winged odynerus vespid wasp
LEPIDOPTERA: CRAMBIDAE	
Glyphodes cyanomichla (Meyrick)	Blue margaronian moth
Omiodes anastrepta Meyrick	Molokai sedge hedyleptan moth
Omiodes anastreptoides Swezey	Kohala Mountain sedge hedyleptan moth
Omiodes euryprora Meyrick	Ola'a banana hedyleptan moth
Omiodes fullawayi Swezey	Fullaway's banana hedyleptan moth
Omiodes giffardi Swezey	Giffard's 'ohe hedyleptan moth
Omiodes iridias Meyrick	Kilauea pa'iniu hedyleptan moth
Omiodes meyricki Swezey	Meyrick's banana hedyleptan moth
Omiodes monogona Meyrick	Hawaiian bean leafroller (moth)
Omiodes pritchardii Swezey	Hawaiian lo'ulu hedyleptan moth
Omiodes telegrapha Meyrick	Telegraphic hedyleptan moth
Stemorrhages exaula (Meyrick)	Green margaronian moth
LEPIDOPTERA: GEOMETRIDAE	
Scotorythra megalophylla Meyrick	Kona giant looper moth
Tritocleis microphylla Meyrick	'Ola'a peppered looper (moth)
LEPIDOPTERA: LYCAENIDAE	
Udara blackburni (Tuely)	Blackburn butterfly
LEPIDOPTERA: NOCTUIDAE	
Agrotis crinigera (Butler)	Larger Hawaiian cutworm
Agrotis melanoneura Meyrick	Black-veined agrotis noctuid moth
Agrotis microreas Meyrick	Microreas agrotis noctuid moth
Helicoverpa confusa Hardwick	Confused helicoverpan noctuid moth
Hypena newelli (Swezey)	Hilo hypenan noctuid moth
Hypena plagiota (Meyrick)	Lovegrass noctuid moth
LEPIDOPTERA: SPHINGIDAE	
Manduca blackburni (Butler)	Blackburn's sphinx moth
NEUROPTERA: HEMEROBIIDAE	
Micromus usingeri (Zimmerman)	Usinger's brown lacewing

Table 4 (continued). Arthropod Species of Concern (formerly C2 & C3) Known to Occur (or have historically occurred) on Hawaii Island

Scientific Name	Common Name
NEUROPTERA: MYRMELEONTIDAE	
Distoleon perjurus (Walker)	Molokai antlion
ODONATA: COENAGRIONIDAE	
Megalagrion amaurodytum peles (Perkins)	Pele ie'ie damselfly
Megalagrion nigrohamatum (Blackburn)	Nigrohamatum megalagrion damselfly
ORTHOPTERA: GRYLLIDAE	
Caconemobius varius Gurney & Rentz	Kaumana cave cricket
Thaumatogryllus cavicola Gurney & Rentz	Volcanoes cave cricket
ORTHOPTERA: TETTIGONIIDAE	
Ruspolia remotus (Walker)	Remote conehead katydid

2. METHODS

A total of 80 sampling sites were investigated during this project (see Table 5 for locality (i.e., station number), date(s) and habitat data on each site. See Tables 6 and 7 for a list of the snails and insects and related arthropods collected at each site. See also Maps 1-5 for details on location of each sampling site).

2.1. Snails

Land snails were collected by visual search of leaf litter and vegetation at each site in microhabitats identified as most likely to harbor snail populations. Observations of above-ground vegetation were made in order to search for tree snails. Although 57 sites were investigated for snails, snails were found and collected at only 28 of them. Details of sites are given in Table 5. Sorting and identification were performed at Bishop Museum (Honolulu). Specimens were identified as far as was possible, based on shell characters, and by reference to the literature and to the extensive collections of Bishop Museum. Most specimens were identified to genus level, with "sp. A", "sp. B" and so on indicated as necessary. In some cases, the collected material may represent undescribed species. In addition, specimens were recorded as live, recently dead (shell with at least half the periostracum still present, and the shell retaining its original color and not changed to opaque white), and long dead (less than half the periostracum still present, and/or shell opaque white).

2.2. Insects and other arthropods

2.2.1 *Collecting methods*

Various field collecting methods were employed during the field work portion of the project in order to ensure as complete a survey of existing species of arthropods as possible given the time constraints. The major collecting methods employed were Malaise traps, water traps, beating sheets, sweep nets, and bait traps. Each method and examples of types of animal collected by such method is explained in detail in Appendix I.

2.2.2 *Identifications*

Time constraints did not allow us to identify all the material collected. Instead, priority was given to assessing the sensitive species of arthropods that were known to be collected in the area. Then, as time permitted, other arthropods were identified and added to the list of species. Certain groups of arthropods are still not known well taxonomically or do not have keys for their identification. Wherever possible, identification was to species level. However, in some cases, identification was done to morpho-species (in which cases identification is indicated by "sp. 1", "sp. 2", etc.). In other cases, a genus or species could not be ascertained and the identification for those taxa are labeled as "gen. sp." or "sp."

Voucher specimens of all reported taxa are preserved in the collections of the J. Linsley Gressitt Center for Entomological Research, Bishop Museum.

2.3 Special habitats: Caves

A special survey of cave habitats was undertaken to investigate lava tubes reported along the Saddle Road alignments. Over 16 potential cave entrances at six sites were checked, and four separate cave segments found and investigated. Animals were searched for visually, especially in suitable habitats, such as tree roots and other natural food resources, crevices,

along edges where the wall met the floor, under stones, and moist substrates. Baits (dried shrimp, corn chips, and fresh bean sprouts) were placed in suitable habitats in Strawberry Cave and checked on subsequent trips one to three days later. Particular attention was devoted to recognizing the environmental zones present. Many rare and sensitive species are obligate cave species and restricted to deep zone habitats; that is, moist still-air passages beyond direct environmental effects of climatic events on the surface (Howarth, 1993). See Appendix II for detailed descriptions of the caves known to occur in the Saddle Road area.

Table 5. Sampling locations with associated site numbers and vegetation habitats for each site.

Site No.	Date(s)	Location	Habitat
1	20.8.96	EX-3 163 + 000 Milepost 14	*Ohia* forest
2	20-22.8.96	EX-3 155 + 000 Milepost 19.3 (*Kipuka* 9)	*Ohia/Cibotium* fern forest *kipuka*
3	20,23.8.96	EX-3 156 + 103.039	*Ohia* scrub
4	21.8.96	PTA-3 11+260	Mamane/Naio forest
5	21-24.8.96	PTA-1 25+000 (Malaise)	Mamane/Naio forest
6	21.8.96	PTA-1 24 + 460	Mamane/Naio forest
7 (part)	21-24.8.96	W-2 113 + 620 (Malaise)	rangeland with scattered *Dodonaea* (a'ali'i) scrub
8	21.8.96	W-2 112 + 720	rangeland grass with scattered *Dodonaea* (a'ali'i) scrub
9	21.8.96	W-3 110 + 620	rangeland grass
10	21.8.96	W-2 112 + 060	rangeland grass
11	21.8.96	W-2 111 + 520	rangeland grass
12	21.8.96	W-2 109 + 720	rangeland grass
13	21.8.96	W-3 109 + 960	rangeland grass with scattered *Dodonaea* (a'ali'i) scrub
14	21.8.96	W-2 114 + 500 (Parker Ranch access gate)	rangeland grass with scattered *Dodonaea* (a'ali'i) scrub
15	22.8.96	W-2 104 + 122 and W-2 104 + 140	rangeland grass
16	22.8.96	W-2 104 + 500 (2nd Parker stop-gulch)	rangeland grass
17	22.8.96	W-3 100 + 180	rangeland grass
18	22.8.96	W-3 100 + 240	rangeland grass
19	22.8.96	W-3 100 + 300	rangeland grass
20	22.8.96	EX-1 103 + 064 (1.9 mi E jct)	rangeland grass with scattered *Dodonaea* (a'ali'i) scrub
21	22.8.96	EX-1 103 + 951 (2.45 mi E. jct)	rangeland grass with scattered *Dodonaea* (a'ali'i) scrub
22	22.8.96	PTA-1 30 + 400	pahoehoe lava flow/ sparse vegetation
23	22.8.96	EX-3 154 + 180	*Ohia* scrub
24	22.8.96	EX-2 142 + 700	pahoehoe lava flow/ sparse vegetation
25	23.8.96	PTA-1 19 + 480 (6000')	Mamane/Naio forest
26	23.8.96	PTA-1 18 + 155.35 (5880')	Mamane/Naio forest
27	23.8.96	PTA-1 15 + 760 (5640')	scattered Mamane/Naio scrub
28	23.8.96	PTA-1 11 + 620	scattered Mamane/Naio scrub
29	23.8.96	PTA-1 11 + 560 (5420')	scattered Mamane/Naio scrub
30	23.8.96	PTA-1 26 + 860 (6480')	Mamane/Naio forest

Table 5 (continued). Sampling locations with associated site numbers and vegetation habitats for each site

Site No.	Date(s)	Location	Habitat
31	23.8.96	PTA-1 22 + 344.27 (6300')	Mamane/Naio forest
32	23.8.96	PTA-3 12 + 160	'A'a lava flow with sparse vegetation
33	24.8.96	EX-2 126 + 391.429 (5820')	scattered *Dodonaea* (a'ali'i)/eucalyptus
34	24.8.96	EX-2 126 + 340	scattered *Dodonaea* (a'ali'i)/eucalyptus
35	24.8.96	EX-2 130 + 960 (6120')	Mamane/Naio forest
36	24.8.96	EX-2 131 + 020 (6080')	Mamane/Naio forest
37	24.8.96	EX-3 155 + 500 (4800')	*Ohia* scrub on 'a'a lava flow/*Ohia-Cibotium kipuka*
38	24.8.96	EX-3 163+ 000	*Ohia* scrub on 'a'a lava flow
39	4.9.96	W-2 114 + 580	scattered *Dodonaea* (a'ali'i) scrubland
40	4.9.96	W-2 115 + 000 and W-2 115 + 060 and W-2 115 + 120 (5240')	scattered *Dodonaea* (a'ali'i) scrubland
41	4.9.96	W-2 114 + 940 (5220')	scattered *Dodonaea* (a'ali'i) scrubland
42	4.9.96	W-2 115 + 858.362	scattered *Dodonaea* (a'ali'i) scrubland
43	4.9.96	EX-2 121 + 660 (5680') (mile post 40)	scattered *Dodonaea* (a'ali'i) scrubland
44	4.9.96	EX-2 123 + 282.354 (mile post 39)	scattered *Dodonaea* (a'ali'i) scrubland
45	5.9.96	E-3 43 + 900 (1500')	Pasture land and weedy scrub
46	5.9.96	EX-4A 21 + 397.068	*Ohia* forest
47	5.9.96	EX-4 173 + 260 (1840') (jct. of Nolemana St.)	*Ohia* forest/uluhe fern
48	5/9/96	PTA 1A 13 + 200	pahoehoe lava flow/sparse vegetation
49	5.9.96	PTA-1A 12 + 940	pahoehoe lava flow/sparse vegetation
50	5.9.96	PTA 1 30 + 998.930	pahoehoe lava flow/sparse vegetation
51	5.9.96	PTA-1 30 + 280	pahoehoe lava flow/sparse vegetation
52	5.9.96	PTA-1A 12 + 880	pahoehoe lava flow/sparse vegetation
53	5.9.96	PTA-1 30 + 220	pahoehoe lava flow/sparse vegetation
54	5.9.96	PTA-1 30 + 160	pahoehoe lava flow/sparse vegetation
55	5.9.96	PTA-1 30 + 100 (6380')	pahoehoe lava flow/sparse vegetation
56	5.9.96	PTA-1 30 + 028.92	pahoehoe lava flow/sparse vegetation
57	5.9.96	PTA-1A 12 + 040 (6400')	pahoehoe lava flow/sparse vegetation
58	5.9.96	PTA-1A 11 + 986	pahoehoe lava flow/sparse vegetation
59	5.9.96	PTA-1A 11 + 980	pahoehoe lava flow/sparse vegetation
60	5.9.96	PTA-1A 11 + 920 (6400')	pahoehoe lava flow/sparse vegetation
61	5.9.96	EX-2 139 + 240	pahoehoe lava flow/sparse vegetation
62	5.9.96	PTA-1A 13 + 000	pahoehoe lava flow/sparse vegetation
63	5.9.96	PTA-1A 12 + 280 (6400')	pahoehoe lava flow/sparse vegetation
64	5.9.96	PTA-1A 12 + 220 (6400')	pahoehoe lava flow/sparse vegetation
65	5.9.96	EX-2 132 + 100 and EX-2 132 + 220 (6180') and EX-2 132 + 230	'A'a lava flow/roadside weeds
66	5.9.96	PTA-1 27 + 270.87 (6560')	pahoehoe lava flow/sparse vegetation
67	5.9.96	PTA-1 27 + 220 (6580')	Mamane/Naio forest
68	5.9.96	PTA 3 10 + 300 (6580')	scattered Mamane/Naio forest
69	5.9.96	PTA 1 25 + 120	Mamane/Naio forest
70	6.9.96	EX-1 111 + 902.063 (4940')	rangeland grass with eucalyptus
71	6.9.96	EX-1 113 + 200	rangeland grass
72	6.9.96	EX-1 115 + 660 (5460')	scattered *Dodonaea* (a'ali'i) scrubland

Table 5 (continued). Sampling locations with associated site numbers and vegetation habitats for each site

Site No.	Date(s)	Location	Habitat
73	6.9.96	PTA-1 13 + 360 (5780')	pahoehoe lava flow/sparse vegetation
74	19.10.1996	EX-2 139 + 600 to EX-2 140 + 700	cave
75	19.10.1996	EX-3 140 + 700 to EX-3 140 + 860	cave
76	19.10.96	EX-3 141 + 880	cave
77	19-22.10.96	EX-3 148 + 240	cave
78	20.10.96	Upper Kaumana Cave (1881 Lava flow) no stake markers	cave
79	21.10.96	PTA 16 + 600	cave
80	21.x.1996	EX-3 156 + 760	cave

Table 6. Numbers of specimens of each snail species found at each site. Sites that were investigated but at which no snails were found are not listed. Some survey sites were only investigated for insects. Numbers (e.g., RHC 96.42, etc.) are RHC's field numbers.

Site	Species	Live	Recently dead	Long dead
1. (RHC 96.42)				
	Oxychilus alliarius	2	9	1
	Euconulus thaanumi	0	4	0
	"tornatellinid" D	1	0	0
2. (RHC 96.43)				
	Oxychilus alliarius	15	1	0
	?*Deroceras* sp.	6	0	0
3. (RHC 96.44)				
	Oxychilus alliarius	7	11	0
	?*Deroceras* sp.	5	0	0
4. (RHC 96.45)				
	Oxychilus alliarius	0	1	0
	Succinea konaensis	0	22	25
	Vitrina tenella	0	0	2
	?*Striatura* sp.	0	4	12
	Lamellidea sp.	0	1	7
	"tornatellinid" A	0	5	29
	"tornatellinid" B	0	2	27
	"tornatellinid" C	0	0	3
	Leptachatina lepida	0	1	14
5. (RHC 96.46)				
	Oxychilus alliarius	1	9	3
	Succinea konaensis	0	2	14
	Striatura sp. cf. *meniscus*	0	0	2
	?*Striatura* sp.	0	0	1
	Nesopupa subcentralis	0	0	1
	"tornatellinid" A	0	0	4
	"tornatellinid" B	0	0	6
	Leptachatina lepida	0	0	5
6. (RHC 96.47)				
	Succinea konaensis	0	80	2
	?*Striatura* sp.	0	0	1
	"tornatellinid" B	11	18	9
	Leptachatina lepida	4	1	0
7. (RHC 96.48)				
	Succinea konaensis	0	0	1
8. (RHC 96.49)				
	Succinea konaensis	0	0	2
23. (RHC 96.50)				
	Oxychilus alliarius	1	3	5

Table 6 (continued). Numbers of specimens of each snail species found at each site.

Site	Species	Live	Recently dead	Long dead
25. (RHC 96.51)				
	Succinea konaensis	0	9	16
	?*Striatura* sp.	0	0	1
	"tornatellinid" B	0	8	16
	Leptachatina lepida	0	9	6
26. (RHC 96.52)				
	Succinea konaensis	0	5	0
	?*Striatura* sp.	0	19	5
27. (RHC 96.53)				
	Succinea konaensis	0	1	2
	?*Striatura* sp.	0	2	13
28. (RHC 96.54)				
	Succinea konaensis	0	1	2
	?*Striatura* sp.	0	0	8
	"tornatellinid" B	0	0	16
	Leptachatina lepida	0	0	4
30. (RHC 96.55)				
	Succinea konaensis	1	90	22
	Lamellidea sp.	1	0	0
	"tornatellinid" A	1	6	21
	"tornatellinid" B	0	1	4
	"tornatellinid" C	0	0	5
	Leptachatina lepida	7	13	11
31. (RHC 96.56)				
	Succinea konaensis	0	48	41
	?*Striatura* sp.	0	2	20
	"tornatellinid" B	0	0	3
34. (RHC 96.57)				
	Succinea konaensis	0	1	12
	?*Striatura* sp.	0	7	6
35. (RHC 96.58)				
	Succinea konaensis	0	24	14
	Striatura sp. cf. *meniscus*	2	16	4
	?*Striatura* sp.	0	12	8
	Lamellidea sp.	0	0	1
	Leptachatina lepida	14	34	12
39. (RHC 96.59)				
	Succinea konaensis	0	1	2
	?*Striatura* sp.	0	3	12
	"tornatellinid" A	0	0	1
	"tornatellinid" B	0	0	1
	"tornatellinid" C	0	0	4

Table 6 (continued). Numbers of specimens of each snail species found at each site.

Site	Species	Live	Recently dead	Long dead
40. (RHC 96.60)				
9	*Succinea konaensis*	0		4
8	?*Striatura* sp.	0		20
41. (RHC 96.61)				
	Succinea konaensis	0	3	16
	?*Striatura* sp.	0	30	10
	"tornatellinid" B	0	1	4
	Leptachatina lepida	0	0	5
	Leptachatina sp. A	0	0	3
43. (RHC 96.62)	?*Striatura* sp.	0	13	5
44. (RHC 96.63)				
	Succinea konaensis	0	3	11
	?*Striatura* sp.	0	0	1
46. (RHC 96.64)	?*Deroceras* sp.	1	0	0
47. (RHC 96.65)				
	?*Deroceras* sp.	1	0	0
	Euglandina rosea	0	0	1
65. (RHC 96.66)				
	Succinea konaensis	1	4	8
	?*Striatura* sp.	0	3	28
66. (RHC 96.67)				
	Succinea konaensis	0	27	38
	?*Striatura* sp.	0	3	28
	Vitrina tenella	0	0	1
	"tornatellinid" A/C	0	10	60
	Leptachatina lepida	1	20	43
72. (RHC 96.68)	*Oxychilus alliarius*	0	12	4
73. (RHC 96.69)	*Succinea konaensis*	0	4	5

Table 7. Insects collected at each site (Species in boldface are those determined as "sensitive". See text for discussion. NIR = New Island Record [for Hawaii Island]; NSR = New State Record.)

Site No.	Insects	Related Arthropods
1	DIPTERA: Syrphidae: *Toxomerus marginatus* (Say) HYMENOPTERA: Bethylidae: *Sierola* sp. 1 HYMENOPTERA: Braconidae: *Meteorus laphygmae* Viereck	
2	COLEOPTERA: Aglycyderidae ***Proterhinus*** sp. COLEOPTERA: Staphylinidae: ***Liophaena gracilipes*** Sharp COLEOPTERA: Coccinellidae: *Hippodamia convergens* Guérin *Scymnus loewii* Mulsant *Hyperaspis fimbriolata* Melsheimer DIPTERA: Dolichopodidae: *Campsicnemus* n. sp. nr. *loxothrix* *Campsicnemus scolimerus* Hardy & Kohn *Eurynogaster* sp. DIPTERA: Calliphoridae: *Dyscritomyia* sp. DIPTERA: Drosophilidae: *Drosophila paracracens* Hardy *Drosophila crassifemur* Grimshaw *Drosophila immigrans* Sturtevant *Drosophila suzukii* (Matsumura) DIPTERA: Muscidae: *Brontaea quadristigma* (Thomson) DIPTERA: Sphaeroceridae: *Poecilosomella punctipennis* (Wiedemann) HYMENOPTERA: Bethylidae: *Sierola* sp. 1 HYMENOPTERA: Eucoilidae: *Pseudeucoila* cf. *oreias* (Perkins) HYMENOPTERA: Scelionidae: *Baeus* sp. HYMENOPTERA: Diapriidae: *Trichopria ?soror* (Perkins) HYMENOPTERA: Formicidae: *Cardiocondyla* sp.	
3	ODONATA: Coenagrionidae: ***Megalagrion amaurodytum* peles** (Perkins)	

Table 7. Insects collected at each site (continued). (NIR = New Island Record [for Hawaii Island]; NSR = New State Record.)

Site No.	Insects	Related Arthropods
4	COLEOPTERA:	
	Hyperaspis fimbriolata Melsheimer	
	HYMENOPTERA: Bethylidae:	
	Sierola sp. 1	
	HYMENOPTERA: Braconidae:	
	Habrobracon hebetor (Say)	
	HYMENOPTERA: Vespidae:	
	Ectemnius sp.	
	HYMENOPTERA: Colletidae:	
	***Hylaeus* (*Nesoprosopis*)** sp. 1	
	HYMENOPTERA: Encyrtidae:	
	Copidosoma sp.	
5 (part)	COLEOPTERA: Carabidae:	
	Pristonychus complanatus Dejean	
	COLEOPTERA: Cerambycidae:	
	Plagithmysus blackburni (Sharp)	
	Plagithmysus filipes sophorae Gressitt & Davis	
	DIPTERA: Agromyzidae:	
	Calcomyza humeralis (Roser)	
	Liriomyza sativae Blanchard	
	DIPTERA: Calliphoridae:	
	Calliphora vomitoria (Linnaeus)	
	DIPTERA: Cecidomyiidae:	
	gen. sp. 1	
	gen. sp. 2	
	DIPTERA: Ceratopogonidae:	
	Forcipomyia hardyi Wirth & Howarth	
	DIPTERA: Chamaemyiidae:	
	Leucopis obscura Haliday	
	DIPTERA: Chironomidae:	
	gen. sp. 1	
	DIPTERA: Drosophilidae:	
	Scaptomyza apiciguttula Hardy	
	Scaptomyza sp. near *articulata* Hardy	
	DIPTERA: Muscidae:	
	Lispe metatarsalis Thomson	
	DIPTERA: Phoridae:	
	Megaselia sp.	
	Diplonevra peregrina (Wiedemann)	
	DIPTERA: Sarcophagidae:	
	Helicobia morionella (Aldrich)	
	DIPTERA: Scatopsidae:	
	Coboldia fuscipes (Meigen)	
	DIPTERA: Sphaeroceridae:	
	Leptocera sp.	
	DIPTERA: Syrphidae:	
	Allograpta obliqua Say	
	Toxomerus marginatus (Say)	
	Simosyrphus grandicornis (Macquart)	

Table 7. Insects collected at each site (continued). (NIR = New Island Record [for Hawaii Island]; NSR = New State Record.)

Site No.	Insects	Related Arthropods
5 (cont.)	HETEROPTERA: Lygaeidae: *Nysius coenosulus* (Stål) HETEROPTERA: Miridae: *Opuna sharpianus* (Kirkaldy) HYMENOPTERA: Colletidae: ***Hylaeus* (*Nesoprosopis*)** sp. 1 HYMENOPTERA: Vespidae: ***Ectemnius*** sp. *Vespula pensylvanica* (Saussure) HYMENOPTERA: Halictidae: *Halictus* sp. HYMENOPTERA: Bethylidae: *Parasierola* sp. **NSR** *Sierola* sp. HYMENOPTERA: Ichneumonidae: *Spilichneumon superbus* (Provancher) HYMENOPTERA: Trichogrammatidae: gen. sp. HYMENOPTERA: Braconidae: *Cotesia marginiventris* (Cresson)	
6	COLEOPTERA: Curculionidae: *Asynonychus godmanni* Crotch DIPTERA: Sarcophagidae: *Ravinia lherminierii* (Robineau-Desvoidy) HYMENOPTERA: Bethylidae: Parasierola sp. **NSR** *HYMENOPTERA*: Braconidae: *Cotesia* sp. HYMENOPTERA: Vespidae: *Vespula pensylvanica* (Saussure) ***Odynerus*** sp. ***Ectemnius*** sp.	
7 (part)	HYMENOPTERA: Vespidae: ***Ectemnius*** sp. 1 ***Ectemnius*** sp. 2 ***Odynerus*** sp. HYMENOPTERA: Colletidae: ***Hylaeus* (*Nesoprosopis*)** sp. 1 ***Hylaeus* (*Nesoprosopis*)** sp. 2 HYMENOPTERA: Sphecidae: *Dryudella immigrans* (Williams) HYMENOPTERA: Aphelinidae: gen. sp. HYMENOPTERA Encyrtidae: *Copidosoma* sp. *Ooencyrtus* sp. HYMENOPTERA: Eulophidae: *Diglyphus* sp. *Tetrastichus* sp. gen. sp.	

Table 7. Insects collected at each site (continued). (NIR = New Island Record [for Hawaii Island]; NSR = New State Record.)

Site No.	Insects	Related Arthropods
7 (cont.)	HYMENOPTERA: Mymaridae:	
	Polynema sp.	
	HYMENOPTERA: Pteromalidae:	
	Pteromalus puparum (L.)	
	Cyrtogaster sp.	
	Norbanus sp. **NSR**	
	HYMENOPTERA: Bethylidae:	
	Epyris sp. not *extraneus* **NSR**	
	HYMENOPTERA: Eucoilidae:	
	Ganaspidium utilis Beardsley	
	HYMENOPTERA: Braconidae:	
	Chelonus blackburni Cameron	
	Meteorus laphygmae Viereck	
	gen. sp.	
	HYMENOPTERA: Halictidae:	
	Halictus sp. **NSR**	
	HYMENOPTERA: Apidae:	
	Apis mellifera Linnaeus	
	HYMENOPTERA: Ichneumonidae:	
	Pimpla punicipes Cresson	
	Diadegma blackburni (Cameron)	
	Diadegma sp. 1	
	Pristomerus spinator (Fabricius)	
	Spilichneumon superbus (Provancher)	
	HYMENOPTERA: Platygasteridae:	
	gen. sp.	
	HYMENOPTERA: Scelionidae	
	Trissolcus basalis (Wollaston)	
	Trissolcus sp.	
	gen. sp. 2	
	gen. sp. 3	
	HYMENOPTERA: Diapriidae:	
	Stylaclista sp.	
	DIPTERA: Agromyzidae:	
	Liriomyza sativae Blanchard	
	Ophiomyia lantanae Froggatt	
	DIPTERA: Anthomyiidae:	
	Delia platura (Meigen)	
	DIPTERA: Scenopinidae:	
	Scenopinus lucidus Becker **NIR**	
	DIPTERA: Tachinidae:	
	Trichopoda pilipes (Fabricius)	
	Lespesia archippivora (Riley)	
	Eucelatoria armigera (Coquillett)	
	DIPTERA: Tephritidae:	
	Trupanea n. sp. 1	
	DIPTERA: Chloropidae:	
	gen. sp.	
	DIPTERA: Phoridae:	
	Diplonevra peregrina (Wiedemann)	

Table 7. Insects collected at each site (continued). (NIR = New Island Record [for Hawaii Island]; NSR = New State Record.)

Site No.	Insects	Related Arthropods
7 (cont.)	DIPTERA: Cecidomyiidae:	
	Anarete johnsoni (Felt)	
	gen. sp.	
	DIPTERA: Ceratopogonidae:	
	Forcipomyia hardyi Wirth & Howarth	
	DIPTERA: Sciaridae:	
	gen. sp.	
	DIPTERA: Sphaeroceridae:	
	Leptocera sp.	
	DIPTERA Calliphoridae:	
	Chrysomyia rufifacies (Macquart)	
	Pollenia rudis (Fabricius)	
	DIPTERA: Sarcophagidae:	
	Heliconia morionella (Aldrich)	
	Ravinia lherminierii (Robineau-Desvoidy)	
	DIPTERA: Syrphidae:	
	Allograpta obliqua Say	
	Allograpta exotica (Wiedemann)	
	Simosyrphus grandicornis (Macquart)	
	Toxomerus marginatus (Say)	
	LEPIDOPTERA: Crambidae:	
	Hellula undalis (Fabricius)	
	Mestolobes nr. *minuscula* (Butler)	
	Orthomecyna ?n. sp.	
	LEPIDOPTERA: Cosmopterigidae:	
	Hyposmocoma spp.	
	LEPIDOPTERA: Oecophoridae:	
	Stoeberhinus testaceus (Butler)	
	Thyrocopa sp.	
	LEPIDOPTERA: Pieridae:	
	Pieris rapae (L.)	
	LEPIDOPTERA: Tortricidae:	
	Cryptophlebia illepida (Butler)	
	HOMOPTERA: Cicadellidae:	
	Deltocephalus sonorus Ball	
8 (part)	COLEOPTERA: Coccinellidae:	
	Scymnus sp.	
	COLEOPTERA: Curculionidae:	
	Hypera postica (Gyllenhal) **NSR**	
	COLEOPTERA: Tenebrionidae:	
	Blapstinus dilatus LeConte	
	Gonocephalum ?bilineatum Walker	
	DIPTERA: Lonchopteridae:	
	Lonchoptera furcata (Fallén)	
	DIPTERA: Anthomyiidae:	
	Delia platura (Meigen)	
	DIPTERA: Chloropidae:	
	Monochaetoscinella anonyma (Williston)	
	DIPTERA: Muscidae:	
	Lispocephala sp.	

Table 7. Insects collected at each site (continued). (NIR = New Island Record [for Hawaii Island]; NSR = New State Record.)

Site No.	Insects	Related Arthropods
8 (cont.)	DIPTERA: Phoridae: *Diplonevra peregrina* (Wiedemann) HETEROPTERA: Nabidae: *Nabis capsiformis* Germar HETEROPTERA: Lygaeidae: *Geocoris punctipes* (Say) HETEROPTERA: Miridae: *Rhinacloa forticornis* Reuter HOMOPTERA: Cicadellidae: *Carneocephala sagittifera* (Uhler) *Balclutha incisa hospes* (Kirkaldy) *Balclutha* sp. HYMENOPTERA: Diapriidae: *Stylaclista* sp. HYMENOPTERA: Eucoilidae: gen. sp. HYMENOPTERA: Eulophidae: *?Diglyphus* sp. HYMENOPTERA: Ichneumonidae: *Diadegma blackburni* (Cameron) HYMENOPTERA: Pteromalidae gen. sp. HYMENOPTERA: Scelionidae: *Trissolcus basalis* (Wollaston) ORTHOPTERA: Gryllidae: *Trigonidomorpha sjostedti* (Chopard)	
9	DIPTERA: Tachinidae: *Eucelatoria armigera* (Coquillett)	
10	<material being processed>	
11	<material being processed>	
12	<material being processed>	
13	HYMENOPTERA: Vespidae: ***Ectemnius*** sp. HETEROPTERA: Pentatomidae: *Nezara viridula* (Linnaeus) LEPIDOPTERA: Crambidae: *Tamsica* cf. *hyacintha* (Meyrick) COLEOPTERA: Chrysomelidae: *Diachus auratus* (Fabricius) COLEOPTERA: Coccinellidae: *Hippodamia convergens* Guérin-Méneville *Otiorhynchus cribricollis* Gyllenhal COLEOPTERA: Tenebrionidae: *Gonocephalum ?bilineatum* Walker	

Table 7. Insects collected at each site (continued). (NIR = New Island Record [for Hawaii Island]; NSR = New State Record.)

Site No.	Insects	Related Arthropods
14	HETEROPTERA: Scutellaridae ***Coleotichus blackburniae*** White	
15	no insects found	
16	HYMENOPTERA: Apidae: *Apis mellifera* Linnaeus COLEOPTERA: Tenebrionidae: *Blapstinus dilatatus* LeConte *Gonocephalum ?bilineatum* Walker	ARANEAE: Araneidae: *Gasteracantha mammosa* C.L. Koch
17	ORTHOPTERA: Acrididae: *Oedaleus abruptus* (Thunberg) COLEOPTERA: Tenebrionidae: *Gonocephalum ?bilineatum* Walker *Lobometopon diremptus* (Karsch) DIPTERA: Sarcophagidae: *Helicobia morionella* (Aldrich)	
18	no insects found	
19	no insects found	
20	ORTHOPTERA: Tettigoniidae: *Conocephalus saltator* (Saussure) ORTHOPTERA: Gryllidae: *Trigonidomorpha sjostedti* (Chopard) HETEROPTERA: Scutellaridae: ***Coleotichus blackburniae*** White COLEOPTERA: Bruchidae: *Algarobius bottimeri* Kingsolver DIPTERA: Scenopinidae: *Scenopinus lucidus* Becker **NIR** COLEOPTERA: Coccinellidae: *Diomus notescens* (Blackburn) *Scymnus loewii* Mulsant	
21	COLEOPTERA: Coccinellidae: *Cryptolaemus montrouzieri* Mulsant *Diomus notescens* (Blackburn) *Rhizobius forestieri* (Mulsant) *Scymnus loewii* Mulsant COLEOPTERA: Curculionidae: *Hypera postica* Gyll. NSR *Otiorhynchus cribricollis* Gyll. COLEOPTERA: Elateridae: *Conoderus exsul* (Sharp) HETEROPTERA: Pentatomidae: *Thyanta custator accerra* McAtee	

Table 7. Insects collected at each site (continued). (NIR = New Island Record [for Hawaii Island]; NSR = New State Record.)

Site No.	Insects	Related Arthropods
22	—	
23	<material being processed>	
24	no insects found	
25	HETEROPTERA: Lygaeidae: *Nysius* sp. 2 *Nysius* sp. 7 COLEOPTERA: Cerambycidae: ***Plagithmysus looki*** Swezey COLEOPTERA: Anobiidae: *Ozognathus* sp. COLEOPTERA: Curculionidae: *Asynonychus godmanni* Crotch COLEOPTERA: Coccinellidae: *Hyperaspis fimbriolata* Melsheimer *Hippodamia convergens* Guérin *Scymnus loewii* Mulsant gen. sp.	
26	HETEROPTERA: Lygaeidae: *Nysius* sp. 5 HYMENOPTERA: Braconidae *Diadegma blackburni* (Cameron) HYMENOPTERA: Bethylidae: *Sierola* sp. 1 *Sierola* sp. 4 COLEOPTERA: Cerambycidae: ***Plagithmysus looki*** Swezey COLEOPTERA: Coccinellidae: *Hyperaspis fimbriolata* Melsheimer *Hippodamia convergens* Guérin *Scymnus loewii* Mulsant COLEOPTERA: Curculionidae: *Asynonychus godmanni* Crotch	
27 (part)	COLEOPTERA: Cerambycidae: ***Plagithmysus looki*** Swezey COLEOPTERA: Coccinellidae: *Hyperaspis fimbriolata* Melsheimer *Hippodamia convergens* Guérin gen. sp. COLEOPTERA: Curculionidae: *Asynonychus godmanni* Crotch COLEOPTERA: Dytiscidae: *Rhantus ?binotatus* Harris **NSR** COLEOPTERA: Carabidae: *Pristonychus complanatus* Dejean DIPTERA: Sarcophagidae: *Helicobia morionella* (Aldrich)	

Table 7. Insects collected at each site (continued). (NIR = New Island Record [for Hawaii Island]; NSR = New State Record.)

Site No.	Insects	Related Arthropods
27 (cont.)	HYMENOPTERA: Halictidae: *Halictus* sp. **NSR** HYMENOPTERA: Bethylidae: *Sierola* sp. 2	
28	DIPTERA: Tephritidae: ***Trupanea arboreae*** Hardy & Delfinado ***Trupanea neoapicalis*** Hardy & Foote	
29	COLEOPTERA: Cerambycidae: ***Plagithmysus looki*** Swezey COLEOPTERA: Coccinellidae: *Cryptolaemus montrouzieri* Mulsant *Hyperaspis fimbriolata* Melsheimer *Rhyzobius lophantae* (Blaisdell) *Scymnus loewii* Mulsant DIPTERA: Tachinidae: *Gonia longipulvilli* Tothill DIPTERA: Syrphidae: *Toxomerus marginatus* (Say) HETEROPTERA: Lygaeidae: *Nysius* sp. 6 *Nysius* sp. 7 *Nysius* sp. 8 HYMENOPTERA: Vespidae: ***Odynerus*** sp. HYMENOPTERA: Encyrtidae: ?*Aenasius advena* Compere	
30	COLEOPTERA: Algycyderidae: ***Proterhinus*** sp. COLEOPTERA: Carabidae: *Pristonychus complanatus* Dejean *Gnathaphanus* sp. DIPTERA: Tachinidae: *Gonia longipulvilli* Tothill DIPTERA: Agromyzidae: *Liriomyza sativae* Blanchard DIPTERA: Muscidae: *Brontaea quadristigma* (Thomson) HETEROPTERA: Lygaeidae: *Nysius* sp. 4 HYMENOPTERA: Encyrtidae: *Epidinocarsis californicus* (Compere) *Copidosoma* sp. gen. sp. HYMENOPTERA: Bethylidae: *Sierola* sp. HYMENOPTERA: Vespidae: *Vespula pensylvanica* (Saussure) ***Odynerus*** sp.	

Table 7. Insects collected at each site (continued). (NIR = New Island Record [for Hawaii Island]; NSR = New State Record.)

Site No.	Insects	Related Arthropods
31	COLEOPTERA: Coccinellidae: *Rhyzobius lophantae* (Blaisdell) COLEOPTERA: Carabidae: *Pristonychus complanatus* Dejean COLEOPTERA: Anobiidae: **Holcobius** sp. *HYMENOPTERA*: Halictidae: *Halictus* sp. **NSR** HYMENOPTERA: Bethylidae: *Sierola* sp. 4 *Sierola* sp. 5	
32	HETEROPTERA: Miridae: *Orthotylus* sp. 1 *Orthotylus* sp. 2	
33	COLEOPTERA: Coccinellidae: gen. sp. HYMENOPTERA: Halictidae: *Halictus* sp. **NSR** HYMENOPTERA: Braconidae: *Cotesia* sp. ?*Habrobracon hebetor* (Say) HYMENOPTERA: Encyrtidae: ?*Ooencyrtus* sp.	
34	—	
35	COLEOPTERA: Anobiidae: ***Holcobius*** sp. COLEOPTERA: Coccinellidae: *Hyperaspis fimbriolata* Melsheimer *Scymnus loewii* Mulsant gen. sp. COLLEMBOLA: Entomobryidae: gen. sp. COLLEMBOLA: Isotomidae: gen. sp. DIPTERA: Tachinidae: *Gonia longipulvilli* Tothill	ACARI from leaf litter: *Spinibdella thori* (Meyer & Ryke) *Neophyllobius* sp. *Ctenacarus* sp. *Damaeus* sp. *Raphignathus* n. sp. *Eustigmaeus segnis* group *Tydeus* sp.
36	COLEOPTERA: Coccinellidae: *Scymnus loewii* Mulsant	
37 (part)	DIPTERA: Tachinidae: *Gonia longipulvilli* Tothill HETEROPTERA: Lygaeidae: *Nysius* sp. 1 HOMOPTERA: Cicadellidae: *Nesophrosyne pluvialis* Kirkaldy	

Table 7. Insects collected at each site (continued). (NIR = New Island Record [for Hawaii Island]; NSR = New State Record.)

Site No.	Insects	Related Arthropods
37 (cont.)	HYMENOPTERA: Vespidae: *Vespula pensylvanica* (Saussure) HYMENOPTERA: Colletidae: ***Hylaeus* (*Nesoprosopis*)** sp.	
38	ORTHOPTERA: Gryllidae: *Leptogryllus* sp.	
39	HETEROPTERA: Lygaeidae: *Nysius* sp. 3 HETEROPTERA: Pentatomidae: *Nezara viridula* (Linnaeus) COLEOPTERA: Anobiidae: gen. sp. COLEOPTERA: Coccinellidae: *Diomus notescens* (Blackburn) *Diomus* sp. *Hyperaspis fimbriolata* Melsheimer *Nephus bilucernarius* (Mulsant) gen. sp.	
40	HETEROPTERA: Lygaeidae: *Nysius* sp. 3 *Nysius* sp. 5 *Nysius* sp. 8 DIPTERA: Tephritidae: ***Trupanea*** sp. COLEOPTERA: Coccinellidae: *Scymnus loewii* Mulsant COLEOPTERA: Curculionidae: *Asynonychus godmanni* Crotch	
41	<material being processed>	
42	no insects found	
43	HYMENOPTERA: Ichneumonidae: *Diadegma blackburni* (Cameron) *Pristomerus hawaiiensis* (Perkins) *Trathala flavoorbitalis* (Cameron)	
44	<material being processed>	
45 (part)	DIPTERA: Agromyzidae: ?*Melanagromyza* sp. DIPTERA: Drosophilidae: *Drosophila immigrans* Sturtevant *Drosophilidae* sp. near *melanogaster/immigrans* DIPTERA: Neriidae: *Telostylinus lineolatus* (Wiedemann)	

Table 7. Insects collected at each site (continued). (NIR = New Island Record [for Hawaii Island]; NSR = New State Record.)

Site No.	Insects	Related Arthropods
45 (cont.)	DIPTERA: Lonchaeidae: *Lonchaea polita* Say	
46	COLEOPTERA: Curculionidae: *Syagrius fulvitarsus* Pascoe	
47	HOMOPTERA: Flatidae: *Siphanta acuta* (Walker)	ARANEAE: Araneidae: *Gasteracantha mammosa* C.L. Koch
48	no insects found	
49	<material being processed>	
50	no insects found	
51	<material being processed>	
52	<material being processed>	
53	ORTHOPTERA: Acrididae: *Oedaleus abruptus* (Thunberg)	
54	<material being processed>	
55	no insects found	
56	<material being processed>	
57	no insects found	
58	—	
59	—	
60	no insects found	
61	—	
62	—	
63	no insects found	
64	no insects found	
65 (part)	COLEOPTERA: Chrysomelidae: *Diachus auratus* (Fabricius) COLEOPTERA: Coccinellidae: *Diomus notescens* (Blackburn) *Hyperaspis fimbriolata* Melsheimer *Scymnus loewii* Mulsant	

Table 7. Insects collected at each site (continued). (NIR = New Island Record [for Hawaii Island]; NSR = New State Record.)

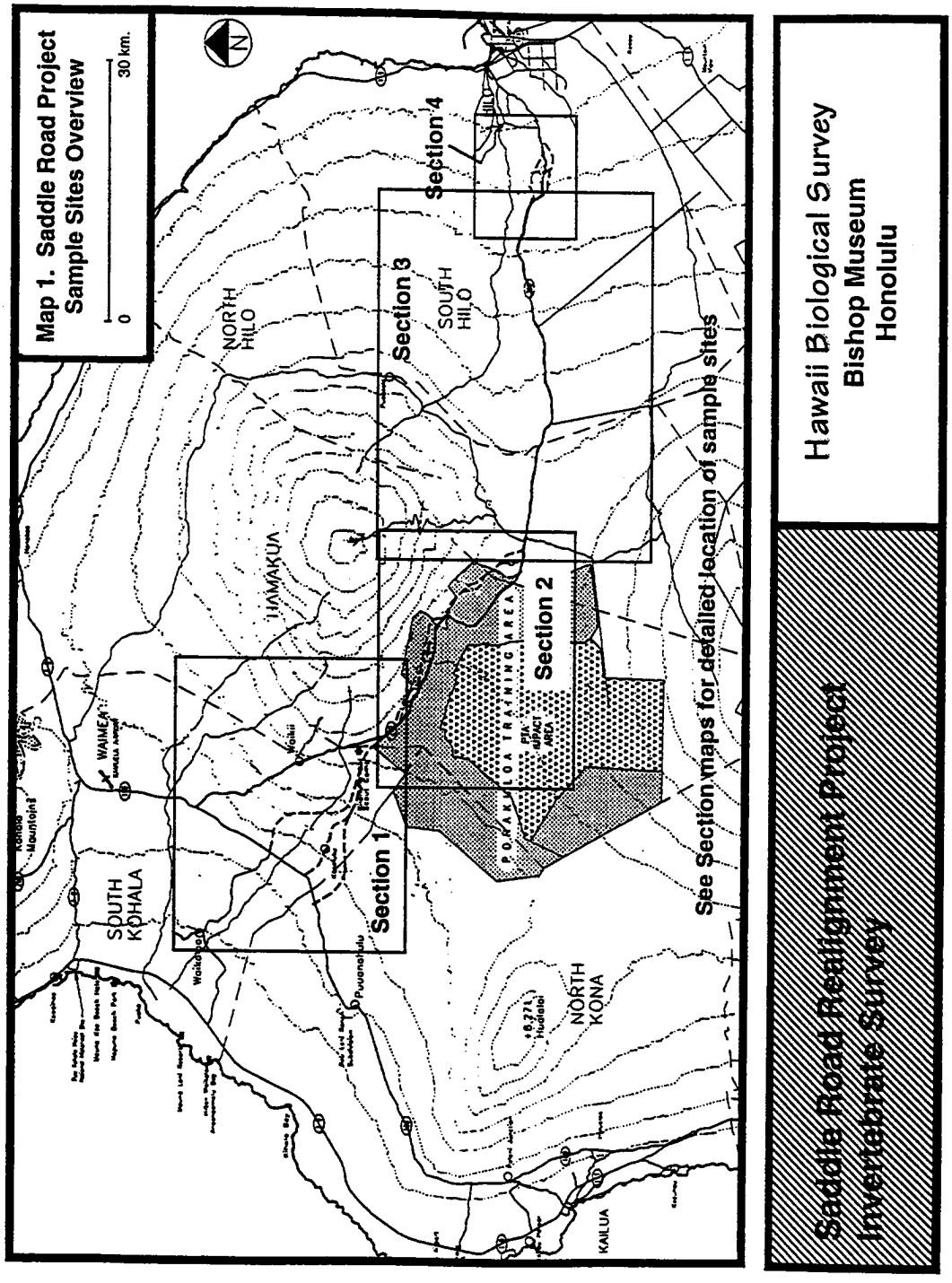
Site No.	Insects	Related Arthropods
65 (cont.)	DIPTERA: Agromyzidae:	
	?Melanagromyza sp.	
	DIPTERA: Anthomyiidae:	
	Delia platura (Meigen)	
	DIPTERA: Chamaemyiidae:	
	Leucopis obscura Haliday	
	DIPTERA: Chloropidae:	
	Monochaetoscinella anonyma (Williston)	
	DIPTERA: Muscidae:	
	Lispocephala sp.	
	DIPTERA: Sarcophagidae:	
	Helicobia morionella (Aldrich)	
	DIPTERA: Sepsidae:	
	Sepsis thoracica (Robineau-Desvoidy)	
	DIPTERA: Syrphidae:	
	Allograpta obliqua Say	
	Allograpta exotica (Wiedemann)	
	Toxomerus marginatus (Say)	
	HETEROPTERA: Lygaeidae:	
	Nysius sp. 2	
	Nysius sp. 5	
	HYMENOPTERA: Bethylidae:	
	Parasierola sp. **NSR**	
	HYMENOPTERA: Braconidae:	
	Cotesia sp.	
	?*Habrobracon hebetor* (Say)	
	HYMENOPTERA: Halictidae:	
	Halictus sp. **NSR**	
	HYMENOPTERA: Colletidae:	
	***Hylaeus* (*Nesoprosopis*)** sp. 1	
	***Hylaeus* (*Nesoprosopis*)** sp. 2	
	HYMENOPTERA: Chalcidae:	
	Dirhinus anthracina Walker	
	HYMENOPTERA: Ichneumonidae:	
	Pristomerus hawaiiensis (Perkins)	
	Pristomerus spinator (Fabricius)	
	Trathala flavoorbitalis (Cameron)	
	Casinaria infesta (Cresson)	
	Pristomerus hawaiiensis (Perkins)	
	Anomalon californicum Cresson	
	Diplazon laetatorius (Fabricius)	
	Cryptinae gen. sp.	
	HYMENOPTERA: Pteromalidae:	
	Pachyneuron sp.	
	gen. sp. 3	
	gen. sp. 4	
	HYMENOPTERA: Encyrtidae:	
	Epidinocarsis californicus (Compere)	
	HYMENOPTERA: Eucoilidae:	
	gen. sp.	

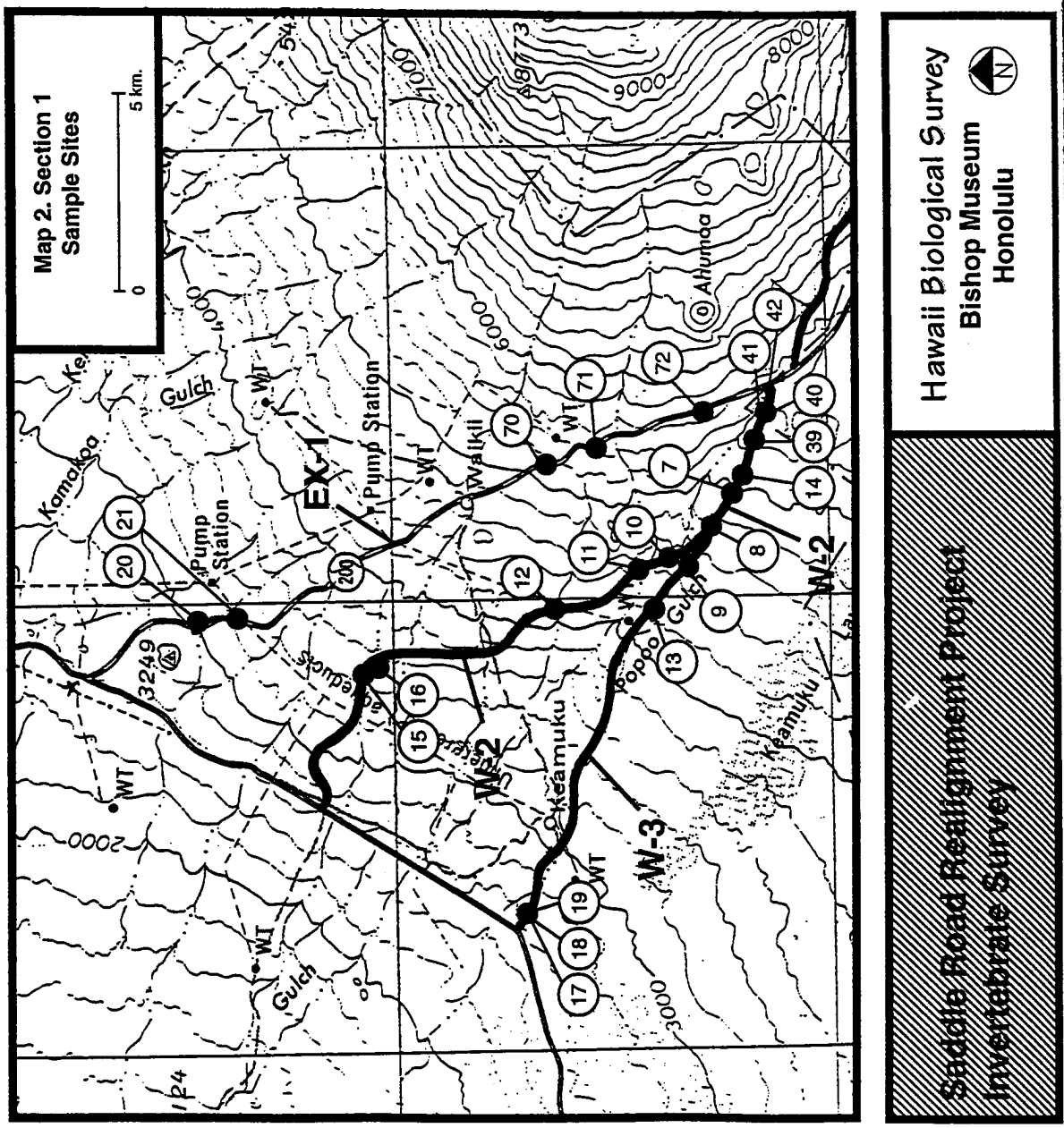
Table 7. Insects collected at each site (continued). (NIR = New Island Record [for Hawaii Island]; NSR = New State Record.)

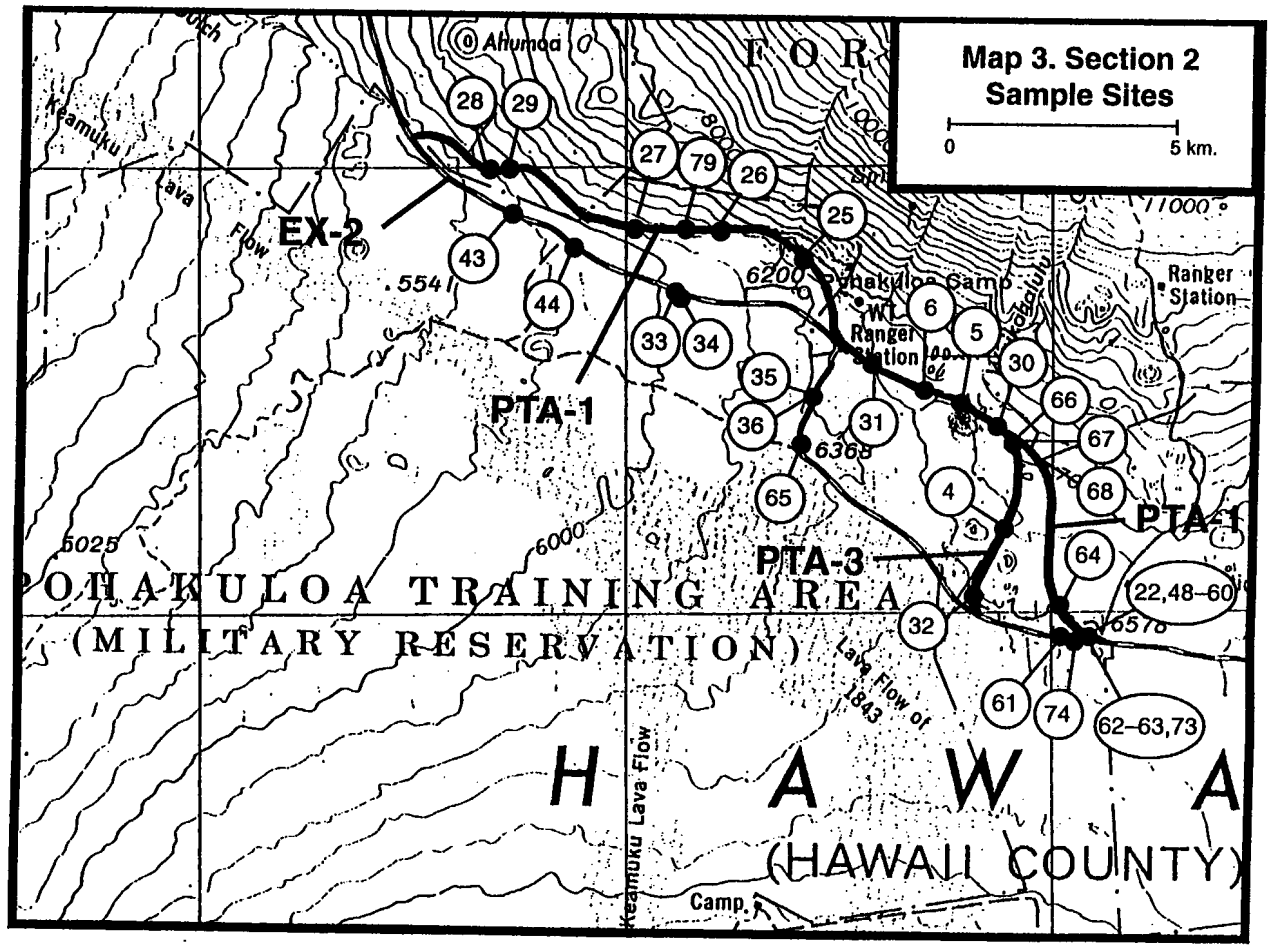
Site No.	Insects	Related Arthropods
66	DIPTERA: Drosophilidae: *Scaptomyza* sp. near *articulata* Hardy DIPTERA: Asteidae: *Asteia montgomeryi* Hardy HYMENOPTERA: Vespidae: ***Odynerus*** sp. HYMENOPTERA: Colletidae: ***Hylaeus (Nesoprosopis)*** sp. 1 HYMENOPTERA: Braconidae: *Diadegma blackburni* (Cameron) HYMENOPTERA: Ichneumonidae: *Pimpla punicipes* Cresson HYMENOPTERA: Bethylidae: *Sierola* sp. 3	
67	no insects found	
68	no insects found	
69	no insects found	
70	no insects found	
71	no insects found	
72	DIPTERA: Tachinidae: *Gonia longipulvilli* Tothill COLEOPTERA: Curculionidae: *Asynonychus godmanni* Crotch	
73	DIPTERA: Syrphidae: *Toxomerus marginatus* (Say)	
74	HYMENOPTERA: Formicidae: *Linepithema humile* (Mayer)	ISOPODA: Porcellionidae: *Porcellio* sp. ARANEAE: Lycosidae: *Lycosa* sp.
75	HYMENOPTERA: Formicidae: *Linepithema humile* (Mayer)	ISOPODA: Porcellionidae: *Porcellio* sp. ARANEAE: Lycosidae: *Lycosa* sp.
76	HYMENOPTERA: Formicidae: *Linepithema humile* (Mayer)	ISOPODA: Porcellionidae: *Porcellio* sp. ARANEAE: Lycosidae: *Lycosa* sp.

Table 7. Insects collected at each site (continued). (NIR = New Island Record [for Hawaii Island]; NSR = New State Record.)

Site No.	Insects	Related Arthropods
77	COLEOPTERA: Carabidae: *Mecyclothorax* sp. COLLEMBOLA: Hypogastruridae: *Neanura hawaiiensis* (Bellinger & Christiansen) COLLEMBOLA: Entomobryidae: gen. sp. DIPTERA: Tipulidae: *Limonia nigropolita* (Alexander) *Limonia* sp. near *jacoba* (Alexander) DIPTERA: Ceratopoginidae: *Forcipomyia pholetor* Wirth & Howarth DIPTERA: Drsophilidae: *Drosophila* sp. HOMOPTERA: Aphididae: *Rhopalosiphoninus latysiphon* (Davidson) HYMENOPTERA: Ichneumonidae: gen. sp. LEPIDOPTERA: Noctuidae: ***Schrankia*** sp. 1	ARANEAE: Linyphiidae: ***Erigone*** cf ***stygius*** Gertsch ACARI: Rhagidiidae: *Foveacheles* sp. CHILOPODA: Lithobiidae: *Lithobius* sp. DIPLOPODA: Cambalidae: ***Nannolene*** sp. DIPLOPODA: Paradoxosomatidae: *Oxidus gracilis* (Koch)
78	—	
79	<material being processed>	
80	COLLEMBOLA: Hypogastruridae: *Neanura hawaiiensis* (Bellinger & Christiansen) LEPIDOPTERA: Noctuidae: ***Schrankia*** sp. 2 DIPTERA: Tipulidae: *Limonia nigropolita* (Alexander) *Limonia* sp. 1 DIPTERA: Ceratopogonidae: *Forcipomyia pholetor* Wirth & Howarth	ARANEAE: Theridiidae: *Achaearanea tepidariorum* Koch DIPLOPODA: Cambalidae: ***Nannolene*** sp. DIPLOPODA: Paradoxosomatidae: *Oxidus gracilis* (Koch)


Map 1. Saddle Road Project
Sample Sites Overview
0
30 km.
N
SOUTH KOHALA
NORTH HILO
SOUTH HILO
HAMAKUA
NORTH KONA
KAILUA
Waikoloa
Puuanahulu
Section 1
Section 2
Section 3
Section 4
POHAKULOA TRAINING AREA
PTA IMPACT AREA
See Section maps for detailed location of sample sites
Saddle Road Realignment Project
Invertebrate Survey
Hawaii Biological Survey
Bishop Museum
Honolulu


Map 2. Section 1
Sample Sites
0
5 km.
Saddle Road Realignment Project
Invertebrate Survey
Hawaii Biological Survey
Bishop Museum
Honolulu
N
EX-1
W-2
W-3
Pump Station
Pump Station
Gulch
Gulch
Gulch
Kamakoa
Walkii
Ahumoa
Kaamuku
Kaamuku
WT
3249
2000
3000
6000
7000
8000
9000
20
21
200
12
11
10
7
70
71
72
41
42
40
39
14
8
9
13
15
16
17
18
19



Saddle Road Realignment Project
Invertebrate Survey

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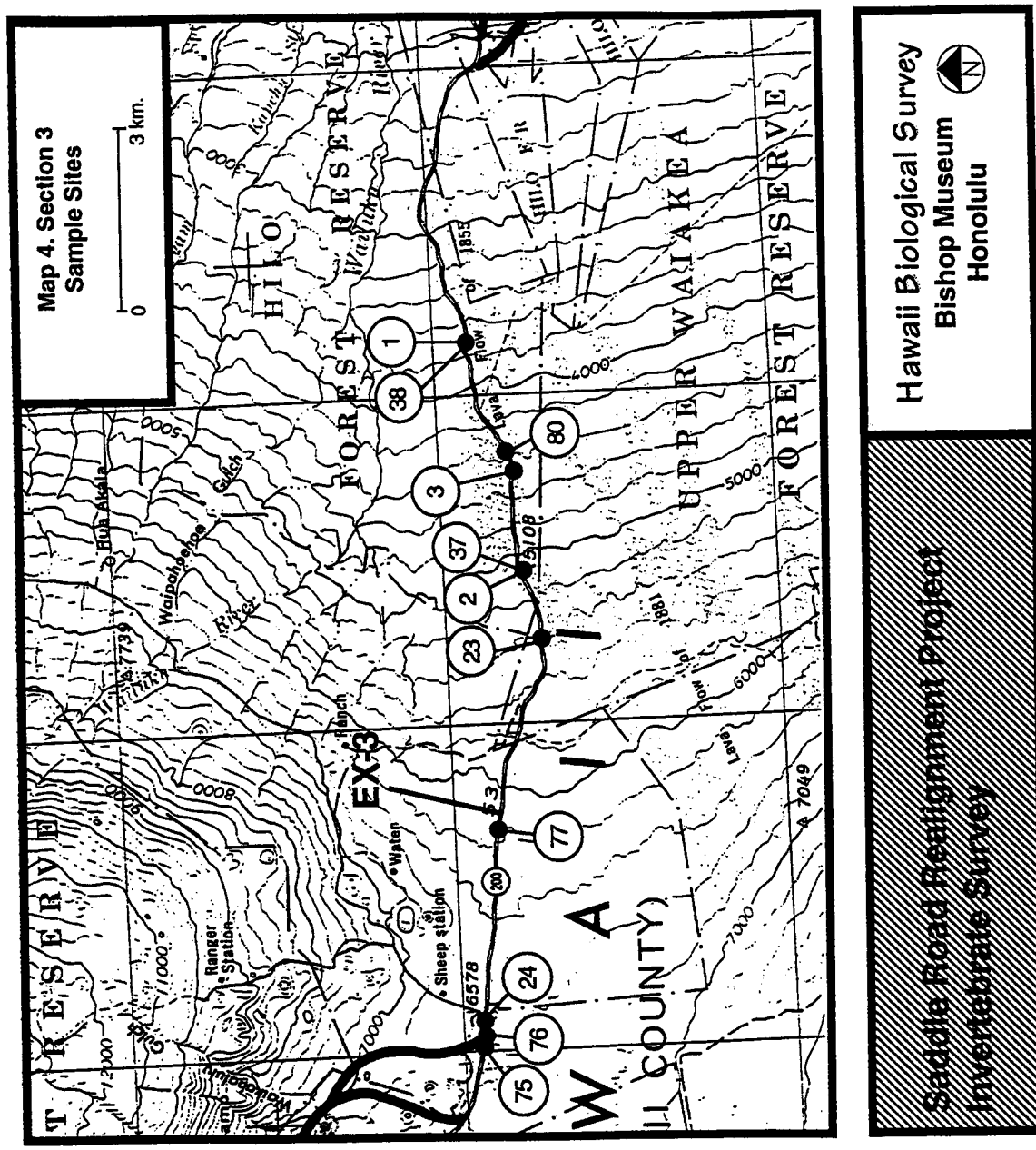
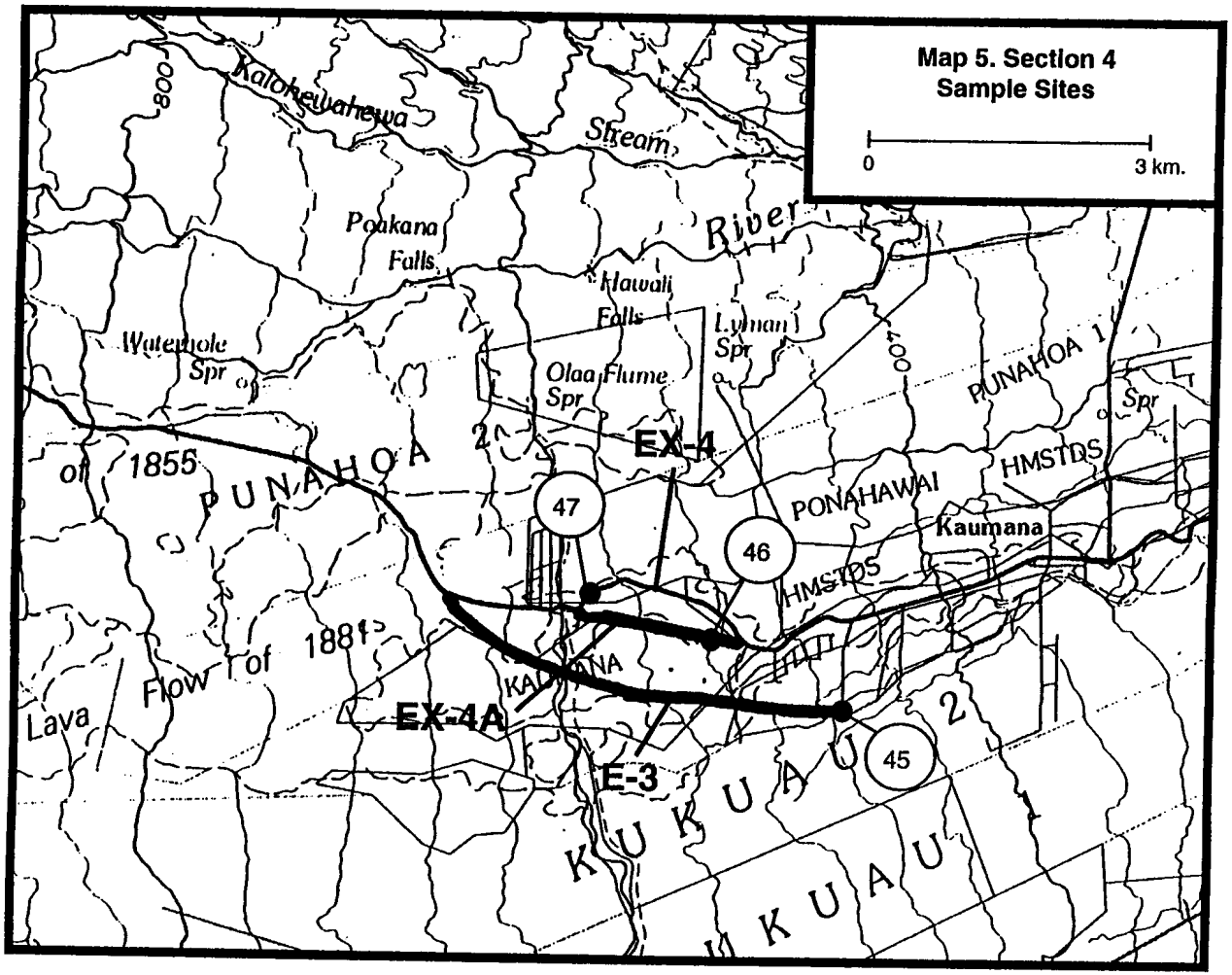
Bishop Museum
Honolulu


Map 4. Section 3
Sample Sites
0
3 km.
Saddle Road Realignment Project
Invertebrate Survey
Hawaii Biological Survey
Bishop Museum
Honolulu
N
HILO FOREST RESERVE
UPPER WAIAKEA FOREST RESERVE
EX-3
Ranger Station
Sheep station
Water
Lava Flow
1855
1881
1908
6578
7049
1
38
3
37
2
23
80
77
24
76
75
200



Saddle Road Realignment Project
Invertebrate Survey

Hawaii Biological Survey
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Honolulu

3. SURVEY LIMITATIONS

A number of particular factors limited the thoroughness of the collections of both snails and arthropods. These relate especially to the spatial and temporal occurrence of the organisms. Clearly, it was not possible to map in detail the precise distributions of all species collected. Species that occur in highly localized patterns of distribution may not have been recorded if the survey sites did not correspond to those distributions. Many species of insects and other arthropods, and conceivably snails, are seasonal in their activity patterns and abundances. The survey took place in late August, early September, and mid October; certain species (including those specific to seasonal hosts) may not have been encountered.

Also, not all possible trapping methods were implemented during this study. For example, pitfall trapping for insects and other terrestrial arthropods, and night trapping for collection of nocturnal organisms were not conducted. A large percentage of arthropods are nocturnal and therefore largely missed in our survey.

Our survey priorities were the western portion of the Saddle Road (i.e., PTA and areas west). The wet forest east of PTA was only spot-checked by us. As the wet forest is known to yield a high percentage of endemic organisms and "sensitive" species, more detailed collecting in these areas would improve the picture of the snail and arthropod constituency of the entire Saddle Road area.

Lava flows, which support aeolian (wind-supported) ecosystems, were largely missed. Many native insects are highly host specific; yet we had time to sample only the more common hosts at most sites. Cave habitats are theoretically widespread especially in pahoehoe flows, but only a few suitable subterranean voids have entrances that allow access to humans. Furthermore, many cave entrances leading into significant caves undoubtedly remain hidden in the forests along the Saddle Road alignment.

Normal insect collecting by sweep nets and more specific trapping techniques allow enormous numbers of specimens to be collected with little effort. However, it was not possible within the time-frame allotted to sort and identify all this material. Instead, selected groups, particularly those considered "sensitive" and for which Bishop Museum has expertise were focused on.

Land snail sampling techniques often include collection of litter and soil samples; these allow recording of some of the extremely small species that might be missed by simple hand picking in the field. However, sifting litter/soil samples is extremely labor-intensive and a decision was made to rely on careful hand picking in the field.

4. AFFECTED ENVIRONMENT

4.1. Snails

First, the fauna observed and collected during the survey is reviewed. This is then followed by a breakdown of the fauna according to the sections and segments of the various alternative alignments.

4.1.1. *Review of the snail fauna*

A total of 1,482 land snail specimens, including 13 specimens of a slug tentatively identified as a species of *Deroceras*, were collected during the survey. This material included at least 13 species (Table 8). Of these, 3 species (*Euglandina rosea*, *Oxychilus alliarius*, and the slug) have been introduced artificially to the Hawaiian Islands; 2 are of unclear status (the species referred below to *Striatura* sp. cf. *meniscus* and ?*Striatura* sp.); the remainder occur naturally in the Hawaiian islands. No tree snails were seen, although the single specimen of "tornatellinid" D was collected from above-ground vegetation (a fern). All other live specimens were found in the litter and soil, often in cracks and crevices in the lava, or around and under rocks in shady locations.

Table 8. Land snail (and slug) species collected during the survey, with status in the Hawaiian Islands as endemic, indigenous, or non-indigenous.
[Nomenclature and taxonomic placement follow Cowie, Evenhuis & Christensen (1995).]

Family	Species	Status
ACHATINELLIDAE		
	Lamellidea sp.	Endemic
	"tornatellinid" A	Endemic
	"tornatellinid" B	Endemic
	"tornatellinid" C	Endemic
	"tornatellinid" D	Endemic
AMASTRIDAE		
	Leptachatina lepida Cooke, 1910	Endemic
	Leptachatina sp. A	Endemic
PUPILLIDAE		
	Nesopupa subcentralis Cooke & Pilsbry, 1920	Endemic
SPIRAXIDAE		
	Euglandina rosea (Férussac, 1821)	Non-indigenous
SUCCINEIDAE		
	Succinea konaensis Sykes, 1897	Endemic
ZONITIDAE		
	Euconulus thaanumi (Ancey, 1904)	Endemic
	Striatura sp. cf. *meniscus* (Ancey, 1904)	?
	?*Striatura* sp.	?
	Vitrina tenella Gould, 1846	Indigenous
	Oxychilus alliarius (Miller, 1822)	Non-indigenous
?LIMACIDAE		
	?*Deroceras* sp. [slug]	Non-indigenous

endemic = only known from and occurs naturally in the Hawaiian Islands.
indigenous = occurs naturally both in the Hawaiian Islands and elsewhere.
non-indigenous = occurs artificially in the Hawaiian Islands as a result of human activities.

The individual species recorded are reviewed briefly below, explaining taxonomic difficulties and difficulties in identification, as well as summarizing what little is known of the ecology of the species and explaining their status as indigenous or otherwise. Those that have special status (Endangered, Threatened, or Species of Concern), are indicated as such.

ACHATINELLIDAE

Lamellidea sp.

Only 3 species of *Lamellidea* have been recorded from Hawaii Island: *L. gracilis, L. oblonga* and *L. peponum*. The shell morphology of all three species is very similar but material in the Bishop Museum does show a range of variation both within and among individual lots, including type lots (the Museum does not hold the holotype of any of them), with some overlap between lots of different species. It is not possible to give a more precise identification without considerable detailed study of the taxonomy of the group. Details given by Pilsbry & Cooke (1914–1916) and Cooke & Kondo (1961) do not allow a more definitive conclusion.

Cooke & Kondo (1961) stated that "*Lamellidea* is both terrestrial and arboreal. It is taken under bark and lichens, but rarely, if ever, is it found on leaves". None of the present material was found in trees. The genus is widespread through the Pacific, but the Hawaiian species are almost all endemic to single Hawaiian Islands. Assuming that the collected material is not *L. gracilis*, which is widely distributed in the Hawaiian Islands, but only to altitudes of 300 m (Christensen & Kirch, 1986), it is likely that the present species is endemic to Hawaii Island.

"Tornatellinids"

The family Tornatellinidae is now considered part of the Achatinellidae (Cooke & Kondo, 1961). *Lamellidea* (above) is also a "tornatellinid", but these other specimens cannot, without considerable additional research, be identified more precisely than to say that species belonging to either or both the genera *Tornatellides* and *Tornatellaria* are present. There is, however, some morphological variation and it has been possible tentatively to divide the material up into 4 morpho-species: species A, B, C, and D. Wagner et al. (1983) identified their "tornatellinids" as *Elasmias* sp. (in a *kipuka* at 2000 ft [610 m] elevation on the Hilo side), and as 4 unidentified species of *Tornatellides* from various localities. No doubt some, if not all, of these species are the same as those recorded in the present survey.

Tornatellides spp. are viviparous; *Tornatellaria* spp. are oviparous (Pilsbry & Cooke, 1914–1916; Cooke & Kondo, 1961). No other useful generalizations can be made about the ecology of these genera as a whole, although some species may be relatively tolerant of non-native vegetation (Christensen & Kirch, 1986). *Tornatellaria* is restricted to the Hawaiian Islands; *Tornatellides* is widespread throughout the high islands of the Pacific, but the majority of the Hawaiian species are endemic to single islands. The present species are no doubt endemic to the Hawaiian Islands and probably specifically to Hawaii Island.

AMASTRIDAE

Leptachatina lepida **Species of Concern**

Much of the collected material matches closely to type (including holotype) material in the Bishop Museum collections, although there is some variation in both size and shape of the present survey material, even within samples.

Leptachatina sp. A

The 3 specimens collected (at a single site) differ from *L. lepida*. They are referred to the species "*Leptachatina* sp. A" of Cowie & Nishida (1993) and Cowie, Nishida et al. (1995). This species is rather tall and narrow with a relatively large protoconch. It is somewhat similar to *L. imitatrix* Sykes, 1900 but probably represents an undescribed species.

Wagner et al. (1983) reported no amastrids in their survey of the Saddle Road power line corridor.

Leptachatina spp. are oviparous, and, with the exception of the arboreal *L. arborea*, which is known from "Kona at 4000 feet", they are ground dwellers (Hyatt et al., 1910-11). Almost nothing is known of the ecology of *L. lepida* specifically, and nothing can be said about *Leptachatina* sp. A. The genus *Leptachatina* is endemic to the Hawaiian Islands and almost all species, including *L. lepida* and presumably *Leptachatina* sp. A, are single island endemics (Hyatt et al., 1910-11).

The family Amastridae is endemic to the Hawaiian Islands. It was once extremely diverse with over 300 species and numerous infra-specific taxa (Cowie, 1995; Cowie, Evenhuis & Christensen, 1995). Most of these taxa are now considered extinct and field biologists with lengthy experience of searching for snails consistently report a drastic decline over the last 40 or more years (e.g. Kondo, 1970; Carl C. Christensen, personal communication; D.J.D. Chung, personal communication; M.G. Hadfield, personal communication). The Nature Conservancy of Hawaii's Heritage Database (with much of its information abstracted from the Bishop Museum collections and associated documentation) has post-1945 records of live snails for only 15 amastrids, with only 4 of those species being recorded live since 1971. The finding of live *Leptachatina lepida* during the present survey therefore constitutes a major discovery of great importance. This species was also reported alive in the MPRC (Cowie & Nishida, 1993; Cowie, Nishida et al., 1995). The present survey localities and those in the MPRC are the only localities where this species is known to be extant.

PUPILLIDAE

Nesopupa subcentralis

The single specimen collected seems to correspond well with material held in the Bishop Museum collections. Wagner et al. (1983) reported *Nesopupa anceyana* Cooke & Pilsbry from their site at mile marker 21, which is on the more humid Hilo side of the saddle; *N. subcentralis* appears to be more characteristic of the dry Kona side. Hawaiian *Nesopupa* spp. are diverse ecologically: "besides the terrestrial forms there are many living on the bark of trees, others on foliage; some in relatively dry, others in very humid habitats" (Pilsbry & Cooke, 1918-1920). But little ecological information is available specifically about *Nesopupa subcentralis*, except that it has been collected on Hawaii Island "on the flow of 1823, 7,000 ft. elevation" and "on ferns" (Pilsbry & Cooke, 1918-1920), and "on ferns in South Kona, in moss on the ground at the 6,000 to 7,000 ft level on Hualalai, and in East Hawaii on *Astelia* and dead tree fern stalks in wet forest at 4,000 ft elevation in Puna" (Christensen, 1983). It is endemic to Hawaii Island.

SPIRAXIDAE

Euglandina rosea

This is the carnivorous or "cannibal" snail deliberately introduced to the Hawaiian Islands in the 1950s in ill-conceived attempts to control the Giant African Snail, *Achatina fulica* (which was not encountered during this survey). More details can be found by consulting the references cited by Cowie (1992).

SUCCINEIDAE

Succinea konaensis

The Hawaiian Succineidae are diverse and in need of taxonomic revision. Most species were originally described in the genus *Succinea* and will remain there until formally removed (or not) to other genera following taxonomic studies concentrating on dissection of the soft parts. The present material corresponds closely to type material of *S. konaensis* in the Bishop Museum collections. Wagner et al. (1983) reported 3 unidentified species of

Succinea in their 1982 survey. Their "*Succinea* sp. B", the only *Succinea* found on the dry parts of their survey, probably corresponds to *S. konaensis*. Their species A and C are probably different species associated with the humid, Hilo side of the saddle, and were not recorded in the present survey, which did not focus strongly on the *kipuka* in this area.

Succineids occupy diverse habitats in the Hawaiian Islands; some species are arboreal, others are ground dwellers (Zimmerman, 1948). Nothing is known of the ecology of *S. konaensis* particularly, except that the type locality is at an altitude of 4,000 ft., suggesting that it is a high altitude species. *S. konaensis* is endemic to Hawaii Island.

ZONITIDAE (Subfamily EUCONULINAE)

Euconulus thaanumi

The four specimens (collected at a single locality) match closely to the holotype, which is held at Bishop Museum. This species is fairly widely distributed on Hawaii Island in damp localities (Baker, 1941). It is endemic to the island.

ZONITIDAE (Subfamily GASTRODONTINAE)

Striatura sp. cf. *meniscus*

Type material of *S. meniscus*, held at the Bishop Museum, contains a range of morphological variation, especially in umbilicus width, and may in fact include more than one species. The holotype has a wide umbilicus, while the specimens from the present survey correspond very closely to those paratypes with the narrower umbilicus, which resemble *S. pugetensis* Dall, 1895. Further detailed study would be necessary to decide whether the present specimens are indeed *S. meniscus* or *S. pugetensis*, or whether they belong to a further closely related but possibly undescribed species. Baker (1941) hinted at this confusion. Wagner et al. (1983) recorded *Striatura meniscus*, but this probably refers to the same species as here referred to sp. cf. *meniscus*.

Baker (1941) described the habitat of *Striatura meniscus* as "under stones, in damp rotten fern debris, alt. 6,700 ft." and "on ground on moss"; and of *S. pugetensis* as "under leaves". For *S. meniscus*, Christensen (1983) indicated a wide distribution and range of habitats on Hawaii Island, on the basis of live collected material in the Bishop Museum collections. However, the taxonomic confusion surrounding this taxon and the possible misidentifications of museum material (see above) mean that in reality the taxon here reported may be less widespread than this. *S. meniscus* is endemic to Hawaii Island; *S. pugetensis* is recorded from the U.S. mainland and from the Island of Kauai. Given the taxonomic uncertainty regarding the present species (see above), its biogeographic status is therefore not clear.

?*Striatura* sp.

Specimens from the present survey, distinct from the previous species, nevertheless appear closely related to it and so are tentatively assigned to the genus *Striatura*. (Some of the larger specimens seem somewhat similar to the widely introduced North American species *Hawaiia minuscula*). Similar specimens in the Bishop Museum collections have been labeled *S. meniscus*, but incorrectly. The survey specimens do not correspond to anything in the type collections of *Striatura* in the Bishop Museum nor to the written treatment of Baker (1941). They cannot be identified further and may belong to an undescribed species. Nothing is known of the ecology or biogeographic status of this species.

Wagner et al. (1983) recorded an unidentified zonitid in their dry sites, frequently in association with *Succinea* sp. B. Undoubtedly, this unidentified zonitid is the species here referred to ?*Striatura* sp., which was often found in association with *Succinea konaensis* (see above), plus other species at some sites, during the present survey.

ZONITIDAE (Subfamily VITRININAE)

Vitrina tenella

The collected material corresponds well with material in the Bishop Museum collections. This species seems to be a species of mid to high altitudes (above 3,000 ft. [914 m]) and to be widely distributed, although apparently never abundant, in a range of habitats (Baker, 1941; Christensen, 1983). Baker considered *V. tenella* probably native, but indistinguishable from *V. alaskana* Dall, 1905 from the western United States, and so not endemic to the Hawaiian Islands.

ZONITIDAE (Subfamily ZONITINAE)

Oxychilus alliarius

This species when alive is distinguished by the strong smell of garlic it emits when irritated; hence its common name "garlic snail". It was first recorded in the Hawaiian Islands, in fact on Hawaii Island, in 1937, based on the collection date of material in the Bishop Museum (Christensen, 1983). This species is at least partially carnivorous, feeding on other snails and their eggs, and may have had an impact on populations of native snails (Mountainspring et al. 1990). Wagner et al. (1983) recorded it widespread, especially on the humid Hilo side of the saddle, as in the present survey.

?LIMACIDAE

?Deroceras sp.

The 13 specimens collected appear to belong to a single species. They would have to be sent to an expert in Europe for identification. However, they may be *Deroceras laeve* (Müller), which has been reported from Hawaii Island (e.g., Matayoshi, 1981). This species is of western European origin and has been in the Hawaiian Islands probably for at least a century. Wagner et al. (1983) recorded 3 species of slugs, including *D. laeve*, on the Hilo side of the saddle.

4.1.2. *Detailed account by section*

Table 9 below shows the lands snail (and slug) species recorded from each segment of proposed alignment in each of the 4 sections of the road.

SECTION I

EX-1. On this segment, the existing road alignment, only the non-indigenous snail *Oxychilus alliarius* was found, at a single site: site 66 (115 + 660). Four other sites: 20 (103 + 064), 21 (103 + 951), 70 (111 + 902.063), and 71 (113 + 200) were investigated but no snails were found.

W-2. On this segment, a relatively diverse assemblage of snails was found at Sites 39 (114 + 580) and 41 (114 + 940). Both sites were around rocky outcrops. This assemblage of snail species included *Leptachatina* sp. A and "tornatellinid" B, the former being found nowhere else during the course of the survey. At Sites 7 (113 + 620), 8 (112 + 720), and 40 (115 + 060) on W-2, only *Succinea konaensis* and/or *?Striatura* sp. were found, these being the two commonest snails found throughout the Kona side of the survey area. At an additional 5 sites investigated for snails: sites 10 (112 + 060), 11 (111 + 520), 12 (109 + 720), 15 (104 + 122), and 16 (104 + 500), no snails were found. In general, the heavily grazed areas along this segment are extremely poor snail habitat.

W-3. Only 4 sites were investigated for snails on this segment: one at the eastern end: site 9 (110 + 620), and three at the Mamalahoa Highway end: sites 17 (100 + 180), 18 (100 + 240), and 19 (100 + 300), and no snails were found.

Table 9. Snail (and slug) species recorded in each section/segment of the proposed alternative alignments.

Section I	Section II	Section III	Section IV
EX-1 *Oxychilus alliarius* **W-2** *Succinea konaensis* ?Striatura sp. "tornatellinid" A "tornatellinid" B "tornatellinid" C *Leptachatina* sp. A **W-3** No snails found at sites investigated	**EX-2** *Succinea konaensis* *Striatura* sp. cf. *meniscus* ?*Striatura* sp. *Lamellidea* sp. *Leptachatina lepida* **PTA-1** *Oxychilus alliarius* *Succinea konaensis* *Striatura sp.* cf. *meniscus* ?*Striatura* sp. *Vitrina tenella* *Nesopupa subcentralis* *Lamellidea* sp "tornatellinid" A "tornatellinid" B "tornatellinid" C *Leptachatina lepida* **PTA-3** *Oxychilus alliarius* *Succinea konaensis* *Vitrina tenella* ?*Striatura* sp. *Lamellidea* sp "tornatellinid" A "tornatellinid" B "tornatellinid" C *Leptachatina lepida*	**EX-3** *Oxychilus alliarius* *Euconulus thaanumi* "tornatellinid" D ?*Deroceras* sp. ?*Deroceras* sp.	**EX-4** ?*Deroceras* sp. *Euglandina rosea* **EX-4A** **E-3** No snails found at site investigated

SECTION II

EX-2. This segment is the least diverse in Section II in terms of numbers of snail species. Six sites were investigated for snails. Site 61 (139 + 240) was bare pahoehoe lava and supported no snails. Four sites: sites 34 (126 + 340), 43 (121 + 660), 44 (123 + 282.354), and 65 (132 + 100) harbored only the two common species *Succinea konaensis* and ?*Striatura* sp. The sixth site (site 35; 130 + 960), which was located in the area just to the east of the Mauna Kea State Recreation Area, supported these 2 species plus *Leptachatina lepida* (including live individuals), *Striatura* sp. cf. *meniscus* and *Lamellidea* sp. These species were most commonly found during the survey in this area to the east of the State Park (see PTA-1, PTA-3).

PTA-1. This segment clearly harbors the most diverse assemblage of land snails encountered during the survey: 11 species. Snails were recorded at 10 sites on this segment: sites 5 (25 + 000), 6 (24 + 460), 25 (19 + 480), 26 (18 + 155.35), 27 (15 + 760), 28 (11 + 620), 30 (26 + 860), 31 (22 + 344.27), 66 (27 + 270.87), and 73 (13 + 360). An additional series of sites on PTA-1, further to the east of the junction between PTA-1 and PTA-3: sites 49, 51-60, 62-64 (see map xx for locations), were investigated but harbored no snails; all were virtually bare pahoehoe lava. The greatest diversity was found in the area of Mamane/Naio forest to the east of the State Park. This segment, plus the single site on EX-2 mentioned above, which is in the same general area, was the only area in which live *Leptachatina lepida* were found. Most frequently, *L. lepida* appeared to be associated with Naio trees.

PTA-3. This segment harbored the second most diverse assemblage encountered during the survey. Only two sites were investigated, one of which (site 32; 12 + 160) was bare 'a'a lava and harbored no snails, but the other (site 4; 11 + 260) contained 9 of the 11 species found on PTA-1.

SECTION III

EX-3. This single segment was investigated at 4 sites: sites 1 (163 + 000), 2 (155 + 000), 3 (156 + 103.039), and 23 (154 + 180). At 3 of these: sites 2 (155 + 000), 3 (156 + 103.039), and 23 (154 + 180) only the introduced garlic snail *Oxychilus alliarius* and the introduced slug species (*?Deroceras* sp.) were found. At the fourth site: site 1 (163 + 000), a single specimen of "tornatellinid" D, 4 specimens of *Euconulus thaanumi* , as well as these 2 introduced species, were collected.

SECTION IV

EX-4. Only the introduced slug (*?Deroceras* sp.) and the introduced carnivorous snail *Euglandina rosea* were found on this segment at Site 47 (173 + 260).

EX-4A. Only the introduced slug (*?Deroceras* sp.) was found at Site 46 (21 + 397.068).

E-3. No snails or slugs were found at the single (highly disturbed) site investigated: site 45 (43 + 900), at the Country Club Road end of this segment. The upper end of this segment was not investigated and probably supports some native habitat, possibly harboring native snails.

4.2. Insects and related arthropods

First, the fauna observed and collected during the survey is reviewed. This is then followed by a breakdown of the fauna according to the sections and segments of the various alternative alignments.

4.2.1. *Review of the insect and related arthropod fauna*

Over 3,000 specimens of insects and related arthropods were collected during the survey. These comprise 215 species in 88 families and 14 orders identified thus far. Table 10 gives a complete list of the taxa of arthropods collected and identified during the study and identified up to this time with indication of whether they are endemic, adventive, or purposefully introduced (imported).

Due to the large number of species collected, only those species determined by us as "sensitive" are annotated below.

Non-Insects:

ARANEAE: LINYPHIIDAE

Erigone stygius Gertsch

Hawaiian sheet web spiders (family Linyphiidae) remain poorly known. Most are small inconspicuous animals in cryptic habitats. Only one obligate cave species (*Erigone stygius* Gertsch) has been formally described and was previously known from a cave at 1200 m elevation in Hawaii Volcanoes National Park, but at least eight additional species are known from Hawaii Island (Howarth et al. 1996). Colorless and eyeless females referable to *E. stygius* were collected in Strawberry Cave (site 77; EX-3 148 + 240). These small spiders make finely woven horizontal sheet webs 5-15 centimeters (2-6 inches) in diameter and hang in the center beneath them waiting for prey to fall or alight on the top of the web.

DIPLOPODA: CAMBALIDAE

Nannolene sp.

Fifteen closely related endemic species of *Nannolene* have been described from the Hawaiian islands, but none from Hawaii Island. However, several distinct blind populations are known from lava tubes on Kilauea, Mauna Loa, and Hualalai. Preliminary analysis indicates that several species may be represented. Two females of a possibly new eyeless species were collected in Strawberry Cave (Site 77; EX-3 148 +240), and dead individuals of an unidentified form were seen in Don's Cave (Site 80; EX-3 156 + 760); during this survey. Another species with vestigial eyes is known from Kaumana Cave at the eastern end of the project area.

ARCHAEGNATHA: MACHILIDAE

Species of concern

Neomachilis heteropus (Silvestri)

Hawaii Island populations of the native jumping bristletail (*Neomachilis heteropus*) are rarely collected and remain poorly known. It is a species of concern (Table 3). In June 1995, a single specimen of *N. heteropus* was collected at night in a cave entrance in the 1935 lava flow near Puu Huluhulu. On the night of 19 October during the present survey, we rediscovered the entrance where *N. heteropus* was previously found (Site 75; EX-3 140 + 860) and also checked other similar habitats on the 1935 flow along the existing Saddle Road alignment but were unable to find the bristletail.

Insects:

COLEOPTERA: AGLYCYDERIDAE

Species of concern

Proterhinus spp.

Aglycyderids are small primitive weevils found almost exclusively on oceanic islands. Over 170 species, all in the genus *Proterhinus,* are endemic to the Hawaiian Islands, of which 24 are known from Hawaii Island, but many species remain undiscovered. Hawaiian species are twig-, stem- and wood borers, and a few are leaf miners. Each species has a very narrow host and habitat range, but in concert the group attacks a wide range of woody plant species in Hawaii. One Hawaii Island species restricted to *Hibiscadelphus* is believed to be extinct, and surviving populations are considered sensitive as their hosts become rarer. One undetermined species of this genus was collected at Site 2 (EX-3 155 + 000) during this study.

Table 10. Checklist of the insects and other arthropods collected during the Saddle Road invertebrate survey (August-October 1996)

STATUS	TAXON
ACARI	**Mites**
?	*Ctenacarus* sp.
?	*Damaeus* sp.
?	*Eustigmaeus segnis* group
?	*Foveacheles* sp.
?	*Neophyllobius* sp.
?	*Raphignathus* n. sp.
?	*Spinibdella thori* (Meyer & Ryke)
?	*Tydeus* sp.
ARANEAE	**Spiders**
	Araneidae
adventive	*Gasteracantha mammosa* C.L. Koch
	Linyphiidae
endemic	*Erigone* cf. *stygius* Gertsch
	Lycosidae
endemic	*Lycosa* sp.
	Theridiidae
adventive	*Achaearanea tepidariorum* (C.L. Koch)
CHILOPODA	**Centipedes**
	Lithobiidae
endemic	*Lithobius* sp.
DIPLOPODA	**Millipedes**
	Cambalidae
endemic	*Nannolene* sp.
	Paradoxosomatidae
adventive	*Oxidus gracilis* (Koch)
INSECTA	**Insects**
	COLLEMBOLA: Springtails
	Entomobryidae
	genus? species?
	Hypogastruridae
endemic	*Neanura hawaiiensis* (Bellinger & Christiansen)
	Isotomidae
	genus? species?
	ODONATA: Dragonflies & Damselflies
	Coenagrionidae (Damselflies)
endemic	*Megalagrion amaurodytum peles* (Perkins)

Table 10. Checklist of the insects and other arthropods collected during the Saddle Road invertebrate survey (August-October 1996) (continued)

STATUS	TAXON
	ORTHOPTERA: Grasshoppers, Katydids & Crickets
	Acrididae (Grasshoppers)
adventive	*Oedaleus abruptus* (Thunberg)
	Gryllidae (Crickets)
endemic	*Leptogryllus* sp.
adventive	*Trigonidomorpha sjostedti* (Chopard)
	Tettigoniidae (Katydids)
adventive	*Conocephalus saltator* (Saussure)
	HETEROPTERA: True Bugs
	Lygaeidae (Seed Bugs)
adventive	*Geocoris punctipes* (Say)
endemic	*Nysius coenosulus* Stål
endemic	*Nysius* sp. 1
endemic	*Nysius* sp. 2
endemic	*Nysius* sp. 3
endemic	*Nysius* sp. 4
endemic	*Nysius* sp. 5
endemic	*Nysius* sp. 6
endemic	*Nysius* sp. 7
endemic	*Nysius* sp. 8
	Miridae (Plant Bugs)
endemic	*Orthotylus* sp. 1
endemic	*Orthotylus* sp. 2
endemic	*Opuna sharpianus* (Kirkaldy)
adventive	*Rhinacloa forticornis* Reuter
	Nabidae
adventive	*Nabis capsiformis* Germar
	Pentatomidae
endemic	*Coleotichus blackburniae* White
adventive	*Nezara viridula* (Linnaeus)
adventive	*Thyanta custator accerra* McAtee
	HOMOPTERA: Leafhoppers, Planthoppers
	Aphididae
adventive	*Rhopalosiphoninus latysiphon* (Davidson)
	Cicadellidae (Leafhoppers)
adventive	*Balclutha incisa hospes* (Kirkaldy)
endemic?	*Balclutha* sp.
adventive	*Carneocephala sagittifera* (Uhler)
adventive	*Deltocephalus sonorus* Ball
endemic	*Nesophrosyne pluvialis* Kirkaldy
	Flatidae (Flatid planthoppers)
adventive	*Siphanta acuta* (Walker)

Table 10. Checklist of the insects and other arthropods collected during the Saddle Road invertebrate survey (August-October 1996)

STATUS	TAXON
	COLEOPTERA: Beetles
	Aglycyderidae
endemic	*Proterhinus* sp.
	Anobiidae
endemic	*Holcobius* sp.
adventive	*Ozognathus* sp.
	Apionidae
imported	*Perapion antiquum* (Gyllenhal)
	Bruchidae
adventive	*Algarobius bottimeri* Kingsolver
	Carabidae
adventive?	*Gnathaphanus* sp.
endemic	*Mecyclothorax* sp.
adventive	*Pristonychus complanatus* Dejean
	Cerambycidae (Long-horned beetles)
endemic	*Plagithmysus blackburni* (Sharp)
endemic	*Plagithmysus filipes sophorae* Gressitt & Davis
endemic	*Plagithmysus looki* Swezey
	Chrysomelidae
adventive	*Diachus auratus* (Fabricius)
	Coccinellidae (Lady-bird beetles)
imported	*Cryptolaemus montrouzieri* Mulsant
imported	*Diomus notescens* (Blackburn)
imported	*Hippodamia convergens* Guérin-Méneville
imported	*Hyperaspis fimbriolata* Melsheimer
imported	*Nephus bilucernarius* (Mulsant)
imported	*Rhyzobius forestieri* (Mulsant)
imported	*Rhyzobius lophanthae* (Blaisdell)
imported	*Scymnus loewii* Mulsant
	Curculionidae (Weevils)
adventive	*Asynonychus godmanni* Crotch
adventive	*Hypera postica* (Gyllenhal)
adventive	*Otiorhynchus cribricollis* Gyllenhal
adventive	*Syagrius fulvitarsus* Pascoe
	Dytiscidae
adventive?	*Rhantus ?binotatus* Harris
	Elateridae (Click beetles)
adventive	*Conoderus exsul* (Sharp)
	Staphylinidae (Rove beetles)
endemic	*Liophaena gracilipes* Sharp
	Tenebrionidae (Darkling beetles)
adventive	*Blapstinus dilatatus* Le Conte
adventive	*Gonocephalum ?bilineatum* (Walker)
adventive	*Lobometopon diremptus* (Karsch)

Table 10. Checklist of the insects and other arthropods collected during the Saddle Road invertebrate survey (August-October 1996) (continued)

STATUS	TAXON
	LEPIDOPTERA: Butterflies & Moths
	Cosmopterigidae
endemic	*Hyposmocoma* spp.
	Crambidae
adventive	*Hellula undalis* (Fabricius)
endemic	*Mestolobes* nr. *minuscula* (Butler)
endemic	*Orthomecyna* ?n.sp.
endemic	*Tamsica* cf. *hyacinthina* (Meyrick)
endemic	*Tamsica hydrophila* (Butler)
	Noctuidae
endemic	*Schrankia* sp. 1
endemic	*Schrankia* sp. 2
	Oecophoridae
adventive	*Stoeberhinus testaceus* Butler
endemic	*Thyrocopa* sp.
	Pieridae
adventive	*Pieris rapae* (Linnaeus)
	Tortricidae
adventive	*Cryptophlebia illepida* (Butler)
	DIPTERA: Flies
	Agromyzidae
adventive	*Calycomyza humeralis* (Roser)
adventive	*Liriomyza sativae* Blanchard
adventive	?*Melanagromyza* sp.
imported	*Ophiomyia lantanae* (Froggatt)
	Anthomyiidae
adventive	*Delia platura* (Meigen)
	Asteiidae
endemic	*Asteia ?montgomeryi* Hardy
	Calliphoridae
adventive	*Calliphora vomitoria* (Linnaeus)
adventive	*Chrysomya rufifacies* (Macquart)
endemic	*Dyscritomyia* sp.
adventive	*Pollenia rudis* (Fabricius)
	Cecidomyiidae
adventive	*Anarete johnsoni* (Felt)
?	genus? species? 1
?	genus? species? 2
	Ceratopogonidae
endemic	*Forcipomyia* prob. *hardyi* Wirth & Howarth
endemic	*Forcipomyia pholetor* Wirth & Howarth
	Chamaemyiidae
imported	*Leucopis obscura* Haliday

Table 10. Checklist of the insects and other arthropods collected during the Saddle Road invertebrate survey (August-October 1996) (continued)

STATUS	TAXON
	DIPTERA: Flies (continued)
	Chironomidae
?	genus? species?
	Chloropidae
?	genus? species?
adventive	*Monochaetoscinella anonyma* (Williston)
	Dolichopodidae
endemic	*Campsicnemus* n. sp. nr. *loxothrix*
endemic	*Campsicnemus scolimerus* Hardy & Kohn
endemic	*Eurynogaster* sp.
	Drosophilidae
endemic	*Drosophila crassifemur* Grimshaw
adventive	*Drosophila immigrans* Sturtevant
adventive	*Drosophila melanogaster/simulans*
endemic	*Drosophila paracracens* Hardy & Kaneshiro
endemic	*Drosophila* sp. 1 (cave species)
?	*Drosophila* sp. 2 (surface species)
adventive	*Drosophila suzukii* (Matsumura)
endemic	*Scaptomyza apiciguttula* Hardy
endemic	*Scaptomyza* nr. *articulata* Hardy
	Lonchaeidae
adventive	*Lonchaea polita* Say
	Lonchopteridae
adventive	*Lonchoptera furcata* (Fallén)
	Muscidae
adventive	*Brontaea quadristigma* (Thomson)
endemic	*Lispe metatarsalis* Thomson
endemic	*Lispocephala* sp.
	Neriidae
adventive	*Telostylinus lineolatus* (Wiedemann)
	Phoridae
adventive	*Diplonevra peregrina* (Wiedemann)
?	*Megaselia* sp.
?	genus? species?
	Sarcophagidae
adventive	*Helicobia morionella* (Aldrich)
adventive	*Ravinia lherminieri* (Robineau-Desvoidy)
	Scatopsidae
adventive	*Coboldia fuscipes* (Meigen)
	Scenopinidae
adventive	*Scenopinus lucidus* Becker
adventive	*Toxomerus marginatus* (Say)
	Sciaridae
?	genus? species?
	Sepsidae
adventive	*Sepsis thoracica* (Robineau-Desvoidy)

Table 10. Checklist of the insects and other arthropods collected during the Saddle Road invertebrate survey (August-October 1996) (continued)

STATUS	TAXON
	DIPTERA: Flies (continued)
	Sphaeroceridae
adventive?	*Leptocera* sp.
adventive	*Poecilosomella punctipennis* (Wiedemann)
	Syrphidae
adventive	*Allograpta exotica* (Wiedemann)
adventive	*Allograpta obliqua* Say
adventive	*Simosyrphus grandicornis* (Macquart)
adventive	*Toxomerus marginatus* (Say)
	Tachinidae
adventive	*Eucelatoria armigera* (Coquillett)
adventive	*Gonia longipulvilli* Tothill
imported	*Lespesia archippivora* (Riley)
adventive	*Trichopoda pilipes* (Fabricius)
	Tephritidae
endemic	*Trupanea arboreae* Hardy & Delfinado
endemic	*Trupanea neoapicalis* Hardy & Foote
endemic	*Trupanea* n. sp. 1
endemic	*Trupanea* sp.
	Tipulidae
endemic	*Limonia nigropolita* (Alexander)
endemic	*Limonia* sp. nr. *jacoba* (Alexander)
endemic	*Limonia* sp. 1
	HYMENOPTERA: Wasps, Bees & Ants
	Aphelinidae
?	genus? species?
	Apidae
imported	*Apis mellifera* Linnaeus
	Bethylidae
?	*Epyris sp.* not *extraneus*
?	*Parasierola* sp.
endemic	*Sierola* sp.
	Braconidae
endemic?	*Chelonus blackburni* Cameron
imported	*Cotesia marginiventris* (Cresson)
?	*Cotesia* sp.
?	genus? species?
adventive	*Habrobracon hebetor* (Say)
imported	*Meteorus laphygmae* Viereck
	Chalcidae
imported	*Dirhinus anthracina* Walker
	Colletidae
endemic	*Hylaeus* (*Nesoprosopis*) sp. 1
endemic	*Hylaeus* (*Nesoprosopis*) sp. 2

Table 10. Checklist of the insects and other arthropods collected during the Saddle Road invertebrate survey (August-October 1996) (continued)

STATUS	TAXON
	HYMENOPTERA: Wasps, Bees & Ants (continued)
	Diapriidae
adventive	*Stylaclista* sp.
endemic	*Trichopria ?soror*
	Encyrtidae
?	*?Aenasius advena* Compere
?	*Copidosoma* sp.
adventive	*Epidinocarsis californicus* (Compere)
?	genus? species?
?	*Ooencyrtus* sp.
	Eucoilidae
imported	*Ganaspidium utilis* Beardsley
?	genus? species?
?	*Pseudeucoila* cf. *oreias* (Perkins)
	Eulophidae
?	*Diglyphus* sp.
?	*Tetrastichus* sp.
?	genus? species?
	Formicidae
adventive	*Cardiocondyla* sp.
adventive	*Linepithema humile* (Mayr)
	Halictidae
adventive?	*Halictus* sp.
	Ichneumonidae
adventive	*Anomalon californicum* (Cresson)
adventive	*Casinaria infesta* (Cresson)
adventive	*Diadegma blackburni* (Cameron)
?	*Diadegma* sp.
adventive	*Diplazon laetatorius* (Fabricius)
?	genus? species? (Cryptinae)
adventive	*Pimpla punicipes* Cresson =*Coccygimus pimpla punicipes*
endemic?	*Pristomerus hawaiiensis* Perkins
imported	*Pristomerus spinator* (Fabricius)
imported	*Spilichneumon superbus* (Provancher)
	Mymaridae
?	*Polynema* sp.
	Platygasteridae
?	genus? species?
	Pteromalidae
?	*Cyrtogaster* sp.
?	genus? species? 1
?	genus? species? 2
adventive?	*Norbanus* sp.
adventive?	*Pachyneuron* sp.
imported	*Pteromalus puparum* (Linnaeus)

Table 10. Checklist of the insects and other arthropods collected during the Saddle Road invertebrate survey (August-October 1996) (continued)

STATUS	TAXON
	HYMENOPTERA: Wasps, Bees & Ants (continued)
	Scelionidae
?	*Baeus* sp.
?	genus? species? 1
?	genus? species? 2
imported	*Trissolcus basalis* (Wollaston)
?	*Trissolcus* sp.
	Sphecidae
adventive	*Dryudella immigrans* (Williams)
endemic	*Ectemnius* sp. 1 (?*weberi*)
endemic	*Ectemnius* sp. 2 (?*hawaiiensis/unicolor*)
	Trichogrammatidae
?	genus? species?
	Vespidae
endemic	*Odynerus* sp.
adventive	*Vespula pensylvanica* (Saussure)

ISOPODA	sowbugs and pillbugs
	Porcellionidae
adventive	*Porcellio* sp.

COLEOPTERA: ANOBIIDAE

Holcobius sp.

There are over 130 species of endemic anobiid wood boring beetles, with 14 species belonging to the endemic genus *Holcobius*. Only four *Holcobius* species have been recorded from Hawaii Island. Most species are restricted to one or a few closely related host plants and are often restricted to particular areas within the island. They are threatened by host plant loss and habitat destruction. Species of this genus were collected at Sites 31 (PTA-1 22 + 344.27) and 35 (EX-2 130 +960) during this study.

COLEOPTERA: CERAMBYCIDAE

Plagithmysus spp.

The long-horned wood borers in the endemic genus *Plagithmysus* represent one of the most remarkable examples of adaptive radiation in Hawaii. There are 139 species described, which evolved from only one successful colonization (Gressitt, 1978). Most species are confined to single islands and even to small areas within their island. Each species is restricted to a single host plant species or rarely to a group of closely related hosts, but in concert the group attacks a large percentage of the native woody flora in a wide variety of habitats. Some species remain common and are ideal candidates for ecological studies; others are extremely rare because of habitat and host loss, as well as from predation by introduced predators. Three species of this genus were collected during this study (*P. looki, P. blackburni,* and *P. sophorae*).

COLEOPTERA: STAPHYLINIDAE

Liophaena gracilipes Sharp

The endemic rove beetle genus contains three species, one of which, *Liophaena gracilipes* Sharp, is endemic to Hawaii Island. The group is rarely collected and considered rare.

They are predators in rotting organic substrates. Threats include introduced predators, especially ants, and alien beetles, and habitat destruction. This species was collected at Site 2 (EX-3 155 + 000) during this study.

DIPTERA: CALLIPHORIDAE

Dyscritomyia spp.

Twenty-five species are known of this endemic Hawaiian genus, 12 of which occur on Hawaii Island. These flies, related to the common blue-bottle and green-bottle flies, have declined precipitously in numbers (both species and individuals) in recent years. The immature stages are carrion feeders and were no doubt an important part of the Hawaiian ecosystem before the appearance of Europeans. Loss of original carrion hosts (presumably birds and land snails) and the introduction of alien calliphorids to the Hawaiian Islands has ultimately led to some species of this genus becoming extinct (e.g., of the 8 known species of *Dyscritomyia* originally described from Oahu, only one species [*D. fasciata* (Grimshaw)] is still found [in the Waianae mountains]). Adults feed on snail slime trails and other liquid protein foods. Some species have dispensed with a feeding larval stage; the female giving birth to a mature larva which transforms to a pupa and adult without feeding (James, 1981). Native *Dyscritomyia* are now largely confined to high elevation habitats in the Saddle Road area. One undetermined species was collected at Site 2 (EX-3 155 + 000) during this study.

DIPTERA: TEPHRITIDAE

Trupanea spp.

Twenty-one endemic species are known in Hawaii, but a few more await description. There are ten species on Hawaii Island (Hardy & Delfinado, 1983). Most species breed in flower heads of native composites, while a few make galls in stems of native composites. They are threatened by the decline of their hosts as well as mortality from alien predators and parasites, especially some of the species introduced to control the alien pestiferous fruit flies. Four species were collected in this survey. *Trupanea neoapicalis* Hardy & Foote and *T. arboreae* Hardy both of which probably breed in *Dubautia* flower heads, were collected at Site 28; one undescribed (probably new) species of unknown biological habits was collected in the Malaise trap at Site 7 (W-2 113 + 620), and another undetermined species was collected at Site 40 ((W-2 115 + 120) near the junction of W-2 with the existing Saddle Road.

HETEROPTERA: REDUVIIDAE

Nesidiolestes spp.

The cave-adapted thread-legged bugs (*Nesidiolestes* spp.) are sit-and-wait predators, which capture active prey with praying mantis-like forelegs. They walk slowly and crane-like on exceptionally long thin middle and hind pairs of legs. They are found in stagnant air passages in mid to high elevation caves on Mauna Loa and Kilauea on Hawaii Island, including caves near the Saddle Road alignment on windward Mauna Loa and in PTA; however, they were not found in caves during this survey. Their close surface relatives are well-pigmented, have functional eyes, and are rare denizens of Hawaiian rain forests such as in the *kipuka* along the eastern Saddle Road corridor.

HETEROPTERA: SCUTELLARIDAE

Coleotichus blackburniae White **Species of concern**

The native shield bug, *Coleotichus blackburniae*, is the largest and most conspicuous native bug in Hawaii. It was abundant on native *koa* and *aalii* until the 1970s, when its populations began a precipitous decline (Howarth et al., 1995). It and other larger native true bugs are extremely rare, probably victims of parasites [e.g., the tachinid fly *Trichopoda pilipes* (Fabricius)] introduced to control the alien pestiferous southern green stink bug, *Nezara viridula* . The koa bug was collected at Sites 14 (W-2 114 + 500) and 20 (EX-1 103 + 064) in association with stands of *a'ali'i.*

HOMOPTERA: CIXIIDAE

Oliarus spp.

The blind, white cave planthopper (*Oliarus polyphemus* Fennah) occurs only in younger caves on Hawaii Island that have roots of its host tree *ohia lehua* (*Metrosideros polymorpha*). The species was thought to be widespread in caves on Kilauea, Mauna Loa, and Hualalai, but recent research on mating behavior and morphology has shown that individual caves often harbor populations distinct from those in neighboring caves (Hoch & Howarth, 1993). A unique form of *O. polyphemus* lives in Kaumana Cave at the eastern end of the project area, and other populations occur in caves near Saddle Road. We did not find specimens in the caves surveyed during this project, but they are expected to occur in Don's Cave (Site 80; EX-3 156 + 760).

HYMENOPTERA: COLLETIDAE

Hylaeus (*Nesoprosopis*) spp. **Species of concern**

Over 60 species of native yellow faced bees are known from Hawaii. Of these, 33 are found on Hawaii Island. They are important pollinators of many native plants, and as the bees decline their associated plants also decline. Once abundant in most environments, the distributions of these native bees have retracted to higher elevations and wetter forests. They are sensitive to habitat destruction, invading plant species, and alien predators, as well as to competition from the introduced honey bee. At least two and possibly more species of this genus were collected primarily at collecting sites at various points along PTA-1, at Site 4 (PTA-3 11 + 260), and Site 7 (W-2 113 + 620).

HYMENOPTERA: VESPIDAE

Odynerus spp.

Over 100 species of these solitary predatory wasps are endemic to the Hawaiian Islands; about 35 species are found on Hawaii Island. Most species provision their nests, which are built in the ground or in hollow twigs, with caterpillars. Populations of most species have declined in recent decades, and some species are believed to be extinct. Threats include loss of habitat and competition with alien predators. Species of this genus were collected at Sites 6 (PTA-1 24 + 460), 30 (PTA-1 26 + 860), and 66 (PTA-1 27 + 270.87) during this study.

LEPIDOPTERA: NOCTUIDAE

Schrankia spp.

The cave moths in the genus *Schrankia* are another group, like the planthoppers, crickets, and millipedes, in which each cave seems to harbor forms differing from related forms in neighboring caves. Also, larger caves often have two kinds, a facultative cave form with gray and white patterned wings and functional eyes in the twilight and transition zones, and a cave-adapted form in the deep zone. These forms are undescribed, and the total number of species inhabiting caves on Hawaii Island is unknown. Their larvae feed on tree roots and hang their cocoons from root tips in the cave. A rain forest form was collected in the entrance of Strawberry Cave (Site 77; EX-3 148 +240), and cocoons of presumably the twilight zone form were seen on roots in the cave. In Don's Cave (Site 80; EX-3 156 + 760), cocoons, probably representing both the twilight and deep zone forms, were abundant; over 100 were noted during our brief visit. A distinctive species with golden wing scales lives in Kaumana Cave and in the neighboring rain forests at the eastern end of the project area.

ODONATA: COENAGRIONIDAE

Megalagrion spp. **Species of concern**

The 28 species of native Hawaiian damselflies all belong to the endemic genus *Megalagrion*. Nine species occur on Hawaii Island; but the Hawaii Island populations of two of these may be extinct, and another (*M. xanthomelas* Selys-Longchamps) currently has C1 status (Polhemus & Asquith, 1996). The lowland pool breeders are the most threatened by habitat destruction and introduced predators, but all species are sensitive to these factors. One species, *M. amaurodytum peles* (Perkins), was observed hawking insects in the canopy in the wet forest at Site 3 (EX-3 156 + 103.039). Its immatures breed in the damp litter in axils of *Astelia* and *Freycinetia* in the rain forest. Though not collected during this study, immatures of this species have been collected from leaf axils of *Astelia* at Site 2 (EX-3 155 + 000) on previous occasions.

ORTHOPTERA: GRYLLIDAE

Caconemobius spp.

Thaumatogryllus spp.

The Hawaiian cave crickets belong to two groups, the rock crickets *Caconemobius* (subfamily Nemobiinae) and the tree crickets *Thaumatogryllus* (subfamily Oecanthinae). *Caconemobius* is endemic to the Hawaiian Islands, and all known species are restricted to bare wet-rock habitats, including rocky seacoasts, new lava flows, and caves. Cave populations on Hawaii Island are extremely variable, with each suitable cave often harboring two or three distinct forms differing in behavior and morphology, and also differing from populations in neighboring caves (Otte, 1994). All three forms are known from Kaumana Cave at the eastern end of the project, and populations are known from caves on the windward slopes of Mauna Loa and within PTA near Saddle Road. We were unable to find crickets in either Strawberry Cave or Don's Cave. However, our survey of Don's Cave was too brief. Judging from the environment, these crickets are predicted to occur there.

The underground tree crickets (*Thaumatogryllus*) belong to a remarkable endemic Hawaiian complex of three closely related genera of true crickets (Otte 1994). The cave species are more restricted in distribution than the rock crickets; disjunct populations have been found in high elevation caves on Mauna Loa, and low to mid elevation caves in areas with mesic to dry climates on Mauna Loa, Hualalai, and Kilauea. They have not been found in mid to low elevation caves in rain forests, and we did not find them during this survey. However, populations are known from caves near Saddle Road, such as within PTA.

4.2.2. *Detailed account by section*

Due to the large numbers of specimens and species of insects and related arthropods collected during this project, only the species determined by us to be "sensitive" are discussed segment-by-segment below.

SECTION I

EX-1. On this segment (the existing road alignment), the koa bug, *Coleotichus blackburniae* White, was collected at Site 20 (103 + 064) in association with stands of *aalii* (*Dodonaea* sp.). Historically, the rare weevil *Rhyncogonus giffardi* Sharp is known from a location along this segment in association with stands of *aalii*. However, no live specimens of this weevil were collected during this phase of the study. The weevil is thought to be seasonal, so collecting in February or March would be an optimal time to search for and verify the status of this species.

W-2. The koa bug, *Coleotichus blackburniae* White, was collected at Site 14 (114 + 500) in association with aalii. An undetermined species of the flower-head breeding fly *Trupanea* was collected at Site 40 (115 + 120).

W-3. No sensitive species of insects were found at the three sites: sites 17 (100 + 180), 18, 100 + 240), and 19 (100 + 300) investigated during this study.

SECTION II

EX-2. The anobiid *Holcobius* sp. was collected at Site 35 (130 +960). At Site 65 (132 + 220), two undetermined species of the native colletid bee *Hylaeus* (*Nesoprosopis*) were collected.

PTA-1. A total of 29 sites were investigated along this segment during this study. The anobiid *Holcobius* sp. was collected at Site 31 (22 + 344.27). The endemic long-horned beetle, *Plagithmysus looki* Swezey, was collected at Sites 25 (19 + 480), 26 (18 + 155.35), 27 (15 + 760), and 29 (11 + 560). *Plagithmysus blackburni* (Sharp) and *P. filipes sophorae* Gressitt & Davis were collected at Site 5 (25 + 000). The endemic colletid bees of the genus *Hylaeus* (*Nesoprosopis*) were collected at Sites 5 (25 + 000) and 66 (27 + 270.87). The endemic vespid wasp, *Odynerus* sp., was found at Sites 6 (24 + 460), 29 (11 + 560), 30 (26 + 860), and 66 (27 + 270.87). The flower-head breeding flies *Trupanea apicalis* Hardy & Delfinado and *T. arboreae* Hardy & Delfinado, were found in association with *Dubautia* at Site 28.

PTA-3. The colletid bee *Hylaeus* (*Nesoprosopis*) sp. was collected in association with composite flowers at Site 4 (PTA-3 11 + 260).

SECTION III

EX-3. A total of 11 sites (sites 1, 2, 3, 23, 24, 37, 38, 75, 76, 77, and 80) were investigated for insects along this segment. Site 2 (155 + 000) was found to harbor the beetles, *Proterhinus* sp. and *Liophaena gracilipes* Sharp and the endemic calliphorid fly, *Dyscritomyia* sp. Though no specimens were collected during this survey, immatures of the damselfly *Megalagrion amaurodytum peles* (Perkins) have been collected previously from Site 2. Adults of this damselfly were observed at Site 3 (156 + 103.039). The colletid bee *Hylaeus* (*Nesoprosopis*) sp. was found at Site 37 (155 + 500). Site 77 (Strawberry Cave) (EX-3 148 + 240) harbored the following sensitive species: the noctuid *Schrankia* sp. 1, the spider *Erigone* cf. *stygius* Gertsch, and the millipede *Nannolene* sp. At site 80 (Don's Cave) (EX-3 156 + 760), the noctuid *Schrankia* sp. 2 and the millipede *Nannolene* sp. were found.

SECTION IV

EX-4. No insects of significance were found along this segment.

EX-4A. No insects of significance were found along this segment.

E-3. Though few insects have been processed and identified from this segment, there may be sensitive species in the material collected as this area is composed of wet forest known to normally yield high numbers of endemic and native insects and related arthropods. The upslope portions of Kaumana Cave, though not surveyed in this study, most likely cross under parts of E-3 (following the 1881 lava flow). If surveyed, these cave portions should yield additional native and cave-adapted species of arthropods.

5. ENVIRONMENTAL CONSEQUENCES

The Environmental Consequences of construction in the Saddle Road Area is broken down here into three areas: 1) snails, 2) insects and related arthropods, 3) and cave ecosystems. The last category has been treated separately because of its uniqueness in the ecosystems of Hawaii and the fact that cave ecosystems support a wide variety of organisms not limited to either snails or insects and related arthropods.

5.1. Snails

5.1.1. *General*

Snails are sedentary. Populations of individual species may be highly localized. Clearly, road construction will involve destruction of snail habitat and hence snails. If the snails that are destroyed represent highly localized populations of rare species, then the impact on that species will be significant.

Unfortunately, the present survey was insufficiently detailed to allow the accurate mapping of populations of snail species. Nevertheless, it has been possible to obtain a general assessment of the relative importance of the various proposed road segments from the perspective of snail diversity.

5.1.2. *Detailed account by section*

SECTION I

EX-1. This segment, the existing road alignment, passes almost entirely through ranchland, which harbors very few snails. Since only a single, non-indigenous species (*Oxychilus alliarius*) was found along this segment, impacts of construction on native snails, which may occur here but were not found during the survey, would be negligible.

W-2, W-3. These segments also pass almost entirely through ranchland and in these ranchland areas very few snails were found, only the two relatively common species, *Succinea konaensis* and ?*Striatura* sp. Populations of these species might be impacted by construction, but they are widely distributed, so these impacts would not be highly significant. However, in the upper part of W-2, the part designated W-2B above the junction of W-2A and W-3 (in the PTA), a relatively diverse assemblage of native snail species was found; this being the only area in the entire survey at which *Leptachatina* sp. A was found. These species were found in highly localized rocky outcrops. There are a small number of these outcrops in the area, and some others of them may also harbor these and perhaps other species. If road construction destroys these outcrops it will also destroy these snail populations.

SECTION II

EX-2. This segment is the least diverse of the alternative routes in Section II in terms of numbers of snail species. At all but one of the sites at which snails were found, only the two common, widespread species *Succinea konaensis* and ?*Striatura* sp. were recorded. Construction impacts on these species would not be highly significant. However, a single site, located in the area just to the east of the Mauna Kea State Recreation Area, supported additional species, in particular a living population of *Leptachatina lepida*, a USFWS Species of Concern. Construction could therefore destroy populations of this species in this area. This species is one of only a handful of species in the once extremely diverse family

Amastridae that have been seen alive in the last decade or so. Apart from being found alive in this area of the PTA east of the State Park (see also PTA-1, PTA-3), this species is only known to survive in the MPRC.

PTA-1. This segment, especially the part to the east of the State Park, harbors the most diverse assemblage of land snails encountered during the survey, including living populations of the USFWS Species of Concern *Leptachatina lepida*. This is the area in which road construction would have the most serious impact on the land snail fauna, and from a land snail perspective this segment should be discounted as a possible alternative.

PTA-3. This segment harbored the second most diverse assemblage encountered during the survey. In terms of the habitat, this segment is similar to the part of PTA-1 between the State Park and the junction of PTA-1 and PTA-3. Impacts on land snails, including the USFWS Species of Concern *Leptachatina lepida*, would be similarly severe.

SECTION III

EX-3. This is essentially the current alignment, slightly adjusted. There are no alternative routes. The sites investigated were dominated by introduced species (*Oxychilus alliarius* and the slug species, ?*Deroceras* sp.), which are of no concern in terms of impacts of road construction. Possibly, native species of snails may be more common in native vegetation some distance away from the existing road, the road having acted as a corridor for the introduction of these non-native species. If the minor realignments that are planned destroy native habitat, especially *kipuka*, there may be impacts on snails. Two native species of snails were recorded on this section, "tornatellinid" D and *Euconulus thaanumi*. The present status of these species in terms of their extant wider distribution on Hawaii Island is unknown, so it is not possible definitively to assess the significance of any destruction of populations along the Saddle Road.

SECTION IV

EX-4, EX-4A, E-3. Only the slug (?*Deroceras* sp.) and the introduced carnivorous snail, *Euglandina rosea* were found in this section. Much of the habitat is disturbed, and even in relatively undisturbed habitat (segment EX-4A), no native snails were found. Nevertheless, they may be present but simply not recorded during this very superficial survey. From a land snail perspective therefore, it is difficult to assess the impact of road construction; it may be only minor, and probably negligible along the existing road (EX-4).

5.1.3. *Alternatives comparison*

The land snail fauna on the dry, Kona side of the saddle, including the PTA, is essentially a subset of the fauna recorded in the MPRC by Cowie & Nishida (1993) and Cowie et al. (1995). Diversity on the Kona side is correlated to a great extent with the level of habitat disturbance. Thus the heavily grazed areas in Parker Ranch support few or no snails, while the less disturbed areas within the PTA support greater diversity. In general, however, even within the PTA, sites sampled alongside the existing Saddle Road exhibit lower diversity than sites sampled along the alternate alignments that run through less disturbed habitat. Disturbed sites that support snails are dominated by *Succinea konaensis* and to a lesser degree the species here referred to as ?*Striatura* sp. The most diverse area with respect to snails seems to be the part of the PTA to the east of the Mauna Kea State Recreation Area, with the most consistent levels of diversity along route PTA-1 between and including sites 5, 6, 30, and 66. It is in this area that the majority of the living *Leptachatina lepida*, a USFWS Species of Concern, were found.

The fauna of the much wetter Hilo side of the Saddle Road corridor is characterized by low diversity almost completely dominated by introduced species, most notably *Oxychilus alliarius*. This may well be a phenomenon associated with the existing Saddle Road acting as a corridor along which non-native species are introduced; these species subsequently spreading out away from the road.

Table 11 below is a summary, by alternative routes and sections of the likely level of impact of road construction on land snails.

Table 11. Impacts of road construction on land snails. These assessments are based on the present survey and are therefore necessarily somewhat tentative (except PTA-1 and PTA-3 in Section II, where the significance of the impact of road construction is clear). [See text for discussion. See Table 13 for segment designation within Alternative and Section.]

Alternative	Section I	Section II	Section III	Section IV
B-3	Possible minor	Minor	Possible minor	Possible minor
B-4	Possible minor	Significant	Possible minor	Possible minor
B-6	Possible minor	Significant	Possible minor	Possible minor
B-7	Negligible	Minor	Possible minor	Possible minor
B-8	Negligible	Significant	Possible minor	Possible minor
B-9	Possible minor	Significant	Possible minor	Possible minor
C-3	Possible minor	Minor	Possible minor	Possible minor
C-4	Possible minor	Significant	Possible minor	Possible minor
C-6	Possible minor	Significant	Possible minor	Possible minor
C-7	Possible minor	Significant	Possible minor	Possible minor
C-8	Possible minor	Minor	Possible minor	Possible minor
C-9	Possible minor	Significant	Possible minor	Possible minor

From this Table 11 it can be seen that in Section I, because of the possible impacts on land snails on W-2/W-3 (at the upper end where these segments coalesce into W-2B), the preferred route is the existing road, EX-1. In Section II, the highly significant impacts that would occur if either PTA-1 or PTA-3 were chosen, again mean that the preferred route is the existing road, EX-2. There are no alternatives in Section III, the existing road, EX-3, is the only option. In Section IV, there may be slightly more impact if E-3 (or EX-4A) were chosen over the existing road (EX-4), but this is difficult to assess on the basis of this limited survey.

In general, therefore, in terms of impacts on land snails, the existing alignment is the favored alignment in all 4 Sections. This is most especially the case in Section II, which harbors the greatest diversity of snails as well as being the only section in which live *Leptachatina lepida* (A USFWS Species of Concern) were found.

5.2. Insects and related arthropods

5.2.1. *General*

Insects are generally mobile and can occupy diverse habitats and ranges of altitudes and ecosystems. However, the general faunal constituency of the Saddle Road contains a large number of species of insects that are known to be habitat or host-specific. The brief amount of time allotted to surveying the fauna of insects and related arthropods has shown that there are a few "sensitive" species that may be impacted by construction through a specific habitat. Discussion below will be on a segment-by-segment basis. A tabular summary of assessed impacts is presented in Table 12. Potential impacts on cave habitats are discussed in setion 5.3 below.

5.2.2. *Detailed account by section*

SECTION I

EX-1. The only historical population of the rare weevil *Rhyncogonus giffardi*, which is presumed to be found in association with stands of *aalii*, could be impacted by realignment construction through this area. Since the historical population is presumed to be more than 30 meters away from the center line of the proposed realignment, negligible impact could be expected from construction. However, if a collecting trip in February or March discovers populations of the weevil close to the center line of the proposed realignment, then significant impact could be expected on the fragile existence of this species. The koa bug, *Coleotichus blackburniae*, is also found along this segment, in association with stands of *a'ali'i*. Since its populations are in decline, destruction of its host plant during construction could very well impact the survivability of this species.

W-2, W-3. These segments run through ranchland and a portion of PTA, and on the whole, may not harbor many sensitive insect species. However, near the eastern part of W-2 at Site 14, the koa bug, *Coleotichus blackburniae* was collected in association with stands of *a'ali'i*. This site is a few hundred meters from the center line of the proposed alignment, hence there would be little direct impact of construction on insects of importance along either of these two segments, but indirect impacts by providing corridors for alien species is a concern.

SECTION II

EX-2. Only the anobiid, *Holcobius*, the native colletid bees of the genus *Hylaeus* (*Nesoprosopis*), and the cave machilid (*Neomachilis heteropus* Silvestris) were found long this segment. The first two taxa occur at other localities, but the last of the three, the cave machilid, is rarely seen. We feel that construction through this segment would on the whole have a negligible impact on the fauna of sensitive species in this area, but care should be taken to avoid impacts of construction on caves in the areas noted (see Appendix II) along this segment.

PTA-1. A number of sensitive species of insects were collected along this segment. Since this area of Mamane/Naio forest harbors a significant number of species of concern and those we consider sensitive, we feel that construction along this segment would unduly impact on the potential survivability of the species in question. This is especially true for species of the endemic colletid bee *Hylaeus* (*Nesoprosopis*) as well as the species of the long-horned beetle, *Plagithmysus*.

PTA-3. Because of the finding of species of the endemic colletid bee, *Hylaeus* (*Nesoprosopis*) along this segment, we feel that construction along this segment would unduly impact on the survivability of these bees.

SECTION III

EX-3. The beetles *Proterhinus* and *Liophaena* and the damselfly *Megalagrion amaurodytum peles* were collected or observed in *kipuka* at sites along this segment. We feel that construction that may impact on the *kipuka* will unduly impact on the survivability of these sensitive species. If construction does not impact the integrity of the *kipuka*, then the survivability of these species should be unaltered. Caves have been surveyed along this segment and others exist that were not surveyed (see Appendix II for full details). The species observed or collected in the caves during this survey include the sensitive species *Nannolene* sp., *Schrankia* spp., and *Erigone* cf. *stygius* Gertsch. Construction along this segment should be aware of cave locations along this segment and care should be taken to avoid impacts on the cave ecosystem such as heavy equipment causing collapses of cave roofs.

Table 12. Impacts of road construction on insects and related arthropods. These assessments are based on collection, some of which are currently being processed for identification and are therefore necessarily somewhat tentative.
[See text for discussion. See Table 13 for segment designation within Alternative and Section.]

Alternative	Section I	Section II	Section III	Section IV
B-3	Probably negligible	Probably negligible	Possible minor	Unknown
B-4	Probably negligible	Significant	Possible minor	Unknown
B-6	Probably negligible	Significant	Possible minor	Unknown
B-7	Probably negligible	Probably negligible	Possible minor	Unknown
B-8	Probably negligible	Significant	Possible minor	Unknown
B-9	Probably negligible	Significant	Possible minor	Unknown
C-3	Probably negligible	Probably negligible	Possible minor	Unknown
C-4	Probably negligible	Significant	Possible minor	Unknown
C-6	Probably negligible	Significant	Possible minor	Unknown
C-7	Probably negligible	Probably negligible	Possible minor	Unknown
C-8	Probably negligible	Significant	Possible minor	Unknown
C-9	Probably negligible	Significant	Possible minor	Unknown

SECTION IV

EX-4, EX-4A, and EX-3. At this time (until material from collecting has been fully processed and identified), we can not accurately assess the impacts on the insect and related arthropod fauna from any proposed construction along any of the segments. The Hilo rainforest side of the saddle area harbors a diverse fauna of native arthropods, including many rare and sensitive species. *Kipuka* habitats are particularly sensitive to disturbance and should be avoided or impacts mitigated (see Section 6.2.2 below). A new cave passage of Kaumana cave may be found and impacted during construction over any segments of the 1881 lava flow.

Table 13. Alternative routes with segment per route.

Alternative	Section I Segment #	Section II Segment #	Section III Segment #	Section IV Segment #
B-3	W-2	EX-2	EX-3	E-3
B-4	W-2	PTA-1	EX-3	E-3
B-6	W-2	PTA-3	EX-3	E-3
B-7	W-2	EX-2	EX-3	EX-4A
B-8	W-2	PTA-1	EX-3	EX-4A
B-9	W-2	PTA-3	EX-3	EX-4A
C-3	W-3	EX-2	EX-3	E-3
C-4	W-3	PTA-1	EX-3	E-3
C-6	W-3	PTA-3	EX-3	E-3
C-7	W-3	EX-2	EX-3	EX-4A
C-8	W-3	PTA-1	EX-3	EX-4A
C-9	W-3	PTA-3	EX-3	EX-4A

5.2.3. *Alternatives comparison*

Table 12 gives a summary of the perceived impacts of proposed realignment on the areas in question.

The only clear significant impact we have determined is any alteration of the existing habitat along segments PTA-1 and PTA-3 due to the fragility of the fauna specifically associated with the Mamane/Naio area. Construction or other alteration along the other alternates and segments presented in the table would have a lesser potential impact than on PTA-1 and PTA-3. It must be noted that, because of the lack of processed and identified material from the segments in Section IV, we cannot at this time make any conclusions as to perceived impacts on the insect and related arthropod fauna found in this area. However, the *kipuka* within this Section are known to harbor sensitive species (Wagner et al., 1983)

5.3 Caves

Construction activities associated with building and upgrading the Saddle Road can break into known caves as well as into hidden or previously unknown cave passages. In addition to being hazardous to construction workers, these breaks will change the airflow patterns in the cave usually making them less suitable for cave animals (Howarth, 1993). Clearing vegetation for staging areas and other uses related to the road, as well as from its other impacts, will reduce the amount and quality of food entering the cave ecosystem. Many Hawaiian cave animals require native plant species over their cave habitats. Changing water flow patterns and infiltration rates may desiccate some caves or flood others. Chemical spills and runoff may enter caves and have devastating effects on the fauna. Many pollutants break down slowly in total darkness, so their effects may be long-lasting underground. The road may seal caves making them no longer available for study or enjoyment. Other caves may be made more accessible to human visitors, which could be detrimental as many cave resources are highly vulnerable to human disturbance (e.g., archaeological sites, geological formations, paleontological material, and living animals can be crushed or irreversibly disturbed by the careless visitor (Howarth & Stone, 1982)).

6. DISCUSSION

6.1. General

Our survey focused on Sections I and II of the proposed realignment, especially the area around the PTA, with rather less detailed sampling on the eastern, Hilo side.

The land snails recorded in this dry high saddle area around the PTA are characteristic of the general area across to Mauna Loa and to Hualalai, based on previous sampling in the MPRC and elsewhere (Cowie & Nishida, 1993; Cowie, Nishida et al., 1995; Wagner et al., 1983). This fauna is essentially endemic to the area, and because of this uniqueness it is important to make every effort to conserve it. In particular, the present survey sites along segments PTA-1 and PTA-3 in the area of Mamane/Naio forest east of the State Park represent one of only two localities at which the amastrid land snail *Leptachatina lepida* (a USFWS Species of Concern) is known to survive. This area supported the greatest diversity of land snails encountered during the survey.

Insects and other arthropods found along all existing and alternative proposed realignments of Saddle Road are difficult to characterize as the road extends through a number of vegetation and climatic zones. The easternmost (and lowest altitudinally) part of the road passes through lowland rain forest. This limited survey discovered no significant impacts to the area. However, this area is dominated by *Acacia koa* and as the road gains altitude, *Metrosideros polymorpha* (ohia), both of which are hosts to a large number of endemic species of arthropods. As the number of *Acacia* trees is dwindling, owing mostly to housing development, and parts of the ohia forest have undergone dieback, restriction of habitat alteration is urged during construction to insure survivability of localized populations of endemic species.

Hawaiian cave habitats, like *kipuka* and wet lands, are island like habitats within islands. Recent research (e.g., Hoch & Howarth, 1993; Otte, 1994) has shown that many cave animals on Hawaii Island have differentiated within different caves, so that each cave may harbor a distinct and unique fauna found no where else. These cave systems are vulnerable to perturbations to the surface environment over the caves as well as to direct and indirect disturbances within the caves. Many additional cave segments lie hidden beneath the proposed road alignments and some of these may be broken into or impacted during construction. Mitigation is discussed in section 6.2.2 below.

Higher in elevation, in the wet rain forests and cloud forests, road construction may impact several *kipuka*. These *kipuka* are well known shelters of endemic species. Road construction that impinges on the integrity of any *kipuka* may have serious and irreversible consequences to native species of plants and animals that are residents of that *kipuka*. In one of the *kipuka* (Site 2), flightless flies of the genus *Campsicnemus* were collected in the 1970s. They have not been collected since, despite repeated collecting efforts for almost 20 years. Since the original collections of that species were made, there has been a noticeable increase in pig damage in the *kipuka*. It is no doubt that the feral ungulate damage as well as possible other perturbations that have led to the demise of the flightless flies and possibly other unique Hawaiian organisms found only in Hawaiian *kipuka*. Realigning the Saddle Road closer to any *kipuka* may permit easier access of alien weeds and other potentially disruptive elements, such as pigs or ants, that will cause habitat or faunal alteration and probable reduction in species richness. Argentine ants have been found near *kipuka* by the stations EX-3 140 + 860 and EX-3 141 + 880. These ants are particularly dangerous to the continued welfare of native invertebrate faunas and, if unabated, will destroy many of the native insects and other small organisms living in this area. In order to alleviate the

possibility of further introductions of these ants into other *kipuka* along the saddle area, care should be taken to minimize any activity that may disrupt the integrity of a *kipuka* (see 6.2. Mitigation below for more details).

Pigs use roads and trails to obtain easier access to parts of the forest, thereby threatening native vegetation. The rooting and feeding activity of pigs have a serious impact on both the flora and fauna of Hawaiian habitats. Any threats to native vegetation affect the arthropods that are host-specific to those plants, therefore the pigs secondarily threaten arthropods. Pigs also secondarily affect birds by creating wallows in the wetter areas, which facilitates and increases mosquito breeding. Mosquitoes transmit avian malaria. Efforts to reduce the potential access of pigs should be considered.

The upper dry area of the saddle is populated by a set of different plant communities each characterized by a different arthropod faunal composition. The main communities sampled included pioneer vegetation on lava (mostly *Styphelia* and ferns) in which we perceive little or no impact on arthropods by the proposed road construction. Much of Parker Ranch consists of disturbed grassland dominated by alien species of grasses and weeds, where we also perceive little or no impact from proposed construction. However, the uppermost section of the Ranch has isolated stands of *Dodonaea viscosa* or *a'ali'i*. *Dodonaea* shrubland also occurs along PTA-1 on the Mauna Kea side of Pohakuloa cantonment and in ravines and isolated stands along the existing Saddle Road above Mamalahoa Highway. *Dodonaea viscosa* is the host of the koa bug, *Coleotichus blackburniae*. Another plant community is dominated by aweoweo, *Chenopodium oahuense*. Though a number of native species of arthropods occur on aweoweo, arthropod diversity is limited as may be the potential impact due to road construction. The highest diversity in the dry area of the saddle occurred in Mamane/Naio (*Sophora chrysophylla/Myoporum sandwicense*) forest. The two dominant plant species in this dry subalpine forest are hosts to a number of endemic species of arthropods. *Coprosma montana* is often seen among the Mamane/Naio, and it also is a host of endemic species. PTA-1 is routed through a particularly rich section of Mamane/Naio forest.

Clearly, there will be direct impacts of road construction resulting from the physical destruction of habitat and the animals that live in it, especially the more sedentary species. However, there will also be less direct impacts resulting from the facilitation of the spread and introduction of non-native species. These could be predators or competitors of native species, but may also include non-native plants that become more readily established, modifying the habitat in ways that make it unsuitable for the native animal species. Many animals, especially insects but also snails, are known to be strongly associated with particular plant species. If these plants are destroyed or replaced by non-native species, their associated faunas will also be destroyed.

The concept of corridors is important in assessing the likely impacts of construction of roads, pipelines, power lines, and so on (e.g., Andrews, 1990; Bennett, 1991; Seabrook & Dettmann, 1996; Zink et al., 1995). Clearly, populations of animals, especially more sedentary ones like snails and non-volant arthropods, will be directly affected by destruction or modification of habitat. However, a new road (including access roads built for construction purposes only) can permanently introduce an additional conduit along which non-indigenous (alien, exotic) plants and animals can gain access to areas of undisturbed native habitat. From this corridor, these species can spread into the adjacent native habitat along the entire length of the corridor. This is a major concern when considering the alternative routes that involve construction of new roads rather than rebuilding the existing road. The existing road already acts as a corridor for invasive species (as suggested for some of the non-native snails along the Saddle Road that have been collected in the rather cursory investigations taken in these areas. No doubt detailed investigation should show a

more complete inventory of alien invasions). Construction of new roads will generate corridors that will greatly facilitate invasive species, both plants and animals, gaining access to native habitat. This likelihood is of special concern in the Mamane/Naio forest area along PTA-1 and PTA-3 to the east of the Mauna Kea State Recreation Area.

Alien plants and insects can be spread by road construction equipment. A special concern on the Saddle Road is the spread of fountain grass (*Pennisetum setaceum* (Forssk.) Chiov.) and the resultant increased threat of fire.

6.2 Mitigation

Two major points need to be addressed concerning mitigation with regard to any potential road construction that may take place in the Saddle Road area.

6.2.1. *Kipuka*

The *kipuka* represent a unique island-within-an-island ecosystem. Each *kipuka* can harbor species that are found nowhere else. A protective management program for sensitive *kipuka* in the saddle area should be set up.

- In order to exclude unwarranted traffic (human or other animal) into *kipuka*, fenced exclosures should be erected around the perimeters of each in the area from milepost 10 to milepost 28.
- Restoration of *kipuka* that have evidence of pig damage should be monitored on a periodic basis by biologists to ensure that pigs are kept out of the *kipuka* and that the fauna and flora of the *kipuka* are as native as possible (e.g., non-native invasive plants should be eradicated through manual, biological, or carefully administered chemical means).

6.2.2 *Caves*

Lava tubes are characteristic of relatively young pahoehoe lava flows and are important landforms on young volcanoes such as Mauna Loa. Since the Saddle Road traverses the saddle staying mostly on Mauna Loa lavas, construction and realignment of the Saddle Road can be expected to encounter numerous lava tubes. Because most lava tubes have no entrance or remain unknown, they can not be surveyed before construction begins. Discovering these hidden caves by breaking through the roof will be hazardous to workers and detrimental to the cave resources. The highest risk will occur on pahoehoe flows, but some caves are buried beneath 'a'a and other substrates. Often if a flow is known to contain a cave, there is a high probability that other caves also occur in the same flow. Known cavernous flows are identified in the cave descriptions (Appendix II).

- The significant caves known along the Saddle Road that will be directly affected are portions of the 1881 flow, Don's Cave, and Strawberry Cave. Of these, additional surveys are requested for Don's Cave before construction to determine its extent and to complete the faunal survey.

- Conduct faunal survey and resource inventory of all lava tubes discovered during survey and construction of Saddle Road.

- Construct and place bypass conduits to allow continued access to exceptional caves discovered.

- Where feasible, reinforce the overburden over significant caves rather than crushing and filling the passage.
- Minimize disturbance to native vegetation in the vicinity of known or suspected caves.
- Minimize oil, gas, and other chemical spills near caves.
- Devise protective protocols to prevent workers and machinery from dropping into caves.

7. CONCLUSIONS

Because of the different conclusions of snails and insects and related arthropods, we have elected to split the conclusions section into two parts: 1) snails; and 2) insects and related arthropods.

In general, the survey of land snails supports selection of the existing road as the alignment along which the new road should be constructed/upgraded in all four sections. The same is true for insects and other arthropods except for Section I, where an alternative route would be preferred. Use of the existing corridor is especially recommended in Section II, which harbors the greatest diversity of snails and perhaps the greatest diversity of insects and other arthropods. Section II was the only section in which live individuals of the snail *Leptachatina lepida* were found. A significant number of sensitive species of arthropods were found in Section II also. The kipuka in Section III may harbor some of the most sensitive native species of arthropods. Significant caves may be broken into or impacted during construction in all Sections of the proposed Saddle Road. however, the greatest potential for impacts to cave ecosystems occurs in Section III and possibly Section IV.

7.1 Snails

Section I. Land snails will be little impacted whichever alternative is selected, although because of the possible impacts on land snails on W-2/W-3 (at the upper end where these segments coalesce into W-2B), the preferred route is the existing road, EX-1.

Section II. The highly significant impacts on land snails that would occur if either PTA-1 or PTA-3 were chosen, mean that the preferred route is the existing road, EX-2.

Section III. There are no alternatives in Section III, the existing road, EX-3, is the only option. However, the realignments that are proposed should avoid all impacts to the many kipuka along this section of the corridor.

Section IV. There may be slightly more impact if E-3 (or EX-4A) were chosen over the existing road (EX-4), but this is difficult to assess on the basis of this limited survey. The conservative and safest choice would be EX-4, the existing road.

7.2 Insects and related arthropods

Section I. Insects and other arthropods will be least affected by selecting alternatives W-3 or W-2. Although a sensitive species, *Coleotichus blackburniae*, was found in the upper end of W-2, other stands of its host plant occur elsewhere, including EX-1 where it was also found. As another sensitive species, *Rhyncogonus giffardi* is historically known from EX-1, EX-1 is the least preferred route and either W alternative ins preferable through Section I.

Section II. This section has the largest number of significant potential impacts. PTA-1 has the largest concentration and the greatest diversity of native species and should be avoided. PTA-3 also has a sensitive species and as it is an alternative route that would take the proposed alignment into the most diverse part of PTA-1, it should also be avoided. Although a sensitive species was found on EX-1, that species also occurred on PTA-1. Therefore EX-2 is the preferred route through Section II.

Section III. EX-3 is the only alternative through Section III. However, in areas where the route passes significant kipuka, consideration should be given to aligning the road to least impact the kipuka and their sensitive fauna. Two significant caves are known along this

route and others may be found or impacted during construction. Mitigation (see 6.2.2 above is recommended).

Section IV. Although no sensitive arthropods have been identified from material collected in this section, the alternative proposed routes, E-3 and EX-4A pass through stands of undisturbed wet forest where sensitive species are expected to be found. Owing to the potential of spreading alien species of plants and animals by establishing a new corridor, the existing road, EX-4, is the preferred choice. The upslope section to the significant Kaumana Cave (which essentially follows the 1881 lava flow) occurs under parts of each alternative segment of this Section. The existing route (EX-4) probably will have the least impact on this cave.

8. ACKNOWLEDGMENTS

Frank Heff and staff of Parker Ranch allowed us access to their property for the purposes of this study. The staff of the Safety and Police Divisions of the U.S. Army Pohakuloa Training Area are thanked for allowing us access to the sections of PTA necessary for survey purposes. Aside from the authors of this report, species identifications for insects and related arthropods were made by Keith Arakaki, David Preston, and Sabina Swift, of the Bishop Museum, Honolulu, who are thanked for their help. We thank Lisa Hadway for information on the distribution of *Partulina* on Hawaii Island. David Preston is thanked for his assistance in the field. Locations of caves in the saddle area were kindly provided by R. David, T. Wolforth, F.D. Stone, and D. Hemmes. This report constitutes Contribution No. 1996-015 to the Hawaii Biological Survey.

9. GLOSSARY

`A`a: one of two general types of basaltic lava flow, distinguished by a rough, spiny clinker surface overlying a dense, sometimes massive, core. See **Pahoehoe.**

Adaptive radiation: the phenomenon wherein a single species, through time, evolves and speciates to a high degree adapting to an environment or other external condition. Excellent examples in the Hawaiian Islands are the 800 or so endemic Hawaiian *Drosophila* flies (which account for about 50% of the world's fauna of that genus).

Adventive: relating to organisms introduced to an area by means other than purposeful.

Aeolian: a discrete natural community that is supported by organic matter carried on the wind. Example: at PTA found on unvegetated lava flows.

Alien: (see also **adventive, exotic, introduced, or non-native**) relating to a species that is not native, i.e., one introduced accidentally or purposefully by man. In Hawaii, these include Polynesian introductions (such as kukui, coconut, pig, rat, and jungle fowl) and many post-Cook introductions (such as guava, Christmas berry, mosquitoes, pigs, goats, cattle, deer, and sheep). See **Endemic, Indigenous, Native.**

Alluvial: made up of sand, clay, or other particles deposited by moving water, as along a river bed.

Amphipod: a small crustacean invertebrate that can be found in aquatic or terrestrial habitats.

Arthropod: insects and related invertebrate animals.

Avian: relating to birds.

Avifauna: the birds of a specified region.

Basaltic: referring to a desne fine-grained, basic igneous rock characteristic of young oceanic volcanoes.

Biota: all plants and animals of a given area. A general term for living things.

Biotic: pertaining to plants and animals and characteristics related to their presence.

Canopy: the highest vegetation cover of a community. In a forest, the canopy is made up of the tallest and most numerous trees. In a shrubland, the canopy is the tallest shrub layer. Closed canopies are those where the foliage interlocks to form a continuous layer over the underlying vegetation or ground. Open canopies are those where there are gaps in the foliage, and more light may reach the lower vegetation layers or ground.

Cave: a subterranean void large enough for a human to enter. See **Lava tube.**

Cave-adapted species: species that are modified morphologically, physiologically, and behaviorally to live permanently in caves and mesocaverns. See **Obligate cave species.**

Ceratopogonid: flies of the family Ceratopogonidae (biting midges, no-see-ums).

Chironomid: flies of the family Chironomidae; aquatic non- biting midges.

Cixiid wax: thread-like wax scales produced by abdominal glands of cixiid planthopper nymphs. They function probably as protection against predators.

Cocoon: the spun silken case in which an immature lepidopteran remains as a pupa until it metamorphoses into an adult and emerges.

Collapse sink, collapse depression: any depression in the earth's surface. May be caused by solution of limestone or gypsum or by collapse of the roof of a cave or lava tube.

Conspecific: two or more individuals that belong to the same species.

Corridors: in the context of this report, conduits of potential traffic of plants and animals through an existing ecosystem created by construction and resultant clearing of paths through the existing ecosytstem.

Crawlway: a cave passage that requires moving on knees or stomach.

Deep cave zone: any area in a cave or mesocavern with saturated humidity and reduced or absent air motion, with minor or no influence from changing surface climate conditions. Obligate cave species can be found in this zone.

Depredation: mortality caused by a predator.

Dieback: the cessation of vegetative growth on the uppermost portions of mature plants. In the context of this report, this condition found in*Ohia lehua* (*Metrosideros polymorpha*), the cause of which is unkown.

Diptera, dipteran: flies, mosquitoes.

Disjunct: not contiguous; separated by intervening land.

DLNR: Department of Land and Natural Resources.

DOFAW: Division of Forestry and Wildlife: a division of the State Department of Land and Natural Resources (DLNR).

Ecosystem: an assemblage of animals and plants and its interaction with the environment.

Endangered: a species officially recognized by federal or state officials to be in immediate danger of extinction due to natural or man-made factors.

Endemic: naturally restricted to a locality. Most of Hawaii's native plants and animals are endemic (restricted) to the Hawaiian Islands. Many are restricted to a single island, mountain range, or even gulch. See **Alien, Native, Indigenous**.

Endemism: the extent to which the species of a region are unique to that region. See **Endemic**.

Entrance zone: in caves, the zone or area of green plant growth within the entrance.

Exclosure: a closed-in area (usually achieved by fencing) erected in order to exclude animals such as feral ungulates from potential damage to an otherwise fragile environment.

Exotic: not native. See **Alien.**

Fauna: the animals of a specified region.

Federal Status: previous and current U.S. Fish and Wildlife Service categories for endangered and candidate endangered taxa according to the Federal Register:

- C1 = Candidate Taxa for which the USFWS has substantial information on biological vulnerability and threats to support the proposal to list them as endangered or threatened species.
- C1* = Same as C1, possibly extinct.
- C2 = Candidate Taxa for which the USFWS has information which indicates that proposing to list them as endangered or threatened species is possibly appropriate. More data on biological vulnerability and threat(s) are needed before they can be proposed for listing as endangered or threatened. No longer used; now considered "Species of Concern" and not formally listed.
- 3A = Taxa for which the USFWS has persuasive evidence of extinction. If rediscovered, such taxa might acquire high priority for listing.
- 3B = Taxa that are no longer being considered for listing as threatened or endangered species on the basis of current taxonomic understanding (i.e., species do not represent distinct taxa).
- 3C = Taxa that are no longer being considered for listing as threatened or endangered species.
- LE = Taxa formally listed as endangered.

Feral Ungulate Activity: detectable damage or sign of feral ungulates (e.g., pigs, goats) including: scat, browsing, trails, trampling, wallows, and rooting.

Feral: formerly domesticated animals reverted to wild state or living in wild habitat.

Holotype: the single specimen (only if so designated) on which a species was originally described. The remainder of the series of specimens used by the original author in describing the species are termed **paratypes**. If no single specimen is designated as such, the original series of specimens upon which the species was described are termed **syntypes**.

Immature: the stage of an animal that is not an adult. In the context of this report, damselfly and dragonfly immatures are termed naiads; other insects are called larvae or nymphs.

Imported: See **Purposefully introduced.**

Indigenous: naturally occurring in a given area as well as elsewhere. Indigenous Hawaiian taxa also occur naturally outside of the Hawaiian Islands (e.g., the long-legged fly genus *Campsicnemus* is indigenous to Hawaii, yet is also found naturally in French Polynesia and continental land masses above the equator). See **Alien, Endemic, Native.**

Introduced: See **Alien.**

Invertebrate: animals without backbones, including such groups as insects, spiders, shrimps, and snails. Some Hawaiian invertebrates are rare and endangered.

Kipuka: an "island" of land (older substrate) with vegetation surrounded by a more recent lava flow (often without vegetation). Also applies to other discrete islands of vegetation within lava flows, such as vertical lava tube entrances that protect native plants from damage by fe ungulates.

Larva/larval: an immature stage of an insect.

Lava Tube: roofed-over lava channel, usually in pahoehoe basalt, formed after the lava flow builds lateral levees and the roof solidifies, insulating the molten lava, which can flow through the tube for long periods of time allowing the tube to lengthen downslope.

Litter: usually, plant and other mixed organic debris found on the surface of a substrate such as rock or soil; often harboring small organisms that can be potential prey for other animals.

Lowland: one of five elevation zones used to classify Hawaiian natural communities. The Hawaiian lowland zone lies above the coastal zone, up to about 1000 m. (roughly 3000 ft.) elevation. There is lowland zone on all of the main islands.

Makai: seaward, toward the ocean.

Malacological: having to do with the branch of zoology dealing with mollusks, including snails.

Malaise: a type of flight intercept trap using a fine mesh net to collect flying insects.

Mamane/Naio: a Hawaiian ecosystem comprised of the *mamane* (*Sophora chrysophylla*) and *naio* (*Myoporum sandwicense*) trees. Found principally on Hawaii Island, it occurs in the more mesic to arid areas surrounding Mauna Kea.

Mauka: mountainward, away from the ocean.

Mesic: a moisture regime or requirement between wet and arid; receiving from 50-75 inches of annual rainfall, or otherwise provided with sufficient water to result in moist soil conditions.

Mesocavern: in cave biology, an intermediate-sized space (0.5 to 20 centimeters) in the substrate; formed by gas bubbles, cooling cracks, earth cracks, spaces between lava flow units, etc. Cave species live in mesocaverns, only venturing into larger cave spaces when the atmosphere is close to saturated humidity.

Metamorphosis: the change in shape of an insect that takes place through time and stages from immature to adult (e.g., from a caterpillar to a butterfly). Commonly, four stages are found: egg, larva, pupa, and adult.

Microhabitat: habitats within habitats. For example, within a rainforest habitat, a microhabitat could include the moss growing on only a single species of plant.

Mollusk: invertebrates in the phylum Mollusca. Common representatives are snails, mussels, clams, oysters, squids, and octopuses.

Montane: one of five elevation zones used to classify Hawaiian natural communities. The Hawaiian montane zone lies above the lowland zone and runs from 1000 m. (roughly 3000 ft.) to 2000 m. (roughly 6000 ft.) elevation. There is a montane zone on Kauai, Oahu, Molokai, Maui, Lanai, and Hawaii.

Morpho-species: specimens grouped together based on similar appearance. This type of sorting is usually done as a preliminary step to more detailed analysis using other examination and identification techniques.

MPRC: Multi-Purpose Range Facility, located at PTA south of the Saddle Road on Hawaii Island.

Naiad: the immature aquatic, arboreal, or terrestrial stage of a damselfly or dragonfly.

Naio: See **Mamane/Naio**.

Native: found naturally in an area, not introduced accidentally or purposefully by man; includes both indigenous and endemic taxa. See Alien, Endemic, Indigenous.

Naturalized: non-native plants with established populations in the wild.

Nocturnal: active or most apparent at night.

Non-native: See **Alien**.

Obligate cave-adapted species: troglobite; a population that can survive only in caves and mesocaverns (e.g., the endemic Hawaiian cave planthopper, *Oliarus polyphemus*).

Odonata/odonates: damselflies and/or dragonflies.

Organic ooze: deposit of moist colloidal organic material that leaches from the surface into the cave through cracks.

Oviparous: a type of reproduction in which females lay eggs that hatch outside the body. Compare **Viviparous**.

Pahoehoe: one of two general types of basaltic lava flow, distinguished by relatively smooth, sometimes glassy, or ropy surface. See **`A`a**.

Paleontological: having to do with fossils or the study of fossil organisms.

Paratype: see **Holotype**.

Periostracum: the thin, outermost horny layer of the shell of a mollusk.

Predatory: the state of being a predator; preying on other biota for food requirements.

Protected: legally dedicated to the perpetuation of native resources and managed to mitigate or remove threats to those resources, if necessary. Areas lacking either legal protection or management are considered incompletely protected.

Protoconch: the first shell formed by a larval gastropod.

PTA: Pohakuloa Training Area, Hawaii Island.

Pupa: the resting stage in metamorphosis between the larva and adult stages.

Purposefully introduced: organisms that are brought into an area for a specific purpose; often as biological control agents in the control of unwanted plants or animals. See **Alien**.

Puu: hill or volcanic cone.

Rare: threatened by extinction due to low numbers. Any plant, animal, or natural community that can be immediately threatened by such factors as alien invasion, direct destruction, or loss of habitat.

Sensitive species: in the context of this report on invertebrates, those species that have been listed previously by the USFWS as either Endangered, Threatened, C1, C2, Species of concern, or have not been listed, but are considered rare and populations threatened by specialists of the group.

Speciate: to evolve into different species through time.

Species of concern: rare or threatened species formerly given the designation of C2 by USFWS. Now, not formally listed but given this designation. See **Federal Status**.

spp.: abbreviation for more than one species.

Stagnant air zone: in caves, area usually in deeper caves and mesocaverns where air exchange with the surface is slow. Humidity is saturated and concentrations of oxygen and carbon dioxide can fluctuate. Carbon dioxide concentrations may be above 6 percent, and oxygen may drop below 12 percent. This zone is rare in younger lava tubes, but it undoubtedly occurs in the mesocaverns within lava flows. This is the zone to which obligate cave species are adapted.

Subalpine: an ecological zone immediately below the timberline.

Subspecies: (abbreviated ssp.) a taxonomically distinguishable geographic or ecological subdivision of a species. See **Variety**.

Syntype: see **Holotype**.

Taxon (plural = **Taxa**): a group of plants or animals making up one of the categories or formal units in taxonomic classification. In this report a taxon can be a phylum, order, family, genus, species, subspecies, variety, or form. This distinction is important because certain species have endemic Hawaiian subspecies and varieties that are considered rare.

Transition zone: in caves, the area in total darkness between the twilight zone and the deep cave zone that experiences measurable influence from changing surface climate conditions.

Transmission Line: the electrical wiring where the transporting of electrical energy in bulk occurs.

Troglobite: see **Obligate cave-adapted species**.

Twilight zone: in caves, area between the entrance zone and total darkness, which receives some light but vascular green plants are absent, and the environment is influenced by surface conditions.

UH: University of Hawaii.

Ungulate: a subdivision of hoofed mammals including pigs, goats, cattle, sheep, mouflon, and deer.

USFWS: United States Fish and Wildlife Service.

USGS: United States Geological Survey.

Vagile: endowed with or having freedom of movement; wandering.

Variety: (abbreviated var.) a taxonomically distinguishable subdivision of a species or subspecies. See **Subspecies**.

Vertebrate: an animal with a backbone; native vertebrate species in Hawaii include fish, birds, a bat, and a seal. See **Invertebrate**.

Viviparous: giving birth to live young, which are nourished within the female before birth.

Volant: flying; capable of moving through the air.

Voucher specimen: specimen deposited in a recognized collection that can be used as a reference in future studies.

Weed: an undesirable plant. In native ecosystems all alien plants are weeds.

Wetlands: permanently to seasonally inundated areas on land.

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Appendix I—Collecting Methods

The following methods used during the present survey are decribed in detail and examples of those insects collected by each method are listed.

- **Malaise traps**—this trapping method (a flight intercept trap) consists of a fine mesh net strung between two uprights (trees, etc.) in a predicted or known flight path of flying insects. Insects are trapped by flying into the net where they then instinctively either crawl or fly upward. At the top of the net is a canister with a killing agent (gas or fluid) into which the insects fall, and which is collected on a periodic basis (daily, weekly, etc.). Two Malaise traps were set up during this study. One at the eastern end of Parker Ranch along W-2; the other in the Mamane/Naio area east of the Mauna Kea State Recreation Park. Traps were left in place for three days each.
  Main types of insects collected: flying beetles, flies, moths, butterflies, wasps, bees, flying ants, aphids, etc.

- **Water traps** (pans)—water traps (a shallow dish with water and surfactant to promote sinking and drowning of organisms caught in the water) were placed on the ground or slightly above the ground on rocks and/or in trees. The yellow color of the traps serve to initially attract certain types of invertebrates, which then hop, fly, fall, or crawl into the water where they sink to the bottom and drown. Traps were left in place for a period of two to three days depending on the locality. Trapped organisms were transferred into a fluid preservative and taken back to the laboratory for examination and identification. Water trapping methods were employed at Sites 2, 4, and 5.
  Main types of invertebrates collected: crawling beetles, flies (including flightless flies), moths, wasps, bees, ants, aphids, true bugs, etc.

- **Beating sheets**—this type of collecting method uses a sheet or pan and a beating stick. The stick is used to beat shrubbery, moss, trees, branches, etc. whereupon the insects loosened from their perch, or those that instinctively drop to escape predators, fall into the pan or sheet where they are aspirated or hand collected. This method was employed to collect insects that are plant feeders and are species-specific in their feeding habits.
  Main types of insects collected: true bugs, certain beetles, flightless insects.

- **Sweep nets**—this method is the most common and general method of collecting insects in the field. A fine mesh net was used and the net was swept across plants, leaf litter, rocks, etc. to collect any flying, perching or crawling insects that may have been there. Transfer from the net was done either manually, by aspiration, or placement of the contents of the net into a temporary holding container for later sorting, processing, and identification.
  Main types of insects collected: most flying and perching insects.

- **Bait trapping/species specific collection**—some taxa (e.g., Drosophilidae, predaceous flies, etc.) require special collecting techniques such as bait trapping and aspirating off of substrate and hosts in order to collect. These techniques were employed for more species-specific collections.

Appendix II—Cave Descriptions

Lava tubes characteristically form in pahoehoe lava flows; in fact, it is the formation of tubes that distinguishes pahoehoe from a'a and other types of basaltic lava flows. Not all tubes drain to form caves, and not all caves have entrances to the surface. In addition, the entrance to a cave passage under Saddle Road may be hundreds of meters from the road alignment. Thus most passages remain hidden from study, and many unsurveyed cave passages undoubtedly occur along the proposed alignments for the Saddle Road. Although they are more likely within younger pahoehoe lava flows and beneath a'a flows that cover cavernous pahoehoe, they could occur anywhere along the alignments. These lava tubes present both hazards to construction activities and resources for studying the archaeology, geology, and biology of the island. For example, the entrance to Strawberry Cave is about 50 meters from the proposed alignment, but the passage extends downslope about 270 meters and crosses beneath the existing road some distance east of 148 + 240, the nearest stake to the entrance. The passage ceiling is fractured in many places and will likely collapse if road construction is extensive.

Cave 1, PTA 16 + 600; Archaeological Site # 1522-301; **Bradshaw Field Cave**

The cave at PTA 16 + 600 is a surface tube in a small isolated Mauna Kea spatter cone near the western end of the Bradshaw airfield. The cave is a dusty low crawlway about 15 meters (50 feet) long between two entrances. The passage ranges from 30 to 60 centimeters (one to two feet) high and from 60 to 200 centimeters (two to six feet) wide. The air temperature in the cave was 21.5 C, indicating a strong climatic influence from the entrances. No living arthropods were found during our reconnaissance, but numerous fragments of spiders, moths, beetles, and other arthropods were noted in the dust, especially near the upper entrance. Thin dry roots, probably from native *Dodonaea* bushes on the surface, were growing in the soil, especially near the wall. When these roots flush during rains, they may support many cave and soil arthropods. The cave probably continues both up- and down-slope on the cone, but no other entrances were found.

Cave 2; 139 + 600 to 140 + 860; **1935 Lava Flow Cave A**

Several small pit entrances occur in the 1935 flow near Puu Huluhulu. The more significant of these range in size from one to three meters (three to 10 feet) in diameter and up to two meters (six feet) deep. They were all sealed and entered no true cave, but most contained small shelter caves where wind borne organic material accumulated. In June of 1995, an endemic jumping bristletail (*Neomachilis heteropus*) (the first live specimen in many decades) was collected in one of these entrances, suggesting that the species is a scavenger on young lava flows. On the evening of 19 October 1996 we surveyed eight of these pits hoping top find more native bristletails, without success. The Argentine ant (*Linepithema humile*) was abundant on the flow.

Cave 3; 141 + 880; **1935 Lava Flow Cave B**

An area similar to cave site 2 was found on the 1935 lava flow about one kilometer east of Puu Huluhulu, and several small entrances were investigated on the evening of 19 October. A small cave about ten meters (30 feet) long and 60 to 120 centimeters (two to four feet) high was found connecting two entrances in a roofed over portion of a lava trench. The cave was entirely in twilight and dry. The Argentine ant was also common here, and we did not find the native bristletail.

Cave 4; EX-3 148 + 240; **Strawberry Cave**

The entrance to Strawberry Cave is about 30 meters north of the existing alignment in a small vegetated kipuka. Smaller sinkholes in the kipuka are sealed, but indicate the existence of passages beneath. In the main entrance, a small crack leads through the breakdown to a small upslope passage which goes a short ways under the a'a flow on the surface. The main passage goes downslope for about 270 meters. The passage is two to five meters wide and one to four meters high. Most of the floor is obscured by breakdown blocks, and the ceiling is unstable in places. A breakdown pile and row of ceiling drips possibly mark approximately where the cave goes under the existing Saddle Road about 75 meters from the entrance. The deep cave is wet with numerous ceiling drips and moist walls characteristic of the deep zone environment. The winter effect (cold dry air sinking into the cave) from the large downward sloping entrance passage is relatively strong. The air temperature was relatively cool at 12 C also suggesting a strong winter effect.

A large patch of tree roots enters the cave over a large breakdown pile 30 meters from the entrance. After this patch, few roots or organic matter enter the cave, except that brown organic oozes occur on the walls in many areas. These oozes support the native *Limonia* crane flies, *Forcipomyia* biting midges, and other arthropods. Fifteen species of arthropods were found in the cave (Table 6). Eleven of these are native, and seven are obligate cave species and known only from underground environments. The presence of the linyphiid spider, lithobiid centipede and cambalid millipede indicates that the cave supports a significant cave fauna; however, no crickets or planthoppers were found. The wax cocoons of the native cixiid planthoppers are often conspicuous on tree roots, so their absence from the cave may be real. The crickets often respond to the baits used, and their absence is surprising, although the winter effect may limit their distribution in the cave. The cave beetle, *Mecyclothorax* sp., was recorded from dead specimens only.

Cave site 5; Sta. EX-3 156 + 760; **Don's Cave**

The entrance pit to Don's Cave is located within 50 meters north of Sta 156 +760 LT. The pit is only a 1.5 by 0.6 meter (5 X 2 foot) hole 2.4 meters (8 feet) deep and is completely overhung, requiring a ladder or rope to enter. The downslope passage is sealed, but upslope the cave enters a small room 10 meters in diameter and one to two meters high. The room is festooned with ohia roots dangling from floor to ceiling. The air is still and humid and typical of deep zone environment in spite of being close to the small entrance. The air temperature at the back of this room was 16.5 C. A low a'a crawl, 0.4 meters tall and four meters long leads upslope to at least two similar but larger rooms which are more humid and with numerous roots. We found only eight species (Table 6) in the cave, six of which are native and three are obligate cave species. However, we were only able to spend a short time in the cave. More species, such as *Oliarus* planthoppers and *Caconemobius* crickets, are expected to occur. The cave deserves more study.

1881 Lava Flow --- **Kaumana Cave**

Kaumana Cave is in the 1881 lava flow which parallels or lies under Saddle Road near the eastern end of the project area. The main entrance to Kaumana Cave proper is about three miles east of the project area, but the cave extends at least two miles upslope towards the project boundary. We briefly checked the surface for entrances and exposed lava along the existing roadways in the area near Country Club Road but did not find promising entrances. Much of the surface of the 1881 flow in this area is built up as a subdivision, and cave passages, if they exist, may already be altered. If the new Saddle Road alignment goes south of the 1881 flow (Alternate E-3), the new road and cavernous flow will coincide for about one kilometer between 2000 and 2200 feet elevation. If Alternate E-4A is chosen, the

new road will also cover parts of the cavernous 1881 flow. Kaumana Cave is a large and significant cave biologically, and it is likely that road construction will discover or open new entrances to the system. It will be important to be able to investigate any caves found during surveys and construction of the road.

Other potential cave sites:
Routes W-2, W-3, W-4 and A routes along EX-1
No caves are recorded along the alignments at the western end of the project area. However, a potential entrance was noted but not checked about 300 meters (1000 feet) north of W-2 somewhere near sta 107. The area should have caves, but they appear to be obscured by Mauna Kea ash and soil.

Routes EX-2, PTA-1, PTA-3, PTA-3A
The shallow cave at PTA 16 + 600 (described above) is the only cave found during surveys of these alignments. Similar shallow surface tubes probably occur in the Mauna Kea spatter cones in the area. An extensive system of shallow surface tubes is also known in Mauna Loa lavas west of EX-2 between sta 130 +000 and 131 +000. This area was not checked during this survey, as it is just outside the current project area.

Routes EX-3
Sta 160 +000
Several lava tube entrances lie about 250 meters south of the existing road near here. Most enter small caves. The largest pit enters a large lava tube which extends downslope and parallels the road for about 200 meters. The cave is significant biologically, but was outside the project area and not surveyed during this project. Other hidden passages may occur closer to the road alignment.

Sta 166 + 700
A large cave entrance, located 30 meters north of road, is sealed, but there may be large passages in the vicinity. The entrance was not relocated during the current survey.