REPORT FOR THE 2002 PACIFIC BIOLOGICAL SURVEY, BISHOP MUSEUM AUSTRAL ISLANDS, FRENCH POLYNESIA EXPEDITION TO RAIVAVAE AND RAPA ITI

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Le programme sur l'Etude Biologique du Pacifique (Pacific Biological Survey ou PBS) du Bishop Museum a mené des prospections biologiques dans les îles de Raivavae et Rapa aux Australes dans le cadre du programme de recherche "Inventaire et Valorisation de la Biodiversité" mené en Polynésie française avec le soutien et le concours de la Délégation à la Recherche (Ministère de la Culture, de l'Enseignement Supérieur et de la Recherche, Gouvernement de la Polynésie française).

Les objectifs du PBS dans les îles Australes étaient : 1) d'évaluer la faune des insectes indigènes d'eau douce et de décrire la biodiversité complète de cette faune, 2) d'évaluer la biodiversité et le statut des Hétéroptères et d'autres insectes d'importance dans les zones de forêts naturelles, 3) d'évaluer l'impact ou l'absence d'impact des espèces aquatiques introduites sur la biocénose indigène d'eau douce, 4) d'évaluer de façon qualitative les impacts des espèces introduites, ongulés en liberté et urbanisation sur les insectes indigènes, et 5) de fournir des spécimens de musée et des informations de base pour les recherches futures.

Parmi les découvertes significatives issues de ces études figurent une faune d'eau douce intacte sans introduction de poissons, d'amphibiens ou de reptiles aquatiques non indigènes dans les deux îles de Rapa et Raivavae. Des recherches approfondies menées à Hawaii ont démontré les impacts dévastateurs des poissons introduits sur la faune d'eau douce indigène et tous les efforts devraient être mis en place pour éviter toute introduction d'espèces aquatiques non-indigènes à Rapa et Raivavae. De nombreuses espèces d'insectes aquatiques encore non décrites ont été trouvées à Rapa et Raivavae, dont des nouvelles espèces et de nouvelles aires de répartition d'Hétéroptères (punaises), de Diptères (mouches aquatiques), et d'Odonates (libellules et demoiselles). Une entomofaune terrestre indigène riche avec de nombreuses espèces non décrites de Coléoptères (scarabés), Diptères (mouches), Hétéroptères (punaises) et Homoptères (sauterelles) a été aussi trouvée à Raivavae et Rapa, bien que les habitats de forêts naturelles pour ces insectes ont été fortement réduits sur les deux îles. Les espèces indigènes trouvées sur les deux îles sont importantes à un niveau mondial, et la préservation de cette biodiversité est cruciale pour la conservation de la culture Polynésienne trouvée sur ces îles. Il est également nécessaire de préserver la biodiversité pour permettre une meilleure compréhension des mécanismes biologiques de dispersion et de colonisation naturelles de la faune dans ces zones insulaires éloignées et isolées. Les forêts indigènes de Raivavae et Rapa sont cruciales pour la survie de l'entomofaune terrestre et aquatique des îles Australes. Un bon exemple de cette inter-relation entre forêts et habitats d'eau douce est trouvé chez les demoiselles à Rapa et Raivavae qui sont aquatiques durant leur phase immature, mais nécessitent des zones forestières à l'âge adulte pour trouver de la nourriture. La demoiselle endémique de Rapa a été uniquement trouvée dans les zones boisées, et n'a jamais été observée lors d'échantillonnages le long des nombreux kilomètres d'habitat d'eau douce déforestés. La végétation indigène est aussi cruciale pour la nouvelle espèce de demoiselle découverte à Raivavae qui présente les mêmes exigences forestières. La majeure partie de la biodiversité des insectes terrestres indigènes subsistant sur l'île de Rapa est trouvée dans la zone étroite de forêt

naturelle située entre 450 et 650 m au sommet du mont Perau. La récolte de nombreuses espèces non décrites au mont Perau illustre le fait que malgré des travaux monographiques sur les Lépidoptères et les charançons Miocalles de Rapa, beaucoup d'études restent à mener sur l'entomofaune dans cette forêt naturelle intacte. Afin de préserver une biodiversité indigène et un patrimoine culturel polynésien riches, il est impératif de protéger les vestiges de forêts naturelles à Raivavae et Rapa. Des réserves forestières devraient êtres installées, en travaillant en collaboration avec les habitants de chaque île, pour protéger les zones les plus importantes et biologiquement les plus diversifiées. Les zones qui doivent être protégées en priorité seraient le mont Perau sur Rapa et la région du sommet du mont Hiro et de ses vallons associés sur Raivavae.

ABSTRACT

The Pacific Biological Survey (PBS) of the Bishop Museum conducted biological surveys on the Austral Islands of Raivavae and Rapa as part of an “Inventaire et Valorisation de la Biodiversité” or inventory and evaluation of biodiversity, a research program conducted in French Polynesia with the assistance and support of the Délégation à la Recherche (Ministère de la Culture, de l’Enseignement Supérieur et de la Recherche, Gouvernement de la Polynésie française). The objectives of the PBS Bishop Museum surveys in the Austral Islands were: 1) to assess the native aquatic insect fauna and describe the overall biodiversity of this fauna, 2) assess the biodiversity and status of Heteroptera and other important insects in native forest areas, 3) to assess the impacts or lack of impacts of introduced aquatic species on native stream biota, 4) to qualitatively assess the impacts of introduced species, feral ungulates, urbanization, on native insects, and 5) to provide museum specimens and an information baseline for future researchers.

Significant findings of these surveys include a pristine native freshwater fauna lacking introductions of nonindigenous fish, amphibians, or aquatic reptiles on both Rapa and Raivavae Islands. Extensive research in Hawaii has shown the devastating impacts of alien fish species on the native stream fauna, and every effort should be made to avoid introductions of any non-native aquatic species to Rapa and Raivavae. Numerous undescribed aquatic insect species were found in Rapa and Raivavae, including new species and range extensions of Heteroptera (true bugs), Diptera (aquatic flies), and Odonata (dragonflies and damselflies). A rich terrestrial native insect fauna with numerous undescribed species of Coleoptera (beetles), Diptera (flies), Heteroptera (true bugs), and Homoptera (planthoppers) and was also found on Rapa and Raivavae, although stands of native forest habitat for these insects were found to be severely reduced on both islands. The native species found on both islands are important on a worldwide basis, and preservation of this biodiversity is critical in preserving the rich Polynesian culture found on these islands. It is also necessary to preserve biodiversity to allow a greater understanding of the natural biological processes of dispersal and colonization of the fauna to these remote and isolated island areas.

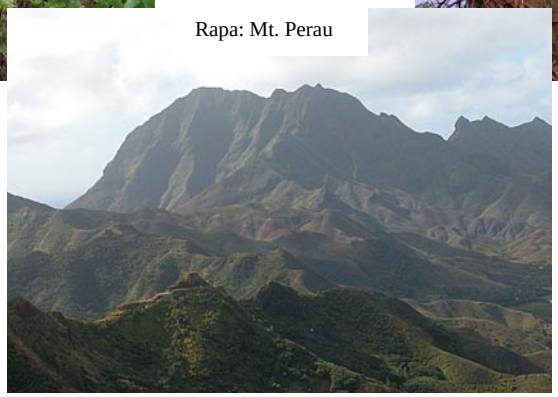
Native forests on Raivavae and Rapa were found to be critical for the survival of both the terrestrial and aquatic fauna of the Austral Islands. A good example of this interrelationship between forests and aquatic habitats is found with the damselflies on both Rapa and Raivavae that are aquatic during their immature phase, but as adults require forested areas to forage for food. The endemic native damselfly on Rapa was only found in forested areas, and never observed during sampling along many kilometers of deforested stream habitat. Native vegetation was also critical for the newly found species of Raivavae damselfly, with this species also having similar forest requirements. Most of the native terrestrial insect biodiversity remaining on the island of Rapa is found in a narrow zone of native forest between 450-650 m at the summit of Mt. Perau. The collection of many undescribed species from Mt. Perau illustrates the point that despite two monographic works on the Lepidoptera and *Miocalles* weevils from Rapa, much remains to be studied on the insect fauna from this most intact native forest found on Rapa.

To preserve a rich native biodiversity and Polynesian cultural heritage, it is imperative to protect the limited remaining native forests on Raivavae and Rapa. Working with the inhabitants of each island, forest reserve areas should be set up to protect the most important and biologically diverse areas. The areas that should receive the highest priority for protection would be the Mt. Perau area on Rapa, and the Mt. Hiro summit region and associated gulches on Raivavae.

Rapa: Mt. Perau, mossy *Metrosideros collina* habitat

Raivavae: Mt. Hiro, mossy *Hernandia* habitat

Rapa: Mt. Perau



INTRODUCTION

From 18 November to 18 December 2002 the Pacific Biological Survey (PBS) of the Bishop Museum conducted biological surveys in the Austral Islands of Raivavae and Rapa as part of an "Inventaire et Valorisation de la Biodiversité" or inventory and evaluation of biodiversity, a research program conducted in French Polynesia with the assistance and support of the Délégation à la Recherche (Ministère de la Culture, de l'Enseignement Supérieur et de la Recherche, Gouvernement de la Polynésie française). These floral and faunal surveys were conducted in cooperation with the Bishop Museum, French, and American scientists from the parc naturel régional de Corse; Paris Muséum National d'Histoire Naturelle; Délégation à la Recherche de la Polynésie française; and the University of California at Berkeley.

Funding for these biodiversity surveys originated from the Gouvernement de la Polynésie française (Contrat de Développement Etat-Territoire), with matching funding coming from the Pacific Biological Survey of the Bishop Museum. The objectives of this biodiversity assessment of the Austral Islands were: 1) to assess the native aquatic insect fauna and describe the overall biodiversity of this fauna, 2) to assess the biodiversity and status of Heteroptera and other important insects in native forest areas, 3) to assess the impacts or lack of impacts of introduced aquatic species on native stream biota, 4) to qualitatively assess the impacts of introduced species, feral ungulates, urbanization, on native insects, and 5) to provide museum specimens and an information baseline for future researchers.

This preliminary report describes general habitats and sampling areas on Raivavae and Rapa, Austral Islands that were assessed during this expedition, and also reports on some important findings and discoveries made during this trip. Additionally, Sherwood and Englund (2003) provide a companion report on new records of freshwater macroalgae found during this expedition. A comprehensive list of insect species collected during this expedition is not yet possible because of the great amount of specimens generated, and because many of these are either species are new to science and undescribed, or must be identified by a limited number of worldwide taxonomic experts.

STUDY AREA

Biodiversity surveys took place on Raivavae and Rapa, which are located in the southernmost part of the Austral Island chain (Figure 1). Lying at 23°S, Raivavae is still tropical in climate and has the same latitude as the island of Kauai has to the north in the Hawaiian archipelago, while Rapa is located at 27° S and is more temperate in climate. Raivavae is surrounded by a large barrier reef with an extensive set of low-lying offshore motus (islets) while Rapa entirely lacks a fringing reef system. The Austral Islands span 1500 km in a northwesterly direction starting from the submerged Macdonald Seamount to the Marotiri Rocks lying

90 km from Rapa, to the northernmost coral atoll of Maria. The average geological age of Raivavae is 6.5 Myr and the highest altitude is 438.5 m on Mt. Hiro; Rapa averages 5 Myr (Craig et al. 2002) with Mt. Perau the highest point at 650 m. Rapa (Figure 2) is significantly larger than its nearest high-island neighbor Raivavae, and is 40 km^2 in size, while Raivavae is 16.7 km^2. Rapa should not be considered geologically separate from the other Austral Islands as its estimated age is consistent with the formation of a hotspot at the Macdonald Seamount, while an additional two hotspots have been postulated for Rarotonga and Rurutu (Turner and Jarrard 1982). The Cook-Austral Islands hotspot has been active for at least 18 million years, and extends from Mangaia to Macdonald Seamount (Guille et al. 1998).

Both Rapa and Raivavae have been inhabited and extensively disturbed for long time periods, with only remnant native forest vegetation remaining. On Raivavae, native vegetation is found only in upper elevation gulches and a few surrounding areas below the ridgetops, and the summit ridges here are periodically burned to allow islanders easy access to this grassy goat pastureland. Some remnant montane summit forest exists on Rapa, but similar to Raivavae most of the ridge tops have been overgrazed. On Rapa, a disturbed, overgrazed grassland is found in all but the highest summit areas and a few interior gulches. When possible attempts were made to use indigenous names for geographic locations, however, sometimes-conflicting names were given to us by locals, but more often the name of the stream, waterfall or other geographic landmark in question was unknown.

Figure 1. Southern French Polynesia showing the Macdonald Seamount hotspot, and the Austral and Cook Islands chain. Adapted from Craig et al. (2001) with permission of the author.

Figure 2. Map of Rapa, from Hanson (1970).

Aquatic Habitats- Raivavae

Drainages on Raivavae are short, and all drainages on the island are interrupted by a concrete captage (drinking water diversion). The largest flowing drainage on the island was an apparently unnamed stream that drained into the extensive taro fields between Mahanatoa and Rairua villages, and was easily accessed at the concrete bridge crossing the stream (see Table 1 for GPS readings). Above the captage this stream was 1-2 m wide, and contained some pools up to nearly 1.0 m in depth, although most areas were much shallower and consisted of 3-10 cm shallow riffles and runs. Many of the riffles were flowing over tree roots, although this stream did contain a small amount of gravel riffles, riffle habitat containing gravels was very rare in aquatic habitats throughout the rest of Raivavae.


Vaipa Stream

Vaipa Stream, located above Vaiuru village and one valley away from Tuarani was extensively sampled and was nearly as large was as the Tuarani Stream but was quite different in character. Vaipa Stream, and the streams draining into the Tuarani taro fields contained little to no loose gravel or cobble substrate, and flowed through bedrock chutes and pools. Vaipa Stream was accessed by hiking above the captage at approximately 50 m elevation, and then hiking through the thick *Hibiscus tiliaceus.* At 122 m elevation the stream corridor opens up into a series of spectacular cascades where taro is semi-cultivated on a long series of vertical cascades. Vaipa Stream was then sampled until the stream became completely overgrown by *Dicranopteris linearis* at 207 m elevation.

One important observation is that virtually all Raivavae streams still contained extensive riparian or streamside vegetation throughout most of their lengths. Riparian vegetation in the lowland areas consisted of secondary growths of *Hibiscus tiliaceus* and other species, but became increasingly more native as elevations increased. For example, water flow first appeared in a drainage of Mt. Araua at 164 m elevation in an area of still relatively intact native vegetation. Mt. Hiro is the highest peak on Raivavae, and water flow first appeared in the main gulch here at 213 m elevation in an area of native ferns and plants. The highest permanent waterbody on Raivavae was at 262 m elevation and started as a perched spring and wetland that turns into a small trickle on the Anatonu village side of Mt. Hiro.

The two largest taro-growing areas on Raivavae were the Tuarani taro fields located north of Vaiuru village, and the region between Mahanatoa and Rairua, and these areas were extensively sampled for native and non-native aquatic biota.

Aquatic Habitats- Rapa

Being a much larger island with a wetter climate regime, especially in the summit areas, Rapa has a greater quantity of aquatic habitats than Raivavae. In contrast to Rapa, almost all streams on Rapa are fully flowing, and not interrupted by a captage or diversion. A large water storage tank exists along the stream flowing into the main Ha‘urei town, but it was uncertain if this tank is fed by a surface water diversion or groundwater wells, and municipal water in Ha‘urei town is available only intermittently. However, the Ha‘urei town stream flows uninterrupted from its headwaters to the ocean, where it is channelized. All streams in the other currently uninhabited valleys on Rapa flow uninterrupted to the ocean, although small and occasional water diversions for taro still occur in many valleys.

Overgrazed Rapa stream

Forested Rapa stream: damselfly habitat

Extensive taro wetlands can be found both above Haʻurei Town, along the shores of Haʻurei Bay, and in the many currently uninhabited valleys such as Hiri Bay and elsewhere. Stream habitats can be separated into two distinct classes in Rapa: areas containing and lacking overtopping riparian vegetation, with grazed areas containing only low grasses along the stream corridor. Most lowland stream habitats have been severely overgrazed by cattle, goats, and horses, with the resultant effect of a complete loss of stream vegetation. Photographs included above in this report show the stark contrast between heavily overgrazed areas such as that above Tumu Cascade, and a portion of the stream flowing to Hiri Bay where feral ungulates have been excluded because taro is still cultivated. These fenced areas exist to keep out grazing animals where taro is currently still grown, and some of the fenced riparian areas include mixture of introduced strawberry guava (*Psidium cattleianum*), native ferns and plants, with the alien plants appearing to have little negative impacts on native aquatic biota such as the large endemic Rapa damselfly. This includes areas around Haʻurei town where a large wooden fence extends far out into Haʻurei Bay to keep cattle out of the town; this fence also has the effect of keeping cattle out of mountainous areas behind the town, and parts of Hiri Valley where taro is still grown.

Terrestrial Insect Habitats- Raivavae and Rapa

Because tropical terrestrial insects usually are found on a specific plant host, native forest habitats on Raivavae and Rapa are closely correlated with native insect biodiversity. It is not in the scope of this report to provide a comprehensive vegetation analysis found during this trip; this can be found in Meyer (2003). However, vegetation patterns have an extremely important influence on terrestrial insect distributions, and

most terrestrial insect sampling effort was directed towards native plant communities found on both islands. Observations for new immigrant agricultural insect pests were also made during the expedition.

The summit areas of Raivavae consisted primarily of short grass pastureland that is regularly burned and grazed, and was unsuitable to most native insects. No forested areas were found along the uppermost summit areas of Raivavae, but instead the best remaining native forest was found in gulches slightly below the narrow mountain spine running the length of the island. Although generally small in total area, some of these invariably steeply-sloped gulch areas in Raivavae contained completely native vegetation and hence were ideal habitats for native insects. One of the best gulch areas was at our Raivavae Mt. Hiro summit camp area, where large trunks of mossy *Hernandia moerenhoutiana* and *Metrosideros collina* were some of the predominant vegetation in an understory of mostly to all native plants.

Insects were also extensively sampled on the low-lying offshore islets or (motu) that fringe Raivavae, and some of the motu contained a nearly completely intact native plant community. All major vegetative communities were extensively surveyed for terrestrial insects at the motu sampling stations. Of particular interest was assessing insects associated with the remnant sandalwood (*Santalum insulare* var. *raivaveense*) forests still found on some of these offshore motu, and also any areas where sandalwood was still found on the main Raivavae Island. One of the expedition members, Jean-François Butaud, is conducting research on the status of the sandalwood in French Polynesia, and was instrumental in locating sandalwood stands. A full accounting of terrestrial insects associated with sandalwood during this expedition will be provided in a later report, as it not possible until taxonomic experts have had time to make identifications or describe new species.

Rapa contrasts with Raivavae in that the very summit of Mt. Perau, the highest point on the island, is still in excellent shape and contains a largely ungrazed and pristine area. The cattle grazing line is quite remarkable, and appears where the forest is decimated at approximately the 370–400 m elevation level at Mt. Perau. Cattle are slowly working their way to the very of summit Mt. Perau by tromping down the *Freycinetia* sp., and were observed during this expedition from the Mt. Perau summit (650 m) to have traversed some incredibly steep areas to at least 520–540 m elevation. However, the native forest remaining on the summit and high slopes of Mt. Perau is spectacular habitat for native insects, albeit even steeper than Raivavae and more difficult to sample. Although sampling time on Rapa was limited during the present expedition, the summit ridges of most other areas appeared to be heavily overgrazed and consisted of mainly short grasses. Occasional pockets of native plants were observed in gulch areas, and also in fenced areas such as the taro growing area on the trail down to Hiri Bay and above Ha‘urei Town.

Table 1. Sample localities, GPS coordinates, and host plant or habitat sampled on Raivavae, Austral Islands during terrestrial and aquatic surveys conducted in November and December 2002.

Locality	Date[1]	Lat Long Coords	Host Plant/Habitat	Elev (m)
Mt. Taraia summit	19-Nov-02	S23.87868 W147.67039	grassland at summit	305
Mt. Taraia slope	19-Nov-02	S23.88134 W147.66882	Xylosma suaveolens	65
Mt. Taraia slope	19-Nov-02	S23.88053 W147.66942	Macaranga raivavaeensis	155
Mt. Taraia slope	19-Nov-02	S23.88070 W147.66961	Ixora raivavaensis	135
Mt. Taraia (base of gorge)	19-Nov-02	S23.87929 W147.67176	Coprosma velutina	235
Mt. Taraia	19-Nov-02	S23.88000 W147.67176	Hernandia moerenhoutiana	195
Mt. Taraia	19-Nov-02	S23.88064 W147.66967	Celtis pacifica	145
Mt. Taraia	19-Nov-02	S23.88064 W147.66967	Glochidium raivavense	145
Mt. Taraia	19-Nov-02	S23.88117 W147.66901	Psychotria raivavense	110
Tuarani Valley, River at 1st road crossing at cement bridge	20-Nov-02	S23.86903 W147.65465	stream pools	6
Tuarani Valley-stream on hike up to Mt. Araua	20-Nov-02	S23.86591 W147.65851	Midstream	67
Mt. Araua	20-Nov-02	S23.86022 W147.65964	Metrosideros collina	351
Mt. Araua	20-Nov-02	S23.86022 W147.65964	Pilea bisepala	351
Motu Vaiamanu	21-Nov-02	S23.88188 W147.62035	Coastal Sophora tomentosa	0
Motu Vaiamanu	21-Nov-02	S23.88188 W147.62035	Santalum insulare var. raivaveense	0
Motu Vaiamanu	21-Nov-02	S23.88188 W147.62035	Scaevola sericea	0
Motu Vaiamanu	21-Nov-02	S23.88188 W147.62035	Pemphis acidula	0
Motu Vaiamanu	21-Nov-02	S23.88188 W147.62035	Suriana maritima	0
Motu Vaiamanu	21-Nov-02	S23.88830 W147.61856	Guettarda speciosa	0
Motu Vaiamanu	21-Nov-02	S23.88072 W147.67054	Coastal Hedyotis romanzoffiensis	0
Motu Vaiamanu	21-Nov-02	S23.88072 W147.67054	Pemphis acidula	0
Motu Vaiamanu	21-Nov-02	S23.88072 W147.67054	Rocks along shoreline	0
Mt. Hiro	22-Nov-02	S23.85602 W147.65671	Spring/Taro patch below summit	265
Mt. Araua	21-Nov-02	S23.86045 W147.65937	Sophora raivaveensis-sweeping	268
Mt. Hiro -just below summit	22-Nov-02	S23.85742 W147.64884	Metrosideros colllina -sweeping	430
Mt. Hiro-campsite just below summit	23-Nov-02	S23.85930 W147.65329	Metrosideros/Hernandia mossy log canopy fog	335
Mt. Hiro-west ridge	23-Nov-02	S23.85881 W147.65381	Myoporum stokesii (exact same tree also sampled on 5 Dec 2002)	335
Mt. Hiro-small streamlet hiked while descending, above pakalolo plantation	23-Nov-02	S23.86100 W147.65059	small, wooded stream	170
Vaipa Stream	25-Nov-02	S23.86222 W147.64679	Above capitage & upstream of dense Hibiscus	158-207
Large Taro fields above Vaiuru town	26-Nov-02	S23.86954 W147.64908	Taro wetlands	3-6
Taro fields btw. Mahanatoa and Rairua	26-Nov-02	S23.86918 W147.67701	Taro wetlands	2-3
Above Anatonu, just above pine plantation above church	26-Nov-02	S23.85559 W147.64169	Santalum insulare var. raivaveense	120
Motu Rani	27-Nov-02	S23.87779 W147.60814	Santalum/Chamaesyce/Triumfetta procumbens	0
Motu Numiri	27-Nov-02	S23.87933 W147.61006	Myoporum stokesii	0
Motu Niupapa Rahi	27-Nov-02	S23.86750 W147.59225	Sandy beach	0
Mid-elevation slope of Mt. Taraia	29-Nov-02	S23.88087 W147.67149	Wetland/streamlet	159
Mid-elevation slope of Mt. Taraia	29-Nov-02	S23.88074 W147.67063	Canopy fog of 1) mossy citrus log, 2) Metrosideros mossy log	170
Vaipa Stream, mid/upper elevations	29-Nov-02	S23.86333 W147.64676	Stream- yellow pan traps at 122 m	122-220
Unnamed stream	30-Nov-02	S23.87456 W147.65155	taro field/stream reported to have alien fish, but none observed	0
Mt. Raraterepa	30-Nov-02	S23.86906 W147.66248	Fern understory (Angiopteris, Thelypteridaceae, Diplazium sp., Asplenium nidus. Davallia solida)	152
Mt. Maunanui	30-Nov-02	S23.86586 W147.66490	Metrosideros canopy fog/Meryta sweeping	159

Table 1. (cont.). Sample localities, GPS coordinates, and host plant or habitat sampled on Raivavae, Austral Islands during terrestrial and aquatic surveys conducted in November and December 2002.

Locality	Date[1]	Lat Long Coords	Host Plant/Habitat	Elev (m)
Mt. Maunanui	30-Nov-02	S23.86617 W147.66478	Cyclophyllum barbatum	159
Stream draining Mt. Maunanui	1-Dec-02	S23.86744 W147.66497	Small stream	98
Taro fields btw. Mahanatoa and Rairua	2-Dec-02	S23.86994 W147.68104	Taro wetlands	0
Capitage at unnamed stream feeding taro fields btw. Mahanatoa and Rairua, going upstream	2-Dec-02	S23.87330 W147.67847	Forested stream	12
Bridge at unnamed stream crossing (taro fields btw. Mahanatoa and Rairua)	2-Dec-02	S23.87065 W147.67918	Stream-rotenone station in isolated pool	1
Pahonu (Mahanatoa area)	4-Dec-02	S23.85603 W147.65691	Santalum	100
Mt. Hiro summit	5-Dec-02	S23.85888 W147.65297	ridge top	370
Mt. Hiro summit	5-Dec-02	S23.85890 W147.65884	Metrosideros/Hernandia mossy log canopy fog (using Baygone, not Ortho)	347
Mt. Hiro summit	5-Dec-02	S23.85908 W147.65774	Metrosideros moss canopy fog	341

[1]Dates taken from Garmin GPS reflect Greenwich Mean Time (GMT) dates.

Table 2. Sample localities, GPS coordinates, and host plant or habitat sampled on Rapa Iti, Austral Islands during terrestrial and aquatic surveys conducted in December 2002.

Locality	Date[1]	Lat Long Coords	Host Plant/Habitat	Elev (m)
Valley behind Ha'urei town, base of cliffs	9-Dec-02	S27.62655 W144.34265	Meryta/Sophora rapaensis/Macropiper	195
Mt. Mangaoa ridgetop	9-Dec-02	S27.62742 W144.33329	Apetahia magdalenae/Eurya rapensis/sweeping ferns	268
Mt. Mangaoa ridgetop	9-Dec-02	S27.62972 W144.33499	Metrosideros collina mossy log canopy fog	305
Mt. Mangaoa ridgetop	9-Dec-02	S27.62994 W144.33518	Weinmannia/Eurya rapensis/Melicope/Corokia collenettei/ Pittosporum rapense/Collected female damselfly at 329 m near here	305
Ha'urei Valley	10-Dec-02	S27.62316 W144.33615	taro wetlands	24
Mt. Perau-trail to summit	10-Dec-02	S27.59305 W144.36497	Eurya rapensis/Metrosideros collina	372
Mt. Perau - camp just below summit	11-Dec-02	S27.59427 W144.37046	Metrosideros moss canopy fog (2 fogs)/Sweeping Corokia collenettei	580
Mt. Perau - at summit	11-Dec-02	S27.59515 W144.37356	Sweeping Corokia collenettei/Metrosideros	650
Mt. Perau - summit streamlet	11-Dec-02	S27.59260 W144.37327	Springs/small streamlet	457
Mt. Perau- streamlet/gully just below summit and back to summit camp	11-Dec-02	S27.59416 W144.37391	Meryta/Macropiper/Apetahia magdalenae /Geniostoma rapaensis/Fitchia/Pilea occulta	530-600
Mt. Perau - summit trail, flat spot near camp	12-Dec-02	S27.59437 W144.36797	Metrosideros mossy log canopy fogs (6 fogs)/some with small Corokia and Freycinetia sp. growing off trunks	550
Unnamed stream in the vicinity of Ile Tapui in Ha'urei Bay	13-Dec-02	S27.59917 W144.35160	Stream	2
Tumu Cascade- at base	13-Dec-02	S27.60702 W144.35401	Largest cascade visible from road circling bay	12
Tumu Cascade - above large cascade	13-Dec-02	S27.60766 W144.35516	Myoporum rapense/Stream	122
Tumu Cascade - stream above large cascade	13-Dec-02	S27.60786 W144.35819	Stream	159
Mt. Tepahiu	13-Dec-02	S27.61689 W144.31830	Metrosideros collina(Nabid only)	200

[1]Dates taken from Garmin GPS reflect Greenwich Mean Time (GMT) dates.

Table 2 (cont.). Sample localities, GPS coordinates, and host plant or habitat sampled on Rapa Iti, Austral Islands during terrestrial and aquatic surveys conducted in December 2002.

Locality	Date[1]	Lat Long Coords	Host Plant/Habitat	Elev (m)
Base of large cascade entering ocean on west side of Agairao Valley	14-Dec-02	S27.58225 W144.32577	Stream	0
Agairao Valley Stream	14-Dec-02	S27.59120 W144.32358	Stream	110
Above large cascade/stream entering ocean on west side of Agairao Valley	14-Dec-02	S27.58481 W144.32932	Stream/Metrosideros/Fagraea berteroana	85
Stream draining Ha'urei Valley/Town	15-Dec-02	S27.62401 W144.33551	Forested stream; sweeping grass in taro loi near stream for Nabids	61
Trail to Hiri Bay, Ha'urei side	16-Dec-02	S27.61925 W144.34390	Myoporum rapense (in flower)	122
Hiri Bay side of Morogouta, below ridge trail	16-Dec-02	S27.62356 W144.34457	Mixed Metrosideros/Straw. Guava/Syzygium cumini/Freycinetia forest: male damselfly collection	238
Hiri Bay side of Morogouta, below ridge trail	16-Dec-02	S27.62358 W144.34572	Forested, small streamlet/Acalypeha stokesii /Apetahia magdalenae	190
Trail down to Hiri Bay, before cultivated taro fields	16-Dec-02	S27.61806 W144.34720	Sophora rapaensis	116
Ha'urei Town (Cedran's House)	18-Dec-02	S27.62068 W144.33488	Yard/inside house	10

[1]Dates taken from Garmin GPS reflect Greenwich Mean Time (GMT) dates.

Rapa: Mt. Perau summit forest: 525 m

Rapa: *Pilea occulta* sampled for insects

Rapa: Sampling *Myoporum* on trail to Hiri Bay, several undescribed Homoptera species on this plant

METHODS

Sampling concentrated in two major areas: freshwater habitats and remnant native forest habitats. Observations and collections of insects were conducted when native or introduced species of interest were encountered. Although these surveys were primarily concerned with terrestrial arthropods, representative vouchers of freshwater fish, crustaceans, and mollusks were collected on Raivavae and Rapa.

Identified specimens and newly described species from this biodiversity assessment will be returned to the insect collection at Paea (Laboratoire d'Entomologie médicale, Institut Louis Malardé) on Tahiti, with other specimens divided between the Bishop Museum in Honolulu, Hawaii, the Museum National d'Histoire Naturelle in Paris, and the Smithsonian Institution in Washington, D.C. as identification and description of new species permits.

Aquatic Insects

Aquatic insect sampling methodology followed Englund (2001) and Englund and Polhemus (2001). Yellow pan traps, aerial nets, dip nets, selective fogging of aquatic habitats with pyrethrins, and benthic kick samples were used to collect larval and mature stages of aquatic insects. Benthic sampling was conducted at aquatic sampling stations by holding an aquatic dip net while disturbing the rock substrate upstream of the net. Immature aquatic insects were also collected from rocks found in riffles by using a toothbrush and fine-point tweezers to extricate larvae from algae covering the rocks and into a yellow pan. Visual observations for aquatic insects, especially of larger taxa such as Odonata (dragonflies and damselflies) were also conducted during hiking along the streambed and in terrestrial habitats as well. Although sampling effort was focused on habitat suitable for native insects: splash zones around riffles and cascades and wet rock faces associated with springs and seeps, waterfalls, and wetland areas near and along the stream corridor, all aquatic habitats were sampled. General collecting was conducted in prime native aquatic insect habitats with numerous aerial net sweeps taken around riffle splash-zones, cascades, seeps, and waterfall areas.

The sampling of damselflies and dragonflies (Odonata) was emphasized as part of an assessment of the evolution and biogeography of Odonata in the Pacific Islands, and particularly to investigate similarities or differences between the faunas of Hawaii and French Polynesia. To preserve color patterns crucial in identifying and describing new species of Odonata, photographs were taken of the endemic Odonata fauna found on each island. All insect specimens were stored in 95% ethanol and subsequently transported to the Bishop Museum collection for curation and identification. All insect voucher specimens are currently housed at the Bishop Museum; specimens are in the process of being sorted and loaned to taxonomic experts that will describe new species collected. Odonata from this survey, and previous surveys of the Marquesas and Society Islands (Polhemus et al. 1999) are in the process of being described by R. Englund,

D. Polhemus of the Smithsonian Institution; and S. Jordan, Laboratoire d'Ecologie Alpine, Université Joseph Fourier, Grenoble, France.

Terrestrial Insects

Canopy fogging using small, hand-held pyrethrin foggers was one of the most effective methods to capture insects. Fogging was especially effective for the rich and mostly undescribed insect fauna found deeply embedded in thick mossy tree habitats in upper elevation areas. Insects are killed or stunned on contact with the fog and fall into a white collecting sheet suspended beneath the tree. Attempts were made to fog in areas of native forest where wind disturbance was minimal, and individual trees were sampled randomly within the forest.

Yellow pan traps were set overnight in areas where we established summit camps. Sampling involved a bright yellow pan or container filled with a surfactant (a soapy solution), and this diluted soapy water in the pan will breaks the surface tension of the water, ensuring the insects do not escape. Yellow pan traps were placed on the ground and in tree limbs near mossy areas.

Other methods used included hand collections, sweeping and beating vegetation with insect nets, and directly aspirating insects on vegetation into a collecting jar. Emphasis was also placed on sampling endemic and rare native plants; host plant identifications are certain because these surveys were conducted in coordination with field botanical surveys.

Freshwater Fish, Crustaceans, and Mollusks

One of the primary objectives of this study was to assess whether aquatic organisms have been introduced into Raivavae and Rapa. Thus, limited collections of freshwater fish, crustaceans, and mollusks undertaken. Collections of native freshwater fish were not the primary objective of this biodiversity assessment, but were conducted to assess the status of native and introduced species, and to provide voucher specimens for future researchers. Emphasis was placed on observations for alien fish species, especially the widespread poeciliid and tilapia species that have caused so much damage in Hawaii (Englund 1999) elsewhere in Polynesia. Aquatic dip nets and hand-held seines were the primary collection methods of the aquatic macrofauna, and were effective in collecting most species, especially on Rapa where very high densities of fish and crustaceans were encountered. To confirm the absence of nonindigenous fish species, on Raivavae one small rotenone collection station was made in an isolated section of non-flowing portion of stream, but the use of rotenone was not necessary on Rapa because of the great abundance of water and organisms.

RESULTS AND DISCUSSION

Significant findings of these surveys include a pristine native freshwater fauna lacking introductions of nonindigenous fish, amphibians, or aquatic reptiles in both Rapa and Raivavae Islands. Extensive research in Hawaii has shown the devastating impacts of alien fish species on the native stream fauna (Englund 1999, Englund and Eldredge, 2001), and every effort should be made to avoid introductions of any non-native aquatic species to Rapa and Raivavae. Numerous undescribed aquatic insect species were found in Rapa and Raivavae, including new species and range extensions of Heteroptera (true bugs), Diptera (aquatic flies), and Odonata (dragonflies and damselflies). A rich terrestrial native insect fauna with numerous undescribed species of Coleoptera (beetles), Diptera (flies), and Heteroptera (true bugs), and was also found on Rapa and Raivavae, although stands of native forest habitat for these insects were found to be severely reduced on both islands. The native species found on both islands are important on a worldwide basis, and preservation of this biodiversity is critical in preserving the rich Polynesian culture found on these islands. It is also necessary to preserve biodiversity to allow a greater understanding of the natural biological processes of dispersal and colonization of the fauna to these remote and isolated island areas.

The following sections provide a summary of important findings of the terrestrial and freshwater surveys of Raivavae and Rapa Islands, and should be considered preliminary as new species descriptions and identifications by taxonomic experts are currently ongoing.

Freshwater Findings–Raivavae

Despite relatively limited amounts of freshwater habitat, an extensive freshwater biota was found in Raivavae streams and wetland areas. Raivavae Island appears to have closer biogeographic affinities in its freshwater fauna to the other high Austral Islands than to the remote Rapa Island. Every permanent, and many intermittent streams on Raivavae are diverted for domestic water consumption; however, the amphidromous freshwater fish and crustaceans are able to get above the captages, but in relatively low numbers compared to Rapa. Freshwater fish species found in Raivavae during this expedition are shown in Table 3. The four Austral Islands shown on the overall French Polynesia fish and crustacean distribution maps in Keith et al. (2002) are Rimarata, Rurutu, Tubuai and Rapa, thus apparently all fish and crustacean records from the present expedition are new Raivavae records. The large scale Austral Islands maps on page 96 (*Poecilia reticulata*) and page 119 (*Oreochromis mossambicus*) of the recent book by Keith et al. (2002) indicate these two nonindigenous species are found on Tubuai, and not Raivavae (Philippe Keith, personal communication), and no introduced fish species were observed on Raivavae during this expedition. Neither introduced fish species was observed in 19 days of sampling of most aquatic habitats on the island. It is beneficial for all native aquatic fauna of this island that guppies and tilapia are indeed still absent from Raivavae. All major taro growing areas were examined, and only mullet (*Mugil cephalus*) were found; in Hawaii and elsewhere guppies and tilapia predominate in taro wetland areas, and would be

expected to be found in these areas. The introduction of tilapia into taro fields in either Rapa or Raivavae would also negatively impact the endangered Gray Duck or Canard à sourcils (*Anas superciliosa*) as tilapia will reduce or entirely eliminate food required for these birds from taro wetland areas (Englund and Eldredge 2001).

Streams in Raivavae had very small amounts of alluvial substrate, and generally flowed over either bare rock, or masses of rootwads. No species of aquatic Coleoptera (beetles) or the Ephemeroptera, Plecoptera, and Trichoptera (EPT) orders were found on Raivavae. A meager benthic aquatic insect fauna was observed in what little substrate that was found. Most aquatic Diptera were collected on waterfall and seep habitats. Although present on Rapa, water skating Dolichopodidae were surprisingly absent from Raivavae aquatic habitats. Also missing from Raivavae (and Rapa) were the large neritid snails, although found in the Societies, Marquesas, and Hawaii.

Aquatic Heteroptera

Despite intensive search efforts, aquatic and terrestrial Saldidae appear to be absent from Raivavae but are common on a number of Polynesian islands such as Hawaii, the Marquesas, and Society Islands of Tahiti, Moorea, and Raiatea. The only aquatic Heteroptera captured during this expedition was *Microvelia* nr. *prompta* which were common in still water and pool habitats. The Raivavae species appears to have close affinities to the Society Islands *Microvelia prompta*.

Odonata

There is no available scientific literature available regarding the Odonata of Raivavae, and it appears they have never been sampled prior to this expedition. One of the most significant findings was that of an undescribed species of damselfly, probably in the genus *Ischnura*. This damselfly is a large species with a mostly black abdomen having a striking blue-tip; the thorax is a bright sky-blue with one black stripe in the middle of the thorax, and bichromatic green-yellow eyes with the lower-half greenish yellow, tending to yellow ventrally. The new Raivavae species has a total abdomen length of 32 mm, which is similar to the length of 33 mm of *Ischnura thelmae*; the remarkable Rapa species that is noted as the largest *Ischnura* species (Lieftinck 1966). An important finding was that this new damselfly species was found from near sea level in the stream habitat below the large taro fields between Mahanatoa and Rairua to a series of perched springs at 265 m elevation below the summit of Mt. Hiro. This spring area was the highest permanent water source on Raivavae.

Other Odonata found include one common species of native damselfly, *Ischnura aurora* found in taro patches and wetland areas, and two species of dragonfly, *Pantala flavescens* and a possible new species of

Table 3. Preliminary results of Pacific Biological Survey, Bishop Museum aquatic surveys conducted in Raivavae in November and December, 2002.

Taxon	Comments/Notes	Austral Island Status
Fish		
Awaous ocellaris	Moderately Common	Indigenous
Eleotris fusca	Common	Indigenous
Stiphodon elegans	Relatively uncommon	Indigenous
Sicyopterus lagocephalus	Common	Indigenous
Anguilla spp.	Specimens still in Tahiti	Indigenous
Crustaceans	(identifications not yet complete)	
Caridina spp.	Common	Indigenous
Macrobrachium australe	Common	Indigenous
Macrobrachium spp.	Common	Indigenous
Mollusks		
Thiaridae		
Melanoides tuberculata	Uncommon, found in Tuarani Stream	Introduced
Hydrobiidae		
Fluviopupa rapaensis	Common in spring areas	Indigenous
Aquatic Insects		
Anisoptera (Dragonflies)		
Libellulidae		
Pantala flavescens	Common in taro fields	Indigenous
Corduliidae		
Hemicordulia new sp.	Very rare, only 3 observed, 1 collected from 18 Nov to 7 Dec 2002	Endemic?
Zygoptera (Damselflies)		
Coenagrionidae		
Ischnura aurora	Common in taro fields	Indigenous
Ischnura ? new sp.	Common, found to near sea level	Endemic
Heteroptera (True Bugs)		
Veliidae		
Microvelia nr. *prompta* (Cheesman)	Common, appears close to Tahiti *Microvelia* clade	Indigenous

[1]Aquatic mollusk identifications provided by Benoît Fontaine and Olivier Gargominy,

Hemicordulia. The orange and yellow *Pantala flavescens* was quite common throughout Raivavae. However, the *Hemicordulia* new sp. was exceedingly rare; only one was collected while two additional individuals were briefly observed during 19 days of extensive sampling on Raivavae, with all individuals observed in upper elevation forest or ridgetop areas.

Freshwater Findings–Rapa

Aquatic habitats on Rapa range from a small spring and streamlet starting just below the summit of Mt. Perau at 457 m to substantial streams and taro wetlands at the ocean. A wide variety of aquatic habitats were sampled, ranging from taro fields near the Ile Tapui in Ha‘urei Bay to higher elevation taro fields sampled along the trail down to Hiri Bay at 116 m elevations. A wide variety of stream habitats were also sampled both in forested and deforested areas. The most significant finding of this expedition was a

complete lack of introduced fish or crustacean species, indicating Rapa still maintains a pristine native aquatic fauna. Other important preliminary findings indicate that isolated Rapa has less of a biogeographical affinity with Raivavae than Raivavae has to the other Austral and the Society Islands. For instance, the aquatic bug *Microvelia* nr. *prompta* is more closely related to the Society Islands clade than the *Microvelia* new sp. found on Rapa during this expedition, which appears very different from the other Austral and Society Island species (J.T. Polhemus, pers. comm.). Rapa also has two island endemic species

Table 4. Preliminary results of Pacific Biological Survey, Bishop Museum aquatic surveys conducted in Rapa in December, 2002.

Taxon	Comments	Austral Island Status
Fish		
Eleotris fusca	Common in lower stream areas	Indigenous
Sicyopterus rapa	Extremely abundant everywhere	Endemic
Stiphodon julieni	Uncommon only in lower Agairao Bay stream	Endemic
Anguilla spp.	Not as common as in Raivavae	Indigenous
Kuhlia marginata	Estuary areas only – Agairao Bay	Indigenous
Crustaceans	(identifications not yet complete)	
Caridina rapaensis	Common	Indigenous
Caridina sp.	Common	Indigenous
Macrobrachium australe	Common	Indigenous
Macrobrachium latimanus	Uncommon	Indigenous
Macrobrachium sp.		Indigenous
Mollusks[1]		
Hydrobiidae		
Fluviopupa rapaensis	Common, found in spring below Mt. Perau summit	Indigenous
Fluviopupa obtusa	Common, found in spring below Mt. Perau summit	Indigenous
Lymnaeidae sp.	Found in Ha‘urei Town stream	?
Thiaridae		
Melanoides tuberculata	Common in taro fields	Introduced
Aquatic Insects		
Anisoptera (Dragonflies)		
Aeschnidae		
Anaciaeschna jaspidea	New Island Record, very rare (only 1 observed/captured)	Indigenous
Libellulidae		
Diplacodes bipunctata	Abundant in taro fields	Indigenous
Pantala flavescens	Abundant everywhere	Indigenous
Zygoptera (Damselflies)		
Coenagrionidae		
Ischnura aurora	Abundant in taro fields	Indigenous
Ischnura thelmae	Rare, found only in forested areas	Endemic
Heteroptera		
Veliidae		
Microvelia new sp.	New sp. unrelated to Tahiti *Microvelia* clade	Indigenous
Diptera		
Dolichopodidae		
Campsicnemus new species	New species of water skating fly, Mt. Perau springs at 457 m	Endemic

[1]Aquatic mollusk identifications kindly provided by Benoît Fontaine and Olivier Gargominy

of amphidromous freshwater gobies (Table 4), while Raivavae appears to share its indigenous fish species with other Austral and Society Islands (Keith et al. 2002). The dragonfly genus *Hemicordulia* is present throughout French Polynesia from the Marquesas, to the Society Islands, and to the Austral Islands as far south as Raivavae, but is apparently not present in Rapa.

Aquatic Heteroptera

Aquatic and terrestrial Saldidae appear to be missing from Rapa, but because of the short time available for sampling on Rapa it is not certain whether saldids are present or absent from this island, as can be said for Raivavae where much more sampling time was available. Several very large wetted rock faces were examined for saldids, and none were observed. One new species of *Microvelia* was collected (see above), this species appeared to be more common in forested stream areas, but was found in low numbers in pool and still water habitats in some disturbed and overgrazed stream areas.

Odonata

A literature review found one paper (Lieftinck 1966) available on the dragonflies and damselflies of Rapa. The other most recent reports on the Odonata of French Polynesia are five brief papers on Tahiti and Marquesas Odonata by Mumford (1942) and Needham (1932, 1933, 1935a,b). However, with the exception of Lieftinck (1966), these papers only partially cover a few islands, and some such as Needham (1935a) contain flawed species descriptions (Polhemus et al. 1999). Thus, with the exception of Rapa, little accurate information is available on Odonata for French Polynesia. However, Lieftinck did not visit Rapa but was given Odonata specimens collected by J.F.G. Clarke and his wife Thelma during Clarke's (1971) fieldwork for his monograph on the Lepidoptera of Rapa. Because Odonata were only secondarily collected by Clarke it is not surprising that at least one dragonfly species was overlooked, and that some observations relayed by Clarke to Lieftinck (1966) were inaccurate. For instance, Clarke's speculation that the larvae of the endemic Rapa damselfly *Ischnura thelmae* inhabit the phytotelmata (Lieftinck 1966) of *Freycinetia* sp. now appears to be incorrect.

Lieftinck (1966) found that *I. thelmae* was unique because it was the largest damselfly in the widespread genus *Ischnura,* and was even larger than individuals in the allied genus *Amorphostigma* found in Samoa. Another unusual feature of this species is that females have a heterochromatic orange form and a darker bluish form. *Ischnura thelmae* habitat was at first difficult to determine, as the first specimen collected was a heterochromatic orange female from the Mt. Mangaoa summit at 305 m in a *Weinmannia* and *Corokia* forest with an *D. linearis* understory. One male *I. thelmae* was collected in the forest draining into Hiri Bay in a disturbed strawberry guava, Java plum, *Freycinetia* sp. and *Metrosideros* forest at 238 m elevation. As both of these locations were substantially distant from water sources, it is understandable that Clarke thought this damselfly was possibly terrestrial and might live in *Freycinetia* sp. leaf axils as do some Fijian

and Hawaiian damselflies. However, no damselfly larvae observed in numerous leaf axils that were examined during this expedition in the wettest areas of the Mt. Perau summit. Collections of the three adult *I. thelmae* during the present expedition were made as the damselflies were slowly flying vertically away from calm stream pools. These individuals were found in shaded and forested stream sections. Also, phytotelmata damselfly larvae are not mentioned in Paulay (1985), all of which point to the fact that this damselfly is in fact aquatic. A lack of time prevented thorough searches or collections for larvae near areas where adults were captured in the stream.

Unlike the Hawaiian *Megalagrion* damselflies, or the new endemic damselfly found during this expedition on nearby Raivavae, *I. thelmae* does not appear to patrol territories or dwell around the stream for long. For example, if an individual damselfly on Raivavae was missed during a collection attempt it would often be observed to return to the stream, whereas on Rapa the damselfly would take off from the water surface and go into the forest. This is also similar to damselfly behavior observed in the Marquesas Islands of Fatu Hiva and Ua Huka. Although mating pairs were not observed, three of the four female *I. thelmae* collected on Rapa were taken from forested stream habitats. Female damselflies in Polynesian Island areas generally forage away from stream areas; this indicates the females were at the stream to breeding and oviposition.

Ischnura thelmae was most likely more common during the 1960's when Clarke originally collected this species incidentally to his Lepidoptera collections, and he collected a total 46 individuals. During our brief expedition, only 6 individuals were collected despite intensive collection efforts in a wide range of aquatic habitats. This species seems to be an obligate forest-dweller; it was never found during miles of hiking along the overgrazed stream and open pasture areas currently comprising the vast majority of riparian habitats on Rapa. The pictures on page 5 illustrate the contrast between these areas, and the right picture of the forested area shows the precise stream habitat where a bluish-colored female was collected in a forest of mixed strawberry guava, *Freycinetia* sp., *Metrosideros*, and banana. It was also quite unexpected to collect *I. thelmae* a very short distance above the main Ha'urei Town (at 61 m elevation), in a section of stream lined with strawberry guava and ginger, with taro being cultivated 1-3 m above the streambed. Significantly, this area was forested, and there was a small high-gradient stair step cascade nearby. This is the same stream that flows through the town, and the damselfly capture area was located near the very large blue water tank providing municipal water for the town. This damselfly was only found in areas where livestock have been excluded, and they are still found even in relatively low, semi-disturbed forested areas.

One new island record of the dragonfly *Anaciaeschna jaspidea* was collected at Tumu Cascade, but this species was rare, and the only individual observed was collected. Other Rapa Odonata found during this expedition included the common and widespread damselfly, *Ischnura aurora*, and another common native dragonfly species, *Pantala flavescens* that was commonly observed ridge topping, and was even found in the large spider webs of an orb weaver at the summit of Mt. Perau. The small reddish *Diplacodes*

bipunctata dragonfly was also abundant in taro fields above Ha‘urei Town, and in the taro fields behind Ile Tapui in Ha‘urei Bay. Surprisingly, *Hemicordulia* sp. were not observed in the upper-forested ridge areas of Rapa, where a substantial amount of time was spent during this expedition. *Hemicordulia* were also not collected by Clarke during his Odonata collections made in 1963 (Lieftinck 1966), so it appears likely that this genus is missing from at least from Rapa, but is present throughout the rest of French Polynesia.

Terrestrial Insect Sampling

Because botanists familiar with the local flora were on this expedition, it was possible to obtain excellent plant-insect host association data. Extremely rare plants, such as *Pilea bisepala* on Raivavae, and *Pilea occulta* with < 10 remaining plants on Rapa (J.Y. Meyer, pers. comm.), and others on both Raivavae and Rapa were sampled when possible for terrestrial insects, with generally negative results. The lack of insects on most rare plants may be a result of some of these plants having too few individuals remaining on each island. It is possible that these rare plant populations are too low now to support an associated endemic insect fauna. Insect collections made during this expedition in native forest areas will provide an important baseline for future researchers. While it will take many years to fully assess terrestrial insect collections made during this expedition, it is possible to summarize some of the exciting preliminary findings. Many new insect species and new island records were found during this expedition and are either in the process of being sorted or have been sent to taxonomic various experts. Preliminary terrestrial insect findings are shown in Table 5.

Raivavae Terrestrial Insects

The upper native forest areas of Raivavae were found to harbor a diverse terrestrial insect fauna, and many new and undescribed species were collected during this expedition. One of the most spectacular findings of this expedition was that of a new species of emesine reduviid (assassin bug) that can attain the size of small praying mantid. After weeks of intensive sampling on Raivavae, this endemic assassin bug was found only in patches of native forest at the highest elevations. Over 20 individuals were captured during canopy fogging of mossy *Metrosideros* and *Hernandia* logs at the Mt. Hiro basecamp at (335 m elevation) where the expedition members established a basecamp. The moss was on these trees was quite dry and crispy during sampling, but the new assassin bug was one of the major components of the canopy fog. Only two specimens were collected sweeping ferns near these native high forested regions, thus the primary habitat appears to be mossy logs in native forest. Numerous canopy fogs were conducted on *Metrosideros* at lower elevations such as at Mt. Maunanui at 150-159 m elevation, or fogging moss on citrus trees at 170 m elevation on the slopes of Mt. Taraia, with no captures of this new insect. Thus, it appears this species is restricted to the remnant native forest, but only at the highest elevations of Raivavae.

Several other new species of Heteroptera were collected on Raivavae, including a native scutellerid in the genus *Coleotichus* found on the large individual *Myoporum* plant sampled several times in the col of Mt. Hiro. This species is the same genus as the large endemic Hawaiian Koa bug (*Coleotichus blackburni*) and is closely related to the Hawaiian and Marquesan species. Unfortunately this individual was immature and an adult will be needed for a species description. Although one immature (and hence uncertain identification) pentatomid *Catacanthus ?viridicatus* Distant was collected at the base of Mt. Taraia during the current expedition, this was in an area similar to where Zimmerman collected an adult specimen in 1934 during the Mangareva Expedition (BPBM collection data), and the immature appears quite similar. In 1934 Zimmerman also collected one *Catacanthus viridicatus* on *Alyxia* between 60–90 m elevation in a location called Pic Rouge on Raivavae (BPBM Entomology Collection data). Several new species of Lygaeidae (seedbugs) were also collected in the native forests of Raivavae, and will be described by Dan Polhemus of the Smithsonian Institution.

New Raivavae emesine reduviid.
Photo © O. Gargominy

The motus (offshore islets) of Raivavae were intensively sampled, and a diverse native insect fauna was collected from the native vegetation here. Several species of possibly new bugs in the Miridae family were found in the motus, and an especially rich and striking insect community was found on *Chamaesyce*. For some reason, higher densities of a wide variety of lygaeids, mirids, beetles and other insects were found on *Chamaesyce* in comparison to other plants sampled on the motus. Comparing insect communities from other islands on the same or similar native plant communities in French Polynesia will provide further insights into biodiversity and conservation of fragile island ecosystems. Sandalwood (*Santalum*) was still common on many of the motus, and the analysis of the insect community associated with sandalwood is still ongoing. Although not specifically targeted, five species of ants were incidentally collected on Motu Vaiamanu, and two of these species (*Tetramorium pacificum* and *Paratrechina bourbonica*) were found from the motus at sea level to the Mt. Hiro summit. The only probable native ant species collected on Raivavae was *Tetramorium pacificum* (Paul Krushelnycky, pers. comm.), with the rest of the ants being widespread tramp species introduced throughout the Pacific via commerce.

Rapa Terrestrial Insects

For a small island in French Polynesia, Rapa has received considerable attention related to insect collections and biogeography studies (Cameron 1936, Lieftinck 1966, Clarke 1971, Paulay 1985), perhaps because it is one of the most isolated and beautiful islands in the Pacific, and unlike many other islands still

Table 5. Preliminary list of notable insect species collected during terrestrial sampling in Raivavae and Rapa, Austral Islands, from November-December, 2002.

Taxon	Comments/Notes	Austral Island Status
Coleoptera		
Aglycyderidae		
Proterhinus fimbriatus Zimmerman	Mt. Perau (580 m), 12 Dec 2002, (New Rapa record); Mt. Hiro summit (347 m) New Raivavae record	Indigenous to Rapa and Raivavae
Anobiidae		
Mirosternus sericeovariegatus (Blair)	Raivavae, 23 Nov 2002, Metrosideros fog	Indigenous
Carabidae		
Colpodes monticola Fairmaire	Rapa, 9 December 2002	Indigenous
Curculionidae		
Cossoninae undet.	Rapa, 9 December 2002	?
Cranopoeus sp.	Raivavae, 5 December 2002	Indigenous
Miocalles	All from Mt. Perau Metrosideros moss fogging	
Miocalles albolineatus Paulay	Rapa, 12 December 2002	Rapa Endemic
Miocalles akao Paulay	Rapa, 12 December 2002	Rapa Endemic
Miocalles carinatus (Zimmerman)	Rapa, 12 December 2002	Rapa Endemic
Miocalles hemata Paulay	Rapa, 10 and 12 December 2002	Rapa Endemic
Miocalles ?*irregularis* (Zimmerman)	Rapa, 10 December 2002	Rapa Endemic
Miocalles perau/maii Paulay	Rapa, 10 and 12 December 2002	Rapa Endemic
Miocalles pusillus (Zimmerman)	Rapa, 12 December 2002	Rapa Endemic
Miocalles setifer (Zimmerman)	Rapa, 12 December 2002	Rapa Endemic
Miocalles ?*silvestris* (Zimmerman)	Rapa, 10 and 12 December 2002	Rapa Endemic
Miocalles species A nr *varians*	Rapa, 10 December 2002	Rapa Endemic
Miocalles species B nr *sanctijohni*	Rapa, 10 December 2002	Rapa Endemic
Rhyncogonus sp. 1	Rapa, 9 December 2002, Mt. Perau	Rapa Endemic
Rhyncogonus sp. 2	Rapa, 12 December 2002, Mt. Perau	Rapa Endemic
Silvanidae		
Cryptamorpha desjardinsi (Guerin-Meneville)	Rapa, 9 December 2002, Mt. Perau fog	Indigenous
Staphylinidae		
Mimopaederus samuelsoni n.sp.	Rapa, 10 and 12 December 2002: 550-580 m, Mt. Perau fog	New Species (Rapa Endemic)
Mimopaederus insularis Cameron, 1936	Rapa, 10 and 12 December 2002, Mt. Perau fog	Rapa Endemic
Tropoleptusa n.sp. sensu Samuelson	Rapa, 10 December 2002, Mt. Perau fog	Rapa Endemic
Diptera		
New Dolichopodidae sp. 1	Raivavae, Mt. Raraterepa ferns, 30 Nov 2002	Raivavae Endemic
Heteroptera		
Lygaeidae		
New Raivavae sp. 1	Mt. Hiro camp, mossy Hernandia/Metrosideros logs, 23 Nov 2002	Raivavae Endemic
New Raivavae sp. 2	Motu Rani, 27 Nov 2002, on Triumfetta procumbens	Raivavae Endemic
New Raivavae sp. 3 (Rhyparochromidae)	Mt. Maunanui, 30 Nov 2002, Metrosideros fog	Raivavae Endemic
New Raivavae sp. 4 (Rhyparochromidae)	Mt. Maunanui, 30 Nov 2002, Metrosideros fog	Raivavae Endemic
New Rapa sp. 1	Mt. Perau, 12 December 2002, Metrosideros fog	Rapa Endemic
Miridae		
New Raivavae sp.1	Motu Rani, 27 Nov 2002, Chamaesyce	Raivavae Endemic?
Tayloriligus new sp.	Raivavae: Mt. Hiro, 5 Dec 2002, Myoporum	Raivavae Endemic
Nabidae		
New Rapa sp. (immature)	Mt. Perau, 12 December 2002, Metrosideros fog	Rapa Endemic

Table 5 (cont.). Preliminary list of notable insect species collected during terrestrial sampling in Raivavae and Rapa, Austral Islands, from November-December, 2002.

Taxon	Comments/Notes	Austral Island Status
Nabis prob. *capsiformis* (Germar)	Raivavae: Mt. Taraia summit, 19 Nov 2002 grassland, Rapa: Ha'urei taro field/grassland area, 15 Dec 2002	Rapa and Raivavae Indigenous
Pentatomidae		
Catacanthus ?*viridacatus* (immature)	Raivavae: Mt. Taraia, 85 m, 2 Dec 2002, general colln	Indigenous
Reduviidae		
Emesinae new sp.	Raivavae: Mt. Hiro camp, mossy Hernandia/ Metrosideros logs, 23 Nov 2002	Raivavae Endemic
Rhopalidae		
Plinachtus new sp.	Raivavae: Mt. Taraia, 85 m, 2 Dec 2002, general colln	Raivavae Endemic
Niesthrea new sp.	Raivavae: Motu Rani, 27 Nov 2002, Chamaesyce	Raivavae Endemic
Scutelleridae		
Coleotichus new sp. (immature)	Raivavae: Mt. Hiro, 5 Dec 2002, Myoporum	Raivavae Endemic
Homoptera		
Cicadellidae		
Sophonia rufofascia	23 Nov 2002, Mt. Hiro, on Myoporum, New Agricultural Pest	Raivavae Introduction
Delphacidae		
New Rapa sp. 1	16 Dec 2002, Myoporum host: on trail to Hiri Bay, black-spotted	Rapa Endemic
New Rapa sp. 2	16 Dec 2002, Sophora host: on trail to Hiri Bay, yellow, no spots	Rapa Endemic
Hymenoptera		
Formicidae		
Cardiocondyla emeryi	Raivavae: Mt. Taraia summit, 19 Nov 2002, grass	Alien
Monomorium antarcticum	Rapa: Mt. Perau, 11 Dec 2002; 9 Dec 2002 Mt. Mangaoa	prob. Indigenous
Paratrechina bourbonica	Raivavae: Motu Vaiamanu, 21 Nov 2002, misc. plants; Mt. Hiro Hernandia canopy fog, 23 Nov 2002	Alien
Pheidole prob. *fervens*	Raivavae: Motu Vaiamanu, 21 Nov 2002, misc. plants	Alien
Technomyrmex albipes	Raivavae: Motu Vaiamanu, 21 Nov 2002, misc. plants	Alien
Tapinoma melanocephalum	Raivavae: Motu Vaiamanu, 21 Nov 2002, misc. plants	Alien, New Island Record
Tetramorium pacificum	Raivavae: Motu Vaiamanu, 21 Nov 2002, misc. plants; Mt. Hiro Hernandia canopy fog, 23 Nov 2002	prob. Indigenous

contains a highly significant albeit increasingly threatened native cloud forest at the summit of Mt. Perau. Even though monographic studies have been conducted on Lepidoptera (Clarke 1971) and *Miocalles* weevils (Paulay 1985), many undescribed species of insects were collected from Rapa during this expedition (Table 5). Although intensive work has been done on the Lepidoptera and the *Miocalles* weevils, it appears that other large insect groups such as the Diptera (N.L. Evenhuis, pers. comm.) and the Heteroptera (D. Polhemus, pers. comm.) in Rapa and the rest of the Austral Islands have almost been completely overlooked. One habitat that appears to have been overlooked is mossy log habitat found in an increasingly narrow zone (due to cattle, goat, and horse overgrazing) from the 440–650 m elevation at the summit of Mt. Perau. Mossy habitats in the dominant *Metrosideros*, *Corokia* and *Freycinetia* sp. high native forests of Rapa (and other high islands of French Polynesia) support a unique micro-ecosystem containing an unusually rich and often undescribed native insect fauna.

Despite very little time (2 days) spent collecting Mt. Perau, the most diverse and richest collections of native insects during the entire expedition were made here, although much more work needs to be done. Canopy fogs and general collections in the Mt. Perau summit area found several new lygaeid species, and one large new nabid species that is unfortunately immature and thus cannot yet be described until further collections of adults can be made. The one ant species (*Monomorium antarcticum*) incidentally collected during canopy fogs on Mt. Perau and Mt. Mangaoa is assumed native to Rapa, and is of great biogeographic interest. *Monomorium antarcticum* was also collected by Zimmerman during the 1934 Mangareva Expedition (Wheeler 1937). Described by Wheeler (1937) as *Monomorium rapaensis*, this species since then has been revised several times, and is also found in New Zealand, Chatham and Kermadec Islands.

In a preliminary examination of beetles collected at Mt. Perau by Dr. G. Allen Samuelson, at least 16 species of smaller beetles were collected, including one new species and 11 species of *Miocalles* weevils. This initial tally also does not include the several species of larger *Rhyncogonus* weevils from Mt. Perau which have not yet been examined. An undescribed staphylinid beetle species from was collected during *Metrosideros* moss canopy fogging at the Mt. Perau summit during this expedition, and will be named *Mimopaederus samuelsoni* by György Makranczy, University of Kansas, in honor of the Bishop Museum's Al Samuelson. The following information related to the endemic genus of Rapa staphylinid beetles was kindly provided for this report by G. Makranczy:

> "*Mimopaederus* Cameron, 1936 was a monobasic genus endemic to Rapa, with the single species *Mimopaederus insularis* Cameron, (1936) occurring exclusively on Rapa Island. Within the subfamily Oxytelinae this genus appears to be a very basal member of the *Carpelimus* group of genera (consisting of genera such as *Ochthephilus, Carpelimus*, *Thinodromus*, amongst others), therefore of great importance for phylogenetic studies. It appears to be the only member of Oxytelinae on Rapa Island."

Another significant finding was the first record for the Aglycyderidae beetle family (*Proterhinus fimbriatus*) from both Rapa and Raivavae, with this species found only in the uppermost native forest areas of each island. A search of the Bishop Museum collection indicates this indigenous species has also been collected in Tahiti, Moorea, and Rurutu.

Only a short period of time was available to collect one offshore island, Tarakoi. Paulay (1985) found at least one new species of *Rhyncogonus* and one species of *Miocalles* at this island, yet goats were subsequently introduced to Tarakoi several years after Paulay's field work. As they have done on virtually all of Rapa's offshore islets, the goats decimated the native vegetation of Tarakoi Island. Apparently goats were eliminated several years ago, but the vegetation on Tarakoi Island now consists almost entirely of an introduced species of molasses grass (*Melinis minutiflora*) that has completely invaded the island after the goats were removed, or fires have been set to clear land for crops. Also on Tarakoi was an individual barely surviving coconut tree with the only native vegetation consisting of a few stubs of remnant *Hisbiscus*

tiliaceus remaining at the island summit. Tapioca or *maniota* (*Manihot esculenta*) was being cultivated on the lower slopes of Tarakoi Island. It is difficult to imagine the undescribed *Rhyncogonus* species found by Paulay (1985), or any other native insects on the island have survived the goat onslaught, and none were observed by expedition members during our visit to the island.

New Nonindigenous Agricultural Pests-Raivavae

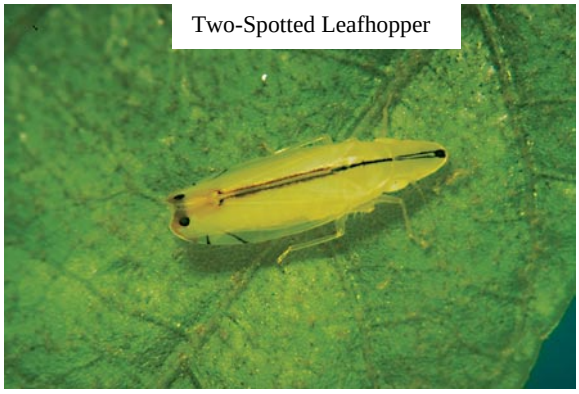
Two new alien agricultural and native plant pests were collected in moderate numbers from Raivavae, while none have yet been identified yet from the Rapa collections. The following section briefly describes some of the most important pest findings, with more pests likely to be found as samples from this expedition are analyzed.

Phasmida: Pseudophasmatidae: Striped Walking Sticks

A striped walking stick was collected on grasses at 23.85689°S, 147.62968°W, 60 m elevation in a *Hibiscus tiliaceus* forest by Benoît Fontaine and Olivier Gargominy. Walking sticks are not native to French Polynesia and are usually minor agricultural pests, however, occasional outbreaks can lead defoliations of trees or other plants

Two-Spotted Leafhopper

Collections of the two-spotted leafhopper were first made on Raivavae Island on native *Myoporum* at the Mt. Hiro summit (335 m) on 23 November 2002. Other collections were made on *Santalum* on 4 December in a stand above Anatonu, with numerous two-spotted leafhopper individuals collected on *Santalum* in this small grove. Originally from China, the two-spotted leafhopper (*Sophonia rufofascia*) is not native to Polynesia, and was first collected in Hawai‘i in 1987 (Howarth et al. 2001) and the Society Islands in 1999 (Polhemus 2001). This species is about 4–5 mm long, thin and yellowish colored bug with distinctive eyespots on the tail end, and a long thin brown strip down the middle of the back. It is now found in all the Hawaiian Islands to 1220 m elevation and in association with more than 250 species of native and alien plants (Howarth et al. 2001). In the Society Islands it has been found on Tahiti to as high as 1280 m on Mt. Marau (Polhemus 2001). Problems caused in Hawai‘i include yellowing, death, and dieback in many plants as the bugs suck the sap out of the plants and also transmitting plant diseases. In Hawai‘i, two-spotted leafhoppers are a major agricultural pest damaging agricultural crops such as coffee, banana, taro, guava, mango, and macadamia nuts (Howarth et al. 2001). Two-spotted leafhoppers have also caused massive diebacks of the



Two-Spotted Leafhopper

native *uluhe* (*Dicranopteris linearis*) fern in Hawai‘i, and impact other native Hawaiian plants (Howarth et al. 2001).

CONSERVATION IMPLICATIONS

To preserve a rich native biodiversity and Polynesian cultural heritage, it is imperative to protect the limited remaining native forests on Raivavae and Rapa. Working with the inhabitants of each island, forest reserve areas should be set up to protect the most important and biologically diverse areas. The areas that should receive the highest priority for protection would be the Mt. Perau area on Rapa, and the Mt. Hiro summit region and associated gulches on Raivavae.

Native forests are critical for the survival of both the terrestrial and aquatic fauna of the Austral Islands. A good example of this interrelationship between forests and aquatic habitats is found with the damselflies on both Rapa and Raivavae that are aquatic during their immature phase, but as adults require forested areas to forage for food. The endemic native damselfly on Rapa was only found in forested areas, and never observed during sampling along many kilometers of deforested stream habitat. Native vegetation was also critical for the newly found species of Raivavae damselfly, with this species also having similar forest requirements. Most of the native terrestrial insect biodiversity remaining on the island of Rapa is found in a narrow zone of native forest between 450-650 m at the summit of Mt. Perau. The collection of many undescribed species from Mt. Perau illustrates the point that despite two monographic works on the Lepidoptera and *Miocalles* weevils from Rapa, much remains to be studied on the insect fauna from the most intact native forest found on Rapa.

On both Rapa and Raivavae, grazing by goats and cattle are the major reason for the loss of native forests. Horses were also observed to be causing major impacts on Rapa, and the horse population has apparently increased from on Rapa from one in 1980 (Paulay 1985) to a substantial herd of 10+ that were observed in lower Agairao Valley alone during a brief two-hour hike. As stated in the Study Area section of this report, the cattle grazing line at the summit of Mt. Perau starts at about 370-400 m elevation, and cattle were actively beating down *Freycinetia* sp. to gain further access up into the summit areas, with goats already fun near the very summit. A visit to an offshore island on Rapa, Tarakoi, found the native vegetation on this island devastated by introduced goats that has almost certainly led to the extinction of a large species of *Rhyncogonus* beetle from this island.

While less native forest is left on Raivavae than Rapa, and none remains on the summit top ridges, there are still substantial amounts of native forest left in gulch areas just below the summits. The Raivavae forests also maintain significant amounts of native biodiversity in the form of unique and rare insects, such as the large undescribed assassin bug discussed earlier in this report. Some of the offshore Raivavae Motu still maintain many rare plant species such as *Santalum* and its associated insect fauna. *Santalum* is increasingly

being harvested on Raivavae, and pieces were for sale in the community arts and craft store during this expedition. This is alarming, as the remaining *Santalum* stands are quite limited on Raivavae and could be eliminated very quickly, along with the associated native insect fauna.

The finding of at least two new agricultural pests on Raivavae such as the two-spotted leafhopper, the walking stick, and at least five alien ant species demonstrates the need for strict plant quarantines and regular monitoring to stop the spread of these alien insect species, as they can cause great economic harm to agricultural crops and native species.

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Raivavae: Expedition Participants

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Rapa: *Sicyopterus rapa*

Raivavae: *Stiphodon elegans*

APPENDIX I – PHOTOGRAPHS OF NATIVE RAIVAVAE AND RAPA INSECTS

Rapa: *Ischnura thelmae*, male

Rapa: *I. thelmae*, orange female

Rapa: *I. thelmae*, blue female

Rapa: Mt. Perau new Lygaeidae species

Raivavae: Mt. Hiro, new *Coleotichus* species on *Myoporum*

Rapa: new Delphacidae species on *Sophora*

Rapa: new Delphacidae species on *Myoporum*

Raivavae: Mt. Hiro, *Rhyncogonus* sp. on *Hernandia*

Raivavae: Mt. Hiro, *Hemicordulia* new sp.

Raivavae: Motu Vaiamanu, new Lygaeid sp. from *Chamaesyce*

Rapa: *Diplacodes bipunctata*

Raivavae: Motu Vaiamanu, *Rhyncogonus* sp. from *Santalum*

Rapa: *Rhyncogonus* sp. from Mt. Perau