Rapid Assessment Program

A Rapid Biodiversity Assessment of the Nakorotubu Range, Ra and Tailevu Provinces, Fiji.

Clare Morrison, Sefanaia Nawadra & Marika Tuiwawa (Editors)

RAP Bulletin of Biological Assessment 59

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Conservation International (Fiji)

South Pacific Regional Herbarium

Division of Biology, University of the South Pacific

NatureFiji-MareqetiViti

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Cover photos:
Top: Nakorotubu CI RAP survey team (M. Tuiwawa)
Bottom left: Endemic *Nesobasis erythrops* (M. Marinov)
Bottom middle: Endemic member of the family Trocomorpha (G. Brodie)
Bottom right: Endemic Fiji tree frog, *Platymantis vitiensis* (N. Thomas)

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Organizational Profiles

CONSERVATION INTERNATIONAL

Conservation International (CI) is an international, non-profit organization based in Arlington, VA. CI's mission is to conserve the Earth's living natural heritage, our global biodiversity, and to demonstrate that human societies are able to live harmoniously with nature.

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CONSERVATION INTERNATIONAL - FIJI

The focus of CI – Fiji is to conserve larger landscapes of natural forest and wilderness that still exist in the country. Work mainly focuses on Viti Levu, the largest island of the Fiji Group specifically on the Sovi Basin Nature Reserve, the islands' most important land ecosystem and a cradle for much of Fiji's biodiversity and natural heritage. Sovi Basin is located in one of the seven high-priority Key Biodiversity Areas (KBA) and is also working closely with local communities, partners, in particular the National Trust to build capacity for and implement effective conservation action. To protect its marine resources Fiji has a flourishing network of Locally Managed Marine Areas (LMMAs) and CI - Fiji is supporting research to help to local communities improve their management of these areas.

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The South Pacific Regional Herbarium (SPRH) is maintained and administered by the Institute of Applied Sciences at the University of the South Pacific (USP). The SPRH serves the member countries of USP which consists of the Cook Islands, Fiji, Kiribati, Marshall Islands, Nauru, Niue, Solomon Islands, Samoa, Tonga, Tokelau, Tuvalu and Vanuatu. It currently houses more than 50,000 vascular plant specimens in the main collection and has a wet collection of plant parts, bryophytes and algae from the Pacific region. The SPRH serves as an important resource in matters pertaining to the taxonomy, conservation and ecology of plants, forestry, land use planning, economic plants and weed problems in the Pacific region. As a member of an international network of herbaria, the SPRH participates in programs to maintain collections of botanical plants specimens for study by both local and international botanists and scientists working in associated fields.

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BIOLOGY DIVISION, UNIVERSITY OF THE SOUTH PACIFIC

The Biology Division at USP is part of the Faculty of Science, Technology & Environment. The Division's primarily task is undergraduate and postgraduate teaching with a biology focus. This includes undergraduate subjects in invertebrate biology, plant diversity and conservation biology plus a postgraduate course in biodiversity and conservation. USP provides opportunity for in-depth, first-hand studies of two of the most diverse, yet contrasting ecosystems in the world – tropical rainforests and coral reefs. Several advanced courses emphasize the ecology and conservation of these systems, which are important throughout the South Pacific region. The Division also plays an active role in the Faculty's Biodiversity

and Conservation Research Group and is perfectly placed for field studies in tropical terrestrial, freshwater, and marine ecosystems.

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Wetlands International – Oceania exists to sustain and restore wetlands, their resources and biodiversity for future generations through research, information exchange and conservation activities, particularly in the Pacific Islands region.

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The Fiji Museum is a statutory body that is governed by the Fiji Museum Act and the Preservation of Objects of Archaeological and Palaeontological Interest Act. The Archaeology Department at the Fiji Museum utilizes the Acts in all its operations with the aim of identifying, protecting and conserving archaeological and cultural heritage for the current and future generations.

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SYSTEMATICS AND ECOLOGY LABORATORY, NATIONAL UNIVERSITY OF SINGAPORE

The Systematics and Ecology Laboratory conducts systematics and ecological research on a wide variety of

taxonomic groups. Much of the current taxonomic work focuses on systematic revisions of key groups of crabs and fishes and many projects are ongoing collaborative efforts with international crustacean and fish specialists from over a dozen countries.

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FRESHWATER ECOLOGY RESEARCH GROUP, UNIVERSITY OF CANTERBURY

The FERG is primarily field-based, and covers a broad array of applied and theoretical ecological topics including the natural history of New Zealand's freshwater biota, the influence of land-use change, acid mine drainage, ecosystem size and disturbance on stream communities, and biogeochemistry and nutrient cycling.

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FIJI WATER FOUNDATION

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Report at a Glance

A RAPID BIODIVERSITY ASSESSMENT OF THE NAKOROTUBU RANGE, RA AND TAILEVU PROVINCES, FIJI

Expedition Dates

November 29- December-12, 2009

Description of Expedition

This 12-day RAP expedition surveyed several sites in the Nakorotubu Range, a 19071 ha isolated forested remnant in the Ra and Tailevu Provinces, Fiji. The survey sites were located in lowland and upland rainforest vegetation, and their associated streams and rivers in the northeast of Fiji's largest island, Viti Levu. The actual field work began at Matuku settlement where the team hiked through secondary forest into the more forested mountains. The first base camp was located at 120 m on a flood plain next to the Nabavatu Creek in lowland rainforest vegetation. The second base camp was located at Nalalau at the headwaters of the Lequ Creek at 500 m altitude in upland rainforest vegetation. The third camp was located at 200 m altitude in lowland rainforest vegetation. Three days were spent at each base camp. The surveyed sites at Base camp 1 showed signs of human disturbance. Study sites at Base camps 2 and 3 showed very little human disturbance with the exception of traditional trails that led to the areas which provided access to relatively undisturbed forest habitats.

Reason for the RAP Survey

In April 2008, the Fiji Water Foundation and Conservation International (CI) entered into a three-year grant agreement to protect the natural resources of Viti Levu, Fiji. One of the three key objectives of the Fiji Water Grant involves technical assessments and community consultations to facilitate conservation initiatives within the Yaqara and Nakauvadra watersheds. The Nakorotubu Range is adjacent to the Nakauvadra watershed and the purpose of this Nakorotubu RAP was to assess (i) its flora and fauna and, (ii) its relationship with Nakauvadra. Both Nakauvadra and Nakorotubu are part of the Viti Levu Conservation Corridor whose definition is also part of the grant agreement.

MAJOR RESULTS

In total the RAP survey documented 556 confirmed species (Table 1), including a number of rare and endangered species. Three of Viti Levu's globally threatened bird species were recorded, the Pink-billed parrotfinch (*Erythrura kleinschmidti*), the Black-faced shrikebill (*Clytorhynchus nigrogularis*) and the Friendly ground dove (*Gallicolumba stairii*) along with two rare and endemic stick insects *Nisyrus spinulosus* and *Cotylosoma dipneusticum*. Two plant species of particular interest found were *Acmopyle sahniana* (Critically Endangered, Viti Levu endemic) and *Calamus vitiensis* (endemic palm, rare in Fiji). High levels of endemism were recorded in the damselflies and dragonflies group (58%) as well as the terrestrial

gastropods (50%), birds (40%) and plants (31%). New records and range extensions were made for a number of species in all taxa. These results suggest that due to its moderate to high biodiversity and relative isolation, the Nakorotubu Range should be targeted for conservation action.

Species of conservation concern (IUCN 2008 and CITES 2008)

Amphibians
Fiji tree frog *Platymantis vitiensis* (NT)

Birds
Fiji goshawk *Accipter rufitorques* (CITES II)
Pacific harrier *Circus approximans* (CITES II)
Black-faced shrikebill *Clytorhynchus nigrogularis* (VU)
Friendly ground dove *Gallicolumba stairii* (VU)
Pink-billed parrotfinch *Erythrura kleinschmidti* (VU)
Masked shining parrot *Prosopeia personata* (NT, CITES II)
Collared lory *Phigys solitarius* (CITES II)

Mammals
Pacific sheath-tailed bat *Emballonura semicaudata* (EN)
Samoan fruit bat *Pteropus samoensis* (NT, CITES I, II)
Tongan fruit bat *Pteropus tonganus* (CITES I, II)

Reptiles
Pacific Boa *Candoia bibroni* (CITES II)

Plants
Acmopyle sahniana (CR, CITES II)
Astronidium tomentosum (NT)
Degeneria vitiensis (VU)
Cycas seemannii (VU, CITES II)
Dendrobium biflorum (CITES II)
Geniostoma cf. clavigerum (CR)
Oberonia heliophila (CITES II)
Podocarpus neriifolius (CITES III)
Cyathea alta (CITES II)
Cyathea hornei (CITES II)
Cyathea lunulata (CITES II)
Cyathea medullaris (CITES II)
Cyathea propinqua (CITES II)
26 Orchid species (CITES II)

Table 1: Number of species recorded during the 2009 Nakorotubu Range RAP survey. Insects are not included due to incomplete identification of specimens (completed down to family only).

	Total	No. of endemic species	No. of native species	No. of introduced species
Plants	425	132	229	64
Herpetofauna	10	3	6	1
Birds	38	15	19	4
Bats	3	0	3	0
Terrestrial gastropods[1]	22	11	2	7
Freshwater crustaceans	12	1	11	0
Damselflies and dragonflies	31	18	13	0
Freshwater fish	15	0	13	2
Total	**556**	**180**	**298**	**78**

[1]Two species remain unidentified

KEY CONSERVATION RECOMMENDATIONS

Additional recommendations are presented in the Executive Summary.

- *Protection of important habitats*
  Because of the relative pristine nature of the forests in the Nakorotubu Range and the fact that it is one of the last remaining intact forest systems along the transition zone (dry and wet zone) on Viti Levu, every effort should be made to collaborate with local communities, Government departments, conservation NGOs and academic researchers to conserve the forests in the region. This will also include rehabilitation of adjacent forest areas decimated by clearing (especially fire) for agriculture and grazing by domesticated animals. In particular, forests in the upper reaches of the three main river headwaters, the Wailou, Nabavatu and Wailotua should be preserved as protected areas to maintain water quality and act as a repository for

potable water for the local communities.

- *Community awareness and education*
  As the land in the Nakorotubu Range is owned by local communities, they will play a vital role in the future conservation management of the region and the biodiversity within. As such, it is critical that local communities are made aware of the negative impacts of some of their activities as well as offered potential solutions and/or information to ameliorate the impacts of their daily activities.

- *Future research*
  Due to the short-term nature of this RAP survey, the data collected represents a 'snapshot' of the Nakorotubu Range and its biodiversity and conservation value. All researchers involved in this survey agree that further surveys are needed to improve the quality of the data and provide more complete checklists of biodiversity in the area. Additional surveys are also important for assessing the conservation status and distribution of threatened or endangered species recorded during this RAP survey. In addition, future surveys will provide information on seasonal variation as well as provide a more robust baseline for long-term monitoring of biodiversity trends in the region.

Executive Summary

INTRODUCTION

The Republic of Fiji consists of approximately 300 islands located roughly 3000 km east of Australia in the Pacific Ocean (between 16° and 20°S, 177°W and 175°E). There are four main islands in the Fiji group: Viti Levu, Vanua Levu, Taveuni and Kadavu. The two largest islands, Viti Levu (10,544 km^2) and Vanua Levu (5,535 km^2) comprise 88% of the total land area (~18,300 km^2). It is estimated that no more than 100 islands are permanently inhabited.

Most of the islands are the remnants of once active volcanoes sitting on a piece of the Pacific Plate. The landforms of the major islands are diverse and often spectacular, marked by sharp volcanic plugs, ruined calderas, deep gorges and ravines carved by mountain streams, wide flat-bottomed valleys, extensive flood plains and mangrove dominated deltas. Fiji's larger volcanic islands are dominated by steep mountainous country. The highest mountain, Mt Tomaniivi on Viti Levu is 1323 m and there are 30 peaks over 1000 m (Nunn 1998).

The tropical maritime climate is without great extremes of heat or cold. The mean monthly temperature ranges from 23°C in July and August to 27°C in January. In all seasons the predominant winds are the light to moderate tradewinds from the east or southeast. Strong winds are uncommon with the exception of cyclones which generally occur between November and April. Although rainfall is extremely variable, the average rainfall increases steadily inland from coastal areas. In addition, the windward sides of the major islands intercept the easterly air stream and experience far greater rainfall than the leeward sides, consequently resulting in distinctly 'wet' and 'dry' zones. Generally, the 'dry' zone of the larger islands receives an average rainfall of between 1650-2300 mm, the 'wet' zone 3050-3450 mm. Some localities (Waisoi, Lake Tagimoucia) commonly receive over 10,000 mm per year.

Fiji is large enough to support a wide range of habitats. These include lowland, cloud forest, coastal and mangrove communities, wetlands, mixed grasslands and dry forests (Mueller-Dombois and Fosberg 1998).

Scope of project

In April 2008, the Fiji Water Foundation and Conservation International (CI) entered into a three-year grant agreement to protect the natural resources of Viti Levu, Fiji. The agreement focused on three key objectives:

1) Definition of the Viti Levu Conservation Corridor;
2) Contribution to the Sovi Basin Trust Fund; and
3) Scientific and technical assessments and community consultations to facilitate conservation initiatives within the Yaqara and Nakauvadra watersheds.

This RAP survey was undertaken as part of the process to facilitate conservation initia-

tives within and linked to the Yaqara and Nakauvadra watersheds. More specifically, the survey was conducted to gain a better understanding of the existing environment in the Nakorotubu Range that is part of the Viti Levu Conservation Corridor. This information will then be used to make informed decisions on the conservation management of the biodiversity in the area in conjunction with local landowning communities and relevant government departments.

RAP SURVEY OVERVIEW AND OBJECTIVES

Conservation International's Rapid Assessment Program (RAP) is an innovative biological inventory program designed to use scientific information to catalyze conservation action. RAP methods are designed to rapidly assess the biodiversity of highly diverse areas and to train local scientists in biodiversity survey techniques. Since 1990, RAP's teams of expert and host-country scientists have conducted 60 terrestrial, freshwater aquatic (AquaRAP), and marine biodiversity surveys and have contributed to building local scientific capacity for scientists in 26 countries. Biological information from previous RAP surveys has resulted in the protection of millions of hectares of tropical forest, including the declaration of protected areas in Bolivia, Peru, Ecuador, and Brazil and the identification of biodiversity priorities in numerous countries.

Criteria generally considered during RAP surveys to identify priority areas for conservation across taxonomic groups include: species richness, species endemism, rare and/or threatened species, and habitat condition. Measurements of species richness can be used to compare the number of species between areas within a given region. Measurements of species endemism indicate the number of species endemic to some defined area and give an indication of both the uniqueness of the area and the species that will be threatened by alteration of that area's habitat (or conversely, the species that may be conserved through protected areas). Assessment of rare and/or threatened species (IUCN 2008) that are known or suspected to occur within a given area provides an indicator of the importance of the area for the conservation of global biodiversity. The confirmed presence or absence of such species also aids assessment of their conservation status. Many of the threatened species on IUCN's Red List carry increased legal protection thus giving greater importance and weight to conservation decisions. Describing the number of specific habitat types or subhabitats within an area identifies sparse or poorly known habitats within a region that contribute to habitat variety and therefore to species diversity.

The primary aim of this RAP survey was to document the terrestrial flora and fauna diversity and the cultural significance of the Nakorotubu Range in the Ra and Tailevu Provinces on Viti Levu, Fiji. The information collected will be used to make informed decisions on the conservation management of the biodiversity in the area. We selected survey sites to encompass the major habitat types found within the Nakorotubu Range.

Our specific objectives were to:

- Collect baseline data on the diversity and conservation significance of major terrestrial flora and fauna taxa in the Nakorotubu Range
- Identify potential threats to biodiversity in the area, and propose mitigation strategies to enhance biodiversity conservation in the Nakorotubu Range
- Increase local capacity by providing hands-on training in field biodiversity inventory techniques for students, local guides and local government researchers
- Make RAP data available for conservation management decision makers in Government, local communities, NGOs, academia and the general public

Study area

The Nakorotubu Range is located on the northeast portion of Viti Levu, the largest island of the Fiji group. It is an important forest refuge for Fiji's native flora and fauna covering the whole mountain range that runs along the eastern side of Viti Levu from the Tailevu province in the south up to the province of Ra in the north. It connects the lowland tropical rainforests of southern and central Viti Levu and the dry forests of northern Viti Levu like the Nakauvadra Range. The elevation of the study area ranges from about 100 m to 560 m on the highest peaks. Much of the mountainous interior area is covered with primary forest, but the vegetation of many other areas comprises secondary forest, agroforest, and village land. The primary or native forest is not homogeneous, because elevation, topography, and substrate all contribute to differences in species composition, density and distribution. The two principle vegetation types (Mueller-Dombois and Fosberg 1998) observed for the area includes the Low Land Rainforest and the Upland Vegetation.

The Nakorotubu Range lies in one of the drier areas in Fiji along the transitional zone (dry and wet zone) on northeast Viti Levu. There are no rainfall data or meteorological data available from within the Nakorotubu Range and the nearest weather station is located at the Penang Sugar Mill. The Range lies on the leeward side of the main island and being situated on the rain shadow it receives on average around 2000 mm of rain per year, half the amount it would get if located on the windward side (Raj 1993). Monthly rainfall data ranges from about 50 mm during the dry season to about 400 mm during the wet or cyclone season (Fiji Meteorological Office). Mini-

mum monthly temperatures range between 20.2-23.5°C while maximum monthly temperatures range between 27.1-20.1°C.

The Nakorotubu Range is divided amongst traditional landowning units (Mataqali) that are based in 3 districts; Bureivanua, Nakuilava, Bureiwai and Sawakasa.

Site descriptions

Camp site 1

Base camp 1 (S 17°59; E 178°36) was established on a flood plain next to a tributary of the Uloa Stream at about 162 m elevation. More recent (and regular) impacts on the vegetation were evident in the presence of more plants and animals associated with human activities. These included *Dioscorea* spp ("wild yams"), *Bambusa vulgaris* and *B. simplex* (bamboos), Citrus limon (wild lemon), *Mangifera indica* (mango), *Colocasia* spp. (taro), *Derris malaccensis* (derris) and *Syzygium malaccensis* (malay apple). Most of these plants were noticed along the trail. The presence of feral cattle was evident in hoof-prints and cattle dung noticed along the trails and river flats. Overall the vegetation is secondary forest.

Camp site 2

Base Camp 2 (S 17°35'53.4" ; E 178°23'02.4") was next to Nalalau Stream at approximately 550 m elevation. The surrounding area was very wet with stunted trees covered with mosses, liverworts and lichens. On average, tree heights were about 2-4 m with dbh of 8 cm. There were more epiphytes and vines (*Freycinetia* spp.) and ground cover was total. The more common subcanopy trees were *Psychotria* spp. and canopy trees were *Metrosideros colina*. Overall species richness and density was very high especially for native species and the vegetation was that of a primary upland forest.

Camp site 3

Base Camp 3 (S 17.72; E 178.42) was established near the Wailotua River at approximately 50 m elevation. The vegetation around the campsite was that of a lowland rainforest vegetation type exposed to anthropogenic activities and/or damaged by natural disasters like floods and cyclones. The vegetation is dominated by edible ferns, paragrass (*Brachiara mutica*) and clumps of bamboos (*Bambusa vulgaris*). Away from the riparian vegetation the forest canopy was generally closed as evident in the low levels of ground cover. Occasionally along the slopes and ridges native trees with dbh of up to 80 cm were encountered. Here the tree species density and diversity was higher than that encountered in Base camp 1. Overall away from the campsite the vegetation is lowland primary rainforest.

SUMMARY OF RAP RESULTS BY TAXONOMIC GROUP

Vegetation

Two principle vegetation types based on Mueller-Dombois & Fosberg (1998) description were observed in the study area. They are the Lowland Vegetation Type and the Upland Vegetation Type. Within these vegetation types four main plant communities or forest types were distinguished—(1) Secondary Forest, (2) Primary Forest, (3) Freshwater Swampland and (4) Karst or Limestone Forest. A total of 425 plant taxa (including 32 undetermined species) were recorded representing 118 families. This comprises 75 dicot families, 19 monocots, 2 gymnosperms and 21 fern and fern ally families. Two of the largest families include Orchidaceae with 20 genera and 26 species; followed by Poaceae with 19 genera and 20 species. For the 393 species identified 78% (307 species) are native with 35% (131) endemic species. The 307 native species comprise about 17% of the entire native flora for Fiji. The Angiosperms and Gymnosperms recorded during the survey added up to 337 species. Of these, 75% (251) are native species including 53% (132 species) endemics. A total of 64 exotic plant species were recorded during the survey out of which six species are internationally recognized invasive species.

Two species of conservation interest include the Critically Endangered gymnosperm *Acmopyle sahniana* and the endemic palm *Calamus vitiensis* considered Least Concern in the IUCN Red list. The presence of A. sahniana in the study area has resulted in its range extension to a third province of Ra in Fiji. The palm is known to occur in only two locations (small populations) on Viti Levu - Wailekutu (within the vicinity of Nasaua village) and the interior of Namosi, but is common on Taveuni.

Herpetofauna

A total of ten frog and reptile species were documented from the Nakorotubu Range representing approximately 24% of Fiji's 33 presently known terrestrial herpetofauna. This included one frog species, one toad, five skinks, two geckoes and one snake. All species were observed in relatively low abundances. Three of the species are endemic to Fiji (*Platymantis vitiensis*, *Emoia concolor* and *E. parkeri*). With the exception of the introduced cane toad (Bufo marinus), all remaining species are native to Fiji and the Pacific.

Birds

A total of 38 bird species were recorded in the surveys, fifteen of which were endemic species, four introduced and the remainder native species. Three globally threatened species for Fiji were recorded – Pink-billed Parrotfinch (Viti Levu endemic), Black-faced Shrikebill and the Friendly Ground-Dove. For birds, the Nakorotu-

bu Range has the same conservation significance as other large forest blocks on Viti Levu including the Nakauvadra Range.

Bats

Only three species of bats were recorded: Pteropus tonganus, P. samoensis and Emballonura semicaudata. The latter two species are listed in the IUCN Red List 2007 as Near Threatened and Endangered respectively. At least three large roosts of *P. tonganus* were recorded within the area covered during the survey. More surveys are needed to locate possible roosting sites and monitor the presence of other bat species that forage within the area.

Land snails and slugs

Twenty-two different species of terrestrial land snails and slugs were identified during the survey period. Eleven of these species are endemic to Fiji and another two species are either endemic or native. It is likely that at least some of the endemic species found during this survey are threatened and should be listed on the IUCN Red List as in need of some level of conservation action since closely related taxa from the same genera (e.g. *Placostylus*) in other Pacific Island areas are listed. Seven of the species found are introduced and two species are of unknown status. The introductions include *Parmarion martensi* Simroth 1893 which has well documented human health risks in overseas countries. Based on the total number of terrestrial gastropod species found in the Fiji archipelago a higher number of land snail species might be expected.

Freshwater crustaceans

A total of 12 decapod crustacean species from four genera and three families were collected from this RAP, (Varunidae: *Varuna*; Atyidae: *Atyopsis*, *Caridina*; and Palaemonidae: *Macrobrachium*). The number of taxa is less than reported in previous surveys in the region. This may be due to the lack of adequate sampling equipment for the habitats surveyed, such as electro-fishing gear as well as the lack of intensive survey due to time limitations.

Terrestrial Insects

The order Coleopetera (beetles) was the most common insect order encountered throughout the surveys and was the target taxa. Overall, there were 25 Coleoptera families recorded. Rare families encountered during the surveys included: Pselaphidae, Callirhyphidae, Cerambycidae and Cicindellidae. The highlight of the survey was the discovery of the two rare Fijian stick insects *Nisyrus spinulosus* and *Cotylosoma dipneusticum* which were both found at Base camp 2. One of Fiji most unique forest systems, i.e. comprised of upland forest area was identified at this study site. The uniqueness and isolation of this forest system explains much of the diversity of insects from the Nakorotubu Range.

Damselflies and Dragonflies

A total of 31 Odonata taxa were found during the RAP-Fiji in the Nakorotubu Range. These taxa represent more than 50% of the all species recorded for the whole Fijian archipelago and about 67% of the species established for Viti Levu. Endemism was high at around 58%.

Freshwater fish

A total of 15 species from eight families were collected and/or observed. These included the native species *Bunaka grinoides* and *Ophioeleotris sp.* (Eleotridae)*; Awauous guamensis, A. ocellaris, Glossogobius sp., Sicyopus zosterophorum* and *Sicyopterus lagocephalus* (Gobiidae)*; Microphis leiaspis* (Syngnathidae)*; Kuhlia marginata* and *K. rupestris* (Kuhliidae); the freshwater eels *Anguilla marmorata* and *A. megastoma* (Anguillidae), freshwater moray eel *Gymnothorax polyuranodon* (Muraenidae); and the introduced *Oreochromis mossambicus* (Cichlidae) and *Gambusia affinis* (Poecilidae). There were no endemic or rare species collected or observed during this survey.

Surveyed streams and rivers in the Nakorotubu watershed showed low fish diversity ranging from zero to ten with an average of four species per streams surveyed. The fish species collected from Nakorotubu represented 9% of the total freshwater fish diversity of Fiji.

Cultural significance

Utilizing the guides knowledge and local stories providing some hint of a greater past, the oral history of several archaeological sites in the Nakorotubu Range was documented. A major portion of the cultural sites identified during the survey belong to the people in the districts Bureivanua, Nakuilava and Bureiwai. While most sites in the area have been well preserved over the years, a select few have been disturbed by human and non-human interaction over recent years with the introduction of livestock farming and agriculture in the area.

CONSERVATION RECOMMENDATIONS

Address potential threats
Protection of Nakorotubu Range

The forests in the Nakorotubu Range are one of the last remaining intact forest systems on Viti Levu. These forests are currently not protected by any environmental legislation or conservation initiatives in Fiji. As the forests in the mountainous area are comparatively pristine and isolated due to their relative current inaccessibility, they provide potential security for a number of endemic taxa and unique habitats in Fiji. As a result, the area should be included and nominated as a key or important biodiversi-

ty area for Fiji and efforts to list it as a "protected area" for Fiji pursued. The results of this RAP survey can be used to develop a sustainable, long-term conservation plan for the Nakorotubu Range in collaboration with local land-owning communities, relevant government institutions (at the local, regional and national scales), conservation NGOs, and academic institutions.

Taxa-specific threats

Herpetofauna

Several threats were identified during the survey. The first was the presence and seemingly high abundance of feral cattle in the forest near Base camp 1. The presence and apparent preference of the ridge top trails pose a potential threat to frog breeding sites and to skinks and geckoes. The effect of cattle trampling on the ridge tops is already showing in the presence of invasive and weedy plants along the ridges, landslides, and the state of the tributaries of Nabavatu stream. The feral cattle, if they persist, could have a significant negative impact on the herpetofauna population at the forest around Base camp 1.

The second major potential threat to herpetofauna is the presence of the introduced mongoose *Herpestes fuscus* and rats. There is no evidence as yet on the direct impacts of the mongoose and rats on herpetofauna populations in the Nakorotubu Range. A more detailed survey is needed to document this relationship.

Land snails and slugs

The unique nature of Fiji's land snail fauna, and the high potential for its irretrievable loss by high risk invasive species, makes strategic planning for their long-term conservation vital. These goals would be best achieved by relatively large scale habitat conservation in areas such as native forest and areas with significant deposits of limestone (needed by many terrestrial gastropod species for shell development).

Freshwater fish

The thick deposit of algae in the lower reaches is due to the use of Derris roots, weedicides and pesticides to harvest fish. The use of these poisonous *Derris* sp. plants for fishing should be strongly discouraged. It can change the quality of water by depleting oxygen and asphyxiating all aquatic life, particularly in pools and slower flowing reaches of streams. It is indiscriminant and will also kill all juveniles, thus removing future potential populations.

In addition, the combination of cattle farming and agricultural waste are affecting the water quality and habitat for the fish. Overfishing and destructive fishing practices also affect the fish biodiversity and abundance. Furthermore, the abundance of the introduced species *Oreochromis mossambicus* and *Gambusia affinis* greatly contributes to the poor diversity and abundance of native species and the complete absence of any endemic species.

Therefore, watershed management and rehabilitation mitigations should be put in place to restore the freshwater ecosystem function and its rich resources. Plans to rehabilitate the Nakorotubu Range watershed should involve the whole system from upper to lower reaches as the fish population needs the entire water system to complete their life cycle.

Potential suggestions for watershed rehabilitation include:

- encourage replanting of buffer zones particularly in areas that are adjacent to human habitation, subsistence agriculture and cattle farms,
- form a village environment committee to plan monitoring of waste levels and water management (e.g. the committee will be responsible for construction of ecological or livestock waste areas, harvesting of the fish resources, and monitor the introduction of alien species).

Community awareness

As the land in the Nakorotubu Range is owned by local communities, they will play a vital role in the future conservation management of the region and the biodiversity within. As such, it is critical that local communities are made aware of the negative impacts of some of their activities as well as offered potential solutions and/or information to ameliorate the impacts of their daily activities. Some of these have been discussed previously for specific taxa. Additional community education and awareness will include:

- Awareness on the impacts of feral cattle. The feral cattle and their easy access to streams not only pose threats to the flora and fauna, but also to the quality of water sources of Matuku Village
- Awareness of the impacts of invasive species on both local fauna and flora due to uncontrolled access to all sites within the region.
- Awareness of the significance of the native fauna and flora and the need to conserve forested areas for biodiversity conservation.
- Awareness of alternative forms of sustainable livelihoods.
- Awareness of the need to preserve cultural sites and oral traditional stories from within the region.
- Awareness of the importance of bats and their ecological role, something which has been neglected in many Fijian communities where bats are not seen as important species, but only a nuisance.

Future research

Further surveys are needed to improve data quality and provide more complete checklists of biodiversity in the area. Additional surveys are also important for assess-

ing the conservation status and distribution of threatened or endangered species recorded during this RAP survey. In addition, future surveys will provide information on seasonal variation as well as provide a more robust baseline for long-term monitoring of biodiversity trends in the region.

Plants

1. More collections are needed. The checklist of vascular species present is only preliminary and probably includes only 60 to 75% of the species present. The orchids and ferns are much underrepresented, since many of the species are restricted to the tops of trees, where they were not observed. The most difficult groups during the present work included the genera *Psychotria* (76 native species in Fiji), *Syzygium* (28 species), and Gesneriaceae (37 species), and the Lauraceae family (34 species).
2. The forests on limestone areas around Nasau village should be explored in more detail, since this is an entirely different substrate than most of the other forests in the area. With current developments (road works, agriculture) in progress nearby this should be treated as a priority.
3. A thorough assessment of the relatively intact freshwater swampland that is the source and headwater of most of the major rivers originating from this mountain range should be undertaken as soon as possible. Such a system is rare for Fiji and the two currently known high altitude swamps (Nadrau Swamp, Lake Tagimoucia) are very much threatened and already impacted by development.

Herpetofauna

1. A study of the tree skink diversity will be interesting because of the varying levels of disturbance and types of habitat at the site. The Nakorotubu Range has potential to support rare endemic species such as *E. campbelli* and new undiscovered species.
2. The absence of the Fiji ground frog from the Nakorotubu Range is interesting. Future herpetofauna surveys should extend to parts of the Nakorotubu Range closest to the Nakauvadra range (northwestern portion of the Nakorotubu Range) and Viwa Island and Ovalau Island (southeastern portion of the Nakorotubu Range) to confirm if the Fiji ground is indeed absent.

Birds

1. Further surveys are required to determine the presence/absence of rare species such as the Long-legged Warbler and the Red-throated Lorikeet.
2. Being an important refuge for birds and the fact that it is connected to other large forest blocks, there is a need to set aside some portions of the Nakorotubu Range as permanent reserves.

Bats

1. More surveys are needed to locate the presence of any roosting colonies of each of the three bat species and also to monitor population sizes of the different bat species foraging in the Nakorotubu Range.
2. Other species like the Fiji blossom bat (species) could also be present in the Nakorotubu Range (apart from Wailotua) and there is a need to survey the limestone outcrops of Nakorotubu for caves and bats.

Terrestrial gastropods

Land snails are excellent sentinel taxa for ecosystem change. Identification of taxa to genus or species level for native or endemic fauna is currently hindered by a lack of readily accessible taxonomic identification information. There is a need for more baseline surveys like this one in the priority forest areas highlighted by Olson et al. 2009 as the unique nature of Fiji's land snail fauna, and the high potential for its irretrievable loss by high risk invasive species, makes strategic planning for their long-term conservation vital. Relatively large scale habitat conservation in areas such as native forest, small islands and areas with significant deposits of limestone (needed by many terrestrial gastropod species for shell development) is required.

Two obvious follow-up studies are needed.

1. A review of the Fijian Placostylus species and an investigation of the cause of the observed high mortality in *Placostylus gracilis*.
2. Further investigations into the human health risks and feeding habits of *Parmarion martensi* to fully assess its potential to impact on humans and native fauna in Fiji.

Insects

1. A thorough ecological study for the two Fijian stick insect species *Nisyrus spinulousus (*syn *Cotylosoma)* and *Cotylosoma dipneusticum* be conducted within the survey areas as this is the only known site so far to harbour these two rare Fijian stick insect species. Studies on population, seasonality patterns, behaviour and host plant associations would be essential for conservation measures.
2. There should be an intensive host fruit collection conducted in the Nakorotubu Range to determine the host fruits of the fruit fly species present there.
3. Weather conditions especially at Base camp 2 were not ideal for insect sampling and because this harbours a unique forest system (i.e. upland forest), a quantitative survey in suitable conditions for leaf

litter, pitfall, light trap and malaise sampling within the three campsites are essential to confirm its uniqueness.

Damselflies and dragonflies

Based on the results of this survey, the following general recommendations are proposed:

1. Intensified taxonomic work for establishing the true specific status of Fijian Odonata. In some occasions a clear separation between species is not always possible in the field and requires further lab work. Identification keys for Fijian species need to be updated with more reliable features for distinguishing between closely related species.
2. Re-evaluation of the species diversity of Fijian archipelago. It is necessary that the specimens so far collected from the country to be checked in regard to the new taxonomic findings. Special attention was paid above to the Orthetrum sabina/serapia situation. Other species that must be treated with special attention include Agriocnemis exsudans, Ischnura heterosticta, Tramea transmarina as well as species with unclear taxonomic position, like Hemicordulia sp.
3. Mapping odonate distribution within Fijian islands. Visualisation of the data compiled for species distribution always helps in establishing gaps in the research, outlining future initiatives and planning urgent conservation measures. Such a mapping scheme is imperative and must be considered as a baseline for any study.
4. Combining the mapping scheme with environmental variables and biological/ ecological data for producing predictive habitat models for each species. It is considered as the pinnacle in the preliminary conservation planning process. Predictive habitat models could reveal the landscape features that approach the individual species requirements to the local environment. They, in combination with environmental variables and land use data, would visualise the potential of the local environment for supporting the habitat diversity and related species.

Cultural diversity

In order to avoid the loss of traditional knowledge of the region, we recommend the following:

1. Proper and complete documentation of the survey area and oral history be undertaken. This to be translated into the Fijian language with copies made available to the locals.
2. The old village site belonging to the people of Vunisea (and other villages) displaying a formation of fortification wall that is unique (and not recorded previously in Fiji), be cleaned and maintained by the local villagers.
3. Traditional knowledge of biodiversity overall is poor and training for the locals with the assistant of elders from the locality should be encouraged and supported.

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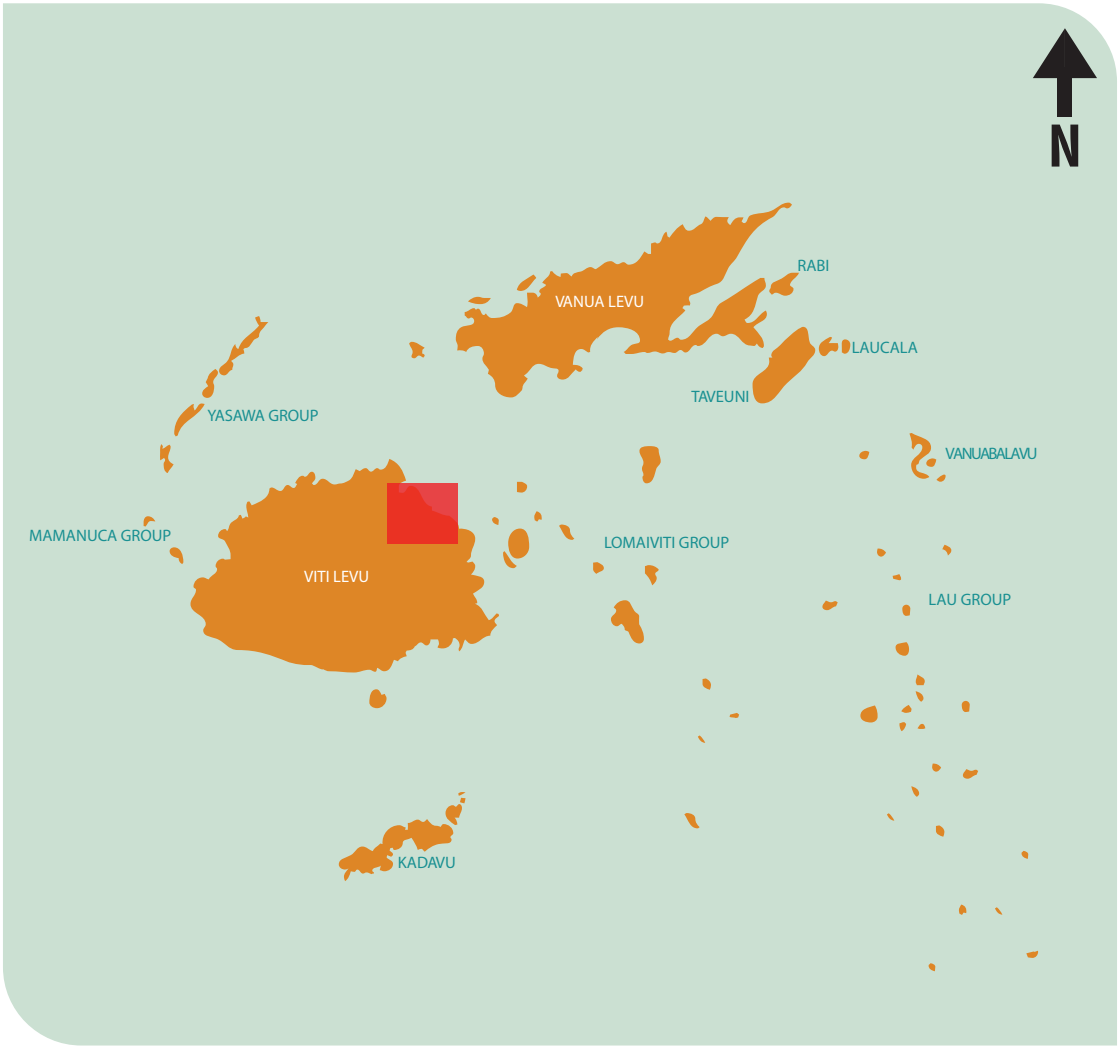
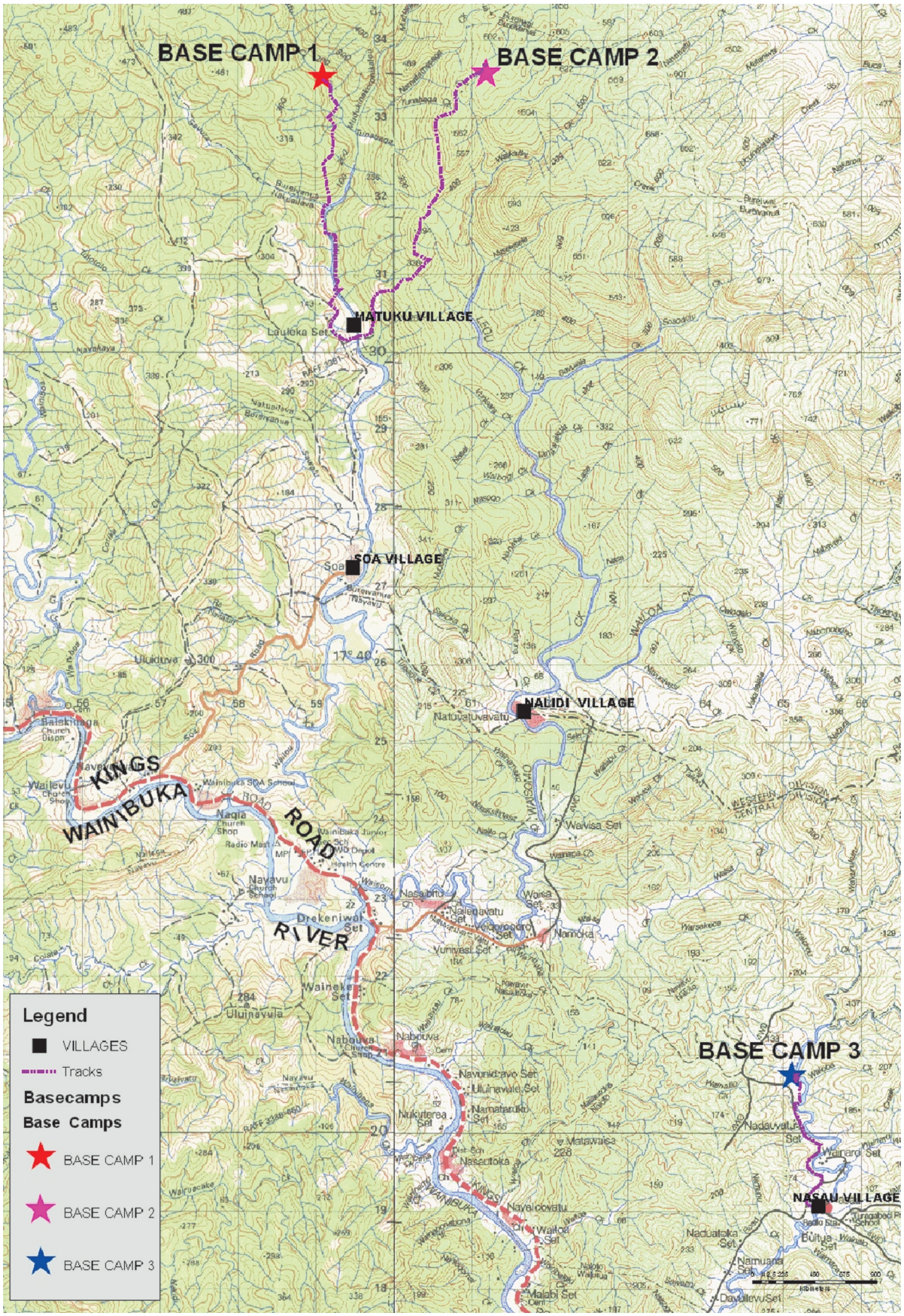
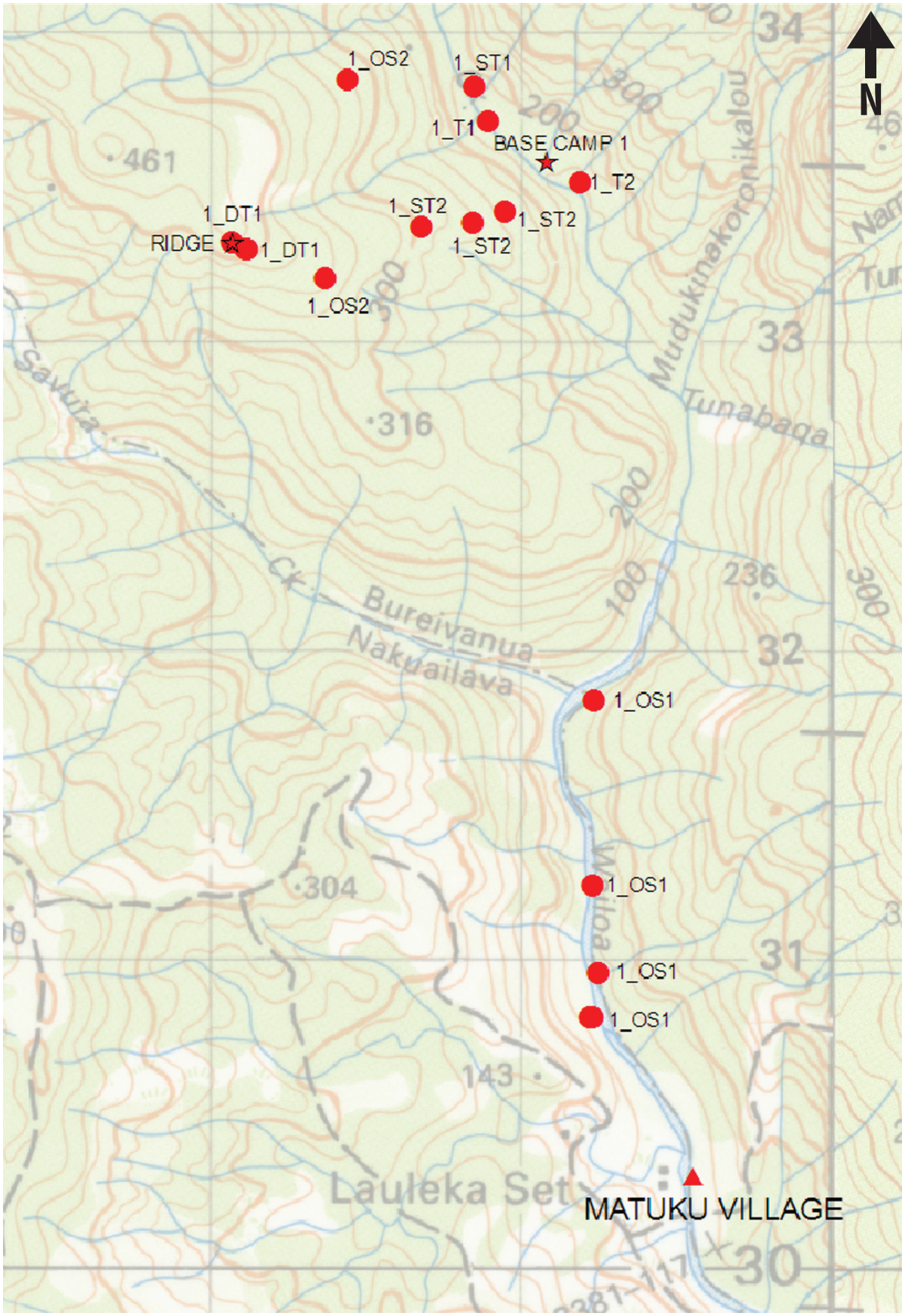
Raj, R. 1993. Extreme rainfall in Fiji and its socio-economic implications. Paper presented at the Western Pacific Workshop on Seasonal to Inter-Annual Climate Variability. Bureau of Meteorology, Melbourne, Australia.



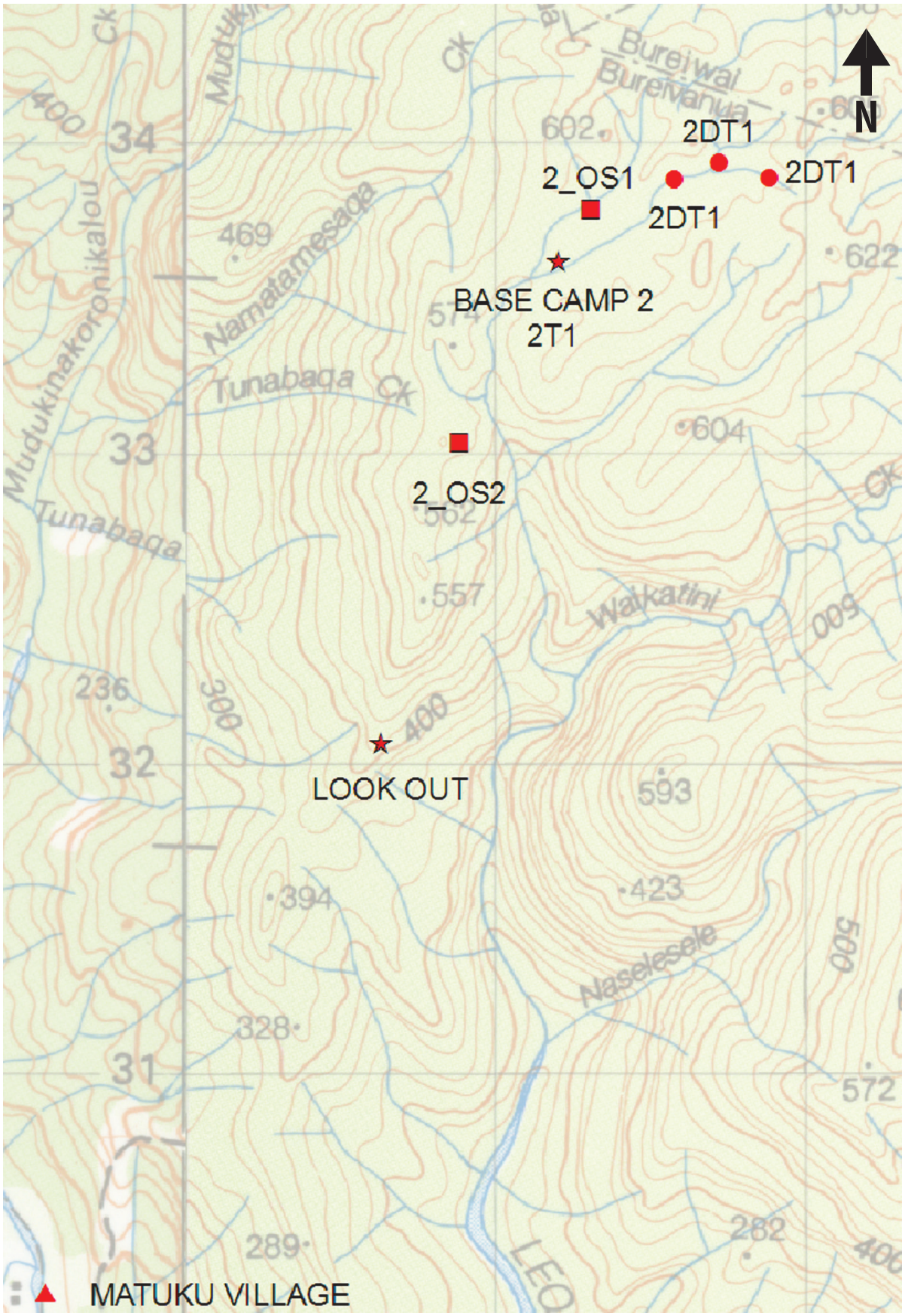
Map 1a. *Map of Fiji with location of Nakorotubu Range on Viti Levu*



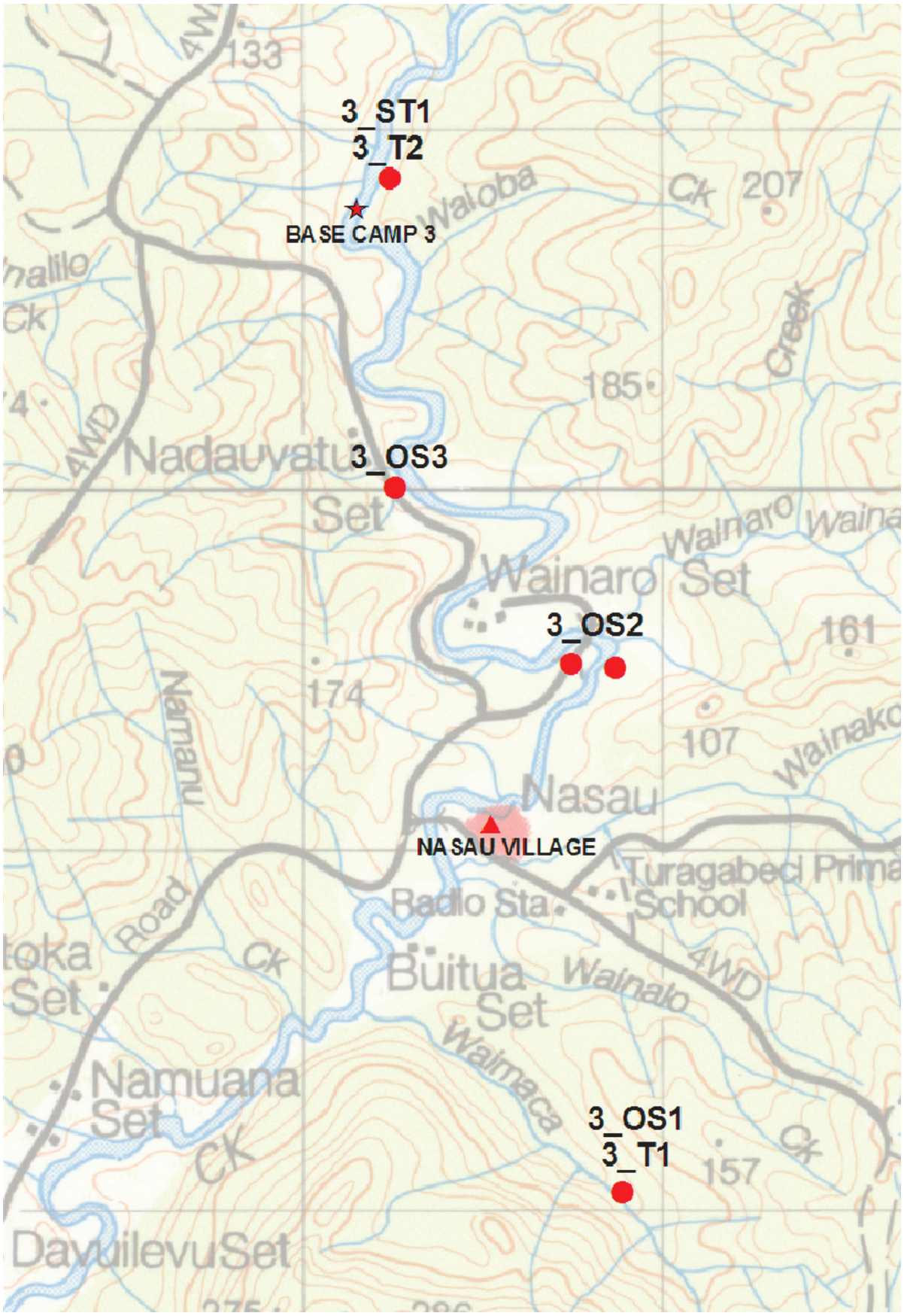
Map 1b. *Location of survey areas within the Nakorotubu Range*



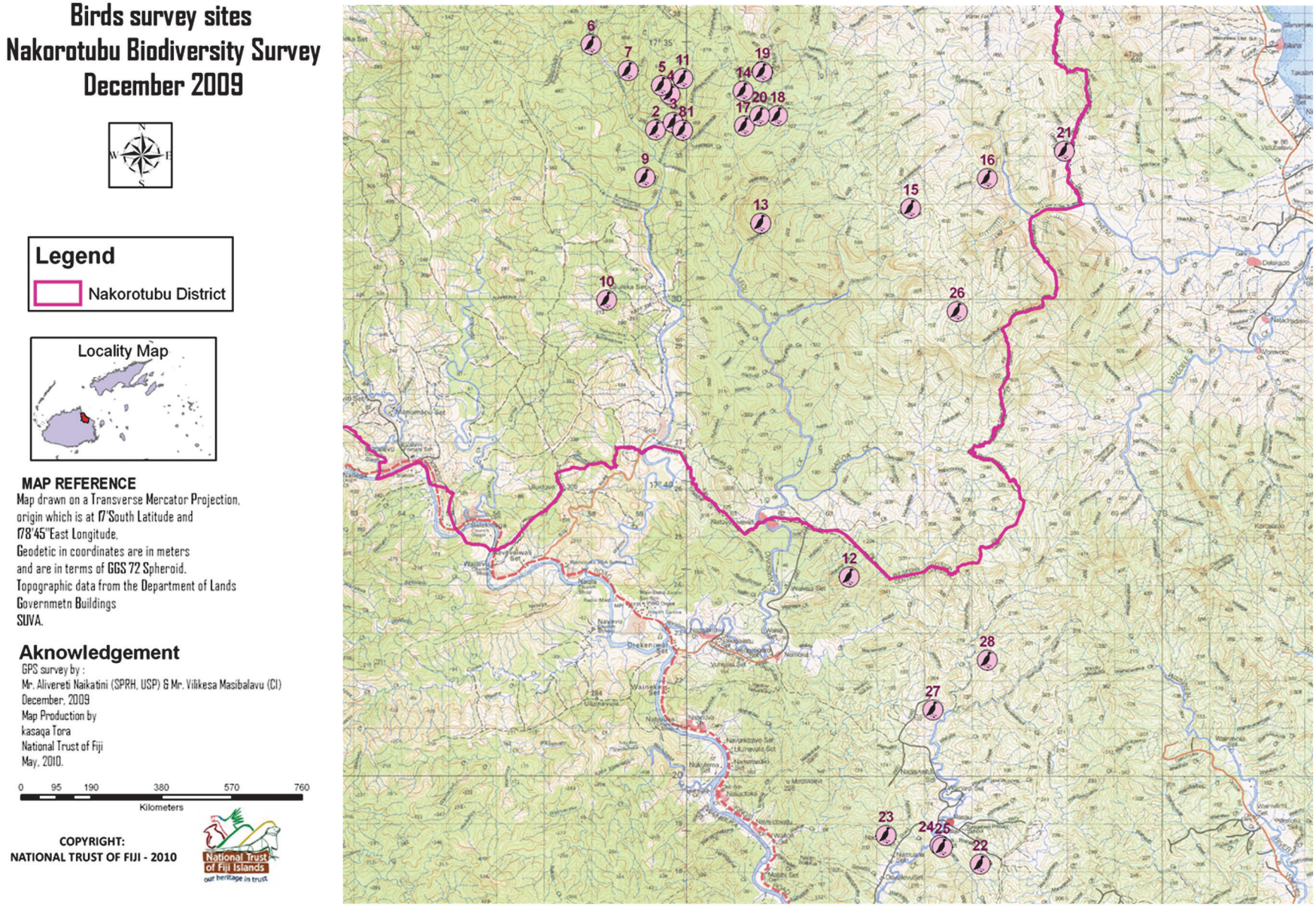
Map 2. *Herpetofauna sampling sites around Base camp 1 in the Nakorotubu Range*



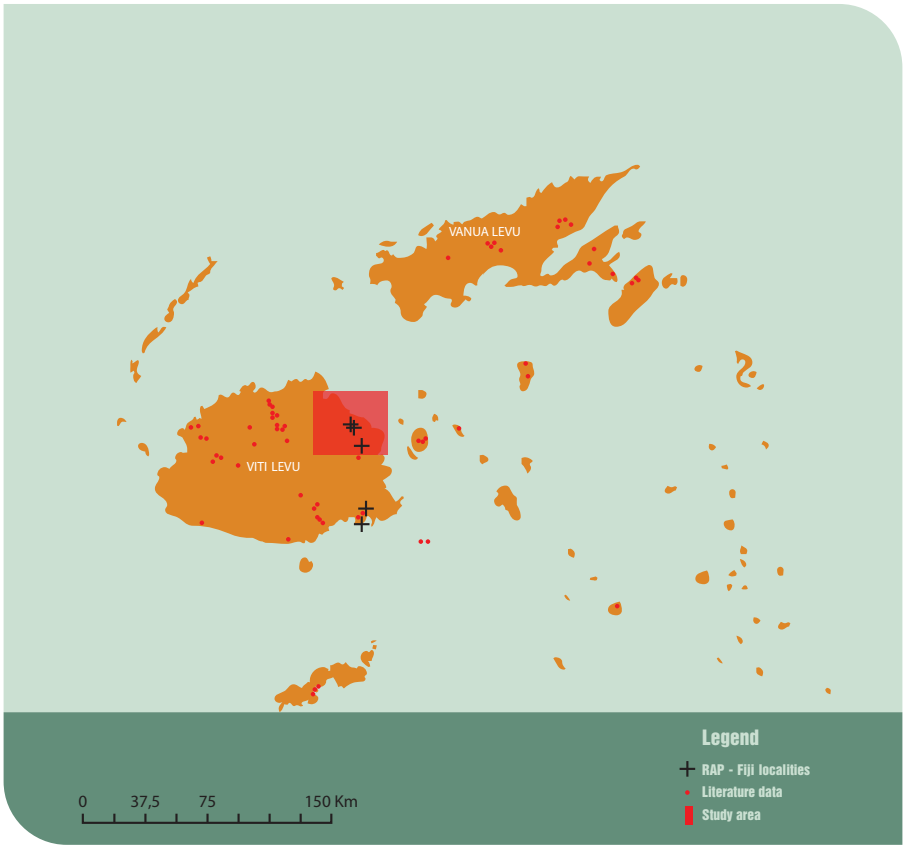
Map 3. *Herpetofauna sampling sites around Base camp 2 in the Nakorotubu Range*



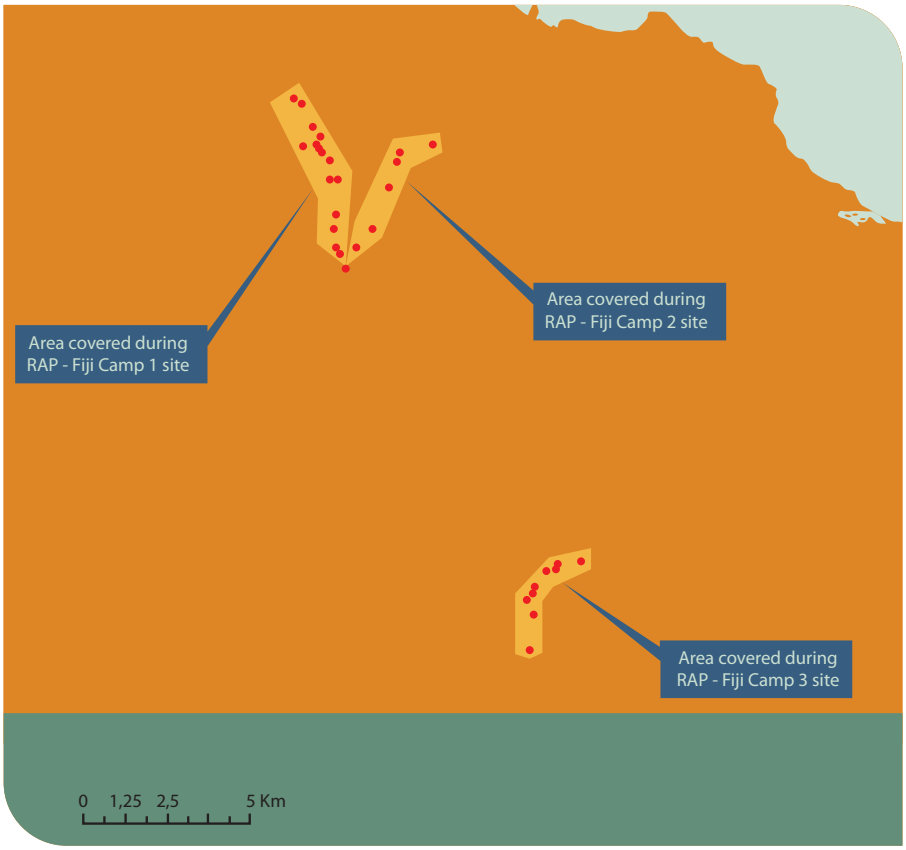
Map 4. *Herpetofauna sampling sites around Base camp 3 in the Nakorotubu Range*



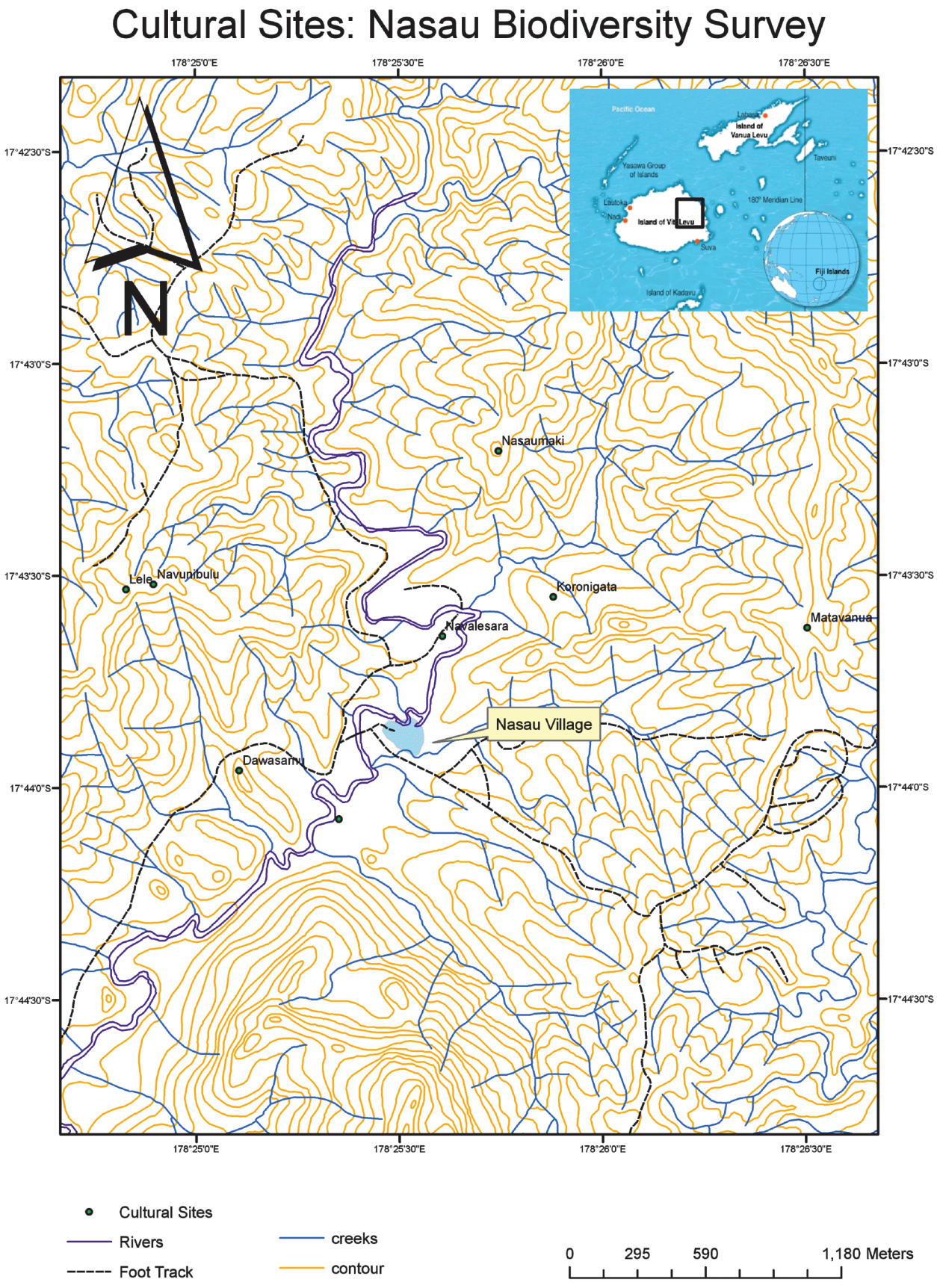
Map 5. *Bird survey sites in the Nakorotubu Range*



Map 6. *Total area coverage based on Odonata records from Fiji*



Map 7. *Total area coverage for Odonata during RAP - Fiji*



Map 8. *Cultural survey sites in the Nakorotubu Range*

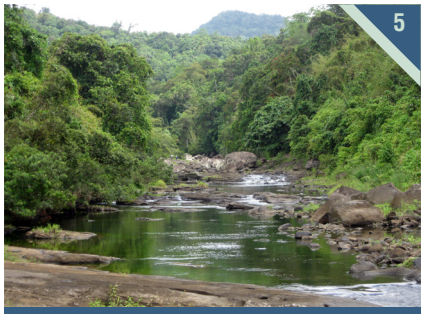
Species Photos

Upland Vegetation - Primary forest. Trees in general have smaller trunks and are partially covered in mosses and filmy ferns. Tree density is very high (MT)

Lowland vegetation - Primary forest around Nasau. Tree density is lower when compared to Upland Forest (MT)

Upland Vegetation - Freshwater Swamp dominated by *Pandanus vitiensis* (MT)

Karst or limestone forest. Limestone outcrop in a secondary forest system near Nasau Village (MT)

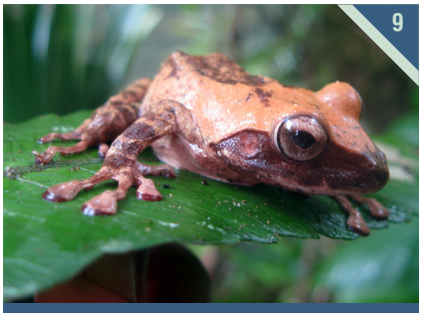


The section of Wailoa stream known as Olou is about 20m in width, with dense bamboo on either side (NT)

Emoia cyanura is an evasive native ground skink. They were easily caught with the sticky traps during the survey (NT)

Emoia parkeri is an endemic tree skink that is usually observed between 2m – 5m on tree trunks or branches (NT)

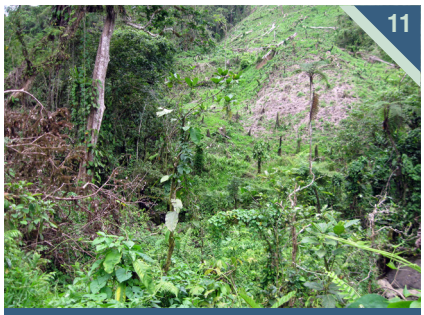
The eggs of the endemic skink species *Cryptoblepharus eximus* were found beneath large boulders along Olou of the Wailoa stream (NT)



Platymantis vitiensis were found in all three base camp sites (NT)

10

Eggs of *P. vitiensis* within the leaf axils of the *Pandanus* trees in Base camp 2 (NT)

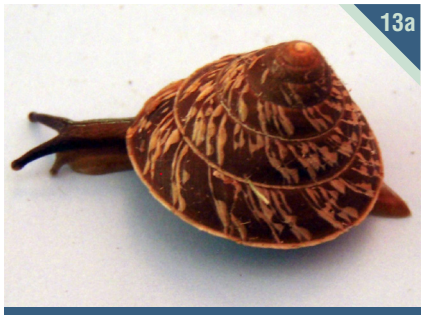


11

Nasau agricultural area (NT)

12

A living unidentified *Placostylus*, shell appears to be juvenile. Shell height 22 mm (GB)



13a

Living, endemic member of the family *Trochomorpha*, shell diameter 13 mm (GB)

13b

Living, endemic member of the family *Trochomorpha*, shell diameter 14 mm (GB)

14

Minnow trap (JL)

15

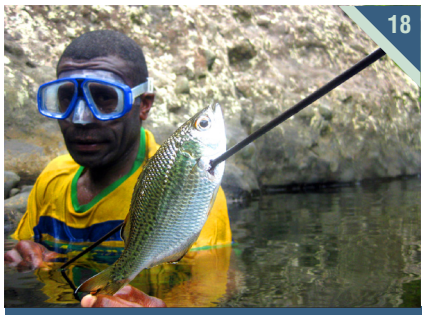
Hand collection (JL)

16

Net (JL)

17

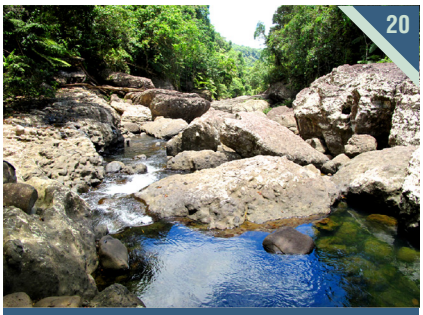
Tray nets and hand nets (JL)


18

Artisanal spear fishing (JL)


19

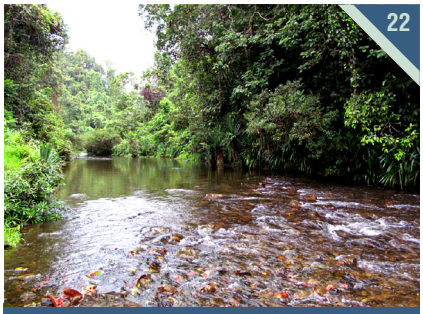
Habitat at Station 2 (JL)


20

Habitat at Station 5 (JL)


21

Habitat at Station 7 (JL)


22

Habitat at Station 10 (JL)


23

Varuna litterata (Fabricius, 1798) collected from Station 1 (JL)


24

Machrobrachium lar (Fabricius, 1798) collected from Station 2 (JL)


25

Machrobrachium lar (Fabricius, 1798) collected from Station 4 (JL)


26

Machrobrachium idae (Heller, 1862) collected from Station 9 (JL)

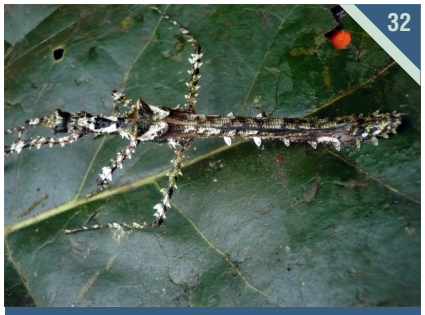
Machrobrachium latimanus (Von Martens, 1868) collected from Station 8 (JL)

Leaf litter sifting (HW)

Winkler sacks (HW)

Pitfall traps (HW)

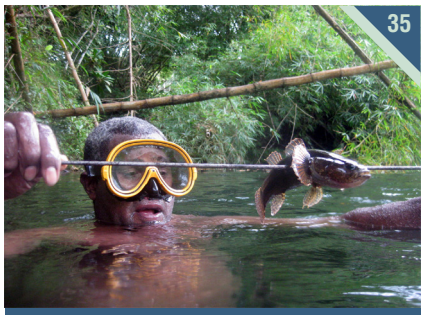
Nisyrus dipneusticum (female) (HW)



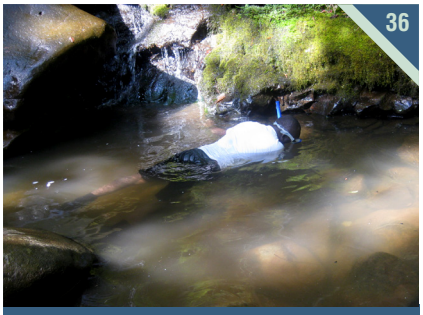
Nisyrus dipneusticum (male) (HW)

Taking water quality samples (DB)

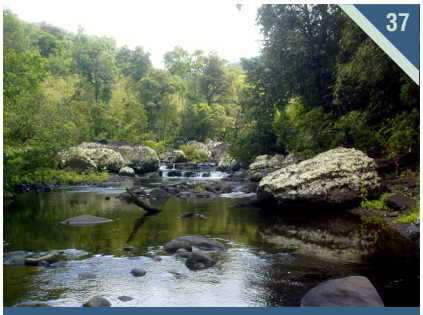
Pole seine net (DB)



Fijian hand-sling spear gun (DB)



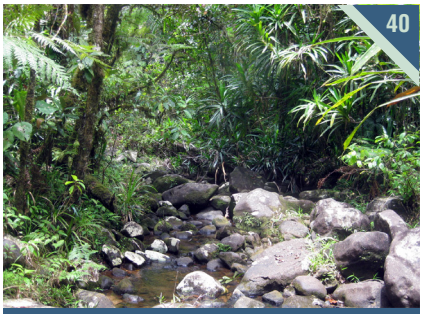
Underwater observation and photography (DB)



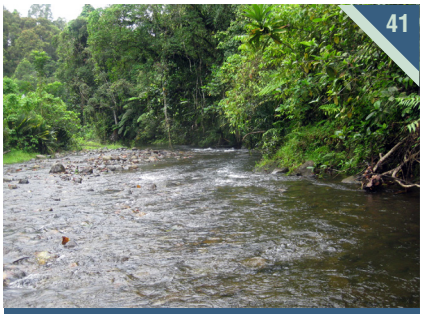
Fish sampling site 1 (DB)

Fish sampling site 4 (DB)

Fish sampling site 6 (DB)



Fish sampling site 7 (DB)



Fish sampling site 11 (DB)

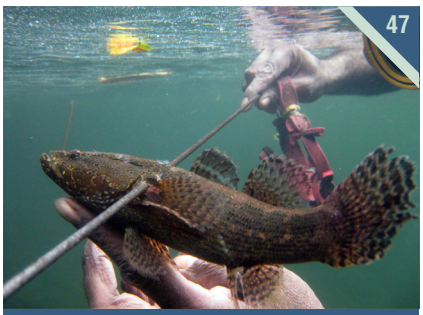
Green and brown algae at Site 5 (DB)

Anguilla marmorata (DB)

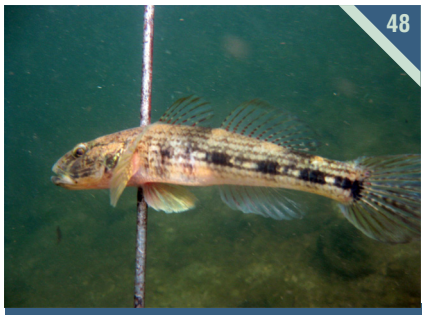
Anguilla megastoma (DB)

Awaous guamensis (DB)

Awaous ocellaris (DB)



Bunaka grinoides (DB)

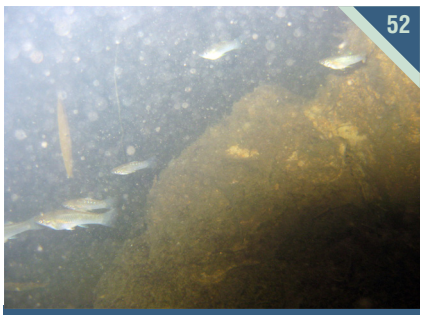


Glossogobius sp. (DB)

Gymnothorax polyuranodon (DB)

Kuhlia marginata (DB)

Sicyopterus lagocephalus (DB)



Gambusia affinis (DB)

Oreochromis mossambicus (DB)

Chapter 1

Flora and Vegetation Survey of the Nakorotubu Range, Ra and Tailevu Provinces, Viti Levu, Fiji.

Marika Tuiwawa and Arthur Whistler

Team members: *Sukulu Cavu and Ilimo Tulevu (Fiji Department of Forests), Isaac Rounds (Conservation International (Fiji), Seremaia Namanuloa (Matuku Village), Senilolia Heilala Tuiwawa and Manoa Maiwaqa (SPRH).*

SUMMARY

A series of eight 1000m^2 plots were used in selected forest types to assess the vegetation and flora of the Nakorotubu Range. Two principle vegetation types based on Mueller-Dombois & Fosberg (1998) description were observed in the study area. They are the Lowland Vegetation Type and the Upland Vegetation Type. Within these vegetation types four main plant communities or forest types were distinguished—(1) Secondary Forest, (2) Primary Forest, (3) Freshwater Swampland and (4) Karst or Limestone Forest. Only the secondary and primary forest types were quantitatively assessed and the other two briefly described qualitatively.

The flora of the Nakorotubu Range is described from a rapid biodiversity assessment survey. A total of 425 plant taxa (including 32 undetermined species) were recorded representing 118 families. This comprises 75 dicot families, 19 monocots, 2 gymnosperms and 21 fern and fern allies families. Two of the largest families include Orchidaceae with 20 genera and 26 species; followed by Poaceae with 19 genera and 20 species.

Of the 393 species identified 78% (307 species) are native with 35% (132) endemic species. The 307 native species comprise about 17% of the entire native flora for Fiji. The Angiosperms and Gymnosperms recorded during the survey added up to 337 species. Of these, 75% (251) are native species and of this native species, 53% (132 species) are endemic. A total of 64 exotic plant species were recorded during the survey of which six species are internationally recognized invasive species.

Two species of conservation interest include the Critically Endangered gymnosperm *Acmopyle sahniana* and the endemic palm *Calamus vitiensis* considered Least Concern in the IUCN Red list. The presence of *A. sahniana* in the study area has resulted in its range extensión to a third province of Ra in Fiji. The palm is known to occur in only two locations (small populations) on Viti levu- Wailekutu (within the vicinity of Nasaua village) and interior of Namosi, but common on Taveuni.

The findings are discussed in a conservation framework that highlights the taxonomic and/or ecosystem value of notable plant species and vegetation types.

INTRODUCTION

This botanical survey is part of a Rapid Assessment Program (RAP) conducted in the Nakorotubu Range, on the northeast portion of Viti Levu, the largest island of the Fiji group. The elevation of the study area ranges from about 100 m to 560 m on the highest peaks. Much of the mountainous interior area is covered with primary forest, but the vegetation of many other areas comprises secondary forest, agroforest, and village land. The primary or native forest is not homogeneous, because elevation, topography, and substrate all contribute to differences in species composition, density and distribution. The two principle vegetation types (Mueller-Dombois and Fosberg 1998) observed for the area includes the Low Land Rainforest and the Upland Vegetation. Hardly any botanical collecting has been done in this area, hence a reason for its selection as a RAP site.

A research team conducted a biological survey of the area from 30 November to 12 December 2009 with the results of the botanical survey included here. The botanical team was

headed by Marika Tuiwawa, Curator of the South Pacific Regional Herbarium (SPRH), University of the South Pacific (USP) assisted by Dr. Art Whistler – botanist from the University of Hawai'i, Botany Department; Senilolia Tuiwawa and Manoa Maiwaqa also from IAS/USP and Isaac Rounds – Conservation International (Fiji). Other scientists not specifically part of the botanical team also helped with some aspects of the field work, i.e., bringing in interesting specimens and assisting with the quantitative work in the plots.

The expedition

The expedition commenced when the team, about 30 strong, left Suva for Matuku (a settlement that is part of Soa Village), where they set up headquarters in the village meeting house. The team hiked north from the village to a site where Base camp 1 (S 17.59; E 178.36) was established on a flood plain next to a tributary of the Uloa Stream at about 162 m elevation. Reconnaissance trips were made from Base camp 1 into the surrounding forests during the rest of the arrival day and over the next two days, during which time plant specimens were collected, vegetation was sampled, and notes were taken. After three nights at this site, the research team hiked back to Matuku, where they spent the night. The next morning they hiked into the mountains east of Matuku and established Base camp 2 at S 17°35'53.4" ; E 178°23'02.4" next to Nalalau Stream at approximately 550 m elevation. Collecting trips were made from Base camp 2 into the surrounding forest, and the vegetation and flora surveys were conducted as they were at the first base camp.

After three nights at the second site, the research team members hiked back to Matuku, where they packed up and moved south to Nasau Village during the same afternoon. Because of the arduous work and hiking conditions over the previous three days, the team spent the next day doing short biological excursions around Nasau Village. The following day, the team hiked east into the mountains and set up Base camp 3 at S 17.72, E 178.42 for the following three nights near the Walotua River at approximately 50 m elevation. After doing their biological surveys, the team hiked back to Nasau Village, packed up, and returned to Suva on the 12th of December, ending the two-week excursion.

METHODOLOGY

The botanical survey comprised two main parts, flora and vegetation. All plants identified during the hikes and vegetation sampling were compiled into an annotated checklist (see Appendix 1). Plants that were fertile (bearing fruits and/or flowers) and those that were not able to be identified in the field were collected. The vouchers were labeled and trimmed or arranged to the requisite size and placed in a sheet of newspaper. Each was then given a collection number. The newspaper-bound specimens were then transported back to the village headquarters in Matuku for drying. At the end of the field survey the specimens were further processed at the South Pacific Regional Herbarium at the University of the South Pacific.

The vegetation was studied by taking samples of trees found in eight 1000 m^2 plots. Each plot measured 100 x 10m. Four plots were sampled in the Matuku area (Appendix 2: Tables 2A.1-A.4); two in the Nalidi area east of Matuku (Appendix 2: Tables 2A.5 and A.6); and two in the Nasau area (Appendix 2: Tables 2A.7 and A.8). These plots were placed in representative vegetation generally lacking recent disturbance. To facilitate the sampling, ten 10 x 10 m subplots were marked off within the plot with sticks placed in their corners as boundary markers. These subplots were usually in a straight line, but because it was sometimes difficult to find a suitable 100 m long patch of homogeneous vegetation, the subplots were sometimes arranged in a different pattern (depending upon the topography).

Once the plot boundaries were laid out, the field crew went through and measured every tree with a dbh (diameter at breast height) greater then or equal to 5 cm. This was done by means of a "dbh tape" wrapped around the trunk at breast height (1.3 m). These measurements and the identities of the sampled trees were recorded in a field book. Trees that could not be recognized immediately had their flowers, fruits, and/or leaves collected by means of a long pole or by someone climbing the trunk (when feasible). Non-tree species [epiphytes (orchids and ferns), lianas, vines, shrubs and herbs] were also recorded in each of the plots.

The tree data for the eight plots sampled is shown in Appendix 2. The determination of which tree or trees were "dominant" was based on biomass, using the parameter of stem cross-sectional area (basal area). This produced the column headed by "Basal Area." The species were arranged in order based on this parameter, from highest total basal area to the lowest. The column after the species name, headed by "No. Trees" (number of trees) is the total number of individuals of each species found in the plot. This is an indicator of frequency, but the trees may be small and have a low overall dominance because of a relatively small dbh. The third column, headed by "No. Trees >15 cm," is an indicator of typical tree size. If all of the trees of a species are under 15 cm dbh, it is likely that the species is small and not a canopy species (or all of the trees are young, an indicator of recent disturbance). The last column, headed by "Relative Dominance," is an important parameter for determining "dominance," i.e., which species has the greatest biomass in the sampled area. It is obtained by dividing the basal area of each species by the total basal area of all trees in the plot. The total basal area of all trees in the plot is found in the lower right-hand corner of the table. High numbers here (e.g., over 60,000 cm^2) usually indicate a lot of relatively large trees present.

RESULTS

Vegetation

The vegetation of the study area can be divided into several entities based upon elevation, topography, species composition and distribution, and density the life form of

the species that dominate (e.g., trees, grasses, etc.).

Two principle vegetation types based on Mueller-Dombois & Fosberg's (1998) description were observed in the study area. They are the Lowland Vegetation Type and the Upland Vegetation Type. Within this vegetation types four main plant communities or forest types were distinguished - (1) Secondary Forest, (2) Primary Forest, (3) Freshwater Swampland and (4) Karst or Limestone Forest. Only the secondary and primary forest types were quantitatively assessed and the other two briefly described qualitatively.

(1) Secondary Forest – Lowland vegetation, Base camp 1, north of Matuku settlement.

The first four plots sampled (see Appendix 2, Tables 2A.1-A.4 for details), around Base camp 1 had a forest type that was classified as Secondary Forest. Table 1.1 shows a summary compilation of the data from the four plots. The plots were placed in areas with elevations ranging from 120-320m.

The most common species in these plots was *Gironniera celtidifolia* (sisisi). In the four plots, a total of 140 individuals of this species were measured, which is roughly equal to the total for the next four most common species combined. It is a subcanopy or medium-sized tree, with only about a quarter of the measured individuals being larger than 15 cm dbh. Because of its relatively small size, it ranked only third in relative dominance. Other medium-sized Secondary Forest trees in Table 1.1 are *Dillenia biflora* (kuluva), *Pagiantha thurstonii* (tadano), *Litsea magnifolia* (lidi), and *Cupaniopsis concolor* (no common Fijian name). These species totaled 113 individuals, only 51 of which were 15 cm dbh or greater in diameter.

The overall dominant tree in the four plots was *Myristica castaneifolia* (kaudamu), which in primary forests is a canopy tree species. Its dominance often indicates that the forest has been logged for the large canopy species, allowing kaudamu to dominate the depleted canopy. The fact that few valuable timber species, especially conifers, such as *Agathis macrophyllum* (dakua) were present, suggest occurrence of logging at sometime in the past or perhaps extensive agriculture.

Table 1.1: Matuku Combined Secondary Forest Tree Composition (4 Plots).

Species	No. of Trees	No. > 15 cm	Basal Area	Rel. Dom.	Frequency
Myristica castaneifolia	40	18	28978	13%	4/4
Bischofia javanica	16	16	21980	10%	3/4
Gironniera celtidifolia	140	34	17989	8%	4/4
Trichospermum calyculatum	9	8	17447	8%	2/4
Burckella sp.	7	4	14314	7%	2/4
Endospermum macrophyllum	4	4	11313	5%	3/4
Dillenia biflora	37	18	10374	5%	4/4
Pagiatha thurstonii	37	18	10274	5%	4/4
Parinari insularum	15	9	9341	5%	2/4
Viticipremna vitilevuensis	1	1	8258	4%	1/4
Litsea magnifolia	23	7	7721	4%	4/4
Cupaniopsis concolor	16	8	5519	2%	3/4
Dysoxylum sp.	18	9	4156	2%	4/4
Haplolobus floribundus	10	7	4083	2%	4/4
Terminalia cf. capitanea	5	3	3114	2%	4/4
Syzygium sp.	12	2	3080	1%	2/4
Elaeocarpus sp.	5	2	2921	1%	4/4

The second most dominant tree in the four combined plots was *Bischofia javanica* (koka), which is a canopy tree. All sixteen measured individuals were over 15 cm dbh.

The average number of tree species above 5 cm dbh was 35 per 1000 m2 plot (ranging from 29 to 42) in these areas of Secondary Forest. This is a measure of tree biodiversity of a forest. The average number of individuals per 1000 m^2 plot was 155 (ranging from 122 to 190). This is a measure of the density of trees in the forest. In both of these categories, the Secondary Forest ranks below the primary forests discussed in the next two sections.

The presence in relatively high numbers of the tree species *Bischofia javanica, Trichospermum calyculatum, Dillenia biflora* and *Gironniera celtidifolia* but to a lesser extent *Vietchia joanis* is indicative of a secondary forest. This is especially true for the presence of *B. javanica, G. celtidifolia* and *V. joannis* as they are also associated with old village and garden sites.

Endospermum macrophyllum (kauvula) and *Trichospermum calyculatum* (mako) were represented in the four plots by 13 individuals, all but one of which was over 15 cm dbh. Given enough time, the dominant canopy tree species for the area sampled by the four plots would be expected to be primary forest dominated by trees such as *Planchonella* sp. (sarosaro), *Burckella* sp.(bau), *Syzygium* spp.(yasiyasi), and *Terminalia capitanea* (tivi).

Overall, the immediate area surrounding Base camp 1 is secondary forest infested with feral cattles and pigs which are abundant and the impacts of these animals on the environment is very evident i.e hoofprints, uprooted plants and dug up soil.

(2) Primary Forest – Upland Vegetation, Base camp 2, north of Nalidi village.

Upland Forest is a variation of rainforest that occurs on rugged topography between lowland and cloud forest, and in the study area was found around 500 m elevation. The two plots sampled around Base camp 2 north of Nalidi are best classified as Upland Rainforest vegetation because of the overall stature of the forest (generally stunted), high density of species and the mid-elevation mountainous topography. Table 1.2 shows a compilation of the data from the two plots (see Appendix 2, Tables 2A.5 and 2A.6 for details). The most common species in these plots were *Garcinia myrtifolia* (laubu, 90 individuals), *Canarium harveyi* (kaunicina, 57), *Calophyllum cerasiferum* (damanu dilo, 37), *Myristica castaneifolia* (kaudamu, 37), *Alstonia pacifica* (sorua, 36), and the tree fern *Cyathea hornei* (balabala, 32). *Gironniera celtidifolia* (sisisi), which is so characteristic of Secondary Forest, was virtually absent.

Table 1.2: Nalidi Combined Primary Forest Tree Composition (2Plots).

Species	No. of Trees	No. > 15 cm	Basal Area	Rel. Dom.	Frequency
Garcinia myrtifolia	90	14	9463	12%	2/2
Agathis macrophylla	4	4	5900	8%	1/2
Canarium harveyi	57	9	5652	7%	2/2
Myristica castaneifolia	37	9	5611	7%	2/2
Hernandia olivacea	25	7	4541	6%	2/2
Dacrydium nidulum	1	1	4416	6%	1/2
Syzygium sp.	23	8	3134	4%	2/2
Calophyllum cerasiferum	37	3	2312	3%	2/2
Retrophyllum vitiensis	8	3	2220	3%	2/2
Calophyllum neo-ebudicum	20	6	2163	3%	2/2
Parinari insularum	9	5	2140	3%	2/2
Garcinia pseudoguttifera	13	4	1760	2%	2/2
Alstonia pacifica	36	1	1715	2%	2/2
Myristica chartacea	15	3	1617	2%	2/2
Unknown	7	2	1574	2%	2/2
Hedycarya dorstenioides	14	3	1554	2%	1/2
Cyathea hornei	32	1	1368	2%	2/2

This forest is dominated (in basal area) by a combination of species. The first of these in the two sampled plots was *G. myrtifolia*, which had only 12% relative dominance. This tree is more of an understory species (only 14 of the 90 individuals in the two plots were over 15 cm in dbh) in lowland rainforest. The high number of individuals (averaging 45 per 1000 m^2 plot) of this medium-sized tree species, which gave it its prominence, is probably related to the dissected topography (ridges and steep slopes) of the two plots. The second dominant in Table 1.2, with 8% average dominance, was *Agathis macrophylla*. Two other conifer trees were shown in Table 1.2, *Retrophyllum vitiensis* (dakua salusalu, 3% in 8 individuals) and *Dacrydium nidulum* (yaka, 6% in a single tree). Two additional, smaller gymnosperm trees were also recorded in the plots, but both had a negligible relative dominance—*Podocarpus neriiformis* (kuasi, 22 trees) and *Gnetum gnemon* (sukau, 14 trees). Other canopy species include *Canarium harveyi* (kaunicina, 7% relative dominance), *Hernandia olivacea* (no Fijian name, 6%), *Syzygium* sp. (4%), *C. cerasiferum* (3%), and *C. neo-ebudicum* (damanu, 3%). As in the Secondary Forest, *M. castaneifolia* is both common and a co-dominant as a subcanopy tree.

The average number of tree species above 5 cm dbh was 55 per 1000 m^2 plot (ranging from 53 to 59). This is a measure of tree biodiversity in the primary ridge forests around Nalidi forests, and is relatively high (Plate 1) compared to the average of 35 species for the first four plots in Secondary Forest near Matuku. The average number of individuals per 1000 m^2 plot was 352 (ranging from 290 to 414). This is a measure of the tree density (number of individuals per area) in the forest, and compares to an average of 155 in the Secondary Forest plots - less than half. This indicates the greater density of trees in this type of ridge forest compared to secondary and lowland rainforest, probably caused by the steep dissected topography and higher elevation.

(3) Primary Forest - Lowland Vegetation, Base camp 3, northwest of Nasau village.

Lowland Rainforest is a variation of rainforest that occurs on flatland and gentle slopes in Fiji, ranging from near sea level up to about 600 m elevation. The two plots sampled northwest of Nasau are best classified as Lowland Rainforest based upon the dominant species and population structure. Table 1.3 shows a compilation of the data from the two plots. The most common species in these plots were *Canarium harveyi* (kaunicina, 62 individuals), *Gnetum gnemon* (sukau, 59), *Calophyllum vitiense* (damanu, 38), *Myristica castaneifolia* (kaudamu, 37) making up more than 50% of trees assessed. As in the Upland Rainforest, *Gironniera celtidifolia* (sisisi), which is so characteristic of Secondary Forest, was virtually absent.

This forest is dominated by a combination of species. The first of these in the two plots sampled was *C. vitiense*, which had 15% relative dominance. Other significant species with at least 4% relative dominance were *Gonostylus punctatus* (mavota, 13%), *M. castaneifolia* (10%), *Parinari insularum* (sea, 8%), *Canarium harveyi* (kaunicina, 7%), and *Endospermum macrophyllum* (kauvula, 7%). These six tree species made up 60% of the relatively dominant trees in the two plots.

The *C. vitiense, G. punctatus, P. insularum, E. macrophyllum, Agathis macrophylla*, and possibly *Syzygium* sp are all typical Fijian Lowland Rainforest canopy trees. Only two gymnosperm species were found in the plots, the 59 small individuals of the understory species *G. gnemon*, and the one large *A. macrophylla*. As in the Upland and Secondary Forests, the canopy tree *M. castaneifolia* was both common and a co-dominant in this forest (third in dominance, fourth in the number of individuals).

Table 1.3: Nasau Lowland Rainforest Tree Composition (2 Plots).

Species	No. of Trees	No. > 15 cm	Basal Area	Rel. Dom.	Frequency
Garcinia myrtifolia	90	14	9463	12%	2/2
Agathis macrophylla	4	4	5900	8%	1/2
Canarium harveyi	57	9	5652	7%	2/2
Myristica castaneifolia	37	9	5611	7%	2/2
Hernandia olivacea	25	7	4541	6%	2/2
Dacrydium nidulum	1	1	4416	6%	1/2
Syzygium sp.	23	8	3134	4%	2/2
Calophyllum cerasiferum	37	3	2312	3%	2/2
Retrophyllum vitiensis	8	3	2220	3%	2/2
Calophyllum neo-ebudicum	20	6	2163	3%	2/2

(Cont'd - Table 1.3)

Species	No. of Trees	No. > 15 cm	Basal Area	Rel. Dom.	Frequency
Parinari insularum	9	5	2140	3%	2/2
Garcinia pseudoguttifera	13	4	1760	2%	2/2
Alstonia pacifica	36	1	1715	2%	2/2
Myristica chartacea	15	3	1617	2%	2/2
Unknown	7	2	1574	2%	2/2
Hedycarya dorstenioides	14	3	1554	2%	1/2
Cyathea hornei	32	1	1368	2%	2/2

The average number of tree species above 5 cm dbh was 52 per 1000 m^2 plot (ranging from 42 to 60). This is a measure of tree diversity in the Lowland Rainforest around Nasau, and is relatively high (Plate 2) compared to the average of 35 for the first four plots in Secondary Forest near Matuku, and a little less than that found in the Upland Rainforest. The average number of individuals per 1000 m^2 plot was 243 (ranging from 160 to 326). This is a measure of the tree density (number of individuals per area) in the forest, and compares to an average of 155 in the Secondary Forest plots (less than half), but considerably less than in the dense Upland Rainforest.

(4) Freshwater Swampland, Upland Rainforest, Base camp 2, north of Nalidi village.

Due to time constraints a brief qualitative assessment was carried out for this uncommon vegetation type. The Freshwater Swampland is part of a system of "landlocked" body of water found amongst the undulating hills (Plate 3) that form the headwaters of the Nalalau River. Water that streams out of this swamps is slow moving. Similar high altitude wetland systems are found in the highlands of Taveuni (Lake Tagimoucia), Viti Levu (Nadrau swamps), and Vanua Levu (Bua and Macuata).

In the study area the swampland is dominated by the endemic pinescrew tree *Pandanus vitiensis*. Other common species observed included the tree *Macaranga* spp.,*Hedycarya* sp., *Dillenia biflora, Gnetum gnemon*, the sedges *Hypolytrum nemorum* and *Mapania parvibracteata*, the liana *Faradaya* sp. and *Freycinetia* spp. and the aboriginal introduced *Bambusa vulgaris*.

Vegetation along the fringes of the swamp is thick and comprise mostly of shrubs and vines. The shrubs include *Dolicholobium* sp., *Fagraea beteroana*, *Neuburgia* sp., *Geniostoma* sp., *Astronidium* spp. and *Syzygium* spp. The vines include *Geitonoplesium cymosum*, *Smillax vitiense*, *Piper* sp., *Lygodium* sp., *Freycinetia* spp. and *Epipremnum pinnata*. The epiphyte flora is diverse with ferns and orchids being the most common.

(5) Karst Forest or Limestone Forest, Base camp 3, outskirts of Nasau village.

Due to fatigue and time constraints a brief qualitative assessment was carried out for this unique forest type. For the Nakorotubu Range this forest type is restricted to the immediate surrounding of Nasau Village. Most of the limestone outcrops encountered had intact forest cover (Plate 4) except for those systems near roads and villages.

Overall the dominant native trees in terms of biomass are *Pometia pinnata*, *Dysoxylum richii*, *Calophyllum vitiensis*, *Myristica chartacea* and *Palaquium vitilevuense*. These tree species on average have dbhs that are ca. 45 cm and form the bulk of the trees in the canopy layer. In sections of the forest that are least disturbed the forest has a closed canopy with an occasional emergent like Endospermum macrophyllum. Native tree species that form the subcanopy layer are *Alangium vitiense*, *Garcinia pseudoguttifera*, *Dendrocnide vitiense*, *Dillenia biflora*, *Gironniera celtidifolia*, *Dolicholobium latifolium* and saplings of most of the canopy trees.

In sections of the forest where it is relatively intact and the canopy is closed, there is very little ground cover except for a thin layer of leaf litter and terrestrial orchids like *Calanthe triplicata*, *Peristylus aliformis*, *Corymborkis veratrifolia*; the ferns *Tectaria latifolia*, *Trichomanes boryanum*, *Selaginella breynioides*. Some of the more common creeping plants and lianas include *Calamus vitiense*, *Entada phaseoloides*, *Connarus pickeringii*, *Derris malaccensis* and *Freycinetia* spp.

Common epiphytes observed included the ferns *Asplenium nidus*, *Epipremnum pinnatum*, *Pyrrosia adnascens*, *Ophioglossum pendulum*, *Rhaphidophora spuria* and *Davallia solida*. Other terrestrial species include *Phymatosorus scolopendria*, *Tectaria* sp. and *Nephrolepis biserrata*.

Flora

The flora of an area comprises all the plants that are found there. Based on the specimens collected (see Appendix 3 for a list of voucher specimens) and visual identification by the field team, 425 vascular plant species were recorded (see Appendix 1) including 32 undetermined species. This can be broken down into 270 dicots, 91 monocots, 7

gymnosperms, and 57 ferns and fern allies. A total of 223 voucher specimens were collected (see Appendix 3) during the field work.

There were 108 families identified during the survey. This comprised of 75 dicot families, 19 monocots, 2 gymnosperms and 21 fern and fern allies families. There were 317 genera recorded comprising 197 dicots, 77 monocots, 7 gymnosperms and 36 fern and fern allies.

The four largest families were Orchidaceae with 20 genera and 26 species; followed by Poaceae with 19 genera and 20 species; Rubiacea with 15 genera and 23 species and Euphorbiacea with 11 genera and 17 species.

For the 393 species identified 78% (307 species) are native with 35% (131) endemic species. The 307 native species comprise about 17% of the entire native flora for Fiji. With more time to collect in this area and more plots, no doubt the number of native plant species recorded in the area would significantly increase.

The Angiosperms and Gymnosperms recorded during the survey added up to 337 species. Of these, 75% (251) are native species and of this native species, 53% (132 species) are endemic. Endemism for Fiji ranges from 35% in lowland rainforest to 60% in the rich upland and cloud forest (Watkin 1995) especially in southeast Viti Levu. This is similar to plant species endemism for low land forest systems in Fiji

The most significant species in a flora are threatened or endangered species. Although there are no officially listed Threatened or Endangered Species by the government of Fiji, the IUCN has a "Red List" of plants of concern in the Pacific. However, the list is quite out of date and full of errors. There are many species that are rare in Fiji (some known from only a single collection) (Tuiwawa 1999) and others are probably extinct (although the IUCN list notes only one species being officially classified as "extinct"). Although some of the voucher specimens collected during this survey could not be identified by the time this report was written, none of the species recorded could be identified as "Threatened" or "Endangered, except the Critically Endangered gymnosperm *Acmopyle sahniana* and the endemic palm *Calamus vitiensis* considered Least Concern in the IUCN Red list. The palm is known to occur in only two locations (small populations) on Viti Levu, Wailekutu (including vicinity of Nasaua village) and interior of Namosi but common on Taveuni.

Invasive plants

A total of 64 exotic plant species were recorded during the survey. The first six are internationally recognized invasive species (see web search on the Global Species Database or http//www.issg.org/database/species/search.asp/st=100ss) and the last thirteen species are known to show invasive characteristics (Table 1.4) and have the tendency to grow or encroach into forest beyond where they were originally introduced. This was not only observed in the surveyed area but elsewhere in Fiji.

Table 1.4: List of recognized invasive species and potential invasives in the areas surveyed. A brief description of where they are found and local abundance/distribution is also provided.

Family	Botanical Name	Local name	locality	Abundance
Melastomataceae	*Clidemia hirta*	Qatima, koster's curse	All forest and vegetation types	Widespread & very common
Asteraceae	*Mikania macrantha*	Mile a minute	All forest and vegetation types	Widespread & common
Poaceae	*Arundo donax*	Gasau ni vavalagi	Along roadside, villages and river flats.	Uncommon
Verbenaceae	*Lantana camara*	Lantana	Roadsides, paddocks and other degraded vegetation types,	Uncommon
Bignoniaceae	*Spathodea campanulata*	African tulip tree	Secondary forest, fallowed land, near gardens & settlements.	Widespread & very common
Asteraceae	*Sphagneticola trilobata*	Wedelia	Near villages, settlements & roadsides.	Locally common
Convolvulaceae	*Merremia peltata*	wa bula, merremia	Widespread forest opening and degraded vegetation.	Widespread and common

(Cont'd - Table 1.4)

Family	Botanical Name	Local name	locality	Abundance
Zingiberácea	*Hedychium coronarium*	cevuga vula	Disturbed stream/ river flats & village outskirts.	Locally common
Passifloraceae	*Passiflora foetida*	loli mei rakalavo	Secondary forest and forest openings.	Locally common
Piperaceae	*Piper aduncum*	Onalulu, yaqoyaqona	River and creek embankment.	Locally common
Zingiberaceae	*Zingiber zerumbet*	Cagolaya	Secondary forest.	Common
Asteraceae	*Ageratum conyzoides*	Botebotekoro	Secodary forest, village outskirts, river flats.	Very common and widespread
Musaceae	*Musa velutina*	Ornamental banana	Outskirts of villages a& roadsides	Common
Fabaceae	*Derris malaccensis*	duva ni niuqini	River and creek embankment.	Locally common
Verbenaceae	*Gmelina aborea*		Pastures and village outskirts.	Uncommon
Solanaceae	*Solanum torvum*	Prickly solanum	Secondary forest, creek, river flats.	Common
Meliaceae	*Swietenia macrophylla*	Mahogany	Near villages & plantations.	Locally common
Zingiberaceae	*Costus speciosus*		Roadsides, along tracks to gardens.	Common
Zingiberaceae	*Alpinia purpurata*		Roadside, outskirts of villages & settlement.	Common

DISCUSSION

The study area north of Matuku settlement is secondary forest characterized by species such as *Bischofia javanica* (koka), *Gironniera celtidifolia* (sisisi), *Dillenia biflora* (kuluva), *Trichospermum calculatum* and *Schizostachyum glaucifolium* (bitu dina). The description of this forest being disturbed is reinforced by the number of anthropogenic trees, such as *Artocarpus altilis* (breadfruit), *Vietchia joannis*, and *Citrus* spp., which are present in more exposed "sunny" places in this study area. No conifers were found in any of these plots but with the presence of *S. glaucifolium* this usually suggests some kind of logging or similar development has probably occurred there in the past. Despite the disturbance, which does not appear to be very recent, only a single tree, *Spathodea campanulata* (African tulip-tree), is an alien species among the 619 trees measured. Alien or exotic herbaceous species like *Clidemia hirta*, *Hedychium* sp., *Zingiber zerumbet* and *Crassocephalum crepidioides* and shrubs like *Solanum torvum*, *Leucaena leucocephala* and *Piper aduncum* are the more common species in the area, especially along stream flats. Overall, the disturbed forest in the area surveyed does not have any significant alien tree invaders whilst elsewhere in Secondary Forest in Fiji, the African tulip-tree is a serious native forest invader.

The Upland Rainforest in the area north of Nalidi village is characterized by high species diversity, high tree density, and relatively low growing (stunted?) trees. The dominant species, *Garcinia myrtifolia* (laubu), is typically a sub canopy species, but the conditions on ridges favor its growth over the canopy species of nearby lowland forest. The top six tree species that make up about 50% relative dominance for the two plots sampled included typical dominant canopy and emergent tree species that would be observed in similar forest types in Fiji. These included *Agathis macrophylla*, *Hernandia* sp., *Canarium* sp. and *Myristica* sp. Ten other tree species had at least 3% relative dominance in the two plots sampled. *Gironniera celtidifolia* (sisisi), which is characteristic of Secondary Forest, was virtually absent (only 6 individuals with negligible relative dominance were measured in this forest). The average size of the trees is relatively small, with only 15% of the individuals measuring over 15 cm dbh. This compares to the Secondary Forest, which had 40%, and Lowland Rainforest, which had 24%. Because of this and the dissected topography, this native forest is not of much commercial interest, but is of great biodiversity inter-

est. Not a single tree measured was an alien species, which shows how good this forest is in terms of its intactness and biodiversity. Overall in the area assessed the only alien plant species observed was a few *Clidemia hirta*, an invasive species naturalized in Fiji's forests. All tree species documented are native and those that would be typically found in a primary forest. The high diversity of gymnosperms (seven species out of the nine species known for Fiji) augurs well for the pristine state of the forest in the area.

The forest sampled north of Nasau village is primary Lowland Rainforest. It has high species diversity like the Upland Rainforest north of Nalidi village. The dominant species in the plots was *Calophyllum vitiense*, with a relative dominance of 15%. Most of the other large trees species are typical Lowland Rainforest canopy species like Gonystylus sp., *Myristica* sp., and *Parinari* sp., with no monodominant species. These four trees make up more than 50% relative dominance of all trees sampled in the two plots. No secondary species were present including *Gironniera celtidifolia* were recorded in the plots. Also, the general lack of alien tree species except for a few naturalized invasive species of *Clidemia hirta* and *Mikania macrantha* found in the plots showed how pristine this forest is.

When compared with other similar forest systems in Fiji (especially Sovi Basin, Nakauvadra) the Nakorotubu forests are relatively pristine, judging by the form of the vegetation (closed canopy forest) as well as the general absence of most alien weeds. Only a few naturalised alien weedy species were found during the survey (restricted to forest gaps and exposed "sunny" areas on flood plains along streams), which included *Crassocephalum crepidioides* (thick head), *Mikania micrantha* (mile-a-minute vine), *Clidemia hirta* (Koster's curse), and *Piper aduncum*.

In summary, the Nakorotubu Range is home to large areas of native forest, both Primary and Secondary Rainforest. It is rich in species, and most of it is virtually free of invasive tree species. Every effort should be made to work with the local villagers to preserve these forests.

CONCLUSIONS AND CONSERVATION RECOMMENDATIONS

Future surveys

The following recommendations are made:

1. More collections are needed. The checklist of vascular species present is only preliminary, since all the fieldwork was done over only thirteen days. The list probably includes only 60 to 75% of the species present. The orchids and ferns are much underrepresented, since many of the species are restricted to the tops of trees, where they were not observed. (Fiji has about 150 native species of orchid and ca. 300 species of ferns). The most difficult groups during the present work included the genera *Psychotria* (76 native species in Fiji), *Syzygium* (28 species), and Gesneriaceae (37 species), and the Lauraceae family (34 species).
2. The forests on limestone areas around Nasau village should also be explored in more detail, since this is an entirely different substrate than most of the other forests in the area. With current developments (road works, agriculture) in progress nearby this should be treated as a priority.
3. A thorough assessment of the relatively intact freshwater swampland that is the source and headwater of most of the major rivers originating from this mountain range should be undertaken as soon as possible. Such a system is rare for Fiji and all the currently known high altitude swamps (two - Nadrau Swamp, Lake Tagimoucia) are very much threatened and already impacted by development.

Conservation recommendations

1. The Nakorotubu mountain range area should be included and nominated as a key or important biodiversity area for Fiji and efforts to list it as a "protected area" for Fiji should be pursued.
2. Awareness regarding the ecological and botanical importance of the area to the landowners should take place as soon as possible for the purpose of protecting the area. Currently logging operations are underway on the northern part of the mountain range.

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Chapter 2

Herpetofauna of the Nakorotubu Range, Ra and Tailevu Provinces, Viti Levu, Fiji.

Nunia Thomas

Team members: *Orisi Ratulevu (Matuku Village), Kiniconi Tikoinakavu (Nasau Village).*

SUMMARY

A total of ten frog and reptile species were documented from the Nakorotubu Range, Ra and Tailevu Provinces, Fiji representing approximately 24% of Fiji's 33 presently known terrestrial herpetofauna. This included one frog species, one toad, five skinks, two geckoes and one snake. All species were observed in relatively low abundances.

Three of the species are endemic to Fiji (*Platymantis vitiensis*, *Emoia concolor* and *E. parkeri*). With the exception of the introduced cane toad (Bufo marinus), all remaining species are native to Fiji and the Pacific.

Several threats to the herpetofauna in the area were identified and are discussed in light of potential mitigation measures and future research.

INTRODUCTION

Fiji is home to 33 species of terrestrial herpetofauna: three frogs (two endemic species), four iguanas (two endemic species), four snakes (two endemic species), 10 geckoes (two endemic species) and 10 skinks (six endemic species) (Morrison 2003, Watling et al. 2010). Over forty percent of these are endemic, with possibly more (new) endemic species to be described in future.

Despite the wide geographic distribution of Fiji's native terrestrial herpetofauna, their conservation status is unknown. With the exception of the Fiji crested iguana (*Brachylophus vitiensis*) and the Fiji ground frog (*Platymantis vitianus*), there has been no recent assessment of the population status of any of Fiji's terrestrial herpetofauna other than accounts from opportunistic surveys conducted by visiting biologists and through baseline biodiversity surveys (Bustard 1970, Gibbons 1981, 1984, Zug 1985, 1991, Zug and Ineich 1983, Harlow and Biciloa 2001, Worthy 2001, Morrison 2003a, 2003b, 2003c, Kuruyawa et al. 2004, Morrison et al. 2004, Morrison 2005, Thomas, 2006; Harlow et al. 2007; Thomas 2008; Watling 2010). To date, no specific herpetofauna surveys have been conducted in the Nakorotubu Range and consequently, its herpetofauna diversity is poorly known.

The primary aim of this survey was to identify the herpetofauna species found in the Nakorotubu Range using a combination of nocturnal and diurnal active surveys and sticky trap surveys. In addition, we also wanted to identify potential threats to the herpetofauna community in the area.

METHODS AND SITE DESCRIPTIONS

Site descriptions

Base Camp 1: Olou, Nabavatu Stream, Ridge (Map 2, Appendix 4)

The section of Wailoa stream known to the people of Matuku as Olou (between Matuku Village and Rest Spot 1 on Map 2; Plate 5) was at least 20 m in width with large boulders both within the stream and along the stream bank. Riparian vegetation was severely disturbed with intermittent agricultural areas and patches of bamboo. Cattle hoof prints were obvious along

the trail.

Nabavatu Stream (between night transect 2 [T2] and sticky trap transect 1 [ST1] in Map 3) was on average 10 m in width, with big boulders within the stream and on stream banks. Riparian vegetation was again severely disturbed with cattle hoof prints obvious along the river bank and along the trails.

The slope extending from T2 to day transect 1 (DT1), though densely vegetated by trees with high canopy cover, was quite disturbed with obvious feral cattle and feral pig presence. Undergrowth was sparse particularly in areas with cattle hoof prints.

Despite the obvious disturbance, the trees and stream vegetation displayed good frog, gecko and skink habitats.

Base Camp 2: Matuku Village, Look out, Base camp 2, Montane forest. (Map 3, Appendix 4)

The track from Matuku Village to the look-out point enroute to Base camp 2 was dominated by agricultural land and cattle pasture land. Streams around Base camp 2 were slow flowing with dense vegetation cover. Stream widths were relatively similar, averaging 2 m. Stream vegetation was relatively undisturbed being dominated by pandanus and native riparian plants. The most disturbed part of the forest surrounding Base camp 2 was the main track. Epiphyte cover on trees was high. There were no signs of feral cattle presence. The area displayed ideal habitats for native tree skinks, geckoes and frogs.

Base Camp 3: (Map 4, Appendix 4)

Base camp 3 was located within an abandoned cattle pasture field and banana plantation. The stream and riparian vegetation were relatively disturbed and open with intermittent stands of native riparian plants such as Pandanus and *Inocarpus fagifer*. Stream width averaged at 10 m, with rare encounters of riffles and pools. Stream vegetation displayed ideal habitats for Fiji's native frogs, geckoes and skinks in some places.

Survey methods

Opportunistic diurnal surveys (OS), standardized diurnal visual encounter surveys with a pair of binoculars (DT), standardized nocturnal visual encounter surveys (T) and sticky traps (ST) methods were used to assess herpetofauna biodiversity and potential threats in the survey sites.

Skinks are more likely to be seen during day, particularly during hot and sunny conditions. Diurnal transect surveys were thus conducted along trails enroute to Camps 1, 2 and along stream edges – particularly amongst boulders and exposed trees, and in forest habitats surveyed by other survey teams in the expedition: vegetation and flora survey sites and freshwater fauna survey sites (1_DT1 in Map 2; 2_DT1, 2, 3 in Map 3; 3_DT1, 2, 3 in Map 4). The opportunistic diurnal surveys (OST) began at 08:00 and ended at 17:00 each day from the 30th November – 03rd December and 05th – 10th December, 2009. The team had a minimum of two searchers at any one time.

Frogs and geckoes are active and more visible at night. Standardized 2-hour nocturnal surveys (T) with a minimum of two observers at any one time were conducted along the major streams: Nabavatu Stream and its tributaries (1_T1, 1_T2 in Map 2), at Base camp 2 (2_T1 and 2_T2 in Map 3); and along the riparian vegetation along the Wailotua Creek at Base camp 3 (3_T1 and 3_T2 in Map 4). These were conducted over five nights (Appendix 5). The standardized surveys usually commenced at around 20:00, ending two hours later. Captured ground and tree frogs were given a frog number (M #) and toe-clipped. The toe-clips were stored in ethanol vials for future DNA analysis.

Surveys using sticky traps to capture skinks and geckoes were also conducted at ideal locations around Base camp 1 (1_ST1 in Map 2), Base camp 2 (2_ST1 in Map 3), and Base camp 3 (3_ST1 in Map 4). The traps were left out for 2 hours during hot days; or in shady areas overnight (Table 1) and collected early the next morning.

Environmental variables such as air temperature (°C), water temperature (°C), weather conditions (rain) and cloud cover (%) were taken at the beginning and end of each survey. Moon phase was also recorded for nocturnal surveys. Habitat characteristics and other basic ecological and biological information of herpetofauna found were recorded. Observations on possible threats to herpetofauna species and populations were noted.

RESULTS

Environmental Variables

Weather during the expedition was predominantly cloudy with light drizzles with only two days of strong sunshine. Average air and water temperature were 23°C and 22°C respectively.

Species Diversity and Abundance

General herpetofauna

Nine species were observed encountered the survey (Table 2.1), including one frog, one toad, three skinks, and two geckoes (captured and identified). The eggs of one unconfirmed species of skink were encountered – it would most likely have been the eggs of the endemic *Cryptoblepharus eximus*.

Three of the nine species observed are endemic to Fiji: Fiji tree frog (*Platymantis vitiensis*), Fiji copper headed skink (*Emoia parkeri*) and the Fiji green tree skink (*E. concolor*); five are native: Blue-tailed copper-striped skink (*E. impar*), Brown-tailed copper-striped skink (*E. cyanura*), Giant forest gecko (*Gehyra vorax*), Skink-toed gecko (*Nactus pelagicus*) and Pacific boa (*Candoia bibroni*); and one introduced and invasive species: Cane toad (*Bufo marinus*).

Table 2.1: List of herpetofauna species observed or reported in the Nakorotubu Range from 30th November – 10th December, 2009.

Latin Name	Common Name	Fijian name	Status
Frogs			
Bufo marinus	Cane toad	Boto ni valagi, Boto karokaro	Introduced and invasive
Platymantis vitiensis	Fiji tree frog*[a]	Ula	Endemic
Reptiles			
Candoia bibroni	Pacific Boa	Gata, Balei	Native
Cryptoblepharus eximus	Pygmy snake-eyed skink		Endemic
Emoia concolor	Fiji green tree skink	Mokosari	Endemic
Emoia cyanura	Brown-tailed copper-striped skink	Mokosari	Native
Emoia impar	Blue-tailed copper-striped skink	Mokosari	Native
Emoia parkeri	Fiji copper headed skink a	Mokosari	Endemic
Gehyra vorax	Giant forest gecko	Moko kabi, Boliti	Native
Nactus pelagicus	Skink-toed gecko		Native

*Denotes species listed as threatened under IUCN (2006)
a Denotes species listed as endangered under Fiji's list of 50 endangered species (2008) (NatureFiji-MareqetiViti, www.naturefiji.org).

Herpetofauna species were present at all three camp sites (Table 2.2), but representation of species at each camp site differed. Base camp 1 yielded the highest species diversity (8 species): only four species were encountered at Base camps 2 and 3. Abundance of each species was low at each site. The Fiji tree frog *P. vitiensis* was the most commonly encountered species (24 individuals) followed by *E. cyanura* (6) and *B. marinus* (6).

Table 2.2: Number of individuals encountered at each site in the Nakauvadra Range. 1 = Base camp 1; 2 = Base camp 2; 3 = Base camp 3. T = Nocturnal transect; DT = Diurnal transect; OS = Opportunistic survey.

Latin Name	Common Name					Fijian name						Status				
	1_T1	1_T2	1_DT1	1_DT2	1_ST1	2_OS1	2_T1	2_DT1	2_DT2	2_DT3	2_DT4	3_T1	3_DT1	3_T2	3_ST1	TOTAL
B. marinus				1								5				6
C. bibroni									1							1
C. eximus			1													1
E. concolor			1	1					1		1					4
E. cyanura					5										1	6
E. impar															1	1
E. parkeri			1								1					2
G. vorax				1												1
N. pelagicus	1															1
P. vitiensis	1	8	2			5					1	6	1			24
Total	**2**	**8**	**5**	**3**	**5**	**5**	**0**	**0**	**2**	**0**	**3**	**11**	**1**	**0**	**2**	**41**

Frogs

Fifteen of the twenty four *P. vitiensis* encountered were captured during the standard 2-hour surveys. The remaining nine were captured during opportunistic diurnal surveys and diurnal standard transect surveys. Frog eggs were encountered only once during Base camp site 3's opportunistic survey (3_OS1 in Map 4).

All twenty four frogs were measured. Snout-vent lengths (SVL) and weights of the twenty four *P. vitiensis* measured were variable, ranging from 21.8-49 mm and 0.5-13 g. (Appendix 5).

Cane toads were encountered on both nocturnal and diurnal surveys, but not in high numbers.

Platymantis vitiensis

The low calls of *P. vitiensis* were heard during the surveys. Frogs encountered during the day were captured from their diurnal retreats [in axils of climbing pandanus (*Freycinetia* sp.); and Pandanus trees]. Individuals captured at night were usually found on the leaves of tree saplings. All individuals captured were encountered less than 5 mm from the stream edge. The highest abundance of frogs in a given time (2_OS1 in Table 2.2) was encountered in a field of Pandanus trees in a swampy area during an opportunistic survey with the vegetation team.

Bufo marinus

Cane toads (*B. marinus*) encountered during the day were also found in their diurnal retreats. There was a notably low encounter of adult cane toads, and no tadpoles observed.

Reptiles

Skinks

Skink encounter rates were quite low (Table 2.2), and were only observed during the day. Ground skinks E. cyanura (Plate 6) and *E. impar* were mainly found foraging on the ground and on boulders. The high number of skinks observed in base camps 1 (5 individuals) and 2 (2 individuals) were due to the use of sticky traps (ST in Table 2.2). The arboreal skinks, *E. parkeri* (Plate 7) and *E. concolor* were mainly encountered from 0.2-15 m above the ground on tree trunks, and branches during opportunistic surveys (OS) and diurnal transects (DT) on the two days of good sunshine.

Geckoes

The Giant Forest Gecko (*G. vorax*) was encountered after clearing of vegetation for Base camp 1 while *N. pelagicus* was found during a nocturnal survey (1_T1 in Table 2.2) along a stream.

Snakes

The Pacific Boa *C. bibroni* was encountered by the vegetation survey team along a trail, in a tree at more than 20 m height.

DISCUSSION

All the herpetofauna species found in this expedition are new records for the Nakototubu Range, and have been recorded from sites of similar altitude within Viti Levu (e.g., Wabu Forest Reserve, Monasavu, Sovi Basin, Nakauvadra Range).

Only two of the three sites (Base camps 1 and 2) appear to generally support a healthy population of native herpetofauna; however, all three sites appear to support healthy populations of the endemic Fiji tree frog. The frogs were even found in agricultural areas which could be attributed to the fact that they had intact native riparian vegetation at the edge of the plantations.

Based on lessons learnt from a previous similar survey (Thomas 2008), several herpetofauna search methods were employed in this survey. All four methods of survey (diurnal opportunistic surveys, diurnal transect surveys with a pair of binoculars, nocturnal transect surveys and sticky trap surveys) contributed to the encounter rate of herpetofauna at all sites.

The ground skinks (*E. cyanura* and *E. impar*) are usually evasive animals and were only encountered due to the use of the sticky traps. No other species of skinks, geckoes or frogs were captured by the sticky traps, and these have proven to be an effective method for surveying for the usually evasive ground skinks.

The tree skinks (*E. concolor* and *E. parkeri*) on the other hand remain elusive and were only observed at a distance through a good pair of binoculars on a good sunny day. Additional targeted diurnal transect surveys to the usual opportunistic surveys had to be conducted in the search for these two species. There were possibly more individuals present in the three sites, but they were only observed on days of good sunshine. Sticky traps were also placed on tree trunks during the survey, but the average height at which these species were observed suggests that sticky traps ought to be placed at about 3 m or more above the ground.

Surveying during ideal weather conditions using all four methods of searching for herpetofauna would undoubtedly yield higher abundance and diversity of species in the Nakorotubu range.

Interesting Species or Genera

Pygmy snake-eyed skink *(Cryptoblepharus eximus)*

The probable encounter of the endemic pygmy snake-eyed skink is significant. This endemic species was thought to be a predominantly lowland coastal species until it was recorded from Marou Settlement (Tikina Savatu, Ba) in the interior of Viti Levu (Thomas 2004). Previous inland records of this species on Viti Levu have only been recorded once – in the upper Sigatoka catchment (Morrison 2003). The occurrence of this species in Nakorotubu Range is only the third record of its inland occurrence on Viti Levu. The discovery of its eggs beneath a large boulder along the stream bank is the first record of its eggs deposition site (Plate 8).

Fiji Tree Frog *(P. vitiensis)*

The Fiji tree frog is known to only occur on Ovalau, Viti Levu and Vanua Levu in Fiji (Osborne 2007). Its macro- and microhabitat distribution within the Nakorotubu Range is similar to its distribution in other parts of Fiji (e.g., Wabu Forest Reserve, Sovi Basin, Savura Forest Reserve, Nakauvadra Range) where they are usually found along streams. It was interesting to note that despite the high occurrence of the climbing pandanus within the ridges at 1_DT1, no frogs were encountered. The presence of feral cattle in forest at 1_DT1 poses a threat to the persistence of the Fiji tree frog and other herpetofauna as the cows are good dispersers of invasive and weedy plants (Plates 9 and 10).

The geographic position of the Nakorotubu Range suggests that the recently rediscovered population of the endangered sister species of the tree frog – the Fiji ground frog (*P. vitianus*) (Thomas, 2008), should also occur here. The Nakorotubu Range lies between the Nakauvadra range, Viwa Island and Ovalau Island – all of which have the Fiji ground frog. The absence of the Fiji ground from the Nakorotubu Range is indeed interesting.

Endemic Skinks *(E. concolor and E. parkeri)*

The presence of the two arboreal endemic skinks, *E. concolor* and *E. parkeri* is encouraging. The main difficulty faced when searching for these two skinks was their distance from the ground – two specimens were observed up to 15 m above the ground, in a tree. Their arboreal nature and the dense epiphytes on the trees often made it difficult to identify them. Identification was only possible when using a pair of binoculars. Closely observed individuals (2 m above the ground) were only observed in relatively disturbed sites.

Cane toads *(B. marinus)*

The cane toad (*B. marinus*) is listed in the Invasive Species Specialist Group's (2004) list of 100 of the world's worst invasive species (Lowe et al. 2004). Few adults were encountered during the survey. It was encouraging to note that there were no tadpoles found. The cane toads may not be a direct threat to the herpetofauna populations in the Nakorotubu range. The absence of tadpoles in likely egg deposition sites in Base camp sites 1 and 3 are notable, and should be compared against the freshwater fauna data.

CONCLUSIONS AND CONSERVATION RECOMMENDATIONS

Identified threats to herpetofauna in the Nakorotubu Range

Several threats were identified during the survey:

1. The presence and seemingly high abundance of feral cattle in the forest at Base camp 1 and their apparent preference of the ridge top trails poses a potential threat to frog breeding sites and to tree and ground skinks and geckoes. The effect of cattle trampling on the ridge tops is already showing in the presence of invasive and weedy plants in along the ridges and the landslides and state of the tributaries of Nabavatu stream (Plate 11). The feral cattle, if they persist, could have a significant negative impact on the herpetofauna population at the forest around Base camp 1.

2. The presence of the introduced mongoose *Herpestes fuscus* and rats pose a potential threat. There is no evidence as yet on the direct impacts of the mongoose and rats on herpetofauna populations in the Nakorotubu range. A more detailed survey is needed to document this relationship.

General recommendations

1. The herpetofauna of the Nakorotubu range is a relatively unknown group. A study of the tree skink diversity will be interesting because of the varying levels of disturbance and types of habitat at the site. The Nakorotubu Range has potential to support rare endemic species such as *E. campbelli* and new undiscovered species.
2. Any detailed surveys in the future should employ all three methods of survey used in this survey and also conduct the following:
   a. Document the phenology of frogs in the Nakorotubu Range and compare with other sites in Fiji.
   b. Collect DNA tissue and compare with other sites in Fiji.

   For reptile surveys:
   c. As above (a-b).
   d. Continue the use of sticky traps. The ground skinks were only captured through the use of the sticky traps.
   e. The Giant forest gecko *(G. vorax)* is more likely to be found under the bark of live trees rather than dead trees and therefore future surveys should place more emphasis on live trees.
2. The absence of the Fiji ground frog from the Nakorotubu Range is interesting. Future herpetofauna surveys should extend to parts of the Nakorotubu Range closest to the Nakauvadra range (North-western portion of the Nakorotubu Range) and Viwa Island and Ovalau Island (South-eastern portion of the Nakorotubu Range) to confirm if the Fiji ground is indeed absent.
3. Awareness on the impact of feral cattle should also be conducted. The feral cattle and their easy access to streams not only pose threats to the herpetofauna, but also to the quality of water sources of Matuku Village.

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Chapter 3

Preliminary Baseline Survey of the Avifauna of the Nakorotubu Range, Ra and Tailevu Provinces, Fiji.

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SUMMARY

This report is a preliminary baseline survey of the avifauna of the Nakorotubu Range, Ra-Tailevu Provinces, Viti Levu. The report provides observations and comments on the avifauna observed in the study area.

A total of 38 bird species were recorded in the surveys, fifteen of which were endemic species, four introduced and the remainder native species.

Three globally threatened species for Fiji were recorded – Pink-billed Parrotfinch (Viti Levu endemic), Black-faced Shrikebill and the Friendly Ground-Dove. For birds, the Nakorotubu Range has the same conservation significance as other large forest blocks on Viti Levu.

INTRODUCTION

The Nakorotubu Range is an important forest refuge for Fiji's native flora and fauna covering the whole mountain range that runs along the eastern side of Viti Levu from the Tailevu province in the south up to the province of Ra in the north. It connects to the lowland tropical rainforests of southern and central Viti Levu and also to the dry forests of northern Viti Levu like the Nakauvadra Range. Little bird work has been done in the whole area except a survey that was conducted by Dr Dick Watling around Soa village. The main objectives of this survey were to do a checklist of the bird species of Nakorotubu, look at their abundance and also the presence of Fiji's threatened birds in the area.

Conservation Significance

In the annotated accounts and discussion of the observations, prominence is given to the Conservation Significance of the species concerned. Conservation Significance is based on the following:

- Endemicity – Single Island, National, Regional or Regional Near-endemic for those birds whose distribution is primarily within the region but which extends to a few islands or an island group outside the region.
- Global Threat Status - according to the `2008 IUCN Red List of Threatened Species'. The threatened species categories now used in Red Data Books and Red Lists have been in place, with some modification, for over 30 years. Since their introduction these categories have become widely recognised internationally, and the Red List categories provide an easily and widely understood method for highlighting those species under higher extinction risk, so as to focus attention on the need for or efficacy of existing conservation measures. A simplified description of the categories applicable for this guide are as follows (refer http://www.redlist.org for a full description and the annually updated status):
  - CRITICALLY ENDANGERED - when a species is facing an extremely high risk of extinction in the wild in the immediate future;
  - ENDANGERED – when a species is not Critically Endangered but is facing a very high risk of extinction in the wild in the near future;
  - VULNERABLE – a species is Vulnerable when it is not Critically Endangered or Endangered but is facing a high risk of extinction in the wild in the medium-term future;

– NEAR THREATENED – is a sub-category of LOWER RISK category, for species which are close to qualifying for Vulnerable; and,
– DATA DEFICIENT – there is insufficient information to make an evaluation.

Introduced and naturalised species, some of these species pose a threat to native species and generally increase in abundance as a result of habitat disturbance, especially loss of forest.

National Conservation Status – IUCN's Global Status is used wherever a threatened category has been applied, especially for national endemic species. However, the majority of species in Fiji are resident and breed in other Pacific island countries or even further afield. In such cases the Global Status does not reflect the often differing status in each country, which is very important for the countries concerned. To rectify this, two categories for the conservation status of the Fijian populations of these birds are used.

These follow Watling (2001):

– **At Risk** - the higher category for birds considered to be severely threatened in Fiji;
– **Conservation Concern** – a lower category for birds whose status is known to be declining, under threat or very vulnerable because of small population size, introduced predators or competitors, or adverse land use practices here in Fiji.

METHODS AND STUDY AREA

Study area and base camps

The study area in the Nakorotubu Range is demarcated on Map 6. The team hiked from Matuku village to Base camp 1 (Nabavatu) along the Nabavatu Creek on November 30 and spent three nights there and hiked back to Matuku village on December 3. On December 4 we visited the limestone forests of Nalidi looking for caves and on December 5 hiked from Matuku village to Base camp 2 (Nalalau) on the headwaters of the Lequ Creek which flows down to Nalidi village. We spent two nights at Base camp 2, before hiking back to Matuku village on December 7. The team departed Matuku village for Nasau village on December 7 and spent December 8 surveying the forests around the village. On December 9 the team departed Nasau village for Base camp 3 (Nubunivonu) and spent two nights at Base camp 3 before hiking back to Nasau village on December 11.

Field methods

Bird observations were categorized according to three different observational methods:

1. Standardised Transects: Observations during timed transects along paths and river/stream beds – these are then expressed as encounter rates (number of individuals observed divided by number of standardised observer hours (Masibalavu and Dutson 2006);
2. Observations during timed periods at an observation post with a 200o view over the forest;
3. Incidental observations around the base camps and when hiking between camps.

A summary of the location of the sites surveyed is listed in Table 3.1, and shown in Map 5. A total of 38 hours was spent on bird surveying, 29.25 hours was spent on forest observations, 3.3 hours was spent in 'forest edge – garden' habitats and 5.4 hours in open country (Table 3.2).

RESULTS

Species Recorded

A total of 38 species were recorded in the Nakorotubu Range, primarily in forested habitats but including peripheral open habitats. Fifteen of these are Fijian endemic species (Table 3.3). Three introduced bird species (Common mynah, Jungle mynah and Red-vented bulbul) now considered as invasive were also observed, mainly close to villages and settlements. The Fiji-bush Warbler is the most common species encountered during the survey.

The Pink-billed Parrotfinch (Endangered) one of Viti Levu's most threatened birds, was observed a couple of times in the intact lowland rainforests of Nasau. The other two threatened birds of Viti Levu, the Red-throated Lorikeet (Critically Endangered) and the Long-legged Warbler (Endangered) were not recorded. Two species, the Friendly Ground Dove and the Black-faced Shrikebill that are categorized as Vulnerable, were also recorded.

Four caves visited during the survey had White-rumped swiftlets colonies. The three caves in Nasau had approximately more than 1000 swiftlets in each, whereas the rock overhang near Base camp 1 had about 100 swiftlets.

DISCUSSION

The composition of the birds of Nakorotubu is similar to other large forest blocks on Viti Levu – given the paucity of data (this survey, Watling 2003, Masibalavu 2003, Watling 2008).

No Long-legged warblers were observed despite the healthy state of the native forests. The reason for this could be the lack of running creeks at elevations of more than 300 m above sea level found at other sites like Monasavu, Wabu, and Nakauvadra, where this species was previously recorded (Masibalavu 2004, Masibalavu 2008).

Weather conditions at Base camp 1 and Base camp 2 were drier permitting more work to be done; however, rain was encountered in Base camp 3 which affected the field work. The drier state of the forest in Base camp 1 and Base camp 2 could be a factor affecting the bird composition of this area but this needs follow up work. The vegetation around Base camp 3 is typical lowland tropical rainforest like the Sovi Basin (Naitasiri Province), with a similar bird composition (Masibalavu et. al. 2003, Watling, 2003). The presence of birds like the Pink-billed parrotfinch and Friendly ground dove in the forests of Nasau is noteworthy and would be worth follow up monitoring. Base camp 3,

despite the poor weather, had greater bird activity compared to the two other camps, and this could be attributed to the healthy state of the forest, large forest size and connectivity to other forest systems.

An interesting observation made in this survey was that of the Polynesian starling in Base camp 2. This species is usually rare in forests of Viti Levu; however, we observed this species to be fairly common here moving and foraging in large groups of up to ten individuals. This was observed for the two days we spent at this site. They also showed signs of aggressive behavior towards other species. Whether they were mating or marking out their territory is not clear, but the observation is worthy of a follow up survey.

The presence and abundance of large birds such as Masked-shining parrot and barking pigeon (Table 3.2) in the area can show that both the health and size of the forest is large enough to contain a viable population of birds and other species.

Few trees were observed to be flowering except for some *Bischofia javanica*, *Erythrina* sp., *Garcinia* sp. and *Parinari insularum* which attracted species like White eyes, Slaty monarch, Collared lorry, Wattled honeyeater and Orange-breasted myzomela. However, there were more trees with fruits like *Endorspermum macrophyllum*, *Parinari insularum*, *Callophylum* spp., *Ficus* spp., *Amoraria* sp., *Garcinia* spp., and *Cananga odorata* which attracted birds like the Barking pigeon, Many-colored fruit dove and Golden dove. White-rumped Swiftlets were found nesting during the survey. The three caves visited in Nasau have a good population of this species with each cave having well over 1000 birds. The limestone forests of Nakorotubu were not well covered in this survey and this is noteworthy for future surveys in this area.

Interestingly, not many introduced bird species were encountered during this survey. The majority recorded were mainly near and around villages and settlements. None were observed in any of the camp sites, which show that they have not really been able to spread to these forest areas. However, this should be monitored in the future.

CONCLUSIONS AND CONSERVATION SIGNIFICANCE

The birds of the Nakorotubu Range are similar in composition and approximate abundance, and hence conservation significance, to other large forest blocks on Viti Levu. Further surveys are required to determine the presence/absence of rare species such as the Long-legged Warbler and the Red-throated Lorikeet. Being an important refuge for birds and the fact that it is connected to other large forest blocks, there is a need to set aside some portions of the Nakorotubu Range as permanent reserves. Future surveys are needed and monitoring program in place for the birds of Nakorotubu. The site could qualify to be one of Fiji's Important Bird Areas (IBA's) due to the presence and abundance of some of Fiji's threatened birds.

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Table 3.1: Summary of the dates and sites surveyed for birds during the Nakorotubu Biodiversity Survey. These points are also shown on Map 6.

No.	Date	GPS 1 (E)	GPS 2 (N)	Name of site	Description
1	1/12/2009	019-59-091	039-33-557	Base Camp 1	Session1: camp to swiftlet cave, then up to the ridge, before heading back to camp.
2	1/12/2009	019-59-350	039-33-056	Esiesi	Rock overhang. White-rumped swiftlet, colony 1 about 30, colony 2 about 100.
3	1/12/2009	019-59-719	039-33-721	Korotibi ridge	Session 2: camp 1 towards Korotibi ridge, lowland rainforest, lower portion disturbed by cattle
4	2/12/2009	019-59-649	039-34-310	Korotibi ridge	Session 3:1º lowland trf, still intact. Birding along ridge
5	2/12/2009	019-59-407	039-34-489	Old fort/ village site	Session 4: Bird lookout (not very clear though, overgrowth, b/fast)
6	2/12/2009	019-57-991	039-35-358	near Lou creek	Session 5: Lou crk, heading back to camp, follow ridge dividing Nabavatu and Savura.
7	2/12/2009	019-58-767	039-34-080	Upper Base Camp 1	Session 6: sitting at viewpoint, about 1.5km upstream from camp.
8	3/12/2009	019-59-091	039-33-557	Base Camp 1	Session 7: upstream from Camp 1, open area, viewpoint.
9	3/12/2009	019-59-122	039-32-562	Base Camp 1	Session 8: following track back to Matuku from Camp, closed forest, partial disturbance from cattle.
10	3/12/2009	019-58-315	039-29-990	Na Me.	Session 9: Birding from Na Me back towards Matuku village, closed intact lowland rainforest.
11	3/12/2009	019-59-092	039-30-464	Matuku village	Session 10: Birding along road from Agriculture Office towards Matuku road. Disturbed, open
12	4/12/2009	019-63-042	039-24-186	Leuleu, Nalidi.	Session 11: Intact limestone forest, raining.
13	4/12/2009	019-60-156	039-30-106	Matuku village	Session 12: Birding along track from Matuku village to base camp 2.
14	5/12/2009	019-61-188	039-34-372	Base Camp 2	Session 13: Camp 2 - Along track to about 1km from base camp towards verevere route
15	5/12/2009	019-60-471	039-31-916	Matuku paddock.	Session 14: open area, vegetation partially cleared for paddock. Some introduced species
16	5/12/2009	019-60-632	039-32-054	Vatukeresia peak.	Session 15: Vatukeresia lookout to Camp 2, Intact lowland rainforest.
17	5/12/2009	019-61-201	039-33-604	Base Camp 2	Intact montane forest. Unique vegetation. Common birds, no introduced species.
18	5/12/2009	019-61-911	039-33-861	Burewai trail.	Session 16: Intact lowland-montane forest. Disturbed vegetation along track.
19	6/12/2009	019-61-590	039-34-782	Burewai trail.	Session 17: Intact lowland-montane forest. Disturbed vegetation along track to Verevere.
20	6-7/12/2009	019-61-532	039-33-856	Burewai trail	Set up 2 mist-nets, along track to Burewai about 200m from Camp 2.
21	7/12/2009	019-60-794	039-33-012	Camp 2 - Matuku	Session 18: Along track from camp 2 back towards Matuku village
22	8/12/2009	019-66-176	039-18-106	Nasau village	Session 19: Nasau village - up Waimaca creek. Open secondary forest.
23	8/12/2009	019-64-188	039-18-762	Nasau village	Session 20: Nasau village - along road from village to about 2km, Open, disturbed.
24	8/12/2009	019-65-323	039-18-506	Waimaca cave 1 & 2	Limestone caves, big, at least more than 1000 swifltets in each cave. Signs of a lot disturbance and visit by graffiti on the walls
25	8/12/2009	019-65-378	039-18-515	Waimaca cave 3	
26	9/12/2009	019-65-687	039-20-975	Base Camp 3	Session 21: Birding from Base Camp 3 along ridge on opposite side of stream. Intact lowland rainforest.
27	9/12/2009	019-65-177	039-21-396	Base Camp 3	Session 22: Walked upstream for about 1km and follow creek up to waterfall then follow ridge back to paddock
28	10/12/2009	019-66-032	039-22-437	Base Camp 3	Session 23: Upstream and follow 2 creeks to waterfalls to search for LL Warbler.

Table 3.2: Observation time (minutes) in different habitats and for different methods

Observation Method		Standardised Transect	Observation Site	Incidental		
Date	Time (hr)	Forest	Forest	Open	Forest Edge/ Gardens	Forest
1-Dec	0600-1000	240				
	1530-1800	150				
2-Dec.	0725-0830				65	
	0900-1000		60			
	1500-1730		150			
	1600-1800	120				
3-Dec	0645-0730		45			
	940-1000	65				
	1540-1630	50				
	1640-1700			20		
4-Dec	1420-1440	20				
	1430-1700		150			
5-Dec	645-745			60		
	630-830	120				
	910-1010	60				
	1720-1800		40			
6-Dec	1230-1530	180				
7-Dec	650-800	70				
8-Dec	1100-1230		90			
	1500-1700			120		
9-Dec	1530-1800	150				
	1500-1730				150	
10-Dec	915-1100	105				
	Tot. Obs Time (min)	1330	210	325	200	215

Table 3.3: Land and Freshwater Birds of Viti Levu with those Species Observed at Nakorotubu. English and Scientific names follow Watling (2001).

	Common Name	Scientific Name	Origin	Endemicity	Threat Status (IUCN Listing)	Number recorded	10 hour Abundance Index	Abundance category	Comment (observations of this survey)
1	Pacific Black Duck	*Anas superciliosa*	N			7	2.1	U	Observed along the main streams
2	Reef Heron	*Egretta sacra*	N			4	1.2	U	Observed at Forest Edge , open areas and along streams flying
	White-faced Heron	*Ardea novaehollandiae*	RI			0	0		Not observed
3	Fiji Goshawk	*Accipiter rufitorques*	N	E		7	2.1	U	Mainly observed from lookout points
4	Pacific Harrier	*Circus approximans*	N			3	0.9	R	Observed in Open Area and lookout points
	Peregrine Falcon	*Falco peregrinus*	N			0			Not observed
5	White-throated Pigeon	*Columba vitiensis*	N			3	0.9	R	
6	Spotted Turtle-dove	*Streptopelia chinensis*	I			3	0.9	R	Observed in Open Areas only
7	Friendly Ground-dove	*Gallicolumba stairii*	N	RE	V	3	0.9	R	Observed foraging on forest floor in intact lowland rainforest in Camp 1 and Camp 3.
8	Barking Pigeon	*Ducula latrans*	N	E		119	33.4	VC	
9	Many-coloured Fruit-dove	*Ptilinopus perousii*	N	RE		7	2.1	U	
10	Golden Dove	*Chrysoenas luteovirens*	N	E		47	13.6	C	
11	Collared Lory	*Phigys solitarius*	N	E		83	23.3	VC	
	Red-throated Lorikeet	*Charmosyna amabilis*	N	E	CE	0	0		Not observed

(Table 3.3 Contn'd)

	Common Name	Scientific Name	Origin	Endemicity	Threat Status (IUCN Listing)	Number recorded	10 hour Abundance Index	Abundance category	Comment (observations of this survey)
12	Masked Shining Parrot	*Prospeia personata*	N	ES	NT	34	10	C	
13	Fan-tailed Cuckoo	*Cacomantis flabelliformis*	N			20	5.9	F	
	Barn Owl	*Tyto alba*	N			0	0		Not observed
14	White-rumped Swiftlet	*Aerodramus spodiopygia*	N			68	20.1	VC	
15	White-collared Kingfisher	*Todiramphus chloris*	N			36	10.6	C	
16	Polynesian Triller	*Lalage maculosa*	N	RE*		66	19.5	C	
17	Red-vented Bulbul	*Pycnonotus cafer*	I			10	3	U	Observed near villages only
18	Island Thrush	*Turdus poliocephalus*	N			75	22.2	VC	
19	Fiji Bushwarbler	*Vitia ruficapilla*	N	E		150	44.3	VC	
	Long-legged Warbler	*Trichocichla rufa*	N	E	E	0	0		Not observed
20	Streaked Fantail	*Rhipidura spilodera*	N	RE*		37	10.9	C	
21	Slaty Monarch	*Mayrornis lessoni*	N	E		114	33.7	VC	
22	Lesser Shrikebill	*Clytorhynchus vitiensis*	N	RE		31	9.2	C	
23	Black-faced Shrikebill	*Clytorhynchus nigrogularis*	N	E	V	7	2.1	U	
24	Vanikoro Broadbill	*Myiagra vanikorensis*	N	RE*		53	15.7	C	
25	Blue-crested Broadbill	*Myiagra azureocapilla*	N	E		72	20.7	VC	
26	Scarlet Robin	*Petroica multicolor*	N			25	7.4	C	
27	Golden Whistler	*Pachycephala pectoralis*	N			48	14.2	C	

(Table 3.3 Contn'd)

	Common Name	Scientific Name	Origin	Endemicity	Threat Status (IUCN Listing)	Number recorded	10 hour Abundance Index	Abundance category	Comment (observations of this survey)
28	Fiji White-eye	*Zosterops exploratory*	N	E		140	14.1	VC	
29	Silvereye	*Zosterops lateralis*	N			4.0	1.2	U	Observed at Forest Edge only
30	Orange-breasted Myzomela	*Myzomela jugularis*	N	E		48	14.2	C	
31	Wattled Honeyeater	*Foulehaio carunculata*	N	RE*		121	35.7	VC	
32	Giant Forest Honeyeater	*Gymnomyza viridis*	N	E		92	27.2	VC	
33	Fiji Parrotfinch	*Erythrura pealii*	N	E		39	11.5	C	
34	Pink-billed Parrotfinch	*Erythrura kleinschmidti*	N	ES	V	2	0.6	R	Observed in intact lowland rainforest near Camp 3 and open habitat near village.
	Red Avadavat	*Amandava amandava*	I			0	0		Not observed
35	Polynesian Starling	*Aplonis tabuensis*	N	RE*		22	6.5	F	Common in the forest around Camp 2
36	Common Mynah	*Acridotheres tristis*	I			10	3	U	Observed only in village & farmland
37	Jungle Mynah	*Acridotheres fuscus*	I			4	1.2	U	Observed only in open habitats near villages
38	Fiji Woodswallow	*Artamus mentalis*	N	E		3	0.9	R	

Chapter 4

Bats of the Nakorotubu Range, Ra and Tailevu Provinces, Fiji.

Alivereti Naikatini

Team members: *Senivalati Vido (Fiji Department of Forestry), Sowane Nasemira (Soa Village), Mitieli Toakece (Nasau village).*

SUMMARY

Three main survey techniques were used: general observations, bat detector, mist nets and harp trap. Only three species of bats were recorded: *Pteropus tonganus*, *P. samoensis* and *Emballonura semicaudata*. The latter two species are listed in the IUCN Red List 2007 as Near Threatened and Endangered respectively. At least three large roosts of P. tonganus were recorded within the area covered during the survey. More surveys are needed to locate possible roosting sites and monitor the presence of other bat species that forage within the area.

INTRODUCTION

There are fifteen species of mammals native to Fiji, of which six are terrestrial (bats belonging to the order Chiroptera) and nine are marine (whales belonging to the order Cetacea) (IUCN 2007). There are fourteen non-native species of mammals present in Fiji, all of which are terrestrial and have been introduced to Fiji in the last 3000 years since the arrival of humans (Pernetta and Watling 1978). This survey focused on the native bat species present in the Nakorotubu Range.

To date there has been no record of terrestrial mammal research conducted in the Nakorotubu Range area, apart from the limestone caves near the villages of Wailotua and Nasau which have been visited in the past to survey the Fiji blossom bat (*Notopteris macdonaldi*). Fiji's native bats are poorly studied, yet this group should be of high conservation importance as they include an endemic monospecific genus (*Mirimiri acrodonta*) and several near endemic species. Additionally, Fiji's bats play an essential role as seed dispersers, pollinators of flowers and in controlling nocturnal insect populations in rainforest and other terrestrial ecosystems (Manueli 2001, Palmeirim et al. 2007).

Some previous work on bats in Fiji includes a collecting trip in 1990–1991 by the Australian Museum, the results of which is published in Flannery (1995); work by Dr. Jorge Palmeirim (Universidade de Lisboa, Portugal) in 2000-2001 (Palmeirim et al. 2007); and studies on Pteropus samoenis by Dr. Ruth Utzurrum (Department of Wildlife and Marine Resources, American Samoa, Pagopago) in 2002. The work by the Australian Museum and Palmeirim provide good baseline data for bat research in Fiji.

The main objectives of this survey were to:

a) produce a checklist of the bat species found in the Nakorotubu Range and

b) focus on the conservation status of the rare and endangered species and their habitats.

METHODS

Three main methods were used to survey the bat fauna of Nakorotubu:

1) Mist nets and harp trap,
2) Bat detectors and
3) General observation.

The location of sites and surveys are shown on Map 6.

Mist nets and harp traps

A pair of 12 x 2.7 m mist nets was used to trap larger fruit bats. The use of the nets was mainly to verify the identity of the larger fruit bat species, especially to the locals. The mist net was only used in fine weather conditions, set up for use from dusk to dawn and was regularly checked every hour.

Bat detector

A Tranquillity II bat detector was used to detect the presence of microbats in caves. It was also used during the night around the camp by walking a 50 m non-linear transect to detect foraging microbats.

General observations

We made general observations while walking through and around the forest during the day and hiking from one camp to another. Any species of fruit bat observed were noted. This was also carried out while conducting bird surveys in the early mornings and afternoons.

RESULTS

Only three species of bats (50% of the bat species found in Fiji) were recorded during the survey. Two were confirmed based on direct observations and one was only detected using a bat detector. They are presented in Table 4.1 along with their conservation status as assessed by the IUCN 2007, Red List. Table 4.2 shows a summary of the sites surveyed for bats which are also presented in Map 6.

The most common species observed was *Pteropus tonganus* with about three large roosts each containing at more than 1000 bats, recorded from Matuku, Soa and Nasau villages. *P. samoensis* was rarely observed in Base camp 2 and none were observed in Base camp 1 however it was more commonly observed in the intact lowland rainforest around Base camp 3. While conducting a bird survey along a transect near Base camp 3 for two hours we observed four *P. samoensis*. However no *P. samoensis* were observed while surveying along bird transects in Base camp 1 and Base camp 2. Only one *Emballonura semicaudata* was detected on the night of December 6 using the Tranquillity II bat detector while walking a 50 m non-standardised transect near Base camp 2. Two mist nets were set up near Base camp 2 in a clearing on the ridge along the traditional track to Bureiwai on December 5 and 6; however, we were not able to catch any bats despite the fine weather. We did not set up mist nets in Base camp 1 as there was no ideal clearing and neither at Base camp 3 due to the rainy weather encountered. The harp trap was also not set up near the cave openings and entrance at these camp sites because we did not detect their presence using the bat detector.

Table 4.1: Checklist of species of native bats found in the Nakorotubu Range and their IUCN 2007 threatened status.

Common Name	Scientific Name	IUCN Status	Notes	No. of introduced species
Insular flying fox	*Pteropus tonganus*	Lower risk	Common. Three large roosts recorded.	64
Samoan flying fox	*Pteropus samoensis*	Near Threatened	None in Base camp 1 and very rare in Base camp 2 but more common in Base camp 3.	1
Polynesian sheath-tailed bat	*Emballonura semicaudata*	Endangered	Only noted using bat detector in Base camp 2, none seen or caught.	4

DISCUSSION

Pteropus tonganus

This was the most common species recorded in Nakorotubu Range. The presence of three large roosts near each of the base camps is indicative of an abundance of food. This was evident in the presence of extensive stands of *Cananga odorata* (makosoi) and *Piper aduncum* (onalulu) trees in secondary forests and fruit trees and crops near cultivated areas, agro-forest and abandoned gardens, villages and settlements. Some *Pteropus* bat species are known to forage for up to eight kilometres away from their roosts (Markus and Hall 2004). Only a small portion of the Nakorotubu Range was surveyed so there is a high chance of other roosts existing within the range.

Pteropus samoensis

This species is known to be locally rare. As shown in other parts of the Pacific, this species in American Samoa is rarer than *P. tonganus* with the density ranging from 1-18 bats/km² (Brook 2001). As only a few were observed in Base camp 1 and Base camp 2, this may be a sign of the declining health of the forest. The presence of *P. samoensis* has been used to assess the state of a forest system, as these bats roost in smaller colonies preferably in primary forest compared to *P. tonganus* which tends to forage in agro-forest and cultivated areas (Banack 1998). This species was commonly observed in the forests around Base camp 3. This could mean that the lowland rainforests and limestone forests of Nasau are still intact and remain connected to other healthy forest systems.

Emballonura semicaudata

This species only roosts in caves (Tarburton 2002); however, we did not record any in the caves that we visited in Base camp 1 north of Matuku village, at Base camp 2 north of Nalidi village and Base camp 3 north of Nasau village. This species is believed to be extirpated from Viti Levu but is still found in other parts of Fiji; the closest roost to Viti Levu is in the Yasawa Group (Palmeirim et al. 2007). Only a single detection of this species was made using the bat detector along a ridge at Base camp 2. This species, like *P. samoensis*, prefer to forage in well forested areas (Esselstyn et al. 2004). It is highly likely that there are caves in the limestone outcrops near Nalidi and Nasau villages that have not been recorded and/or surveyed. The known caves surveyed were close to villages and are more accessible. For future work, we recommend that the area be surveyed more intensively for other caves and the possible presence of cave-dwelling species, such as *E. semicaudata*.

Similar to the Nakauvadra bat survey in 2008, a problem encountered was that the majority of the local guides at Base camp 1 and Base camp 2 mistook this species for the White-rumped swiftlet (*Aerodramus spodiopygius*), a bird which also nests in caves and sometimes also under large boulder and cliff overhangs. Sites which the guides had marked out on the map as locations of bat caves were actually cliff and large boulder overhangs where the White-rumped swiftlets were nesting.

Other bat species

Of the other three species that occur in Fiji but were not recorded in the Nakorotubu Range, the only species that may yet be found in this area is the Fiji blossom bat (*Notopteris macdonaldi*). The Fiji monkey face bat (*Mirimiri acrodonta*) is only found in Taveuni, and the Fijian mastiff bat (*Chaerephon bregullae*) has been only known to roost in Vanua Levu and Taveuni (Palmeirim et al. 2007). There are only three recorded roosts for the Fiji blossom bat in Fiji, one in Sawene (Nadroga/Navosa), Kalabu (Naitasiri) and Wailotua (Tailevu) (Palmeirim et al. 2007). The Wailotua cave is part of the limestone outcrops of Nalidi and Nasau and part of the whole system of the Nakorotubu range. We were not able to visit the main cave in Nalidi due to heavy rain causing flooding, preventing us from entering the main cave. We did not record any Blossom bats in any of the caves visited near Nasau village, however, all the caves were occupied by thousands of White-rumped swiftlets. The caves near Nasau village found along Waimaca creek area are large and deep enough to provide ideal habitat for the blossom bats. It was evident after exploring the caves that they have been disturbed a lot by humans, as the cave wall had graffiti and remains of partially burnt bamboos used as torches attested to. The locals later reported that every year around Christmas holidays (December) they would feast on hundreds of White-rumped swiftlets, which they would roast in open fire, a delicacy during that time of the year. However, this practise had been stopped in the last five years by the elders after they noticed the numbers of swiflets decreasing. This practise by the locals could be a reason why Fiji blossom bats are no longer found in these caves. Cave dwelling bats can be very sensitive to disturbance from humans and a constant influence from humans could cause them to translocate to more ideal roosting places.

CONCLUSIONS AND CONSERVATION RECOMMENDATIONS

Conservation significance of the Nakorotubu Range for bats

Only three species were recorded, two of which are listed as vulnerable and endangered. Apart from *P. tonganus*, no roost for any of other two species were located in this survey and there is a need for more surveys spread over the Nakorotubu Range to locate existing roosts and bat colonies The findings of this survey is similar to the findings of other large forest areas surveyed in Viti Levu including the Nakauvadra Range, Sovi Basin and the Wabu Reserve.

Future work

More surveys need to be conducted to locate the presence of any roosting colonies of each bat species and also to monitor population size of the different bat species foraging in the Nakorotubu Range. Other species like the Fiji blossom bat (species) could also be present in the Nakorotubu Range (apart from Wailotua) and there is a need to survey

the limestone outcrops of Nakorotubu for caves and bats. There is also a need for community awareness and education in the villages and communities surrounding the Nakorotubu Range. Local communities also need to be taught about the importance of bats and their ecological role, something which has been neglected in many Fijian communities where bats are not seen as important species, but only as a nuisance.

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Table 4.2: Summary of the sites surveyed for bats during the Nakorotubu Biodiversity Survey. These sites are also represented on Map 6 marked by the numbers which appears on this table.

No.	Date	GPS 1 (E)	GPS 2 (N)	Name of site	Description
1	12/01/2009	019-59-350	039-33-056	Esiesi	Rocky overhang along Nabavatu stream, plenty swiftlets, at least 2 overhangs but no bats
2	12/01/2009	019-59-091	039-33-557	Base Camp 1	along stream, secondary lowland rainforest, disturbed from feral cattle. Only *P. tonganus* observed flying.
3	12/01/2009	019-59-372	039-33-694	Nakorowaiwai	Rocky overhang, camp site for villagers, a lot of swiftlets. Pair of *P. samoensis* roosting near
4	12/02/2009	019-59-407	039-34-489	old fort, lookout	primary lowland rainforest. A few P. tonganus seen flying.
5	12/03/2009	019-58-315	039-29-990	Na me	Primary lowland rainforest, along Nalilo creek, above Matuku village, P. tonganus roost (>1000 individuals), roosting on several trees.
6	12/04/2009	019-63-042	039-24-186	Leuleu	Intact limestone forest near Nalidi village, could not enter cave due to flooding. Visited 2 small caves and I rocky overhang but no Blossom bats.
7	12/04/2009	019-60-023	039-27-523	Soa village	Secondary forest, *P. tonganus* roost (>1000 bats)
8	12/06/2009	019-61-201	039-33-604	Base Camp 2 (Nalalau)	Intact Montane forest. Few P. tonganus, 1 P. samoensis and detected 1 Pacific sheath tail bat.
9	12/06/2009	019-61-135	039-33-812	Base Camp 2 (Nalalau)	Set up 2 mist nets on ridge along track to Bureiwai, but did not catch any bats.
10	12/08/2009	019-65-531	039-17-973	Delailagi	Intact limestone forest near Nasau village. Big rock overhang, no bats only swiftlets.
11	12/08/2009	019-65-323	039-18-506	Waimaca cave 1 & 2	Large limestone caves suitable site for Blossom bats. No bats but >1000 swifltets in each cave. Signs of a lot disturbance with graffiti on the walls, and burnt bamboos used as torches
12	12/08/2009	019-65-378	039-18-515	Waimaca cave 3	Limestone cave, big, suitable site for Blossom bats. No bats only lots of swifltets. Signs of a lot disturbance and visit from humans by graffiti on the walls and burnt bamboos used as torches.
13	12/09/2009	019-65-287	039-20-788	Camp 3, Nubunivonu.	Intact lowland tropical rainforest above camp, a lot of *P. samoensis* in forest, and a lot of *P. tonganus* as well seen flying.
14	12/10/2009	019-65-882	039-20-186	Nasau village	*P. tonganus* roost above settlement (Wainara) towards camp 3.

Chapter 5

An investigation of the land snails and slugs of Nakorotubu Range, Viti Levu, Fiji Islands.

Gilianne Brodie & Lekima Copeland

Team members: *Samuela Dalivalu (Soa village) and Anasa Turaga (Nasau village). Opportunistic snail collections by many others including Nunia Thomas (NatureFiji-MareqetiViti), Senilolia Tuiwawa, Hilda Waqa & Alifereti Naikatini (SPRH), Leanne Alonso (Conservation International), Milan Marinov (Christchurch).*

Laboratory Team Members: *Richard Singh, Matereti Mateiwai (USP).*

SUMMARY

Twenty-two different species of terrestrial land snails and slugs were identified during the survey period. Eleven of these species are endemic to Fiji and another two species are either endemic or native. It is likely that at least some of the endemic species found during this survey are threatened and should be listed on the IUCN Red List as in need of some level of conservation action since closely related taxa from the same genera (e.g. *Placostylus*) in other Pacific Island areas are listed. Seven of the species found are introduced and two species are of unknown status. The introductions include *Parmarion martensi* Simroth 1893 which has well documented human health risks in overseas countries. Based on the total number of terrestrial gastropod species found in the Fiji archipelago a higher number of land snail species might be expected.

INTRODUCTION

The diversity of Fiji's terrestrial, gastropod snails is known to be very high in respect to land area, with 160 endemic and 49 native species recorded (Barker 2005). Unfortunately this highly diverse and unique fauna is not well documented, particularly for identification purposes, which makes calculation of biodiversity loss estimates very difficult (Brodie 2009).

Despite being of global significance, terrestrial snails in most Pacific Islands countries like Fiji are known to be under serious threat (Lydeard et al. 2004; Cowie 2000) with native and endemic fauna affected by deteriorating habitat conditions and rising invasive species numbers (Cowie 2004).

Eighteen introduced terrestrial-gastropod species are recorded as present in Fiji (Brodie & Barker, in review) however to date these do not include two of the world's worst high-risk invasive land snails, the giant African snail *Lissachatina fulica* (Bowdich 1822) and the rosy wolf snail *Euglandia rosea* (Férussac, 1821). These two species are already a significant problem; for biodiversity loss, agricultural production and economic trade opportunities, in neighboring Pacific Island areas (Cowie 2001a, SPC/LRD pers. comm.) and it is a great credit to the Fiji government quarantine authorities that Fiji is so far free of these destructive high-risk alien snails.

It is vital to know what baseline biodiversity is present in our ecosystems in order to make informed decisions about future resource management. We also need to learn from what has occurred in other regional island areas (e.g. Samoa, New Caledonia, French Polynesia and Hawaii) as the risk of extinction of our unique Fijian endemic snail fauna, from habitat loss and invasive species, is extremely high.

Land snails and slugs are known collectively as "sici ni vanua" by Fijians. Surprisingly no

specific names appear to exist for even the most common species that have been in Fiji for many years.

METHODS

Living snails, and dead snail shells, were collected by hand both opportunistically and by targeted searching throughout the survey period. Overnight pit-trapping was also undertaken. Snails were often found in leaf litter or under rotting wood or climbing on vegetation, such as leafy shrubs or the trunks of small trees. Some climbing (arboreal) snails were also found on human infrastructure such as tents. Almost all sampling was conducted on overcast and relatively wet days.

Specimens were photographed, measured and preserved for future identification in 80% alcohol. DNA samples (optimally small pieces of the tail) were also taken from 14 living species to facilitate future investigations of genetic relatedness to (i) populations in other parts of Fiji and (ii) similar snails being studied in other parts of the Pacific Island region.

Classifications given were determined using Barker (2005) in combination with Burch (1962), Smith & Stanisic (1998), Stanisic (2000) and Cowie (2001a). All specimens will be lodged with the South Pacific Regional Herbarium/ USP Marine Collections.

SITE DETAILS

Targeted snail collection occurred within a few kilometers of the following locations:

Matuku Settlement:	S 17 °37'47.0", E 178°22'07.2" (altitude 59m)
Camp 1	S 17.59; E 178.36 (altitude 162 m)
Camp 2	S 17°35'53.4"; E 178°23'02.4"; (altitude 550m)
Nasau Village	S 17.73, E178.42 (altitude 35 m)
Camp 3	S 17.72, E178.42 (altitude 50 m)

RESULTS

A total of 135 individual terrestrial snails were collected during the survey period. These spanned seven different families (Bulimulidae, Trochomorphidae, Helicarionidae, Helicinidae, Ariophantidae, Veronicellidae (=Vaginulidae), Subulinidae) and least twenty-two different species with an additional two species possible (Table 5.1). Eleven of the species found are endemic to Fiji and another two species are either native or endemic. Therefore 9% of the overall number of species found was native and 45% endemic. This is lower than expected.

Three different endemic species of the flax snail *Placostylus* were found, one of which could not be easily assigned to any of the four *Placostylus* species recorded from Viti Levu. Although 53 specimens of *Placostylus* (Family Bulimulidae) were collected (~ 40% of total number of snails collected) only 6 specimens in total were found alive. The presence of many dead shells of *Placostylus gracilis* (Brodrip 1840) [52 collected plus many more seen] suggests that this species has a very high mortality rate. Only one specimen of each of the other two *Placostylus* species, *Placostylus graeffei* Crosse 1875 and *Placostylus* sp. (Plate 12), were found. Two different endemic species of *Trochomorpha* (Family Trochomorphidae) were found (Figure 13a & 13b). One specimen of *Trochomorpha* sp.1 was found near each of the three camp locations surveyed while the second species was only found at one location.

Seven of the species found are introduced, 32 % of total number of species found. Five of these seven species are known "pests" and at least three have potential human health risks. One of the introduced species, *Parmarion martensi* Simroth 1893, was commonly found in all sheltered habitats searched, including higher altitude forest and is therefore considered very invasive. The species was observed to be extremely hardy and was found regularly both terrestrially and arboreally within forest habitats and on camping equipment such as tents.

DISCUSSION AND CONSERVATION SIGNIFICANCE

Fiji's land snail fauna is known to be highly diverse and the 22 land snail species found during this survey is relatively low compared to the 230 species recorded as being found within the Fijian archipelago by Barker (2005). The proportion of native and endemic fauna recorded is also recorded as high, ~ 90% native and ~78% endemic to the archipelago. Thus the figures of 9% native and 45% endemic found during this study are lower than expected. However, calculation of the number of endemic and native snail fauna expected to be found in the forest habitats of Viti Levu is currently in progress (Brodie & Barker unpublished data) and it should be remembered that Barker's figures include non-forest habitats such as the coastal supra-littoral areas of all islands within the Fiji Group.

Considering the known decline in global land snail biodiversity, and the relevant importance of the Pacific Island endemic fauna to that biodiversity (Lydeard et al. 2004) the presence of living specimens of the families Bulimulidae, Trochomorphidae and Helicarionidae, for which all members recorded in Fiji are considered endemic (Baker 2005), during this survey is good news. This result makes the Nakorotubu and Wailotua forest areas significant in local, regional and global land snail biodiversity terms. The family Bulimulidae already has several endemic species from other Pacific Island regions listed as endangered on the IUCN Red List (Brescia et al. 2008) and it is well known that threatened species of Pacific Island mollusc fauna are currently missing from the IUCN data source.

The relatively high proportion of introduced species found during this study (32%) is worrying in light of the

work of Cowie (2001b) and Cowie & Robinson (2003) that our regionally unique fauna is in decline and introductions are producing increasingly homogenized Pacific faunas. The presence of the introduced invasive species *Parmarion martensi* in the more isolated areas of the forest range is of considerable concern as such a common, hardy alien species is capable of contributing significantly to native species extinction via competition alone. In addition, *Parmarion martensi* is a potential vector for parasitic helminths such as the rat lung worm *Angiostrongylus cantonensis* (Chen, 1935) which is associated with eosinophilic meningitis in humans (Boray 1998). *Angiostrongylus cantonensis* and *Eosinophilic meningitis* are already established in Fiji (Alicata 1962, Uchikawa et al. 1984, Paine et al. 1994). However a recent study of *Parmarion cf. martensi* in Hawaii (Hollingsworth et al. 2007) highlights that this species is of particular concern in respect to spreading *A. cantonensis* because it is often associated with poorly washed home-grown crops such as lettuce and has a high infection rate by the parasite. Its vigorous climbing behavior on human infrastructure as see during this current survey makes it much more likely to come into contact with humans (and their food or water sources) than any of the other known snail vectors currently found in Fiji (Brodie & Barker, in review). However, the presence of *A. cantonensis* in Fijian *P. martensi* has not yet been confirmed.

In a report to the South Pacific Commission and the Fiji Government Parkinson (1982) listed seven relatively large species of *Placostylus* land snails as having potential value as specimen shells in the commercial shell trade industry (selling overseas). However, considerable habitat loss in the last 28 years and a strengthened understanding of the extinction risk to our unique molluscan species places a much more cautious view as to a need for their conservation today. The limitation is that it is very difficult to establish or develop conservation plans when we have so little data about species distribution and life history characteristics.

Many terrestrial snails are nocturnally active because of their need for cool, damp conditions. Targeted sampling at night or during wet season conditions may produce additional species in the surveyed area. Many species are arboreal (found in trees) and therefore spot-lighting in trees at night may be effective as would an increased focus on limestone dominated areas because of the calcium required by snails for shell development.

CONCLUSIONS

Conservation and future research recommendations

Land snails are excellent sentinel taxa for ecosystem change. Identification of taxa to genus or species level for native or endemic fauna is currently hindered by a lack of readily accessible taxonomic identification information. There is a need for more baseline surveys like this one in the priority forest areas highlighted by Olson et al. 2009 as the unique nature of Fiji's land snail fauna, and the high potential for its irretrievable loss by high risk invasive species, makes strategic planning for their long-term conservation vital. Relatively large scale habitat conservation in areas such as native forest, small islands and areas with significant deposits of limestone (needed by many terrestrial gastropod species for shell development) is required.

Two obvious follow-up studies are needed.

1. A review of the Fijian *Placostylus* species and an investigation of the cause of the observed high mortality in *Placostylus gracilis*.
2. Further investigations into the human health risks and feeding habits of *Parmarion martensi* to fully assess its potential to impact on humans and native fauna in Fiji.

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Table 5.1: Details of specimens found in during survey. * Indicates separate DNA sample taken.

Taxon No.	Brodie Code	Species	Common name	Location plus no. found & collected	Body form	Size	Status
1	A26, A30, A31, A37, A41, A43, A52*, A53, A58, A64, A72, A59*, A62*	Family Bulimulidae *Placostylus cf gracilis (Broderip 1840)*	Flax shell	53 in total only 5 alive Camp 2 [A43 (adult), A52 (juv)]; near Nausau village [A58 (juv) A59 (adult)]; and on trip to Camp 3 [A62 (juv)]. Aboreal.	Many weathered shells (white or bleached) collected on ground and one already dead. Fresh and two living shells, mottled brown with pink apex. Thickened aperture in adults, many juvenile shells found dead.	Average size shell height 45 mm, width 25 mm	Endemic
2	A61	Family Bulimulidae *Placostylus cf. graeffei* Crosse 1875	Flax shell	1 x near Nasau village	Dead shell only, not overly weathered, larger and more elongate shape than P. gracilus.	64 mm shell height, shell width 29 mm	Endemic
3	A36*	Family Bulimulidae *Placostylus* sp. (shell appears juvenile)	Flax shell	1 x Camp 1 S 17.35; E 178.21. arboreal	Board foot, tentacles very long and black. Tail much paler almost yellow. Dark strip down each side of neck. Foot uniform pale creamy yellow. Shell irregularly mottled ginger brown and cream.	Shell height 22 mm	Endemic
4	A28, A55	Family Trochomorphidae *Trochomorpha* sp. 1		4 collected in total (1 living each at Camp 1 2 plus two dead shells near Nasau village), arboreal found on tree trunks	Angular pyramid shaped shell with sharp apex, aperture set off to right side, wide umbilicus, distinct pale keel obvious from ventral, aperture oval with pointed sides, aperture edge smooth. Not particularly active when alive.	13 mm shell diameter, 8 mm in shell height	Endemic
5	A65*	Family Trochomorphidae *Trochomorpha* sp. 2		Camp 3 x 2 (one dead, one alive found separately), arboreal found on tree leaf	Flattened shell, no barriers to aperture, distinct keel to outer whorl, large, wide umbilicus, body pale grey but anterior head and tentacles black, living specimen relatively active	14 mm shell diameter, 7 mm shell height, 6 mm aperture width (larger specimen)	Endemic
6	A24*, A27*, A38, A39, A56, A69	Family Helicarionidae Unknown sp 1		11 in total collected, A24 - Camp 1 x 2; A27 x 1 (juv); arboreal	Mottled look probably caused by semi-transparent shell. No keel present. Pale body but with dark stripes to tentacles. Tentacles and tail/foot relatively long. Very active.	A24 - Living crawling length 19 mm, diameter of shell 11 mm; A27 (juvenile) - 7 mm shell diameter, 11 mm length, 3 mm shell height; A38 Shell diameter 9.5 mm, shell height 7 mm. A56 smaller	Endemic

(Table 5.1 Contn'd)

Taxon No.	Brodie Code	Species	Common name	Location plus no. found & collected	Body form	Size	Status
7	A29*	Family Helicarionidae Unknown sp. 2		Forest near Camp 1 arboreal	Rounded shell transparent ginger brown. Similar in shape to A71.	3 mm shell diameter, 8 mm active crawling length, shell height 2 mm	Endemic
8	A42	Family Helicarionidae Unknown sp.3		2 x Camp 1, arboreal on shrubs	dull brown shell not transparent, body brown with black tentacles	15 mm shell diameter, shell height 11 mm; 13 mm shell diameter, shell height 11 mm	Endemic
9	A46	Family Helicarionidae Unknown sp. 4		2 x stuck on limestone on way to Camp 2, terrestrial	Light brown transparent shell, fairly transparent long tentacles	30 mm crawling length, 10 mm width	Endemic
10	A71*	Family Helicarionidae		2 x stuck on limestone on way to Camp 2, terrestrial	Have very uniformly dark iridescent blue body in sunlight. Fast moving, can hang on tight. Shell relatively fragile, similar in shell shape to A29.	30 mm crawling length, 10 mm width	Endemic
11	A44	Family Helicinidae		1 on way to Camp 2, found on ground, fallen?	No photograph of living specimen	12 mm live length, 5mm wide	Native or Endemic
12	A45,	Family Helicinidae		4 x Camp 2	Shell with sharply pointed apex, aperture with a smooth edge, parietal callus present	Shell diameter 5 mm, height, shell height 4 mm	Endemic
13	A66*	Family Helicinidae		1 x Camp 3, arboreal	Globular brown shell, active. Distinctly textured shell, with raised ridges.	Live crawling length 10 mm, shell diameter 5 mm	Native or Endemic
14	A21*, A47, A49, A50, A51, A54*	Family Ariophantidae		All locations, 18 collected , many others seen	Semi-slug, dark colored, semi-slug, relatively narrow, smooth body with small oval shell into which the snail cannot retract	~ 35 mm, live crawling length, 7 mm width	Introduced, (highly invasive, associated health risk).
15	A21	Family Arophantidae *Parmarion aff. martensi* Simroth, 1893		1 x Camp 1	As above but wider rough textured body and distinctly ginger in colour	Not recorded	Introduced, (health risk likely)

(Table 5.1 Contn'd)

Taxon No.	Brodie Code	Species	Common name	Location plus no. found & collected	Body form	Size	Status
21	A25, A60	Family: Ariophantidae *Quantula striata* (Gray, 1834)	luminescent snail	8 in total collected only one alive, 2 worn shells on way to Camp 1, Camp 3 and near Matuku settlement	Relatively large shell, white when worn, dark rosey brown when alive, ventral paler	Shell diameter ~ 28 mm, shell eight approximately 18 mm	Introduced, (little known risk, however clear evidence of flatworm association seen in one specimen [A60]
16	A22, A34, A57	Family Veronicellidae (= Vaginulidae) Laevicaulis alte (Férussac, 1822)	Tropical Leatherleaf	2 on way to Camp1, 2 x Camp 1, 1 x Nasau village	Shell-less slug, relatively large board, uniform dark brown with distinct pale line down central dorsum	~ 50 mm long, 20 mm wide, foot width 6 mm	Introduced, (agricultural pest and documented human health risk)
17	A35	Family Veronicellidae (= Vaginulidae) *Sarasinula plebeia* (Fischer, 1868)	Caribbean Leatherleaf or bean slug	1 on way to Camp 1	Shell-less slug, very active. Paler than A34, faint pale line centrally, mottled network of dots and lines.	Live crawling length 39 mm, width 13 mm, foot with 4 mm.	Introduced, (agricultural pest)
18	A70	Family Veronicellidae (= Vaginulidae) Unknown sp. 1 Likely to be same as A35 & A48.		1 x Camp 3	Shell-less slug, no photograph taken.	Preserved length 31 mm	Introduced
19	A23, A67	Family Veronicellidae (= Vaginulidae) Unknown sp. 2. Could be *Semperula wallacei* (Issel 1874)		2 collected, 1 on way to Camp 1, other near Camp 3	Shell-less slug, relatively dull uniform brown, with pitted appearance to mantle.	A23 = 42 mm length, 24 mm wide; A67 = 49 mm live crawling length, 19 mm wide, 5 mm foot width.	Unknown could be native
20	A48	Family Veronicellidae (= Vaginulidae) Unknown sp. 3. Same as A35 & A70 likely.		2, in leaf litter near Camp 2	Shell-less slugs, no photograph taken	30 mm length, 10 mm width	Introduced

(Table 5.1 Contn'd)

Taxon No.	Brodie Code	Species	Common name	Location plus no. found & collected	Body form	Size	Status
22	A63 *	Family Subulinidae *Subulina* cf. *octona* (Bruguière, 1792)	subulinid	8 collected, 4 dead shells, 4 alive, others seen all Camp 3.	Uniform pale yellow elongate shell, lowest shell whorl with white gonad/egg in living specimens. Terrestrial.	Shell height ~13 mm, width ~ 3 mm, aperture width ~ 2 mm	Introduced, agricultural pest
23	A40	Family Subulinidae Unknown sp. 1 (juveniles)	subulinid	4 x Camp 1 in rotting log	Pale yellow shell and bodies, smooth aperture with no barriers	3-4 mm live crawling length	Introduced, pest species
24	A68*	Unknown		1 x Camp 3	Shell apex sharp, body pale yellow damaged, preserved shell transparent	~ 3 mm	Unknown

Chapter 6

Freshwater crustaceans of the Nakorotubu Range, Ra and Tailevu Provinces, Fiji.

Joelle C.Y. Lai, Ngan. K. Ng and Peter K.L. Ng

Team members: *David Boseto and Kuliniasi Qounadovu (Matuku village)*

SUMMARY

A total of 12 decapod crustacean species from four genera and three families were collected during this RAP, (Varunidae: *Varuna*; Atyidae: *Atyopsis*, *Caridina*; and Palaemonidae: *Macrobrachium*). The number of taxa is less than those previously reported. This may be due to the lack of adequate sampling equipment for the habitats surveyed, such as electro-fishing gear as well as the lack of intensive survey due to time limitations.

INTRODUCTION

The crustacean fauna of Fiji is relatively poorly known with very few studies on the crustacean fauna within Fiji. George (1971) reported on the Spiny Lobster Survey in Fiji. Choy (1983, 1984, 1991) recorded a total of 9 Macrobrachium spp., 2 Palaemon spp., 11 Caridina spp., and one species each of *Antecaridina*, *Atyoidea* and *Atyopsis*. Marquet et al. (2002) compared the freshwater crustacean fauna of Vanuatu with Fiji.

A Rapid Assessment Program (RAP) was conducted between 30 November to 10 December 2009 in the Nakorotubu range of Viti Levu. This report deals with the crustacean fauna that were collected during this RAP. All materials studied have since been deposited in the Zoological Reference Collection (ZRC), Raffles Museum of Biodiversity Research, National University of Singapore with duplicates to be sent to the SPRH and Marine Biodiversity Collection centre at the University of the South Pacific, Fiji.

MATERIALS AND METHODS

Collection of the specimens were carried out using various kind of nets including minnow traps (Plate 14), which were employed mainly at night; hand collection (Plate 15) where even the smallest hand nets are not accessible; nets (Plate 16), and tray nets (Plate 17). Some of the specimens were also collected by artisanal spear fishing (Plate 18)

The habitats of the sampling sites were freshwater streams with rock and boulders on the sides, the bottom was sandy, or covered with small rocks or pebbles and gravels. The rivers were usually shallow (e.g. Station 7, Plate 21), certain region of the river were relatively deep. Some parts of the river were peppered with numerous riffles (Station 10, Plate 22). The width of the river ranged from very narrow (Station 7) to very wide (Station 10). Some of the rivers had cascades with rock pools (Station 5, Plate 20) while some were more or less even.

The detailed sampling station codes, localities and associated data are listed in Appendix 6.

RESULTS

A total of 12 decapod crustacean species from four genera and three families were collected from this RAP. The number of taxa is less than those previously reported. This may be due to the lack of adequate sampling equipment for the habitats surveyed, such as electro-fishing gear as well as the lack of intensive survey due to time limitations.

Species List

Varuna litterata (Fabricius, 1798) (Plate 23)
Stations 1 and 9.
Common name – Pelagic Shore-Crab, Sargassum Crab, Pelagic Crab.
Type locality – India.
Remarks – This euryhaline species has an Indo-west Pacific distribution, and may be found in coastal habitats such as mangroves and estuaries. The species may also be found far inland in freshwater ponds and streams. They are able to swim short distances and may also disperse by clinging on to flotsam or floating Sargassum clumps.

Atyopsis spinipes (Newport, 1847)
Stations 8 and 11.
Common name – Torrent shrimp.
Type locality – Philippines Islands.
Remarks – *Atyopsis spinipes* has an Indo-west Pacific distribution, ranging from Madagascar to Japan and Polynesia. They prefer cooler water, and are usually found in rock crevices of fast flowing streams. It has been reported to be relatively common in the Fiji islands (Choy, 1991). This species can be easily collected by electro-fishing.

Caridina fijiana (Choy, 1983)
Station 8.
Common name – None.
Type locality – Viti Levu, Fiji.
Remarks – According to Choy (1983, 1991), *C. fijiana* is primarily a montane species recorded from altitudes above 600 m. The specimens here were collected from rock pools at the foot of a waterfall at an elevation of 570 m.

Caradina japonica (De Man, 1892)
Station 2.
Common name – Amano algae eating shrimp, Takashi Amano shrimp, The algae eater.
Type locality – Japan.
Remarks – First recorded from Fiji by Choy (1991). This species is found only in several Asian countries, but it has been collected and widely sold in the aquarium trade since it has a reputation as the best algae eater in the freshwater aquarium tank.

Caridina longirostris (H. Milne Edwards, 1837)
Stations 2, 3, 9 and 10.
Type locality – Oran, Africa.
Common name – None.
Remarks – This species is distributed in the Indo-West Pacific. This species was first recorded from Fiji in 1991 by Choy. This species is one of the common inhabitants of inland and lowland freshwater streams (Marquet et al., 2002).

Caridina weberi (De Man, 1892)
Stations 2, 3 5,9 and 10.
Common name – Long-wrist shrimp, Pugnose caridina, Short-haired shrimp.
Type locality – Indonesia.
Remarks – This relatively common species has been widely recorded from India, Japan to Polynesia. It is usually found in low numbers, and hides among the vegetations and roots along the banks of the stream, where the water speed is slower.

Caridina cf. serratirostris (De Man, 1892)
Stations 4 and 8.
Common name – Ninja shrimp, Honey shrimp and Christmas shrimp.
Type locality – Flores, Indonesia.
Remarks – This species is almost identical to *Caridina serratirostris* (De Man, 1892) but it is doubtful because C. serratirostris has been reported mostly from lowland estuarine rivers (see Cai & Shokita 2007, Cai 2007). As has been discussed by these authors and Yeo et al. (1999), the taxonomy of this species remains in flux and several species are probably in what is now called "*C. serratirostris*". This species is found in the Indo-West Pacific. This species is very popular in the aquarium trade due to its ability to change colour quickly to blend into the surrounding.

Macrobrachium australe (Guerin-Meneville, 1838)
Stations 9 and 10.
Common name – Koua river prawn.
Type locality – Tahiti, French Polynesia.
Remarks – This species has an Indo-West Pacific distribution ranging from Madagascar to Seychelles to Samoa and Marqueses Islands in French Polynesia (Holthuis 1950, 1978, Chace & Bruce 1993, Cai & Anker 2004). The species was first recorded in Fiji by Choy (1984) and is relatively common and well established in streams.

Macrobrachium idae (Heller, 1862) (Plate 26)
Stations 9 and 11.
Common name – Orana river prawn.
Type locality – Borneo.
Remarks – This species has a wide distribution in the Indo-West Pacific region ranging from Madagascar to the Admiralty Islands and South-East Asia (Cai et al., 2004). It is characterized by its very long and slender second periopods.

Macrobrachium lar (Fabricius, 1798) (Plate 24 & 25)
Stations 2, 3, 4, 5, 6, 10 and 11.
Common name – Monkey river prawn, Bracelet prawn, French bouqet Singe, Tahitian prawn.
Type locality – Dom. Daldorf, India.
Remarks – This is one of the most common species found in this RAP and the specimens collected in the RAP are exceptionally large. They are a good source of

protein and are often collected for food or commercially reared. This species is can be found in the Indo-Pacific from East Africa to the Ryukyu Islands and the Marquesas. Some 340 individuals of M. lar were brought to Honolulu, Hawaii, from Guam in 1956. Ninety-four were released on Molokai and a year later 27 on Oahu (Brock 1960). Additional specimens were brought from Tahiti in 1961 (Maciolek, 1972). After just nine years, a large specimen was collected on the island of Hawaii (Kanayama 1967). At present M. lar is established in streams on all the main Hawaiian Islands (Devick 1991, Eldredge 1994). This species is cultured in associated with Taro in Vanuatu (Nandlal, 2005).

Macrobrachium latimanus (Von Martens, 1868) (Plate 27)

Station 8.

Common name – Mountain river prawn.

Type locality – The Philippines.

Remarks – This species is commonly found in the Indo-west Pacific, Indo-West Pacific, ranging from India and Sri Lanka to the Ryukyu Islands, the Malay Archipelago and the Marquesas. They can be found in altitudes up to 1300 m above sea level (Holthuis, 1978). Adamson (1933) wrote that in the Marquesas "these prawns are caught by the Marquesans with nets and spears, usually with a light at night". Longhurst (1970) reported a subsistence fishery for this species in Fiji. In both cases M. lar and M. australe were fished at the same time (Holthuis, 1980).

Macrobrachium lepidactyloides (De Man, 1892)

Station 2.

Common name – Malay scale prawn.

Type locality – Borneo.

Remarks – This species is very similar to *M. hirtimanus* (Oliver, 1811) in its overall morphology, which has led to misidentification (see Holthuis, 1950). Holthuis (1952) clarified the identities of *M. hirtimanus* and *M. lepidactyloides* (De Man, 1892) based on the forms of the adult male chelae.

M. hirtimanus is endemic to the Mascarenes area located between Réunion and Mauritius (Keith et al., 1999, Keith & Vigneux 2000). *M. lepidactyloides* is found in the Indo-West Pacific, ranging from the Malay Archipelago to Fiji (Holthuis 1952). It is one the economically important prawns in the Philippines (Holthuis, 1980).

DISCUSSION

The present study documented 12 freshwater decapod crustacean species from four genera and three families (Varunidae: *Varuna*; Atyidae: *Atyopsis*, *Caridina*; and Palaemonidae: *Macrobrachium*).

Only one crab, *Varuna litterata* (Fabricius, 1798) was found, and this is not a wholly freshwater species as its larvae are still planktonic and dispersed by oceanic currents. Interestingly, old records indicate that there was one species of true freshwater crab that was described from Fiji, *Paratelphusa (Liotelphusa) insularis (*Colosi, 1919 (family Gecarcinucidae). This species is now placed in Austrothelphusa. The provenance of collection and identity of this species, however, is in doubt. Ng et al. (2008: 73) commented that "*Austrothelphusa* species are endemic to Australia, except for the poorly known *A. insularis* (Colosi 1919) supposedly from Fiji but not reported since. Two of the authors (P. K. L. Ng and P. J. F. Davie) have discussed this matter at some length with Satish Choy, who was born and raised in Fiji, and he is very certain this record is mistaken. The geographical location is also suspect – the easternmost record for any freshwater crab is in the Solomon Islands, *Sendleria salomonis* (Roux, 1934) (see also Bott 1969, 1970). The identity of *A. insularis* (Colosi 1919) remains unclear and the types need to be checked". Not surprisingly, the present survey did not uncover any trace of this species.

The 11 species of prawns are generally widespread and none have completely or highly abbreviated developments, with their larval cycle completely marine. The atyid *Atyopsis spinipes* (Newport 1847), is typically associated with clean fast flowing streams with large stones; while the various *Caridina species*: *C. fijiana* (Choy 1983), *C. japonica* (De Man, 1892), *C. longirostris* H. Milne Edwards 1837, *C. weberi* (De Man 1892), and *C.*. cf. *serratirostris* De Man 1892, are found in small streams with loose rubble and submerged vegetation. The same is also generally true of the four palaemonid species, *M. idae* (Heller 1862), *M. lar* (Fabricius, 1798), *M. latimanus* (Von Martens, 1868) and *M. lepidactyloides* (De Man, 1892). The largest of all the decapod crustaceans and the only one of any commercial value is the giant river prawn *M. lar*. The large size and healthy population of this species in the drainages sampled suggests the aquatic ecosystem in the area was pristine and relatively undisturbed by man.

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Chapter 7

Insects of the Nakorotubu Range, Ra and Tailevu Provinces, Fiji.

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SUMMARY

In November 2009, an entomological survey of the Nakorotubu Range, Viti Levu was conducted. The entomological quantitative surveys included: leaf litter sampling and pitfall trapping; qualitative surveys included: light trapping to target nocturnal insects, butterfly collections, fruit fly baiting and opportunistic encounters. The surveys were divided into three focal surveys sites averaging three field days per site. Adverse weather conditions on some of the days prevented insect sampling especially at Base camp 3 which limited collections from leaf litter and pitfall traps.

The order Coleopetera (beetles) was the most common insect order encountered throughout the surveys and was the target taxa. Overall Coleoptera recorded a total of 25 families. Rare families encountered during the surveys included: Pselaphidae, Callirhyphidae, Cerambycidae and Cicindellidae. The highlight of the survey was the discovery of the two rare Fijian stick insects *Nisyrus spinulosus* and *Cotylosoma dipneusticum* which were both found at Base camp 2. One of Fiji most unique forest systems, i.e. comprised of upland forest area was identified at this study site.

The uniqueness and isolation of this forest system explains much of the diversity of insects from the Nakorotubu Range.

INTRODUCTION

It is estimated that the Pacific island region is home to about 915,000 species of invertebrates, approximately 15% of the world total with more than half the insect species unknown to science (Allison & Englund 2005). High rates of endemicity are also characteristic of this region, attributed to the extreme geographic isolation of many island groups. However, little is known of the invertebrate fauna of Fiji particularly with respect to their taxonomy, distribution and ecology.

Currently for Fiji and many other Pacific islands, habitat loss (effectively forest loss) remains the most serious threat to the endemic fauna and flora, with deforestation in Fiji continuing (Watling & Chape 1992). However, Fiji is considered one of the best remaining forested areas in the central Pacific with most restricted to the higher and wetter portions of the islands subjected to extensive fragmentation. These upland forested areas are considered to harbour the greatest diversity of native arthropod species and consequently these areas and their constituent native species are most vulnerable to perturbations and possible resulting reductions in populations and even extinctions (Evenhius & Bickel 2005).

The roles of Coleoptera in ecosystems are well known and documented. They are an important food source, recycle vegetation through decomposition and herbivory, provide pollination services and are also regarded as indicators of environmental change. The distribution of Coleoptera in general is related to vegetation types and climatic conditions as a result of changes to landscape forms and altitude. Coleoptera is also known to be the most diverse group. For Fiji alone, a total of 1398 coleopteran species have been recorded and many still await discovery.

Aims and objectives

To date there have been no entomology surveys or records from the Nakorotubu Range. Consequently, the main aims of this survey were to: (a) conduct a baseline entomology survey of the Nakorotubu Range using a variety of survey techniques, (b) identify significant species or taxa (including accurate GPS positions for any significant findings) and (c) collect voucher specimens to be housed at the South Pacific Regional Herbarium (SPRH), University of the South Pacific.

METHODS

Geographic location

The Nakorotubu Range is along a coastal district within the Ra and Tailevu provinces with extensive inland undulating and rugged terrain. The different techniques used at each site are presented in Appendix 7.

Coleoptera (Beetles)

Leaf Litter Surveys

Leaf litter surveys were conducted targeting the altitudinal range (150- 600 m a.s.l.). A 50 m transects marked at 5 m intervals were set up. 1 m2 quadrats were used to sample leaf litter at every 5 m along the transect. Leaf litter was sieved through 12 mm mesh and transferred into Winkler bags. The bags were then hung out for at least 48 hours to dry. Collected specimens were stored in ethanol (80%) in tightly sealed labeled vials for further sorting and identification in the lab (Plates 28 & 29).

Pitfall Surveys

50 m transects were marked at 5 m intervals in which pitfalls were placed into the ground with 80% ethanol as preservative. Samples collected from pitfall traps were collected after 48 hours. Collected specimens were stored in ethanol (80%) in tightly sealed labeled vials for further sorting and identification in the lab (Plate 30).

Nocturnal Surveys

Nocturnal collections for other insect groups were conducted using light traps. These were set up every night where possible when the weather was fine and left to run from 18.00-06.00 hours. Collected specimens were stored in ethanol (80%) in tightly sealed labeled vials for further sorting and identification in the lab.

Other taxa

Opportunistic Surveys

Opportunistic surveys were also conducted whilst carrying out surveys for other taxa. Phasmids (stick insects) and butterflies were sampled opportunistically in open grassland areas and along the Nabavatu and Olou creeks using handheld nets during days with good weather. Voucher specimens were collected for identification. Identification of butterfly species was based on Prasad and Waqa-Sakiti (2007) whilst identification for stick insects was possible through the assistance of Dr. Paul Brock (Natutal History Museum, London) and from reference collections housed at the SPRH. All specimens are currently being curated and catalogued at the SPRH, USP.

Fruit Fly Trapping

Fruit and flower specimens were collected from varying altitudes within the three different campsites. Each specimen was weighed, counted and placed into a sawdust-containing paper bag. The paper bags were then loosely sealed and arranged in cartons, out of reach of ants. The specimens were then transferred into containers at the Koronivia Agriculture laboratory to await dissection.

A second sampling method, fruit fly traps (i.e. using ME and CUE lure) were also set at various locations to trap fruit flies. The trap consists of wire gauze for collecting the fruit flies (it is placed inside the trap like a car mat), dental wicks wired together (white) which are dipped in a mixture of pheromones and insecticide. The pheromones have a 1 km radius strength and last for 3 months.

RESULTS AND DISCUSSION

Taxa results

Coleoptera

1) Leaf litter sampling

Beetles were sampled from 50 m line transects at 5 m intervals from different locations targeting different habitat types. Coleoptera recorded a total of 258 individuals from 13 families (Table 7.1). The most common families encountered included: Zopheridae, Curculionidae and Scolytidae. The families Curculionidae and Scolytidae were evenly distributed across all sampled sites. The family Zopheridae was most dominant in sites sampled from the Base camp 1 area. The rare beetle family Pselaphidae was only found from leaf litter sampled from the Base camp 2 area. Greatest diversity (i.e. 7 coleopteran families) was sampled from transect 7 at a mid altitude of 578 m a.s.l. which confirms that mid-altitudes harbour greatest diversity for insects due to less disturbance and less severe climatic conditions.

2) Nocturnal sampling

Nocturnal sampling was carried out on two nights within the area of each of the three base camps i.e. when weather conditions permitted. A total of 100 individuals representative of 13 coleopteran families were recorded (Table 7.2). The families Elateridae, Scaraebaedae, Carabidae and Eucnemidae were the most common taxa encountered during the nocturnal surveys. Interestingly, the rare family Cerambycidae (i.e. long-horn beetles) were only encountered during nocturnal surveys within the Base camp 3 area. Nocturnal surveys proved that areas within Base camp 2 had the greatest diversty i.e. with an average of 6.5 families sampled.

3) Pitfall Traps

A good number of beetles i.e. 243 were sampled

through pitfall traps (Table 7.3). The beetle family Scolytidae was most abundant from pitfall traps followed by Nitidulidae and Staphylinidae. Overall diversity of Coleopteran families from pitfall trapping were from Base camp 1. Rare families encounted were Cicindellidae and Pselaphidae.

Other Taxa

Phasmida (Stick insects)

Phasmids (stick insects) were sampled opportunistically. A total of 10 individuals from 4 different species were collected (Table 7.4). The area within Base camp 2 yielded the highest diversity for the order Phasmida recording 5 individuals from 3 different species. The endemic Phasmatonea inermis was most commonly encountered of the four species.

Lepidoptera (Butterflies)

Butterflies were also sampled opportunistically. A total of 14 individuals from 6 different species were collected (Table 7.5). The area within base camp 1 yielded highest diversity for the butterflies recording 8 individuals from 4 different species. The species *Euploea biosduvali boisduvali* was most commonly encountered of the six species.

Table 7.1: Coleoptera collected during leaf litter sampling.

Coleoptera Family	BC1_LLT1	BC1_LLT2	BC1_LLT3	BC1_LLT4	BC1_LLT5	BC2_LLT6	BC2_LLT7	BC2_LLT8	BC3_LLT9	Total
Anthribidae	0	0	0	0	1	0	0	0	1	2
Carabidae	0	4	0	0	1	0	0	0	0	5
Chrysomelidae	1	0	0	0	0	0	1	0	0	2
Curculionidae	4	12	13	4	5	10	8	8	3	67
Languridae	0	0	0	1	4	0	0	0	0	5
Nitidulidae	1	0	0	1	0	0	0	0	0	2
Pselaphidae	0	0	0	0	0	3	3	0	0	6
Salpingidae	7	0	2	0	0	0	1	0	1	11
Scirtidae	0	0	0	0	0	0	0	0	1	1
Scolytidae	4	10	0	1	2	7	7	0	1	32
Staphylinidae	0	0	0	3	0	0	1	0	0	4
Tenebrionidae	0	6	0	0	0	0	0	0	0	6
Zopheridae	29	25	43	14	0	2	2	0	0	115
Total	46	57	58	24	13	22	23	8	7	258

Table 7.2: Coleoptera collected during light trap sampling.

Coleoptera Family	BC1_LT1	BC1_LT2	BC2_LT3	BC2_LT4	BC3_LT5	BC3_LT6	Total
Anthribidae	0	1	0	0	0	0	1
Callirhiphidae	0	0	1	2	0	3	6
Carabidae	2	1	4	4	0	3	14
Cerambycidae	0	0	0	0	2	1	3
Chrysomelidae	0	0	3	4	0	0	7
Curculionidae	0	0	3	1	0	0	4
Dytiscidae	1	0	1	0	0	0	1
Elateridae	0	1	0	4	23	1	29
Eucnemidae	1	0	3	5	2	0	11
Oodemeridae	0	0	0	0	0	1	1
Platypodidae	0	0	2	0	2	0	4
Scaraebidae	6	3	0	0	9	0	18
Tenebrionidae	0	0	0	0	0	1	1
Total	9	6	17	20	38	10	100

Table 7.3: Coleoptera sampled from pitfall traps.

Coleoptera Family	BC1_LT1	BC1_LT2	BC2_LT3	BC2_LT4	BC3_LT5	BC3_LT6
Anthribidae	0	0	0	0	0	0
Carabidae	16	3	0	0	0	19
Chrysomelidae	0	0	0	0	0	0
Cicindelidae	0	2	0	0	0	2
Curculionidae	0	2	0	0	0	2
Languridae	0	0	0	0	0	0
Nitidulidae	14	1	9	4	1	29
Pselaphidae	1	0	0	2	0	3
Salpingidae	0	0	0	0	0	0
Scirtidae	0	0	0	0	0	0
Scolytidae	69	34	8	18	13	142
Staphylinidae	16	1	5	1	1	24
Tenebrionidae	2	5	9	5	1	22
Zopheridae	0	0	0	0	0	0
Total	118	48	31	30	16	243

Table 7.4: Phasmida sampled from opportunistic surveys.

Coleoptera Family	BC1_LT1	BC1_LT2	BC2_LT3	BC2_LT4	BC3_LT5
Cotylosoma dipneusticum	0	2	0	1	3
Graeffea crouanii	0	2	0	0	2
Nisyrus spinulosus	0	0	1	0	1
Phasmatonea inermis	1	1	2	0	4
Total	1	5	3	1	10

Table 7.5: Lepidoptera (butterflies) sampled from opportunistic surveys.

Species	BC1_OS	BC2_OS	BC3_OS	Total
Melanitis leda solandra	0	1	1	2
Papilio schmeltzi	2	0	0	2
Euploea biosduvali boisduvali	4	0	2	6
Danaus hamata neptunica	0	0	1	1
Hypolimnas bolina	1	0	1	2
Xois sesara	1	0	0	1
Total	8	1	5	14

Table 7.6: Table showing the trap counts of the fruit flies; *Bactrocera xanthodes*, *B. passiflorae* & *B. distincta*

Date	ME lure	CUE lure	
	B.xanthodes	*B. passiflorae*	*B.distincta*
02/12/09	Nil	4	Nil
06/12/09	Nil	2	6
12/12/09	Nil	nil	Nil

Taxa Discussion

Insecta: Coleoptera

The order Coleoptera (beetles) was the most diverse group of insects sampled from all sampling methods in terms of species richness and abundance. A total of 25 families were recorded from the three sites surveyed. The most diverse beetle families include: Curculionidae (weevils), Zopheridae, Scolytidae, Nitidulidae, Elateridae and Staphylinidae. Greatest diversity for coleopteran families was sampled from Base camp 1. Rare families encountered include: Pselaphidae, Callirhyphidae, Cerambycidae and Cicindellidae. The families Pselaphidae and Callirhyphidae were sampled from Base camp 2.

The high diversity of Coleopteran assemblages and the presence of rare families at the survey sites suggest the forest system within the Nakorotubu Range is still well intact as beetles have been known to be essential drivers of forest ecosystem functions.

Insecta: Lepidoptera

A total of six species of butterflies were sampled from the Nakorotubu Range during this expedition however, it is certain that many more species exist but were not encountered during the survey period. The endemic Fijian swallowtail butterfly, *Papilio schemeltzii* was also encountered along the forest edges which was a good indication that forest systems within the Nakorotubu Range are well intact.

Insecta: Phasmatodea

Phasmida are commonly known as walking, stick or leaf insects due to their remarkable adaptations and resemblance to their immediate environment. Fiji has a relatively rich representation of stick insects with 21 species, from 11 genera. Eight species are endemic to Fiji. Amongst the endemic species are *Cotylosoma dipneusticum* and *Nysirus spinulous* (syn. Cotylosoma) which were both found within the Nakorotubu Range. The current survey collected three specimens of C. dipneuticum (two females and one male, Plates 31 & 32). This is a significant find as little is known of this endemic species. A specimen of the *C. dipneusticum* was found on the native tree 'damanu' (*Calophyllum* spp.). So far only male specimens have been collected for *C. dipneusticum* which has only been recorded from Taveuni and Wailoku (Viti Levu). This is a first record for Nakorotubu Range and from these findings it is suspected that a good population exists within the surveyed area. However, further studies are warranted to confirm this. *C. dipneusticum* occurs in these mountain ranges (17.58902°S & 178.35753°E) where two females and a male specimen were caught in nocturnal surveys using Ultra Violet light traps and through opportunistic encounters.

Other endemic species like *Nisyrus spinulous* and Phasmatonea inermis were also collected in this survey. P. inermis also appears to have a good population within the survey areas with four individuals collected. Both of these species were also recorded for the first time during a recent Nakauvadra Range RAP.

Overall the area surveyed within Base camp 2 proved to be excellent habitat for stick insects as it harbours a good number of endemic species especially for *Colylosoma dipneusticum*. Of the ten individuals found, 5 were caught from within the area surveyed in Base camp 2. The forest system in Base camp 2 is isolated from disturbance and harbours a unique forest system "upland rainforest" which is known as one of the last remaining upland forest systems in Fiji that is relatively intact.

CONCLUSIONS AND RECOMMENDATIONS

Conservation significance

The Nakorotubu Range is an important site for insect conservation. Entomological surveys within the area suggests that forest systems are intact due to (i) the high diversity of Coleoptera which are key elements in the driving of forest ecosystem functions and (ii) some significant finds of Fiji's rare insects such as the stick insects *Cotylosoma dipneusticum*, *Nisyrus spinulousus* and *Phasmatonea inermis*.

Recommendations for conservation and future work

1. A thorough ecological study for the two Fijian stick insect species *Nisyrus spinulousus* (syn Cotylosoma) and *Cotylosoma dipneusticum* be conducted within the survey areas as this is the only known site so far to harbour these two rare Fijian stick insect species. Studies on population, seasonality patterns, behaviour and host plant associations would be essential for conservation measures.
2. There has to be an intensive host fruit collection conducted in the Nakorotubu Range to determine the host fruits of the fruit fly species present there.
3. Weather conditions especially at Base camp 2 were not ideal for insect sampling and because this harbours a unique forest system (i.e. upland forest), a quantitative survey in suitable conditions for leaf litter, pitfall, light trap and malaise sampling within the three campsites are essential to confirm its uniqueness.
4. Environmental awareness workshops should be conducted for resource owners on the significance of the native fauna and the need to conserve forested areas i.e., to minimize activities leading to habitat destruction.

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Chapter 8

Damselflies and Dragonflies of the Nakorotubu Range, Ra and Tailevu Provinces, Viti Levu, Fiji.

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SUMMARY

A total of 32 Odonata taxa were found during the RAP-Fiji in the Nakorotubu range, Ra and Tailevu Provinces, Fiji. These taxa represent more than 50% of the all species recorded for the whole Fijian archipelago and about 78% of the species established for Viti Levu. The significance of the group for environmental appraisals is discussed, individual behavioural traits and short ecological information are provided for each species observed during the investigation, and a preliminary habitat classification scheme is suggested for the species collected from the study area. Due to problems with species taxonomy only general conservation recommendations are proposed without specifying local management actions that need to be taken.

INTRODUCTION

Insects belonging to Order Odonata (commonly known as dragonflies or odonates) are among the most suitable subject for any kind of nature observations and research (Corbet and Brooks 2008). Due to specific morphological characteristics, as well as behavioural and ecological peculiarities, they are often among the top selected invertebrate groups for environmental appraisals, wetland management plans preparation, monitoring programmes development and implementation (Clark and Samways 1996, King et al. 2000, Armstrong 2002, Chovanec et al. 2002, Hawking and New 2002, Briers and Biggs 2003, Clausnitzer 2003, Davies et al. 2003, Chovanec et al. 2004, Hadrys et al. 2005, Oertli et al. 2005, Scher and Thièry 2005, Thomas 2005). Below are some of the features that make dragonflies a priority group for nature conservation programmes and rapid biodiversity assessments:

Big, colourful insects, easily detectable and recognisable even in flight

Experienced observers could, in well studied regions, identify almost all species using a pair of binoculars only. Odonates cannot fold their wings along the body. That keeps them always above the surface and the researchers do not have to turn stones, chop tree bark, search among the leaflitter or dig into the soil to encounter these insects. Dragonflies can hide among dense vegetation however, their life-cycle always "brings" them close to the water bodies for reproduction.

Very specific behavior pattern, which keeps them close to the water

Dragonflies are easily found around wetlands of any kind. Some limits in their distribution and survival are posed by the areas in higher latitudes, fast flowing mountains streams, cold glacial lakes and highly saline coastal lagoons. Otherwise there could be up to 20-25 species encountered (in extremely good mixture of habitat types) during a single walk around water's edge. Normally much fewer occur near water.

Considerably small species number (compared to other insects groups)

With about 6000 currently described species Order Odonata ranks among the species poor insect orders. Low species number around wetlands is a prerequisite for developing effective monitoring programmes involving volunteers with no significant taxonomic knowledge. It is an

important step in wetland management as dragonflies are often used as environmental indicators.

Very important indicators for habitat heterogeneity, pollution, species biodiversity, and global state of the environment

Dragonfly potential as bioindicators has long been recognised and recently assessed in Foot and Hornung (2005). Many aquatic biotic indices, overviewed in Chessman and McEvoy (1998), include odonates as well. Moreover there are biodiversity and habitat indices based entirely on this insect order (Schmidt 1985, Chovanec and Waringer 2001, Simaika and Samways 2009). Some species are very sensitive to habitat fragmentation and special "green corridors" are envisaged to harbour the vulnerable species (Van der Sluis et al. 2004).

This short overview is indicative of the significant role the dragonflies play in environmental studies. The recently prepared global assessment of all odonate species showed that one in 10 species is threatened with extinction (Clausnitzer et al. 2009). That increases the odonates' significance, raises their value in environmental assessments and makes their inclusion in the wetland monitoring programmes imperative especially for poorly studied regions.

The Nakorotubu Range, Viti Levu, Fiji, is among the poorest odonatologically known areas within the Fijian Archipelago. In spite of the 142-years history since the first published record for this part of the world the Odonata knowledge remains insufficient. Map 6 shows the total area coverage of the Fijian Archipelago compiled by published research within the region. A comprehensive literature overview follows, which is necessary for outlining the scientific tasks of the present research. It also acted as incentive for studying dragonflies within the Nakorotubu Range.

Brauer (1867a,b; 1869) appears to be the first recorder of the Fijian Odonata fauna. Six species are reported with no specified localities. Although claimed to be taken from "Viti-Inslen" not all have been sampled from Viti Levu (see Table 98.1). Around the same time Fijian islands appeared in the detailed monographs on the order made by Selys (1871, 1874) and other work of the same author (Selys 1891). He added seven new species with Nesobasis being an endemic genus for the country. Another new genus (Hypothemis) was introduced earlier by Karsch (1889). This monotypic genus is also endemic to Fiji.

Chronologically next in the list is Kirby (1890), however it is not included in Table 98.1 as it does not add new species to the study area. He makes a detailed catalogue of the whole order and refers to previously published records only. Three species (*Orthetrum sabina*, *Pantala flavescens* and *Diplacodes trivialis*) are overlooked and not included in his review. To avoid further misunderstandings and complicated taxonomic discussions other catalogues prepared for the world (Tsuda 1991, Bridge 1994) or regional (Schmidt 1938) fauna are omitted from this analysis.

Two other researchers make important contributions to the knowledge of Odonata fauna of the region in the beginning of the twentieth century. Martin (1901, 1906, 1914) and Ris (1909, 1911, 1916) add two more species to the Fijian Odonata fauna and provide important taxonomic notes on six previously known species. These works contain detailed synonymic lists compiled for the Odonata fauna from various regions worldwide and help in orienting the up-to-date dragonfly taxonomy.

Tillyard (1924) makes the first comprehensive review over the Fijian Odonata. He revises the Mr. Simmonds' (Government Entomologist in Fiji) collection taken mainly from two places on the southern part of Viti Levu Island. Prior to this investigation 17 species had been reported for Fijian islands not 16 as reported by Tillyard (1924) who possibly has overlooked a short note in brackets on Anax guttatus in Ris (1916). The results of Tillyard's study are an updated checklist with 15 new species for Fiji (11 of which were new to science), identification keys and morphological description of the endemic genus *Nesobasis*, general species distribution records and detailed zoogeographical analysis. The author introduces two more taxa *Agriocnemis vitiensis* and *Nesobasis subhumeralis*, however they were later synonymised in Fraser (1925) and Donnelly (1990) with *Agriocnemis exsudans* and *Nesobasis angulicollis* respectively and are excluded from Table 98.1.

Analysing the material collected by Miss Cheesman and Mr. Lever from the Pacific islands Kimmins (1936, 1943, 1953) report on 5 species sampled from Fiji. One of them was new to science.

Surprisingly the next new species for the Fijian Odonata fauna were published in a New Caledonian publication (Lieftinck 1975) after more than 30 years with no information about this archipelago. The author does not specifically refer to this fact however, reports about species global distribution reaching as far east as Fijian islands. On the same manner he mentions other 3 previously known species for the country.

About the same time the Fijian Odonata were "rediscovered" thanks to the intensified scientific expeditions within the area. Wise (1978) does not provide any species names and refers to all sampled material by order names only. Wise (1980) makes records on Auckland Museum's Odonata collection and provides accounts for 8 species with 2 new species for Fiji. Haynes (1987) investigated the benthic invertebrates on Viti Levu and reports on dragonfly larvae presented in the freshwater samples. However, the most important contributions came from researchers working in two different directions. They are the vital sources of information for the region and will be reviewed separately.

With a series of publications starting from this period on, Donnelly (1984, 1987, 1990, 1994, 2005) is presently the most recognisable expert on Fijian Odonata fauna worldwide. His contribution towards understanding Fijian Odonata is outstanding with considerable achievements in the taxonomy, chorology and biology aspects. We owe to his studies a new genus created for 3 previously described species and 4 new ones (three of which occur on Fijian islands and one on Vanuatu) (Donnelly 1984) and 10 other new species (Donnelly 1990) as well as detailed morphological

descriptions and taxonomical analyses of the genus Nesobasis. The author's short notes about the trips within the Pacific islands (Donnelly 1987, 1994) are a real source of inspiration for further research. Of particular interest are remarks on the possible sex-role reversal and inferred parthenogenetic development in certain species noted in earlier publications and explicitly accounted for in Donnelly (2005). Male rarity is observed in species like *N. campioni*, *N. flavifrons*, *N. monticola*, *N. rufostigma* with no males encountered in *N. flavostigma* and *N. caerulescens*. Females of those species have been discovered establishing territories near the water edge together in the same manner as the males of closely related species.

The idea of sex-role reversal has been developed further and studied in greater detail by a team of co-associates. Their suspicions about parthenogetic development at least in two species (*N. flavostigma* and *N. caerulescens*), was firstly expressed in Sherratt and Beatty (2005). Later research paid special attention to *Nesobasis* species diversity and abundance (Beatty et al. 2007, Van Gossum et al. 2008) and confirm the male rarity in 13 species (Van Gossum et al. 2007). The members of the team also sampled 12 new species (Van Gossum et al. 2006, 2008) however, they had been already collected and were pending description by T. Donnelly. Thus they appear with abbreviations in the above mentioned publications and in Table 98.1.

Further general information on Fijian Odonata could be found in Evenhuis and Bickel (2005) and Evenhuis (2007) with no specific species name given and one molecular study where four Fijian species have been used as outgroups for studying phylogenetic history of the Hawaiian genus Megalagrion (Jordan et al. 2003). Molecular studies, aiming in exploring the evolution of the insular insect radiation, are another aspect of scientific work on Fijian Odonata. Although not officially published yet (only presented during scientific meetings) some research have been done by Chris Beatty on the relationships between *Nesobasis* and *Melanesobasis* and with other genera within the Pacific Ocean area.

The literature review revealed no odonatological data on the Nakarotubu Range. The closest region where dragonflies are known from is Wainidruku Creek, 2 km south of Wailotua Village (Donnelly 1990). Thus the Rapid Assessment Programme (RAP) was seen as important step towards contribution to faunal and ecological research of the order on the Fijian main island, Viti Levu. It aimed to establish species lists for the visited regions and make observations on the individual species habitat preferences. Species biology was considered also as highly important, however, for the limited time planned for each of the study areas little attention was paid to the diurnal activities relating to ovipositing, mating or roosting. However, some important data are collected and commented upon in this report.

MATERIALS AND METHODS

Adult Odonata (imago) were collected from three main areas in a total of 40 localities (Map 8) during the period 30 November – 12 December 2009. These include three places outside the Nakorotubu Range. All sites were sampled with aerial nets and captured individuals killed in 90% ethanol. Later, the specimens were dried at room temperature and transferred to paper envelopes. Some of them were prepared for further DNA analyses, the results of which will be published separately. Few freshly emerged individuals (tenerals) were collected together with the larval skin (exuviae). They were preserved for larvae description if it was found to belong to a species with unknown pre-imaginal morphological stage. Larvae were sampled in one locality only (number 25 from the list provided below).

The search for various biotopes and habitat types were planned after consultation with the local guides provided for the RAP. At each site the water edge was checked for flying individuals. The dense vegetation surrounding water bodies made it impractical for special transects to be made unless more time was spent within the study areas (Oppel 2006). The species activity was recorded and compared to what was known from the literature. The same was done for individual occupancy of the sites and observed preferences to sunlight vs shade. Various biotopes were visited with more attention paid to running waters. They were studied for suitable habitats for odonates based on presence/absence data and observed behavioural patterns. The Corbet (1999) system for distinguishing between biotope and habitat was adopted as it makes a clear separation with biotope being the entire ecological system providing specific living environments (habitats) for various living forms. These habitats must be defined by the production rate of the population, which must exceed the death rate in order for a population to be stable even without immigrants from other sources. Population estimations play a crucial role in defining species habitat parameters. However, these are laborious, time consuming and not applicable for rapid ecological investigations. For the purpose of the current research the habitat parameters were established based on records of possible breeding species only. As such, we defined species observed to: a) lay eggs, b) form tandems or copulating wheels, c) defend territories, or d) aggregate in large number. Breeding species (determined upon the larvae skin, newly emerged individuals or larvae prior to emergence) were excluded from the analysis as they need further identification work.

Sampling localities

1. Lake by the Raintree Lodge, Colo-i-Suva (178^{0}27'25.6"E; 18^{0}03'30.4"S; 232 m a.s.l.): 30 November.
2. Open grass vegetation on the hills above the lake by the Raintree Lodge, Colo-i-Suva (178^{0}27'21.9"E; 18^{0}03'25.9"S; 260 m a.s.l.): 30 November.
3. Olou River by Matuku Village (178^{0}22'07.2"E; 17^{0}37'47.0"S; 59m a.s.l.): 30 November.

4. Oxbow lake of Olou River 860m straight line from Matuku village (178°21'56.5"E; 17°37'07.9"S; 52m a.s.l.): 30 November.
5. Stream about 625m straight line S of RAP-Fiji Camp 1 site (178°21'59.3"E; 17°36'19.0"S; 142m a.s.l.): 30 November.
6. RAP-Fiji Camp 1 site (178°21'52.0"E; 17°36'00.0"S; 170m a.s.l.): 01 December.
7. Olou River about 280m straight line NW of RAP-Fiji Camp 1 site (178°21'44.3"E; 17°35'54.5"S; 145m a.s.l.): 01 December.
8. Olou River about 420m straight line NW of RAP-Fiji Camp 1 site (178°21'41.9"E; 17°35'50.1"S; 145m a.s.l.): 01 December.
9. Oxbow lake by Olou River about 455m straight line NW of RAP-Fiji Camp 1 site (178°21'40.8"E; 17°35'49.8"S; 161m a.s.l.): 01 December.
10. Olou River about 610m straight line NW of RAP-Fiji Camp 1 site (178°21'39.2"E; 17°35'44.2"S; 165m a.s.l.): 01 December.
11. Olou River about 735m straight line NW of RAP-Fiji Camp 1 site (178°21'41.3"E; 17°35'38.4"S; 170m a.s.l.): 01 December.
12. Stream 710m straight line NW of RAP-Fiji Camp 1 site (178°21'34.7"E; 17°35'44.4"S; 256m a.s.l.): 02 December.
13. Stream 1115m straight line NW of RAP-Fiji Camp 1 site (178°21'34.6"E; 17°35'27.9"S; no altitude recorded): 02 December.
14. Olou River about 1925m straight line NW of RAP-Fiji Camp 1 site (178°21'21.7"E; 17°35'04.5"S; 214m a.s.l.): 02 December.
15. On the inflow of Wainirea stream to Olou River (178°21'14.9"E; 17°35'00.1"S; 226m a.s.l.): 02 December.
16. Stream about 875m straight line NW of RAP-Fiji Camp 1 site (178°21'25.4"E; 17°35'47.5"S; 295m a.s.l.): 02 December.
17. Stream about 590m straight line S of RAP-Fiji Camp 1 site (178°21'51.5"E; 17°36'19.2"S; 150m a.s.l.): 03 December.
18. Forest stream on the track to RAP-Fiji Camp 1 site at the beginning of the climbing from Olou River (178°21'57.3"E; 17°36'54.1"S; 129m a.s.l.): 30 November and 03 December.
19. Pool by the Olou River about 695m straight line NW of Matuku Village (178°21'57.9"E; 17°37'26.3"S; 43m a.s.l.): 03 December.
20. Olou River about 465m stream about 875m straight line NW of Matuku Village (178°22'00.9"E; 17°37'33.1"S; 34m a.s.l.): 03 December.
21. Stream on the left-hand site on the track from Matuku village to RAP-Fiji Camp 2 site about 725m from the village (178°22'17.8"E; 17°37'25.8"S; 188m a.s.l.): 04 December.
22. Stream on the left-hand site on the track from Matuku village to RAP-Fiji Camp 2 site about 1430m from the village (178°22'34.9"E; 17°37'08.8"S; 347m a.s.l.): 04 and 07 December.
23. Track from Matuku Village to RAP-Fiji Camp 2 site – top of the ridge (178°22'52.4"E; 17°36'27.7"S; 436m a.s.l.): 04 December.
24. RAP-Fiji Camp 2 site (178°23'02.4"E; 17°35'53.4"S; 550m a.s.l.): 04 December.
25. Stream passing by RAP-Fiji Camp 2 site about 270m straight line SW from the camp (178°22'59.9"E; 17°36'01.8"S; 499m a.s.l.): 05-06 December.
26. Swampy area by the track to the coast about 1050m E-NE from the RAP-Fiji Camp 2 site (178°23'37.0"E; 17°35'45.7"S; 585m a.s.l.): 07 December.
27. Namanu Creek about 500m E from Nasau Village (178°25'14.6"E; 17°44'02.6"S; 41m a.s.l.): 08 December.
28. Wailotua River and adjacent oxbow lakes about 500m straight line SW from Nasau Village (178°25'20.3"E; 17°44'02.0"S; 40m): 08 December.
29. Waimaca Creek about 300m S of Nasau Village (178°25'33.2"E; 17°43'55.2"S; 50m): 08 December.
30. Nasau Village (178°25'23.6"E; 17°43'51.7"S; 45 m a.s.l.): 08-09 and 11 December.
31. Wainalimata Creek on the track from Nasau Village to RAP-Fiji Camp 3 site (178°25'18.4"E; 17°43'27.6"S; 35m a.s.l.): 09 December.
32. Wainamatavia Creek on the track from Nasau Village to RAP-Fiji Camp 3 site (178°25'12.6"E; 17°43'12.4"S; 55m a.s.l.): 09 December.
33. Pool within the Nabunavonu area (178°25'18.2"E; 17°43'05.9"S; 10m a.s.l.): 09 December.
34. Seepage within a densely vegetated area about 150-200m S from RAP-Fiji Camp 3 site (178°25'19.1"E; 17°43'02.0"S; 27m a.s.l.): 09 December.
35. Tributary of Wainivana River with a small waterfall (178°25'31.8"E; 17°42'44.5"S; 53m a.s.l.): 10 December.
36. Swampy area by Wainivana River (178°25'43.2"E; 17°42'38.3"S; 67m a.s.l.): 10 December.
37. Oxbow lake of Wainivana River (178°25'41.8"E; 17°42'42.7"S; 58m a.s.l.): 10 December.
38. Tributary of Wainivana River (178°26'07.9"E; 17°42'35.0"S; 70m a.s.l.): 10 December.
39. About 150-200 m downstream from the tributary of Wainivana River (178°26'07.9"E; 17°42'35.0"S; 70m a.s.l.): 10 December.
40. Suva – city garden (178°27'37.6"E; 18°07'24.4"S; 0m a.s.l.):): 12 December.

RESULTS

Species check list

A total of 32 Odonata taxa were found during the current research. Below is a complete species check list with short behavioural and ecological notes for each of them. It follows Evenhuis and Polhemus (2007) and is updated considering the recent taxonomic findings. Species are also

arranged according to the occupancy of the sampling localities (Table 98.2). At least two more species could be added to this list however, their proper identification is pending.

Indolestes vitiensis (Tillyard, 1924)

Localities: 2, 7, 15, 25, 26, 33.

The species is confined to standing water bodies. It could be found around marshy areas at the sources of rivers or small vegetated pools formed along river banks by floods. Usually prefers shadow of the bushes and trees, but individuals were observed at areas with slight sunlight.

I. vitiensis is endemic to Fiji and is widely distributed across the country.

Agriocnemis exsudans (Selys, 1877)

Localities: 1, 2, 3, 7, 19, 28, 33.

The species inhabits mainly stagnant waters, but is observed at the river edges in places where the flow is reduced or nearly absent. It chooses submerged vegetation areas and could be present at sunny and shady areas near the water surface. Mating pairs were observed at such locations as well.

A. exsudans is widely distributed across the Pacific ranging from New Caledonia to Tonga. It is rarely reported for Fiji.

Ischnura aurora (Brauer, 1865)

Localities: 3.

It is a delicate species whose females could be overlooked in nature. However, males possess brightly coloured bodies and are easily detected during field researches. Typical inhabiting areas include stagnant waters overgrown with vegetation, but the species was observed along the river bank during this survey.

I. aurora is an eurytopic species that is well adapted to various environmental situations. It occupies a wide range of the Pacific (Australia to Tonga) and is reported from SE Asia as well. Only five previous records are known for Fiji with just one specified location.

Ischnura heterosticta (Burmeister, 1839)

Localities: 11, 20, 28.

The species inhabits stagnant waters. Single individuals were observed during this survey along some of the study rivers without any evidence of breeding.

I. heterosticta has a wide distribution across the Pacific and is also reported from various locations on the islands of Viti Levu and Vanua Levu.

Melanesobasis corniculata corniculata (Tillyard, 1924)

Localities: 12, 15, 25, 34, 35.

This dark bodied species was usually found near the river edge perched on twigs or leaves hanging just above water surface. In those areas it was well concealed and difficult to observe as in some occasions the individuals preferred shady areas.

M. corniculata is endemic to Fiji. It is widely distributed within Fijian archipelago and is known from various island groups.

Melanesobasis flavilabris (Selys, 1891)

Localities: 13, 16, 25, 27, 31, 32, 35, 38.

No preferences were observed for this species. Individuals were encountered in various habitat types ranging from sunny areas near river edges, underside of stones or big rocks away from the water, bushes and grass vegetation around temporary pools, vegetated locations beneath tree canopies, and around small waterfalls.

M. flavilabris is endemic to Fiji. It is known from various localities across Viti Levu and a single place from Vanua Levu.

Melanesobasis mcleani (Donnelly, 1984)

Localities: 12, 15, 34.

The species was observed only in shady parts of small streams or seepage waters. It was found in three places with single individuals.

M. mcleani is endemic to Fiji and only reported from Viti Levu. Previous observations are scarce and come from two specific locations only.

Nesobasis angulicollis (Tillyard, 1924)

Localities: 6, 9, 14, 15, 25, 29, 31, 38.

The species was observed at various areas along the rivers and streams. No specific requirements were recorded as the individuals were encountered at both sunny and shady regions perching on twigs and leaves or flying around exposed bounders. The stream current seems to be of no particular importance either because *N. angulicollis* individuals from both sexes (including mating pairs and tandems) were sighted along gradients of stream flows.

N. angulicollis is an endemic to Fiji. It has been recorded from all over the main island of Viti Levu.

Nesobasis caerulescens (Donnelly, 1990)

Localities: 22.

The only record during the current research comes from a shady stream with slow to almost no visible water current. A single female was collected perched about one metre above the ground on a tree twig far from the stream edge. This record is insufficient to make any conclusions about the species preferences to the local environment.

N. caerulescens is endemic to Fiji. It is known from single locations only and is represented by low numbers of specimens.

Nesobasis campioni (Tillyard, 1924)

Localities: 21, 28, 32, 35.

The species was observed only in shaded parts of the streams predominantly flowing on the bottom of deep gullies. A single male and three females were observed

without any evidence for autochthonous.
N. campioni is endemic to Fiji. It is previously confirmed from all over Viti Levu, Ovalau and Wakaya islands.

Nesobasis comosa (Tillyard, 1924)
Localities: 8, 15, 16, 17, 18, 21, 25, 29, 31.
Further identification and comparison with *N. heteroneura* is needed to establish the true status of *N. comosa* within Nakorotubu Range. Specimens with typical comosa morphological features were collected from lowland areas to mountain regions. However, the species is known as inhabitant of higher regions, while heteroneura is collected mainly from lower altitudes.
N. comosa is endemic to Fiji. It is distributed all over Viti Levu.

Nesobasis erythrops (Selys, 1891)
Localities: 5, 10, 14, 15, 16, 17, 18, 21, 25, 29, 31, 32.
No preferences to specific habitat type were observed. It was found in both sunny and shady areas along water edge. Tandems and single individuals were encountered perched on exposed boulders at the river bank, high on the tree twigs, or leaves above the water. Males seemed to occupy territories as they attacked other conspecific and heterospecific (*N. comosa*) males. Underwater oviposition was observed in a single occasion with the female laying eggs in the mosses guarded by its mate. During a night walk a male was detected inside forest about 500 m from the water edge hanging on a leaf edge at about 2.5 m above the ground.
N. erythrops is endemic to Fiji. It is recorded from all over Viti Levu Island.

Nesobasis flavifrons (Donnelly, 1990)
Localities: 9, 13, 22, 25 (downstream from this locality).
Only females collected. Pre-oviposition behaviour and actual oviposition were observed. Both took place in shady areas. Prior to oviposition females were flying about 10 cm above the water surface in slow motion faced towards stream banks. It looked like they checked the banks before made a decision to stay for oviposition. They laid eggs unguarded in the dead plant material floating on the water surface.
N. flavifrons is endemic to Fiji. It was previously reported from 6 localities only on Viti Levu Island.

Nesobasis heteroneura (Tillyard, 1924)
Localities: 29, 32, 35.
This species is listed here based on some females collected during the study however, further confirmation is needed as no sure evidence is known for distinguishing between heteroneura and comosa females. It is possible that all specimens observed within the Nakorotubu Range belong to comosa only.
N. heteroneura is endemic to Fiji. It is reported from Northern and Southern Viti Levu, Ovalau and Wakaya Islands.

Nesobasis leveri (Kimmins, 1943)
Localities: 25.
The species was found in both high mountain regions and lowland areas. More individuals were observed at higher altitudes. It was confined mainly to mixed shadow/sunlight areas of fast flowing streams.
N. leveri is endemic to Fiji. It was previously reported from two localities only.

Nesobasis longistyla (Selys, 1891)
Localities: 9, 14, 15, 25, 34, 38.
The species is a stream dweller found predominantly in shady areas. There was a single observation from an ox-bow lake, however no proof of breeding was observed.
N. longistyla is endemic to Fiji. It is previously reported from all over Viti Levu and Kadavu Islands.

Nesobasis monticola (Donnelly, 1990)
Localities: 25.
A single female was observed at a fast flowing section of a mountain stream. No evidence for breeding was recorded.
N. monticola is endemic to Fiji. It is previously reported from Northern Viti Levu and Ovalau Islands.

Nesobasis pedata (Donnelly, 1990)
Localities: Not specified.
Two male specimens obtained only. One of them (A. Caucau leg.) was encountered on 03 December in the forest between localities 3 and 6 at altitude of about 350 m. The second is a dubious young specimen with unclear morphological features. It was found on 04 December close to locality 24 (indicated with a question mark in Table 98.2) along the stream above the RAP_Fiji Base camp 2 site. No coordinates were taken of both localities.
N. pedata is endemic to Fiji. It is previously reported from four localities.

Nesobasis rufostigma (Donnelly, 1990)
Localities: 25, 27, 29, 39.
Females were observed flying in the middle of the streams and rarely in very shady areas. They appeared in sunny parts of the stream.
N. rufostigma is endemic to Fiji. It was previously reported from a wide range on Viti Levu, Kadavu, Ovalau and Koro Islands.

Nesobasis selysi (Tillyard, 1924)
Localities: 9, 25, 29, 31, 32, 35, 39.
This species was observed mainly in lowland areas, flying along stream banks around exposed boulders and between tree branches.
N. selysi is endemic to Fiji. It was previously reported

from all over Viti Levu and Ovalau Islands.

Nesobasis telegastrum (Selys, 1891)

Localities: 9, 12, 13, 22, 34, 38.

The species was only observed in shady areas. It occupied slow flowing streams and in a single occasion was located near an oxbow lake.

N. telegastrum is endemic to Fiji. It was previously reported from 8 localities on Viti Levu Island.

***Anax* sp.**

Localities: 14.

The species was also observed at many sites along the entire stretch of Olou River within the study area (between localities 6 and 15). Flying individuals were observed only, which made precise identification of the species impossible. Ris (1916) recorded A. guttatus from Fiji without specifying location. Possibly the same species occurs within the Nakarotubu Range however, further prove is needed from collected specimens and proper identification.

***Hemicordulia* sp.**

Localities: 4, 7, 11, 14, 28.

Flying individuals were encountered also in other sites along the main transect at Olou River. They mainly hovered over the pool-like sections of the river formed by the slow moving waters kept between the large boulders and rocks. No species identification is possible at this stage. Only two males were collected only and they need to be properly keyed out considering previous research done on Fijian Odonata as well as other regions within the Pacific. It is possible that it belongs to an undescribed species.

Procordulia irregularis (Martin, 1906)

Localities: 25.

The single location for this species was a fast flowing stream situated at high altitude. Males did not appear to be territorial as they passed over the water surface with a fast flight with short-time hovers. A single ovipositing female was observed. She was laying eggs unguarded by dipping her abdomen into a section of the stream with almost no water current. It was shaded completely by the surrounding vegetation and was close to some large bounders.

P. irregularis is endemic to Fiji. It was previously recorded from two localities only on Viti Levu and Vanua Levu Islands.

Diplacodes bipunctata (Brauer, 1865)

Localities: 3, 19, 23.

The species is known as inhabitant of pools, lakes and other stagnant water bodies. It occupies oxbow lakes and that was naturally seen along rivers and streams during the current study. In these areas it often perched directly on stones, but mainly preferred the bank vegetation.

D. bipunctata has a wide distribution across the Pacific. It was rarely reported before and is known from Viti Levu and Lau island group with only one specified locality.

Hypothemis hageni (Karsch, 1889)

Localities: 25, 36.

Observed on two consecutive days at locality 25. Female laid eggs unguarded near boulders. She chose parts of the stream with visible strong current. Males were observed for a very short period. They appeared to be very shy and stayed perched for few seconds only. Tree leaves were chosen as perching substrate and they kept themselves on about 2 metres above the surface.

H. hageni is a monotypic genus endemic to Fiji. It has been very rarely reported before and is known from Viti Levu and Vanua Levu with one specified location.

Lathrecista asiatica (Fabricius, 1798)

Localities: 28.

The species was collected also from another area – on the track to the Base camp 2 site above locality 21. No coordinates were taken as the single male was obtained far from any typical habitat for the species. It is known as inhabitant of stagnant waters and was confirmed from an oxbow lake of Wailotua River. Observation were made of males defending territories perched on the end of dead tree branches at the lake edge.

L. asiatica has a very wide distribution from SE Asia across the Pacific. It was previously reported from Viti Levu, Vanua Levu and the Lau group however, only two precise locations are given in the literature and single specimens were collected from those sites.

Orthetrum serapia (Watson, 1984)

Localities: 2, 3, 7, 15, 17, 19, 28.

The species status within Fiji must be revised. So far almost all previous records have been on the closer species *O. sabina*. After the Watson (1984) revision, the new species *O. serapia* was erected for large number of specimens collected across Pacific. It is likely that all previous records on sabina from Fiji should be assigned serapia. Only *O. seraia* was observed during the current study. Some locations are given above however, individuals were recorded from the entire stretch of Olou River in various habitat types. Preferences were given to stagnant water bodies and flying individuals were often seen moving between those over the river surface.

O. serapia is distributed from SW Pacific to the Philippines. It was previously reported only once from Viti Levu, however when the true status is confirmed it may appear that it is more widely distributed. So far *O. sabina* was collected from Viti Levu, Ovalau and the Lau group.

Pantala flavescens (Fabricius, 1798)

Localities: 30, 40.

No specific preferences were observed for this species. Two locations are given here as one is from the city garden of Suva, but *P. flavescens* could be easily seen in many other areas. Normally individuals chose open areas among the tree and bush vegetation. They could fly well over large open fields and hover above the grasses. P. flavescens is a cosmopolitan species. It was previously only reported from the Lau group.

Rhyothemis phyllis subsp. dispar (Brauer, 1867)

Localities: 2, 19.

The species is a typical inhabitant of stagnant water bodies. Males selected sites around the water edge and perched on the top of dead twigs exposed to sunlight. A freshly emerged female was collected from the top of a hill above a large lake. It was perched low on the ground at the base of the grass vegetation.

R. phyllis ranges widely in the SE Asia and the Pacific. It forms various subspecies as *R. p. dispar* is endemic to Fiji. Previous records are very rare and no specific location has been ever reported.

Tholymis tillarga (Fabricius, 1798)

Localities: 37.

The single observation comes from an oxbow lake of Wainivana River. The individual was observed for few seconds perched on the grass vegetation. No further records were made although the area was investigated continuously during the day.

T. tillarga is very widely distributed from SE Asia and across the Pacific. A male was previously reported from Viti Levu with no specified location.

Tramea transmarina (Brauer, 1867)

Localities: 19.

The species occurred at similar places as P. flavescens, however it is normally observed with fewer individuals compared to cosmopolite species. During the current research *Tramea* sp. were observed flying together with *P. flavescens* and were believed to be *T. transmarina* as that is the only species previously reported from the genus for Fiji and a male of the same species was collected from the above mentioned locality. At that place it chose to perch on the top of dead twigs near water edge.

T. transmarina is known from other Pacific islands, like New Caledonia and Kermadec. It was previously reported from two authors with no specified locations.

Habitat types

The following types of habitats were considered as odonatologically important within the Nakorotubu Range. They are arranged according to the visual stimuli that are believed to be crucial in habitat selection (commented in Beschovski and Marinov 2007) and this arrangement does not necessarily reflect the perceived significance of the habitats. A final conclusion must be drawn upon more consistent research involving equal amounts of time and effort for all biotopes and considering the altitude. Each habitat is described with few examples of their occupants and a code name that is used later in the discussion.

H0 Seepage water with almost no visual current flowing through closed forest floor. Inhabited by *Melanesobasis mcleani*, *Nesobasis flavifrons*, *N. longistyla*, *N. telegastrum*.

H1 Springs flowing at the bottom of shady gullies between boulders and cobbles thus forming small waterfalls downhill. Inhabited by *Melanesobasis corniculata*, *M. flavilabris*, *Nesobasis comosa*.

H2 Streams with scarce submerged aquatic vegetation flowing through regions with mixed shade/sunlight areas between large boulders. Inhabited by *Nesobasis leveri*, *N. longistyla*, *Procordulia irregularis*, *Hypothemis hageni*.

H3 Permanent pools formed between exposed to sunlight boulders of streams and rivers. Inhabited by *Hemicordulia* sp., *Diplacodes bipunctata*, *Orthetrum serapia*.

H4 Exposed boulders on river beds and large rocks by the banks. Inhabited by *Melanesobasis flavilabris*, *Nesobasis eryhrops*, *N. angulicollis*.

H5 Mixed shade/sunlight vegetated areas by the river banks. Inhabited by *Agriocnemis exsudans*, *Ischnura heterosticta*, *Orthetrum serapia*.

H6 Permanent oxbow lakes by the rivers with partly shaded water edge. Inhabited by *Indolestes vitiensis*, *Agriocnemis exsudans*, *Lathrecista asiatica*.

DISCUSSION

In spite of the long history of studies on Fijian odonates dating back to 1867, the species taxonomy posses serious problems for any investigator. The great diversity of endemic species and morphological forms observed in a comparatively small territory among the members of genus *Nesobasis* is probably the biggest challenge. It is, perhaps compatible only with the Hawaiian genus *Megalagrion* (Jordan et al. 2003). This makes it impossible to prepare any final suggestions about the exact species number inhabiting the Fijian archipelago. Moreover, new taxa have been found and are under description at the moment (Donnelly, per. com.). In Table 98.1 they are listed with abbreviation of the possible species name that will be assigned. In the same table it is indicated that at least 61 odonate species are known to occur on the Fijian islands. This number will surely increase in future with more investigations taking place within those interesting areas.

The species list provided above contains more than 50% of the total Odonata fauna known from all islands within the Fijian archipelago, some of which are endemic to islands other than Viti Levu. If however, only Viti Levu taxa (41 species) are included in the analysis the significance of Nakorotubu Range increases significantly to containing about 78% of the odonate species occurring on the island.

It is difficult to classify the habitat types according to their significance for odonates. Some of them were checked for several minutes only on the way to and back from the Base camps while others were investigated over two consecutive days. Moreover, a single locality may support several habitats. Locality 25, for example, was visited twice and it combines habitat types H1, H2 (predominantly) and partly H3, which combined record the highest number of species observed during the investigation (Table 98.2). Species conservation status is another aspect that must be considered for the habitat evaluation scheme. H0, for example, may support low species numbers, but being of high importance (represented with low specimen numbers on other sampling occasions or with limited distribution) those species may increase the significance of the habitat in the generalised classification scheme. That is why a weighted approached is suggested where the habitats gain different values according to various criteria including: a) species population size, b) species global and regional distribution, c) species ecological preferences, d) habitat availability within the investigated region, and e) threats over habitat integrity and heterogeneity. Such estimation is impossible at the present stage. It needs thorough investigation over the region, which to confirm or reject the proposed basic habitat classification scheme. It may or may not be valid for the region in question, however it must be compared with other areas in order to achieve a better understanding of the habitat availability and species occupancy among them.

CONCLUSIONS AND CONSERVATION RECOMMENDATIONS

Future survey recommendations

Based on the results of this survey, the following general recommendations are proposed:

- Intensified taxonomic work for establishing the true specific status of Fijian Odonata. In some occasions a clear separation between species is not always possible in the field and requires further lab work. Identification keys for Fijian species need to be updated with more reliable features for distinguishing between closely related species. They must be combined with detailed investigation on the intraspecies morphological diversity and DNA analysis in order to establish the actual species diversity.
- Re-evaluation of the species diversity of Fijian archipelago. It is necessary that the specimens so far collected from the country to be checked in regard to the new taxonomic findings. Special attention was paid above to the Orthetrum sabina/serapia situation. Other species that must be treated with special attention include Agriocnemis exsudans, Ischnura heterosticta, Tramea transmarina as well as species with unclear taxonomic position, like Hemicordulia sp.
- Mapping odonate distribution within Fijian islands. Visualisation of the data compiled for species distribution always helps in establishing gaps in the research, outlining future initiatives and planning urgent conservation measures. Such a mapping scheme is imperative and must be considered as a baseline for any study.
- Combining the mapping scheme with environmental variables and biological/ecological data for producing predictive habitat models for each species. It is considered as the pinnacle in the preliminary conservation planning process. Predictive habitat models could reveal the landscape features that approach the individual species requirements to the local environment. They, in combination with environmental variables and land use data, would visualise the potential of the local environment for supporting the habitat diversity and related species.

Conservation recommendations

The above points are fundamental questions to be answered for any organisation that plans future Odonata related activities within the Nakorotubu Range. Unfortunately prior to the clarification of these main points no specific recommendations could be made for in situ protection of Odonata species within the Nakorotubu Range. Any specific suggestion requires understanding of the biology and ecology of the species and identifying the potential threats to their natural habitats. The lack of this data makes it very difficult to predict the potential threats to odonates inhabiting the Nakorotubu Range. During the this survey no significant anthropogenic disturbances, like pollution, drainage, intensive harvesting or farming, were recorded. The tracks towards the Base camp sites 1 and 2 were reasonably well maintained however, some parts were hard to follow and according to the local guides were much reduced in size due to under exploration. This is a good indication that the Nakorotubu Range Odonata possibly experience low human pressure. The most worryingsituation was found at the upper section of Olou River near the inflow of Wainirea Stream. Some oil-like spots of unidentified origin were recorded on the water surface. The whole section of Olou River from Base camp 1 site to this point was characterised by intensive algae growth which had developed over the stones and some pool-like sections of the river. It could well be a natural nutrient enrichment or a consequence of effluent waters discharged from tributaries of the main river.

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Table 8.1: Chronological literature review of Odonata records from Fiji.

No.	Verbatim species	Valid species name	Verbatim locality	Page	References
1	*Tramea transmarina*	*Tramea transmarina*	Viti-Inseln	21	Brauer (1867a)
2	*Orthetrum sabina*	*Orthetrum serapia?*	Ovalau 1. Viti-Insel	505	Brauer (1867b)
3	*Rhyothemis dispar*	*Rhyothemis phyllis dispar*	Vanua Balavu	10	Brauer (1869)
4	*Pantala flavescens*	*Pantala flavescens*	Vanua Balavu	10	Brauer (1869)
5	*Orthemis pectoralis*	*Lathrecista asiatica*	Viti Levu	10	Brauer (1869)
6	*Diplax trivialis*	*Diplacodes trivialis*	Viti Levu	10	Brauer (1869)
7	*Synthemis macrostigma*	*Synthemis macrostigma*	Iles Fidji	559	Selys (1871)
8	*Hemicordulia tau*	*Hemicordulia tau*	îles Fidji	256	Selys (1871)
9	*Hypothemis hageni*	*Hypothemis hageni*	Fidji	261	Karsch (1889)
10	*Nesobasis erythrops*	*Nesobasis erythrops*	Iles Viti (Polynésie)	LIII	Selys (1891)
11	*Nesobasis telegastrum*	*Nesobasis telegastrum*	Iles Viti (Polynésie)	LIV	Selys (1891)
12	*Nesobasis flavilabris*	*Melanesobasis flavilabris*	Iles Viti (Polynésie)	LV	Selys (1891)
13	*Nesobasis nigrostigma*	*Nesobasis nigrostigma*	Iles Viti (Polynésie)	LVI	Selys (1891)
14	*Nesobasis longistyla*	*Nesobasis longistyla*	Iles Viti (Polynésie)	LVII	Selys (1891)
15	*Procordulia irregularis*	*Procordulia irregularis*	Iles Viti	16	Martin (1906)
16	*Diplacodes bipunctata*	*Diplacodes bipunctata*	Viti	471	Ris (1911)
17	*Anax guttatus*	*Anax guttatus*	Viti	63	Ris (1916)
18	*Austrolestes vitiensis*	*Indolestes vitiensis*	Suva, Fiji Is.	309	Tillyard (1924)
19	*Pseudagrion pacificum*	*Pseudagrion pacificum*	Waidoi Plantation	311	Tillyard (1924)
20	*Nesobasis corniculata*	*Melanesobasis corniculata*	Waidoi River	319	Tillyard (1924)
21	*Nesobasis simmondsi*	*Melanesobasis simmondsi*	Waidoi River	320	Tillyard (1924)
22	*Nesobasis comosa*	*Nesobasis comosa*	Waidoi River	321	Tillyard (1924)
23	*Nesobasis angulicollis*	*Nesobasis angulicollis*	Waidoi River	322	Tillyard (1924)
24	*Nesobasis selysi*	*Nesobasis selysi*	Waidoi River	327	Tillyard (1924)
25	*Nesobasis campioni*	*Nesobasis campioni*	Sigatoka, Viti Levu	329	Tillyard (1924)
26	*Nesobasis aurantiaca*	*Nesobasis aurantiaca*	Sigatoka, Viti Levu	330	Tillyard (1924)
27	*Nesobasis brachycerca*	*Nesobasis brachycerca*	Bua	332	Tillyard (1924)
28	*Nesobasis heteroneura*	*Nesobasis heteroneura*	Waidoi River	333	Tillyard (1924)
29	*Agriocnemis exsudans*	*Agriocnemis exsudans*	Waidoi River	335	Tillyard (1924)
30	*Ischnura hetersticta*	*Ischnura hetersticta*	Sigatoka, Viti Levu	339	Tillyard (1924)
31	*Ischnura aurora*	*Ischnura aurora*	Waidoi Plantation	339	Tillyard (1924)
32	*Anaciaeschna jaspidea*	*Anaciaeschna jaspidea*	Waidoi Plantation	339	Tillyard (1924)
33	*Nesobasis leveri*	*Nesobasis leveri*	Fiji, Nadarivatu	689-700	Kimmins (1943)
34	*Gynacantha rosenbergi*	*Gynacantha rosenbergi*	Fiji Islands	152	Lieftinck (1975)

(Table 8.1 Contn'd)

No.	Verbatim species	Valid species name	Verbatim locality	Page	References
35	*Hemicordulia hillaris*	*Hemicordulia hillaris*	Lau IS. Lakeba: Top of Tubou Vy.	176	Wise (1980)
36	*Tholymis tillarga*	*Tholymis tillarga*	Fiji. Viti Levu: Suva	177	Wise (1980)
37	*Melanesobasis maculosa*	*Melanesobasis maculosa*	Tavua Dist; Waterfall o.5 km. N of Waikubakuba	95	Donnelly (1984)
38	*Melanesobasis mcleani*	*Melanesobasis mcleani*	Magodro Dist.; Koronubu (10 mi S-E of Ba)	96	Donnelly (1984)
39	*Melanesobasis prolixa*	*Melanesobasis prolixa*	(Fijian Islands): Moala	100	Donnelly (1984)
40	*Nesobasis rufostigma*	*Nesobasis rufostigma*	Nasivi R	102	Donnelly (1990)
41	*Nesobasis flavifrons*	*Nesobasis flavifrons*	VITI LEVU: Waikubakuba	104	Donnelly (1990)
42	*Nesobasis ingens*	*Nesobasis ingens*	VITI LEVU: Monasavu	105	Donnelly (1990)
43	*Nesobasis recava*	*Nesobasis recava*	KADAVU: Tavuki Rd	106	Donnelly (1990)
44	*Nesobasis pedata*	*Nesobasis pedata*	VITI LEVU: Namosi Rd, Waidina R	107	Donnelly (1990)
45	*Nesobasis flavostigma*	*Nesobasis flavostigma*	VITI LEVU: Wailotua	107	Donnelly (1990)
46	*Nesobasis caerulecaudata*	*Nesobasis caerulecaudata*	VITI LEVU: Waikubakuba	108	Donnelly (1990)
47	*Nesobasis monticola*	*Nesobasis monticola*	VITI LEVU: Monasavu	111	Donnelly (1990)
48	*Nesobasis caerulescens*	*Nesobasis caerulescens*	VITI LEVU: Monasavu	113	Donnelly (1990)
49	*Nesobasis malcolmi*	*Nesobasis malcolmi*	VITI LEVU: Waikubakuba	116	Donnelly (1990)
50	*Nesobasis au*			6	Van Gossum et al. (2006)
51	*Nesobasis al*			6	Van Gossum et al. (2006)
52	*Nesobasis c*			6	Van Gossum et al. (2006)
53	*Nesobasis f*			6	Van Gossum et al. (2006)
54	*Nesobasis l*			6	Van Gossum et al. (2006)
55	*Nesobasis r*			6	Van Gossum et al. (2006)
56	*Nesobasis t*			6	Van Gossum et al. (2006)
57	*Nesobasis v*			6	Van Gossum et al. (2006)
58	*Nesobasis uds1*			6	Van Gossum et al. (2006)
59	*Nesobasis uds2*			6	Van Gossum et al. (2006)
60	*Melanesobasis uds*			6	Van Gossum et al. (2006)
61	*Nesobasis uds3*			240	Van Gossum et al. (2008)

Table 8.2: Total number of Odonata species per locality.

	I. vitiensis	*A. exsudans*	*I. aurora*	*I. heterosticta*	*M. corniculata corniculata*	*M. flavilabris*	*M. mcleani*	*N. angulicollis*	*N. caerulescens*	*N. campioni*	*N. comosa*	*N. erythrops*	*N. flavifrons*	*N. heteroneura*	*N. leveri*	*N. longistyla*	*N. monticola*	*N. pedata*	*N. rufostigma*	*N. selysi*	*N. telegastrum*	*Anax* sp.	*Hemicordulia sp.*	*P. irregularis*	*D. bipunctata*	*H. hageni*	*L. asiatica*	*O. serapia*	*P. flavescens*	*R. phyllis dispar*	*T. tillarga*	*T. transmarina*	**Total species number per locality**
Locality 1		+																														1
Locality 2	+	+																									+		+			4
Locality 3		+	+																					+			+					4
Locality 4																						+										1
Locality 5												+																				1
Locality 6								+																								1
Locality 7	+	+																				+					+					4
Locality 8											+																					1
Locality 9								+					+			+				+	+											5
Locality 10											+																				1	
Locality 11			+																			+									2	
Locality 12				+		+														+											3	
Locality 13					+							+								+											3	
Locality 14							+				+				+						+	+									5	
Locality 15	+				+		+	+			+	+				+											+				8	
Locality 16					+					+	+																				3	
Locality 17										+	+															+					3	
Locality 18										+	+																				2	
Locality 19	+																						+			+		+		+	5	
Locality 20			+																												1	
Locality 21									+	+	+																				3	

(Table 8.2 Contn'd)

	Locality 22	Locality 23	Locality 24	Locality 25	Locality 26	Locality 27	Locality 28	Locality 29	Locality 30	Locality 31	Locality 32	Locality 33	Locality 34	Locality 35	Locality 36	Locality 37	Locality 38	Locality 39	Locality 40
I. vitiensis				+	+		+					+							
A. exsudans												+							
I. aurora							+												
I. heterosticta													+	+					
M. corniculata corniculata				+		+				+	+			+			+		
M. flavilabris				+									+						
M. mcleani								+		+							+		
N. angulicollis	+			+															
N. caerulescens							+				+			+					
N. campioni								+		+									
N. comosa				+				+		+	+								
N. erythrops	+			+															
N. flavifrons				+				+			+			+					
N. heteroneura																			
N. leveri				+									+				+		
N. longistyla				+															
N. monticola			(?)	+															
N. pedata						+		+										+	
N. rufostigma				+				+		+	+			+				+	
N. selysi	+			+									+				+		
N. telegastrum																			
Anax sp.							+												
Hemicordulia sp.																			
P. irregularis		+		+															
D. bipunctata															+				
H. hageni				+			+												
L. asiatica							+												
O. serapia									+										+
P. flavescens																			
R. phyllis dispar																+			
T. tillarga																		2	
T. transmarina	3	1	1			2	6	6	1	5	5		4	5	1	1	4	2	1
Total species number per locality				14	1							2							

Chapter 9

Freshwater fish and water quality of two catchments in the Nakorotubu Range, Ra and Tailevu Provinces, Viti Levu, Fiji.

David Boseto

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SUMMARY

A total of 15 species from eight families were collected and/or observed. These included the native species *Bunaka grinoides* and *Ophioeleotris* sp. (Eleotridae); *Awauous guamensis*, *A. ocellaris*, *Glossogobius* sp., *Sicyopus zosterophorum* and *Sicyopterus lagocephalus* (Gobiidae); *Microphis leiaspis* (Syngnathidae); *Kuhlia marginata* and *K. rupestris* (Kuhliidae); the freshwater eels *Anguilla marmorata* and *A. megastoma* (Anguillidae), freshwater moray eel *Gymnothorax polyuranodon* (Muraenidae); and the introduced *Oreochromis mossambicus* (Cichlidae) and *Gambusia affinis* (Poecilidae).

Surveyed streams and rivers in the Nakorotubu watershed showed low fish diversity ranging from zero to ten with an average of four species per streams surveyed. The fish species collected from Nakorotubu represented 9% of the total freshwater fish diversity of Fiji.

There was an abundance of the amphidromous goby *S. lagocephalus* in the Uloa River and the introduced mosquito fish *G. affinis* in the Uloa and Wailotua Rivers. Species from the family Eleotridae were not collected at Uloa River. A single species of *K. marginata* and *K. rupestris* each were collected at Uloa River. There was a low abundance of *K. marginata* and *K. rupestris* from Wailotua River compared to the intact forest of the Sovi Basin. There were no endemic or rare species collected or observed during this survey.

INTRODUCTION

This report documents the freshwater ichthyofauna and habitat (water) quality of eleven sites along the upper reaches Uloa and Wailotua rivers, a small creek beside Base camp 2 and the Nalalau Creek in the Nakorotubu Range which were surveyed between 30 November and 10 December 2009. The findings from this survey will contribute to the overall conservation significance of the Nakorotubu Range. In addition, results from this survey will allow comparison of freshwater fauna with other river/ stream systems in Fiji and other Pacific islands.

Habitat and Catchment Description

The Nakorotubu watershed is covered with well vegetated lowland and upland tropical forest. The stream-bed habitats are covered with sand, small rocks/pebbles, gravels, fused rock bottoms and rocks and boulders on the sides. Morphology of the rivers and creeks surveyed vary widely and range from shallow to deep sections. The rivers and creeks have range from very narrow to very wide. As the water flow rates depend on the river and creek shape and size, the water flow rate of the rivers and creeks are slower in the wide and deeper section of the pools, and rapid in shallow and narrow sections. There are sections within the rivers that have cascades with rock pools.

The rivers and creeks surveyed drain into the Wainibuka River which then flows into the Rewa River. The Wainibuka River catchment is one of the major tributaries of the Rewa River. The geomorphology of the Nakorotubu Range has rugged, mountainous steep slopes and deep weathering, highly erodible grassland soil, farmland and grazing along the mid- upper reaches of the Uloa and Wailotua rivers. There are feral cattle in the forest and along the edge of the Uloa and Wailotua rivers. This survey was undertaken during the dry period of the year, therefore the

water level was low and the water flow very slow. A thick layer of sediments and dense green and brown algae cover were found on the substrate of the Uloa River and creek beside Base camp 2 and Nalalau Creek. Uloa River and the two creeks are at high altitude with many large metamorphic boulders. The Wailotua River is also at high altitude but has a large flood plain area that passes through Nasau Village, cattle ranches and subsistence farm land. There are no major barriers observed in the river, therefore the fish population can move freely between the Wailotua and Wainibuka rivers.

METHODS

Field sampling

Eleven 150 - 200 m sections of the aquatic habitat of the Nakorotubu watershed were sampled. Site details and habitat descriptions are in Appendix 8. Approximately two hours was spent sampling at each site and the equipment used are as follows:

Pole Seine Net (2.0 m x 1.5 m, 2 cm2 mesh) (Plate 34).
The net was used in a variety of ways. Firstly, it was held firmly downstream as people kicked and dislodged rubble upstream. This was a useful method for collecting small, bottom dwelling fish. On vegetated banks the net was thrust under submerged vegetation and the vegetation was disturbed on the bank, dislodging fishes into the net. Also, this net was used to "scoop" (bottom edge held forward, run along substrate for a few seconds then lifted from any accessible shallow body of water. The pole seine net was particularly useful for narrow streams.

Small Hand Net (1m x 10 cm, 2cm2 mesh)
This net was used to scoop the underside of overhanging vegetation in the smaller streams and also to collect fishes in slow flowing and still water bodies.

Aquarium Net (19 cm x 15 cm, 2mm2 mesh)
This net was used to scoop the underside of rocks and in small crevices on small creeks. It was also used to scrape embedded rock walls and waterfalls for climbing gobies.

Fijian Hand Sling Spear Gun (Plate 35)
The Fijian Sling Spear Gun is made of a long thin iron rod (spear) and an elastic rubber. The thin iron rod was placed on a loop at end of the elastic and another loop was made of the other end where the diver put his thumb to pull and stretch the elastic and took aim at the fish and let go of the spear. It was very useful in collecting fast moving fish and those hiding under tree roots or under big rocks in a pool. The spear gun was used while swimming with mask and snorkel.

Observations and underwater photography (mask and snorkel) (Plate 36)

Underwater observations were made in deep pools with a mask and snorkel, and in areas that were shallow and the water clear. Approximately an hour was used to observe, record, collect, and photograph the observed fauna.

Fish photography

Fish photographs were taken in situ when fish were collected with a pole seine net, or caught with a spear and during underwater observation of the surveyed sites. A Canon powershot SD1100 digital camera was used to take fish photographs.

Fish fixation

Fish specimens collected were fixed in 10% formalin solution and transferred to 75% ethanol solution after five days of fixation. Most of the fish voucher specimens are currently with the author but will be deposited at the Marine Collection at the University of the South Pacific (USP) in Suva, Fiji.

The tissues or clipped fins for genetic studies were preserved in 95% ethanol. For each representative sample for genetic studies, the right pectoral fin or a piece of flesh from the right side of the caudal peduncle were taken and preserved in 95% ethanol. Vouchers of these specimens will also be deposited in the Marine Collection at USP.

Fish identification

Fish were identified to family level using the Gestalt Method (Shape/location). Taxonomic keys by Allen (1991) and Marquet et al. (2003) were used to identify specimens to the genus and species levels.

Water quality and habitat characteristics

A 360 YSI meter was used to measure the water quality parameters including water temperature, conductivity, ph and salinity (Plate 33). A Garmin 8 hand-held Global Positioning System (GPS) was used for recording the sampling site locations. Depth, width and length of the sampled areas were measured with a fiberglass measuring tape. Water flow rate (m/s) was measured by using a tree leaf flowing downstream over 2 m and was timed with a stop watch. Personal observation was used to determine the estimation of the water clarity.

RESULTS AND DISCUSSION

Species richness and abundance

A total of fifteen species from twelve genera and eight families were recorded from eleven sites during this survey (Table 9.1). Five species were collected from the family Gobiidae [*Awaous guamnesis* (Plate 45), *A. ocellaris* (Plate 46), *Glossogobius* sp. (Plate 48), *Sicyopterus lagocephalus* and *Sicyopus zosterophorum*]. *S. lagocephalus* (Plate 51) dominated the mid and the upper catchments. *S. zosterophorum* was observed from a pool in Site 8. There were no fish observed

or collected from Site 7. Two species of sleeper's family *Eleotridae* [*Bunaka grinoides* (Plate 47) and *Ophioeleotris* sp.] were collected from the mid reaches of the Wailotua River. Two species of jungle perch family Kuhliidae [*Kuhlia marginata* (Plate 50) and *K. rupestris*] were collected from Uloa and Wailotua rivers. Two species of freshwater eels family *Anguillidae* [*Anguilla marmorata* (Plate 43) and *A. megastoma* (Plate 44)] were collected from the upper reaches of the Uloa River. The freshwater moray eel, *Gymnothorax polyuranodon* (Plate 49) (Family *Muraenidae*), was also observed and photographed from Sites 6 and 11. A species from the family Syngnathidae (*Microphis leiaspis*) was collected from mid reaches of the Wailotua River. The introduced, exotic species were observed and recorded in theUloa and Wailotua rivers. Both rivers were heavily populated by the introduced Mozambique Tilapia *Oreochromis mossambicus* (Plate 53) (Family Cichlidae) and the mosquito fish, *Gambusia affinis* (Plate 52) (Family Poeciliidae).

Table 9.1: Species distribution and abundance of freshwater fish in the Nakorotubu Watershed. The numbers in the column below sites indicates the number of fish collected from each site. Sites 1-6 are different sections of the Uloa River. Site 7 is the creek beside Base camp 2, Site 8 is Nalalau Creek, Sites 9- 11 are different sections of the Wailotua River. Abbreviation Abu = Abundant (>100).

No.	Verbatim species	1	2	3	4	5	6	7	8	9	10	11
Anguillidae	*Anguilla marmorata*											
					2							
	Anguilla megastoma					1						
Ciclidae	*Oreochromis mossambicus*	5					3			Abu	Abu	
Eleotridae	*Bunaka grinoides*									1	1	
	Ophioeleotris sp									2		
Gobiidae	*Awaous guamensis*		3	2			2			1	1	1
	Awaous ocellaris									1	1	1
	Glossogobius sp. *1*									2	1	1
	Sicyopterus lagocephalus	Abu	Abu	Abu	Abu	Abu	Abu		2	2	1	
	Sicyopus zosterophorum								2			
Kuhliidae	*Kuhlia marginata*						1			5	3	2
	Kuhlia rupestris						1				2	
Muraenidae	*Gymnothorax polyuranodon*						1					1
Poeciliidae	*Gambusia affinis*	Abu	Abu				Abu			Abu	Abu	Abu
Syngnathidae	*Microphis leiaspis*									1		

Headwaters

Sicyopterus lagocephalus and *Sicyopus zosterophorum* from the subfamily *Sicydiinae* of the family *Gobiidae* were recorded from the upper reaches (Table 9.1). They are known as *amphidromous* fish - characterized by adults living and breeding in freshwater (McDowall 2004, 2008). Their larvae are transported into the ocean where they grow into post-larval (juvenile fish) before returning to the rivers to complete their life cycle (Keith 2003, 2010). The pattern of such distribution is common amongst amphidromous fish throughout the tropical Pacific freshwater system (Ryan 1991). These fish can navigate through barriers like waterfalls and can also survive in degraded areas where green and brown algae dominate (Plate 42). *S. lagocephalus* is herbivorous and feeds on the algae.

Mid-reaches

The elevation of the middle reaches of the Nakorotubu catchment ranges from 150- 180 m. Species from the Anguillidae, Gobiidae and Poecilidae families were collected from the middle reaches. The species from Anguillidae were *Anguilla marmorata* and *A. megastoma*. The species from the family *Gobiidae* were *Awauous guamensis* and *Sicyopterus lagocephalus* and the introduced *Gambusia affinis* from the family Poecilidae. Sicyopterus lagocephalus and Gambusia affinis were the common species that dominated the middle

reaches. Freshwater eels (Anguillidae) are known as catadromous fishes. They live in freshwater as adults, migrate to the ocean to breed and juveniles return to freshwater to complete their life.

Lower reaches

Fiver lower reaches sites within the Nakorotubu watershed were surveyed. These sites were dominated by two common invasive species Mozambicus Tilapia (*Oreochromis mossambicus*) and the Mosquitofish (*Gambusia affinis*). However, there were species from the families Eleotridae, Gobiidae, Kuhliidae, Muraenidae and Syngnathidae also recorded from the lower reaches (Table 9.1, Appendix 8). It is evident from this survey that there is low freshwater fish biodiversity and species abundance in the lower reaches but high abundance of the two introduced species that are widely distributed in Fiji and the South Pacific. The number of native species is usually lower in places where the introduced Mosquitofish and Mozambicus tilapia dominate (Canonico et al. 2005, Boseto, 2006a,b, Jenkins et al. 2010). Observations made during this survey support the theory that species from the family Kuhliidae are dwindling while endemic species from the subfamily Sicydiinae were absent.

Water quality and habitat characteristics

The water quality in rivers and streams in the Nakorotubu watershed area is still very much pristine as it flows through an intact forest system in the upper and mid reaches. However, in the lower reaches it flows through disturbed areas where agricultural activities and human habitation associated activities take place. The water and habitat conditions exhibit suitable conditions to sustain aquatic life: intact forest cover in the upper and mid reaches, the overhanging riparian plants, water temperature of 22-26°C, average water flow rate of 0.27m/s, over 70 % dissolved oxygen and very little turbidity.

Threats to the fish fauna

The major threats observed were the use of Derris roots, weedicides and pesticides as means of harvesting fish resources from the rivers. The use of these poisonous plants and chemicals can change water quality by depleting oxygen and changing pH thereby providing an unsuitable environment for all aquatic life. The slow water flow, sediment deposits on the substrate and the presence of thick algae in the water are of concern as they will also alter the water chemistry.

The presence of introduced fish species in the lower and middle reaches of the Nakorotubu Range is a major threat. The introduced species *Oreochromis mossambicus* and *Gambusia affinis* are known to feed on the fish larvae of the native species thus their occurrence here in large numbers can be account for the poor fish abundance and diversity of native species.

The other concern was the algal bloom in the lower catchment of the Uloa and Wailotua rivers. This is indicative of high levels of nutrient input which are likely a result of livestock, weedicides, pesticides and agricultural activities. Algae can be very harmful to freshwater biodiversity by altering the physical water parameters and reducing the quality of the water by affecting levels of dissolved oxygen, water temperature and pH.

CONCLUSIONS AND CONSERVATION RECOMMENDATIONS

The Nakorotubu Range watershed is a pristine and intact system in the mid and upper reaches but is disturbed in the lower reaches. In the lower reaches the substrate is covered with green and brown algae. The thick deposit of the algae is due to the use of Derris roots, weedicides and pesticides to harvest fish. In addition, the combination of cattle farming and agricultural waste are affecting the water quality and habitat for the fish. Overfishing and destructive fishing practices also affect the fish biodiversity and abundance. Furthermore, the abundance of the introduced species *Oreochromis mossambicus* and *Gambusia affinis* greatly contributes to the poor diversity and abundance of native species and the complete absence of any endemic species.

Therefore, watershed management and rehabilitation mitigations should be put in place to restore the freshwater ecosystem function and its rich resources. Plans to rehabilitate the Nakorotubu Range watershed should involve the whole system from upper to lower reaches as the fish population needs the entire water system to complete their life cycle.

Below are some potential suggestions for watershed rehabilitation:

1. encourage replanting of buffer zones particularly in areas that are adjacent to human habitation, subsistence agriculture and cattle farms,
2. form a village environment committee to plan monitoring of waste levels and water management (e.g. the committee will be responsible for construction of ecological or livestock waste areas, harvesting of the fish resources, and monitor the introduction of alien species).

The forests in the upper reaches of the Nakorotubu Range should be maintained as a protected area. The concern here is that the logging currently taking place on the northwest end of the mountain range may affect water quality during wet season with the sediment transported into the river. The headwaters forest should be given management priority to prevent destructive development.

Aquaculture of native species should be encouraged and introduction of any exotic aquatic fauna should be closely managed and monitored.

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Chapter 10

Cultural Survey of the Nakorotubu Range, Ra and Tailevu Provinces, Fiji.

Elia Nakoro

Team members: *Tevita Digio (Soa Village), Joji Vuli (Verevere Village) and Sireli Nakanatabua (Nasau Village)*

SUMMARY

An archaeological assessment of any given area involves collecting information about the location, distribution and organization of past human cultures across a large area. Engaging the assistance of several guides, a non-invasive cultural survey of the Nakorotubu Range was conducted identifying and exploring archaeological sites of significance.
Utilizing the guides knowledge and local stories providing some hint of a greater past, the oral history of several archaeological sites in the Nakorotubu Range was documented. A major portion of the cultural sites identified during the survey belong to the people in the districts Bureivanua, Nakuilava and Bureiwai.

While most sites in the area have been well preserved over the years, a select few have been disturbed by human and non-human interaction over recent years with the introduction of livestock farming and agriculture in the area.

INTRODUCTION

Nakorotubu, one of the 19 districts in the province of Ra is rich in cultural history that spans over centuries in time. Given that there have been no previous archaeological records or research conducted in Nakorotubu, the archaeological assessment conducted over a span of two weeks was the first of its kind and nature in this area.

The area is littered with fortified village sites, ancient burial sites, old village sites or koro makawa and other interesting non-invasive archaeological finds. This chapter will explore the various cultural aspects of Nakorotubu, giving site names, descriptions, and brief discussions on folklore, the uses and significance of such locations, the imminent human and non-human threats as well as recommendations on how to maintain and preserve the cultural sites.

METHODS

The Fiji Museum-Archaeology Department's assessment of the archaeological/historical sites in Nakorotubu was documented from the local guide's knowledge of the sites and through the collation of oral history of the sites background and significance from the elders of the village of Matuku, Soa and Nasau.

The sites were mapped using a GPS receiver (GARMIN GPSmap 76CSx) and a rough sketch of the layout of the old villages and settlements was produced.

RESULTS

Nakorotubu Area

An annotation of the sites recorded from the forest area towards the village of Matuku is provided below. The location of the cultural sites in Nakorotubu are presented in Map 9.

Rock Shelter (Plates 54 & 55)

About 20 minutes walk, southeast from the Base camp 1 is the rock shelter. Commonly

known as the qara vatu, the site is a gigantic rock face used by the forest gatherers from the surrounding villages as a resting place at night.

Kena i talanoa [Legends and Myths]

According to the guides, the cave is sacred and renowned for its mysterious aura. The story passed down from their forefathers to the present day community is that if one should spend the night at the shelter he should put away his sharpening tool [flat file] and not leave it lying around carelessly. Should this happen, the tool would disappear the following day and it is said that the sharpening files are taken by spirit inhabitants of the shelter who continue to carve out the cave.

The rock shelter has a few chambers containing scattered remains of potteries. Water seeps through the rock layers from the top of the rock shelter and according to the guides, people would stand underneath the dripping water to fill their containers.

Kena i talanoa [Legends and Myths]

According to the guides, the cave is sacred and renowned for its mysterious aura. The story passed down from their forefathers to the present day community is that if one should spend the night at the shelter he should put away his sharpening tool [flat file] and not leave it lying around carelessly. Should this happen, the tool would disappear the following day and it is said that the sharpening files are taken by spirit inhabitants of the shelter who continue to carve out the cave.

Stone Alignment (Possible Lovo Pit) (Plate 56)

This stone aligned feature was found a few metres away, south from the foot of the hill where the rock shelter is. The stones are clearly visible and are a clear indication of human inhabitance in the area. Within the stone alignment is a depression that could have been an earthen pit or lovo (Plate 57). The diameter of the pit is about 1 m and around 25 cm deep at the deepest point.

Grave Site (Plate 58)

The team stumbled upon an unknown site containing four visible burial mounds with stone alignment (Plate 59). The villagers from Soa who have encountered the burial site previously on hunting expeditions, are unaware of the owners of the site although there are claims from other sources at the camp site of its links to the people of Nabavatu who were fleeing from their place of dwelling during the introduction of Christianity.

This site is located on a high terraced platform overlooking the lower surroundings of the area.

Nabavatu Old Settlement Site (Plate 60)

Similar to the grave site, very little is known about this old settlement site which lies along the hunting paths at the confluence of the Olou and Caquru creeks (Plate 61).

Kena i talanoa [Legends & Myths]

An elder informant claims that when Christianity was introduced, the colonial government made sure that conversion was widespread reaching even people in the highlands. Those who were critical were imprisoned for not accepting the new religion. The people of Nabavatu were believed to have broken out into the forest towards the north. Evidence of this could be given with the existence of several other settlement sites beyond the mountains trailing northward believed to be tied to the ancestors of Nabavatu.

This particular site was made up of terraced platforms outlined with stone formations and huge boulders but no evidence of house mounds that could have probably eroded due to heavy rain. This small settlement is about 22 m wide and about 35 m in length. The site is not strategically located but is close to its source of drinking water and livelihood possibly in the form of agricultural practice.

Unknown Site (Plate 62)

While walking through the forest, the team stumbled upon an unknown site (Plate 63) Located on one of the more elevated points, the site is fortified with visible terraces along the sides of the hill and an almost circular house mound about 20-25 m in diameter. Similar to the other unknown sites, the guides have an idea of its location and existence but know nothing of its past inhabitants or the settlement name.

Nabavatu Old Settlement Site (Plate 64)

The name of this site is confirmed and identified by the guides as Nabavatu. The site sits on a ridge top with terrace-like features identified to be the works of humans and suitable for dwelling. The site contains mostly stone aligned burials and a single raised earthen house mound of about 10 m in width and 15 m in length.

The area along the stream is scattered abundantly with huge boulders and stony bedrock all the way from the village of Matuku towards headwaters. The name Nabavatu translates to "stone barricade" which is a form of cultural identification for the yavusa [tribe] and mataqali [clan] having identified themselves with the natural physical features of the place. The name was carried through to other places of settlement during the time of break away northward.

Caquru Old Settlement Site (Plate 65)

The old village of Caquru (Plate 66) is situated on high grounds where it has been leveled for habitation purposes. On the site are three house mounds, two mounds of which are raised earthen material while the third one is raised and aligned with stones. All the house mounds are about the same size ranging from 15-20 m in length and width (see Table 10.1).

According to the oral history collected, the inhabitants of Caquru are also members of the Nabavatu clan.

In their village role [tutu vaka vanua] the people of

Caquru are the War lord's [Vunivalu of Soa village] companion. Traditionally they are to live right next to the Vunivalu to converse with and entertain so that he does not get bored.

Table 10.1 descriptions of house mounds found at the Caquru Settlement Site

House Mound #	Estimated Length [m]	Estimated Width [m]	Composition of the Mound
1	9	5	Raised earthen rectangular mound
2	11	8	Raised mound with stone alignment
3	9	5	Raised earthen rectangular mound

The following sites are nestled in the hills enclosing the village of Soa

Nakorovia Fortified Site (Plate 67)

This fortified site is located on the mountain range northeast of Soa village. At an elevation of about 251 m, the settlement begins with the entrance at Matauvatukia which was according to guide sources guarded by warriors during its last inhabitation. Running along the range, the site contains seven house mounds (see Table 10.2). One of these mounds accommodated a burekalou [temple] being of circular shape and about 7 m in diameter. At the mid point of this set up is a platform rising up to almost 10 m in height and at the top is a 7x7 m house mound.

Tevita Digio of Soa village, whose ancestral ties to Nakorovia (Plate 68) was in his clans' role as the warriors [liga ni wau] of the land, laments on how the ancestral settlement, called Namolibale was strategically located at the foot of the hill of the Nakorovia site. Given their roles as protectors the warriors were positioned in such a location to ensure the Vunivalu and the people of Nakorovia were well guarded on the mountain range and the people of Nakorovia had the advantage of overlooking the surrounding areas.

Table 10.2 Brief descriptions of house mounds found at the Nakorovia Fortified Site

House Mound #	Estimated Length [m]	Estimated Width [m]	Composition of the Mound
1	11	5	Raised earthen rectangular mound
2	15	2	Raised earthen rectangular mound
3	27	15	Raised earthen rectangular mound
4	7	7	House mound on a high platform
5	11	7	Raised earthen rectangular mound
6	7	5	Raised earthen rectangular mound
7	Diameter 7		Raised circular mound

Namolibale Old Settlement (Plate 69)

This site is located within the area of Base camp 2 north east of Matuku village. It is very widespread and thickly vegetated with cevuga (Hedychium garderianum) plants making it difficult to investigate the total number of house mounds present in the site. According to the guide, this is the initial site before people dispersed elsewhere. Its inhabitants were said to be of heavenly origin and not from Nakauvadra, "from heaven God placed them in Namolibale." The Namolibale site can be found at the foot of the mountain below Nakorovia and contains four raised earthen house mounds. Three of the mounds are almost identical in size ranging from 10-25 m in length and width while the fourth mound, circular in structure is believed to be a temple and has a diameter of about 20 m across (see Table 10.3).

Namolibale (Plate 70) is where the Vunivalu resided with the people of the mataqali Nasea who were the spokespeople.

Table 10.3 Brief descriptions of house mounds found at the Namolibale Old Settlement

House Mound #	Estimated Length [m]	Estimated Width [m]	Composition of the Mound
1	20	10	Raised earthen rectangular mound
2	20	15	Raised earthen rectangular mound
3	25	10	Raised earthen rectangular mound
4	Diameter 20		Raised circular mound

Cuva Old Settlement (Plate 71)

Cuva settlement (Plate 72) is about 463 m southwest of Namolibale. Both settlements are located close to the Cuva creek- a source of strength and livelihood for the people.

Cuva site accommodates 4 raised earthen house mounds with size ranges between 10-20 min length and width (see Table 10.4).

Table 10.4 Brief descriptions of house mounds found at the Cuva Old Settlement

House Mound #	Estimated Length [m]	Estimated Width [m]	Composition of the Mound
1	15	10	Raised earthen rectangular mound
2	15	10	Raised earthen rectangular mound
3	15	12	Raised earthen rectangular mound
4	20	15	Raised earthen rectangular mound

Nalami Fortified Site (Plate 73)

On the mountains northwest of Soa village is the site called Nalami. Constructed on one of the peaks along the ridge (Plate 74) the site offers a spectacular view of the surrounding area. The site is well planned and protected. The western end of the site is a cliff that drops right to the foot of the mountain and the eastern side of the settlement is fortified by a ditch with the only access to the village being a causeway.

Within the fortified settlement, the house mounds are neatly aligned with the burekalou located on a raised platform symbolic of its importance in the settlement. At a lower elevation, house mounds for the commoners are positioned close to the ditches (see Table 10.5).

The site belongs to the people of the yavusa Nakase and their responsibility in the traditional hierarchy is the liga ni magiti. Their role is characterized by the provision of food crops and the rearing of animals such as pigs for the Vunivalu.

Table 10.5 Brief descriptions of house mounds found at the Nalami Fortified Site

House Mound #	Estimated Length [m]	Estimated Width [m]	Composition of the Mound
1	Diameter 10	Height 4	Raised circular mound
2	25	15	Raised earthen rectangular mound
3	23	16	Raised earthen rectangular mound
4	8	5	Raised earthen rectangular mound
5	7	6	Raised earthen rectangular mound
6	9	5	Raised earthen rectangular mound
7	6	5	Raised earthen rectangular mound
8	8	6	Raised earthen rectangular mound
9	7	5	Raised earthen rectangular mound
10	9	8	Raised earthen rectangular mound

Toro ni vuaka [piggery] Site (Plate 75)

The piggery for the Vunivalu can be found east of Nalami about 393 m away. Using the rock formation to contain the pigs, the site is spans to about 70 m enclosed and well designed with a maze-like setup where the animals could move around freely.

NASAU AREA (Map 4)

Nasuku Old Village Site (Plate 76)

Dawasamu is the name of the hill where the old village called Nasuku (Plate 77) is situated, on a raised coral platform just before the village of Nasau. It is a massive site with fully intact house foundations and well preserved under a dense canopy. Nasuku contains about 30 house mounds including both raised plain earthen mounds and the ones with stone alignment (see Table 10.6). The site is extensive and the people utilized the rock outcrops for added protection. The site is used by some of the villagers to harvest wild yams and in doing so an elderly man came across an undamaged clay pot tucked away in the crevices of a rock structure. Covered with a thick layer of algae, the pot has remained hidden and undisturbed by humans and animals for many years (Plate 78).

Kena i talanoa [Legends and Myths]

Nasuku was said to be occupied when the ancestral gods made their way out of Nakauvadra following the ridge or the waka ni vuga yali as it is known locally. The site belonged to the Yavusa Naloto, and the name of their army was Dritabua. The site was set up during the civil war when cannibalism was at its peak. Christianity was introduced first in Bau, then Sawakasa and later to the Dawasamu site. At this point the Vunivalu decided to introduce Christianity to other places known locally as the event called "valu ni lotu" in an effort to end cannibalism. He went up the Wainibuka all the way up to Nalawa and following the traditional protocol he managed to reach Nadroga, Navosa and Naitasiri.

Matavanua Old Village Site

During the site investigation, the guide took us to Matavanua and pointed out the site which has been greatly disturbed-flooded, overrun with bamboo and damage by livestock. It was because the site was so heavily destroyed it was impossible to locate and identify the house mounds.

Koronigata Old Settlement Site (Plate 79)

Koronigata (Plate 80) is located further about 120 m

northwest of Matavanua. Six house mounds were identified however, the wet climate has accelerated erosion and surface runoff in the area (see Table 10.7). Other threats to the site include trampling by livestock and the invasion of the fast growing African Tulip trees.

Table 10.6 Brief descriptions of house mounds found at the Nasuku Old Village Site

House Mound #	Estimated Length [m]	Estimated Width [m]	Composition of the Mound
1	3	2	Mound with stone alignment [Naulunivuaka]
2	3	2	Mound with stone alignment [Naulunivuaka]
3	7	5	Raised earthen house mound [Naulunivuaka]
4	3	2	Mound with stone alignment [Naulunivuaka]
5	8	5	Mound with stone alignment [Naulunivuaka]
6	8	5	Mound with stone alignment [Naulunivuaka]
7	3	1	Mound with stone alignment
8	12	10	Mound with stone alignment
9	5	4	Mound with stone alignment
10	7	5	Half stone alignment and earth
11	7	5	Mound with stone alignment
12	14	9	Mound with stone alignment
13	12	8	Mound with stone alignment
14	10	5	Half stone alignment and earth
15	8	5	Mound with stone alignment [yavu ni turaga]
16	7	5	Half stone alignment and earth
17	3	3	Circular Mound with stone alignment [temple]
18	10	10	Raised earthen house mound
19	8	6	Raised earthen house mound
20	12	8	Mound with stone alignment
21	10	7	Mound with stone alignment
22	5	4	Mound with stone alignment
23	8	6	Raised earthen house mound
24	5	4	Raised earthen house mound
25	5	4	Raised earthen house mound
26	3	3	Raised earthen house mound
27	5	4	Raised earthen house mound
28	7	5	Raised earthen house mound
29	Is not a house mound but the big rock where the pot is tucked away in		
30	5	4	Raised earthen house mound

Table 10.7 Brief descriptions of house mounds found at the Koronigata Old Settlement Site

House Mound #	Estimated Length [m]	Estimated Width [m]	Composition of the Mound
1	7	6	Raised earthen mound
2	7	5	Raised earthen mound
3	8	4	Raised earthen mound
4	7	5	Raised earthen mound
5	6	4	Raised earthen mound
6	7	5	Raised earthen mound

Navalesara Old Settlement Site

This site has been used by the traditional owners as a taro patch and the only house mound that they have preserved is the foundation of a church- circular in structure with stone edge alignment. The foundation is raised to a height of about 80-90 cm with a diameter of about 6-7 m.

Navunibulu Old Settlement Site (Plate 81)

The site at Navunibulu contains four house mounds with overgrown vegetation and grass cover (see Table 10.8). Also abundant on the site are the cevuga vulavula (Hedychium gardnerianum). The house mounds are not in a good state having being eroded and trampled upon by wild cattle that broke out from the nearby dairy farms.

Table 10.8 Brief descriptions of house mounds found at the Navunibulu Old Settlement Site

House Mound #	Estimated Length [m]	Estimated Width [m]	Composition of the Mound
1	7	6	Raised earthen mound
2	5	4	Raised earthen mound
3	6	5	Raised earthen mound
4	6	6	Raised earthen mound

Kena i talanoa [Legends & Myths]

According to oral accounts, the site Lele originally belongs to the people of yavusa Namoa and Delainaloto who stayed in Nasuku, Dawasamu for a brief period. They first settled in a place called Navunibulu for a number of years. Dispute arose when they tried to install their own chief and the Taukei Dawasamu [chief of Dawasamu] caught word of this and sent one of his warriors from the mataqali Colata to force them out.

The group moved and settled in another place they called Lele. The Taukei Dawasamu was displeased to find out that they were still close by and again sent a message for them to move further. It was at this point that the clan members of Delainaloto finally separated from those in the yavusa Namoa and moved on further to build a settlement called Tomuna, in the Sawakasa district. After spending a number of years at Tomuna the Delainaloto faction continued to search for land until they moved to Vorovoro where they have stayed till the present day. The people of Namoa settled in a place known today as Luvunavuaka.

Lele Old Settlement Site

This ancestral site accommodates seven earthen house mounds all of which have been eroded and overrun with thickets and shrubs. The site as mentioned above belongs to the group of people that were sent away from Nasuku village resulting from a dispute

Nasaumaki Old Village Site

Nasaumaki village site has eight eroded earthen house mounds thickly covered with ferns, cevuga and other vegetation. The poor site condition made mapping impossible and a major threat to this site is the presence of an old cattle farm in the vicinity where the livestock are left to roam free and trample the area.

Tomuna Fortified Site

Situated at the very top of a mountain, Tomuna (Plate 82) overlooks the surrounding area, an attribute ideal during inter tribal warfare times. On the site is a very big house foundation more the 10 m in length and about 7 m in width. The site has clearly been disturbed by wild pigs burrowing into the ground looking for wild yams. Some of the plants that are significant indicators of the presence of the settlement is the Cordyline terminalis or vasili.

CONCLUSIONS AND CONSERVATION RECOMMENDATIONS

The inspection of the forest vegetation of the surveyed area revealed that there is much history contained within the district of Nakorotubu pertaining to traditional and cultural development and linked strongly to the identity of its people.

Such history should be preserved whether they are tangible or intangible cultural assets. In this case, some evidence of cultural features has been destroyed influenced greatly by human inhabitance in the form of rearing livestock, and natural processes.

The department wishes to recommend:

- That proper documentation of the survey and oral history be undertaken to avoid the loss of traditional knowledge about these sites.
- The Fiji Museum Archaeology Department be included in any future surveys of the area to allow for the completion of the survey in the overlooked areas within the Biodiversity survey region.
- The villagers should be aware of the threat that livestock pose on their ancestral grounds and
- The department would also be interested in presenting findings and creating awareness should there be any workshop planned for these regions.

REFERENCES

Legislative Council. 1927. Final Report by Chairman on the Province of Lomaiviti, Ra and Tailevu, Native Lands Commission, Council Paper, No. 94.