



Freshwater Fish and Water Quality of Two Catchments in the Nakauvadra Range, Ra Province, Fiji

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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 km²) and Vanua Levu (5,535 km²) comprise 88% of the total land area (~18,300 km²). 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 commonly receive over 10,000 mm per year.

Fiji is large enough to support a wide range of habitats. These include lowland and montane rainforest, cloud forest, coastal communities and mangroves, inland swamps and 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 initiatives within the Yaqara and Nakauvadra watersheds. More specifically, the survey was conducted to gain a better understanding of the existing environment in the Yaqara Valley and provide an ecological baseline assessment of the proposed Nakauvadra Range forest reserve. 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

CI's 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 Nakauvadra Range in the Ra Province 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 Nakauvadra Range.

Our specific objectives were to:

- Collect baseline data on the diversity and conservation significance of major terrestrial flora and fauna taxa in the Nakauvadra Range.
- Identify potential threats to biodiversity in the area, and propose mitigation strategies to enhance biodiversity conservation in the Nakauvadra 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 proposed Nakauvadra Range forest reserve encompasses an area of 11387 ha ranging from 300-866 m elevation in the Ra Province in the northeast of Viti Levu south of Rakiraki town (see Map 1a). The Nakauvadra Range extends for about 22 km along the north coast of Viti Levu with the eastern flank terminating in cliffs at Viti Levu Bay. To the west the range is about 6.5 km wide with the

highest peak Uluda rising to more than 800 m and is bordered by steep cliffs on the northern and southern slopes (Hirst 1965). The range is made up of andesite rocks of the Ba volcanic group formed from two main volcanoes, the Tavua and Rakiraki volcanoes. Radiometric dating of the Ba volcanic group shows a range of between 5.0 to 3.0 Ma (Rodda 1976). Drainage at Nakauvadra Range is controlled by north-westerly fractures some which have been intruded by dykes. Several spurs extend southeast while to the east of the range a large northwesterly spur forms the rounded hills of Rokavukavu Peninsula (Hirst 1965).

In the lower regions there is a mix of disturbed vegetation, such as grasslands, plantations, agroforests, and secondary forest in the relatively flat and accessible land near villages. Native lowland forest, upland forest and cloud forest occur in the more rugged and higher elevation areas. The range is completely surrounded by cleared land with the nearest forested block being 4 km to the southwest. There are many trails through the forested areas which are generally used by local communities to travel between villages and for hunting.

The Nakauvadra Range lies in one of the drier areas in Fiji. There are no rainfall data or meteorological data available from within the Nakauvadara Range. The Nakauvadra 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). The nearest weather station is located at the Penang Sugar Mill. Minimum monthly temperatures range between 20.2-23.5°C while maximum monthly temperatures range between 27.1-20.1°C.

The Nakauvadra Range is divided amongst approximately 75 traditional landowning units (Mataqali) that are based in 3 districts; Naroko, Tokaimalo and Naiyalayala.

Site descriptions

Most of the survey work was carried out along two infrequently used trails (Vatukacevaceva to Nayaulevu Village trail, and Vunisea to Narara Village trail) and their surrounding creeks and streams that form the headwaters of the Wainibuka River. The areas

surveyed along both trails ranged from 100 m to about 700 m in elevation. The majority of the creeks at higher altitudes (500-600 m) were dry and began to fill up at lower altitudes (<400 m). Overall, the higher altitude forest (600-800 m) along the northern border had greater species diversity and was more heterogeneous. In the lower altitude forests (100-300 m) along the southern border there were seral gradients along the larger creek edges and heavy encroachment of some better known invasive trees like *Spathodea campunulata*, *Albizia saman* and *Piper aduncum*. The general lack of ground cover, absence of epiphytes on tree trunks and dry stream beds in a pristine native forest is indicative of a lowland rainforest on the drier side of Viti Levu.

Camp site 1

Camp site 1 was set up at an elevation of about 300 m on a creek flat at the confluence of the Nabiya and Toluwalu creeks which are headwaters of the Wainibuka River. The vegetation around the campsite was that of a lowland vegetation type that is typical of a system previously exposed to anthropogenic activities and/or damaged by natural disasters like floods and cyclones. 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 creek flats native trees with diameter at breast height of up to 80 cm were encountered.

Camp site 2

Camp site 2 was set-up at an elevation of 320 m on a flat area near the Vuniquesa Creek. 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. When compared to Camp 1 the overall species diversity was poorer and the presence of large areas with almost a pure stand of a single sub-canopy tree species was more prevalent.

Camp site 3

Camp site 3 was set up alongside a stream flat at an elevation of about 630 m. 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 was very high especially with native species.

SUMMARY OF RAP RESULTS BY TAXONOMIC GROUP

Vegetation

A total of 418 plant taxa (including eight undetermined angiosperm species) were recorded comprising 75 ferns and their allies, five gymnosperms and 338 angiosperms. Of the recorded species, 338 were native species and 80 were aliens. The 338 native taxa could be divided into two groups; (i) indigenous species (200 species), and (ii) endemic species (138 species) equating to an endemism of 41% of the native flora and 34% for the entire flora. Two species of particular interest were *Degeneria roseiflora* (rare on Viti Levu) and *Neosomitra integrifoliola* (rare in Fiji). Four principle vegetation types were identified: (1) Talasiga Vegetation, (2) Lowland Rainforest, (3) Upland Rainforest, and (4) Cloud Forest. Most of the lower elevation vegetation types were disturbed or partially disturbed while the higher elevation vegetation types were generally primary forest.

Herpetofauna

A total of 11 frog and reptile species were documented representing approximately 33% of Fiji's terrestrial herpetofauna. This included three frog species, four skinks and four geckoes. In addition, skin sheds from the snake *Candoia bibroni* were also observed. All species were observed in relatively low abundances. Four of the species are endemic to Fiji (*Platymantis vitianus*, *P. vitiensis*, *Emoia concolor* and *E. parkeri*). With the exception of the introduced cane toad (*Bufo marinus*), and the mourning gecko (*Lepidodactylus lugubris*), the remaining species are native to Fiji and the Pacific. This survey documented the only known extant population of *P. vitianus* on Viti Levu. This frog species was thought to have been extirpated from Viti Levu in

the last 20 years and as such this result highlights the conservation significance of the Nakauvadra Range for herpetofauna biodiversity.

Birds

A total of 34 bird species were recorded in the surveys. Thirteen species are endemic to Fiji, four were introduced species and the remainder native. Three of Viti Levu's globally threatened species were recorded – Long Legged Warbler (Endangered, auditory record only); Black-faced Shrikebill and the Friendly Ground-Dove which was quite common. Notable species not recorded included the Masked Shining Parrot and the Polynesian Starling, though these have both been recorded previously. For birds, the Nakauvadra Range has the same conservation significance as other large forest blocks on Viti Levu.

Mammals

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 as Near Threatened and Endangered respectively. No roost of any of the bat species was recorded within the area covered during the survey. Six invasive mammal species were recorded during the survey. These included two rat species (*Rattus exulans* and *R. rattus*), one mongoose (*Herpestes fuscus*), domestic horses (*Aquus caballus*), goats (*Capra* sp.), domestic dogs (*Canis familiaris*), and pigs (*Sos scrofa*). Although most of these species were observed in very low densities, they were found throughout the area surveyed including fairly secluded and hard to reach regions on mountain ridges and denser forest. The finding of the mongoose *H. fuscus* is only the second record of the species in Fiji (compared to common small Indian mongoose *H. javanicus*). Due to the size of the area and accessibility, eradication of most of these invasive mammal species is not feasible. However it may be possible to increase reforestation rates of the native flora through the removal and/or exclusion of goats from the area.

Terrestrial gastropods

Even without dedicated sampling at least five different species of terrestrial gastropod were found. One species (*Parmarion martensi* Simroth 1893) is introduced and has documented agricultural pest and human health associations. All of the other species found are very likely to be unique to Fiji

(endemic) and members of their families from other Pacific Island countries are listed as threatened on the IUCN Red List. Based on the previously recorded high diversity of terrestrial gastropods in Fiji, increased sampling effort in wetter conditions would undoubtedly reveal a higher diversity of both endemic and native species being present.

Freshwater macroinvertebrates

The total species richness of macroinvertebrates found in the four sites sampled was 35 species with mayfly abundance and caddisfly larval diversity being high. These results are indicative of relatively “healthy” streams and are as expected for upper catchment streams surrounded by a relatively “undisturbed” catchment area. No obvious invasive freshwater macroinvertebrates were found during sampling. However, there were obvious signs of invasive weeds in the stream beds particularly in the lower Volivoli Stream sites sampled. This is of concern as any similar accidental introductions of non-native freshwater invertebrate species in the future, such as viviparid gastropods, may displace the native fauna and introduce species capable of acting as vectors for human-related illnesses.

Terrestrial Invertebrates

The order Coleoptera (beetles) was the most common insect order encountered through the surveys with a total 18 families. Rare families encountered during the surveys included: *Cerambycidae*, *Lucanidae* and *Buprestidae*. The greatest diversity of insects sampled from the Nakauvadra Range using nocturnal searches, tree beating and butterfly surveys was located within relatively intact, lowland forest near the confluence of the Nabiya and Volivoli Creeks. The highlight of the survey was the discovery of two stick insects both of which are endemic and very rare in the Fiji islands, with virtually nothing known about either species: *Nisyris spinulosus* (syn. *Cotylosoma*) and *Phasmotaenia inermis* (syn. *Hermarchus*) and a shy scorpion *Liocheles australasiae*. These were also found within the lowland forested area.

Freshwater fish

Eight species of fish from five different families were collected or observed during the survey. Two species were collected from the family Gobiidae (*Awaous guamnesis* and *Sicyopterus zosterophorum*)

that dominated the mid and the upper catchments. Also collected were three species of freshwater eels from the family Anguillidae (*Anguilla marmorata*, *A. obscura* and *A. megastoma*). The freshwater moray, *Gymnothorax polyuranodon* (Family Muraenidae), was also observed but not collected. We did not record any introduced exotic species in the mid and upper catchments although we observed that the lower catchment of the river system was heavily populated by the introduced Mozambique Tilapia *Oreochromis mossambicus* (Family Cichlidae) and the mosquitofish, *Gambusia affinis* (Family Poeciliidae). The two catchments surveyed appear depauperate in both diversity and abundance of fishes. There are a number of notably absent families (eg. Kuhlidae, Eleotridae) and the sparse ichthyofauna that remains are among the hardier, ubiquitous species. No endemic or sensitive, rare fauna were observed.

Cultural significance

During the course of the survey, an annotated field map of significant cultural sites was constructed to identify and map sites of historical and cultural significance in the Nakauvadra Range. Our resulting maps generally depicted that resting spots or stop-over spots were found high up in the forest and close to mountain peaks. Fortified settlements in the form of ring-ditches and stone walls were evident further up into the forest and closer to water sources. Also observed were mound features used as native land boundaries showing land holding units amongst the different yavusa or clans during Rt. Sukuna's presence in the Veitarogi Vanua around the early 1950s.

CONSERVATION RECOMMENDATIONS

Address potential threats

Protection of Nakauvadra Range

The forests in the Nakauvadra Range are one of the last remaining intact forest systems on the drier side of Viti Levu. These forests are currently not protected by any environmental legislation or conservation initiatives in Fiji. As the forests in the area are comparatively pristine and isolated due to their relative current inaccessibility, they provide potential security for a number of endemic taxa and habitats in Fiji. For example, the Nakauvadra Range contains the only known population of the endangered Fiji ground frog, *Platymantis vitianus*, which was thought

to have been extirpated from Viti Levu 20 years previously. As such, the results of this RAP survey can be used to develop a sustainable, long-term conservation plan for the Nakauvadra Range in collaboration with local landowning communities, relevant government institutions (at the local, regional and national scales), conservation NGOs, and academic institutions.

In particular, forests in the upper reaches of the three main river headwaters, the Nakauvadra, Penang and the Wainibuka catchments, should be preserved as protected areas to maintain water quality and act as a repository for potable water for the local communities (only three rivers, the Nakauvadra, Penang and the Wainibuka catchments, are currently officially recognized in the area).

Some special micro-habitats were observed where an almost pure stand of a single species of plant was found. This included a Pandanus forest, an intact *Metrosideros colina* forest and a forest dominated by the majestic *Agathis macrophylla*. Such systems are rare and in the Nakauvadra Range they were found in sections of the upper lowland vegetation with primary forest further away from known trails.

Similarly the upland forests found at around the 550-650 m elevation and cloud forests noticed at elevations >600 m had some of the best primary forest stands on Viti Levu. Of particular interest is its rich epiphytic flora especially the orchids and ferns. Such intact forest systems on the drier side of Viti Levu are rare as most have now being replaced with talasiga grassland and plantation forest.

Taxa-specific threats

Herpetofauna

Feral pigs and horses used by hunters pose a serious threat to the breeding habitats of the both the Fiji ground frog and the tree frog. Hunters should be made aware of the impacts of their horses on breeding habitats and encouraged to avoid riparian forest areas.

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 Nakauvadra Range; and the rediscovery of the ground frog questions the previously hypothesized negative impacts of mongoose on the frogs. A more detailed survey is needed to address this issue.

Birds

The size of the Nakauvadra Range forest and its complete isolation from other forest blocks makes it vulnerable to extirpation of species which are poor dispersers over non-forest habitats and have large home ranges such as the Masked Shining Parrot and the Giant Forest Honeyeater. This appears not to have happened as yet but mitigation measures should be taken to prevent any further erosion of forest size or quality.

Invasive mammals

Although rats and mongoose are known to have detrimental impacts on native fauna and flora, the eradication of these species from the Nakauvadra Range is not feasible given the size of the area and the high potential for re-introduction. On the other hand, the removal or exclusion of goats from parts of the Nakauvadra Range is a feasible and useful exercise given that goats are a major hindrance to the re-growth of native forest especially on the periphery and in the high rocky and grassland areas. This could be done by:

- Identifying potential reforestation sites in consultation with local communities.
- Establishing exclusion zones (fencing, etc.).
- Removal of goats from project sites and monitoring vegetation re- establishment.

Terrestrial gastropods

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 macroinvertebrates

The macroinvertebrate biodiversity ratios found (i.e. high mayfly and caddisfly larvae) are as expected for upper catchment streams surrounded by native forest with a relatively "undisturbed" catchment area. However, there is evidence of invasive weed

species along the stream beds which implies there is strong potential for similar introductions of invasive freshwater fauna. Efforts should be made to reduce pathways for introduction and spread including:

- Restricting horse access.
- Keeping the use of camp streams and access tracks to a minimum.
- Controlling the entry of human related waste e.g. chemicals or rubbish, into streams.

Special efforts should be made to keep the natural vegetation intact and undisturbed along all stream banks since the overall health of the waterways is likely to be reliant on organic matter inputs from the surrounding forest.

Freshwater fish

Catchment level management and rehabilitation should be undertaken especially in the lower catchments in order to restore some of the ecosystem function of rivers in the Nakauvadra Range and in turn increase the fish migratory capacity to the upper catchments. Some potential options for assisting in catchment rehabilitation are:

- Community-based replanting of buffer zones particularly in mid-catchment areas adjacent to subsistence agriculture and road crossing areas.
- Village level waste and water management plans (e.g. construction of ecological or compost toilets, livestock waste areas, minimize livestock traversing waterways).

A concerted effort should be made to prevent the introduction of any exotic aquatic fauna to the upper sections these rivers. Any introduction will likely further erode the ecological function of these waterways. Stocking of native species (e.g. Gudgeons) could be considered as well as integrated irrigation/aquaculture of prawns (*Macrobrachium* sp).

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 indiscriminate

and will also kill all juveniles, thus removing future potential populations.

Introduced fish species at the lower catchment of the two rivers are a major threat to native fish diversity. The introduced species *Oreochromis mossambicus* and *Gambusia affinis* will feed on the larvae of the migratory species which must use the river as their migration path. Efforts must be made to ensure that these species are not introduced into other catchments in the Nakauvadra Range.

Community awareness

As the land in the Nakauvadra 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 of the negative impacts of uncontrolled burning on the flora and fauna of the region.
- 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 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.

Plants

1. More specimen collections are needed as only a very small area was accessed during this survey. The checklist of vascular species present is only preliminary and probably includes only 70% of the species present. The orchids are much under-represented, 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). Epiphytic plants and especially ferns are also under-represented for the same reasons.
2. More plots need to be sampled at much higher elevations (cloud forest) and further away from known trails.
3. It is particularly necessary that future collections be carried out at least four months away from November to allow for seasonal variation.

Herpetofauna

Further surveys are needed for the herpetofauna of the Nakauvadra Range. More specifically further studies are needed to:

1. Determine the distribution of *P. vitianus* in the region.
2. Estimate population sizes of *P. vitianus* and *P. vitiensis*.
3. Determine the presence of other herpetofauna species that were likely missed during this survey due to time and weather constraints.
4. Collect DNA for biogeographical comparisons to populations in other areas of Fiji.

Bats

More surveys need to be conducted in the Nakauvadra Range for bats to:

1. Locate the presence of any roosting colonies of each bat species as none were found during this survey. This is to be carried out in nearby forest areas and at different times of the year.
2. Monitor population size of the different bat species foraging in the Nakauvadra Range. Since no roosts for any of the three species were located during this survey it was impossible to carry out density or abundance estimates for bats in the area.
3. Determine whether the Fiji blossom bat (*Notopterus macdonaldi*) is also present in the region.

Terrestrial gastropods

Future, more focused, surveys and research of terrestrial gastropods in more suitable weather conditions are needed to:

1. Obtain a more comprehensive checklist of species in the region.
2. Capitalize on their suitability as excellent sentinel taxa for ecosystem change.
3. Assess the potential of *Parmarion martensi* to detrimentally affect human health (through consumption) and native fauna.

Insects

A more comprehensive and accurate checklist of insects in the Nakauvadra Range can be obtained by:

1. Using more entomological trapping techniques including malaise trapping and active searching.
2. Surveying in more suitable weather and at different times of year to capture seasonal variation.
3. Surveying more specific habitats at a wider range of elevations.
4. Targeting rare and endemic species.

In addition, the rare, endemic and possibly endangered insect species particularly *N. spinulosus* and *P. inermis* should be monitored throughout the year and between years to provide data on population numbers, local distribution patterns and seasonality patterns for the development of appropriate conservation and protection strategies.

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 assistance of elders from the locality should be encouraged and supported.

REFERENCES

Mueller-Dombois, D. and F. R. Fosberg. 1998. Vegetation of the Tropical Pacific Islands. Springer Press, New York.

Nunn, P. D. 1998. Pacific Island Landscapes. The University of the South Pacific, Suva, Fiji.

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.

Pacific Workshop on Seasonal to Inter-Annual Climate Variability: Bureau of Meteorology, Melbourne, Australia.

Terry, J. P. 2007. Tropical Cyclones. Springer, New York.