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

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Source: A Rapid Biodiversity Assessment of the Nakorotubu Range, Ra and Tailevu Provinces, Fiji: 48

Published By: Conservation International

URL: https://doi.org/10.1896/054.059.0109

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.

REFERENCES

Armstrong, A. 2002. Insects and the determination of priority areas for biodiversity conservation in KwaZulu-Natal province, South Africa. African Entomology 10(1): 11–27.

Beatty, C., H. Van Gossum and T. Sherratt. 2007. *Nesobasis* species diversity and abundance: Notes on an endemic genus of the island group of Fiji. Odonatologica 36(1): 13-26.

Beschovski, V. and M. Marinov. 2007. Fauna, Ecology, and Zoogeography of Dragonflies (Insecta: Odonata) of Bulgaria. In: Fet, V. and A. Popov (Eds.). Biogeography

and Ecology of Bulgaria, Springer: 199-231.
Brauer, F. 1867a. Beschreibung neuer exotischer Libellen aus den Gattungen Neurothemis, Libellula, Diplax, Celitheinis und Tramea. Verhandlungen der zoologisch-botanischen Gesellschaft Wien 17: 3-26.
Brauer, F. 1867b. Beschreibung neuer Neuropteren aus dem Museum Godeffroy und Sohn in Hamburg. Verhandlungen der zoologisch-botanischen Gesellschaft Wien 17: 505-512.
Brauer, F. 1869. Beschreibung neuer Neuropteren aus dem Museum Godeffroy in Hamburg. Verhandlungen der zoologisch-botanischen Gesellschaft Wien 19: 9-18.
Bridges, B. 1994. Catalogue of family-group, genus-group and species-group names of the Odonata of the world (third edition). Urbana, Illinois : C.A. Bridges xiv 951 pp.
Briers, R. and J. Biggs. 2003. Indicator taxa for the conservation of pond invertebrate diversity. Aquatic conservation: Marine and Freshwater Ecosystems 13: 323–330.
Chessman, B. and P. McEvoy. 1998. Towards diagnostic biotic indices for river macroinvertebrates. Hydrobiologia 364: 169–182.
Chovanec, A. and J. Waringer. 2001. Ecological integrity of river–floodplain systems—assessment by dragonfly surveys (Insecta: Odonata). Regulated rivers: Research and Management 17: 493–507.
Chovanec, A., F. Schiemer, H. Waidbacher and R. Spolwind. 2002. Rehabilitation of a Heavily Modified River Section of the Danube in Vienna (Austria): Biological Assessment of Landscape Linkages on Different Scales. International Review of Hydrobiololy 87(2-3): 183-195.
Chovanec, A., J. Waringer, R. Raab and G. Laister. 2004. Lateral connectivity of a fragmented large river system: assessment on a macroscale by dragonfly surveys (Insecta: Odonata). Aquatic conservation: Marine and Freshwater ecosystems 14: 163–178.
Clark, T. and M. Samways. 1996. Dragonflies (Odonata) as indicators of biotope quality in the Kruger National Park, South Africa. Journal of Applied Ecology 33: 1001-1012.
Clausnitzer, V. 2003. Dragonfly communities in coastal habitats of Kenya: indication of biotope quality and the need of conservation measures. Biodiversity and Conservation 12: 333–356.
Clausnitzer, V., V. Kalkman, M. Ram, B. Collen, J. Baillie, M. Bedjanič, W. Darwall, K.-D. Dijkstra, R. Dow, J. Hawking, H. Karube, E. Malikova, D. Paulson, K. Schütte, F. Suhling, R. Villanueva, N. von Ellenrieder and K. Wilson. 2009. Odonata enter the biodiversity crisis debate: The first global assessment of an insect group. Biological Conservation 142: 1864–1869.
Corbet, P. and S. Brooks. 2008. Dragonflies. Collins: 454 pp.
Donnelly, T. 1984. *Melanesobasis* gen. nov., a new genus of Fijian damselflies: A possible link between the platycnemidid Lieftinckia and certain coenagrionids (Zygoptera). Odonatologica 13(1): 89-105.
Donnelly, T. 1987. Return to the South Pacific – collecting in Fiji, Vanuatu, and the Solomon Islands, 1987. Selysia 16(2): 4.
Donnelly, T. 1990. The Fijian genus *Neosbasis* Part 1: Species of Viti Levu, Ovalau, and Kadavu (Odonata: Coenagrionidae). New Zealand Journal of Zoology 17: 87-117.
Donnelly, T. 1994. Back to Fiji. Argia 5(4): 4-6.
Donnelly, T. 2005. Oceanic islands in the news – or – Parthenogenesis means never having to remember Valentine's Day. Argia 17(3): 31-32.
Evenhuis, N. 2007. The Godeffroy Museum Catalogs in relation to Fiji Terrestrial arthropods. Part I: Introduction and review of Myriapoda, Diptera, Odonata, and smaller hesapod orders. Fiji Arthropods VII, Bishop Museum Occasional Papers 91: 17-28.
Evenhuis, N. and D. Bickel. 2005. The NSF-Fiji Terrestrial Arthropod Survey: Overview. Fiji Arthropods I, Bishop Museum Occasional Papers 82: 3-25.
Evenhuis, N. and D. Polhemus. 2007. Checklist of Odonata of Fiji. Bishop Museum Technical Report 35(15): available at: http://hbs.bishopmuseum.org/fiji/pdf/tr38%2815%29.pdf.
Foote, A. and C. Hornung. 2005. Odonates as biological indicators of grazing effects on Canadian prairie wetlands. Ecological Entomology 30: 273–283.
Fraser, F. 1925. A preliminary report on the dragonflies of Samoa. Transactions of the Entomological Society London (for) 1924: 429-438.
Hadrys, H., W. Schroth, B. Schierwater, B. Streit and O. Fincke. 2005. Tree hole odonates as environmental monitors: Non-invasive isolation of polymorphic microsatellites from the neotropical damselfly *Megaloprepus caerulatus*. Conservation Genetics 6: 481–483.
Haynes, A. 1987. Species richness, abundance and biomass of benthic invertebrates in a lowland tropical stream on the island of Viti Levu, Fiji. Arch. Hydrobiol. 110(3): 451-459.
Hawking, J. and T. New. 2002. Interpreting dragonfly diversity to aid in conservation assessment: lessons from the Odonata assemblage at Middle Creek, north-eastern Victoria, Australia. Journal of Insect Conservation 6: 171–178.
Jordan, S., C. Simon and D. Polhemus. 2003. Molecular systematics and adaptive radiation of Hawaii's Endemic damselfly genus *Megalagrion* (Odonata: Coenagrionidae). Systematic Biology 52(1): 89-109.
Karsch, F. 1889. Beitrag zur Kenntnis der Libellulinen mit vierseitiger cellula cardinalis (Nannophya Rambur). Entomologische Nachrichten 15(16): 245-263.
Kimmins, D. 1936. Odonata, Ephemeroptera and Neuroptera of the New Hebrides and Banks Island. Annals and Magazine of Natural History (10) 18: 68-88.
Kimmins, D. 1943. A new species of Odonata from Fiji.

Annals and Magazine of Natural History (11) 10: 698-700.

Kimmins, D. 1953. Miss L.E. Cheesman's expedition to New Caledonia, 1949 – Orders Odonata, Ephemeroptera, Neuroptera and Trichoptera. Annals and Magazine of Natural History (12)6: 241-257.

King, R., K. Nunnery and C. Richardson. 2000. Macroinvertebrate assemblage response to highway crossings in forested wetlands: implications for biological assessment. Wetlands Ecology and Management 8: 243–256.

Kirby, W. 1890. A synonymic catalogue of Neuroptera Odonata, or Dragonflies with an appendix of fossil species. London, Gurney and Jackson, IX+202p.

Lieftinck, M. 1975. The dragonflies (Odonata) of New Caledonia and the Loyalty Islands. Part 1. Imagines. Cah. Office Rech. scient. techn. Outre-Mer (Hydrobiol.) 9(3): 127-166.

Martin, R. 1901. Les Odonates du continent Australien. Mémoires de la Société Zoologique de France 14: 220-248.

Martin, R. 1906. Collections Zoologiques du Baron Edm. de Selys Longchamps, Catalogue Systematique et descriptif. Cordulines. Fascicule XVII: 94pp.

Martin, R. 1914. Odonata. Fam. Libellulidae. Subfam. Cordulinae. Genera Insectorum, Fascicule 155: 1-32.

Oertli, B., D. Joye, E. Castella, R. Juge, A. Lehmann and J.-B. Lachavanne. 2005. PLOCH: a standardized method for sampling and assessing the biodiversity in ponds. Aquatic conservation: Marine and Freshwater ecosystems 15: 665–679.

Oppel, S. 2006. Using distance sampling to quantify Odonata density in tropical rainforests. International Journal of Odonatology 9 (1) 2006: 81-88.

Ris, F. 1909. Collections Zoologiques du Baron Edm. de Selys Longchamps, Catalogue Systematique et descriptif. Libellulinen monographisch bearbeitet. Vol. 1. Fascicule IX.

Ris, F. 1911. Collections Zoologiques du Baron Edm. de Selys Longchamps, Catalogue Systematique et descriptif. Libellulinen monographisch bearbeitet. Vol. 2. Fascicule XII, XIII, XIV.

Ris, F. 1916. H. Sauter's Formosa-Ausbeure. Odonata. Supplementa Entomologica 5: 1-81.

Scher, O. and A. Thièry. 2005. Odonata, Amphibia and environmental characteristics in motorway stormwater retention ponds (Southern France). Hydrobiologia 551: 237–251.

Schmidt, Er. 1938. Check-list of Odonata of Oceania. Annals Entomological Society of America 31: 322-344.

Schmidt, Eb. 1985. Habitat inventarization, characterization and bioindication by a „Representative Spectrum of Odonata species (RSO)". Odonatologica, 14(2): 127-133.

Selys-Longchamps, E. de. 1871. Synopsis des Cordulines (1), 2me Légion. – Macromia. Bulletins de L'Académie Royale des sciences, des lettres et des Beaux-Arts de Belgique (2) 31: 519-565.

Selys-Longchamps, E. de. 1891. Causeries odonatologiques. No. 3. Nesobasis Selys (Nouveau sous-genre d'Agrionines). Comptes Rendus des Seances. Societe de Entomologie de Belgique: LI-LVII.

Sherratt, T. and C. Beatty. 2005. Island of the clones. Nature 435: 1039-1040.

Simaika, J. and M. Samways. 2009. An easy-to-use index of ecological integrity for prioritizing freshwater sites and for assessing habitat quality. Biodiversity Conservation 18: 1171–1185.

Thomas, J. 2005. Monitoring change in the abundance and distribution of insects using butterflies and other indicator groups. Philosophical Transaction of the Royal Society B 360: 339–357.

Tillyard, R. 1924. The dragonflies (Order Odonata) of Fiji, with special reference to a collection made by Mr. H.W. Simmonds, F.E.S., on the Island of Viti Levu. Transactions of the Entomological Society London 1923. (III-IV): 305-346.

Van der Sluis, T., M. Bloemmen, and I. Bouwma. 2004. European corridors: Strategies for corridor development for target species. ECNC, Alterra: 32 pp.

Van Gossum, H., C. Beatty, and T. Sherratt. 2006. The Zygoptera of Viti Levu and Vanua Levu, the two larger islands; in the Fiji archipelago. IDF-Report 9: 1-14.

Van Gossum, H., C. Beatty, S. Charlat, H. Waqa, T. Markwell, J. Skevington, M. Tuiwawa and T. Sherrattt. 2007. Male rarity and putative sex-role reversal in Fijian damselflies (Odonata). Journal of Tropical Ecology 23: 591-598.

Van Gossum, H., C. Beatty, M. Tokota'a and T. Sherratt. 2008. The Fijian *Nesobasis*: A further examination of species diversity and abundance (Zygoptera: Coenagrionidae). Odonatologica 37(3): 235-245.

Watson, J. 1984. A second Australian species in the Orthetrum sabina complex (Odonata: Libellulidae). Journal Australian Entomological Society 23: 1-10.

Wise, K. 1978. A preliminary report on the terrestrial invertebrate fauna of the Lau Group of Fiji, collected during the South Pacific Expedition, 1977. The Royal Society of New Zealand Bulletin 17: 53-61.

Wise, K. 1980. Records of South Pacific dragonflies (Hexapoda: Odonata). Rec. Auckland Inst. Mus. 17: 175-178.

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																			
T. transmarina	3	1	1	14	1	2	6	6	1	5	5	2	4	5	1	1	4	2	1
Total species number per locality																			