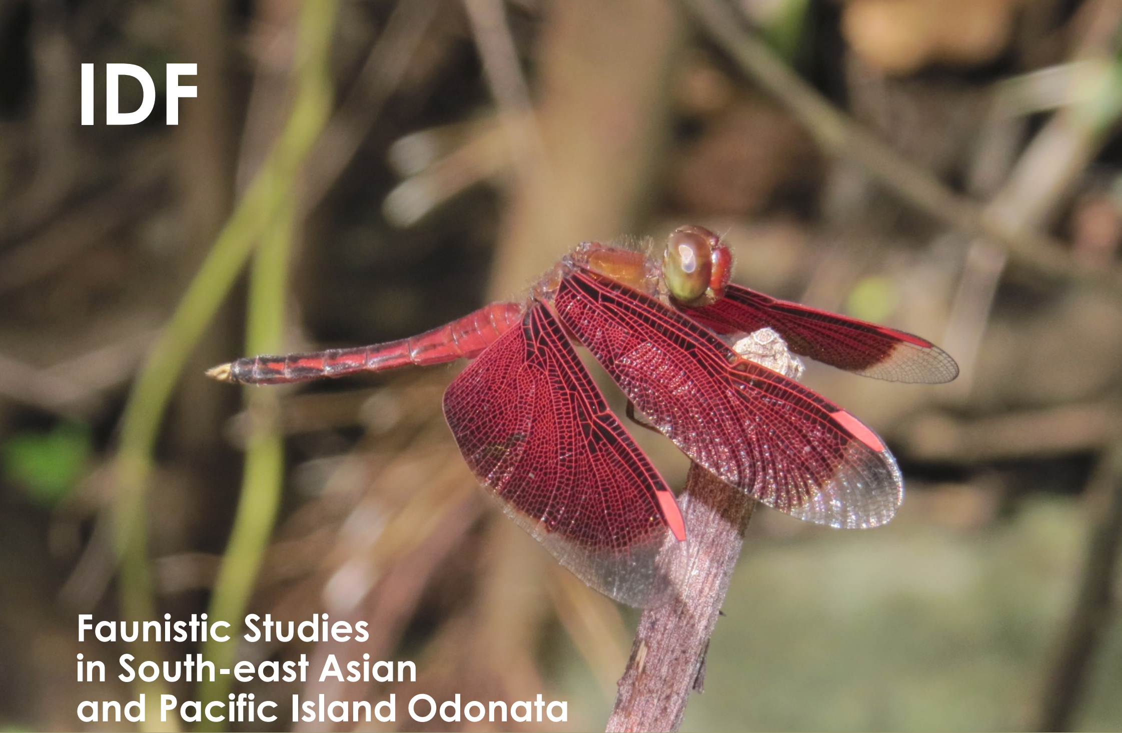

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Faunistic studies on Odonata of the Republic of Vanuatu (Insecta: Odonata)

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Abstract

This study investigates the history of Odonata studies in the Republic of Vanuatu and presents results from a two week field sampling mainly on three islands – Efate, Aneityum and Malekula. A total of 32 species are recognised as currently valid names for the country. Three new species have been collected and will be described elsewhere. Various taxonomic, faunistic and biogeographic issues are discussed in the light of the new material collected during the current study in comparison to already published research.

The general conclusion is that provisional species checklist is far from complete. The territory of Vanuatu is still highly insufficiently studied for its Odonata fauna. The local endemic genus *Vanuatubasis* Ober & Staniczek, 2009 is believed to be far more diverse than currently known with three described and three new species collected during the present study.

Abstract in Bislama

Disfala stadi hemi wandem faendemaot wat nao histri blong stadi blong olketa Odonata blong Ripablik blong Vanuatu mo i presentim olketa risalts from tufla wiks wea oli kolektim sampols from trifala mein aelans- Efate, Aneityum mo Malekula. Totol namba blong ol spisis wea oli stap long kaontri Vanuatu hemi 32. Trifala niu spisis oli bin kolektim mo mbae oli diskraebim long narafala pablikeson. Olketa taksonomic, fonistic mo baeojeokrafik isius nao oli diskasim long disfala pepa abaotim ol niu sampols wea oli kolektim long disfala stadi blong kompea wetem risej wea hemi bin pablis finis.

Jenerol konkluson hemi faendemaot dat disfala provisonol spisis jeklist hemi no bin komplit yet. Fona blong Odonata long teritori blong Vanuatu i no bin gat plenti risej wea oli bin karemaot long past yias. Disfala lokol endemic genas oli kolem *Vanuatubasis* (Ober & Staniczek, 2009) wea oli faendim long Vanuatu nomo mo ino kat eniwea long wol. Disfala lokol endemic genas oli bilivim se hemi stap long plenti ples long kaontri bitim nao trifala niu spesis wea oli jes kolektim mo diskraebim long disfala pepa ia.

Key words: Odonata, Efate, Espiritu Santo, Aneityum, Malekula, Vanuatu

Introduction

According to Marinov (2015), Vanuatu ranks as the 10th best studied country (out of 20) in the Pacific based on the information from less than 200 entries collated in the Pacific Odonata Database (free available on request from the first author). Although the database is not entirely representative for the real state of knowledge on the Odonata fauna of particular island archipelago, it does reflect specific tendencies and bias depending on personal preferences and the proximity of the residence to particular island groups of the researchers involved (Marinov et al., in prep.). It does show that large areas of the Pacific have been more deeply explored. Further, there are other data on Odonata of Vanuatu (e.g., new localities and undescribed species) that are not yet published in the literature but scattered in various private collections (per. comm. from *T.* Donnelly, D. Polhemus, C. Beatty, S. Jordan).

Using the Pacific Odonata Database Marinov (2015) highlighted areas of particular interest in future research. Currently, Vanuatu is probably the most neglected Pacific archipelago in terms of compiled data on Odonata, with Tonga and Samoa not far ahead (M. Marinov, per. comm.). However, Vanuatu surpasses these two nations by the total land area (more than six times larger than Samoa and 10-11 times the size of Tonga) and spans a much longer geographic stretch than either Tonga and Samoa. Samoa as a whole archipelago is smaller than Espiritu Santo – the largest of the 80+ islands of Vanuatu. Further, the human population per land area is more than three times less dense in Vanuatu than either Samoa or Tonga.

The low number of observations for Odonata across Vanuatu may be a consequence of both the very long geographical stretch (about 1,300 km north-south) of the archipelago and its turbulent political situation especially over the XXth century. Below is a short extraction from an on-line resource A Brief History of the Vanuatu Parliament.

Little is known about the first people, the first ni-Vanuatu, but it is supposed that they settled in the islands we now know as Vanuatu about 3500 years ago. The first Europeans to come to Vanuatu were Spanish, the crews of the Capitana, Almiranta and Los Tres Reyes under Pedro Fernandez de Quiros, who called the islands "Tierra Australia del Espiritu Santo" – Southern Land of the Holy Spirit – in May, 1606. Later in 1774 Captain James Cook renamed the islands "The New Hebrides", after some cold and windswept islands off the north-west of Scotland.

In XIX century British and French traders established plantations on the islands and imposed their laws. In 1887, a joint English-French Naval Commission was set up to take control over the English and French people on the islands. Ni-Vanuatu people did not come under either umbrella and had no say in government until 1957, when an Advisory Council was set up. This still gave little power to the indigenous people, and did not satisfy the growing interest in self-government. Demands for independence increased through the 1970s as surrounding countries became independent, and in 1975, the first step towards indigenous government was taken. As a result, discussions began between French and British officials and ni-Vanuatu over the political future of the New Hebrides. A Constitution Committee was set up and finally independence was declared officially on July 30, 1980.

Faunistic and taxonomic history of Odonata species in Vanuatu

We list Odonata species in chronological order as they have been reported for the entire Vanuatu archipelago (Table I). Each species is represented with the original published species name followed by the currently accepted name, verbatim locality information, literature source and page. Species new to science described from Vanuatu are marked with "*".

Kirby (1889) recorded the first two Odonata species (*Rhyothemis apicalis* and *Trithemis rubra*) from Vanuatu both initially introduced as new to science. However, in the catalogue of the world Odonata published soon after, Kirby (1890) included *R. apicalis* only for Vanuatu and for *T. rubra* he gave a general distribution as "Australia&c." (Kirby 1890: 18). Kirby (1890) was followed by Tepper (1899) and Martin (1901) who prepared regional catalogues for Australasia and Australia respectively and included *R. apicalis* only with reference to Vanuatu. Ris (1909-1919: Vol. 3 Fascicule XV(1913): 917) added another new species for Vanuatu and revised the taxonomic status of the two previously reported species: *T. rubra* was found to be a junior synonym of *Diplacodes haematodes* (Burmeister, 1839) in Ris (Vol. 2, Fascicule XII(1911): 474) and *R. apicalis* was recognised as subspecies of *R. phyllis* (Sulzer, 1776) in Ris (Vol. 3 Fascicule XV(1913): 948). Ris (1915) confirmed the subspecific affiliation of *R. p. apicalis*. Tillyard (1913), Campion (1921) and Fraser (1927) each added one additional new species to the country (see the discussion about representatives of the genus *Hemicordulia* Selys, 1870 below for further details).

Miss L.E. Cheesman's missions within the Pacific region marked the next significant period in the Odonata studies of Vanuatu. She collected on Vanua Lava, Erromango, Malekula, Espiritu Santo, Tanna, and Aneityum. Kimmins (1936, 1953, 1958) processed the whole of that material and included records of other specimens collected by J.R. Baker and P.A. Buxton deposited at the Natural History Museum, London (BMNH). All three papers collectively reported on 26 species found throughout Vanuatu, however, two of them are not included in the updated faunistic checklist for the country provided here: Kimmins (1936, 1953) reported both *Agriocnemis exsudans* Selys, 1877 and *A. vitiensis* Tillyard, 1924 which are now considered as synonyms (see Marinov et al. (2013b, 2015) for further discussions); and Kimmins (1953) reported *Ischnura delicata* Hagen, 1876 (which Vick & Davies (1988) considered as a junior synonym of *I. aurora* (Brauer, 1865)), with its general distribution from Ceylon to Tahiti without specifying if the species was established for Vanuatu. Kimmins (1936) reported *Trineuragrion percostale* Ris, 1915 by one male from Vanua Lava, Banks Islands, but

Kalkman & Theischinger (2013) regarded this record as incorrect. However, here this species is kept in the country checklist. A recent examination of the specimens collected by Miss Cheesman in 1929 confirmed the identity of the male specimen (S. Ober per. comm.). In fact Vanua Lava has not been sampled since and before disregarding the record of *T. percostale* as wrong (possibly mislabelled) more studies on the island are needed. Kimmins (1953) claimed *Orthetrum caledonicum* (Brauer, 1865) as known from Vanuatu, however this species has never been reported before this date and the origin of his observation is unclear. Soon after this record Kimmins (1958) noted *O. caledonicum* from two males and two females from Aneityum Island collected by Miss Cheesman in 1955. Although ambiguous, Kimmins (1953) is preferred here as the first report of *O. caledonicum* for Vanuatu.

Kimmins' work on the Odonata from Vanuatu (Kimmins 1936, 1953, 1958) is one of the most significant achievement for this period. It increased the total number of taxa for the country to 22 which is nearly 80% of the presently known 32 species (including the two new country records reported in this study). Kimmins (1936) was used in Schmidt (1938) checklist for Oceania who reported 21 species and subspecies of which 18 are recognised now as valid names. This is an almost complete species checklist for Vanuatu after Kimmins (1936). Schmidt (1938) missed *Agrionoptera insignis similis* Selys, 1879 which Kimmins (1936) originally included for the Odonata of Vanuatu under this name. Kimmins (1953) transferred *A. i. similis* to the newly described *A. i. lifuana* Kimmins, 1953.

Another uncertain record is *I. delicata*. Kimmins (1953) stated its general distribution only. Obviously this record was not accepted by Lieftinck (1959) as validated for Vanuatu because he claimed to be the first to report *I. aurora* (senior synonym of *I. delicata*) for the country.

Lieftinck (1960) described by supposition the naiad of *Indolestes cheesmanae* (Kimmins, 1936). So far it is the sole representative of the genus in Vanuatu.

Lieftinck (1975) is the next contribution which is of considerable importance to the Odonata fauna of Vanuatu. This study was dedicated to the fauna of neighbouring New Caledonia with references to the general distribution of four species going as far as Vanuatu. Lieftinck (1975) established *Tramea transmarina intersecta* subspec. nov. for New Caledonian populations. He had just one teneral female from New Caledonia which was missing most of the abdomen. Therefore, he provided illustrations of the terminal abdomen segments of another female collected from Espiritu Santo which he assigned to the same subspecies "with little doubt" based on general body colouration with particular attention to the marking and venation of hind wings. Lieftinck (1975) also included Kimmins (1958) records of two male *Trapezostigma limbata* (Desjardins, 1832) from Vanuatu into this subspecies. Since Kimmins (1936) already had reported *T. limbata* for Vanuatu we included his data as the first record of this taxon for Vanuatu.

Donnelly (1984) described a new species from Vanuatu. In another short note Donnelly (1987) claimed he knew of seven species in both genera *Melanesobasis* Donnelly, 1984 and *Nesobasis* Selys, 1891 – a genus name which was given for two described species from Vanuatu: *Nesobasis malekulana* Kimmins, 1936 and *N. bidens* Kimmins,

1958. Donnelly (1987) was contemplating of assigning these two species to a new genus. The same view was expressed later on when Donnelly (1990) analysed a large series of *Nesobasis* samples from Fiji and compared them to the specimens he had collected from Vanuatu. This view was additionally supported by Ober & Staniczek (2009) who erected *Vanuatubasis* n. gen. for the two already known species and described a third member of the genus from Espiritu Santo.

Being the largest island in Vanuatu, Espiritu Santo has attracted most attention in the past and consequently is the only one for which a full account of its nature has been published in Bouchet et al. (2011). In this book Odonata has been dealt with by Staniczek (2011) who presented a list of 16 taxa for Espiritu Santo claiming that five of them were new for the country. Only one of them (cf. Table I) is considered here as surely new to the country. Four other taxa are discussed below in the relevant sections (cf. discussions for *Hemicordulia*, *Tramea* and undescribed species).

Three more references of Odonata of Vanuatu are worth mentioning. Endersby (2002) recording the colonisation of Odonata on the Norfolk Island provided extralimital distributions of the species known from this island. For six species he recorded Vanuatu as another known locality. However, one of them, *Hemicordulia australiae* (Rambur, 1842) has never been recorded in any other prior references and the origin of this data is uncertain (I. Endersby, per. comm.). Papazian & Mary-Sasal (2010) described the male of *R.* p. *apicalis* which by then was the unknown sex. In one of the last literature sources Michalski (2012) reported on another new to the country species when referring to its general distribution. He cited unpublished data by *T.* Donnelly.

This literature review of the Odonata records of Vanuatu demonstrates the scarcity of observations and lack of consistency among the studies focused across the archipelago. Further, apart of Espiritu Santo, all other islands within the Republic of Vanuatu have not been sampled for Odonata for at least 30 years. For example, all Odonata records for the island of Aneityum come from two periods in the thirties and fifties, nearly 70 years ago. Surprisingly, all records of Malekula (second largest island of Vanuatu) come from 1929-1930, nearly 90 years ago, thanks to the material collected by Ms Cheesman!

Therefore, in preparation for field sampling of Odonata in Vanuatu we focus our efforts to some of least explore islands in order to collect information on endemic species, with special attention on the genus *Vanuatubasis*.

Material and Methods

Four islands in Vanuatu have been visited between 06th – 20th May 2017. Field sampling was carried out on three of them (Efate, Aneityum and Malekula). The Odonata checklist below includes data of two species spotted on Espiritu Santo during a brief stopover on the way to Malekula. Figure 1 shows the areas sampled during this study and the sampling localities for each island.

To facilitate data collection in the field, observations were recorded using the ArcGIS Collector app on a smartphone (Huawei P9). This app allowed for data points to be collected using the phone's built-in GPS receiver without needing an internet connection or cellphone signal. To record an observation, a new point was created

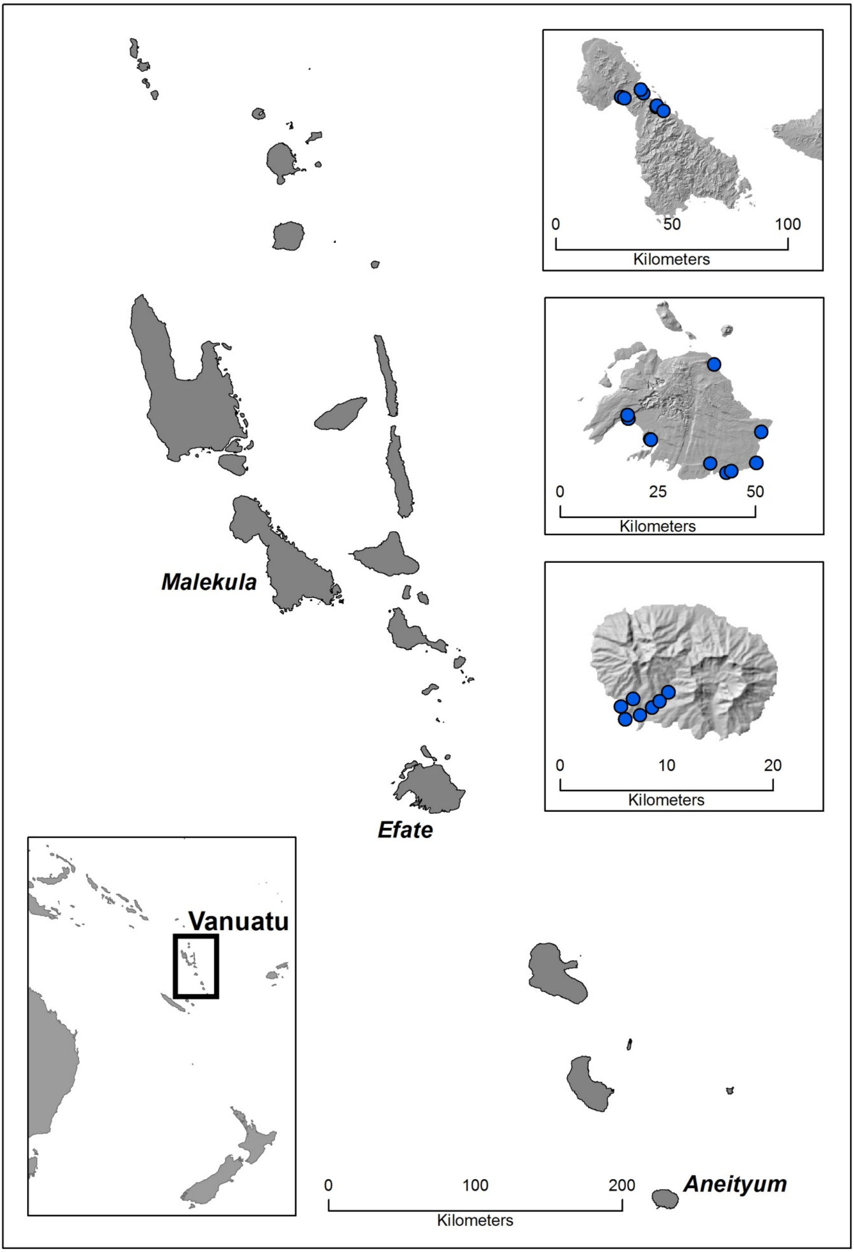


Figure 1. Sampling localities across the archipelago of Vanuatu.

based on the GPS position and important attributes of the observation were recorded, such as species name, sex, and sex stage. These attributes were chosen from a pre-populated set of values to ensure that all text entries were consistent. Specific comments could be added and images could also be stored with each point. When a WiFi or 3G signal was available, the data were synced with and stored on a GIS server at Lincoln University, New Zealand. These observations were later merged with the larger database of Pacific Odonata observations.

Mainly adult odonates were collected with aerial net and either killed in acetone, dried and transferred into paper envelops or preserved in 95% ethanol for molecular analysis.

Vanuatubasis specimens were compared to other Coenagrionidae from neighbouring Pacific archipelagos which are their supposed closest relatives. A total of 94 specimens belonging to four Pacific genera and 30 species were included in the analysis. This comparison targeted mainly *Nesobasis* and *Melanesobasis* (both from Fiji) and *Teinobasis* Kirby, 1890 (Solomon Islands). The platycnemidid *Lieftinckia* Kimmins, 1957 was considered as well following comment by Donnelly (1984) that *Melanesobasis* is a possible link between *Lieftinckia* and certain coenagrionids. Specimens were compared using two indexes: pre-nodal index (Prn) and thoracic index (TI). The first was introduced by Marinov et al. (2015) for comparison between 11 taxa from Samoa. The TI is tested herein for the first time. It was developed for the observed subtle differences in the shape of the synthorax of *Melanesobasis*-*Teinobasis* vs *Nesobasis*. TI is calculated by the formula: TI = Tw/Th, where Tw is the length of the synthorax measured from the ventral end of the mesostigmal plate to posterior end of the interpleural suture and Th is the height measured from the tip of the posterior projection of the dorsal carina to the anterior end of poststernum (Fig. 2). *Agriocnemis exsudans* Selys, 1877 was excluded from both indices. This species was used by Marinov et al. (2015) for comparison of Pacific taxa based on Prn. However, during the present study on the applicability of the TI we found that the two sexes of *A. exsudans* had different ratios in this index and decided to drop the species off both Prn and TI.

Terminology employed here follows Watson & O'Farrell (1991).

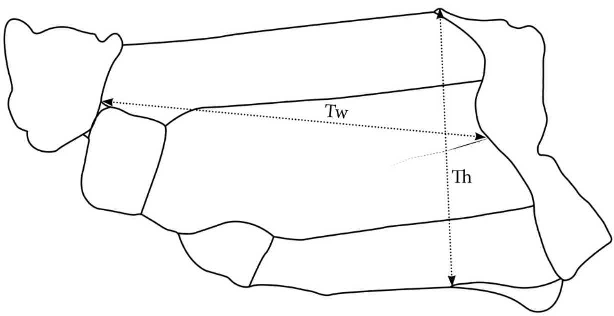


Figure 2. Calculating the thoracic index (TI): TI = Tw/Th, where Tw – distance from the mesostigmal plate to posterior end of the interpleural suture, and Th – distance from the tip of the posterior projection of the dorsal carina to the anterior end of poststernum.

The following localities were investigated (localities presented in chronological order depending on the day of sampling):

Efate Island

1. Vila Hibiscus Motel, Port Vila (-17.7317, 168.3127; 23 m a.s.l.): 07 May.
2. A stretch (2-2.5 km long) of roadside ditches and temporary floods above Mele Cascades (coordinates taken at the starting point: -17.6757, 168.2596; 30 m a.s.l): 07 May.
3. Pool at The Secret Garden restaurant (-17.6841, 168.2616; 16 m a.s.l.): 07 May.
4. Rentapao River by the bridge over the river (-17.7875, 168.4512; 12 m a.s.l.): 09 May.
5. Floods roadside about 4-5 km SE from Rentapao River – 1 (-17.8094, 168.4881; 8 m a.s.l.): 09, 19 May.
6. Floods roadside about 4-5 km SE from Rentapao River – 2 (-17.8051, 168.4990; 15 m a.s.l.): 09 May.
7. Unnamed river (-17.7854, 168.5566; 12 m a.s.l.): 09 May.
8. Ewor River by (-17.7142, 168.5686; 16 m a.s.l.): 09, 19 May.
9. Unnamed river S of Onesua (-17.5582, 168.4604; 14 m a.s.l.): 09 May.
10. Roadside pool on Teoma St. about 100 W from Vila Hibiscus Motel (-17.7320, 168.3141; 17 m a.s.l.): 10 May.

Aneityum Island

11. Swamp area and canals W of Aneghowhat Village (-20.2298, 169.7845; 23 m a.s.l.): 11 May.
12. Anijemhag River NE of Aneghowhat Village (-20.2180, 169.8012; 89 m a.s.l.): 12 May.
13. Nawapeig – Unijim River (-20.2103, 169.8083; 107 m a.s.l.): 12 May.
14. Puddle in Analaigitap area (-20.2233, 169.7946; 48 m a.s.l.): 12 May.
15. Stretch of Inwuje River N of Aneghowhat Village (-20.2228, 169.7681 to -20.2160, 169.7784; 21-120 m a.s.l.): 13 May.
16. Taro plantation in Inhenou swamp, Anleluhu area (-20.2333, 169.7718; 7 m a.s.l.): 13 May.
17. Mystery Island (-20.2479, 169.7737; 0 m a.s.l.): 14 May.

Espiritu Santo Island

18. Market place, Luganville (-15.5143, 167.1753; 0 m a.s.l.): 15 May.

Malekula Island

19. Lakatoro Palm Lodge (-16.0968, 167.4142; 21 m a.s.l.): 16 May.
20. Losinway River (-16.1093, 167.3274; 18 m a.s.l.): 16 May.
21. Roadside pool on the cross-island road between Lakatoro and western side of the island (-16.1145, 167.3394; 115 m a.s.l.): 16 May.
22. Stretch of Lakatchkach River flowing through Postanle Area (-16.1437, 167.4671 to -16.1474, 167.4649; 15-51 m a.s.l.): 17 May.
23. Bushman's Bay River (-16.1650, 167.4925; 7 m a.s.l.): 17 May.
24. Norsup airport (-16.0812, 167.4037; 7 m a.s.l.): 18 May.

Results

Odonata check list

Family Coenagrionidae

Agriocnemis exsudans Selys, 1877

Localities: 2, 6-11, 13-16, 18, 20-21, 23

The most common species during the present study. It was established on all four islands.

Previously reported for Aneityum, Gaua, Espiritu Santo, Malekula and Tanna (Kimmins 1936, 1958; Staniczek 2011).

New species for Efate.

Ischnura aurora (Brauer, 1865)

Localities: 6

One single record of this species is not representative of the actual distribution. Most probably *I. aurora* is more widely distributed throughout the country and future studies are likely to show it as an inhabitant of almost all islands within Vanuatu.

Previously reported on Aneityum, Efate, Espiritu Santo and Tutuba (Lieftinck 1959; Staniczek 2011; P. Maddison unpubl.).

Ischnura heterosticta (Burmeister, 1839)

Localities: 5, 8

Ischnura heterosticta was common among the bank vegetation of the two localities reported here. Due to its wide range within the Pacific it will probably be established on other islands of Vanuatu.

Previously reported from Gaua, Malekula and Tanna (Kimmins 1936).

New species for Efate.

Pseudagrion microcephalum (Rambur, 1842)

Localities: 2, 4, 8, 20

Figures 3-6 illustrate diagnostic features of Vanuatu specimens compared to other Pacific representatives of the genus commented in Marinov et al. (2015). They are further compared to each other on Table II. The latter is a modified version of Table 3 in Marinov et al. (2015). Here some features were removed as they are no longer considered diagnostically significant.

Pseudagrion from Vanuatu is closest to the Fijian congeneric which for the moment is considered as a separate species *P. pacificum* Tillyard, 1924 (Fig. 4). The shape of the ventral lobe of the superior appendages in dorsal view are very difficult to differentiate. Other features on the body like spots on the head and markings on the abdomen may be variable. However, Fijian material comes from a single male only and thus is not representative of the variation. Therefore, no new subspecies name is proposed here for *Pseudagrion* from Vanuatu.

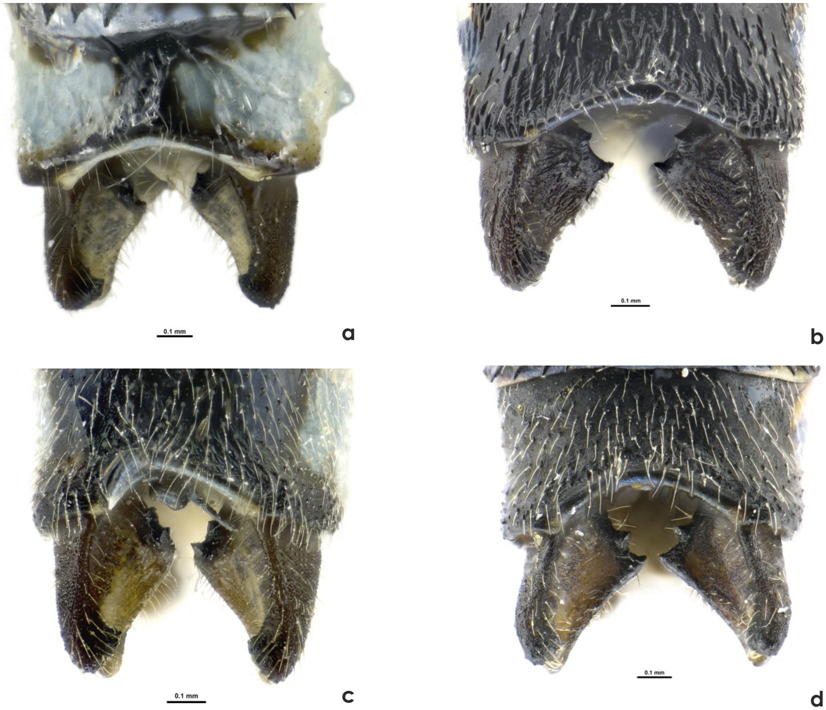


Figure 3. Comparison between the shape of the ventral lobe of the superior appendages of Pacific *Pseudagrion* (dorsal view): a) *m. microcephalum*; b) *m. stainbergerorum*; c) *pacificum*; d) *samoense*; e) Vanuatu specimen.

The species was found to be very common on Efate and Malekula. Adults were actively flying close to roadside ditches, along the vegetation in running water from variable width (usually wider than 7-10m) and even around oxbows that remained around the inundated banks of the main river course. Mating pairs

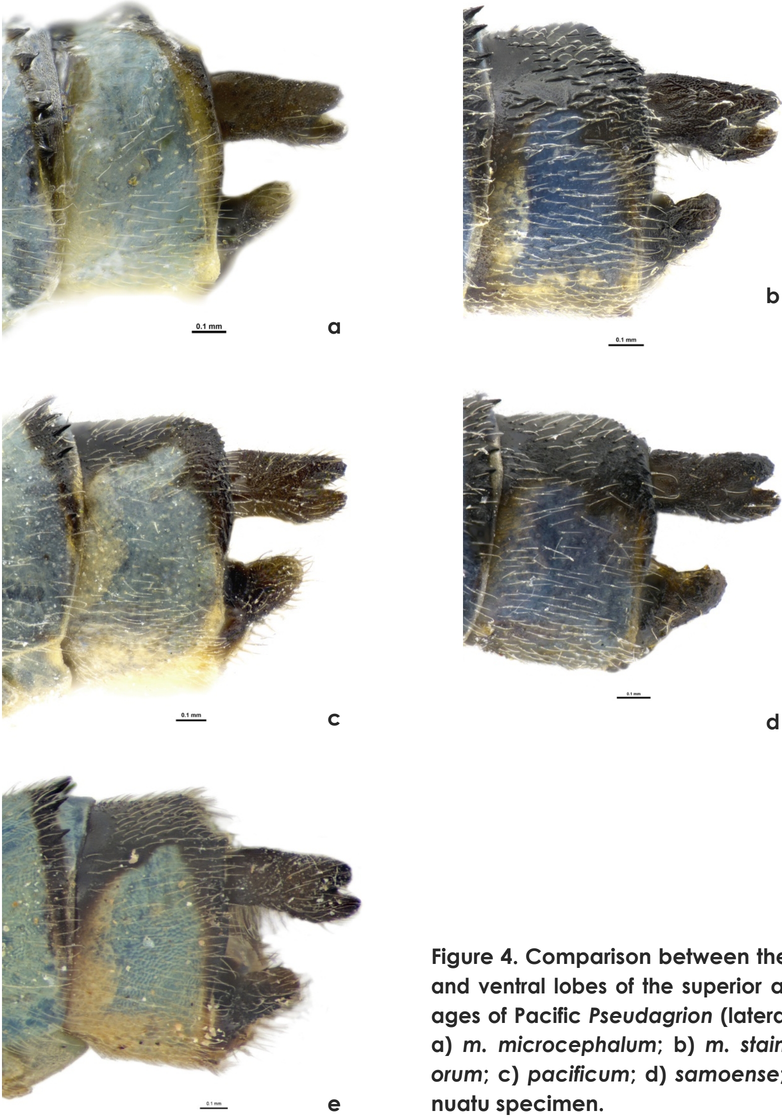
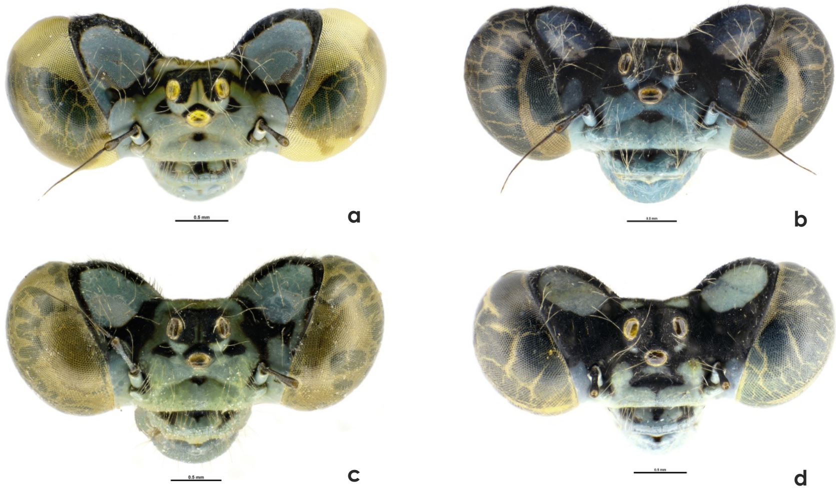


Figure 4. Comparison between the dorsal and ventral lobes of the superior appendages of Pacific *Pseudagrion* (lateral view): a) *m. microcephalum*; b) *m. stainbergerorum*; c) *pacificum*; d) *samoense*; e) Vanuatu specimen.

(Fig. 7) were observed in all habitat types even perching on the vegetation above sections of the river with riffle-like stretches.

Previously reported from Espiritu Santo and Malekula (Kimmins 1936).

New species for Efate.



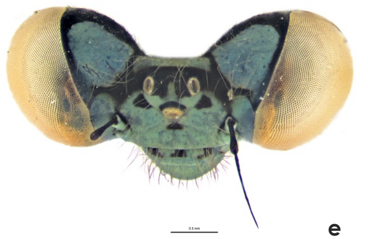


Figure 5. Comparison between the heads of Pacific *Pseudagrion* (dorsal view): a) *m. microcephalum*; b) m. *stainbergerorum*; c) *pacificum*; d) *samoense*; e) Vanuatu specimen.

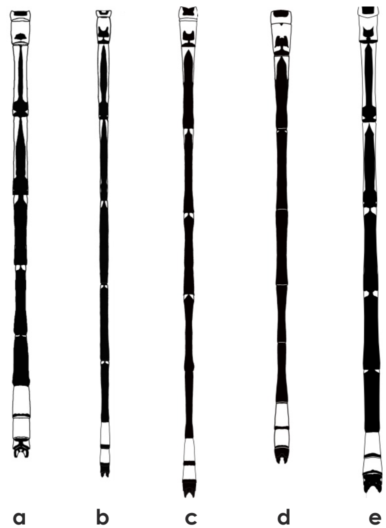


Figure 6. Comparison between the abdomens of Pacific *Pseudagrion* (dorsal view): a) *m. microcephalum*; b) *m. stainbergerorum*; c) *pacificum*; d) *samoense*; e) Vanuatu specimen.

Figure 7. Mating pair of *Pseudagrion microcephalum* from Malekula Island.

Figure 8. Habitat of *Vanuatubasis bidens,* Locality 12.

Vanuatubasis bidens (Kimmins, 1958)

Localities: 12-13, 15

This species is endemic to Aneityum and so far is known from a single male. During the present study *V. bidens* was discovered within the catchments of the three sampled rivers and is probably inhabiting other lotic waters on the island. The typical habitat (Fig. 8) is the mountainous sections of lotic water above human settlements, ranging in width 7-10 m; shallow water with large partly exposed boulders; riparian tree vegetation does not completely cover the water surface leaving sunny patches of grasses along the banks. Steep to almost vertical rocky banks densely vegetated and with seeping waters were found to be the most attractive sites for the species. In those places adults with various body colouration on the thorax ranging from pale yellow to light green were encountered (Fig. 9). These colour differences are considered as changes during the sexual maturity.

Mostly immature insects were collected (although this may have been due to a cyclone that hit the region only days before that cause rivers to swell and scour the edge habitats) including one teneral with its exuviae. The latter was discovered in the mid-section of the river emerging on the sheltered section of the boulder well above the water (Fig. 10).

Figure 9. *Vanuatubasis bidens* males at various stages of maturity: a) immature; b) mature.

Vanuatubasis malekulana (Kimmins, 1936)

Locality: 20

This species was found in an 8-10 m wide river (Fig. 11). Mostly males were collected and only one female was encountered. All individuals were observed in densely shady sites, usually within tall vegetation (Fig. 12). Often, they were encountered close to spider webs where adults persistently remained even after being chased from their sites. One individual appeared to be inspecting spider webs (pers. obs. S. Bybee) similarly to Psuedostigmatinae. On one occasion a male was missed with aerial net and went out of sight, but another (or potentially the same individual) was discovered at the exact location about 15-20 minutes later.

Figure 10. Emerging site for *Vanuatubasis bidens.*

Figure 11. Habitat of *Vanuatubasis malekulana*, Locality 20.

Figure 12. Perching site of *Vanuatubasis malekulana*. Adults utilised the top leaves of the grass clusters about 1.5-2 m from the river bank.

Vanuatubasis spp.

Locality: 22

Certain female specimens (possibly belonging to three different undescribed species, one of which is given in life on Fig. 13) collected during the present study were not associated with any males in the field and their proper generic affiliation was difficult to established. Based on the shape of the posterior edge of the pronotum they were assigned to *Vanuatubasis* as the most probable genus. This morphological feature was the only one that could be used for females from the generic diagnosis given in Ober & Staniczek (2009). For further evidences about their proper generic affiliation, the specimens were included in another comparisons based on the two indices explained in the methodology: Prn (Fig. 14, Table III) and TI (Fig. 15, Table IV).

Figure 13. *Vanuatubasis* sp. – one of the three new species collected from Locality 22.

The females of *Vanuatubasis* spp. had ratios for both indices close to *Vanuatubasis* and *Nesobasis* with both genera appearing with similar scores on Figures 14-15. Tables II and III show the actual values of the indices. The number of specimens involved in this comparison differ between the two tables for the same genera mainly because some of the specimens used in Marinov et al. (2015) for Prn were already employed in molecular studies and not measured for TI here.

All specimens were sampled from the same site – a closed canopy stream with the bed being rocky and muddy which is elevated at various points forming short step-like sections (Fig. 16). Water level was mostly between 0.2-0.5m; in-stream pools were sparse and where they did occurred they were still shallow enough to be easily crossed. The stream appeared to have a high mineral content as many of the roots from trees were coated in a dense, semi-hard coating. Variation

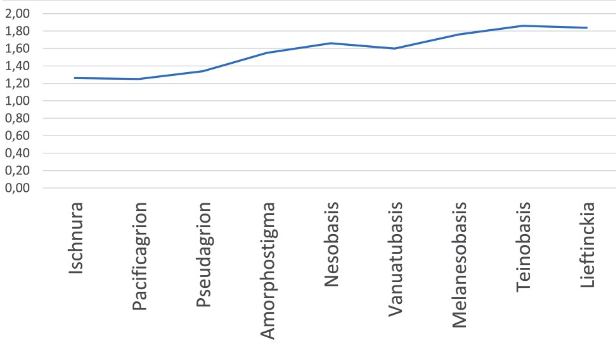
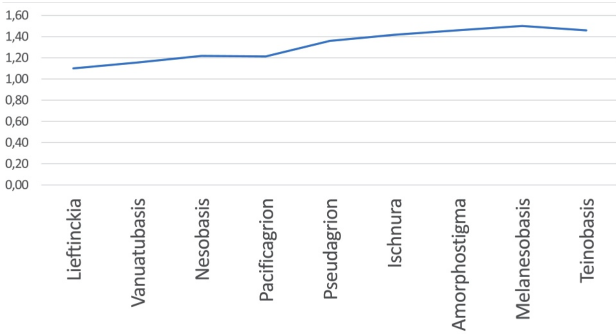


Figure 14. Pre-nodal index (Prn) range for selected Pacific Zygoptera genera and species (based on Marinov et al. 2015 with new information in this study).



15. Thoracic Index (TI) range for selected Pacific Zygoptera genera and species.

Figure 16. Habitat of *Vanuatubasis* spp., Locality 22.

within the stream was made by thick lips or bars from mineral deposits that had formed over the rocky and sandy bed. Banks of the stream were sloping steeply towards the water with limited access. Open areas among the tree vegetation were lacking close to the banks. The stream was waded through for almost its entire length starting from the access at the main road upstream to near the source.

Family Aeshnidae

Anaciaeschna jaspidea (Burmeister, 1839)

Locality: 11

Adults flying at dusk were observed in two consecutive evenings. They were flying low above the water of a drainage canal (Fig. 17). The end of the flight activity could not be recorded as *A. jaspidea* continued to be active even in near complete darkness (to the human eye) when following individuals by sight was no longer possible. It was possible to hear their wings clashing over the canal well into the onset of darkness.

Additional adults were chased off the dense wetland vegetation where they probably remain for the most of the day.

Previously reported from Aneityum (Kimmins 1958). Kimmins (1936) reports this species with a question mark for Malekula.

Figure 17. Habitat of *Anaciaeschna jaspidea*, Locality 11.

Anax sp.

Locality: 4

Patrolling individuals were sighted, but not collected. The most probable candidate would be *A. gutattus* (Burmeister, 1839) as this is so far the only species from the genus given for Espiritu Santo Island by Kimmins (1936). However, this suggestion needs validation.

Family Corduliidae

Hemicordulia hilaris Lieftinck, 1975

Localities: 2, 11, 14-15

In Locality 11 some *Hemicordulia* individuals were sighted only and put as *H. hilaris* as it was the dominant species everywhere on all islands. This assumption was made following the published information, however, it needs validation with the actual specimens collected before (see distribution records) and variously identified as *H. assimilis oceanica*, *H. oceanica* and *H. fidelis* (check Introduction for more details). As those specimens were not available for inspection here we provide diagnostic images of various stages of *H. hilaris* and compare it with *H. fidelis* from New Caledonia (Fig. 18) which is the only other congeneric reported for Vanuatu (Campion 1921; Kimmins 1936, 1958; Lieftinck 1975). Figure 19 shows the yellow-stained distal part of the fore wings in various Corduliidae females, which is a character that seems to be often used for identifying *Hemicordulia* specimens collected from Vanuatu as *H. fidelis* (cf. Lieftinck 1975: 158; Staniczek 2011: 254). Evidently the yellow distal area of the fore wings is a common features in Corduliidae present in species from both wide spread genera *Hemicordulia* and *Procordulia* Martin, 1907.

Hemicordulia hilaris was previously reported from Aneityum, Efate, Espiritu Santo, Malekula and Tanna (Fraser 1927; Kimmins 1936, 1958; Lieftinck 1975).

Family Libellulidae

Agrionoptera insignis (Rambur, 1842)

Localities: 2, 3, 20-21

Figure 20 shows both wings of the here collected specimens from Vanuatu in comparison to the illustrations of *A. insignis lifuana* ssp. n. given in Kimmins (1953). Based on the wing venation only the reported specimens herein closely resemble *A. i. lifuana*. However, the original description does not give any indication as what should be considered as diagnostic for *A. i. lifuana* which is also known from the Loyalty Islands (Kimmins 1953). Therefore, no subspecific affiliation of the newly collected specimens is presented here.

Previously reported from Aneityum, Malekula and Vanua Lava (Kimmins 1936, 1953, 1958).

New species for Efate.

Diplacodes haematodes (Burmeister, 1839)

Localities: 2, 4, 6, 8, 14, 20

Hemicordulia fidelis — Hemicordulia hilaris

Figure 18. Comparison between diagnostic characters in *Hemicordulia fidelis* and *H. hilaris* from Vanuatu: a) head, frontal view; b) thorax, lateral view; c) male appendages, dorsal view; d) male appendages, lateral view.

A common species found in a wide range of habitats on all islands sampled during the present study.

Previously reported from Aneityum, Erromango and Espiritu Santo (Kirby 1889; Kimmins 1936; Staniczek 2011).

New species for Efate.

Diplacodes trivialis (Rambur, 1842)

Localities: 2, 5-6, 10-11, 21

A common species established on the islands visited during the present study. Adults were often encountered resting within the grasses away from any suitable habitats for the development of naiads.

Previously reported from Efate, Erromango, Espiritu Santo and Malekula (Kimmins 1936; Staniczek 2011; P. Maddison unpubl.).

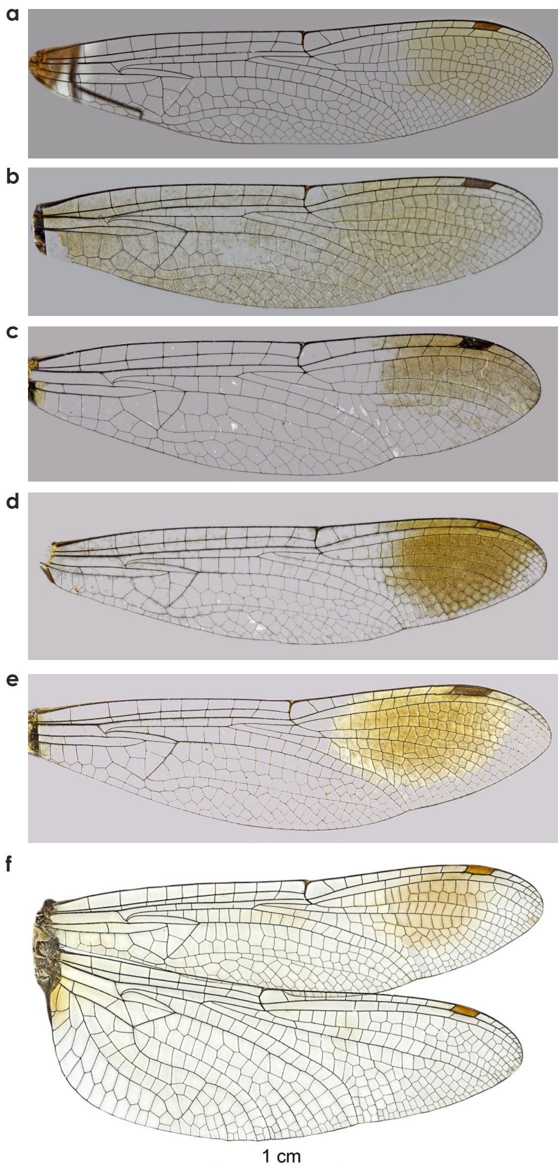


Figure 19. Comparison between the yellow-stained distal part of the fore wings in selected Pacific Corduliidae species: a) *Hemicordulia cupricolor*; b) *H. fidelis*; c) *H. hilaris*; d) *Procordulia irregularis*; e) P. smithii; f) *Antipodochlora braueri* (from Marinov 2014: Fig. 2b).

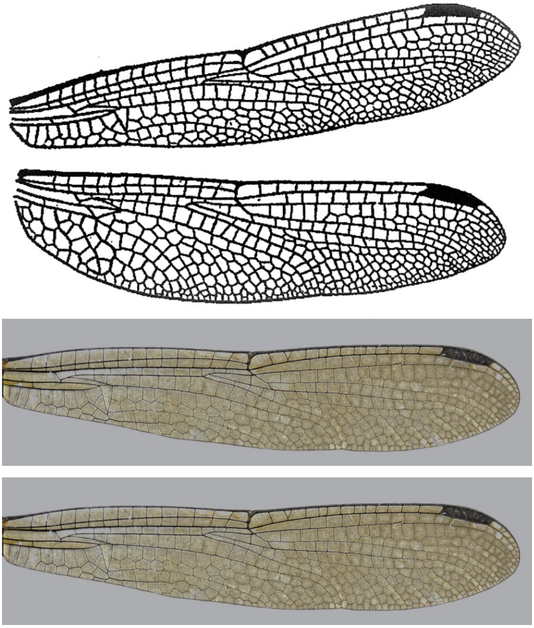


Figure 20. Comparison between the wings of *Agrionoptera insignis* specimens: a) *A. i. lifuana* (from Kimmins 1953); b) *A. insignis* reported here.

Figure 21. *Neurothemis stigmatizans bramina* from Locality 8.

Macrodiplax cora (Brauer, 1867)

Localities: 5-6, 21

The species was abundant in Localities 5-6 (Efate Island) on a bright sunny day. Adults were chased off the grass vegetation on the wetted edges of roadside temporary floods or observed actively flying above the water of the adjacent wetland. In Locality 21 (Malekula Island) only one female was collected from a seasonal pond perched on the top of a very tall stem of emergent vegetation that had overgrown almost the entire water surface.

New species for Vanuatu.

Neurothemis stigmatizans bramina Guérin-Méneville, 1832

Localities: 2, 6, 8-9, 20-21

A very common species encountered even during a day with light drizzle in between two periods of heavy rainfalls (Fig. 21). It was absent from the southern-most end of the country (Aneityum Island) although Locality 16 (Fig. 22), a taro plantation was highly suitable habitat for the species.

Previously reported from Espiritu Santo and Malekula (Kimmins 1936).

New species for Efate.

Figure 22. Taro plantation in Inhenou swamp, Aneityum Island, Locality 16.

Orthetrum serapia Watson, 1984

Localities: 2, 5, 8-10, 20-21

This species was most abundant in Localities 20-21 (Malekula Island). It is probably common everywhere else in the country apart from the southern-most islands. *Orthetrum serapia* was not documented on Aneityum during the present study although suitable habitats were sampled during what was considered to be proper weather for the species (see Discussion).

Previously reported from Espiritu Santo (Kimmins 1936; Staniczek 2011).

New species for Efate and Malekula.

Orthetrum villosovittatum bismarckianum Ris, 1898

Localities: 2, 22

Only males were collected during the present study. They were either scarce in the sampled localities or found far enough away from suitable habitats to be considered as possible breeding individuals.

Previously reported from Espiritu Santo (Staniczek 2011).

New species for Efate and Malekula.

Pantala flavescens (Fabricius, 1798)

Localities: 1, 10, 16, 18-20, 24

Very common species on all islands investigated during the present study.

Previously reported from Aneityum and Espiritu Santo (Ris 1909; Kimmins 1936, 1958; Staniczek 2011).

New species for Efate and Malekula.

Rhyothemis phyllis (Sulzer, 1776)

Localities: 16, 18, 20-21

Specimens collected during the present study were compared to conspecific which have been assigned to various subspecies: *R. p. marginata* Ris, 1913 (Solomon Islands), *R. p. dispar* Brauer, 1867 (Fiji), *R. p. aequalis* Kimmins, 1936 (Vanuatu) and *R. p. apicalis* (New Caledonia). Table V summarises the results on the variations of morphological characters which were proposed as diagnostic for all these subspecies at the time when they were described. *Rhyothemis p. aequalis* type was not available for comparison. The information in Table V is a summary from the original description in Kimmins (1936). More explanations are provided below.

Figure 23 compares the wing pattern (*R. p. aequalis* not illustrated as unavailable for comparison) of the taxa. Fore wings colouration of the newly collected specimens was found to resemble closely the description for *R. p. aequalis* for specimens collected from Malekula (which is also the type locality of the subspecies), but differ slightly from the ones collected from Aneityum. The later have the same general pattern, but expanded in intensity and length with the dark area on the postnodal crossveins almost completely connected to the pterostigma and the extension over the wing tip. For this character Aneityum specimens are closer to *R. p. margi-*

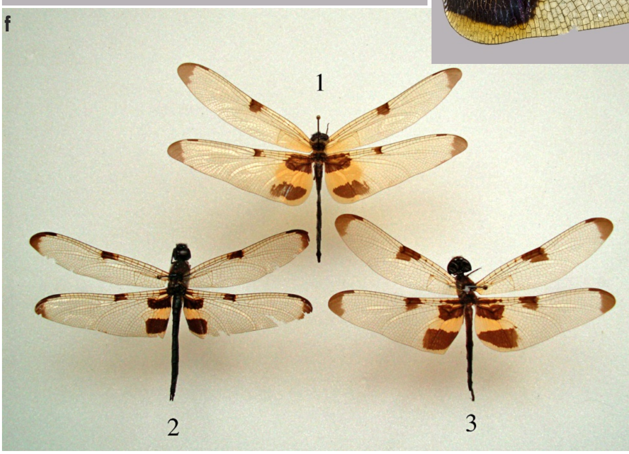
nata from the Solomon Islands than to *R. p. aequalis* from Malekula. In *R. p. dispar* the dark area occupies almost the entire anterior part of the wing in costal and subcostal area. New Caledonian *R. p. apicalis* lack the dark area between the nodus and pterostigma thus deviates considerably from the pattern observed in the specimens from the Solomon Islands, Vanuatu and Fiji.

Hind wings of the same subspecies follow the same general tendency of increased dark area along the anterior edge in specimens from the southern part of the investigated region (Aneityum and Fiji) compared to Malekula (Fig. 23). In this feature only the hind wing of Aneityum specimens are closer to the Solomon Island than to Malekula – similar to what is observed for the fore wings. However, Vanuatu specimens (both Aneityum and Malekula) have similar colour pattern at the base of the wings with dark and yellow band with almost equal width (similar to *R. p. apicalis*) whereas in *R. p. marginata* and *R. p. dispar* the dark bands are much wider to almost touching at the distal ends. Similar to the situation explained for the fore wing, the intensity of the dark areas on the hind wings differ in specimens between islands of Vanuatu and even between specimens collected from the same locality on Aneityum (cf. Fig. 23c-d). In specimens from Malekula the anterior dark band reaches the wing triangle and slightly enters its posterior end (half to fully dark triangle in specimens from Aneityum); and posterior dark band ends up half way within the anal loop (fully crossing the anal loop in specimens from Aneityum). In this character specimens from Malekula are closer to those from the Solomon Islands while Aneityum specimens resemble those from Fiji and New Caledonia.

Figure 24 compares the shape of the superior appendages and the dentation of the ventral surface. The later was found to be of no diagnostic value as it was identical in all specimens and could vary even between the left and right appendages of the same specimen (Fig. 24c-d). The shape of the superior appendages was found to be very similar to almost identical in all specimens from Vanuatu, New Caledonia and Fiji. Specimens from the Solomon Islands differ slightly in this character with appendages slightly bulging distally (Fig. 24a). Kimmins (1936) emphasised the differences in the shape of the superior appendages between *R. p. aequalis* and *R. p. marginata*, however there are slight *dispar*ities between the description in the text and illustrations of the lateral views of superior appendages in the two subspecies. The shape represented on Figure 7 in Kimmins (1936) for *R. p. aequalis* was found to be identical to what is illustrated here for *R. p. marginata* (Fig. 24a), whereas Figure 8 in Kimmins (1936) showing *R. p. marginata* is closer to what is presented here for specimens from Vanuatu (Fig. 24b-d) especially for specimens from Aneityum.

Due to the observed variations in the colour pattern between specimens from Malekula and Aneityum no subspecies affiliation is selected for the specimens collected during the present study. Vanuatu populations are closer to what Kimmins (1936) described as *R. p. aequalis* however the type was not available for investigation and

Figure 23. Comparison between the wings of *Rhyothemis phyllis* specimens: a) *R. p. marginata* (Guadalcanal, Solomon Is); b) *R. phyllis* (Malekula, Vanuatu); c-d) *R. phyllis* (Aneit-



yum, Vanuatu; showing variations of the intensity of the black area in specimens from the same locality); e) *R. p. dispar* (Viti Levu, Fiji); f) *R. p. apicalis* (Grande Terre, New Caledonia; original photo from Papazian & Mary-Sasal 2010).

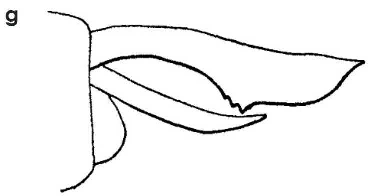


Figure 24. Comparison between the anal appendages of *Rhyothemis phyllis* specimens: a) *R. p. marginata* (Guadalcanal, Solomon Is); b) *R. phyllis* (Malekula, Vanuatu); c-d) *R. phyllis* (Aneityum, Vanuatu; showing variations of the ventral dentation in left and right appendage respectively of the same specimen); e) *R. p. dispar* (Viti Levu, Fiji); f) *R. p. apicalis* (from Papazian & Mary-Sasal 2010); g) *R. p. aequalis* (from Kimmins 1936).

because of the *dispar*ities in the subspecies description (see the Discussion) no definite diagnostic characters could be proposed to distinguish this subspecies from the ones described from the neighbouring archipelagos.

Previously reported from Aneityum, Espiritu Santo and Malekula (Kirby 1889; Ris 1909; Kimmins 1936; Staniczek 2011).

Tholymis tillarga (Fabricius, 1798)

Localities: 6, 10-11, 16

Very common in the localities where it was observed on both islands (Aneityum and Efate) and probably wide spread throughout the entire archipelago.

New species for Vanuatu.

specimens from Samoa

Figure 25. Comparison between morphological characters considered diagnostic for female *Tramea transmarina* specimens: a) head, frontal view; b) head, ventral view; c) thorax, lateral view; d) hind wing; e) appendages, lateral view.

Tramea transmarina Brauer, 1867

Localities: 4, 6, 16-17

Most individuals were eye sighted and were assigned to *T. transmarina* as the most probable species. Only one female was collected during the present study in Locality 4. Figure 25 compares this female to *T. transmarina* from Samoa based on the characters which were considered as possible diagnostic in Marinov et al. (2015) for distinguishing between male *T. t. intersecta* Lieftinck, 1975 (type locality New Caledonia) and specimens from the rest of the Pacific. The female from Vanuatu differs from the Samoan female in most of the characters reported for males: lighter yellow labium with reduced to almost lacking on the lateral lobes (extensive dark on the lateral lobes in Samoan female) and dorsal black spots on S8-9 in lateral view do not extend fully to the ventral dark area for the segments (almost fully encompassing in Samoan female). Colourations of the labrum and synthorax were found to be near identical in both females. The extent of the dark area at the bases of the hind wings is illustrated as well (Fig. 25d), but not given significant attention here (see Discussion).

Figure 26 compares the vulvar laminas of the two females to the illustration of what Lieftinck (1975) considered as *T. t. intersecta* from Espiritu Santo. The vulvar lamina of Vanuatu specimen appears to be longer than the other two illustrations reaching to slightly surpassing the posterior edge of the ninth sternite, however, microscope examination shows that this could be a post-mortem effect with the sternite slightly shrunk. Certainly more female specimens are needed to validate this suggestion. No morphological features were found as distinct enough to suggest and possible diagnostic characters therefore no subspecific affiliation is suggested here for the Vanuatu specimen.

Previously reported from Aneityum, Espiritu Santo and Malekula (Kimmins 1936, 1958; Lieftinck 1975; Staniczek 2011).

New species for Efate.

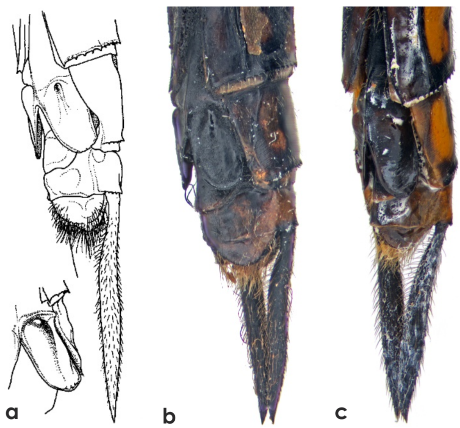


Figure 21. Comparison between the vulvar lamina of specimens from: a) *T. t. interseca* (from Lieftinck 1975), b) Samoa; c) Vanuatu.

Discussions

The present study provides solid evidence that the knowledge of the Odonata of the Republic of Vanuatu is still highly insufficient known, mainly because the islands have been understudied (cf. Introduction). Only ten (Aneityum, Gaua, Efate, Erromango, Maewo, Malekula, Espiritu Santo, Tubuta, Tanna, Vanua Lava) out of 83 islands within the entire archipelago have been sampled and have any information about odonates. However, more than 50% of all records come from the two largest islands Espiritu Santo (41%) and Malekula (14%). Other large islands like Efate and Tanna have only five records (three species each) while smaller islands like Maewo have just a single record. Large islands, like Ambrym, Ambae, Epi, Pentecost have never been sampled.

A total of 32 species are recognised as currently valid names for the country. Three new species have been collected and will be described elsewhere. Ten of the reported species herein were established as new to Efate, which is the capital island of Vanuatu. Malekula, the second largest island, was last visited in 1929/1930! We managed to sample only three sites on Malekula and from a single stream have three species new to science within a single four-five hour bout of effective field work! Certainly the Odonata fauna of Vanuatu is much more diverse and has many more endemic species than presently documented. Kimmins (1936), Donnelly (1987), Staniczek (2011) and this study reported on undescribed species which for various reasons still remain unknown to science.

Kimmins (1936) had three females which were provisionally identified as Platycneminae most probably *Leptocnemis* Selys, 1886, but because of the lack of males he was reluctant to continue further with a formal description. Moreover, *Leptocnemis* is a monotypic genus with *L. cyanops* (Selys, 1869) endemic to the Seychelles (Schütte 2017). These specimens were later examined by T. Donnelly and identified as *Melanesobasis* sp. (two) and *Nesobasis* (now *Vanuatubasis*) sp. (one) (S. Ober, per. comm.). The specimens were labelled as sampled from West Santo (one) and Malekula (two). This is an interesting finding because expands the range of *Melanesobasis* over the two largest islands of Vanuatu. Previously the genus was known by one male specimen from Maewo.

Donnelly (1987) sampled an undescribed *Vanuatubasis* from Espiritu Santo where twenty years later *V. santoensis* was described from (Ober & Staniczek 2009). If Ober & Staniczek (2009) described the same species already collected by Donnelly (1987) remains to be clarified.

Summarising the results on Odonata from Espiritu Santo, Staniczek (2011) reported on two potentially new species: *Pseudagrion* sp. (both sexes from Penaoru River) and *Vanuatubasis* sp. (one female no locality given). The photo of *Pseudagrion* sp. included in the publication resembles very much *Xiphiagrion cyanomelas* Selys, 1876 which was previously reported in Michalski (2012) with its general distribution reaching Vanuatu without specifying where exactly in the country. The female *Vanuatubasis* sp. was inspected by diagnostic images kindly supplied by A. Staniczek. Based on the shape of the prothorax, mesostigmal plate and certain body colouration this female is believed to be conspecific to one of the new species reported here from a single locality on Malekula Island. It will be described separately (Marinov & Bybee, in prep.).

What are considered in the present study as three new species will be assigned to *Vanuatubasis* based on the shape of the posterior end of prothorax only which by far is the only reliable diagnostic generic character for the females. Both indices employed here (Prn and TI) intermixed the representatives of *Vanuatubasis* and *Nesobasis* and are not useful in taxonomic diagnosis between these two genera. The indices may prove helpful for diagnosis at higher taxonomic levels, e.g. subfamily especially Prn where the groups of genera are clearly defined when selected Pacific genera are involved (Figs 14-15).

We expect that the local endemic genus *Vanuatubasis* is far more diverse than presently known with three described species and at another three new species which were sampled during the present study. Future studies will definitely increase the number of endemic species from this interesting genus.

More faunistic and taxonomic issues were encountered during the present research and briefly outlined below for considerations in future studies on the Odonata fauna of Vanuatu.

Hemicordulia

Staniczek (2011) reconfirmed the presence of *H. fidelis* for Espiritu Santo based on three females collected near the Tasmate and Penaoru Rivers. This is another very important observation. The presence of diffuse amber shaded spot near the pterostigma was found to be a distinguishing feature from other females of *Hemicordulia*. However, the same character is considered ambiguous since it is present also in *H. hilaris* for individuals from Samoa (Marinov et al. 2015). The same feature with various intensity of the colouration was found to be an unreliable diagnostic in other corduliids as it is also present in the females of *Procordulia smithii* (White, 1846) and *Antipodochlora braueri* (Selys, 1871) which co-occur in certain habitats in New Zealand (Marinov 2014). Figure 19 shows that the yellow-tipped fore wings are also typical of *Procorudulia irregularis* Martin, 1907 from Fiji and *Hemicordulia cupricolor* Fraser, 1927 from Samoa. In *H. fidelis* from New Caledonia this spot could be so intense that it could be seen even in flight when female hovered over the tree tops. No investigations have been carried out to prove if this is an age-related feature or if *H. fidelis* female occur in different forms in New Caledonia. Therefore the presence of *H. fidelis* on Espiritu Santo needs to be validated with further samplings or examining the specimens reported in Staniczek (2011).

A careful review of the Odonata literature of Vanuatu shows that there are only a few clear evidence that *H. fidelis* is present in the country. Campion (1921) is perhaps the best reliable source who reported on two males from Tanna Island. Fraser (1927) published his identification as *H. assimilis oceanica*. Kimmins (1936) reported two taxa: *H. a. oceanica* (widely distributed throughout Oceania) and *H. fidelis* based on Campion (1921) data from Tanna Island. However, Kimmins (1958) corrected his earlier identifications and claimed that all specimens from the genus previously reported by him were actually *H. fidelis*. All this was before Lieftinck (1975) synonymised many records of *H. oceanica*, *H. pacifica*, *H. assimilis oceanica* from Fiji, Tonga, Samoa, Vanuatu and New Caledonia to the his newly described *H. hilaris*. During his revision and description of the new species he had female specimens, but was reluctant to provide any descriptive features of female *H. hilaris* and even labelled specimens collected from the Cook Islands with question marks (see Marinov 2012b for more on the subject). Lieftinck (1975) also considered some of Kimmins (1936) *H. assimilis oceanica* specimens as identical to *H. hilaris*, these being the same specimens which Kimmins (1958) himself decided were *H. fidelis*. The only records of *H. fidelis* from Vanuatu at the time when Lieftinck (1975) described *H. hilaris* were two females in Fraser's collection. Due to the reluctance of Lieftinck (1975) to describe the female of *H. hilaris* and claim that specimens in Fraser's collection were misidentified and should all be considered conspecific with *H. hilaris*, we regard Lieftinck's *H. fidelis* from Vanuatu as needing validation. Both sexes of *H. hilaris* pass through various colour changes on the abdomen during maturity from bright green with yellow spots to almost completely uniform deep dark green colouration on the entire body. However, even in the very old specimens the traces of yellow markings typical of those at the teneral age are still visible under magnification. Generally, the shape of the markings is traceable, but some of the longitudinal stripes may have developed into two spots isolated by the break in the middle due to intensive deep pigmentation developed at that area. It is possible that all specimens collected from various Pacific areas are in fact conspecific to *H. hilaris* and represent different maturity stages of this species. It is also possible that different female colour variations occur among *H. hilaris* populations in the Pacific. Marinov (2014) described a situation in *A. braueri* where a female with spots on the forewings was compared to what was considered as a typical form of females with yellow stained wings. Perhaps the same is true for *H. hilaris* and possibly females exhibits the same colour variations in various parts of their areas. Should they be considered as separate forms remains to be established by more thorough investigations on the colour change throughout the range of the species.

A recent small collection carried out by the first author (MM) from Rarotonga Island, Cook Islands confirms the necessity of a detail morphological and molecular investigation on the genus *Hemicordulia* in the Pacific. What is considered to be *H. hilaris* in the field appeared slightly different in the shape of the male anal appendages in both lateral and dorsal views during a laboratory investigation. That raised a concern on the proper identification of Cook Island females given in Marinov (2012) and the validity of the description of the female *H. hilaris* provided in this paper. The specimens from Cook Island were indistinguishable from *H. hilaris* from other Pacific islands by general body colouration except the colouration of the labrum which slightly varied between various Pacific archipelagos. No illustrations of the Cook Island *Hemicordulia* are provided herein because there is a small chance that they belong to an unknown taxon that is very similar to *H. hilaris*. If this is proved to be true then a new description of both sexes of *H. hilaris* is necessary. A larger sample size is needed in order to provide a better understanding of the distribution of the Pacific *Hemicordulia*. Until then the description of the male of *H. hilaris* in Lieftinck (1975) and female in Marinov (2012) may be used to distinguish this species from other congeneric of the Pacific.

Agrionoptera

Marinov & Pikacha (2013) commented on difficulties associated with the correct subspecific affiliation of the Pacific *Agrionoptera*. They demonstrated the complexity of the issue with assigning Pacific taxa to various species/subspecies by several authors who changed the taxonomic position even in consecutive articles. The analysis of Marinov & Pikacha (2013) focused on the Solomon Islands, but the situation they explained could well be accepted as general for the Pacific representative of *Agrionoptera*. For Vanuatu initially Kimmins (1936) reported *A. i. similis* from Aneityum Island, which were later found to be identical with specimens collected from Vanua Lava and Malekula. These were transferred to the newly described *A. i. lifuana* from the Loyalty Islands (Kimmins 1953). This view was supported in Kimmins (1958) who added more information from Aneityum. For the apparent needs of a wider review of the subspecific affiliation of the Pacific taxa the samples from Vanuatu reported herein were not assigned to any subspecies.

Orthetrum

One interesting outcome of the present study is the lack of *O. caledonicum* among the specimens collected. This species has been previously recorded from Aneityum in Kimmins (1958) by two males and two females, but not confirmed for the same island now. *Orthetrum caledonicum* is usually one of the most common species during faunistic studies (Marinov et al. 2013a) and is very common in the places where it occurs and is found all year around (Grand et al. in press). Its apparent absence from the studied sites in Vanuatu is unexplainable at the moment. A possible misidentification of the specimens reported in Kimmins (1958) was contemplated, but considered improbable because *O. caledonicum* is a very distinctive species.

Orthetrum serapia was established on Efate and Malekula, but not on Aneityum. A similar situation to what Marinov (2012a) reported for Tonga where the species was reported from the Vava'u group, but not from Tongatapu. So far the southern-most locality for the species in the Pacific is Kadavu, Fiji (M. Marinov, unpublished) which in geographic latitude lays slightly north of Tanna Island, Vanuatu. The species was not established on Aneityum during the present investigation and it is not clear if this was because of the late season or due to limitation of overall species distribution. The species was observed on Kadavu even later in the season (in June, M. Marinov, per. obs.). *Orthetrum serapia* is believed to be a warm tolerant species which is active mostly in bright sunny days and is one of the species that will abandon the site at the first sign of clouds (M. Marinov, per. obs.). During the present study all days on Aneityum Island were sunny enough and within the expectation for the species to be active, but it was not spotted. It is possible that the southern limit of the overall species distribution on the Pacific islands is 18-19° southern latitude. In Vanuatu this area is further north than Aneityum, somewhere between the islands of Erromango and Tanna. Therefore, investigations on these two islands would be important in establishing what is potentially the true southern limit of the species in the Pacific islands. In Australia it reaches even further south to around 22° (Theischinger & Endersby 2009).

Rhyothemis

Two subspecies were previously reported for Vanuatu: *R. p. apicalis* (Kirby 1889; Ris 1909; Kimmins 1936) and *R. p. aequalis* (Kimmins 1936). The wing patterns of the specimens reported herein are nearly identical to *R.* p. *aequalis*, however no suspecific affiliation is proposed because of the uncertainties around the validity of the morphological characters proposed in Kimmins (1936).

It is important to note that Kirby's (1889) type of *R.* p. *apicalis* was one female collected from Aneityum, whereas at the moment all specimens reported here from the same island are closer to what Kimmins (1936) described as *R.* p. *aequalis* with the type locality of Malekula. Newly collected specimens from Malekula are identical to the description of the wing colouration to *R.* p. *aequalis*, but differ in the shape of the superior appendages compared to the illustrations given in Kimmins (1936). However, as discussed above, there is a possibility that the illustrations on Figure 7 and 8 in Kimmins (1936) are mislabelled which would explain the disagreement between the observed shape of the superior appendages of the newly collected specimens and the available description. This issue could be resolved only with a close examination of the type of *R.* p. *aequalis* which was not available in this study.

Another discussion point is the presence of two different subspecies within the same ocean archipelago. It is true that both types of *R.* p. *apicalis* and *R.* p. *aequalis* come from different islands which are about 500 km apart. The spatial isolation could explain the occurrence of two subspecies moreover that Aneityum is slightly closer to New Caledonia (the main distribution area of *R.* p. *apicalis*) than to Malekula. However, during the present study all specimens from Aneityum were found to be much closer to the specimens from Malekula and different from New Caledonian. This raises the question of the validity of the type locality of *R.* p. *apicalis* which also questions the presence of this subspecies in Vanuatu. The possibility of the type female being mislabelled, having actually been collected from New Caledonia has to be considered in the future studies of Odonata of Vanuatu. For the moment *R.* p. *apicalis* is kept in the Odonata checklist for the country until a more detailed study on the local fauna is carried out.

Tramea

Lieftinck (1975) described the holotype male *T. t. intersecta* from New Caledonia and assigned a female collected from Espiritu Santo, Vanuatu to the same subspecies. He did not provide a subspecific diagnosis and it is unclear which morphological character should be considered the most important to distinguish this subspecies from the rest of the Pacific. In fact the only illustrations provided with the subspecies description were the ones of the female from Espiritu Santo in comparison to *T. liberata liberata* Lieftinck, 1949 from Plum Island with no further explanations on whereabouts on the locality. Plum is a village at the south coast of Grande Terre, New Caledonia and is the most likely locality for the subspecies. Michalski (2012) documents *T. l. liberata* on the Admiralty Islands and Solomon Islands while Grand et al. (in press) report *T. liberata* without subspecific affiliation from three historical records on Grande Terre, New Caledonia. The colour of the hind wing membrane is most likely the main feature for his decision to associate the female from Espiritu Santo with the male from New Caledonian as Lieftinck (1975) described it in great detail. He also emphasised the similarity between the colour of other body parts such as the labium, synthorax and abdominal markings.

Marinov et al. (2015) compared males from New Caledonia to conspecifics from Fiji, Tonga and Samoa and also recorded some notable differences in the colouration that is partly overlapping with Lieftinck's (1975) description: New Caledonian specimens were found to have a lighter yellow labium with reduced or almost lacking black on the lateral lobes; labrum dark only in the middle; purple on the dorsum of the head reduced; dark thoracic spots and bands less intense; dorsal black spots on S8-9 in lateral view do not extend ventrad, and bases of superior appendages bright red. Females were not considered in this study as no females from New Caledonia were available at that time. The female from Vanuatu reported herein shares only the colour of the labium and to some extent the black dorsal spots on S8-9 from lateral view with the New Caledonian males illustrated in Marinov et al. (2015). Dark pattern on the hind wing is close to what Lieftinck (1975) described for *T.* t. *intersecta* and illustrated in Marinov (2013). However, Marinov (2013) and Marinov et al. (2015) both pointed out the large degree of variations that occurs among the specimens collected from various parts of the Pacific and regarded colouration of the hind wings as diagnostically untenable. Unfortunately, the question of the subspecies distribution cannot be resolved here because the newly collected female was the only specimen from the genus sampled in the field and it did not completely match the description of *T.* t. *intersecta* given in Lieftinck (1975) and the paratype female from Espiritu Santo was not available for study. Therefore, no subspecies affiliation was diagnosed in this study. Moreover, so far only colour differences have been recorded for the description of *T.* t. *intersecta* with no established morphological characters of any kind.

Staniczek (2011) record on *T. propinqua* from Espirito Santo was given as new for the country. However, this species in not included in the list for Vanuatu due to great colour variations among members of the same populations and between islands of the Pacific. It is our personal belief that any taxonomic status (even subspecific) has to be given to morphological rather than colour variations which could be countless and may vary even depending on the ambient temperature. Colour could still be used as diagnostic when is proven to be associated with certain morphological characters which warrant separate taxonomic status.

Relations of Odonata of Vanuatu to the rest of the Pacific

The present state of knowledge does not allow for a review on the affiliations of the Vanuatu Odonata. The most problematic question to answer in such an analysis is about the origin of the local fauna and how to separate naturally invasive species (if any!) from the ones introduced by humans. Without any good historical evidences we now enter the Pacific and make conclusions on the biogeography, phylogeny and evolution based on the composition of the contemporary fauna, which is an undesirable approach (Marinov 2015). Should the same study have been conducted at the beginning of the XXth century the fauna could have been much different.

One curious observation provided in Tillyard (1913) is worth mentioning here. He gives *A. exsudans* for Port Vila collected by Alan MacCulloch in August, 1910 and refers to it as a rare species. Illustrations on the appendages provide evidence on the correct identification. Presently, *A. exudans* is one of the most common (if not the most common!) species within its range from the Solomon Islands to Samoa and Tonga (cf. Marinov 2012a, 2013; Marinov et al. 2015). It was also the most common species encountered during the current study. Not finding the species at the beginning of XXth century is surprising and raises the question about the importance of the historical records in Odonata biogeorgraphy (Marinov 2015). It is hard to believe that such a common species which is presently found in a great variety of habitats from temporary floods, over vegetated puddles, mountainous pools and lowlands wetlands (including large reservoirs) to lotic waters with any kind of surface flow was overlooked, if is present on this Pacific island during the earlier observations at the beginning of XXth century. It is true that *A. exsudans* is one of the smallest Odonata species in the Pacific, but its current distribution, the size of most populations and highly conspicuous body colouration (especially in immature individuals) make it difficult to overlook. One possible explanation is that Tillyard (1913) in fact gives us the time of the invasion of the species at least for Vanuatu (and probably for the whole Pacific). Similarly Tillyard (1926) reported *H. australiae* as "occasionally taken in New Zealand", however, the species is now one of the most dominant over the North Island and is currently spreading further to the South Island (see Armstrong 1978; Marinov 2010). The mode of transportation between the islands within the Pacific is unclear – chance dispersal (presently the dominant view for Odonata of the oceanic islands) or man facilitated (highly likely, but never investigated before). Both views have to be considered of equal importance for all Odonata with wide distributions across the Pacific islands, especially with historical notes from trusted odonatologists such as Tillyard.

If species do rely on accidental transport by winds over large oceanic areas then the most likely source of invasion (or bi-directional exchange) for Vanuatu would be New Caledonia as the spatially closest archipelago. Indeed Grand et al. (in press) and Marinov et al. (in prep) have evidences of at least 24 species (77% of Vanuatu Odonata fauna) shared between the two countries. This is the highest percentage for Vanuatu compared to Solomon Islands (62%) and Fiji (55%). Such a simplified analysis would be flawed and misleading if it does not consider several taxonomic and faunistic issues. Some examples are provided below:

1) Davies (2002) ranks *O. villosovittatum* as "quite common" for New Caledonia, however, no locality is known and more recent studies showed no evidence of this species present in the country (Grand et al. in press). This same species was recorded at least on two islands of Vanuatu and is also very common in the Solomon Islands (Marinov & Pikacha 2013).

2) Grand (2004) reported *N. stigmatizans* as new to New Caledonia, but this observation was based on a single specimen and no established population presently is known in the country (Grand et al. in press). *Neurothemis stigmatizans* is very common in both Vanuatu and the Solomon Islands.

3) The only record of *O. caledonicum* for Vanuatu comes from Aneityum (Kimmins 1958). The same island was sampled during the present study, but the species was not established, which is surprising with how common it is in New Caledonia (Grand et at. in press). Therefore, we consider this record as needing validation.

4) The status of *Orthetrum sabina* (Drury, 1770) and *O. serapia* is unclear for much of the Pacific archipelagos. Records prior to the actual description of *O. serapia* in Watson (1984) were put as *O. sabina* whereas the recent studies in the Solomon Islands, Fiji, Samoa and Tonga brought up only *O. serapia* (Marinov & Pikacha 2013; Marinov & Waqa-Sakiti 2013; Marinov et al. 2015; Marinov 2012a, 2013). Records from New Caledonia were of *O. sabina* which Davies (2002) reported as "common", but Grand et al. (in press) could not validate and gave the species as "locally unknown". The decision was based on the fact that the only certain locality of *O. sabina* was a temporary swamp where the species was not found in later years.

5) As reported above the type of *R. p. apicalis* was given as Aneityum (Kirby 1889) where at present only specimens similar to *R. p. aequalis* were collected. Sympatry of two separate subspecies on a small island like Aneityum is unlikely. Since Kirby (1889) is the only record for Vanuatu the presence of *R. p. apicalis* in the country is questionable, but for the moment retained in the checklist in Table V here (see comments in the species account).

6) More taxonomic work is needed to validate the taxonomic status of *T. t. intersecta* which for the moment has been reported from New Caledonia and Vanuatu only (Lieftinck 1975) and considered as Regional Endemic in Grand et al. (in press). *Tramea*-like individuals were eye-sighted in numbers on occasion during the present study, but only one female was collected. It was found to be similar to *T. t. intersecta* in two characters only (see species account) which are related to the colouration of certain body parts. Colour variations were found unreliable diagnostics for *T. transmarina* from other regions (Marinov 2013; Marinov et al. 2015). These results demonstrate the need for a revision on the status of *T. t. intersecta* which was separated by the rest of the Pacific populations by the colour (mainly on the wings) only and not by any structural morphological features.

7) Kimmins (1958) is the only record of *Aeshna brevistyla* Rambur, 1842 for Vanuatu. He reported a single female specimen from Aneityum. For the moment this species is retained for the Vanuatu Odonata checklist (Table I), but this record needs validation. The species is widespread in Australia, and also occurs from New Zealand to New Caledonia (Theischinger & Hawking 2006).

8) Davies (2002) reported *A. insignis* for New Caledonia as present with "scattered colonies varying in different seasons" without any precise locality and no current validation of these records is provided (Grand et al. in press).

9) Further studies will surely increase the number of endemic species to Vanuatu.

Future analyses should also exclude widespread species within the Pacific, such as *A. exsudans*, *I. aurora*, *A. jaspidea*, *H. hilaris*, *D. bipunctata*, etc. which will reduce the number of species actually shared between New Caledonia and Vanuatu to four endemics for the region all in need of validation as have not been resampled for a very long time or have some taxonomic problems outlined above: *Indolestes cheesmanae* (Kimmins, 1936), *T. percostale*, *H. fidelis* and *A. i. lifuana*.

Therefore, this preliminary faunistic account begins to demonstrate that the Odonata of Vanuatu have in fact closer relations to both the Solomon Islands and Fiji than to the more spatially closer New Caledonia. Wing colouration in *R. phyllis* (if tenable diagnostically) is a very good example (see species account). *Pseudagrion microcephalum* common within a large area from India to Tonga and south to Australia (Theischinger & Hawking 2006) is not included in the checklist for New Caledonia (Grand et al. in press). Both *N. stigmatizans* and *O. villosovittatum* are very common in the Solomon Islands and recorded on several occasions during the present study. Vanuatu and Fiji share the regional endemic genus *Melanesobasis*. It is likely the Vanuatu endemic *Vanuatubasis* is phylogenetically closer to the Fijian endemic *Nesobasis* than to any other Pacific genera. However, the Odonata fauna of Vanuatu is so insufficiently studied that all statements here should be considered preliminary. They are given more as incentives for future studies than as definite conclusions. More morphological and molecular studies are needed to better understand the taxonomy, fauna, biogeography and phylogeny of Vanuatu Odonata.

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Appendix

Table I. Chronological literature review of Odonata records from Vanuatu.

No	Verbatim species	Valid species name	Verbatim locality	Page	Reference
1	*Rhyothemis apicalis*	*Rhyothemis phyllis apicallis* Kirby, 1889	New Hebrides	319	Kirby (1889)
2	*Trithemis rubra*	*Diplacodes haematodes* (Burmeister, 1839)	Australia and New Hebrides	328	Kirby (1889)
3	*Pantala flavescens* ???	*Pantala flavescens* (Fabricius, 1798)	??? Espirito Santo	917	Ris (1909-1919)
4	*Agriocnemis exsudans* Selys	*Agriocnemis exsudans* Selys, 1877	Vila, New Hebrides	461	Tillyard (1913)
5	*Hemicordulia fidelis* McLachlan	*Hemicordulia fidelis* McLachlan, 1886	Tanna	46	Campion (1921)
6	*Hemicordulia assimilis oceanica* Selys	*Hemicordulia hilaris* Lieftinck, 1975	Teuma, Efate Isl.	37	Fraser (1927)
7	*Austrolestes cheemanae*, sp. n.	*Indolestes cheesmanae* (Kimmins, 1936)	Erromanga	69	Kimmins (1936)
8	*Trineuragrion percostale* Ris	*Trineuragrion percostale* Ris, 1915	Banks Is., Vanua Lava	70	Kimmins (1936)
9	*Ischnura torresiana* Tillyard	*Ischnura heterosticta* (Burmeister, 1839)	Malekula, Ounua	71	Kimmins (1936)
10	*Pseudagrion microcephalum* Rambur	*Pseudagrion microcephalum* (Rambur, 1842)	Malekula, Ounua	72	Kimmins (1936)
11	*Nesobasis malekulana*, sp. n.	*Vanuatubasis malekulana* (Kimmins, 1936)	Malekula, Ounua	72	Kimmins (1936)
12	*Anax gutattus* (Burmeister)	*Anax guttatus* (Burmeister, 1839)	Esp. Santo I., Hog Harbour	73	Kimmins (1936)
13	*Anaciaeschna jaspidea* (Burmeister)	*Anaciaeschna jaspidea* (Burmeister, 1839)	? Malekula	74	Kimmins (1936)
14	*Gynacantha rosenbergi* Brauer	*Gynacantha rosenbergi* Brauer, 1867	Malekula, Ounua	74	Kimmins (1936)
15	*Agrionoptera insignis similis* Selys	*Agrionoptera insignis lifuana* Kimmins, 1953	Banks Is., Vanua Lava; N.E. Malekula; Aneityum	75	Kimmins (1936)
16	*Orthetrum sabina* (Drury)	*Orthetrum serapia* Watson, 1984	Esp. Santo I., E. coast, Shark Bay and Hog Harbour	76	Kimmins (1936)
17	*Diplacodes trivialis* Rambur	*Diplacodes trivialis* (Rambur, 1842)	Malekula, Ounua; Erromanga; N.E. Malekula; Esp. Santo I., E. coast, Shark bay	76	Kimmins (1936)
18	*Diplacodes bipunctata* (Brauer)	*Diplacodes bipunctata* (Brauer, 1865)	Banks I., Central Lake, Gaua; West Santo, Tatarii; Gaua, Hot Springs	77	Kimmins (1936)
19	*Neurothemis stigmatizans bramina* (Guérin)	*Neurothemis stigmatizans bramina* (Guérin-Méneville, 1832)	Malekula, Ounua; Esp. Santo Is., E. coast, Shark Bay; Banks Is., Gaua, Nombur	77	Kimmins (1936)
20	*Rhyothemis phyllis aequalis*, sp. n.	*Rhyothemis phyllis aequalis* Kimmins, 1936	Malekula, Ounua, Esp. Santo I., Shark Bay	78	Kimmins (1936)
21	*Tramea limbata* (Desjardins)	*Tramea transmarina intersecta* Lieftinck, 1975	Malekula, Ounua	80	Kimmins (1936)
22	*Orthetrum caledonicum* (Brauer), 1865	*Orthetrum caledonicum* (Brauer, 1865)	New Hebrides	244	Kimmins (1953)
23	*Nesobasis bidens* sp. n.	*Vanuatubasis bidens* (Kimmins, 1958)	Aneityum, Red Crest	239	Kimmins (1958)
24	*Aeshna brevistyla* Rambur	*Aeshna brevistyla* Rambur, 1842	Aneityum, Red Crest	241	Kimmins (1958)
25	*Ischnura aurora aurora* Brauer	*Ischnura aurora* (Brauer, 1865)	Aneitym I.; Tubuta I., off SE Espiritu Santo	229	Lieftinck (1959)
26	*Melanesobasis bicellulare* sp. n.	*Melanesobasis bicellulare* Donnelly, 1984	Maewo; Sourwari	100	Donnelly (1984)
27	*Zyxomma petiolatum*	*Zyxomma petiolatum* Rambur, 1842	Santo	4	Donnelly (1987)
28	*Vanuatubasis santoensis* n. sp.	*Vanuatubasis santoensis* Ober & Staniczek, 2009	Sanma Province, Esipiritu Santo, surroundings of Penaoru, Penaoru River	487	Ober & Staniczek (2009)
29	*Orthetrum villosovittatum* (Brauer, 1868)	*Orthetrum villosovittatum* (Brauer, 1868)	Tasmat, Mamasa River, and Penaoru	256	Staniczek (2011)
30	*Xiphiagrion cyanomelas* Selys, 1876	*Xiphiagrion cyanomelas* Selys, 1876	Vanuatu	315	Michalski (2012)
31	*Macrodiplax cora* (Brauer, 1867)	*Macrodiplax cora* (Brauer, 1867)	Efate, Malekula	24	this paper
32	*Tholymis tillarga* (Fabricius, 1798)	*Tholymis tillarga* (Fabricius, 1798)	Efate, Aneityum	28	this paper

Table II. Comparison between diagnostic characters of Pacific *Pseudagrion* spp.

Trait	*P. m. microcephalum*	*P. m. stainbergerorum*	*P. pacificum*	*P. samoense*	Vanuatu
Head					
sponts on the postclypeus	joined in a thick transverse bar	separated	joined posteriorly	separated	separated
black area behind lateral ocelli	thin with very small projections	thin with projections	interrupted behind the ocelli	excessive black area	with small projections to no projections
blue occipital spots	large with projections	large with projections	large with projections	small without projections	large with projections
Thorax					
synthorax (poststernum)	no black spot	black spot	no black spot	no black spot	no black spot
Abdomen					
S2	no transverse bar on the basal dorsum; V-shaped mark not joined to posterior ring	transverse bar on the basal dorsum; V-shaped mark joined to posterior ring	no transverse bar on the basal dorsum; V-shaped mark joined to posterior ring	black spot on the basal dorsum; V-shaped mark joined to posterior ring	black spot on the basal dorsum; V-shaped mark joined to posterior ring
S3-9	spear-like marks on S3-4	spear-like marks on S3-4	no spear-like marks on S3-4	no spear-like marks on S3-4	no spear-like marks on S3-4
S10	black could be reduced	black	black	black	black with variable width
secondary genitalia (black area around hamules)	diffuses	straight	diffuses	diffuses	diffuses to straight
Anal appendages (superior only)					
dorsal view (ventral part)					
inner surface	deeply concave	less concave	less concave	near flat	less concave
distal edge	curved	curved	curved	straigth	curved
teeth (size)	small similar	distal larger	distal larger	large similar	distal larger
teeth (position)	separate planes	same plane	same plane	same plane	same plane
teeth (direction)	up-turned	lateral	lateral	lateral	slightly upturned to lateral
teeth (distance)	almost joint at the base	separated at the base	almost joint at the base	almost joint at the base	almost joint at the base
lateral view					
length	lower lobe longer	lower lobe longer	both lobes almost the same length	lower lobe longer	lower lobe longer
size	thinner	thicker	thicker	thinner	thicker
apical notch	shallow	shallow	deep	deep	deep

Table III. Pre-nodal index (Prn) values for selected Pacific Zygoptera genera and species.

Taxa	Min	Max	Average	N
Ischnura	1,00	1,26	1,13	18
Pacificagrion	1,13	1,25	1,19	4
Pseudagrion	1,12	1,34	1,23	24
Amorphostigma	1,28	1,55	1,42	43
Nesobasis	1,27	1,66	1,46	50
Vanuatubasis	1,38	1,6	1,49	18
Melanesobasis	1,64	1,76	1,70	11
Teinobasis	1,60	1,86	1,73	9
Lieftinckia	1,76	1,84	1,80	5

Table IV. Thoracic index (TI) values for selected Pacific Zygoptera genera and species.

Taxa	Min	Max	Average	N
Lieftinckia	1,04	1,10	1,07	5
Vanuatubasis	1,00	1,16	1,08	18
Nesobasis	0,97	1,22	1,09	47
Pacificagrion	1,12	1,21	1,17	4
Pseudagrion	0,98	1,36	1,17	22
Ischnura	1,17	1,42	1,29	18
Amorphostigma	1,23	1,46	1,35	32
Melanesobasis	1,23	1,50	1,37	9
Teinobasis	1,29	1,46	1,37	9

Table V. Comparison between wing colouration of *Rhyothemis phyllis* specimens from various Pacific islands.

Trait	*R. p. marginata*	*R. p. aequalis*	*R. p. dispar*	*R. p. apicalis*	Malekula	Aneityum
Fore wing						
nodal spot (posterior end)	RP1	IRP2	IRP2	RP3+4	RP1	IRP2
nodal spot (poximal ex-tention)	2 cells; faint reaching 7-8 cells	2-3 cells	7-8 cells; faint reaching wing base	2-4 cells; faint max 1 cell proximally	1 cell; faint reaching 3-4 cells	3-4 cells; faint reaching 7-8 cells
nodal spot (distal extent-ion)	1 cell; faint reach-ing half way in the second cell along costal margin	not given	2 cells; faint reach-ing costal end of second cell	1/2 cell	1/3-1/4 cell	1/3-1/4 cell
postnodal black area	joint to the extent-ion of the apical area; faint in 5-6 cells in the sub-costal space	not joint to the extention of the apical area	joint to the extent-ion of the apical area; faint in 1/2 cell in the sub-costal space	absent	not joint to the extention of the apical area; missing in 6-7 cells in the subcostal space	almost joint to the extention of the apical area; missing in 5-6 cells in the subcostal space
other dark spots	absent	not given	present	absent	absent	absent
Hind wing						
nodal spot (posterior end)	RP1	smaller than in FW	IRP2	RP3+4	RP1	RP1
nodal spot (poximal ex-tention)	1 cell; faint reach-ing base of the wing	not given	complete dark to the base of the wing	1-2 cells; faint max 1 cell proximally	1 cell; faint reaching 2-3 cells	1-2 cells; faint reaching base of the wing
nodal spot (dis-tal extention)	1 cell; faint reach-ing half way in the second cell along costal margin	not given	1 cell; faint reach-ing costal edge of postnodal area	1/3-1/4 cell to nearly 1 cell	1/3-1/4 cell	almost 1 cell
postnodal black area	faintly joint to the extention of the apical area; faint in 4-5 cells in the subcostal space	not given	joint to the extention of the apical area; faint in 2-3 cell in the subcostal space	absent	not joint to the extention of the apical area; missing in 6-7 cells in the subcostal space	not joint to the extention of the apical area; missing in 7-8 cells in the subcostal space
anterior basal dark area (dis-tal extention)	proximal edge of the triangle	proximal edge of the triangle	covers triangle; extends 1–2 cells distally	covers triang-le; extends 1–2 cells distally	posterior tip of triangle	covers triang-le; extends 1-2 cells distally
posterior basal dark area (dis-tal extention)	middle of anal loop	not given	MP	surpassing distal edge of anal loop	middle of anal loop	distal edge of anal loop
yellow basal band (width)	almost 1/3 of the posterior dark band	2-4 mm	1/2-1/6 of the posterior dark band	equal to posterior dark band	1/2 to equal to the posterior dark bans	almost equal to the posterior dark band
other dark spots	absent	not given	present	absent	absent	absent

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