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Contribution to the Odonata fauna of the Society Islands, French Polynesia (Insecta: Odonata)

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Abstract

Following field studies in 2018 the Odonata fauna of Society Islands, French Polynesia is reviewed and the validity of all records analysed. An updated species list is provided, bringing the number of breeding species recorded from this island group to ten.

Field studies targeted *Hemicordulia* Selys, 1870 specimens for inclusion in the revision of the Pacific representatives of the genus. Samples were taken mainly from Tahiti and Raiatea, with some additional specimens collected from Bora Bora and Huahine. Only the Society Islands endemic *H. oceanica* Selys, 1871 was encountered on all four islands, being recorded from Bora Bora for the first time. At least one new species of *Hemicordulia* has been reported from the high mountain areas of Tahiti (Jacq et al. 2009, 2014).

The present study also emphasises the need for a revision of Zygoptera records from the French Polynesia and the rest of the Pacific. Presently, about 25 endemic species provisionally assigned to *Ischnura* Charpentier, 1840 and *Hivaagrion* Hämäläinen & Marinov, 2014 are known from the Society, Austral and Marquesas island groups (R. Englund, J. Jacq, T. Ramage, D. Polhemus, per. comm.). Only seven of them have been described so far. Detailed morphological and molecular analyses will likely prove the separate generic status of some of the species presently included under *Ischnura* .

Key words: Odonata, *Hemicordulia*, *Ischnura*, Society Islands, Tahiti, Raiatea, Bora Bora, Huahine, Moorea

Introduction

Located in the southeast Pacific Ocean, French Polynesia is composed of 118 islands oriented northwest-southeast. They originate from geological hot spots and are grouped into five archipelagos: the Marquesas, Tuamotu, Gambier, Society and Austral Islands (Talandier 1993). Except for Raivavae, Rapa & Marotiri, these islands, are located between the equator and the Tropic of Capricorn. The Austral, Gambier, Marquesas and Society archipelagos are mainly composed of high islands while the Tuamotu archipelago is composed of low islands with the exception of Makatea. The highest biodiversity and most endemic species are located on the high islands (Whittaker & Fernández-Palacios 2009). These tend to support characteristic habitats, such as montane cloud forest, where most endemics are found (Ramage 2017).

The Society Islands are located between 15-18° S latitude and 148-154° W longitude and stretch over nearly 750 km (Dupon & Sodter 1993). The archipelago consists of a chain of 14 islands totalling 1,595 km^2, with a maximum elevation of 2,241 m (Mt Orohena, Tahiti). Its volcanic islands are between 0.5 (Tahiti iti) and 4.8 Myr in age (Maupiti) and are the result of the activity of colinear hotspots (Talandier 1993; Clouard & Bonneville 2005). The archipelago is geographically divided into two groups:

- The Windward Islands are the largest islands in French Polynesia with four high islands (Tahiti, Moorea, Maiao, Mehetia) and one atoll (Tetiaroa).
- The Leeward Islands, further to the west, with five high islands (Huahine, Raiatea, Taha'a, Bora Bora, Maupiti) and four atolls (Tupai, Manuae, Maupihaa & Motu One).

The terrestrial arthropod fauna of French Polynesia is unbalanced, with several hexapod orders absent, a phenomenon known as taxonomic disharmony (Roderick & Gillespie 2016). The absence of major taxonomic groups is to some degree counterbalanced by a high degree of endemism resulting from numerous local speciation events (Ramage 2017; Ramage et al. 2018a). This is particularly true of the freshwater insect fauna, with orders Ephemeroptera, Plecoptera or Trichoptera unknown from this territory except for one undescribed species of Trichoptera recently collected in the Marquesas Islands (Polhemus & Englund 2016).

The Odonata of French Polynesia are poorly understood and have been little studied since Bishop Museum surveys conducted in the late 1920s and 1930s (Polhemus et al. 2000). The Pacific Odonata database holds 344 published records for the whole of French Polynesia which makes the country the eighth most well known Pacific nation according to published data, ranking it between Palau and Samoa (Marinov 2015). Those records are distributed almost equally between the three main archipelagos: The Australs, Marquesas and Society Islands. There are only six records for the Tuamotu Islands and no published data from the Gambier Islands. The information about Tuamotu comes from three original records published by Cheesman (1927) which were included in an overview of the Odonata of French Polynesia in Meurgey (2004b). There are five other reviews covering all of French Polynesia (Dommanget & Mashaal 2000; Nishida 2008; Englund & Polhemus 2010; Jacq et al. 2015; Ramage 2017) and Tahiti only (Paulian 1998), which add no new information, relying on published records. Therefore, the total number of unique records for French Polynesia

is even smaller than the figures given above. Taxonomic discussions are scare and many earlier records need validation in the light of current taxonomy.

This paper presents a new overview, limited to the published Odonata records of the Society Islands. Table I provides the species checklist, with annotations given in the text.

Faunistic and taxonomic history of Odonata species in Society Islands

The first information on Odonata of the Society Islands was a report by Selys (1857) of *Pantala flavescens* (Fabricius, 1798) from Tahiti (Table I in Appendix). This was followed by Brauer (1864; 1865a, b, c) who reported on five species collected in Tahiti during the circumnavigation of the globe by the Austrian frigate Novara (1857-1859). Because of taxonomic uncertainties he postponed the description of some new species until a year later (Brauer 1865a). There are some discrepancies between the information published in the two years. Brauer (1864) reported three undescribed Odonata from Tahiti: one Zygoptera (*Agrion* sp. nov.) and two Anisoptera (*Diplax* sp. nov. 3♂♀ and *Diplax* sp. nov. 1♀), however Brauer (1865a) later described two Zygoptera (*Ischnura aurora* and *I. spinicauda*) and one Anisoptera (*Diplacodes bipunctata*) – for verbatim details on the names refer to Table I. *Ischnura spinicauda* is not included in Table I because Papazian et al. (2007) considered it as a synonym of *I. aurora*. Both *I. aurora* and *D. bipunctata* are given in Table I as originally reported for Tahiti in 1865, since although Brauer first saw them in 1864, the actual year of description was 1865.

Brauer (1864) included two more taxa from Tahiti: *Gynacantha* sp. and *Tholymis tillarga* (Fabricius, 1798). Brauer (1865c) stated that the '*Gynacantha*' was actually what he had later described as *Aeshna taitensis* (Brauer, 1865) in Brauer (1865b). However, Cheesman (1927) considered *A. taitensis* as a junior synonym of *Anaciaeschna jaspidea* (Burmeister, 1839).

Brauer (1865c) reviewed all his earlier Odonata records collected during the voyage of the Novara and re-described the new taxa.

Brauer (1868) reported two species he believed to be already named (*Cordulia tau* and *Cordulia oceanica*) as being from Tahiti. He likely knew in advance about the species names which Selys (1871) later introduced for two new corduliids, as *Hemicordulia* tau and *Hemicordulia oceanica*. However, Brauer (1868) was incorrect in his record of *H. tau* as its terra typica was given as Australia and Fiji but not Tahiti (Selys 1871). Therefore *H. oceanica* is included in Table I and the preferred year of the first record from Tahiti is the date of the original description.

In the same paper Selys (1871) described the female of *Hemicordulia assimilis* Hagen in Selys, 1871 with the type locality 'Ile Célèbes' which is now Sulawesi, Indonesia. Although not directly relevant to Tahiti this record is mentioned here, because in the literature on the Pacific *Hemicordulia*, both *H. assimilis* and *H. oceanica* have often been reported from various islands with Fraser (1927), Buxton (1927), Kimmins (1936) and Mumford (1942b) even suggesting a subspecific status as *H.* a. *oceanica*. The Pacific *Hemicordulia* were later discussed in several studies (cf. Marinov & Pikacha 2013; Marinov et al. 2013; Marinov et al. 2019). The most important conclusion reached is that Lieftinck's (1975) statement that *H. oceanica* may have been re-

ported from many oceanic islands but is known only with certainty from the Society Islands, appears correct. So far it remains the only described *Hemicordulia* species known to occur in this island group.

Selys (1876) described as new two *Ischnura* spp. found in Tahiti: *I. taitensis* (endemic to the island) and *I. delicata* (general distribution also reaching Tahiti). Describing the second species, the author treated *I. aurora* (an already known species) as a synonym of *I. delicata*. Presently, *I. delicata* is accepted as a junior synonym of *I. aurora* (see Mumford 1942a).

Four consecutive works (Kirby 1884; Ris 1909-1919; Martin 1914; Campion 1921) reported Odonata species from Tahiti referring mainly to material collected previously. None added any new species to the Society Islands checklist.

New records were added by Cheesman (1927), reporting on results from the St. George Expedition. Seven species were recorded from Tahiti, Bora Bora and Raiatea with *Anax gibbosulus* Rambur, 1842 (male, female and naiads collected on July 1925) a new record for the Society Islands. All Cheesman's specimens were sent for identification to Douglas Kimmins of the Natural History Museum, London (BMNH). However, Schmidt (1938) included a Cheesman (1927) record of *A. gibbosulus* under *A. guttatus*. No justification was provided and it is unclear if the transfer was made based on re-evaluation of the original material or expectations from the general species distribution. BMNH has eight *Anax* specimens (accession numbers 013805539-013805546) deposited from Miss Cheesman's expedition: five naiads and three adults (male collected on February, 1925 and female+male collected on 19 July 1925). All specimens are stored under *A. guttatus* collection in the Museum. Their identity was validated on diagnostic images kindly provided for this study by Ben Price, senior curator in BMN*H*. Even now *A. gibbosulus* is mainly distributed in high mountain zones of the Pacific islands (Donnelly 1986) and observing it in low altitudes is unusual. Therefore, *A. gibbosulus* is removed from the Odonata checklist for Society Islands until further validation.

Apparently Cheesman had provided more specimens than were listed in the paper because Kimmins (1929) described *Ischnura cardinalis*, which is now known as endemic to Raiatea and Bora Bora, from her material.

Needham (1935) included five species which he identified from a collection taken during a Pacific Entomological Survey. Two of the names had never before been reported for Tahiti, but only one (*Tramea transmarina* Brauer, 1867 originally listed as *T. limbata* (Desjardins, 1835)) is included in Table I as new for the Society Islands. We exclude *Diplacodes trivialis* (Rambur, 1842). Currently the species' easternmost range is considered to be the Lau Islands, Fiji (Marinov & Sakiti-Waqa 2013). Records east of this range need validation. Needham (1935) reported two females from Tahiti, but we lack any later confirmation of its presence and it is a hard-to-overlook species. Paulian (1998) also claimed the species to be present on Tahiti, but his photo purporting to be of *D. trivialis* is actually of *Pantala flavescens* (Fabricius, 1798). The same author reported of *D. remota* Ris, 1911 as another representative of the genus on Tahiti, however this name is a junior synonym of *D. trivialis*. Moreover, Paulian (1998) erroneously stated that *D. remota* was described from Samoa, whereas this species was in fact described from one female from the Solomon Islands. This mistake was perpetuated

in Dommanget & Mashaal (2000) and Marinov et al. (2013) who included it for the check list of Samoa. Marinov et al. (2015) suggested removing *D. trivialis* from the Samoan fauna until future confirmation because this otherwise widely distributed and common species was not recorded during any of the studies on the Samoan fauna (Fraser 1925, 1927, 1953; Donnelly 1986; Marinov et al. 2015). No plausible new records of the species have come from Tahiti since Needham (1935).

Schmidt's (1938) review of the Odonata fauna of Oceania should be treated with some caution. It includes a total of 13 species as opposed to ten which are presently known to occur in the Society Islands. The removal of three species from the list (*I. spinicauda*, *H. assimilis* and *D. trivialis*) is explained above.

There were several new taxa recorded for Tahiti after Schmidt's (1938) review but none of them was included in Table I:

- Mumford (1942a) reported a naiad provisionally identified as *Agriocnemis* sp. The identification was based on a single not fully grown specimen. So far, Martens (2010) record of *Agriocnemis exsudans* Selys, 1877 from the Cook Islands is the eastern-most known point of distribution of the genus in the Pacific. Therefore the identification in Mumford (1942a) needs validation. Moreover, no records have been published since and determination of early stadia naiads of coenagrionids is not always reliable.
- Mumford (1942a) described *Ischnura cheesmani* sp. nov. which Lieftinck (1966) synonymised with *I. taitensis*.
- Resh et al. (1990) studied the aquatic macroinvertebrates on Moorea Island and included two Odonata taxa as *Pacificagrion* sp. and Libellulidae identified by naiads only. While presently at least four Libellulidae species are known from Society Island, the occurrence of *Pacificagrion* Fraser, 1926 is highly unlikely because the genus is endemic to Samoa with two species known from Upolu Island only (Fraser 1953). Therefore the genus is not included in Table I.

In fact no accepted new species records for the Society Islands have been published since Schmidt (1938). Most of the publications following this review reflected on already known taxa as follows: Whitehouse (1939) – seven species; Whitehouse & Walker (1941) – short note on the oviposition behaviour of *T. transmarina* (treated as *T. limbata*); Lieftinck (1975) re-described *H. oceanica* and mentioned *I. aurora* with its global distribution to Tahiti; Paulian (1998) – 15 taxa; Dommanget & Mashaal (2000) – 13 taxa; Dommanget & Mashaal (2002) – one species; Endersby (2002) – four species with their global distribution going to Society Islands; Meurgey (2004a, b) – 16 taxa; Ramage (2017) – 12 taxa.

Note that the total number of species/taxa given in Paulian (1998), Dommanget & Mashaal (2000), Meurgey (2004a, b) and Ramage (2017) exceeds the presently accepted 10 species as inhabitants of the Society Islands (Table I). All five of these studies reviewed the previous records on Odonata from the islands with only Meurgey (2004a) including new records. The species not included in Table I from those studies are:

- Paulian (1998) – *Agriocnemis* sp., *I. cheesmani*, *A. gibbosulus* and *D. trivialis* (commented above), *Diplacodes remota* Ris, 1911 (junior synonym of *D. trivialis*). Two of the

photographs presented in this study were wrongly labelled: what is given as *D. trivialis* is in fact *P. flavescens* whereas *P. flavescens* is a species of *Diplacodes* sp., which is difficult to be identified by the photo only.

- Dommanget & Mashaal (2000) – *Agriocnemis* sp., *A. gibbosulus* and *D. trivialis* (all commented above). The authors mentioned *H. oceanica* from Ternate and the Marquesas Islands, however Ternate is not a locality in French Polynesia (J.-Y. Meyer, per. comm.). Moreover, *H. oceanica* is presently considered as endemic to the Society Islands (Lieftinck 1975) and the status of *Hemicordulia* from the Marquesas requires further studies.
- Meurgey (2004a) – *Bedfordia* sp. and *H. assimilis* ? both given for Tahiti, however *Bedfordia* Mumford, 1942 is now replaced with *Hivaagrion* Hämäläinen & Marinov, 2014 because the name *Bedfordia* was already preoccupied by the name *Bedfordia* Fahrenholz, 1936 in Phthiraptera (Hämäläinen & Marinov 2014) and the genus is known as endemic to the Marquesas Islands. For *H. assimilis* see the discussion above.
- Meurgey (2004b) – *Agriocnemis* sp., *A. gibbosulus* and *D. trivialis* (commented above) and *Anax junius* (Drury, 1773). The latter was included in the list of French Polynesia following Corbet (1999, 2000) who claimed the species' range as going to Tahiti. This was firstly suggested in Walker (1958). The nature of these data is uncertain and needs validation. *Anax junius* has never been consequently sampled from the Society Islands and in fact never confirmed for other parts of the Pacific except Hawaii (Zimmermann 1948).
- Ramage (2017) – *A. gibbosulus* and *D. trivialis* (commented above). The author reported *T. transmarina* under *T. limbata*.

Lieftinck (1966) is of particular interest because it is one of the few published studies dealing with Odonata taxonomy in French Polynesia. Describing *Ischnura thelmae* sp. nov. from Rapa Island, Austral Islands, he compared it with three congeneric: *I. taitensis*, *I. cheesmani* and *I. spinicauda*. The study suggested *I. cheesmani* as a junior synonym of *I. taitensis*. The type of *I. spinicauda* was revised and compared with *I. aurora*. The author concluded that there were well expressed morphological differences enabling these two to be retained as separate species. However, these are now considered as synonyms with *I. aurora* being the valid name as a senior synonym (Papazian et al. 2007).

This literature review ends with special recognition of the publications listed below (some already cited above), some of which report undescribed species. The latter were not included in Table I pending their description.

Riviere & Pichon (1979) note the presence of a dragonfly on the Scilly atoll (Manuae) without mentioning any species.

Polhemus et al. (2000) focused on the Marquesas but the authors sampled three sites on Tahiti without giving any species list.

Rais (2004) studied the behaviour of *Ischnura aurora* larvae in the presence of predators in their habitats on Moorea Island.

Jacq (2006a, b) recorded eight species in Huahine (include one *Ischnura* sp. nov.) and four species in Taha'a collected by A. Huguet and F. Jacq.

Butaud (2007) studied the natural area of Tiamape – Teihomanono plateau (Papara) in Tahiti. Two Libellulidae were observed on temporary pools and swamps by A. Huguet (680 – 800 m altitude) and a *Hemicordulia* sp. nov. has also been found (cf. Jacq et al. 2009 with an illustration).

Jacq & Butaud (2006, 2009) investigated the biodiversity on Te Mehani 'ute'ute, Te Mehani Rahi & Te Vaihue plateaus, in Raiatea Island and established four, seven and four species respectively. The 2009 report is illustrated with photos of the species found within the investigated area including *Ischnura cardinalis*, endemic to Raiatea, Bora Bora and Taha'a islands. Three more undescribed *Ischnura* spp. (potential inhabitants of these three trachytic plateaus) are presented with photos of life individuals and short information of the original sampling sites (cited in Butaud & Jacq 2011 too). *Hemicordulia* sp. cf. *oceanica* is another species of interest because it could also represent an undescribed species.

Englund (2008) made an assessment of the invasive species threats to native aquatic insect biodiversity. He included a photo of *I. cardinalis*.

Butaud (2011) recorded five species for Tupai atoll.

As part of a flora and fauna inventory of a wetland on Taha'a Island for a water reservoir project, Jacq (2011) identified 2 odonates: *I. aurora* and *P. flavescens*.

Tanret et al. (2011) listed from Opunohu Valley in Moorea Island; five Libellulidae, one *Hemicordulia* sp., and two Zygoptera: *Ischnura aurora* and a *Ischnura* sp. nov.

"Moorea Biocode Project" is a research programme carried out from 2008 to 2013 in collaboration with UC Berkeley and its research station R. Gump based in Moorea, "l'Ecole Pratique des Hautes Etudes" (EPHE) and its research station CRIOBE Moorea, and French Polynesia government. The aim was to barcode all non-microbial life on Moorea Island (i.e. sequence the mitochondrial COI gene; mooreabiocode.org). In the process, Nishida (2008) compiled a list of the odonates known island by island in French Polynesia based on bibliographic sources, keeping the original names cited in the publications. In total, 24 odonates are listed in French Polynesia, 17 in the Society archipelago and seven on Moorea island.

Ramage et al.'s (2017) work is based on the specimens collected and barcoded in Sylvain Charlat's project on Wolbachia in four islands in the Society archipelago. Seven odonates from Moorea, Huahine & Raiatea islands were barcoded. An unidentified *Ischnura* was collected on Moorea, most likely the new species. All specimens are illustrated on the Moorea Biocode databases website (http://biocode.berkeley.edu/).

Jacq et al. (2009, 2014) analysed the species diversity of Mont Mārau in Tahiti and included photographs of eight species including one undescribed given as *Hemicordulia* sp. nov.

Ramage et al. (2018b) studied the impact of the ant *Wasmannia auropunctata* on the entomofauna and avifauna of the natural parc Te Faaiti in Tahiti Island. They list two Coenagrionidae with a photo of *I. taitensis*, *H. oceanica* and two Libellulidae, mentioning *T. transmarina*.

For an environmental diagnosis of anthropogenic effects on the lower parts (0 to 325 m altitude) of 40 streams in Tahiti island, as a part of the River Action Plan put

in place by the French Polynesia Department for the Environment (DIREN), eight odonates were recorded (Fenua Environnement et al. 2017, 2018). *Hemicordulia oceanica* and *I. taitensis*, considered as endemic species, were encountered in three and five different streams respectively.

In their synopsis of the overseas French Territories biodiversity, Gargominy & Bocquet (2013) counted one indigenous and 25 endemic damselflies, six indigenous dragonflies and four *Hemicordulia* (three endemics and one indigenous) in French Polynesia. They included several undescribed species in their totals.

Jacq et al. (2015) published an overview of the natural heritage of the five groups of islands comprising French Polynesia and reported 19 odonate species (only described species). A photo of the Tahitian endemic *I. taitensis* is included. Using this previous synthesis, the same number of Odonata is cited in the regional ecosystem profile (UICN France 2016).

Analysing previous studies Ramage (2017) recalled the same number of 19 Odonata species which are presently found in French Polynesia of which 11 species are Anisoptera, all widespread at least in the Pacific except for one endemic to the Marquesas Islands, and eight species of Zygoptera, seven of them being endemic. Ramage (2017) included a photo of the endemic *I. cardinalis*.

It is important to note that the above overview does not reflect the actual state of knowledge of the Society Islands Odonata. Local scientists as well as entomologists from Paris, Bishop Museum and the University of California Berkeley have accumulated a substantial unpublished material not only for the Society Islands but for the whole of French Polynesia (*D.* Polhemus, R. Englund, per. comm.). This information is of a great interest as it certainly contains a number of species new to science and new distribution records of known species. Publication should be encouraged as it would be an invaluable source of information for taxonomic and biogeographic studies.

Such an effort is made here with the current study, which was aiming in collecting more information on local Odonata for inclusion in the ongoing revision of the Pacific *Hemicordulia* as well as enhancing the taxonomic investigations on French Polynesian Zygoptera.

Material and Methods

Two islands (Tahiti and Raiatea) were sampled between 29th July – 12th August 2018 by the principal investigator (MM). Additional data collected on *Hemicordulia* after the end of the main sampling period by one of us (FJ) were also included. Figure 1 shows the overall area sampled and the sampling localities for each island.

Freshwater habitats were accessed from the main roads and sampled at the entrance to the habitat. Where the vegetation and the terrain allowed, the habitat was entered on foot. The search was abandoned if no flying individuals were encountered for a distance the width of the stream multiplied by ten, following the protocols of Harding et al. (2009). Adult odonates were mainly collected with aerial nets and either killed in acetone, dried and transferred into paper envelops or preserved in 95% ethanol

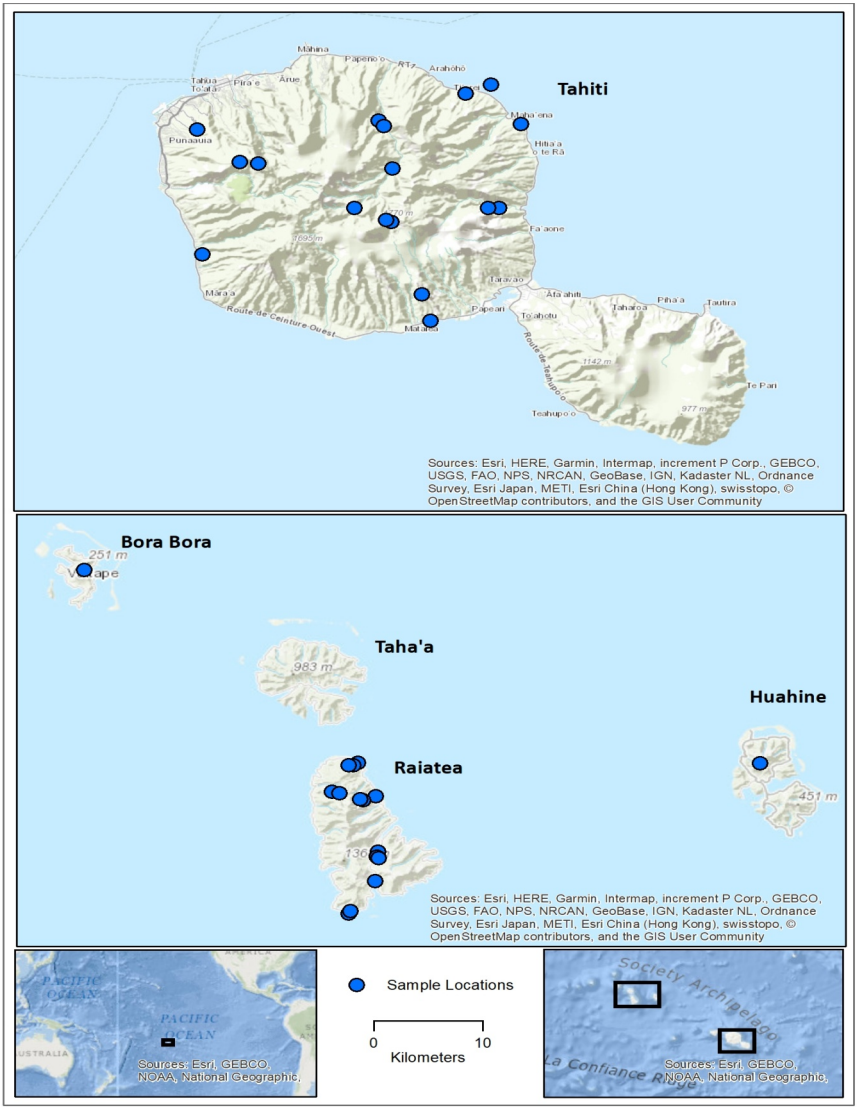

Figure 1. General area and sites sampled.

for molecular analysis. *Hemicordulia* specimens preserved in ethanol will be used for DNA analysis at the Bean Life Science Museum, Brigham Young University, USA. All other specimens will be deposited in the New Zealand Arthropod Collection, Auckland, New Zealand. To ensure accurate locality records, observations were recorded using the ArcGIS Collector app on a smartphone (Huawei P9). The methodology and advantages of using this technology are explained in Marinov et al. (2019).

Microscope photographs of specimens were produced using a series of images taken under high power Nikon AZ100M microscope and stacked with Helicon Focus 6.7.1 software. *Hemicordulia oceanica*, endemic to the Society Islands, is fully illustrated with micro images of much of the body.

Two more species endemic to the Society Islands (*Ischnura cardinalis* and *I. taitensis*) were also photographed and presented below for easy identification in future studies. Both sexes of the two species were compared with species from other Pacific Coenagrionidae genera (*I. aurora* and *I. heterosticta* (Burmeister, 1839) included for *Ischnura*) in a test using the pre-nodal index (Prn) and thoracic index (TI) introduced in Marinov et al. (2015, 2019) respectively.

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

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

Tahiti Island

1. Cross-island road between Papenoo and the tunnel (-17.5694, -149.4331 to -17.6659, -149.4223; 75-794 m a.s.l.): 30 July; 01, 03 August

2. Vaipehi Botanical Garden – stream and hills above it (-17.7603, -149.3898 to -17.7354, -149.3973; 36-445 m a.s.l.): 31 July

3. Pits in Papenoo valley (-17.6528, -149.4530; 416 m a.s.l.): 01 August

4. Stream below the tunnel (-17.6640, -149.4266; 703 m a.s.l.): 01 August

5. Stream with pool on the cross-island road between Papenoo and the tunnel (-17.6149, -149.4216; 157 m a.s.l.): 01 August

6. The three cascades (-17.5348, -149.4011; 114 m a.s.l.): 02 August

7. Stream roadside east of Tiarei (-17.5436, -149.3609; 90 m a.s.l.): 02 August

8. Stream roadside south east of Mahaena (-17.5727, -149.3153; 18 m a.s.l.): 02 August

9. River about 10 km north of Taravao (-17.6525, -149.3332; 30 m a.s.l.): 02 August

10. Tributary to the river about 10 km north of Taravao (-17.6525, -149.3423; 40 m a.s.l.): 02 August

11. Pool roadside on the cross-island road between Papeeno and the tunnel (-17.5746, -149.4288; 80 m a.s.l.): 03 August

12. Marae Arahurahu (-17.6970, -149.5788; 56 m a.s.l.): 04 August

13. Road to Mt Mārau (-17.5779, -149.5834 to -17.6101, -149.5325; 365-1412 m a.s.l.): 05 August

14. Swampy area with a pool roadside on the road to Mt Mārau (-17.6088, -149.5478; 1190 m a.s.l.): 05 August

Raiatea Islands

15. Pool in the yard of the Pension Les 3 Cascades (-16.7709, -151.4240; 6 m a.s.l.): 06-09 August

16. Tourist track to the Three cascades (-16.7757, -151.4371 to -16.7745, -151.4407; 107-182 m a.s.l.): 07-09 August

17. Faaroa River at the junction of the cross-island road (-16.8386, -151.4215; 16 m a.s.l.): 08 August

18. River crossing the cross-island road south of the junction from the main road (-16.8448, -151.4227 to -16.8464, -151.4209; 26-30 m a.s.l.): 08 August

19. River crossing the cross-island road at the southern end north of the junction to the main road (-16.8746, -151.4243; 12 m a.s.l.): 08 August

20. Stream at the south-west corner of the island (-16.9140, -151.4528 to -16.9110, -151.4510; 19-109 m a.s.l.): 08 August

21. Uturoa (-16.7299, -151.4429; 0 m a.s.l.): 08 August

22. Track to Mt Tapioi (-16.7328, -151.4479 to -16.7330, -151.4527; 53-269 m a.s.l.): 09 August

23. Pufau trail - Te Mehani Rahi plateau (-16.7614, -151.4854 to -16.7675, -151.4630; 114-430 m a.s.l.): 13 November 2018

24. Pufau trail - 1st ford - Te Mehani Rahi plateau (-16.7673, -151.4625; 430 m a.s.l.): 01 May 2019

Bora Bora Island

25. Waterfall pond on the Faanui River (-16.4947, -151.7325; 185 m a.s.l.): 18 April 2019

Huahine Island

26. Pond on the Fare river (-16.7308, -151.0175; 136 m a.s.l.): 05 April 2019

Species checklist

Coenagrionidae

Ischnura aurora (Brauer, 1865) (Fig. 2)

Localities: **3, 7-9, 11, 15**

Very common species in small pools and temporary stagnant overflows along streams. It was found in lotic habitats but in low numbers.

Previously reported for Tahiti, Raiatea and Bora Bora (Brauer 1865a; Cheesman 1927; Needham 1935; Meurgey 2004a; Jacq & Butaud 2006, 2009; Jacq et al. 2015; Ramage et al. 2018b), Tupai (Butaud 2011), Huahine (Jacq 2006b), Taha'a (Jacq 2011), Moorea (Rais 2004; Tanret et al. 2011; Ramage et al. 2017).

Figure 2. *Ischnura aurora*, male.

Ischnura cardinalis Kimmins, 1929 (Fig. 3, 4)

Localities: **16, 18, 20**

Figure 3. *Ischnura cardinalis*: a) male, b) female.

Figure 4. Morphology of *Ischnura cardinalis*, a-f) male: a) head, frontal view; b) head (dorsal view) and thorax (lateral view); c) anal appendages, lateral view; d) anal appendages, dorsal view; e) fore wing; f) hind wing; g-m) female: g) head, frontal view; h) head (dorsal view) and thorax (lateral view); i) mesostigmal plate; j) posterior end of pronotum; k) ovipositor, lateral view; l) fore wing; m) hind wing.

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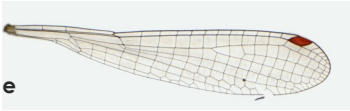

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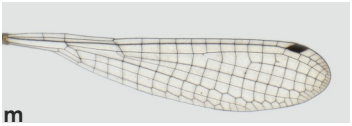

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This local endemic species is illustrated in Figure 4. Males were conspicuous with their vivid red eyes and pterostigmata and elongated inferior appendages. Figures 5-6 show the position of *I. cardinalis* based on the Prn and TI. For both indexes the species is removed away from *Ischnura* and sits between *Pseudagrion* (Selys, 1876) and *Amorphostigma* Fraser, 1925. This is determined by the position of the second antenodal crossvein being situated distally of the midway between the nodus and the

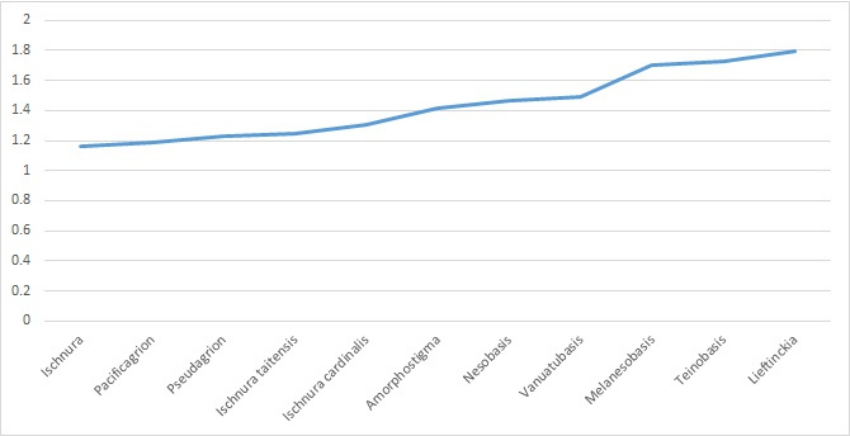

Figure 5. Prenodal index (Prn) range for selected Pacific Zygoptera genera and species (based on Marinov et al. 2015, 2019 with new information in this study) (see Table 2 in Appendix).

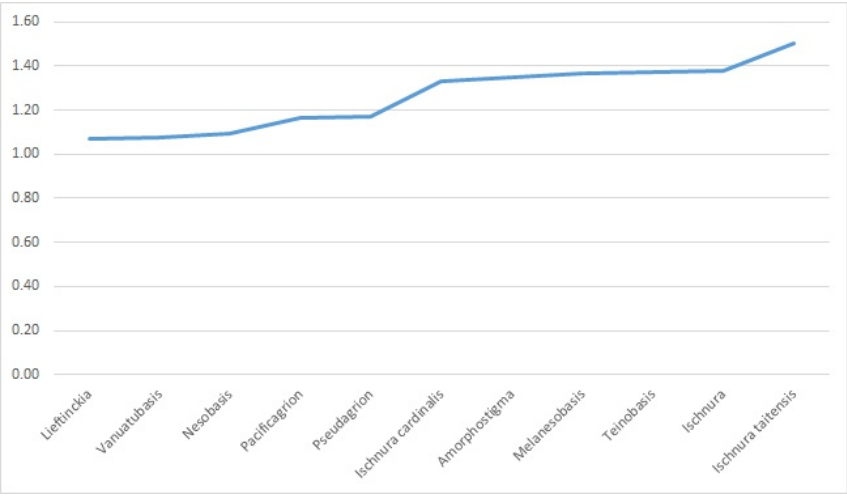

Figure 6. Thoracic Index (TI) range for selected Pacific Zygoptera genera and species (based on Marinov et al. 2019 with new information in this study) (see Table 3 in Appendix).

base of the wing (at or slightly distal in *Ischnura*) and more stouter thorax (more elongated in *Ischnura*) as evident on Tables II-III in Appendix.

Locally common to very abundant at Locality 20 which is a small stream with an average width of 2 m. It was flowing on a steep slope close to the ocean. Large stones create obstacles to accessing the habitat. Vegetation cover was very dense with some sunny spots. Adult males fight over perching sites, rarely returning to the same spot consistently. They may fly short distances chasing other males and not return to the previously occupied substrate. They choose sites with dappled shadow over completely sunlit spots, keeping to vegetation near the stream bank. They often perch high above the water.

Other sites for *I. cardinalis* were broader rivers (Locality 16) and a small stream flowing through a very flat area and open banks with long sections without trees (Locality 18). In both places the species was present in smaller numbers than at Locality 20.

Previously reported for Raiatea and Bora Bora (Kimmins 1929; Jacq & Butaud 2006, 2009; Jacq et al. 2015) and Taha'a Island (Ramage 2017).

Ischnura taitensis Selys, 1876 (Figs. 7, 8, 9)

Localities: **4, 7, 13**

Figure 8 illustrates the two sexes of this Tahitian endemic species. Females colouration changes with the maturity (Fig. 9). The two indexes place *I. taitensis* between *Pseudagrion* and *I. cardinalis* (Prn) and next to *Ischnura* (TI). However, these results have been obtained from two specimens only and should not be considered as reliable for the any final conclusions.

Only single individuals (1♂ and 2♀♀) were discovered in separate localities hence it is uncertain what constitutes suitable habitat for this species. The three sites were distributed over a wide altitudinal range (90 – 703 m) and the species is expected to be more common on the island. The mature female at Locality 4 was perched on branches overhanging the water surface, during rain. The immature female in Locality 7 was among grassy vegetation about 4-5 m from a stream bank. The male in Locality 13 was collected by sweeping roadside grass, well removed from any freshwater habitat.

Previously reported for Tahiti (Selys 1876; Mumford 1942a; Jacq et al. 2009, 2014; Ramage et al. 2018b).

Aeshnidae

Anaciaeschna jaspidea (Burmeister, 1839) (Fig. 10)

Localities: **16** (09 August)

One individual collected and at least one more was observed flying at dusk around 18:00.

Previously reported for Tahiti (Brauer 1865b; Needham 1935), Huahine & Taha'a (Jacq 2006a, b), Moorea (Nishida 2008).

New species for Raiatea.

Figure 7. *Ischnura taitensis*: a) male, b) female.

Figure 8. Morphology of *Ischnura taitensis*, a-f) male: a) head, frontal view; b) head (dorsal view) and thorax (lateral view); c) anal appendages, lateral view; d) anal appendages, dorsal view; e) fore wing; f) hind wing; g-m) female: g) head, frontal view; h) head (dorsal view) and thorax (lateral view); i) mesostigmal plate; j) posterior end of pronotum; k) ovipositor, lateral view; l) fore wing; m) hind wing.

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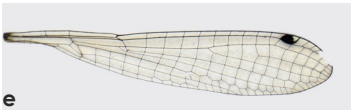

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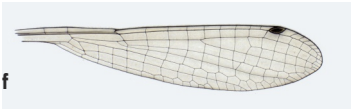

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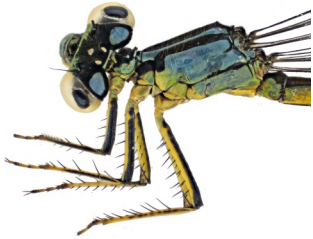

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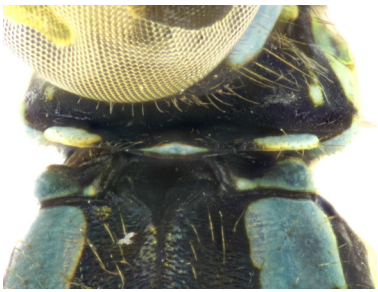

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Figure 9. Colour change in female *Ischnura taitensis*: a) immature; b) mature.

Figure 10. *Anaciaeschna jaspidea*, male.

Anax guttatus (Burmeister, 1839) (Fig. 11)

Localities: **1, 3, 11**

One female collected close to Locality 11. All other flying individuals were assigned to the same species by supposition because so far this is the only known *Anax* species present in the Society Islands.

Previously reported for Tahiti, Raiatea and Bora Bora (Brauer 1865a; Cheesman 1927 (as *A. gibbosulus*); Jacq et al. 2009, 2014), Moorea (Nishida 2008, Tanret et al. 2011), Huahine (Jacq 2006b).

Figure 11. *Anax guttatus*, female.

Corduliidae

Hemicordulia oceanica Selys, 1871 (Fig. 12)

Localities: **1** (03 August), **13, 16** (07, 09 August), **23, 25-26**

An adult male is illustrated in Figure 13. Variation of the colouration of the wings was notable in a few individuals, ranging from clear to a deep amber tint (Fig. 14).

Hemicordulia oceanica was often found flying in clearings and along main roads heading into the island. Flying *Hemicordulia*-like individuals were observed from close to sea level to high in the mountains, above 1,000 m a.s.l. (cf. below the information for *Hemicordulia* sp.). However, they usually remained in territories around human settlements. At roadsides, adults often select sites at the border between shady and sunlit parts of the road. Aggregations of adults were not observed. The usual flight of feeding individuals is at about 1.5-3 m above the ground, often performed above the water surface of temporary rain puddles. Adults flying among vegetation also keep close to the border between tall trees and open grass. At these sites they may make occasional flights up higher. As a general rule adults do not stay permanently at the places where they were observed. They fly very fast, continuously returning to the same area, followed by sudden departures to explore other sites. They do not return if alarmed by unsuccessful sweeps with the net.

Figure 12. *Hemicordulia oceanica*, male.

Previously reported for Tahiti and Raiatea (Brauer 1868; Lieftinck 1975; Meurgey 2004a; Jacq & Butaud 2006, 2009; Jacq et al. 2009, 2014, 2015; Ramage et al. 2018b), Huahine (Jacq 2006b; Ramage et al. 2017).

New species for Bora Bora.

Hemicordulia sp.

Localities: **1** (03 August), **2, 4, 14, 16, 18, 22**

All *Hemicordulia*-like individuals (both Tahiti and Raiatea) which were only observed but not collected for inspection were included here. They are presented separately from *H. oceanica* because Jacq et al. (2009, 2014) suggested there was a second *Hemicordulia* species on Tahiti at higher altitude (>500 m) that is still undescribed. This may be an endemic to Tahiti only and not found on Moorea & Raiatea, however, all records of flying *Hemicordulia* are combined here to show the abundance of the species over the two islands.

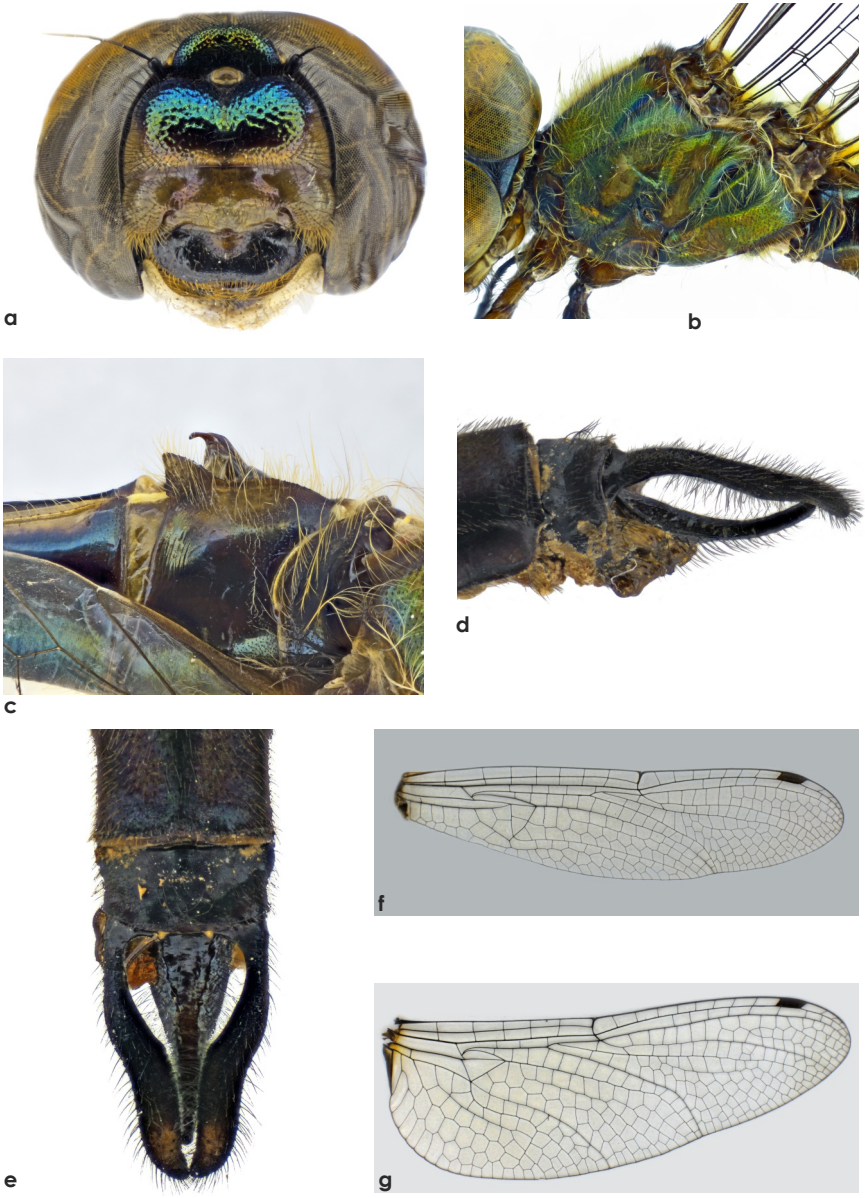

Figure 13. Morphology of male *Hemicordulia oceanica*: a) head, frontal view; b) thorax, lateral view; c) secondary genitalia; d) anal appendages, lateral view; e) anal appendages, dorsal view; f) fore wing; g) hind wing.

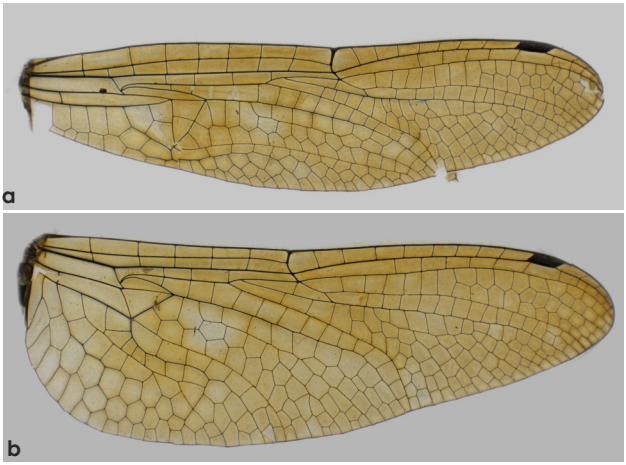

Figure 14. Yellow tinted wings of *Hemicordulia oceanica*: a) fore wing; b) hind wing.

Libellulidae

Diplacodes bipunctata (Brauer, 1865) (Fig. 15)

Localities: **1** (01, 03 August), **3, 11, 13, 15, 16, 22**

Found in many sites on both islands included in this study. Adults often stayed perched on the ground on the main road away from possible breeding habitats.

Previously reported for Tahiti and Bora Bora (Brauer 1865a; Ris 1909-1919; Cheesman 1927; Meurgey 2004a; Butaud 2007; Jacq et al. 2009, 2014), Raiatea (Jacq & Butaud 2009; Jacq et al. 2015), Tupai (Butaud 2011), Huahine (Jacq 2006b).

Figure 15. *Diplacodes bipunctata*, male.

Pantala flavescens (Fabricius, 1798) (Fig. 16)

Localities: **1-3, 9, 11-16, 22**

The most common species during the present study.

Figure 16. *Pantala flavescens*, male.

Previously reported for Tahiti, Raiatea and Moorea (Ris 1909-1919; Cheesman 1927; Meurgey 2004a; Jacq & Butaud 2006, 2009; Jacq et al. 2009, 2014, 2015; Ramage et al. 2017, 2018b; Tanret et al. 2011), Tupai (Butaud 2011), Huahine & Taha'a (Jacq 2006a, b; Ramage et al. 2017).

Tholymis tillarga (Fabricius, 1798) (Fig. 17)

Localities: **1** (03 August), **11, 16**

Single individuals were found flying along the main road during the day. The activity of the adults increased close to dusk when ovipositing females were observed in a roadside ditch at Locality 16.

Figure 17. *Tholymis tillarga*, male.

Previously reported for Tahiti (Cheesman 1927; Meurgey 2004a; Jacq et al. 2014), Moorea (Tanret et al. 2011), Tupai (Butaud, 2011), Huahine & Taha'a (Jacq 2006a, b).

New species for Raiatea.

Tramea transmarina Brauer, 1867 (Fig. 18)

Localities: **1** (01, 03 August), **3, 14, 16, 24**

Figure 18. *Tramea transmarina*, male

All individuals observed during the present study were assigned to this species even if not collected. This is also true for adults sighted but not collected at the single locality for Raiatea. The specimens collected (three males and two females) did not differ from *T. transmarina* from other Pacific islands (cf. Marinov 2012a; Marinov et al. 2013, 2015, 2019). The shape of the hind wing basal patch in males was identical to that of males from Tonga (Marinov 2012a: Fig. 5a), Samoa (Marinov et al. 2015: Fig. 20c) and similar to Fiji (Marinov 2012a: Fig. 5i). They are all compared in Figure 19. The two females reported here showed very different wing patterns (Fig. 20).

Previously reported for Tahiti (Needham 1935; Butaud 2007), Raiatea (Jacq & Butaud 2009; Ramage et al. 2017), Huahine & Taha'a (Jacq 2006a, b).

Discussion

The current study was designed to collect updated information on the Odonata of Society Islands analysing the data from published records and more recently com-

Figure 19. Comparison between the hind wing spots of *Tramea transmarina* from: a) Tonga (Marinov 2012a: Fig. 5a); b) Samoa (Marinov et al. 2015: Fig. 20c); c) Fiji (Marinov 2012a: Fig. 5i); d) Tahiti (this study).

Figure 20. Hind wing spot in female *Tramea transmarina* from Tahiti collected from: a) Locality 1; b) Locality 14.

pleted field studies. The endemic *H. oceanica* was of a special interest as the species is perhaps the most debatable Pacific representatives of the genus. This topic has been already discussed in other studies and briefly outlined here (see Introduction). The reason for the confusion in the past was the lack of a comparative material until Lieftinck's (1975) comparison of *H. oceanica* with the described by him *H. hilaris*. The latter is now known to inhabit a very wide territory of the Pacific (Marinov 2012b). The overall morphological similarity between the two species can easily explain the misidentifications in the past which have created many incorrect records of the species from a very wide range including Rennell Island, Solomon Islands, where it was given by supposition (Kimmins 1959). Because of this uncertainty Marinov & Pikacha (2013) left *H. oceanica* in the species checklist of the Solomon Islands. However, this is now considered incorrect although the specimen reported in Kimmins (1959) has not been re-examined. It was a female given to him by members of the Danish and British expeditions. Female *Hemicordulia* have been problematic for differentiation unless associated with the male. Describing the male of *H. hilaris*, Lieftinck (1975) had some females though not in a good condition. He was also reluctant to give a precise determination for two females collected from the Cook Islands and deposited in the Auckland Museum, New Zealand (see Wise 1980 and Marinov 2012b for more details).

Illustrations provided in Figure 21 are evidence of the close morphological similarity between *H. oceanica* and *H. hilaris*. So far the two species have not been recorded in sympatry and identification based on geography is considered justified at present. *Hemicordulia hilaris* has not been introduced to French Polynesia and for the moment is not known east of the Cook Islands whereas *H. oceanica* is considered to be endemic to the Society Islands. Future studies of specimens from other parts of French Polynesia are needed to establish this with certainty.

Both species display feeding patterns typical of other Pacific corduliids, with adults hovering over clearings in the vegetation. Therefore, they are commonly observed along the major inland roads. No detailed behavioural studies have been undertaken, but a small difference was observed during the current research. Adult *H. hilaris* have been seen multiple times in Fiji, Tonga and Samoa flying very low over substrate (M. Marinov, per. obs.) while *H. oceanica* mainly fly close to the tree tops with occasional descending to lower levels. The height of the flight is possibly determined by the presence of prey items at various levels above the ground. Therefore, the differences reported here (which need validation from more studies) may not sustain further observations.

Another record which is considered interesting was the scarce observations of *H. oceanica* close to human settlements. During the present study, we walked along tourist roads for kilometres without seeing any flying *Hemicordulia* adults. They mostly appeared above the line of the dwellings and were predominantly found in forested areas. At Localities 16 and 22 on Raiatea Island adults *Hemicordulia* were observed very close to the settlements and local farms which seems to be an exception of the overall statement given above. In contrast *H. hilaris* is mostly found associated with human occupied areas and less seen away in the forest. It was often observed in city parks, taro plantations and other local farm crop fields (M. Marinov per. obs.).

Breeding biology of the two species cannot be easily compared. *Hemicordulia oceanica* was not observed close to any potential breeding sites and it is unclear as to what constitutes a typical habitat of the species. Adults were missing from Locality 5 and other similar looking habitats which were elsewhere found to be very attractive for other Pacific species like *H. pacifica* Fraser, 1925 for example (Marinov et al. 2015).

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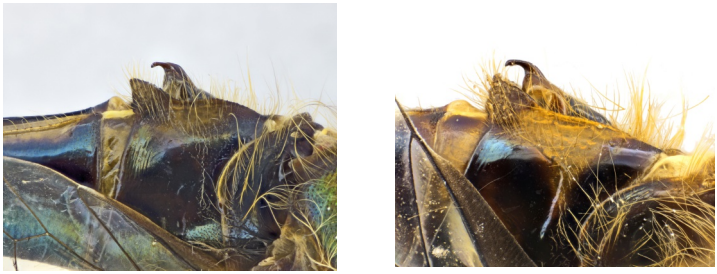

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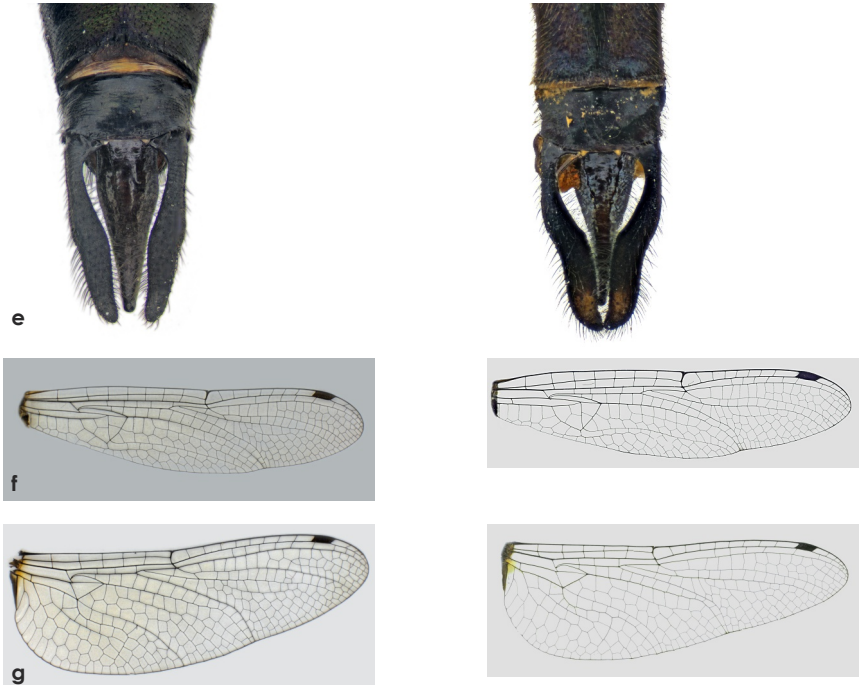

Figure 21. Morphological comparison between *Hemicordulia oceanica* (left column) and *H. hilaris* (right column): a) head, frontal view; b) thorax, lateral view; c) secondary genitalia; d) anal appendages, lateral view; e) anal appendages, dorsal view; f) fore wing; g) hind wing.

No *Hemicordulia*-like individuals were seen along the stretches of the rivers although some were traversed for longer distances than the methodology adopted here.

Walking in the streams in Tahiti was found to be problematic because of their steep slopes rising up almost immediately after accessing them from the main roads. Various small tributaries were inspected but the search for adult odonates was often ended less than 50 m from the starting point because of the inaccessibility of the forest. That is the reason why most of these small streams were not included in the list of sampling localities given above. However, they may be important places for some of the local endemic species presently placed in genus *Ischnura* .

The generic affiliation of a number of the Pacific species currently known as *Ischnura* has been challenged in Donnelly (1986) and Marinov et al. (2016). The second study provided a short morphological comparison of the male appendages, some illustrated by the original hand drawings because specimens were not available for comparison. In the addition to the structure of the male appendages, which is closer to *Amorpho-*

stigma than to *Ischnura* (for *I. taitensis*), and very unique in *I. cardinalis* both Society endemic species depart from Pacific *Ischnura* in the pre-nodal index of the wings. As evident from the thoracic index the body structure of *I. cardinalis* also differs from *Ischnura* due to the more heavily built thorax. In TI *I. taitensis* is compatible with *Ischnura* however, this result is drawn on two specimens only and needs validation with more samples. Being endemic to the region both species are illustrated with microphotographs of diagnostic body parts, presented here for the first time.

French Polynesian *Ischnura* and Zygoptera generally are a very interesting area of study. Presently, 15-20 undescribed species have been sampled from the islands of Raiatea (4-5), Moorea (1-2), Huahine (1-2), Taha'a (1-2) and Marquesas (6-9), (R. Englund, J. Jacq, T. Ramage, D. Polhemus, per. comm.). "In Australs Island, Tubuai has the distinction of being the only island with flowing water in French Polynesia to not have an endemic damselfly species found on it. Further sampling is clearly warranted on Tubuai and initial observations indicate that an endemic upland damselfly could potentially be found in the Mt Panee summit waterfall area, because this section of stream lacks invasive fish" (Englund 2014).

Studies in this subject are strongly encouraged for solving the taxonomic uncertainty around the correct generic placement of the Pacific Zygoptera and their phylogeny. Recently completed research had included selected Pacific species, however more studies are necessary involving undescribed species to increase the taxonomic resolution of the suggested phygenetic trees.

Acknowledgements

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Ben Price, Senior Curator, The Natural History Museum, London, UK, is thanked for photos of specimens collected from French Polynesia and deposited in the museum.

References

Brauer, F., 1864. Erster Bericht über die auf der Weltfahrt der kais. Fregatte Novara gesammelten Neuropteren. Verhandlungen der zoologisch-botanischen Gesellschaft in Wien 14: 159-164.

Brauer, F., 1865a. Dritter Bericht über die auf der Weltfahrt der kais. Fregatte Noavara gesammelten Libellulinen. Verhandlungen der zoologisch-botanischen Gesellschaft in Wien 15: 501-512.

Brauer, F., 1865b. Vierter Bericht über die auf der Weltfahrt der kais. Fregatte Noavara gesammelten Libellulinen. Verhandlungen der zoologisch-botanischen Gesellschaft in Wien 15: 903-908.

Brauer, F., 1865c. Neuropteren. In: Reise der österreichischen Fregatte Novara um die Erde in den Jahren 1857, 1858, 1859. Zoologischer Theil 2, Wien 4: 52-101; 103-104.

Brauer, F., 1868. Verzeichniss der bis jetzt bekannten Neuropteren im Sinne Linné's. Verhandlungen der zoologisch-botanischen Gesellschaft Wien 18: 711-742.

Butaud, J.-F., 2007. Installation d'un dispositif de suivi et d'accompagnement technique des équipes de gestion des espaces naturels de Te Faaiti (Hitia'a o te Ra) et Tiamape – Teihomanono (Papara). Direction de l'environnement, Polynésie française: 55 pp.

Butaud, J.-F., 2011. Flore, formations végétales, faune et enjeux de conservation de l'atoll de Tupai (Iles sous le Vent). Service du Développement Rural Direction de l'Environnement: 61 pp. + 3 Appendixes.

Butaud, J.-F. & F.A. Jacq, 2011. Patrimoine biologique des Marquises. Etudes de groupes taxonomiques à valeur patrimoniale. Ile de Hiva Oa, IRD, Papeete, Polynésie française: 69 pp. + annexes.

Buxton, P., 1927. Dragonflies from Samoa. Proceedings of the Entomological Society London 1 3): 42-43.

Campion, H., 1921. Odonata collected in New Caledonia by the late Mr. Paul *D.* Montague. Annals and Magazine of Natural History 8(9): 33-67.

Cheesman, L., 1927. A contribution towards the insect fauna of French Oceania, part *I.* Transactions of the Entomological Society London 75(1): 147-161.

Clouard, V. & A. Bonneville, 2005. Ages of sea mounts, islands, and plateaus on the Pacific plate. In: Foulger, G.R., J.*H.* Natland, D.C. Presnall & D.L. Anderson (eds.). Plates, Plumes and Paradigms. Geological Society of America Special Paper 388: 71–90.

Corbet, P., 1999. Dragonflies: Behaviour and Ecology of Odonata. Harley Books, Colchester: 829 pp.

Corbet, P., 2000. The first recorded arrival of *Anax junius* Drury (Anisoptera: Aeshnidae) in Europe: a scientist's perspective. International Journal of Odonatology 3(2): 153-162.

Dommanget, J.-L., & M. Mashaal, 2000. Les Départements et Territoires d'Outre-mer français. Géneralités. Martinia 16(3): 85-94.

Dommanget, J.-L., & M. Mashaal, 2002. Les libellules d'Outre-mer. Insectes OPIE 125(2): 8-10.

Donnelly, T., 1986. Preliminary report on Odonata collected in Samoa, 1985. Notulae Odonatologicae 2(7): 109-112.

Dupon, J.F. & F. Sodter, 1993. Les Iles de la Société. Planches 5. In: Dupon, J.F. (ed), Atlas de la Polynésie française. Editions de l'ORSTOM, Paris.

Endersby, I., 2002. The dragonflies of Norfolk Island, with the first record of Pantala flavescens (F.). Entomologist's Monthly Magazine 138: 241-246.

Englund, R., 2008. Invasive species threats to native aquatic insect biodiversity and conservation measures in Hawai'i and French Polynesia. Journal of Insect Conservation 12: 415-428.

Englund, R. 2014. Odonata and Selected Aquatic Insect Taxa. In: Meyer, J.Y. & E.M. Claridge (eds). Terrestrial Biodiversity of the Austral Islands, French Polynesia. Muséum national d'Histoire naturelle, Paris: pp. 103-113 (Patrimoines naturels 72).

Englung, R. & D.A. Polhelmus, 2010. A review of the damselfly fauna of the Austral Islands, French Polynesia, with description of two new species (Odonata: Zygoptera: Coenagrionidae). Tijdschrift voor Entomologie 153: 1-16.

Fenua-Environnement-Speed-Safege-Fred Jacq, 2017. Livrable n 2 du PAR Rivières Phase II – Résultat du diagnostic des 10 premières rivières. Direction de l'environnement, Polynésie française: 233 pp. + annexes.

Fenua-Environnement-Speed-Safege-Fred Jacq, 2018. Livrable n 3 du PAR Rivières Phase II – Résultat du diagnostic de 30 rivières. Direction de l'Environnement, Polynésie française: 917 pp. + annexes.

Fraser, F., 1925. A preliminary report on the Dragonflies (Order Odonata) of Samoa. Transactions of the Entomological Society London 1924 III-IV: 429-438.

Fraser, F., 1927. Insects of Samoa and other Samoan terrestrial Arthropoda. Odonata. London, British Museum (Nat. Hist.) Part VII (Fasc. I): 19-44.

Fraser, F., 1953. Further notes on Samoan Odonata belonging to the Ischnurine complex of species, with descriptions of two new species and some unknown females. Proceedings of the Royal Entomological Society London, B 22: 119-126.

Gargominy, O. & A. Bocquet 2013, Biodiversité d'Outre- mer. UICN France, Ed. Le Guen, Paris: 353 pp.

Hämäläinen, M. & M. Marinov, 2014. *Hivaagrion* nom. nov., a replacement name for the preoccupied genus-group name *Bedfordia* Mumford, 1942 (Odonata: Coenagrionidae). Notulae odonatologicae, 8 (4): 77-116.

Harding, J., J. Clapcott, J. Quinn, J. Hayes, M. Joy, R. Storey, *H.* Graig, J. Hay, *T.* James, M. Beech, R. Ozane, *A.* Meredith & *I.* Boothroyd, 2009. Stream habitat assessment protocols for wadeable rivers and streams of New Zealand. School of Biological Sciences, University of Canterbury, Christchurch, New Zealand: 133 pp.

Jacq, F.A., 2006a. Proposition d'un réseau d'itinéraires de randonnée sur l'île de Taha'a, commune de Taha'a, Archipel des Iles-sous-le-vent. Service du Tourisme: 57 pp. + annexes.

Jacq, F.A., 2006b. Proposition d'un réseau d'itinéraires de randonnée sur l'île de Huahine, commune de Huahine, Archipel des Iles Sous-le-vent. Service du Tourisme: 55 pp. + annexes.

Jacq, F.A., 2011. Inventaire floristique et faunistique, étude de la végétation – dans le cadre de l'étude d'impact sur l'environnement relative à la création d'un réservoir d'eau pour le lotissement agricole de Faahue (Hipu), Commune de Taha'a, Iles sous le vent, Raromatai Environnement, Raiatea, Polynésie française: 50 pp. + annexes.

Jacq, F.A. & J.-F. Butaud, 2006. Inventaire, cartographie de la flore et proposition d'actions conservatoires du domaine du plateau Te Mehani 'ute'ute – Raiatea, Rapport final, Direction de l'environnement, Polynésie française: 84 pp. + annexes.

Jacq, F.A. & J.-F Butaud, 2009. Inventaire et cartographie de la Flore vasculaire et partiel de la Faune, proposition d'actions conservatoires des plateaux Te mehani rahi et Te vaihue, île de Raiatea, Direction de l'environnement, Papeete: 92 pp. + annexes.

Jacq, F.A. & J.-F. Butaud, J. Barbut, L. Faulquier, B. Fontaine, O. Gargominy, *T.* Ghestemme, *A.* Gouni, *A.* Huguet, *D.* Lacoste, *A.* Pham, *T.* Ramage & *T.* Terautahi Vaimeho-Peua, 2009. Etudes préliminaires au classement du Massif du Märau. Inventaire et cartographie de la Flore et de la Faune, proposition d'un plan d'actions conservatoires (Commune de Fa'aä, Tahiti), rapport final, Direction de l'environnement, Polynésie française: 147 pp. + annexes.

Jacq, F.A., J.-F. Butaud & *T.* Ramage, 2014. Mont Mārau. Guide vert. Direction de L'Environnement, Papeete, Polynésie Française: 168 pp.

Jacq, F.A., F. Seguin & *T.* Ramage, 2015. Le patrimoine naturel, Etat de l'environnement en Polynésie française 2007/2014, Chapitre 4. In: Créocéan (Coord. F. Seguin). Etat de l'environnement en Polynésie française 2007/2014. Direction de l'environnement, Polynésie française, Tahiti: pp. 89-137.

Kimmins, D., 1929. *Ischnura cardinalis* sp. n. (Family Agrionidae): an addition to the fauna of the Society Islands. The Entomologist 62: 224-225.

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., 1959. 16. Odonata, Neuroptera and Trichoptera. In: Wolf, *T.* (ed.). The natural history of Rennell Islands, British Solomon Islands, Kopenhagen 2: 67-70.

Kirby, W., 1884. On the Neuroptera collected during the recent Expedition of *H.* M. S. "Challenger". Annals and Magazine of Natural History 7(2): 346-348.

Lieftinck, M., 1966. Some Odonata of Rapa island, with descriptions of three Polynesian species of *Ischnura* Charpentier. Tijdschrift voor Entomologie 109(4): 89-102.

Lieftinck, M., 1975. The dragonflies (Odonata) of New Caledonia and the Loyalty Islands. Part 1. Imagines. Cahier Office de la recherché scientifique et technique Outré-Mer (Série Hydrobiologie) 9(3): 127-166.

Marinov, M., 2012a. Contribution to the Odonata of the Kingdom of Tonga. Faunistic Studies in South-East Asian and Pacific Odonata, Journal of the International Dragonfly Fund 1: 1-18.

Marinov, M., 2012b. Description of female *Hemicordulia hilaris* Lieftinck, 1975 (Anisoptera: Corduliidae) with brief notes on the biogeography of the genus. Records of the Auckland Museum 48: 97-105.

Marinov, M., 2015. The seven "oddities" of the Pacific Odonata biogeography. Faunistic Studies in South-East Asian and Pacific Odonata, Journal of the International Dragonfly Fund 11: 1-58.

Marinov, M. & P. Pikacha, 2013. On a dragonfly collection from the Solomon Islands with overview of fauna from this Pacific archipelago (Insecta: Odonata). Faunistic

Studies in South-East Asian and Pacific Island Odonata. Journal of the International Dragonfly Fund 4: 1-48.

Marinov, M., W. Chinn, E. Edwards, B. Patrick & *H.* Patrick, 2013. A revised and updated Odonata checklist of Samoa (Insecta: Odonata). Faunistic Studies in South-East Asian and Pacific Island Odonata. Journal of the International Dragonfly Fund 5: 1-21.

Marinov, M. & *H.* Waqa-Sakiti, 2013. An illustrated guide to dragonflies of Viti Levu, Fiji. University of South Pacific Press: 148 pp.

Marinov, M., M. Schmaedick, *D.* Polhemus, R. Stirnemann, F. Enoka, P. Siaifoi Fa'aumu & M. Uili, 2015. Faunistic and taxonomic investigations on the Odonata fauna of the Samoan archipelago with particular focus on taxonomic ambiguities in the "Ischnurine complex". International Dragonfly Fund Report 91: 1-56.

Marinov, M., O. Fossati-Gaschignard & M. Schorr, 2016. On a dragonfly collection from Nuku Hiva Island, Marquesas Islands and Paea, Tahiti (French Polynesia) with taxonomic discussion of some Polynesian genera (Insecta: Odonata). Faunistic Studies in Southeast Asian and Pacific Island Odonata 18: 1-12.

Marinov, M., S. Beth, C. Doscher & *D.* Kalfatakmolis, 2019. Faunistic studies on Odonata of the Republic of Vanuatu (Insecta: Odonata). Faunistic Studies in Southeast Asian and Pacific Island Odonata, Journal of the International Dragonfly Fund 26: 1-46.

Martens, A., 2010. New Odonata records from Atiu and Rarotonga, with an overview of the species known from the Cook Islands. Notulae Odonatologicae 7(6): 57-59.

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

Meurgey, F., 2004a. Sur une petite collection d'odonates de Polynésie française. Martinia 20(2): 83-84.

Meurgey, F., 2004b. Listes provisoires des Odonates des départments et terriroires d'outremer français. Martinia 20(2): 85-104.

Moorea Biocode databases website. Available at: http://biocode.berkeley.edu/. Accessed on 04 June 2019.

Mumford, E., 1942a. A new species of *Ischnura* (Order Odonata); a dragonfly-nymph, possibly *Agriocnemis* Selys, and other records from Tahiti. Annals & Magazine of Natural History Ser. 11, 9(56): 644-647.

Mumford, E., 1942b. A new genus, *Bedfordia*, and other records of dragonflies from the Marquesas Island. Annals & Magazine of Natural History Ser. 11, 9(59): 824-831.

Needham, J., 1935. Odonata from Tahiti. Pacific entomological survey publications 6 art. 4 Bulletin of the B.P. Bishop Museum 113: 21-23.

Nishida, G.M., 2008. French Polynesia dragonfly/damselfly checklist. Available at: http://-essigdb.berkeley.edu/checklists/fpOdonata.doc. Accessed on 04 June 2019.

Papazian, M., *H.* Dumont & N. Mary-Sasal, 2007. The Odonata of the Pacific Ocean islands of Wallis and Futuna, with special reference to speciation of *Ischnura aurora* (Brauer). Odonatologica 36(1): 53-62.

Paulian, R., 1998. Les insects de Tahiti. Boubée. Paris. ISBN 2-85004-090-8: 331 pp.

Polhemus, D.A., R. Englund, S. Jordan & J. Polhemus, 2000. Trip report for 1999 entomological and freshwater surveys of the Smithsonian Institution and Bishop Museum expedition to the Marquesas Islands and Tahiti. Contribution No. 2000-002 to Pacific Biological Survey. Bishop Museum: 17 pp.

Polhemus, D.A. & R.A. Englund, 2016. Insectes d'eau douce des îles Marquises. In: Galzin, R., S.-D. Duron & J.-Y. Meyer (eds). Biodiversité terrestre et marine des îles Marquises, Polynésie française. Société française d'Ichtyologie, Paris: pp. 451-460.

Rais, J., 2004. Behavioral ecology and community structure: aquatic assemblage and predator/prey interactions of the native *Ischnura aurora* (Zygoptera) from Mo'orea, French Polynesia. In: Gump, R. (ed.). Biology and Geomorphology of Tropical Islands Integrative Biology 158: Environmental Science, Policy, & Management 107 Research papers: Fall 2004: pp. 123-129.

Ramage, T., 2017. Checklist of the terrestrial and freshwater arthropods of French Polynesia (Chelicerata; Myriapoda; Crustacea; Hexapoda). Zoosystema 39(2): 213–225.

Ramage, T., P. Martins-Simoes, G. Mialdea, R. Allemand, A. Duplouy, P. Rousse, N. Davies, G. Roderick & S. Charlat, 2017. A DNA barcode-based survey of terrestrial arthropods in the Society Islands of French Polynesia: host diversity within the SymbioCode Project. European Journal of Taxonomy 272: 1–13.

Ramage, T., S. Charlat & X. Mengual, 2018a. Flower flies (Diptera, Syrphidae) of French Polynesia, with the description of two new species. European Journal of Taxonomy 448: 1-37.

Ramage, T., F.A. Jacq, Fenua Environnement, 2018b. Étude de l'impact de la Petite Fourmi de Feu, *Wasmannia auropunctata* (Roger, 1863), sur l'entomofaune et l'avifaune du parc naturel Te Faaiti, Tahiti. Rapport final. Direction de l'Environnement, Polynésie française, Tahiti: 72 pp. + annexes.

Resh, V., J. Barnes & D. Craig, 1990. Distribution and ecology of benthic macroinvertebrates in the Opunohu River catchment, Moorea, French Polynesia. International Journal of Limnology 26(2-3): 195-214.

Ris, F. 1909-1919. Collections Zoologiques du Baron Edm. de Selys Longchamps, Catalogue Systematique et descriptif. Libellulinen monographisch bearbeitet. Vol. 1, Fascicule IX(1909): 1-120, Fascicule X(1910): 121-244, Fascicule XI(1910): 245-384; Vol. 2, Fascicule XII(1911): 385-528, Fascicule XIII(1911): 529-700, Fascicule XIV(1912): 701-830; Vol. 3 Fascicule XV(1913): 837-964, Fascicule XVI, part 1(1913): 965-1042, Fascicule NVI, part 2(1919): 1043-1278.

Riviere, F. & F. Pichon, 1979. Observation sur la faune terrestre de l'atoll de Scilly. In: Salvat, B. Scilly, atoll de larchipel de la Société, Polynésie française, compte-rendu préliminaire d'une expedition scientifique interdsciplinaire et interorganisme en janvier 1979. MNHN, Antenne de Tahiti, Bulletin n 1: 67-71.

Roderick, G. & R. Gillespie, 2016. Arthropodes terrestres des îles Marquises: diversité et evolution. In: Galzin, R., S.-D. Duron & J.-Y. Meyer, (eds). Biodiversité terrestre et marine des îles Marquises, Polynésie française. Société française d'Ichtyologie, Paris: pp. 391403.

Schmidt, E., 1938. Check-list of Odonata of Oceania. Annals Entomological Society

of America 31: 322-344.

Selys, E., 1857. Odonates de Cuba. In: Sagra, R., (ed.) Histoire Physique, Politique et Naturelle de l'Ile de Cuba 7: 436-471.

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

Selys, E., 1876. Synopsis des Agrionines, 5me Igion: Agrion (suite). Le grand genre Agrion. Bulletins de L'Académie Royale des sciences, des lettres et des Beaux-Arts de Belgique 41(2): 247-539.

Talandier, J., 1993. Le volcanisme et la sismicité. Planches 26-27. In: Dupon, J.F. (ed). Atlas de la Polynésie française. Editions de l'ORSTOM, Paris.

Tanret, D., F.A. Jacq, J.-F. Butaud, 2011. Étude relative au classement de la baie de 'Opunohu en espace naturel protégé, plan de paysage de 'Opunohu. Rapport final. Direction de l'environnement, Polynésie française: 218 pp. + annexes.

UICN France 2016, Profil d'écosystèmes de la Polynésie Française – Région Pacifique. 2016. Union européennes Régions Ultra-pèriphériques et Pays et Territoires d'Outre-mer, Eleonora Avagliano & Flora Artzner; BEST, contract de service 07.0307.2013/666363/SER/B2, Commission Européenne, 2016: 224 pp. + annexes.

Vick, G. & A. Davies, 1988. A new species of *Ischnura* from New Caledonia (Zygoptera: Coenagrionidae). Odonatologica 17(3): 281-287.

Walker, E., 1958. The Odonata of Canada and Alaska. Volume 2. University of Toronto Press, Ontario: 318 pp.

Watson, J. & A. O'Farrell, 1991. Odonata (dragonflies and damselflies). In: Naumann, I., P. Carne, J. Lawrence, E. Nielsen, J. Spradbery, R. Taylor, M. Whitten & M. Littlejohn, (eds.), The insects of Australia. 2nd Edition. Melbourne University Press, Melbourne: pp. 294–310.

Whittaker, R. & J. Fernández-Palacios, 2009. Island Biogeography. Ecology, evolution, and conservation. Second Edition. Oxford University Press, Oxford: 401 pp.

Whitehouse, F. & E. Walker, 1941. British Columbia Dragonflies (Odonata), with notes on distribution and habits. American Midland Naturalist 26(3): 488-557.

Whitehouse, F., 1939. Notes on some tropical dragonflies. Canadian Entomologist 71: 199-202.

Wise, K., 1980. Records of South Pacific dragonflies (Hexapoda: Odonata). Records of the Auckland Institute and Museum 17: 175-178.

Zimmermann, E., 1948. Insects of Hawaii. Volume 2 Apterygota to Thysanoptera Inclusive. University of Hawaii Press, Honolulu: 485 pp.

Appendix

Table I. Chronological literature review of Odonata records from Society Islands.

No	Verbatim species	Valid species name	Verbatim locality	Page	Reference
1	*Libellula flavescens*, Fabr.	*Pantala flavescens* (Fabricius, 1798)	Taiti	442	Selys (1857)
2	? *Gynacantha* sp. ?	*Anaciaeschna jaspidea* (Burmeister, 1839)	Taiti	161	Brauer (1864)
3	*Pantala tillarga* Fbr.	*Tholymis tillarga* (Fabricius, 1798)	Taiti	162	Brauer (1864)
4	*Libellula* (*Diplax*) *bipunctata* nov. sp.	*Diplacodes bipunctata* (Brauer, 1865)*	Taiti	504	Brauer (1865a)
5	*Agrion* (*Ischnura*) *Aurora* n. sp.	*Ischnura aurora* (Brauer, 1865)*	Taiti	510	Brauer (1865a)
6	*Hemicordulia oceanica*	*Hemicordulia oceanica* Selys, 1871*	Ile de Tahiti	251	Selys (1971)
7	*Ischnura taitensis*, de Selys	*Ischnura taitensis* Selys, 1876	Ile de Tahiti	279	Selys (1876)
8	*Anax gibbosulus*	*Anax guttatus* (Burmeister, 1839)	Lake Vahiria, Tahiti	153	Cheesman (1927)
9	*Ischnura cardinalis*	*Ischnura cardinalis* Kimmins, 1929*	N. Raiatea	224-225	Kimmins (1929)
10	*Tramea limbata*	*Tramea transmarina* Brauer, 1867	Lake Vahiria, Tahiti	22	Needham (1935)

Table II. Prenodal index (Prn) values for selected Pacific Zygoptera genera and species.

Taxa	Min	Max	Average	N
Ischnura	1,00	1,39	1,16	33
Pacificagrion	1,13	1,25	1,19	4
Pseudagrion	1,12	1,34	1,23	24
Ischnura taitensis	1,19	1,31	1,25	2
Ischnura cardinalis	1,22	1,43	1,31	18
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 III. 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 cardinalis	1,22	1,43	1,33	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
Ischnura	1,17	1,67	1,38	33
Ischnura taitensis	1,38	1,61	1,50	2

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