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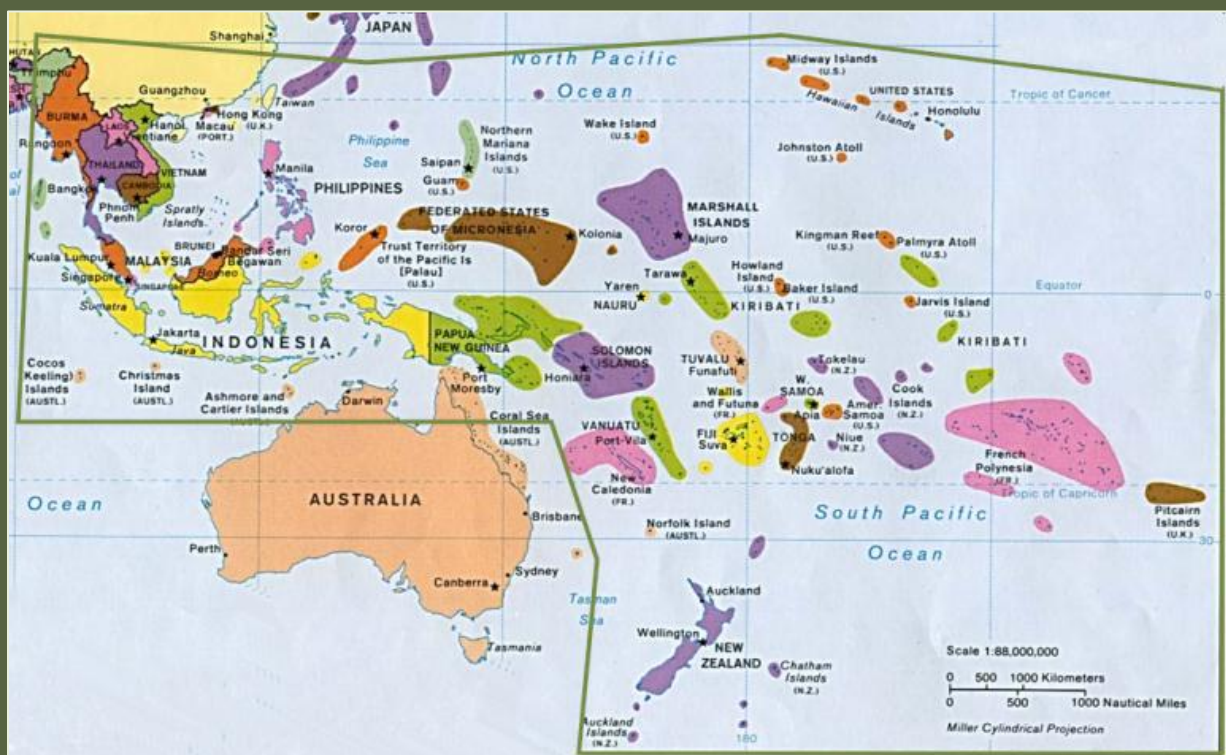
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Pacific Islands comprise of Micronesian, Melanesian and Polynesian Islands.



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Contribution to the Odonata of the Kingdom of Tonga

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Abstract

New data on the Odonata fauna of the Kingdom of Tonga is provided following research carried out on Tongatapu and 'Eua islands in July 2012. New localities for Tongatapu Island are put on record and previous studies are compared with new phenological data from a period during which field surveys are rarely conducted on Pacific islands. Although Odonata have been collected before from 'Eua Island, the data presented here is the first published so far.

'Eua Island is assessed as a very important venue for further research on Odonata. Overall the Kingdom of Tonga is very depauperate in water resources with lotic biotopes very restricted in area and found on 'Eua Island, and possibly on Tofua and Late islands, which are both volcanic. This study on the Odonata of 'Eua resulted in records of eight taxa, including with *Teinobasis* sp. nov., which will be described elsewhere.

Morphological variation in *Pseudagrion microcephalum stainbergerorum* and *Tramea transmarina* are discussed in the context of their subspecific affiliation. Diagnostic features for easier differentiation are proposed for the first of these taxa; the validation of commonly used diagnostic traits is discussed for the second.

Key words: Dragonflies, Odonata, Kingdom of Tonga, 'Eua Island, Tongatapu Island

Introduction

Marinov (2012) provided the most recent update on the Odonata of the Kingdom of Tonga, with a thorough inventory of the known fauna including taxonomic notes and new additions to the country species list, and suggestions for future studies. The general conclusion was that the Odonata of this Pacific archipelago has been inconsistently studied and the knowledge of its odonate fauna is still in its infancy. So far all studies have been based on opportunistic sampling; no systematic research has



been carried out. Marinov (2012) listed 16 species, with the expectation that this number would increase should faunistic studies be performed over the whole year and in new areas. 'Eua Island was pointed out as a potential site of high significance because it has running water habitats, and is isolated from other islands with lotic habitats. Marinov (2012) did not consider Tofua Island (Ha'apai group), which has a large volcanic lake and possibly streams that may be of interest for Odonata. However, this island is non-inhabited and poses logistic problems with transportation. Late Island (Vava'u group) might be another option for interesting odonatological discoveries (Donnelly, per. comm.).

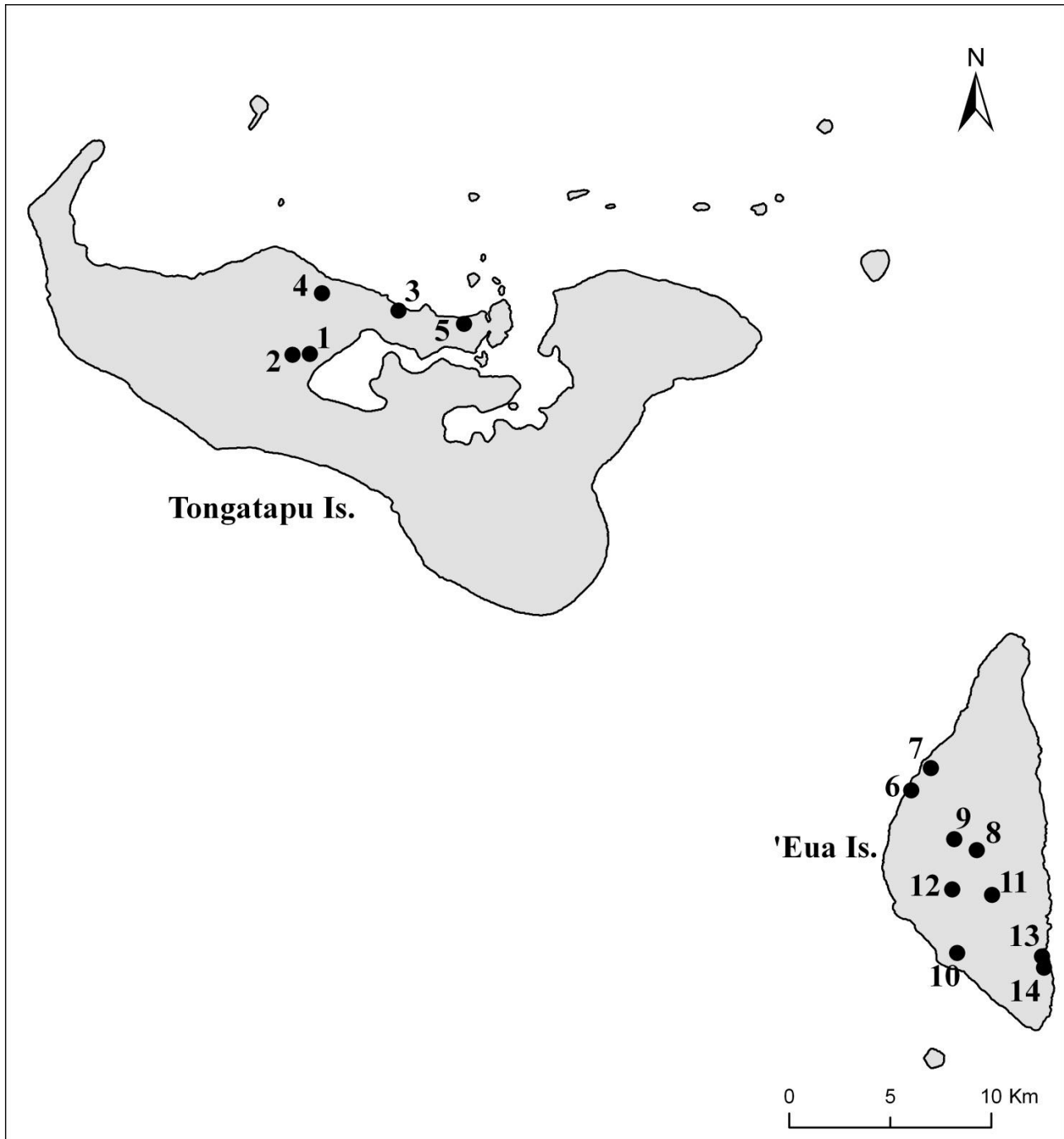


Figure 1. Sampling locations on Tongatapu and 'Eua Islands.



For these reasons, 'Eua Island was selected as a study area for the next step in Odonata research of the Kingdom of Tonga. This is the first time the island has been investigated for its odonates. As well as new faunistic observations, the study was planned to collect more data on species phenology from this poorly known area.

Material and Method

For a detailed geographic description and maps of the region see Marinov (2012).

In this study the Odonata of the Kingdom of Tonga were studied only on the Tongatapu island group (Fig. 1). Two islands (Tongatapu and 'Eua) were visited between 11th July and 19th July, 2012. The time was deliberately selected to be outside of the intensive samplings within the Pacific which have usually been carried out between November-March. A better understanding of species phenology was sought in order to outline the seasonal activity patterns.

Sample sites below are presented with the coordinates as measured on the field. These coordinates are not completely accurate; When plotted on Google Earth some coordinates appeared about 230-240 m S-SW from the actual sampling place. For this reason some descriptive text is provided to aid in finding the sites.

Tongatapu Island

1. Concrete pool at "Toni's guest house" backpacker site, Tofua (21.1573°S; 175.2313°W; 27 m a.s.l.): 11 July 2012.
2. Secondary road W from "Toni's guest house" backpacker site in Tofua (21.1578°S; 175.239°W; 38 m a.s.l.): 18 July 2012.
3. Nuku'aofa waterfront (21.1381°S; 175.1919°W; 0 m a.s.l.): 11, 13, 19 July 2012.
4. Mangrove between the villages Hofua and Sapu (21.1303°S; 175.2259°W; 12 m a.s.l.): 11, 12, 19 July 2012.
5. Mangrove about 3,150 m E from Nuku'alofa waterfront (21.1439°S; 175.1628°W; 0 m a.s.l.): 12 July 2012.

'Eua Island

6. Roadside between Ohonua and Hideaway Resort about 860m N from Hideaway Resort (21.3514°S; 174.9637°W; 18 m a.s.l.): 13 July 2012.
7. River by Ohonua (21.3416°S; 174.9549°W; 0 m a.s.l.): 13 July 2012.
8. Stream within the 'Eua National Park & plantation borders (21.3781°S; 174.9346°W; 175 m a.s.l.): 14 July 2012.



9. Puddle on the road about 1,200 m NW from the 'Eua National Park & plantation (21.3732°S; 174.9446°W; 112 m a.s.l.): 14 July 2012.
10. Roadside between Ohonua and Rock Garden formation at the SE part of the island about 50 m after the junction to Ha'aluma beach (21.4237°S; 174.9433°W; 57 m a.s.l.): 15 July 2012.
11. Forest road about 1,900 m E/SE from "Taina's Place" backpacker site (21.3979°S; 174.9278°W; 226 m a.s.l.): 16 July 2012.
12. "Taina's Place" backpacker site (21.3955°S; 174.9455°W; 127 m a.s.l.): 16-17 July 2012.
13. Vaiangina spring (21.4253°S; 174.9056°W; 111 m a.s.l.): 17 July 2012.
14. Forest road about 540 m S of Vaiangina Spring (21.4304°S; 174.9046°W; 88 m a.s.l.): 17 July 2012.

Here Locality 1 from Marinov (2012) is split in two and given as Localities 1 and 2. This is to emphasise on the importance of the second site. The top of the secondary road listed above attracted various species which were observed in both studies.

Localities 3 and 4 were the only others that were resampled; the rest were new study sites for Odonata in Tonga.

Results

Commented species check-list

COENAGRIONIDAE

Agriocnemis exsudans Selys, 1877

Localities: 1, 3 (11 July), 4 (12 July), 8, 9, 11.

Mostly immature individuals were encountered on Tongatapu and only mature ones on 'Eua Island.

Ischnura heterosticta (Burmeister, 1839)

Localities: 4 (12, 19 July).

Mainly mature individuals.

Pseudagrion microcephalum stainbergerorum Marinov, 2012

Localities: 4 (12 July).

Six males and one female were collected from the type locality and compared with the specimens from the type series for any variation. The most significant differences were established in the colouration of the head. These are illustrated on Fig. 2 for the new specimens in comparison with the type specimens and six other *P. m. micro-*

cephalum (Rambur, 1842) males collected from Guadalcanal, Solomon Islands (the precise data on localities and dates will be published separately). Figure 2 shows two extremes in the colourations of the head in the representatives of the two subspecies: *P. m. stainbergerorum* (type specimens collected in April vs new specimens collected in July) and *P. m. microcephalum* (collected in April). The three spots at the posterior edge of postclypeus were found to be of no taxonomic importance because they vary greatly with almost every specimen with its own arrangement of the black areas. The most crucial point of distinction was in the composition of the two black semi-oval spots on the anterior bases of lateral ocelli in conjunction with the transverse bar behind the lateral ocelli and the shape of the blue occipital spots (cf. description of the holotype male). April *m. stainbergerorum* specimens have a characteristically reduced black area on the head in comparison to the July ones. The later has the black bar behind the lateral ocelli connected with the two semi-oval spots. The black area runs towards the bases of the antennae and also cuts off the outer corners of the occipital spots, which keep the typical trapezoidal shape with no forward pointing projections. In contrast, all *m. microcephalum* examined have occipital spots with stout outer projections nearly connected with the blue area on the epicranium and in all but one specimen the black bar behind the lateral ocelli was interrupted at the level of both lateral ocelli.

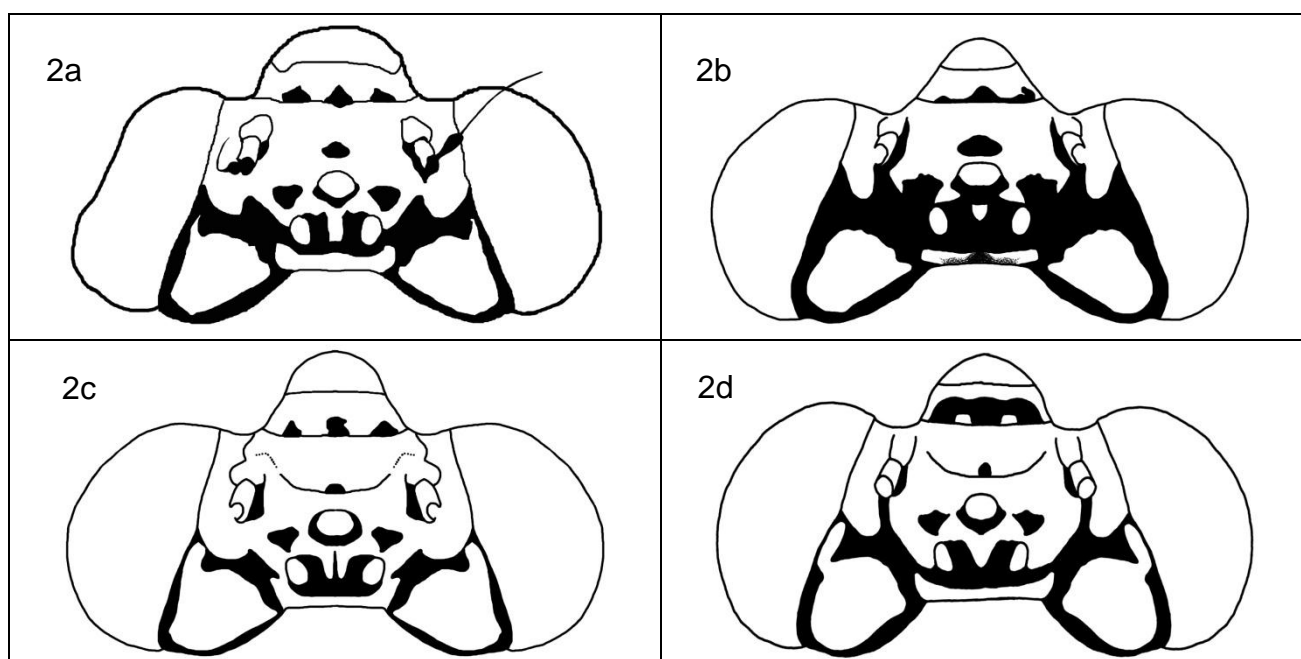


Figure 2. Colour variations of the heads of: (a) *P. microcephalum stainbergerorum* (Tongatapu-April); b) same (Tongatapu-July); (c)-(d) *P. m. microcephalum* (Solomon Islands).

Figure 3 compares the abdomens of both subspecies. It uses the original drawings presented in Fig. 5 in Marinov (2012). No significant variation were observed in the newly collected specimens of both subspecies. The spear-like dark spots on S3-4 are



consistently narrower in *m. microcephalum* compared to *m. stainbergerorum*. Also the dorsum of S10 in *m. stainbergerorum* is always entirely black while in *m. microcephalum* the lateral blue markings extend dorsally, but do not join on the top. This feature again could be variable because one *m. microcephalum* has the blue area largely reduced.

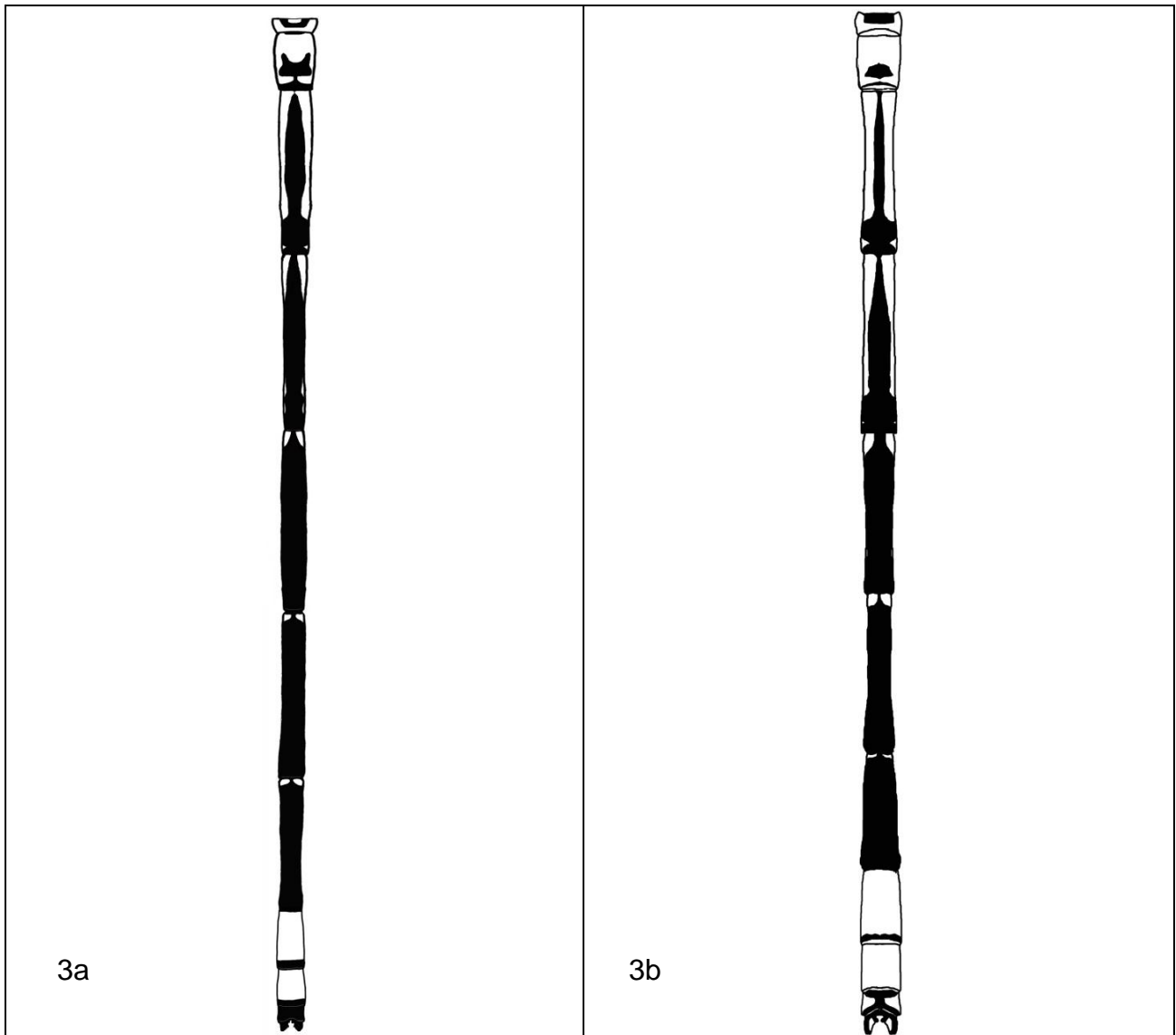


Figure 3. Comparison between the abdominal colour pattern of: (a) *P. microcephalum stainbergerorum*; (b) *P. m. microcephalum*.

Figure 4 compares the two inner teeth of the superior appendages of both subspecies. The shape is consistent in all *m. stainbergerorum* specimens (both April and July ones) and differs from all *m. microcephalum* from the Solomon Islands. In *m. stainbergerorum* they are larger, well aligned and with a greater distance between them compared to *m. microcephalum*. The later subspecies had both teeth pointed up, very close each other and the proximal tooth situated slightly below the distal one (cf. both dorsal and dorso-lateral views).

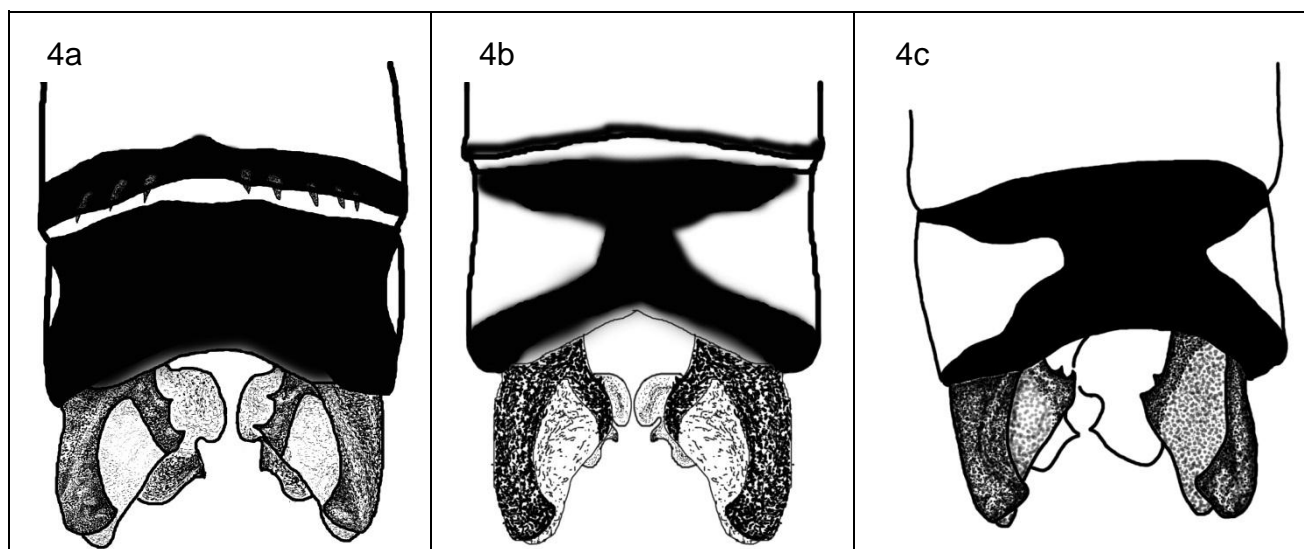


Figure 4. Comparison between the superior appendages of: (a) *P. microcephalum stainbergerorum* (dorsal view); (b)-(c) *P. m. microcephalum* (dorsal and dorso-lateral views respectively).

The female *m. stainbergerorum* will be described elsewhere. In view of the morphological variation demonstrated here for the males, one must be careful as to what the typical distinguishing features of the female *m. stainbergerorum* might be in order to differentiate it from *m. microcephalum* and other closely related species, such as *P. pacificum* Tillyard, 1924 and *P. samoense* Fraser, 1925. Because of a lack of sufficient material for comparison, the description of the female will be postponed for now.

Teinobasis sp. nov.

Localities: 8.

A morphological description, habitat data and behavioural notes of this new species will be published separately.

AESHNIDAE

Anax guttatus (Burmeister, 1839)

Localities: 4 (19 July).

Although the site was visited three times, males patrolling territories were active on the last occasion only, when the air temperature had risen to about 30°C.

CORDULIIDAE

Hemicordulia hilaris Lieftinck, 1975

Localities: 2.

This is the second record of the species from this locality after Marinov (2012). This site is on the top of a road with no wetlands visible nearby.



Hemicordulia sp.

Localities: 11.

One individual patrolling over a forest road was seen, but not collected. Therefore its correct species affiliation cannot be established.

LIBELLULIDAE

Diplacodes bipunctata (Brauer, 1865)

Localities: 2, 3, 4, 9.

A very common species in all localities, with both immature and mature individuals encountered.

Lathrecista a. asiatica (Fabricius, 1798)

Localities: 4 (11 July), 11, 14.

Observations were mostly made of single individuals perched on dead twigs in areas with mixed shade. On only one occasion the insect was established above the water (locality 4).

Pantala flavescens (Fabricius, 1798)

Localities: 2, 3, 7, 10.

This was the most common species everywhere on the islands. The few localities given here are for the main places where assemblages were encountered, however, single individuals were observed on a number of occasions.

Tholymis tillarga (Fabricius, 1798)

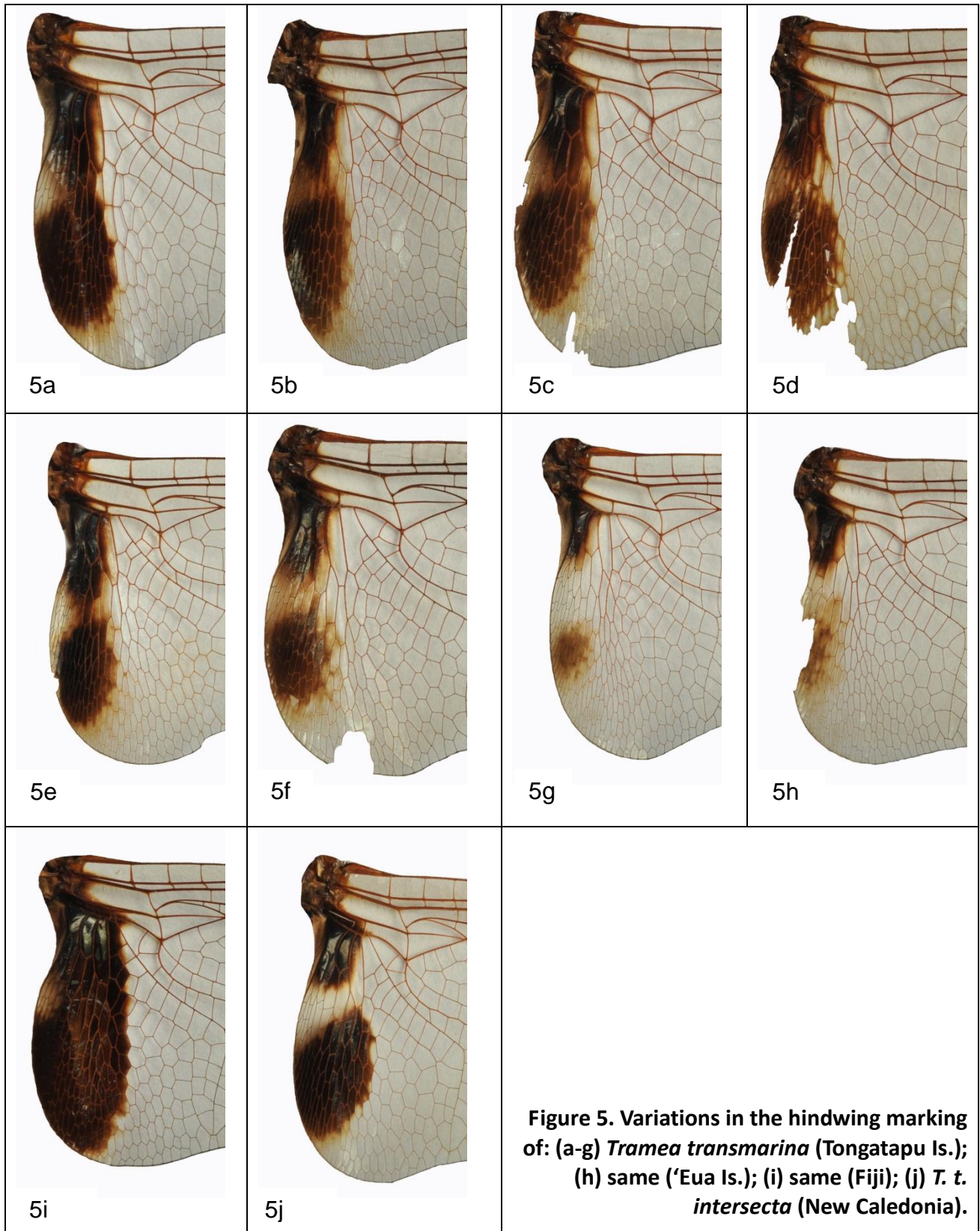
Localities: 4 (12 July), 5, 7, 11, 12.

This was another common species on both islands. Individuals were mostly active in dawn, with a single observation of a female flying earlier.

Tramea transmarina Brauer, 1867

Localities: 2, 3, 4 (19 July), 6

All eight males collected from both Tongatapu and 'Eua Islands were consistent with the morphological characteristics given in Brauer (1867). As the original description was based on a holotype female, an additional comparison was made involving male specimens identified as *T. transmarina* (T. Donnelly det.), which were collected from Fiji (the origin of the holotype). Variation was observed in the shape and extent of the dark spot at the bases of the hind wings. As this feature is among the important taxonomic characteristics that have been used for species/subspecies distinction all variations were illustrated and compared to conspecific from Fiji and New Caledonia (Fig. 5).



Discussion

One of the objectives of the present study was to gather the first ever information on the Odonata fauna of 'Eua Island, Tonga. This small island exceeded initial expectations.



A total of eight taxa were recorded, although for half of them no suitable reproductive habitats were visited. Adult *P. flavescens*, *T. transmarina*, *L. a. asiatica* and *Hemimcordulia* sp. were encountered flying at various locations with no wetlands that meet larval requirements available nearby. According to local people ponds and marshes are scarce on the island and difficult to access. Moreover they are usually on private land so any study must be negotiated with the landowners. Thus a local guide is required, something which can be arranged, but requires preliminary contacts and communication with the right people. Further study on the Odonata of 'Eua is encouraged and should be planned mainly in two directions: a) Odonata fauna composition, and b) ecological studies of the site given above as Locality 8. Faunistic investigations carried out systematically during the course of a whole year will definitely increase the number of species known and give important information on two interesting topics: distribution and phenology of Pacific island Odonata. The most recent investigation allows for some preliminary comments on these two issues.

Many Odonata have a powerful flight, for this reason people easily ascribe dispersal abilities to them that may not exist (Marinov in press). The hypothesis of long-distance dispersal is widely used in the literature to describe the present day distribution of species. However, as Heads (2012: 404-405) points out, multiple working hypotheses must be considered because the acceptance of one only theory to explain a given phenomenon (island biogeography in particular) could hold up progress for decades.

Teinobasis sp. nov. reported here exemplifies this situation. This very delicate species (Fig. 6) was established in a small area within the remnant of rainforest within the borders of 'Eua National Park and plantation. Individuals were flying only around small forested streams (Fig. 7) or near completely shaded wider sections (Fig. 8) and were not found even at the same stream further down where it was flowing through the pine plantation. The here inferred high site attachment must be proved by further ecological research (suggested above), but the preliminary information suggests that the species does not travel to open habitats and prefers the deep shade of the native forests only. A number of other species (*P. flavescens*, *T. transmarina*, *D. bipunctata*, *A. exsudans*, *L. asiatica*, *H. hilaris*), in contrast, have been observed during the two studies at both Nuku'alofa waterfront and along the shore roads on 'Eua Island. This type of behaviour exposes them to the oceanic air fronts that could transport the individuals between the islands. The ferry which operates four days a week between Tongatapu and 'Eua could further facilitate an exchange of species. Mosquitoes and moths were observed trapped onboard of the ferry. They may attract predators like dragonflies which can then easily be transferred on the other shore. However, this is plausible only for species that at various stages of their life leave the larval habitat in search of food or hiding places during maturation. For example, only immature *A. exsudans* were observed at the waterfront on Tongatapu. If it is true that *Teinobasis* sp. nov. shows a high site attachment, then it requires something other than a chance



Figure 6a. *Teinobasis* sp. nov.





Figure 6b. *Teinobasis* sp. nov.

dispersal and founder effect for a small damselfly species to settle nearly 3,000 km away from its closest known relatives in the Solomon Islands. The main distribution of *Teinobasis* is the Australia-Papua New Guinea-SE Asia region, with species occupying the Solomon Islands and Micronesia. A single species *T. alluaudi* Martin, 1896 occurs on the Eastern coast of Africa (Clausnitzer 2003). There are no reliable reports of species from the genus from the island archipelagos in between the Solomon Islands and the Kingdom of Tonga. Therefore the apparent highly disjunctive distribution of *Teinobasis* requires special investigation, involving molecular and morphological comparison of genera *Teinobasis*, *Nesobasis* (endemic to Fiji), *Vanuatubasis* (endemic to Vanuatu), and *Melanesobasis* (Fiji and Vanuatu).

The phenology of Pacific island Odonata is another understudied issue. The current investigation was specially designed to contribute faunistic records from a period which is usually outside of the main research efforts in the region. Generally Odonata species composition did not differ much between April and July. This conclusion is drawn based on the studies within Locality 4, which is the largest wetland on Tongatapu and the only place on the island of high significance for Odonata. *Ischnura aurora* (Brauer, 1865) and *Anaciaeschna jaspidea* (Burmeister, 1839) were the only species

not discovered in July, but found in April (Marinov 2012). The second is famous for its crepuscular life style; in July none of the localities was sampled late in the day, this may well be the explanation of the lack of records. It is not yet clear if the absence of



Figure 7. Type locality of *Teinobasis* sp. nov.





Figure 8. Wider sections of the type locality of *Teinobasis* sp. nov.

I. aurora was due to seasonality. In fact other Zygoptera in the area were much less abundant in July compared to April. In July both *A. exsudans* and *I. heterosticta* adults were found at various stages of maturity, but *P. m. stainbergerorum* individuals were mostly fully mature, with only one teneral discovered. All *P. m. stainbergerorum* individuals were observed perched on leaves of the mangrove fern *Acrostichum aureum* L. during fine weather conditions, which is in contrast to the April data when Marinov (2012) found them during rainy days and only amongst the prop roots of *Rhizophora* sp. What two observations in April and July had in common was the complete lack of larger dragonfly predators, like *A. guttatus* and *T. tillarga*. They were not active in bad weather which included not just the rain, but the lower air temperature (cf. comment of *A. guttatus* above). If there is a clear correlation between the diurnal activities of the species must be established with additional observations. *A. exsudans*, *I. heterosticta* and *I. aurora*, in contrast to *P. m. stainbergerorum*, were very abundant in April in spite of the high activity of *A. guttatus*.

It is also interesting to note another difference between the April and July *P. m. stainbergerorum* specimens: the variation in the extent of the black area on the head. The transition between the two extremes shown in Fig. 2(a-b) could be achieved by individuals building up dark colour between the bar behind the lateral ocelli and the

two semi-oval spots. One of the specimens from July was intermediate between the two states and a teneral individual (photographed, but not preserved) had a colour pattern typical of April specimens. More material from between April and July, and from other parts of the year, is needed to understand this variation because it infers a very long life-span for the imago. This variation makes subspecies separation difficult because obviously no particular colour pattern can be pointed out as typical of one subspecies and not found in the other. In fact, the abdominal pattern seems to be different in the two subspecies, with *m. microcephalum* having the dark spear-like markings narrower. Blue occipital spots in all studied *m. microcephalum* had stout outer projections, while in *m. stainbergerorum* the same were either very weak (April specimens) or completely lacking (July specimens). Those features may help in subspecies differentiation to a certain point, but because of the overall high colour variability, one must search for structural characters for precise identification. Marinov (2012) made a short comment on the distinction between subspecies based on the shape of the male superior appendages, but did not go further because the specimens from the *m. stainbergerorum* type series were compared with one *m. microcephalum* only. What was hypothesised to be a difference due to the preservation method – “... shrunk and concave to a larger extent than what is supposed to be normal.” – in the single *m. microcephalum* specimen, now was found to be consistent with all new specimens from the Solomon Islands. Therefore this difference is treated here with a special attention and proposed for reliable subspecies differentiation. Both dorsal and dorso-lateral views on Fig. 4 show larger teeth in *m. stainbergerorum* than in *m. microcephalum*. They are also well aligned with a larger distance between them compared to *m. microcephalum*. The later subspecies had both teeth pointed up, very close each other and the proximal tooth situated slightly below the distal one.

Colour variation in other species inhabiting the country is another issue that must be considered very carefully. The list of *Tramea* species/subspecies introduced based on the basis of the shape and size of the dark area at the bases of the wings is really very long. However this feature was found to be very variable and not useful for identification of *Tramea* from the Kingdom of Tonga. The colour variation could be the reason why two species have been recorded for the country while at the same time only one has been discovered during the two recent studies. Marinov (2012) reported *T. limbata* (Desjardins, 1832) referring to Fraser (1927). He also suggested that *T. limbata* could be another subspecies of *T. transmarina*. Such a statement is worth exploring further because *T. transmarina* is so far the only species from the genus confirmed for the country after the two recent field samples. Whether Tongan specimens should be assigned to a separate subspecies and if *limbata* is the proper name to accommodate it are two separate issues. According to Mahlendorf & Martens (2004), the range of *T. limbata* includes sub-Saharan Africa, the southern Arabian Peninsula, India, Nepal, Maldives, Chagos and Seychelles. Tarboton & Tarboton



(2002) lists it from South Africa with an extralimital distribution including Madagascar. However, *T. limbata* has been reported many times for the Pacific islands too: Mariana Islands (Ris 1909-1919; Asahina 1940; Schmidt 1941; Swezey & Williams 1942) and other Micronesian islands within the Caroline and Marshall groups (Asahina 1940); New Caledonia (Ris 1909-1919, 1915; Kimmins 1953; Davies 2002); Vanuatu (Kimmins 1936, 1958); Fiji (Tillyard 1924); Samoa (Ris 1909-1919; Fraser 1925, 1927); and French Polynesia (summarised in Dommaget & Marshaal 2000 and Meurgey 2004). It is possible that some of those records come from misidentified specimens, however if that is the case and how many of them were mistaken with *limbata*, are two questions that cannot be answered at the moment. It is evident that the true taxonomic status of *Tramea* from the Pacific must be established in a thorough phylogenetic study set in a much broader geographical context. Also any further identification of *Tramea* species must include structural characters rather than merely colour features.

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