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THE ODONATA OF THE PACIFIC OCEAN ISLANDS OF WALLIS AND FUTUNA, WITH SPECIAL REFERENCE TO SPECIATION IN *ISCHNURA AURORA* (BRAUER)

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A collection of adult specimens made during a hydrobiological mission (5-23 Oct. 2004) to the French Pacific Island Territories of Wallis and Futuna is studied. It constitutes the first odon. inventory from this archipelago, and is composed of 10 spp. (8 Anisoptera, 2 Zygoptera), all of which were known from the Pacific before. Pacific island material of *Ischnura a. aurora* (Brauer, 1865) is compared with specimens from the western part of the range of this species. These represent a good ssp., *I. a. rubilio* Selys, 1876. Furthermore, 2 new synonyms of *I. aurora* are proposed.

INTRODUCTION

The main objective of the hydrobiological survey that permitted one of us (N.J.M.-S.) to gather the present odon. collection was to improve our knowledge on the biota of the hydrosystems of Wallis and Futuna, with an aim at conservation and rational management of the aquatic resources of these islands. In a broader perspective, the evaluation of the biodiversity of the islands may contribute to the ongoing debate on insular evolution.

Previous studies on Odonata in the geographic sector of Wallis and Futuna have dealt with the island group of Samoa, situated 375 km further to the East (DONNELLY, 1986; FRASER, 1925, 1926, 1927, 1953), and the Fiji archipelago, 300 km to the South-East (DONNELLY, 1984, 1990; TILLYARD, 1924). The only previous citation of a dragonfly from Wallis, *Rhyothemis regia chalcoptilon* Brauer, was by LIEFTINCK (1962).

Ten species have been recorded during the present survey; one of the two zygopterans involved, *Ischnura aurora* (Brauer), was subjected to a broader geographic scrutiny.

THE ENVIRONMENT

NATURAL AQUATIC ENVIRONMENTS: RIVERS AND LAKES – The archipelago of Wallis and Futuna, situated in the centre of the Pacific, is composed of three main islands, organized in two groups: Wallis (77.5 km^2), and Futuna and Alofi (64.5 km^2), with a gap of 230 km between both. The islands are volcanic but have had a different history and therefore developed different characteristics. Wallis is devoid of running surface water due to the extreme permeability of its soils and a weak relief (highest point 151 m). Several lakes occupy depressions (Kikila, Alofivai) and craters (Lalolalo, Lano, Lanutavake) in the landscape. The surface of some is below sea-level. Futuna and Alofi have a more pronounced relief. Futuna is about 20 km long, and 5 km wide at its broadest; a longitudinal mountain chain culminates at 524 m. Its slopes are cut down into valleys by numerous short, permanent rivers. In addition, freshwater springs appear at low tide on the littoral platform that encircles the island. Alofi is separated from Futuna by a narrow sea-strait, 1.8 km wide. This small island, without permanent surface water, but on which infiltrated rain-water reappears as springs near the shores (ANGLEVIEL et al., 1994), was not explored by us.

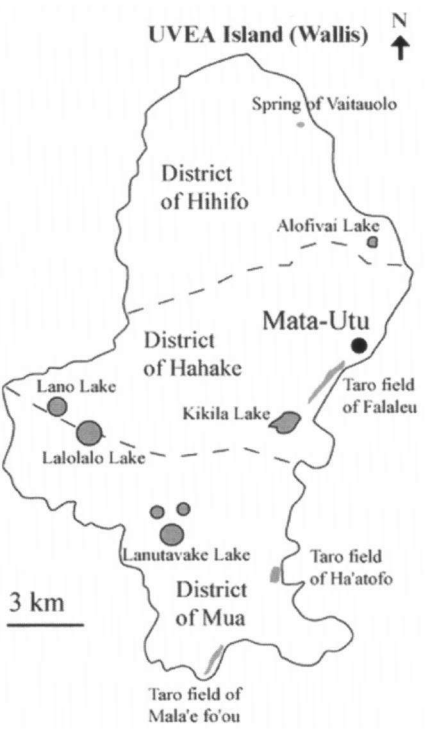


Fig. 1. Map of Wallis, showing the hydrographic network and all localities visited.

ARTIFICIAL ENVIRONMENTS: THE TARODIÈRE WETLANDS OF WALLIS AND FUTUNA – On Wallis, taro fields (tarodières, in French) are wetlands situated in depressions where the groundwater table intersects the surface. They cover about 50 hectares and are situated between the littoral and the first slopes. On Futuna, taro fields occupy over 70 hectares, and are irrigated. They occur at the bottom of valleys and narrow terraces up to 120 m asl and in alluvial plains. They are regularly and permanently flooded, water forming a sheet of 5-10 cm thickness (MALAU et al., 1999).

CLIMATE – Wallis and Futuna are situated close to the equator, in the centre of the Pacific Ocean. The climate is warm (27°C on average on Wallis, 26°C on Futuna), humid, and subject to tropical cyclones. The yearly temperature amplitude is extremely low (1°C). Rain-

fall is abundant (over 3 m in 260 days on Wallis, and up to 4 m on Futuna). There is significant seasonal variation, and, even in the absence of a true dry period, a strong rainy season occurs between October and May. The wettest month on Wallis is December, at which time three times more rain falls than during August (ANGLEVIEL et al., 1994). Our dragonfly collections were made in the period immediately preceding the strong rains, viz. 5-23 October 2004.

METHODS AND LOCALITIES

In all, 24 sites (rivers, lakes, and taro fields) were visited. Larvae (not further dealt with in this paper) were collected using a Surber net, adults by means of a butterfly net. All material was conserved either in ethanol 70%, or dried in papers, and deposited with ETHYCO (Corneilla del Vercol, France). Adult dragonflies were caught at exactly half (12) of the sampled localities.

On Wallis (Fig. 1: map) the following 9 localities were sampled: the lakes Kikila, Alofivai, Lanutavaké, Lalolalo and Lano; the taro fields of Ha'atofo, Mala'efo'ou and Falaleu, and the freshwater spring of Vaitauolo, close to the coast.

On Futuna (Fig. 2: map), 15 localities were visited: lake Nuku ; the taro fields of Leava, and Sausau; and the rivers Vainifao (lower, middle and upper courses), Galoli (middle course), Leava (lower and middle courses), Vailasi (middle course), Gutavai (lower course), Sofala (lower course), Sausau (lower and middle courses), and Vainui (lower course).

Table I
List of dragonfly-yielding localities on Wallis and Futuna

Localities	Date	CoordinatesGPS (WGS 84)
Wallis		
(1) Lanutavake lake	5-X-2004 and 6-X-2004	S 13.32301 ; W 176.21430
(2) Kikila lake	6-X-2004	S 13.29470 ; W 176.18918
(3) Lalolalo lake	7-X-2004	S 13.29922 ; W 176.23585
(4) Taro field of Ha'atofo	7-X-2004	S 13.32581 ; W 176.19127
(5) Alofivai lake	8-X-2004	S 13.25798 ; W 176.17020
(6) Taro field of Falaleu	9-X-2004	S 13.28586 ; W 176.17954
Futuna		
(7) Dam in Vainifao River	12-X-2004	S 14.29546 ; W 178.14038
(8) Taro field of Leava	14-X-2004	S 14.29329 ; W 178.15872
(9) Dam in Sausau River	18-X-2004	S 14.28506 ; W 178.16482
(10) Taro field of Sausau	19-X-2004 and 21-X-2004	S 14.28852 ; W 178.16758
(11) Nuku lake	20-X-2004	S 14.28183 ; W 178.15478
(12) Vainui River (lower course)	23-X-2004	S 14.25474 ; W 178.15245

LIST OF THE SPECIES AND THEIR RECORDS

Numbers refer to localities as stated in Table I. Specimens collected are given in brackets.

Zygoptera
Coenagrionidae
Ischnura aurora (Brauer, 1865): (8 ♂, 6 ♀): **2, 4, 8, 10, 11**
Agriocnemis exsudans Selys, 1877: (2 ♂): **4**

Anisoptera
Libellulidae
Diplacodes bipunctata (Brauer,1865) (24 ♂/♀): **8, 10, 11, 12**
Orthetrum sabina (Drury, 1770) (1 ♂): **5.**
Pantala flavescens (Fabricius, 1798) (2 ♂): **5, 9.**
Rhyothemis phyllis dispar Brauer, 1867 (1 ♂): **2.**
Rhyothemis regia chalcoptilon (Brauer, 1867): (6 ♂): **1, 2, 3.**
Tholymis tillarga (Fabricius, 1798): (2 ♂): **1, 6.**
Tramea transmarina Brauer, 1867 (1 ♂, 1 ♀): **5, 7.**

Aeshnidae
Anax guttatus (Burmeister, 1839) (1 ♂): **1.**

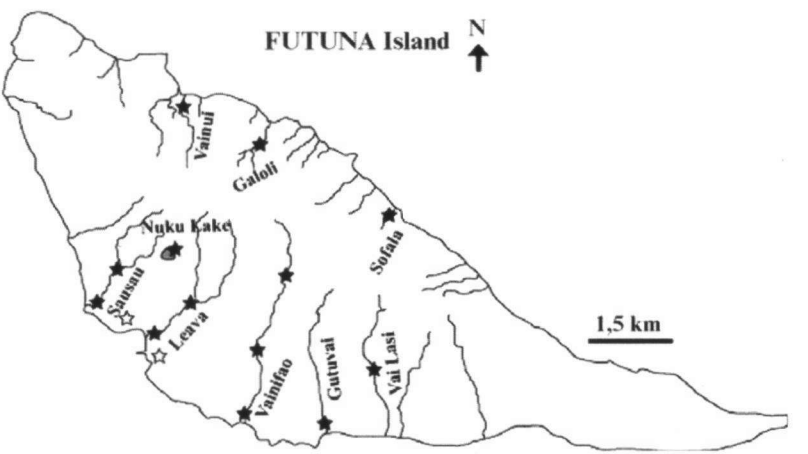


Fig. 2. Map of Futuna, showing the hydrographic network and all visited localities. Black stars represent the sampling sites in rivers and streams; open stars are taro fields.

DISCUSSION

Not unexpectedly in view of its geographic situation, the odonate fauna of Wallis and Futuna is largely congruent with that of the archipelagoes of Samoa and Fiji, and no endemic species were discovered.

The zygopterans amount to only 20% of the total fauna, in stark contrast with the fauna of Samoa, where half of the dragonfly richness is due to zygopterans, and Fiji, where the genera *Melanesobasis* and *Nesobasis* are represented by not less than 29 taxa.

Among the anisopterans, *Pantala flavescens* is a true world-dweller, found on all continents with the near-exception of Europe, and known from almost every Pacific island between Australia and South America, including even Easter Island (DUMONT & VERSCHUREN, 1991).

Orthetrum sabina, *Tholymis tillarga* and *Diplacodes bipunctata* occur in Africa, Asia and Australia, but seem to reach their eastern limit of extent on the South Pacific archipelagoes Fiji, Wallis-Futuna and Samoa (TSUDA, 2000). *D. bipunctata* is the species most abundantly observed in our study, while *O. sabina* appears to be relatively uncommon. According to LIEFTINCK (1962), the range of these three libellulids covers the entire Pacific basin.

Anax guttatus, extending across the Indian Ocean, Asia, and Australia definitely reaches its limit of eastern extent on Wallis, Futuna, and Samoa.

The nominal *Rhyothemis p. phyllis* (Sulzer) occurs in continental and insular southeastern Asia and reaches Japan. The subspecies, *R. p. dispar*, described from Fiji, extends to Wallis and Futuna.

Similarly, the nominal *Rhyothemis r. regia* Brauer occurs in most of the insular southeastern Asia (Indonesia, the Phillipines, Taiwan, Papua New-Guinea) (TSUDA, 2000). That the subspecies *R. r. chalcoptilon*, described from the Samoa archipelago and cited by LIEFTINCK (1962) from the Mariannas, extends to Wallis and Futuna, is therefore only natural.

Tramea t. transmarina Brauer inhabits the Pacific islands, from New Zealand to French Polynesia, including Samoa and Fiji; different subspecies occur in Australia, continental SE Asia, and in Japan.

Agriocnemis exsudans, shows a comparatively restricted geographic range, and is restricted to a limited number of island groups of the South Pacific, viz. New Caledonia, Vanuatu, Samoa and Fiji, and the Norfolk Island group (TSUDA, 2000).

Ischnura aurora is a reputed passive disperser, carried over long distances in the aerial plankton. To our surprise, a confrontation of Pacific material, representing the true *aurora*, with material from the western part of its range, revealed a need for the revision of the status of some taxa and populations presented hereunder.

ISCHNURA AURORA AURORA (BRAUER, 1865)

Figure 3

Agrion (Ischnura) aurora: Brauer 1865, p. 510; 1866 p. 56, pl. 1, fig. 12.
New synonyms :
Ischnura spinicauda Brauer 1865, p. 511; 1866, p. 57, pl. 1, fig. 13
Ischnura rhodosoma Lieftinck 1959, p. 220, figs 1, 4

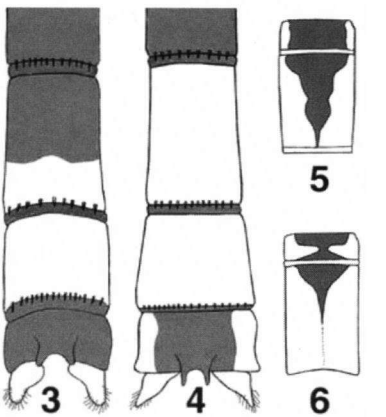
Material. – Wallis and Futuna: Lake Kikila, 6-X-2004, 2 ♂, 2 ♀; Haatofo, 7-X-2004, 2 ♂, 2 ♀; Tarodière Leava, 14-X-2004, 1 ♂, 1 ♀; Tarodière Sausau, 18-X-2004, 1 ♂; 19-X-2004, 1 ♂; Lake Nuku, 20-X-2004, 1 ♂, 1 ♀. – INDIA: Dehra Dun, N. India, 24-III-1999, several males and females (1 male with top of segment 7 narrowly blue); Keoladeo nature reserve, N. India, 21-III-1999, series; Bharadpura River, Kerala, 15-I-1998, series (one male with tip of segment 8 narrowly black); Chennai, Tamil Nadu, VIII-2000, series. – IRAN: Sarbaz River near Sarbaz City, E. Iran, series (some males with blue postocular spots confluent; app. sup. yellow).

I. aurora was described from nine specimens, collected on the Island of Tahiti in the Pacific (BRAUER, 1865, 1866). As often happens, the type locality is all but representative of the species' geographic range, being close to its eastern boundary. The brief original description of 1865 is not illustrated, while only the male terminalia were figured in BRAUER (1866), in a rather "exaggerated way" according to LIEFTINCK (1966). This exaggeration resides in Brauer's representation of the dorsal tubercles of abdominal segment 10, shown as very low and with the two tubercles widely separated, while he pictures the related *spinicauda*, based on a single male, almost exactly as an average *aurora* (see below).

Some authors (e.g. FRASER, 1933; KUMAR & PRASAD, 1981; SUI & SUN, 1984) have used the name *Ischnura delicata* (Hagen, 1858) instead. *Agrion delicatum* is clearly senior, but Hagen failed to produce any description (body size can hardly be considered as such) for his animals from "Rambodde, Bengalia, Nova Hollandia, etc" which, as we shall see, actually represent a mix of two taxa. FRASER (1933) considers Sri Lanka as the *terra typica* of this *Agrion delicatum*, since Rambodde is the first-cited locality. Rambodde (Ramboda), a well-known mountain resort, famous for its waterfalls, is indeed situated in central Sri Lanka, but Hagen also had specimens from Australia (= Nova Hollandia) and possibly other origins, which represent a second (sub)species. SELYS (1876) is responsible for the reinstatement of the name *delicatum*. In the *Synopsis des agrionines*, he offers a detailed description based on specimens from his own rich collection (again representing two taxa), and perhaps from Hagen's collection. He credits Hagen with the authorship, but this is clearly untenable, and LIEFTINCK (1966) and others are undoubtedly correct in considering *Agrion delicatum* Hagen, 1858 a *nomen nudum*, while *Ischnura delicata* Selys, 1876 is a junior synonym of *I. aurora* Brauer, 1865.

The question now arises whether *I. aurora* is homogeneous across its vast geographic range, extending from the Society Islands in the East, over most of the Pa-

cific (BRAUER, 1866; LIEFTINCK, 1962) to the south-east Asiatic continent, India and Pakistan, to Iran in the West (DUMONT & HEIDARI, 1996; HEIDARI & DUMONT, 2002). Our males from Wallis and Futuna share all critical characters with Brauer's original description (in females, no structural differences could be found across the entire range of *aurora*). In particular, the dorsum of segment 8 is partly black, partly blue (Fig. 3), the end rings of segments 2-6, 8, and 9 are black, the blue postocular spots are small and circular, and the dark superior appendages are broadly rounded apically. Brauer explicitely records this mixed colour character of segment 8 in his description, but does the same for *I. spinicauda*, defined after a single male from "Polynesia". The structure of the appendages of the latter by BRAUER (1866, fig. 13) and re-drawn in a more realistic way by LIEFTINCK (1966) are actually more like *I. aurora* than the original illustration of that species by Brauer himself! The only character that SELYS (1876) could find to discriminate *I. spinicauda* from *I. aurora* was the colour of segment 7 (pale, but apically darkened), and the "blue" of segments 8-9 replaced by "purple". Selys added an appendix to his 1876 paper, which was printed in two consecutive volumes of the Bulletin of the Belgian Academy of Science. Between the printing of part 1 (containing the description of *delicata*) and part two, he traveled to Vienna, and re-examined Brauer's Novarra collection, giving him the status of first revisor. We consequently accept his suggestion that the pale colour of segment 7 may either have been an aberration or due to the teneral condition of the specimen. LIEFTINCK (1966) added good figures to the discussion, but failed to conclude that both taxa are conspecific, although he seems to have contemplated the possibility. Not enough was known of individual variability of morphological characters at that time, such as the dorsal tubercles of segment 10, and the shape of the posterior lobe of the prothorax. According to modern standards, *I. spinicauda* should be sunk in the synonymy of the nominal, "dark" form of *I. aurora*. This dark form extends over the entire Pacific, reaching the North Island of New Zealand (ROWE, 1987), Australia and Tasmania (WATSON et al., 1991), and perhaps Taiwan (WANG, 1999) and continental China (SUI & SUN, 1984) where it fails to occur in the southern provinces including Hong-Kong (WILSON, 1995). New Guinea presents a special case (see below), but in the Indonesian ar-



Figs 3-6. Diagnostic features of *Ischnura a. aurora* (Fig. 3) and *I. a. rubilio* (Figs 4-6): (3) *I. a. aurora* from Lake Kikila, Wallis: abdominal segments 8-10 and superior appendages; – (4) same, in *I. a. rubilio* from Sarbaz, Iran; – (5) *I. a. rubilio* from Keoladeo, northern India: abdominal segments 1-2; – (6) same, from Sarbaz, Iran.

chipelago, LIEFTINCK (1959) found *I. aurora* to be rare and to occur in few isolated colonies on the island of Java only. This still applies to Thailand, where *I. aurora* is uncommon and restricted to the northern, hilly provinces (ASAHINA, 1982; HÄMÄLÄINEN & PINRATANA, 1999) and to subtropical China. This reputed "disperser" is actually discontinuous between the two parts of its range, the South-East and the West. Moreover, on some Pacific islands, but especially on New Guinea, a centre of adaptive radiation occurs, where *I. aurora* is in the process of splitting into a number of local taxa (LIEFTINCK, 1959), each confined to a particular mountain habitat. One such melanic isolate has been named *Ischnura aurora viduata* Lieftinck, 1959. One other case, however, *Ischnura rhodosoma* Lieftinck from the Arfak Mountains, Vogelkop Peninsula, seems to be nothing but a larger (abdomen 26 mm) version of *I. aurora*, structurally identical to that species, and deserving subspecific status at best.

In India and Pakistan (FRASER, 1933), including the island of Sri Lanka (DE FONSEKA, 2000), as well as in SE Iran (DUMONT & HEIDARI, 1996), *I. aurora* typically has segment 8 of the abdomen entirely blue dorsally, the blue colour sometimes spilling over to the top of segment 7, while the black spot on segment 10 contracts. The end-rings of segments 1-6 are greyish, and the superior appendages are pale, triangular, and apically pointed (Fig. 4). The black markings on segments 1-2 are also smaller than in eastern populations, but vary according to localities and populations (Figs 5-6), while the postocular spots are larger and sometimes confluent across the occiput. The apical tubercles vary substantially throughout the range, but the modal type is closer to that figured as *spinicauda* by BRAUER (1866) and LIEFTINCK (1960) than that figured by BRAUER (1866) for *aurora* itself.

These "western populations", i.e. West of the gap of the Sunda islands and Indochina-Thailand deserve at least subspecific status, even if we failed to find any distinctive characters in the females. Moreover, a name is available for them: SELYS (1876), in his redescription of *I. delicata*, singles out an Indian specimen as having segment 8 entirely blue, and coins the name *rubilio* for it. The name *rubilio* is not explained, and was found not to exist in classical Latin, but can be construed, by analogy with *pumilio* (a noun, signifying a dwarf), to mean "the red(dish) one", and hence the name of the subspecies should be *Ischnura aurora rubilio* Selys, 1876, as suggested by Selys in the "note additionelle" to his paper.

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