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HABITAT ASSOCIATIONS OF ODONATA IN MOUNTAINOUS WATER SITES IN NORTHEASTERN PORTUGAL

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A total of 19 spp. (9 Zygoptera and 11 Anisoptera) was recorded in a survey carried out at 28 water sites located in the Alvão Natural Park, NE Portugal. Multivariate statistical procedures were used to analyse the relationship between the spp. and the characteristics of their habitat, in order to determine different spp. biotope preferences. Aside from spp. with unspecific habitat requirements, 2 main species assemblages could be detected. *Enallagma cyathigerum, Sympetrum fonscolombeii, S. sanguineum, Ischnura pumilio, Lestes virens* and *Anax imperator* preferred permanent water bodies characterized by high temperatures, while *Calopteryx virgo*, *Pyrrhosoma nymphula*, *Cordulegaster boltonii* and *Onychogomphus uncatus* preferred sites with fast-flowing water characterized by low and moderate temperatures. Conservation strategies should take these patterns and habitat requirements into consideration.

INTRODUCTION

Odonata are among the most important and remarkable arthropods found in freshwater habitats. With origins spanning back some 300 million years, they are the oldest known insects with close to 6000 species identified so far (ASKEW, 1988). However, many species have shown a significant decline in Europe over the last decade and they are included in red lists of threatened species. The destruction of suitable habitats, as a consequence of human activity, habitat fragmenta-

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tion and the drying up of smaller freshwater ecosystems are the common causes of decline. Ecological studies have revealed that Odonata population surveys have been recognised as essential tools in the ecological assessment of aquatic ecosystems, since dragonflies are reliable indicators of biotope health (CORBET, 1993; CLARK & SAMWAYS, 1996, CHOVANEC & WARINGER, 2001, SCHINDLER et al., 2003). Odonata distribution depends on a large number of environmental factors (CORBET, 1999), and the characteristics of the habitat determines which species will appear there (HAWKING & NEW, 1999; GIBBONS et al., 2002; CARCHINI et al, 2005; HOFMANN & MASON, 2005; ROUQUETTE & THOMPSON, 2005; SCHER & THIÈRY, 2005). Thus, the odonate abundance and distribution patterns are a result of the interaction between the species concerned, the physical parameters of the freshwater ecosystems and the interaction with other living organisms. The relationship between Odonata and their habitats has been shown to vary between different geographical and topographical regions (SAHLÉN & EKESTUBBE, 2001). In Portugal, several studies have supplied further information (SEABRA, 1942; AGUIAR & AGUIAR, 1985; MALKMUS, 2002; BEKKER et al., 2004; FERREIRA et al., 2005) and a total of 65 species was so far recorded (FERREIRA et al., 2006). However, field mapping and distribution studies are still in their early stages (FERREIRA et al., 2006). The main goal of the present work was to analyse the relationships between odonate species recorded in the mountainous water sites of the Alvão Natural Park (NE Portugal) and the selected habitat variables using multivariate analysis. This could help to explain the status and biodiversity observed in the Park and help in their future management.
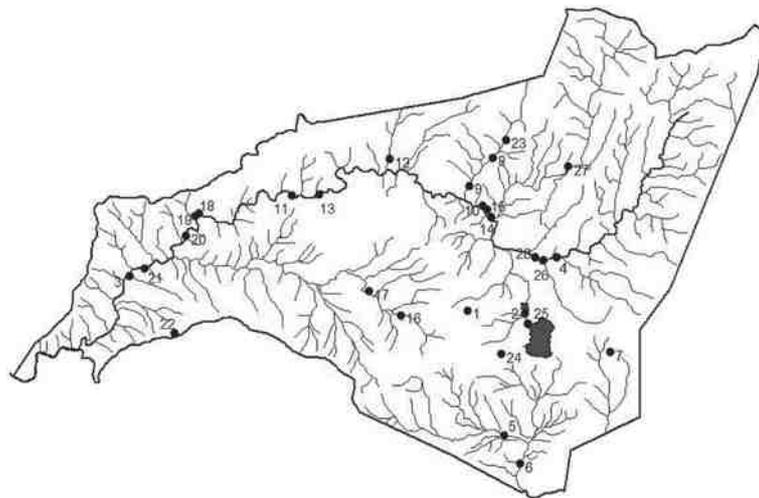
Fig. 1. A map of the Alvão Natural Park showing the 28 sampling sites.

MATERIAL AND METHODS

STUDY SITE AND METHODS. – This survey was conducted on 28 water sites located in the Alvão Natural Park, in northeastern Portugal (Fig. 1) where the geographical location and altitude of each site were recorded. From May 2006 to September 2006, each site was sampled three times, when also the physical parameters, such as pH, water temperature and dissolved oxygen were measured and average values were calculated. In addition, the site parameters were also recorded: the distance of the margins, with a distance of <1m between margins classed as (1) and >1m classed as (2); the presence of floating vegetation was registered as (1) with vegetation and (2) without vegetation; the presence of exposed rocks registered as (1) with rocks and (2) without rocks; the use of adjacent land was classified as (1) agricultural use, (2) forest and (3) uncultivated; and the water flow classified as (1) fast-flowing water and (2) slow-flowing water and permanent bodies of water.

The odonate assessment was performed on sunny days between 10:00 and 16:00 h, when most species were active. The adults were caught and the species identified using ASKEW (2004) and D'AGUILAR & DOMMANGET (1998). The occurrence estimates were ranked within a two-class system (0 = absent and 1 = present) and abundance estimates were ranked within a five-class system: D = dominant (>21 individuals), A = abundant (11-20 individuals), C = common (6-10 individuals), O = occasional (2-5 individuals) and R = rare (1 individual).

DATA ANALYSIS. – The specimens were separated per suborder and families. A cluster analysis was performed in order to group 27 out of the 28 study sites on the basis of their environmental characteristics (at site 23 the environmental physical parameters could not be measured). For the
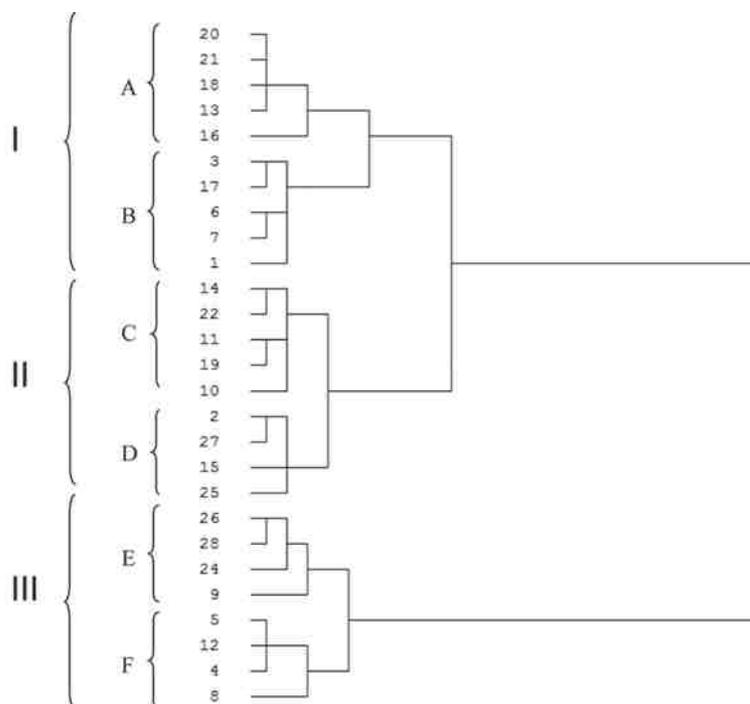
Fig. 2. Cluster analysis classification of 27 study sites based on the selected environmental variables. Squared Euclidean distance and linkage rule: Ward's method). – [I-III: clusters; – A-F: groups].

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Table I
Species occurrence and their status at the study sites: (D) dominant, (A) abundant, (C) common, (O) occasional, (R) rare

|	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
Platycnemididae																												
Platycnemis acutipennis											O,O		O,O							O	O							
Platycnemis latipes											O							O										
Coenagrionidae																												
Enallagma cyathigerum		D																										
Ischnura pumilio																								O	O			
Pyrrhossoma nymphula	O			C	O	O	O	O			O	O	O															
Lestidae																												
Lestes virens																								O	O			
Calopterygidae																												
Calopteryx haemorrhoidalis																				R	O	R						
C. virgo				C	C,O	A,O	A	C	A	D	O,O	D	C,O	O		C	O	O	O	C	O		O	R		C	O	R
C. xanthostoma		O									C							O										
Aeshnidae																												
Aeshna cyanea																								O				R
Anax imperator		O,C									R													R				
Boyeria irene											O															R	R	R
Gomphidae																												
Onychogomphus uncatus					O						A	R	R,C			R	O	R	O	C	O					R	R	
Cordulegastridae																												
Cordulegaster boltonii				R	R,R			R			R	O,O	R			R	R		R	O	R	R				R	R	
Cordullidae																												
Oxygastra curtisii											R																	
Libellulidae																												
Libellula depressa		R																										
Orthetrum coerulescens													R		O					R		O						
Sympetrum fonscolombii		A,D																						R		R		
S. sanguineum																								O				

Cluster I, group A: localities 13, 16, 18, 20, 21, group B: localities 1, 3, 6, 7, 17; − Cluster II, group C: localities 10, 11, 14, 19, 22, group D: localities 2, 15, 25, 27; − Cluster III, group E: localities 9, 24, 26, 28, group F: localities 4, 5, 8, 12.

analysis, Squared Euclidean distance and Ward's method were used to measure distance and linkage rule, respectively. Floating vegetation was not used as a cluster variable because it occurred in all sites studied.

In order to find any possible relationships between species occurrence and the environmental variables, the Categorical Principal Component Analysis (CAT-PCA) was performed, in which the presence/absence matrix of species and habitat variables such as water flow, the use of adjacent land, distance of margins, exposed rocks and categorized water temperature, pH, dissolved oxygen and the altitude were used. A biplot scaling was chosen for graphical outputs. All the calculations were performed using SPSS, version 13.

RESULTS

A total of 19 species were recorded (Tab. I). The status of species assessment ranged from dominant (D) to rare (R). Dominance was observed locally for *Enallagma cyathigerum, Calopteryx virgo* and *Sympetrum fonscolombii* which had more than 21 individuals recorded.

C. virgo was the most widely observed species, recorded from 22 sites, followed by *Cordulegaster boltonii* and *Onychogomphus uncatus,* which were present at 15 and 12 sites, respectively.

The cluster analysis of habitat structure, based on the selected environmental variables, resulted in three main clusters with two groups each (Fig. 2). Clusters I and II comprised sites with a high pH while cluster III included sites with low pH. The main difference between cluster I and II was the use of adjacent land, with agriculture and forest sites for cluster I and uncultivated sites for cluster II. From cluster I, groups A and B comprised sites with both fast-flowing and limpid water and presence of rocks, while water temperature and dissolved oxygen levels were higher in group A. From cluster II, groups C and D were made up of sites with a high water temperature and high levels of dissolved oxygen, with both fast-flowing and limpid water sites in group C and permanent bodies of water in group D. From cluster III, groups E and F comprised sites with low levels of dissolved oxygen. Group E were also made up of sites with moderate water temperature while group F comprised sites with fast-flowing and limpid water sites, low temperature and adjacent margins used for agriculture.

The Cat-PCA ordination resulted in three initial axes that explain 21%, 15% and 12% of the species/environment relationship, respectively. The reliability of the axes was given by Cronbach's Alpha and shows values higher than 0.7 (Tab. II).

Table II
Summary statistics of the Categorical Principal Component Analysis (Cat-PCA)

Axes	1	2	3	Total
Eigenvalues	5.709	4.109	3.360	13.259
Cumulative percentage variance	21.14	36.56	49.00	
Cronbach's Alpha	0.857	0.791	0.729	0.96
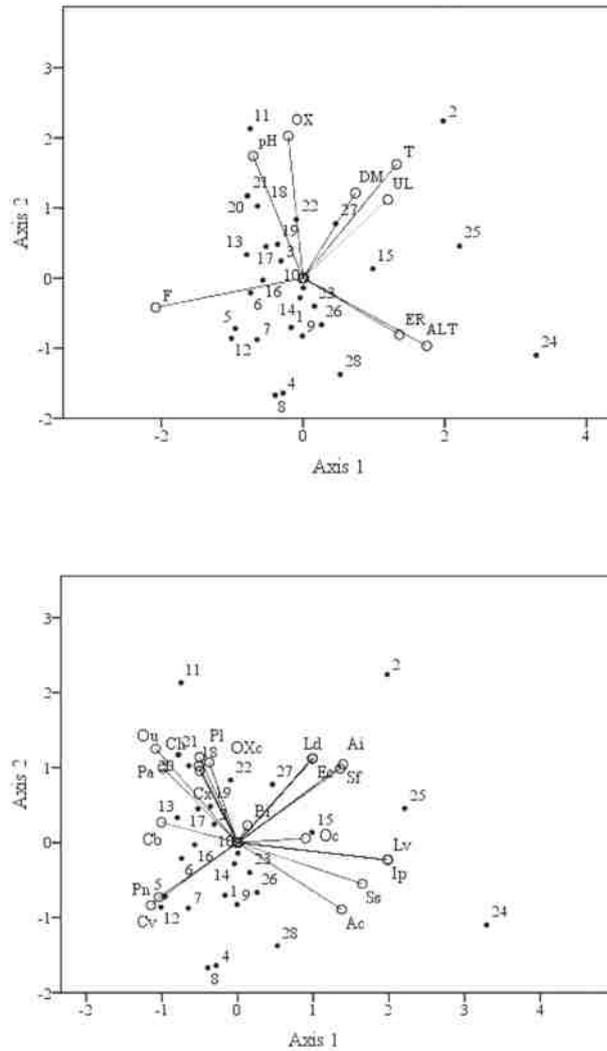
Fig. 3. Categorical PCA biplot of: (A) environmental variables, and (B) presence/absence of species at the 28 study sites. − [For the environmental variables and species codes, see Table III]

The water flow, the dissolved oxygen, the pH, the altitude and the water temperature were the major environmental factors that affected the distribution of Odonata (Tab. III). The first two axes indicate that environmental variables and species (Figs 3a, 3b) were related, with the cluster sites defined by the above cluster analysis (Fig. 2). In the first axis, altitude and water temperature plotted against water flow created three main groups (D, E, F) (Fig. 4). Group D is characterized by the occurrence of *E. cyathigerum, S. fonscolombii, I. pumilio, L. virens* and *A. imperator.* Group F runs along the negative part of the first axis with *C. virgo* and *P. nymphula* occurring in all the sites studied, while *C. boltonii* and *O. uncatus* occurred at least at one site. In the second axis, the dissolved oxygen and the pH plotted against the altitude create two main groups (A and E) (Fig. 4). Group A is characterized by the occurrence of *C. virgo* in all the sites, *C. boltonii* and *O. uncatus* occurred at four of the five sites while *P. acutipennis* and *C. haemorrhoidalis* occurred mainly at the lowest altitude sites. Group E is characterized by the occurrence of *S. sanguineum, A. cyanea* (a spe-

cies that only occurred in this group) and *I. pumilio* and *L. virens*. The other species recorded exhibited unspecific habitat requirements.

DISCUSSION

In this study, a total of 19 Odonata species was recorded. In the same area, previous studies had shown different results with a total of 18, 22 and 10 species being recorded by MALKMUS (2002), BEKKER et al. (2004) and FERREIRA et al. (2005) respectively. *Calopteryx virgo* was the most widely occurring species in the Alvão Natural Park, recorded from 22 sites and was the dominant species there. *C. boltonii* and *O. uncatus* were present at 15 and 12 study sites, respectively.

Table III

Component loadings between aquatic environmental variables and Odonata species with the first three axes of the Cat-PCA

Variables	Codes	Loadings Axis 1	Variable/component Axis 2	Axis3
Temperature	T	**0,56**	**0,58**	-0,05
pH	pH	-0,15	**0,74**	-0,39
Dissolved oxygen	OX	-0,08	**0,78**	-0,14
Altitude	ALT	**0,62**	-0,41	-0,20
Exposed rocks	ER	0,51	-0,33	-0,09
Flow	F	**-0,80**	-0,14	0,03
Distance of margins	DM	0,29	0,43	0,23
Use of adjacent land	UL	0,46	0,44	-0,03
Platycnemis acutipennis	Pa	-0,37	0,34	0,32
Platycnemis latipes	Pt	-0,20	0,35	**0,75**
Enallagma cyathigerum	Ec	0,39	0,45	-0,20
Ischnura pumilio	lp	**0,77**	-0,14	0,20
Pyrrhossoma nymphula	Pn	-0,45	-0,34	0,22
Lestes virens	Lv	**0,77**	-0,14	0,20
Calopteryx haemorrhoidalis	Ch	-0,18	0,43	-0,20
Calopteryx virgo	Cv	-0,42	-0,36	0,33
Calopteryx xanthostoma	Cx	-0,20	0,34	**0,64**
Aeshna cyanea	Ac	**0,51**	-0,41	0,37
Anax imperator	Ai	**0,52**	0,30	**0,57**
Boyeria irene	Bi	0,03	0,00	**0,50**
Onychogomphus uncatus	Ou	-0,41	0,45	0,21
Cordulegaster boltonii	Cb	-0,37	0,11	-0,35
Oxygastra curtisii	OXc	-0,15	0,31	**0,78**
Libellula depressa	Ld	0,39	0,45	-0,20
Orthetrum coerulescens	Oc	0,35	0,02	0,02
Sympetrum fonscolombeii	Sf	**0,55**	0,39	-0,20
Sympetrum sanguineum	Ss	**0,63**	-0,27	0,36
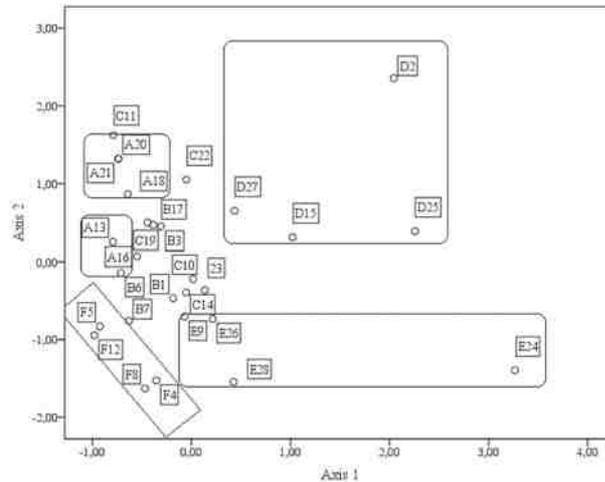
Fig. 4. Axes 1 and 2 of the Cat-PCA for the environmental variables and presence/absence of species at the study sites. − [The sites are indicated by group letter and locality numbers]

The results showed different distribution patterns across the study sites. Habitat requirements of the species recorded, as obtained by Cat-PCA analysis, show that water flow, dissolved oxygen, pH, altitude and water temperature were the major factors that affected the distribution. Previous studies on the relationship between Odonata species and habitat structure have shown varying results.

There is still no agreement as to which habitat variables should be considered and, because different data analyses were used, comparing the results of different studies is not easy. The results obtained in this present study were in line with those described in the literature (CLARK & SAMWAYS, 1996; SCHINDLER et al., 2003), which point out that water permanency and flow rate are among the determinant factors in the formation of Odonata assemblages. The latter authors also considered the floating macrophytes as an important factor. The importance of macrophyte coverage of the pond surface was also observed by CARCHINI et al. (2005). However, this habitat variable could not be used in the present study, since floating vegetation was present at all the sites studied.

Through the results obtained by Cat-PCA ordination, two main species assemblages could be detected. Species such as *E. cyathigerum, S. fonscolombeii, S. sanguineum, I. pumilio, L. virens* and *A. imperator* preferred permanent bodies of water, characterized by high water temperatures, while *C. virgo*, *P. nymphula*, *C. boltonii* and *O. uncatus* preferred sites with fast-flowing water, characterized by low and moderate temperatures. Within this habitat type, *P. acutipennis* and *C. haemorrhoidalis* occurred mainly at the lowest altitude sites. The habitat preferences of these are in line with the literature (ASKEW, 1988; HOFMANN & MASON, 2005).

The identification of Odonata associations, and the knowledge on habitat requirements of the species could represent an important basis for the wetland site conservation and management.

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THREE NEW *DREPANOSTICTA* SPECIES FROM SRI LANKA (ZYGOPTERA: PLATYSTICTIDAE)

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D. mojca sp. n. (holotype ♂: 10km NEE of Deniyaya; Matara distr.; Southern prov.; N 6.36⁰, E 80.46⁰; 02-V-2003; to be deposited at Sri Lanka National Museum, Colombo), *D. bine* sp. n. (holotype ♂: Opanayake, Ratnapura distr.; Sabaragamuwa prov.; N 6.62⁰, E 80.66⁰; 13-X-1970; deposited at National Museum of Natural History, Smithsonian Institution, Washington, USA) and *D. anamia* sp. n. (holotype ♂: Katugas Falls near Ratnapura; Ratnapura distr.; Sabaragamuwa prov.; N 6.68⁰, E 80.41⁰; 04-V-2003; to be deposited at Sri Lanka National Museum, Colombo), are described. Their currently known distribution, phenology, ecology and threat status are presented and discussed. The remarkable *Drepanosticta* diversity in Sri Lanka makes the island a globally important Platystictidae hotspot.

INTRODUCTION

Due to their small size, dull colours, inconspicuous behaviour and hidden life along seepages and small streams that are mostly overgrown by dense vegetation or located in the dark shade of forests, Platystictidae usually escape the attention of general entomologists and naturalists. Apart from the fact that they are underrepresented in many entomological collections, their overall similar general appearance often conceals the exceptional species diversity and variation in minute morphological structures.

Around 120 species from the genera *Drepanosticta* Laidlaw, *Platysticta* Selys, *Protosticta* Selys, *Sulcosticta* van Tol and *Sinosticta* Wilson have so far been described from the Oriental region (KALKMAN et al., 2008, VAN TOL, 2009) and many new species are still awaiting description. Most species have very small ranges and many are island endemics. As far as southeastern Asia is concerned, the knowledge on taxonomy, biogeography and phylogenetic relationships of this extremely interesting family of forest damselflies has made a marked progress

only recently, mainly through the work of J. VAN TOL (2009) and some other authors.

Sri Lanka's remarkably diverse Platystictidae were recognized by some of the most prominent odonatological researchers of the last 150 years. E. de Selys-Long-champs, H.A. Hagen, W.F. Kirby, F.F. Laidlaw, F.C. Fraser and M.A. Lieftinck described numerous species. Around 20 endemic platystictide taxa are current-ly known from the island (FRASER, 1933a, 1933b; LIEFTINCK, 1940, 1955, 1971; BEDJANIČ, 2004, 2009; BEDJANIČ et al., 2007, 2009). This diversity is impressive, since the distribution of all Playstictidae species is limited to the wet and intermediate zones in southwestern and central parts of Sri Lanka – in an area of only ca 20,000 km^2. Thus, Sri Lanka can legitimately be classified as one of the global Platystictidae »hotspots«.

Particularly interesting and remarkable on the global scale is the *Drepanosticta* species radiation, with a total of 14 described endemic representatives. From examination of odonatological collections in the Natural History Museums of Vienna (Austria) and London (UK) and, above all, the ongoing revision of the abundant Platystictidae material in the Entomological Collection at the Smith-sonian Institution, Washington DC, USA (the Smithsonian insect project in Sri Lanka: 1969-1975) brought new insights into the diversity of this genus. Together with the material and observations made during the author's expeditions to Sri Lanka in 1995, 2001, 2003 and twice in 2009, there is now sufficient knowledge to make taxonomic descriptions of three new species. Revisions of the genera *Drepanosticta* and *Platysticta* in Sri Lanka, with descriptions of additional new taxa, determination keys and biogeographical and phylogenetic considerations will follow in subsequent papers.

SYSTEMATIC PART

DREPANOSTICTA MOJCA SP. NOV.
Figures 1-5

M a t e r i a l. – **Holotype**: ♂ (mature), Deniyaya, stream in the forest 10km NEE of Deniyaya; Matara district; Southern province; N 6.36^0, E 80.46^0; alt. 330m; 2-V-2003; M. Bedjanič leg.; – **Para-types**: 1♂ (from entomological collection of NMNH, Smithsonian Institution, Washington DC, USA: USNM ENT 00359674); Kottawa Forest Reserve; Kottawa; Galle district; Southern prov-ince; N 6.1116^0, E 80.3145^0; 6-X-1973; R. & B. Robinson leg.; 1♂ (in alcohol), Stream in Haycock area between tea plantations; Hiniduma; Galle district; Southern province; N 6.3422^0, E 80.3099^0; alt. 120m; 15-V-2009; M. Bedjanič & S. Gunasinghe leg. Holotype is to be deposited at Sri Lanka National Museum (Colombo, Sri Lanka). Paratypes are deposited in the USNM (Washington DC, USA) collection.

E t y m o l o g y. – The species epithet, a noun in apposition, is a patronym honouring my wife M o j c a B e d j a n i č.

DIAGNOSIS. — Medium-sized, dark brown *Drepanosticta* with remarkable,

almost totally reduced male inferior appendages. Last tergite in males dorsoposteriorly prolonged, unknown in other Platystictidae species. Anterior lobe of prothorax with a pair of long stalked processes, similar to two other species from Sri Lanka, viz. *D. tropica* (Selys) and *D. subtropica* (Fraser). Differs from these by mono-coloured dark brown prothorax and processes, by prothorax shape and by brown sides of synthorax, with sky-blue thoracic stripes on mesepimeron and brownish ventral surface of thorax. Metepimeron and ventral thorax portions in *D. tropica* and *D. subtropica* yellowish. Males are distinguished at a glance based on the shape of anal appendages.

MALE (**holotype**, dried specimen]. – H e a d . – Labium light brown, bases of mandibles dark brown, with light grey (blue in life) dorsolateral portions towards labrum and anteclypeus. Labrum and anteclypeus light grey (blue in life), anterior part of labrum brown, with rather dense long light brown setae. Genae shiny black, as is postclypeus. Frons flattened, also shiny black, below antennae near postclypeus with some long light setae, which are also present on anterior border of postclypeus. Vertex, occiput and epicranium black, with a tint of very dark metallic-green lustre, slightly brownish around posterior ocelli. Occiput behind ocelli with a row of few setae. Bases of antennae greyish brown, scapus and
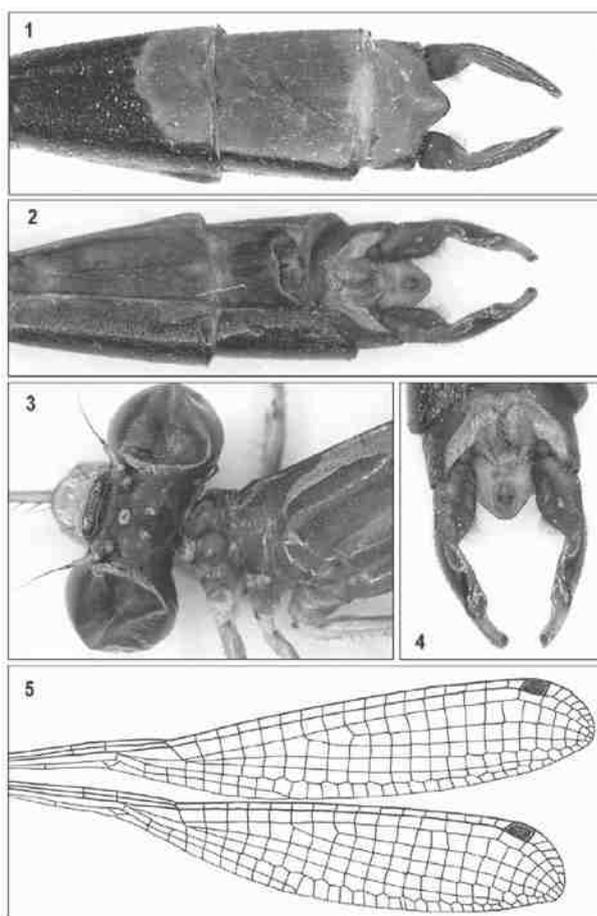
Figs 1-5. *Drepanosticta mojca* sp. nov.: (1) abdomen with anal appendages, dorsal view [male holotype]; — (2) abdomen with anal appendages, ventral view [male holotype]; — (3) head and prothorax, lateral view [male holotype]; — (4) the same, enlarged appendages [male holotype]; — (5) wings, right pair [paratype].

pedicellus brown, flagellum dark brown (Fig. 3). Rear of the head shiny black. Transverse occipital carina black, angulated. Eyes in preserved specimen dark brown.

T h o r a x . – Prothorax dark greyish brown (Fig. 3). Anterior lobe with elevated, up-turned anterior margin, which is laterally strongly prolonged and erected in a pair of flat, narrow processes. Processes directed dorsally and slightly posteriorly, with rounded tips, curled up towards head (possibly due to preservation) and reaching back as far as posterior lobe. Median lobe gently raised on each side with a median cleft and laterally with a small posterior embossment Posterior lobe narrow, slightly elevated in the middle, posterior margin slightly expanded and elevated laterally (Fig. 3). Dorsum of synthorax blackish dark brown, with a tint of very dark metallic-green lustre, brown towards humeral suture. Mesepimeron and metepisternum brown, as are mesinfraepisternum, metinfraepisternum, coxae and metepimeron. Sky blue stripe along obsolete mesometapleural suture, starting from thickened dark brown upper margin of metepisternum and ending above spiracle. Under surface of thorax of lighter brown colour. Legs light brown.

W i n g s . – Clear, venation dark brown. Forewings with 15½ (2 additional veins between C and Sc in right wing), hindwings with 16 and 15 Px (1 additional vein between C and Sc in left wing). Arculus distal to Ax2, R4+5 at subnodus, somewhat thickened in forewings, slightly proximal to subnodus in hindwings. IR3 separates from R4+5 at the level of first crossvein distal to arculus, in hindwings it starts slightly distal of subnodus. Y vein stalked. CuP reaching hind margin of forewing approximately at level of Px5, in hind wing at level of Px5. Number of cells between Arc and place where CuP meets hind margin of hind wing 10. Pterostigma dark brown, encircled by narrow lighter line and surrounded by thick dark brown veins, proximal side oblique, distal side slightly convex, wider than high. Venation in distal portions of forewings damaged in holotype, wing venation of paratype male is shown in Figure 5.

A b d o m e n . – Slender, brown, segments 8-10 black. Segment 1 with light brown ventrolateral portion which is narrower distally, segment 2 also light brown ventrolateraly, in distal half light portion narrower, limited to ventral side. Segments 3-6 basally with narrow light brown rings which are not connected dorsally and are narrowly prolonged ventrally to almost end of segments. Segment 7 with light markings reduced. Dorsum of segment 9-10 light blue, segment 8 with rounded dorsal blue marking, occupying slightly more than distal third of the segment (Fig. 1). Segment 10 with rounded, slightly triangular distal prolongation of last tergite, measuring approximately half of the segment and with tip bordered narrowly brown (Figs 1, 2, 4). Anal appendages dark brown. Superiors strong, more than twice of segment 10 in length, broad at the base, at one quarter rapidly flattened laterally and angulated inwards. Basal parts covered with setae, which are very dense medially and ventrally. Inferiors extremely reduced, shifted strongly proximally towards base of segment as seen in Figures 2 and 4. Basal

portions expanded, each with robust medially directed spine, which only reach bases of superiors.

FEMALE (photographs only, Figs 17-18). − Colouration in life very similar to male (Fig. 17). Labrum and anteclypeus sky-blue, anterior part of labrum dark brown, with rather dense long light brown setae. Eyes grey in dorsal and ventral thirds, in-between brown. Prothorax dark brown, with a pair of processes, as in male, but their tips straight, only very slightly curved anteriorly towards the top (Fig. 18). Vertex of synthorax very dark as in male, brown towards humeral suture. Blue thoracic band starts from upper margin of metepisternum and reaches spiracle, then ends conically narrowed, rest of thorax brown. Legs greyish, as in Figure 18. Dorsum of abdominal segments 9-10 sky-blue, dorsum of 8 of same colour, blue part rounded proximally, with tip almost reaching segment base. Ovipositor and styli reach half of segment 10.

NOTES ON LIFE COLOURATION AND VARIATIONS. − Eyes of males in life bluish grey dorsally, with broad median brown to yellowish belt and ventral portion again light grey. (Fig. 16). Labrum, anteclypeus and small portion of mandibulae bases sky blue. Trochanters and small proximal parts of femora yellowish.

As for variation in paratypes, the male from Kottawa does not have any thoracic blue band, but this might be due to preservation. It has strongly pronounced mesostigmal lamellae, which are erected, triangular, with rounded tip. Forewings with 14, hindwings with 13 Px. Vein R4+5 proximal to subnodus in fore- and hindwings, IR3 starts slightly distal of subnodus in all wings. Y vein sessile in all four wings. Additionally, dorsal blue marking on segment 8 occupies distal two thirds of the segment and distal prolongation of last tergite at extreme tip is not rounded, but slightly concave. Structurally, as for prothorax and anal appendages, similar to holotype, therefore more material is needed to validate extent and importance of above variations in southernmost populations. Paratype from Haycock, possibly also due to preservation, with reduced blue stripe on thorax, which is clear sky blue in the upper third only, but then faints and is hardly visible towards spiracle. Prothorax processes with tips straight, only very slightly curved anteriorly. Venation is shown in Figure 5. Origin of veins R4+5 and IR3 slightly different in all wings, arising approximately at subnodus. Y vein stalked in all four wings. Dorsal blue marking on segment 8 broadly triangular, occupying distal two thirds of the segment.

M e a s u r e m e n t s (in mm, paratype's range in brackets), ♂. – Head width: 4.1; abdomen length: 37.8 (34.2-35.7); fore- and hindwing length: 23.3, 22.2 (20.3-21.5, 19.5-20.3); fore- and hindwing pterostigma length: 1.0, 1.1; prothorax projections: 0.8; superior appendages: 1.3.

FAUNISTIC RECORDS. – (1) Bodhinagala; Ingiriya Forest Reserve, about 30km SE of Colombo; Kalutara district; Western province; N 6.7647^0, E 80.1498^0; alt. 50m; 15-VI-2008; K. Conniff; 1♀; 11-V-2009; M. Bedjanič & K. Conniff; 1♂; – (2) Deniyaya, stream in the forest 10km NEE of Deniyaya; Matara district; Southern province; N 6.36^0, E 80.46^0; alt. 330m; 2-V-2003; M. Bedjanič; 1♂; – (3)

Stream in Sinharaja Forest Biosphere Reserve, 1km NE of Beverly Estate Lower Division; Deniyaya; Ratnapura district; Sabaragamuwa province; N 6.4088⁰, E 80.5461⁰; alt. 330m; 1-V-2003; M. Bedjanič;1♂; – (4) Enselwatte; Ratnapura district; Sabaragamuwa province; N 6.4043⁰, E 80.6175⁰; 25-V-1975; S. Wood & J. Petty; 1♂; – (5) Stream in Haycock area between tea plantations; Hiniduma; Galle district; Southern province; N 6.3422⁰, E 80.3099⁰; alt. 120m; 15-V-2009; M. Bedjanič & S. Gunasinghe; 7♂; – (6) Kottawa Forest Reserve; Kottawa; Galle district; Southern province; N 6.1116⁰, E 80.3145⁰; 6-X-1973; R. & B. Robinson; 1♂

DREPANOSTICTA BINE SP. NOV.
Figures 6-10

M a t e r i a l. – **Holotype**: ♂ (mature, from entomological collection of NMNH, Smithsonian Institution, Washington DC, USA: USNM ENT 00359717); Opanayake, M.P. 84; Ratnapura district; Sabaragamuwa province; N 6.62⁰, E 80.66⁰; 13-X-1970; O. Flint leg. – **Paratypes**: 3♀ (from entomological collection of NMNH, Smithsonian Institution, Washington DC, USA: USNM ENT 00359723, 00359726, 00359727), faunistic data same as holotype; 5♂ (from entomological collection of NMNH, Smithsonian Institution, Washington DC, USA: USNM ENT 00359718- 00359722), faunistic data same as holotype; 4♂ (from entomological collection of NMNH, Smithsonian Institution, Washington DC, USA: USNM ENT 00359728-00359731), Kalatuwawa Reservoir; Ratnapura district; Sabaragamuwa province; N 6.8560⁰, E 80.2031⁰; 19-IX-1970; O. Flint leg.; 2♂, 1♀ (in alcohol), small stream on the road Laxapana-Norton Bridge, 1km E of Laxapana; Nuwara Eliya district; Central province; N 6. 9263⁰, E 80. 4895⁰; alt. 550m; 28-VII-2009; M. Bedjanič & K. Conniff leg. — Holotype is deposited in USNM (Washington DC, USA). Paratypes are deposited in USNM (Washington DC, USA) and in author's collection from which a pair is to be deposited at Sri Lanka National Museum (Colombo, Sri Lanka).

E t y m o l o g y. – The species epithet, a noun in apposition, is a patronym honouring my son B i n e B e d j a n i č.

DIAGNOSIS. — Medium-sized, brown to dark greenish brown *Drepanosticta*. Distinguished from all of its congeners by brown head, by remarkable green, blue and brown colouration of the eyes in living animal and by dark brownish synthorax with only a very narrow, largely obscured or even totally missing bluish stripe along obsolete mesometapleural suture. It is related to *D. montana* (Selys), *D. submontana* (Fraser) and *D. fraseri* Lieftinck, but they all have at the most a small brownish patch on the head behind occeli, well developed thoracic stripes on metepisternum, as well as obtuse postmedian tubercles on superior anal appendages of males.

MALE [holotype, dried specimen]. – H e a d . – Labium light brown and greyish, bases of mandibles dark brown, slightly bluish towards labrum, genae brown. Labrum and anteclypeus light blue, anterior border of labrum brownish laterally and gradually becoming dark brown in the median part. Postclypeus dark brown, almost black, anterior border with strong setae. Frons flattened, glossy brown, flattened squarish area between antennae and below anterior ocellus light

brown with slightly darker striae. Vertex and epicranium brown, lustreless (Fig. 6). Antennae with scapus dark brown basally, light brown apically, pedicellus brown, as are distalia. Rear of the head of lighter brown tone. Occiput behind ocelli with a row of some quite long and some shorter setae. Transverse occipital carina brown, acutely angulated. Eyes in preserved specimen dark brown.

T h o r a x . – Prothorax brown, median part of posterior lobe as well as rounded tubercles on median lobe blackish brown (Fig. 6). Anterior lobe simple and rounded with elevated anterior margin. Median lobe raised on each side forming two rounded dark tubercles which are densely overgrown by long light setae (Fig. 8). Posterior lobe depressed and only very slightly elevated in the middle, but with expanded lateral lobes gently turned to the front. Prosternum brown, distal half medially black. Dorsum of synthorax blackish dark brown, with slight dark metallic-green shine. Humeral suture narrowly brown, slightly wider portion of lighter brown colouration only along its upper fifth. Mesepimeron and metepisternum dark brown without any blue marking on metepisternum, lower fifth of both lighter brown, as are mesinfraepisternum, metinfraepisternum, coxae and metepimeron. Under surface of thorax brown, with lighter portion in the middle. Legs light brown.

W i n g s . – Clear, venation brown. Forewings with 14½ (2 additional veins between C and Sc in left wing), hindwings with 14½ and 13½ Px. One Pcv, only in right forewing an additional Pcv, situated halfway between proximal one and Y vein. Arculus distal to Ax2, R4+5 at subnodus, IR3 arising
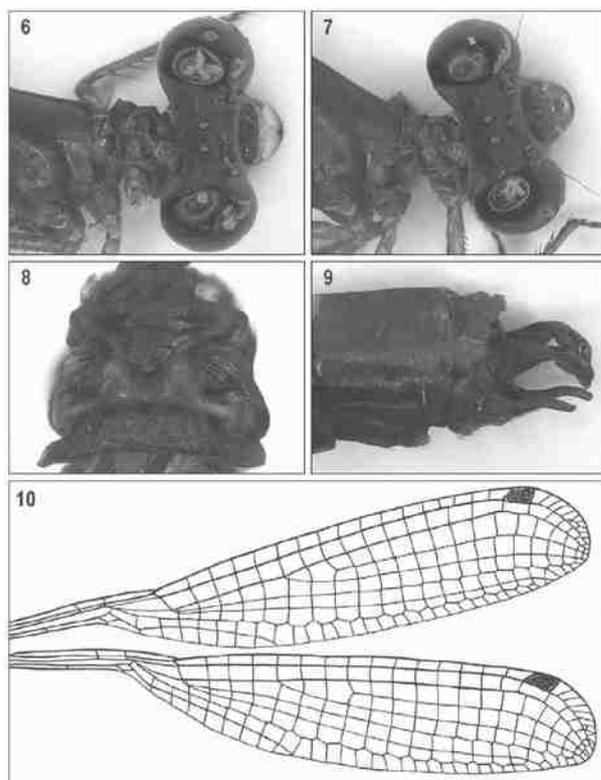
Figs 6-10. *Drepanosticta bine* sp. nov.: (6) head and prothorax, lateral view [male holotype]; − (7) head and prothorax, lateral view [female paratype]; − (8) prothorax, dorsal view [male holotype]; − (9) anal appendages, lateral view [male holotype]; − (10) wings, right pair [paratype].

from proximal fourth of first cell distal to subnodus. Y vein stalked. CuP reaching hind margin of fore wing at level of Px4, in hind wing at level of Px5. Number of cells between Arc and place where CuP meets hind margin of hind wing 10. Pterostigma light brown, encircled by narrow lighter line and surrounded by thick dark brown veins, proximal side oblique, distal side convex, wider than high. Wing venation of paratype male is shown in Figure 10.

A b d o m e n. – Slender, posterior segments slightly expanded. Segments 1-7 castaneous brown, 8 dark brown, 9-10 almost black. Narrow light brown basal rings on segments 3-7, dorsum of segment 9-10 dirty grey (blue in life, FIG. 9). Anal appendages dark brown, robust. Superiors broad at the base, then angulated strongly inwards and downwards at the middle. Dorsally, superiors without any postmedian tubercle or tooth as observed in *D. montana*, *D. submontana* and *D. fraseri*. Inferiors almost as long as superiors, stout. Basal portion expanded, inner side with a small robust spine, which is pointed inwards and curved slightly downwards. Proximal portions in lateral view almost straight, slightly sinuous, curved inwards distally (Fig. 9).

FEMALE (dried specimen). – Similar to male, but smaller and more robust insect. Colouration lighter brown, almost without dark brown, blackish or metallic-green tones (i.e. Fig. 7). Prothorax brown, as in male, median lobe raised on each side forming two rounded dark tubercles which are densely overgrown by long light setae (Fig. 7). Dorsum of intersegmental membrane between 8-9 segment as well as dorsum of 9-10 segments dark grey (blue in life). Cerci triangular, brownish. Ovipositor and styli brown, proximally slightly exceeding cerci.

NOTES ON LIFE COLOURATION AND VARIATIONS. – Pedicellus of antennae light brown, flagellum dark brown. Eyes beautifully coloured in adult animals – upper, dorsal third grass green, changing into a narrow stripe of sky blue, which is widened dorsally near the occiput, but ventraly clearly changes into contrasting yellowish brown portion which occupies little more than half of the eyes (Figs 19-20).

In adult male vertex of synthorax clearly dark metallic-green, in some males this lustre is present also on mesepimeron and mesepisternum. Some males have a very narrow, feint bluish stripe along obsolete mesometapleural suture, starting from upper border of metepisternum and ending above spiracle. In single male specimen, a small patch of bluish colouration is visible also on the wing side of upper metepisternum border and very mildly also on midcoxa and median lobe of prothorax. In adult males, brown abdomen is marked dorsally with sky blue on diffusely defined apical portions of segments (2)3-7 (Fig. 20). Dorsum of segments 9 and 10 sky blue, as is the intersegmental membrane between segments 8 and 9. In some specimen blue coluration is also present on segment 8, occupying maximally distal fifth of segment and being narrowly squarish or rounded.

Also in some adult females, a very narrow, feint or obscure bluish stripe along obsolete mesometapleural suture, starting from upper border of metepimeron

and ending above spiracle can be observed (Fig. 19). Sky blue apical portions of segments 2-6 more clearly defined than in males. Dorsum of segments 10 and 9 sky blue, as is the intersegmental membrane between segments 9 and 8, the later segment without blue markings (Fig. 19).

Measurements (in mm, paratype's range in brackets), ♂ – Head width: 4.9 (4.4-4.7); abdomen length: 38.3 (35.1-43.5); fore- and hindwing length: 24.1, 24.4 (22.1-28.3, 22.1-28.5); fore- and hindwing pterostigma length: 1.2, 1.2; superior and inferior appendages: 1.1, 0.9; ♀ – head width: 4.3; abdomen length: 31.0 (30.2-33.8); fore- and hindwing length: 23.5, 23.4 (22.3-25.7, 22.1-25.7); fore- and hindwing pterostigma length: 1.3, 1.4; ovipositor length: 2.3 (2.4-2.6).

FAUNISTIC RECORDS. – (1) Mahabage, Ing Oya, Kithulgala; Kegalla district, Sabaragamuwa province; N 7.0011⁰, E 80.4346⁰; alt. 240m; 15-VI-2006; K. Conniff; 1♂; 1-VII-2006; K. Conniff; 1♀; – (2) Small stream in the secondary forest 1km S of the bridge near Plantation Hotel in Kithulgala; Kegalla district, Sabaragamuwa province; N 6.9844⁰, E 80.4137⁰; alt. 430m; 21-V-2009; M. Bedjanič; 2♂, 1♀; – (3) Left tributary of Kelani river in secondary forest 3km upstream of the bridge near Plantation Hotel in Kithulgala; Kegalla district, Sabaragamuwa province; N 6.9739⁰, E 80.4278⁰; alt. 160m; 22-V-2009; M. Bedjanič; 2♂; – (4) Small stream on the road Kithulgala towards Hitigegama, 5km NW of Laxapana; Nuwara Eliya district; Central province; N 6.9729⁰, E 80.4510⁰; alt. 255m; 27-VII-2009; M. Bedjanič; 1♂; – (5) Small stream on the road Laxapana-Norton Bridge, 1km E of Laxapana; Nuwara Eliya district; Central province; N 6.9263⁰, E 80.4895⁰; alt. 550m; 28-VII-2009; M. Bedjanič & K. Conniff; 10♂, 2♀; – (6) Laxapana, 6.9km NW; Kegalla district, Sabaragamuwa province; N 6.9674⁰, E 80.4379⁰; alt. 330m; 25-IX-1970; O. Flint; 1♂; – (7) Kalatuwawa Reservoir; Ratnapura district; Sabaragamuwa province; N 6.8560⁰, E 80.2031⁰; 19-IX-1970; O. Flint; 4♂; – (8) Bodhinagala; Ingiriya Forest Reserve, about 30km SE of Colombo; Kalutara district; Western province; N 6.7647⁰, E 80.1498⁰; alt. 50m; 25.VI.2006; G. de Silva Wijeyeratne; 1♂; 11-V-2009; M. Bedjanič & K. Conniff; 5♂; – (9) Agalawatta, malaise trap; Kalutara district; Western province; N 6.5417⁰, E 80.1551⁰; 23/25-VII-1975; Y.M. Huang, E.L. Peyton, S. Karunaratne and Mahinda; 1♂; – (10) Opanayake, M.P. 84; Ratnapura district; Sabaragamuwa province; N 6.6226⁰, E 80.6555⁰; 13-X-1970; O. Flint; 6♂, 5♀; – (11) Sinharaja Forest Biosphere Reserve, stream along the road from Martin's Guesthouse to the new visitors centre; Kudawa; Ratnapura district; Sabaragamuwa province; N 6.4315⁰, E 80.4152⁰; alt. 400m; 14-V-2009; M. Bedjanič & K. Conniff; 2♂; – (12) Sinharaja Forest Biosphere Reserve, forest around the outflow of the pond at information centre near Martin's Guesthouse; Kudawa; Ratnapura district; Sabaragamuwa province; N 6.4328⁰, E 80.4147⁰; alt. 490m; 13-V-2009; M. Bedjanič; 2♀; – (13) Stream in Haycock range; Hiniduma; Galle district; Southern province; N 6.3335⁰, E 80.3112⁰; alt. 120m; 15-V-2009; M. Bedjanič & S. Gunasinghe; 5♂; – (14) Stream in Haycock area between tea plantations; Hiniduma; Galle district; Southern province; N 6.3422⁰, E 80.3099⁰; alt. 120m; 15-V-2009; M. Bedjanič & S. Gunasinghe; 5♂, 2♀; – (15) Stream on the road Morawaka-Diyadawa on

the slopes of Diyadawa forest; Matara district; Southern province; N 6.3122⁰, E 80.5430⁰; alt. 145m; 16-V-2009; M. Bedjanič & S. Gunasinghe; 3♂; – (16) Small tributaries to Hiyare lake on the N shore; Galle district; Southern province; N 6.0585⁰, E 80.3165⁰; alt. 100m; 15-V-2009; M. Bedjanič & S. Gunasinghe; 10♂, 1♀

DREPANOSTICTA ANAMIA SP. NOV.
Figures 11-15

M a t e r i a l. – **Holotype** ♂ (mature), Katugas Falls 2km N of Ratnapura; Ratnapura district; Sabaragamuwa province; N 6.68⁰, E 80.41⁰; 4-V-2003; M. Bedjanič leg.; – **Paratypes**: 2♂, 4♀, Deniyaya, stream in the forest 10km NEE of Deniyaya; Matara district; Southern province; N 6.36⁰, E 80.46⁰; alt. 330m; 29-IV-2003; M. Bedjanič leg.; 2♂ (from entomological collection of NMNH, Smithsonian Institution, Washington DC, USA: USNM ENT 00359688, 00359691), Laxapana, 6.9km NW; Kegalla district, Sabaragamuwa province; N 6.9674⁰, E 80.4379⁰; alt. 330m; 25-IX-1970; O. Flint leg; 1♀ (from entomological collection of NMNH, Smithsonian Institution, Washington DC, USA: USNM ENT 00359690), Laxapana; Nuwara Eliya district; Central province; N 6.9270⁰, E 80.4821⁰; alt. 400m; 24-28-IX-1970; O. Flint leg.; 4♂ (from entomological collection of NMNH, Smithsonian Institution, Washington DC, USA: USNM ENT 00359684- 00359687), Tunmodera, near Labugama; Colombo district, Western province; N 6.8638⁰, E 80.1660⁰; alt. 65m; 19-IX-1970; O. Flint leg.; 1♀ (from entomological collection of NMNH, Smithsonian Institution, Washington DC, USA: USNM ENT 00359689), Kalatuwawa Reservoir; Ratnapura district; Sabaragamuwa province; N 6.8561⁰, E 80.2032⁰; alt. 100m; 19-IX-1970; O. Flint leg. – Holotype and paratype female are to be deposited in Sri Lanka National Museum (Colombo, Sri Lanka). Other paratypes are deposited in USNM (Washington DC, USA) and in author's collection

E t y m o l o g y. – The species epithet, a noun in apposition, is a patronym honouring my daughter A n a M i a B e d j a n i č.

DIAGNOSIS. – Large, dark brown to almost black *Drepanosticta*, recognized by characteristic orange-yellowish colouration of prothorax, distinctive small nipples on pronotum as well as by peculiarly shaped inferior appendages in males. It does not seem to have any near allies.

MALE (**holotype**, dried specimen). – H e a d . – Labium light brown and greyish, mandibles dark brown below, bases greyish (light blue in life) towards labrum, narrow ventral stripe dark brown. Labrum and anteclypeus greyish (light blue in life), anterior border of labrum black (Fig. 11). Postclypeus black, anterior border laterally with some long setae. Frons flattened, shiny black below ocelli and antennae. Occiput, vertex and epicranium black, lustreless, behind antennae, to the level of posterior ocelli, shiny black. Small light patches arising lateral of posterior ocelli. Antennae with scapus black, only distal part narrowly whitish, pedicellus dark brown, flagellum broken. Rear of the head black. Hind border of occiput behind ocelli with four separated groups of long and some short setae, two placed transversely in the middle and two diagonally, slightly above the edges of occipital carina. Transverse occipital carina black, acutely angulated. Eyes in preserved specimen dark brown.

T h o r a x . – Prothorax light beige (orange-yellowish in life) in the median part, posterior lobe black, anterior margin of anterior lobe dark brown. Anterior prothorax lobe with elevated and thickened anterior margin. Median lobe slightly raised and rounded on each side, with a distinct, small, apically inclined nipple, base of which is anteriorly excavated, forming pronounced sulcus towards anterior lobe. Posterior lobe depressed, with expanded and rounded lateral lobes (Fig. 11). Dorsum of synthorax black, small portion of brown only in posteriolateral and anteriolateral corners of mesepisternum, brown also mesinfraepisternum. Mesepimeron and metepisternum black, light brown only in posteriolateral and anteriolateral corners. Distinct blue stripe along obsolete mesometapleural suture, starting from thickened dark brown upper margin of metepisternum and passing spiracle, after which it becomes narrower and gradually vanishes from blue into light brown colour ventrally. Metinfraepisternum and coxae greyish brown, metepimeron dark brown in the middle, greyish brown posteriorlly and ventrally. Under surface of thorax light beige. Legs greyish brown, femora with lighter distal portions.

W i n g s . – Clear, venation dark brown, almost black, lighter brown near the bases. Forewings with 18½, hindwings with 17 Px. Arculus distal to Ax2, R4+5 well proximal to subnodus, IR3 arising from R4+5 at the level of subnodus. Y vein stalked. CuP reaching hind margin of fore wing at level of Px6, in hind wing at level of Px7. Number of cells between Arc and place where CuP meets hind margin of hind wing 12. Pterostigma dark
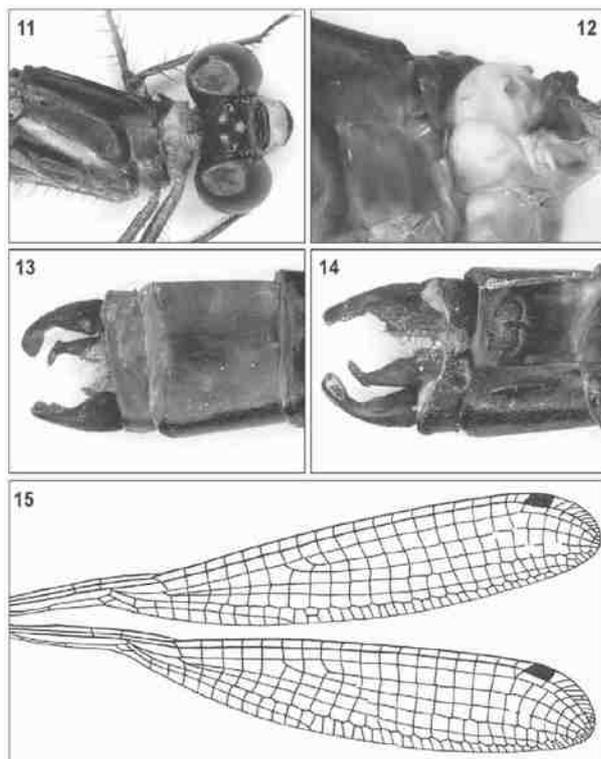
Figs 11-15. *Drepanosticta anamia* sp. nov.: (11) head and synthorax, lateral view [holotype]; − (12) prothorax, lateral view [female paratype]; − (13) anal appendages, dorsal view [holotype]; − (14) anal appendages, ventral view [holotype]; − (15) wings, right pair [holotype].

brown with a tint of dark reddish, encircled by narrow lighter line and surrounded by thick dark brown veins, proximal side oblique, distal side only slightly convex, wider than high. Wing venation of holotype male is shown in Figure 15.

A b d o m e n . – Slender and long, dark brown almost black, especially on segments 7-10. Segment 1 brown, with light brown proximal portion, segment 2 brown, segments 3-7 dark brown, gradually almost black towards end of abdomen, basally with narrow light brown rings which are not connected dorsally and are narrowly prolonged ventrally to almost end of segments. Dorsum of segment 9-10 greyish blue (sky blue in life), segment 8 with small triangular dorsal blue marking, occupying distal fifth of the segment. Anal appendages blackish brown, inner sides and inferiors brown. Superiors very broad and rounded at the base, but inner sides strongly excavated. Distal half flattened laterally, strongly angulated downwards and inwards, with rounded tips. Proximal half of inferiors broad and strong, with dorsal spine in the middle. Distally narrowed and turned slightly up, ending in a peculiar structure, similar to a narrow inverted boot, with totally flat surface of the sole turned slightly upwards and tips pointing inwards (Figs 13-14).

FEMALE (dried specimen). – Similar to male, but smaller and more robust insect. Wings slightly enfumed. Colouration somewhat lighter, except for the head all other black parts of male, dark brown in female. Anterior part of labrum black, posteriorly slightly brownish, the line between whitish part (probably blue in life) not straight as in male but with whitish notch in the middle. Prothorax similar to male, whitish, lateral parts of posterior lobe slightly different and more rounded (Fig. 12). In wings, R4+5 well proximal to subnodus, IR3 arising from subnodus. Dorsum of abdominal segments 9-10 greyish blue (blue in life), segment 8 with small triangular dorsal blue marking, occupying distal third of the segment. Cerci triangular, black. Ovipositor finely serrated at the end, styli proximally slightly exceeding cerci.

NOTES ON LIFE COLOURATION AND VARIATIONS. – Unlike in other species of Sri Lankan *Drepanosticta*, the eyes are uniformly dark brown in adult animals, similar to *Platysticta* (Figs 21-22). Labrum and anteclypeus, as well as mandibulae bases sky blue in adults. Flagellum of antennae dark brown, almost black. Middle lobe of prothorax orange or yellowish in adults of both sexes, whitish in juveniles (Figs 21-22). Nipples on midlobe of prothorax sometimes tipped with grey or with blackish tips. Rounded lateral expansions and hind margin of posterior lobe with slightly different shape in specimens from different regions. Thoracic stripe sky blue. Wings slightly enfumed in some specimens. In all paratypes vein IR3 arising from subnodus. Y vein in some specimens very short stalked, in one specimen sessile. Dorsum of segments 10 and 9 sky blue. In some specimens blue triangular mark occupies more than a distal third of segment 8 in some it is narrower and squarish or even indented with black, in some this segment is completely black with only intersegmental membrane being blue.

M e a s u r e m e n t s (in mm, paratype's range in brackets), ♂. – Head width: 5.0 (4.5-4.9); abdomen length: 44.1 (42.7); fore- and hindwing length: 27.9, 27.2 (26.9-28.4, 26.0-27.8); fore- and hindwing pterostigma length: 1.3, 1.4; superior and inferior appendages: 1.0, 0.7; ♀ – head width: 4.9 (4.8); abdomen length: 39.0 (34.0-39.0); fore- and hindwing length: 28.4, 27.8 (26.1-29.3, 25.3-28.7); fore- and hindwing pterostigma length: 1.4, 1.4; ovipositor length: 1.9 (1.8-2.0).

FAUNISTIC RECORDS. – (1) Mahabage, Ing Oya, River Resort Hotel; Kithulgala; Kegalla district, Sabaragamuwa province; N 7.0012⁰, E 80.4346⁰; alt. 240m; 26-II-2006; K. Conniff; 1♂; 21-VI-2006; K. Conniff; 4♂, 2♀; 1-VII-2006; K. Conniff; 5♂, 3♀; 15-VIII-2006; K. Conniff; 1♂, 25-VII-2009; M. Bedjanič; 10♂, 5♀; – (2) Mahabage, Ing Oya, small seepage beside the road from River Resort to Beliena Cave; Kithulgala; Kegalla district, Sabaragamuwa province; N 7.0072⁰, E 80.4295⁰; alt. 240m; 26-VII-2009; M. Bedjanič; 2♂; – (3) Mahabage, Ing Oya, Left tributary of Ing Oya on the way from River Resort to Beliena Cave; Kithulgala; Kegalla district, Sabaragamuwa province; N 7.0082⁰, E 80.4291⁰; alt. 260m; 26-VII-2009; M. Bedjanič; 2♂; – (4) Small stream in the secondary forest 1km S of the bridge near Plantation Hotel in Kithulgala; Kegalla district, Sabaragamuwa province; N 6.9844⁰, E 80.4137⁰; alt. 430m; 21-V-2009; M. Bedjanič; 3♂, 1ten.; – (5) Small stream on the road Kithulgala towards Polpitiya, 6km NW of Laxapana; Nuwara Eliya district; Central province; N 6.9729⁰, E 80.4510⁰; alt. 270m; 27-VII-2009; M. Bedjanič; 1♂; – (6) Small stream on the road Kithulgala-Laxapana, 1km NW of Laxapana; Nuwara Eliya district; Central province; N 6.9335⁰, E 80.4773⁰; alt. 400m; 28-VII-2009; M. Bedjanič & K. Conniff; 1♂; – (7) Small stream on the road Laxapana-Norton Bridge, 1km E of Laxapana; Nuwara Eliya district; Central province; N 6.9263⁰, E 80.4895⁰; alt. 550m; 28-VII-2009; M. Bedjanič & K. Conniff; 2♂; – (8) Laxapana, 6.9km NW; Kegalla district, Sabaragamuwa province; N 6.9674⁰, E 80.4379⁰; alt. 330m; 25-IX-1970; O. Flint; 2♂; – (9) Laxapana; Nuwara Eliya district; Central province; N 6.9270⁰, E 80.4821⁰; alt. 400m; 24/28-IX-1970; O. Flint; 1♀; – (10) Tunmodera, near Labugama; Colombo district, Western province; N 6.8638⁰, E 80.1660⁰; alt. 65m; 19-IX-1970; O. Flint; 4♂; – (11) Kalatuwawa Reservoir; Ratnapura district; Sabaragamuwa province; N 6.8561⁰, E 80.2032⁰; alt. 100m; 19-IX-1970; O. Flint; 1♀; – (12) Bodhinagala; Ingiriya Forest Reserve, about 30km SE of Colombo; Kalutara district; Western province; N 6.7647⁰, E 80.1498⁰; alt. 50m; 15-VI-2008; K. Conniff; 1♀; 11-V-2009; M. Bedjanič & K. Conniff; 2♂, 2♀; – (13) Katugas Falls 2km N of Ratnapura; Ratnapura district; Sabaragamuwa province; N 6.6825⁰, E 80.4121⁰; 4-V-2003; M. Bedjanič; 1♂; – (14) Stream at 10th bend in Balutota Pass on the road Deniyaya-Rakwana; Rakwana; Ratnapura district; Sabaragamuwa province; N 6.4572⁰, E 80.6246⁰; alt. 800m; 17-V-2009; M. Bedjanič & S. Gunasinghe; 5♂, 1♀; – (15) Sinharaja Forest Biosphere Reserve, stream along the road from Martin's Guesthouse to the new visitors centre; Ratnapura district; Sabaragamuwa province; N 6.4315⁰, E 80.4152⁰; alt. 400m; 14-V-2009; M. Bedjanič & K. Conniff; 1♂; – (16) Sinharaja Forest Biosphere Reserve; Mure Kale, near villgers hut; Ratnapura district; Sabaragamuwa province; N 6.4316⁰, E 80.3989⁰; 13-VI-2006;

G. de Silva Wijeyeratne; 1♂; – (17) Sinharaja Forest Biosphere Reserve; Kudawa; Ratnapura district; Sabaragamuwa province; N 6.4085⁰, E 80.4445⁰; 01-VII-2008; K. Conniff; 1♂; – (18) Deniyaya, stream in the forest 10km NEE of Deniyaya; Matara district; Southern province; N 6.36⁰, E 80.46⁰; alt. 330m; 29-IV-2003; M. Bedjanič; 10♂, 5♀, 5 ten.; – (19) Stream on the road Morawaka-Diyadawa on the slopes of Diyadawa forest; Matara district; Southern province; N 6.3122⁰, E 80.5430⁰; alt. 145m; 16-V-2009; M. Bedjanič & S. Gunasinghe; 3♂; – (20) Small stream near the entrance to Kanneliya Biosphere Reserve; Galle district; Southern province; N 6.2509⁰, E 80.3381⁰; alt. 65m; 15-V-2009; M. Bedjanič & S. Gunas-
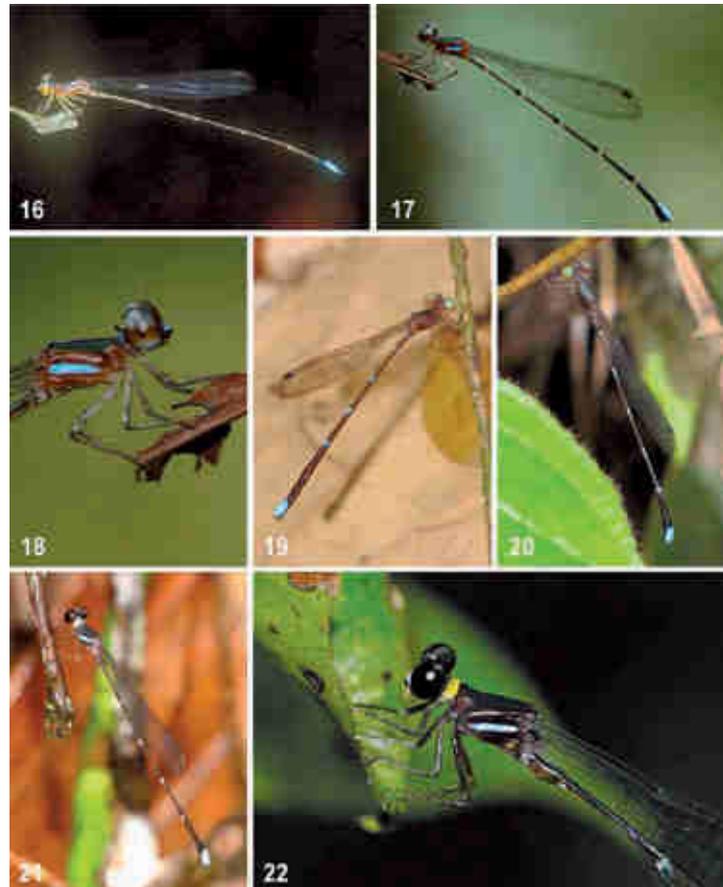
Figs 16-22. Life colouration of newly described species: (16) *Drepanosticta mojca* sp. nov. [male]; − (17) the same [female]; − (18) the same, synthorax and head with visible prothorax projections [female]; − (19) *D. bine* sp. nov. [female]; − (20) the same [male]; − (21) *D. anamia* sp. nov. [juvenile male]; − (22) the same, synthorax and head [male]. − (Figs 17, 18 and 22 photographed by K. Conniff).

inghe; 1♂; – (21) Shady river along forest trail in Kanneliya Biosphere Reserve; Galle district; Southern province; N 6.2595^0, E 80.3436^0; alt. 110m; 1-VII-2007; K. Conniff; – (22) Small tributaries to Hiyare lake on the N shore; Galle district; Southern province; N 6.0585^0, E 80.3165^0; alt. 100m; 21-VI-2006; K. Conniff; 4♂, 2♀; 15-V-2009; M. Bedjanič & S. Gunasinghe;1♂.

TAXONOMIC NOTES AND DISCUSSION

The diversity of the genus *Drepanosticta* in Sri Lanka is remarkable at a global level, and with our three new species, bringing the current total to 17 described species, the island can legitimately be declared as one of the global Platystictidae hotspots.

As already suggested by VAN TOL (2009), the Sri Lankan *Drepanosticta* taxa, based on an example of *D. nietneri* (Fraser), phylogenetically pertain to a basal clade that is separated from the rest of Southeast Asian Platystictidae and species currently ascribed to the genus *Drepanosticta*. It should be noted, however, that based on morphology, even among Sri Lankan representatives, some clearly defined species groups can be recognized. Revision of generic characters and grouping is beyond the scope of this paper. An ongoing molecular analysis of the extensive material from Sri Lanka might bring new insights and changes in this segment as well (M. Bedjanič & J. van Tol, in prep.). In this respect, the three new species do not appear related, but at least *D. mojca* and *D. bine* have closely related species among previously described taxa in Sri Lanka. Some comments on the species relations are given below, based on morphological characters only.

D. mojca – The notable and almost total reduction of inferior appendages in males of this species is unmatched in the family. Furthermore, the curious distal prolongation of the male's last tergite has no comparison among congeners. However, the anterior projections of the prothorax (Figs 16-18) are developed in two other Sri Lankan species, viz. *D. tropica* (Selys) and *D. subtropica* (Fraser). Moreover, both of them have somewhat similarly shaped and quite long superior appendages, but the inferior appendages are not reduced and have strong basal spine and are markedly attenuated towards apex (FRASER, 1933a; 1933b). It is possible that these very thin parts of inferiors lost their role in mating and have been evolutionary reduced to the extent seen in *D. mojca*. An answer to this hypothesis and relations in this species group will be provided by molecular analysis. It should be noted that another new species with almost totally reduced inferior appendages has been recently discovered in forests around Kithulgala and Laxapana. It is closely related to *D. mojca*, but its taxonomic status requires further study.

D. bine – At a glance it is distinguished from all of its congeners by its brown head and beautiful green, blue and brown colouration of the eyes in living animal (Figs 19-20). The only described species with small chocolate brown patch on

vertex and front of occiput are *D. montana* (Selys), *D. submontana* (Fraser) and *D. fraseri* Lieftinck, the latter being of doubtful identity, which will be dealt with elsewhere. Also in the colouration of prothorax and presence of robust rounded tubercles on pronotum, these species seem to be related to *D. bine*. However, they all have clearly defined light thoracic stripes on the metepisternum, while in some specimens of *D. bine* the blue thoracic markings are totally reduced and in others there is only a narrow largely obscured blue stripe along obsolete mesometapleural suture. At the moment, it is not clear whether this variation is age dependant or a stable character of populations from different regions. Here, too, molecular analysis will show relations within this group of species more exactly.

D. anamia – It does not seem to have any near allies and can be recognized by its considerable size, characteristic orange-yellowish colouration of prothorax, distinctive small nipples on the pronotum (Figs 21-22) and curious shape of inferior anal appendages in the male. In the field, as far as eyes colouration, flight, resting posture and general appearance are concerned, it superficially resembles a *Platysticta* more than a *Drepanosticta*. It will be interesting to see the taxonomic placement of *D. anamia* after a detailed revision of Sri Lankan Platystictidae is made, based on morphological as well as molecular analyses.

DISTRIBUTION, PHENOLOGY AND ECOLOGICAL NOTES

Complete distribution and phenology data for all three new *Drepanosticta* species are listed under individual taxonomic descriptions. A short summary of the current knowledge and observations with added notes on their habitats is given in the following lines.

D. mojca – It is known from 6 localities, all confined to Sri Lanka's »Wet zone«, in Kalutara, Ratnapura, Galle and Matara districts (Fig. 23). The localities are widely scattered at distances of 50 to 20 kilometres and only the ones in Sinharaja Forest Biosphere Reserve and its surroundings seem to be potentially connected by the presence of suitable habitats. The southern and the easternmost records are both more than three decades old, so the presence of *D. mojca* there should be checked through additional fieldwork. At least in the South, in the Kottawa Forest Reserve, characteristic rainforest habitats are fortunately still present. It should be noted that *D. mojca*, although easily determined when closely observed in the hand, is rather inconspicuous in the field and might be easily overlooked. Individuals can be found some meters away from streams, in shady and dark undergrowth below higher canopy, usually perching motionless on leaves and twigs at knee height. Along a small stream in the Haycock area flowing through a narrow forest corridor surrounded by sparsely cultivated tea plantations, we have observed several *D. mojca* males in a single place – all other records are more or less coincidental observations of single males. At this locality also *D. lankanesis* (Fraser) and *D. bine* were present. As regards phenology, based on hereto known

data, the adults of *D. mojca* fly in May and June as well as in October. It is expected that through additional fieldwork the species will be discovered in more localities and that a thorough knowledge of its habitat requirements and phenology will be improved as well. However, even with this surmise, *D. mojca* can still be assessed as a rare species. Due to isolation of its populations and continued destruction of appropriate lowland habitats, it should be listed among the endangered endemic dragonflies of Sri Lanka.

D. bine – It is currently known from 16 localities, all confined to Sri Lanka's »Wet zone«, in Kegalla, Nuwara Eliya, Kalutara, Ratnapura, Galle and Matara districts (Fig. 24). In *D. bine*, the populations are isolated but the records are more numerous than in previous species and have been mostly gathered in the last few years. The species is found around minor water habitats in rainforests, such as trickles, marshy springs and very small streams, where individuals can be found near the ground or clinging a few decimetres high from leaves or twigs. Its habitats are not influenced by human activities, but apart from primary forests, the species also inhabits well shadowed habitats with secondary vegetation. At localities of *D. bine* also *D. lankanensis* and *D. brincki* Lieftinck have been observed quite frequently, while *D. anamia*, *Platysticta* cf. *maculata* Selys, *D. mojca* and *Platysticta apicalis* Kirby also occurred at some locations. The altitudinal range of its localities is between 50-500m. Phenologically, the flying period of *D. bine* adults can be ascribed to a general Platystictidae pattern in Sri Lanka, i.e. from end April-May until September-October, which traditionally corresponds with start and end of the monsoon period in the southwestern part of the island. Apart of its generally hidden life, the colouration and markings of *D. bine* are quite characteristic. Therefore, it is easily determined without being captured and is less often overlooked. With additional fieldwork, the species will be discovered in more locations. However, its populations are isolated and due to further destruction of the appropriate small forest wetland habitats in south-western part of Sri Lanka, *D. bine* requires nature conservation attention as well.

D. anamia – It is currently known from 22 localities, all in Sri Lanka's »Wet zone«, in Kegalla, Nuwara Eliya, Colombo, Kalutara, Ratnapura, Galle and Matara districts (Fig. 25). In contrast to the previous two species, *D. anamia* is a fairly large and conspicuous damselfly that is not overlooked by experienced odonatologists. Animals are usually found near streams, hanging from leaves at belt or chest height. When juvenile, due to the size and light colour of the prothorax the adults can be mistaken for a *Platysticta* by less experienced observers. This species seems to be more common among the three new species described, but many localities are grouped in the same forested areas around Kithulgala and Laxapana as well as in the Sinharaja and Kanneliya Forest Biosphere Reserves and their surroundings. *D. anamia* inhabits small to mid-sized shaded streams in primary and secondary forests. It has been found in rather disturbed landscapes but with a corridor of well preserved trees and bushes along the stream. A stream

in Balutota Pass near Rakwana, for example, flows through sterile pine planta-
tions, but at least in the short term, even a narrow shaded corridor of primary
and secondary vegetation still offers suitable conditions for this species. The ac-
companying Platystictidae at localities of D. anamia were most commonly D.
lankanensis, D. brincki, Platysticta cf. maculata and D. bine. The altitudinal range
of its localities is between 50-800m, so D. anamia apparently has a wider ecologi-
cal tolerance than D. mojca and D. bine. The flight season stretches from the end
of April till September, with a single end-February record, which could indicate
that it flies also during the end of the »dry season« in the southwestern part of
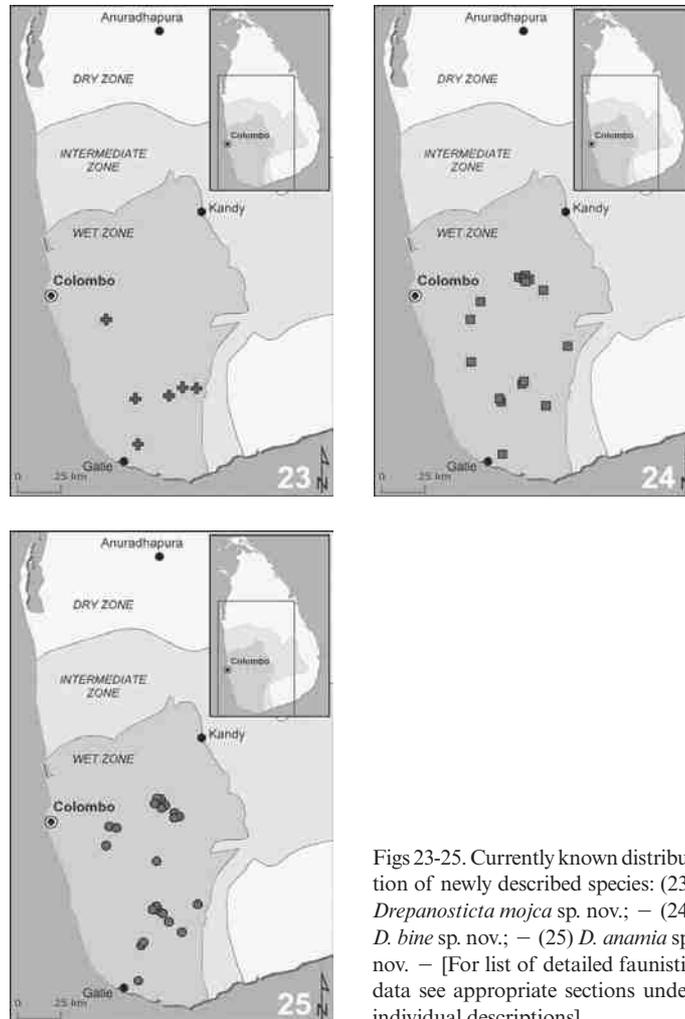
Figs 23-25. Currently known distribu-
tion of newly described species: (23)
Drepanosticta mojca sp. nov.; − (24)
D. bine sp. nov.; − (25) D. anamia sp.
nov. − [For list of detailed faunistic
data see appropriate sections under
individual descriptions].

the island. More fieldwork will provide new records of *D. anamia*, however, as in *D. mojca* and *D. bine,* potentially suitable habitats have been severely fragmented and mainly left only as small pockets among vast areas of sterile tea plantations, clear-cut eroded slopes and fields. Therefore, even the potential area of its occupancy is small. Also in this species, a detailed assessment of its distribution, estimation of population sizes and future monitoring are needed.

CONSERVATION ASPECT

The island of Sri Lanka is, together with the south Indian Western Ghats, classified as one of the global »biodiversity hotspots« (MITTERMEIER et al., 2000). In odonatological terms, the number of around 125 hitherto recorded species is not extremely high by itself, but the very high level of endemism, reaching almost 50% in some genera and families, is indeed remarkable at the global scale (KALKMAN et al., 2008).

However, apart from being one of the »hottest« in biodiversity terms, the region has by far the highest human population density in this prestigious company. In the case of Sri Lanka's »Wet zone«, which accounts for only a quarter of the land surface in the central and southwestern parts of the island but contains roughly three quarters of the island's endemic biota, a density of nearly 700 people/km^2 was calculated (MITTERMEIER et al., 2000). The rapid destruction and fragmentation of rainforests have brought the island to the brink of disaster in the last few decades. Today, the surface covered by relatively undisturbed natural forests is estimated at much less than 10%. In other words, only around 800 km^2 of undisturbed natural forest remains in the southwestern part of Sri Lanka and most of it has been severely fragmented and isolated.

In this respect, the restriction of several Platystictidae species to the small streams in the rainforests' shadows is fatal. The meticulously cut tea plantations and bare, eroded slopes covered with grass are far from being suitable for their survival. In addition to the rainforest destruction and fragmentation, the destruction of forest corridors along streams, water extraction for irrigation purposes, over-use of pesticides and heedless pollution of streams and rivers in the central and southwestern parts of Sri Lanka represent significant risk factors for the survival of these tender damselflies. Particularly so, as most *Drepanosticta* species have very restricted ranges and many of them are persisting only in small remaining pockets of their original habitat.

Looking from a slightly more optimistic perspective, the distribution of the three new species seems not to be very limited and it is definitely a good news that there are many recent records confirming their presence at different sites. Another positive finding is that some populations can obviously survive also in rather disturbed forests or even in habitats with only a narrow forest corridor along streams. Therefore, at least in the case of *D. anamia* and *D. bine*, their conservation status,

in the short run, is not critical. However, the estimation that their populations are in fact already severely fragmented and isolated is very likely. Although their extent of occurrence according to the international IUCN criteria is more than 5,000 km², their presently known area of occupancy is much smaller and will due to the above reasons not change considerably also with discovery of new sites. In the future, therefore, all three beautiful new *Drepanosticta* species surely deserve our close conservation attention and monitoring.

ACKNOWLEDGEMENTS

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SEX RATIOS AT EMERGENCE IN POPULATIONS
OF SOME CENTRAL EUROPEAN GOMPHIDAE SPECIES
(ANISOPTERA)

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At emergence (F-0) a significant bias for ♀♀ was observed within the Moravian (Czech Republic) populations of *Gomphus flavipes* (Charp.), *G. vulgatissimus* (L.) and *Ophiogomphus cecilia* (Fourcroy). ♂♂ represented 45.6% of all specimens (43.5% in the first and 46.4% in the second research year). The results of the χ^2 test supported the ♀-biased sex ratio in populations of all 3 spp. The sex ratio in populations varied significantly in time during the emergence season, caused by the fact that all 3 spp. demonstrated a significant protandric trend. The greatest changes in sex ratio during the emergence season were demonstrated by *G. flavipes* (coefficient value -0.007542); the smallest were recorded in *G. vulgatissimus* (CV -0.008617). Environmental impact did not prove to act be a factor which has an effect on the sex ratio of species with phenotypical determination of sex.

INTRODUCTION

The sex ratio is the ratio of males to females in a population. The primary sex ratio is the ratio in the egg phase, the secondary is at the time of hatching, the tertiary is of immature adults and the quarternary is of breeding adults (PIANKA, 2000). Sex determination in odonates is under genetic control, sex being determined by sex chromosomes (KIAUTA, 1969). Consequently, the theory predicts equal numbers of males and females (HARDY, 2002), but biased sex ratios are relatively common in dragonfly populations (CORDERO RIVERA & STOKS, 2008). The sex ratio at emergence should be more female-biased in territorial than in non-territorial species (CROWLEY & JOHANSSON, 2002). A comprehensive

review of sex ratio at emergence in odonates (CORBET & HOESS, 1998) shows a slightly male biased sex ratio in Zygoptera and a slightly female biased one in Anisoptera.

The question remains whether the difference in sex ratio reflects a real difference in the proportion of males to females or rather an artificially observed and incorrectly assessed phenomenon. The choice of method often plays an important role in the results regarding the sex ratio in dragonfly populations. Several mark recapture studies have concluded that there is a male biased sex ratio, especially since different recapture probabilities occur in the two sexes (see CORDERO RIVERA & STOKS, 2008). Female dragonflies are more 'hidden' than males; however, statistical methods, robust against variant recapture probabilities, have yielded data supporting the male-biased sex ratios in mature Zygoptera populations (ANHOLT et al., 2001; STOKS, 2001a). Several hypotheses explaining the causes for male-biased sex ratio in dragonflies have been proposed, based on observations of just a few species of Zygoptera (ANHOLT et al., 2001; STOKS, 2001a, b). Analyses of the sex ratio in numerous groups of dragonflies, especially from the Anisoptera, are not available or show inconclusive results.

The objective of this work was to assess the sex ratios at emergence, from the larval stage to the adult stage, in populations of Central European species of Gomphidae, based on the high number of collected exuviae, and to analyse trends in the sex ratio during the season and in different types of environment.

METHODS

STUDY SITE. − The study site is situated in the south-east of Moravia in the Czech Republic. From the biogeographical point of view, it is a promontory of the Pannonia province. Four localities were studied on the Morava river between Uherské Hradiště and Hodonín (Loc1: 49°1'51"N, 17°23'35"E; Loc2: 49°0'42"N, 17°23'53"E; Loc3: 48°52'50"N, 17°12'20"E; Loc4: 48°55'11"N, 17°16'30"E; elev. 165-170 m). The individual sites varied significantly due to the anthropogenic impact, from straightened and regulated parts of the river to natural meandering stretches untouched by humans. Three 100 metre stretches were observed (altogether 1200 metres) at each locality. Exuviae were collected up to 150 cm from the bank line. Data collections took place over 2 years; from the third week in May to the end of June 2007 and from the second week in May to the first week in July 2008 (38 research days).

The works of GERKEN & STERNBERG (1999) and HEIDEMANN & SEIDENBUSCH (1993) were used to determine the species and sex. A sex ratio was calculated for each species and tested for expected 'equal ratio' using the χ^2 test. Furthermore, differences in sex ratios over time and as influenced by other factors were evaluated using a generalized linear model (GLM) for binomial response (quasibinomial respectively due to overdispersion). The terms were added sequentially, evaluated by Mallows' Cp statistic (closely related to AIC) and tested by F-test (FARAWAY, 2005). The model was examined for each sex ratio weighted by number of individuals. The analysis was carried out using R software (R DEVELOPMENT CORE TEAM, 2007). The response variable (sex ratio) was weighed by the number of exuviae, as usual.

RESULTS

In 2007/2008, 6897 exuviae of four Gomphidae species were collected: *Gomphus vulgatissimus* (4064 specimens), *G. flavipes* (1181 specimens), *Ophiogomphus cecilia* (1645 specimens) and *Onychogomphus forcipatus* (only 7 specimens; evaluated no further due to the low number).

Of the 6890 exuviae of the three analysed species, 3122 were males and 3722 were females. Damaged exuviae that could not be sexed were excluded (46 specimens). Males represented 45.6% of all specimens (43.5% in 2007 and in 46.4% in 2008). Females were dominant in all three species and also in both years. The results of the χ2 test supported the female-biased sex ratio in populations of all three species (Tab. I, Fig. 1).

Table I

Sex ratio of the three gomphids calculated for both years and sites in total and the p-value of χ^2 test for an equal proportion of males and females

Species	Male	Female	Male (%)	p
Gomphus flavipes	550	619	47.05	0.0436
Gomphus vulgatissimus	1833	2205	46.05	<0.0001
Ophiogomphus cecilia	739	898	45.05	<0.0001

Despite the main analysis is based on GLM, we can see five of the twelve data sets revealed a significant difference from a 1:1 sex ratio (with majority of females) whereas seven did not when the data was broken down into individual sites (Tab. II).
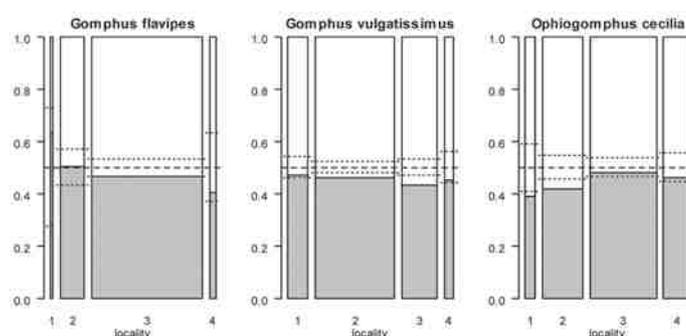

Fig. 1. Proportion of males (gray) and females (white) for the samples from the sites (1-4; severely degraded to natural habitat) with respect to number of specimens (different bar width) in comparison with equal proportion (dashed line) and 95 % confidence intervals for sex ratio = 0.5 (dotted lines).

Table II

Sex ratio of three gomphids in each of the four localities. Values in bold indicate significant difference from a 1:1 sex ratio

Locality	Species	Male	Female	Male (%)	p-value χ^2 test
1	*Gomphus flavipes*	12	7	63.2	0.251
	Gomphus vulgatissimus	270	303	47.1	0.168
	Ophiogomphus cecilia	**46**	**72**	**39.0**	**0.017**
2	*Gomphus flavipes*	100	99	50.3	0.943
	Gomphus vulgatissimus	**1020**	**1198**	**46.0**	**<0.001**
	Ophiogomphus cecilia	**190**	**266**	**41.7**	**<0.001**
3	*Gomphus flavipes*	**415**	**479**	**46.4**	**0.032**
	Gomphus vulgatissimus	**424**	**559**	**43.1**	**<0.001**
	Ophiogomphus cecilia	360	392	47.9	0.243
4	*Gomphus flavipes*	23	34	40.4	0.145
	Gomphus vulgatissimus	119	145	45.1	0.111
	Ophiogomphus cecilia	143	168	46.0	0.156

The differences in sex ratios in individual species and dates of collections were demonstrated by the analysis of deviance. Different localities did not indicate any differences in sex ratios despite significant variation in the character of the environments and the levels of anthropogenic influence (Tab. III).

Using Mallows' Cp statistics for GLM diagnostics of explanatory variable importance we found 'time×species' interaction as the best variable to explain the trends in the sex ratio (Tab. III). All regression coefficient values were negative (see Fig 2) which means that sex ratio is decreasing during emergence season. However, subsequently their proportion in the population declined and at the last stage of emergence time it was females that were in the majority (F=3.4698, p=0.0193). This protandric trend was observed in all three species (Fig. 2). The greatest changes in sex ratio during the emergence season were demonstrated by *G. flavipes* (coefficient value -0.007542); the smallest were recorded in *G. vulgatissimus* (coefficient value -0.008617).

Table III

Comparison of Mallows' Cp statistics for GLM models using different factors

	Df	Deviance Res.	Df	Resid. Dev.	Cp
NULL			95	154.95	158.03
habitat	1	0.111	94	154.84	161.00
year	1	4.353	94	150.50	156.58
species	2	1.194	93	153.76	163.03
time	1	8.635	94	146.32	**152.13**
time×species	3	14.782	92	140.17	**151.53**

DISCUSSION

The collection of exuviae has proved to be the optimal method for determining the sex ratio in a population at emergence. When observing imagos, the sex ratio is often misrepresented due to the fact that low numbers of females in breeding habitats are sampling artefacts caused by sex-specific differences in patterns of habitat use (e.g. ANHOLT, 1997; CORDOBA-AGUILAR, 1993; FOSTER & SOLUK, 2006; STOKS, 2001a, 2001b). For instance, in a complex database, DOLNÝ et al. (2008) have drawn from the available data, it is evident that male gomphid imagos were clearly more numerous than females. The real sex ratio in adults at emergence is quite different according to 'the final instar (F-0)' observation. Our results have shown that the real sex ratio is female biased in all three of the observed Gomphidae species. Having also studied exuviae, MÜLLER (1995), stated a slight prevalence of females in *G. flavipes* and *G. vulgatissimus*. A study of *Asiagomphus pryeri*, another representative of the family, demonstrated significantly fewer males than females at emergence. Sex ratios in the three years of this study were 38.8% to 41.5% males (AOKI, 1999). Similar findings were recorded in the representatives of other Anisoptera families. KÉRY & JUILLERAT (2004), based on the mark-recapture method, described a balanced sex ratio for *Orthetrum coerulescens* with a slight female bias (statistically inconclusive, perhaps caused by a small number of marked specimens). The predominance of females over males was also confirmed by BEUTLER (1986), who stated that in Anisoptera almost always emerge more females than males. The situation is usually entirely different in the Zygoptera. Numerous studies concerned with the sex ratio of several species of Zygoptera have yielded data demonstrating a significant prevalence of males (ANHOLT, 1997; ANHOLT et al., 2001; STOKS, 2001a, 2001b). Whereas some studies on Zygoptera have suggested that the sex
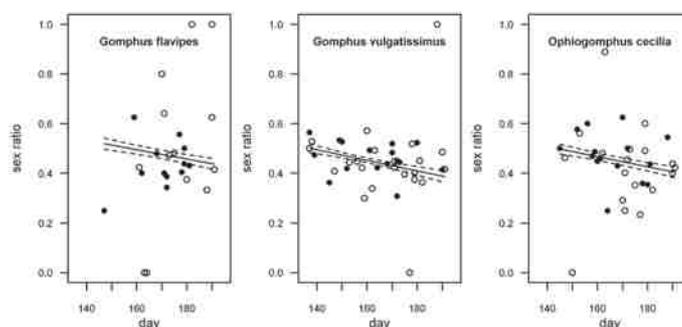

Fig. 2. Changes in proportional representation of males in populations during the season (dark colour is used for the higher statistical-weight values; − empty circles: ratio based on less than 30 individuals).

ratio does not significantly differ from 1:1 (e.g. BENNETT & MILL, 1995), other workers have found that the sex ratio may differ from 1:1 in one researched species but not in the other analysed species (PURSE & THOMPSON, 2003).

There are different opinions regarding the reasons, purposes and advantages of unbalanced sex ratios in dragonflies. There are several evolutionary ecological hypotheses explaining biased sex ratio in dragonflies at emergence and these focus on the larval stage as well as on adults. LAWTON (1972) pointed out that higher mortality in males during the larval stage may be a reason for the unbalanced sex ratio. According to this theory, the subsequent higher numbers of females should act as an advantage during selection. Nevertheless, he does not mention what may be the cause for the higher mortality in males. However, a recalculation of Lawton's data, separating larvae from exuviae, revealed that no difference from 1:1 at emergence was found. There was no significant difference in the proportions of larvae or exuviae (BENNETT & MILL, 1993). BAKER et al. (1992) stated that male and female larvae can differ in activity level, though little is known about this. Alternative reasoning for the biased sex ratio at emergence highlights the importance of the adult stage, and especially immature adults. It is thought that, from the evolutionary point of view, one of the sexes should incur higher losses during the maturation period or asymmetric selection pressure on one of the sexes (which is the case in the Zygoptera).

The higher mortality rate in male imagos may be caused by different life histories of each sex (CROWLEY, 2000; CROWLEY & JOHANSSON, 2002). It is to a certain extent determined by the length of the maturation period. The length of maturation period is significantly longer in females of primarily non-territorial species. This relates to a higher level of foraging and dispersal rates in immature females (STOKS, 2001b). CORBET (1999) also pointed out that the highest natal dispersal is connected with immature stages. Due to the fact that higher dispersal rates as well as foraging rates generally correlate with higher risks of predation (WERNER & ANHOLT, 1993), it may be assumed that immature individuals, in this particular case females, will have higher mortality rates. Different life histories may result in different preferences of females for alternative habitats. This bias has been attributed, in particular, to the females of non-territorial species using alternative habitats to avoid male harassment (FOSTER & SOLUK, 2006; UTZERI et al., 1988).

It was remarkable to observe that the sex ratio in the gomphid populations changed with time, therefore it changes significantly during the emergence season. Males emerged earlier than females. However, the situation gradually changed to the point of females being prevalent (Fig. 2). This protandric trend in Gomphidae was also observed by SUHLING & MÜLLER (1996) and it was observed during one season by AOKI (1999). Very few studies have attempted to explain the causes and consequences of this phenomenon. INDEN-LOHMAR (1997) speculated that there is a connection between protanders and the reproductive

success of *Aeshna cyanea*, where individuals hatched earlier had a greater reproductive success. According to this hypothesis, there is a higher selection pressure for faster development on males than on females and it may correspond with the mating system of a given species (CORBET, 1999).

No significant differences were found in the sex ratios from different localities, even though there were significant differences among the environments in individual localities. Environmental impact (such as predation, resources, habitat quality) could be one of the important factors influencing the sex ratio (CORBET, 1999; CORDERO RIVERA & STOKS, 2008; STOKS, 2001b). However, the impact of the environment on the sex ratio in the studied species has, according to our results, proved to be insignificant.

ACKNOWLEDGEMENTS

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BEHAVIOURAL RESPONSES OF *ENALLAGMA* TO CHANGES IN WEATHER (ZYGOPTERA: COENAGRIONIDAE)

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Odonates exhibit a variety of weather associated behaviours, including abandoning ponds just before storms begin. They may be able to detect changes in weather that alert them to approaching storms and allow them to escape the water's edge before it begins to rain. *E. annexum* and *E. boreale* were observed at a Colorado marsh (USA) to determine which weather factors contributed to the weather-induced behaviours they exhibit. They were observed for 191 five-minute periods and their flight activity quantified. Weather parameters were measured during each interval to account for rapid changes in conditions. Based on results from multiple regression analysis, it is clear that light intensity is the strongest weather parameter affecting zygopteran flight activity, but temperature, wind speed, and the presence of rain are also significant. The 2 spp. exhibited pond abandonment behaviour during storms. It is likely that storms are dangerous to zygopterans and their apparent ability to detect impending storms is a survival mechanism. Alternatively, pond abandonment behaviour may be triggered by the same factors necessary to trigger roosting and the zygopterans simply return to their roosting sites during storms.

INTRODUCTION

Weather is known to dramatically affect odonate behaviour (CORBET, 1999). Parameters such as temperature, light intensity, wind speed, and rain are known to impact odonate patrolling and diel patterns, posture, and prevalence of shade or sun seeking, among other behaviours (e.g. CORBET, 1962; BICK & BICK, 1963; MILLER, 1982; GONZALES-SORIANO, 1987). In one behaviour, called pond abandonment, odonates may be able to sense changes in the weather that

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prompt them to leave the water prior to the onset of storms (BICK & BICK, 1961; KIAUTA, 1964; OKAZAWA & UBUKATA, 1978). Indeed, few odonate species have been observed flying during rains (e.g. McVEY, 1988; GARRISON, 1989; KIAUTA & KIAUTA, 1994; CORBET, 1999), and those that do are usually strong fliers. For example, one of the strongest fliers is *Pantala flavescens*, a species able to fly both across oceans and during storms (SAMWAYS & CALD-WELL, 1989; MOORE, 1993).

Despite the wealth of knowledge available regarding odonate behavioural responses to weather, few researchers have focused specifically on the role weather plays in odonate behaviour. Most of what is known has been culled from works focusing on other subjects, such as life history or diel patterns (e.g. DELL'ANNA et al, 1990; CORDOBA-AGUILAR, 1994). Responses to weather are often mentioned in the discussion as a possible explanation for aberrant data or unusual observed behaviours. Other researchers have left these data out (e.g. SWITZER & EASON, 2000; KIRKTON & SCHULTZ, 2001; STOKS, 2001), stating in the methods that data from days of inclement weather were not included in the analyses presented. Statements like these suggest that weather plays a major role in shaping odonate behaviour and that, by eliminating these data from analyses, we are left with an incomplete understanding of how odonates truly behave.

Few studies have focused specifically on the impacts of weather parameters on odonate behaviour (e.g. CALVERT, 1926; MITCHELL, 1962; MAY, 1976, 1978) and even fewer have studied more than one parameter simultaneously (e.g. BELYSHEV, 1967; LUTZ & PITTMAN, 1970). However, in most studies each parameter was analyzed independently of the others, making it impossible to determine how all of the parameters together affect odonate behaviour. A study by DE MARCO & PEIXOTO (2004) compared four weather factors in a multiple regression analysis, but such studies are rare.

Here I present data on the impacts of seven weather parameters (wind speed and direction, humidity, temperature, light intensity, barometric pressure, and presence of rain) on flight activity of a population of an *Enallagma* population (Zygoptera: Coenagrionidae) in a Colorado wetland. My objectives were to determine how the suite of weather parameters together impacted *Enallagma* flight activity levels and which parameters were most important in determining flight activity levels.

METHODS

The site was located in Fountain Creek Regional Park in Fountain, Colorado, USA (N 38º 42.95" W 104º 43.05", elevation 1,980 m). The area is a protected wetland containing several marshy ponds. All observations were made at a small, shallow pond (surface area = 1,060 m², maximum depth = 0.6 m) located near the northeastern boundary of the park. The pond was surrounded by cattails (*Typha* sp.) and other aquatic macrophytes. A representative 5.5 m² study area was selected that included 90% open water and 10% vegetation that was similar in plant composition and density to the

remaining areas of the pond. All observations were made within this study area.

Observations were made on *Enallagma annexum* (Hagen) and *E. boreale* (Selys). Because they showed similar behavioural patterns in response to weather, both species were treated as a single group in the statistical analyses.

Observations were made on 18 days in June and July 1999 between 1600 and 1700 hours. Each observational period was divided into five-minute intervals for a total of 191 observations. During the first minute of each interval, the weather conditions were measured directly offshore: wind speed (m/s), wind direction (°), temperature (°C), light intensity (ft-c), relative humidity (%), barometric pressure (Pa), and the presence or absence of rain. A hand-held compass and digital anenometer oriented directly into the wind were used to determine wind direction and speed. A simple thermometer was used for temperature measurements. To measure light intensity, a hand-held light meter was pointed toward the water. A hygrometer was used to measure relative humidity and a barometric pressure gauge for barometric pressure. Presence of rain was noted visually.

The remaining 4 minutes of each time interval were spent counting the number of *Enallagma* flights within the study area. Flight was defined as any movement within the study area requiring the use of wings such that the damselfly was not in contact with a perch or substrate. All flights within the study area were counted for each time interval using a clicker counter. Individuals could be counted more than once and tandem pairs counted as two flights. *Enallagma* flying into the study area from outside were counted. At the end of 4 minutes, the total number of flights was recorded before starting the next 5 minute interval.

A multiple regression analysis was completed in JMP Version 6.0 (SAS Institute) using the seven weather variables as the explanatory variables and the number of flights per time interval as the response variable. Light intensity and the number of flights were log transformed to improve equality of variance. The presence of rain was indicated by coded numeric values with a 1 representing rain and a 0 the absence of rain.

RESULTS

Wind direction ($p = 0.12$), humidity ($p = 0.09$), and barometric pressure ($p = 0.16$) did not contribute significantly to flight activity after accounting for other variables and were removed from the final multiple regression analysis.

Temperature showed a positive relationship with flight activity (slope $= 0.02 \pm 0.009$ SE, n $=191$, p $= 0.042$) (Fig. 1). The minimum temperature at which flights were observed was 24°C. Flight continued up to the maximum observed temperature of 37°C.

An increase in wind speed was significant-
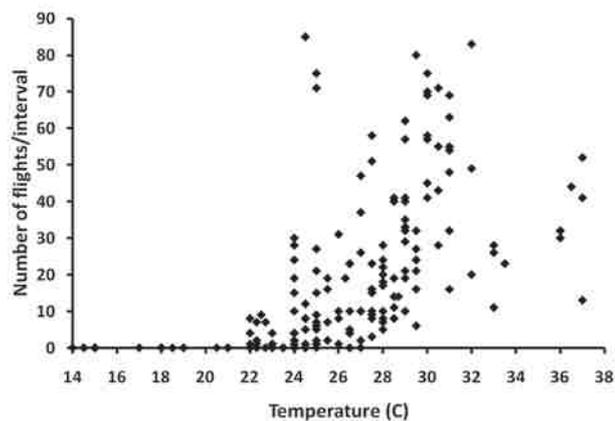

Fig. 1. Temperature and *Enallagma* flight activity.

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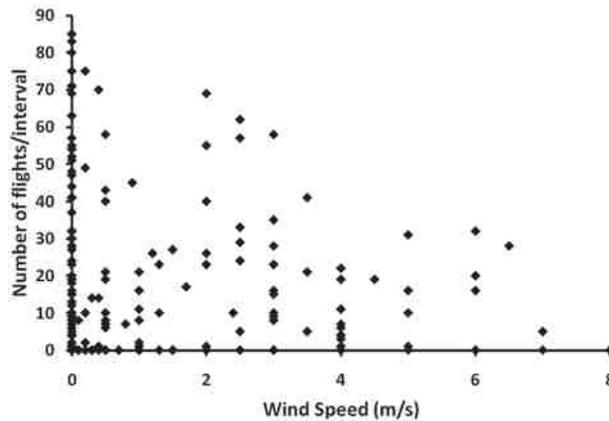
Fig. 2. Wind speed and *Enallagma* flight activity.

ly associated with a small decrease in flight activity (slope = -0.05 ± 0.012 SE, n =191, p < 0.0001) (Fig. 2). Wind speeds varied between 0 m/s and 8m/s throughout the study.

The number of flights increased with light intensity (slope = 0.94 ± 0.087 SE, n =191, p < 0.0001) (Fig. 3). The minimum light intensity recorded during the study was 25 ft-c and the maximum 950 ft-c.

Presence of rain significantly decreased the number of flights observed, with a slope estimated at –0.12 (± 0.029 SE, n = 191, p = 0.0003) (Fig. 4).

A predictive model was produced by the multiple regression analysis. The full model is:

μ {log(flights+1): temperature, wind speed, log light intensity, presence of rain} = -1.71 + 0.02 [temperature (ºC)] – 0.05 [wind speed (m/s)] + 0.94 [log light intensity (ft-c)] – 0.12 [presence of rain]

The predicted number of flights can be obtained by entering measurements of the four weather factors within the range of values reported herein in the appropriate positions in the above model. Figure 5 represents the number of flights predicted by the model in poor, average, and good weather conditions, falling within the range of those conditions observed during this study.

The four weather factors included in the model explain about 80% of the variation in the data (R^2 = 0.794).
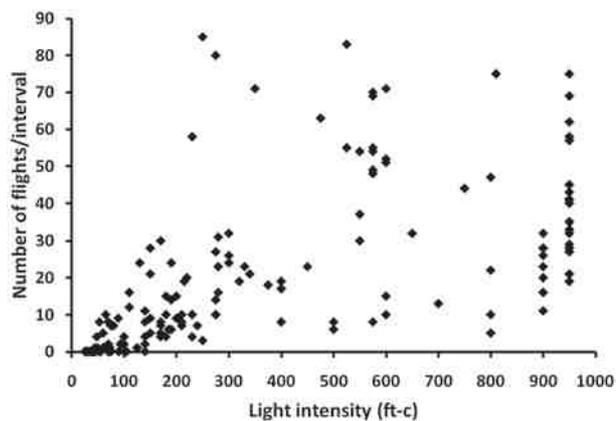

Fig. 3. Light intensity and *Enallagma* flight activity.

DISCUSSION

The positive relationship between flight activity and wind speed observed here is not surprising. Many insects are hindered by strong winds, and odonates are no exception. Hilfert (referenced in CORBET, 1999) suggests that Zygoptera rarely fly in winds above 3.5 m/s. WARINGER (1982) reported flight at a maximum wind speed of 8 m/s for *Coenagrion puella*, suggesting that some damselflies are capable of flying in wind speeds greater than 3.5 m/s. The *Enallagma* species I observed flew at speeds much greater than 3.5 m/s, up to 7 m/s, although there were no flights observed at the highest wind speed recorded (8 m/s).

Because zygopterans have large, broad wings and small, light bodies, wind likely severely impedes their flight and may even pose a threat if it reaches sufficient strength. Serious consequences may arise if an individual is blown into a perch, the ground, or the water, so they may not fly in strong winds to avoid these threats. Some studies have found that zygopterans do fly during high winds, but only in wind-protected areas (DUNKLE, 1976; CORBET, 1999). It is likely that most species do not fly in open areas during strong winds, as observed here and in other studies (BELYSHEV, 1967; WARINGER, 1982).

The relationship between temperature and flight activity is also no surprise. Odonates, like all arthropods, are exothermic and their body temperatures are close to ambient temperature. Below a certain temperature, odonates are unable to warm their flight musculature sufficiently to fly. This threshold appeared to be 24ºC in the population I studied as no flights were observed below that temperature. Attempting to fly at low temperatures likely has similar consequences to flight in strong winds. A chilled zygopteran runs the risk of crashing into a perch or into the water, potentially damaging it or increasing its vulnerability to predation.

Light intensity has a strong impact on flight activity. Several researchers have examined the role light intensity plays in odonate behaviour (e.g. PINHEY, 1962; WILLIAMS, 1976; BOANO & ROLANDO, 2003) and it is clear that light is an important factor. LUTZ & PITTMAN (1970) found that light intensity had the largest impact on flight behaviour in the population they observed. My analysis corroborates their conclusion. Most of the decreases in light intensity
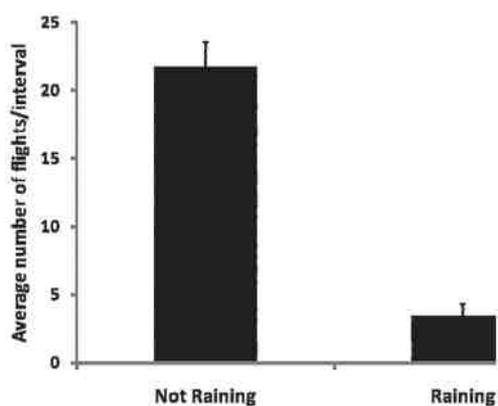

Fig. 4. Rain and *Enallagma* flight activity. Bars represent standard error.
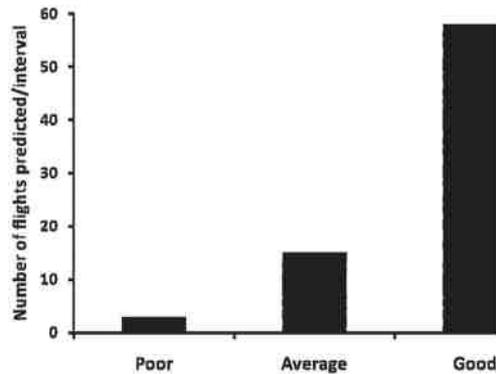
Fig. 5. Predicted number of *Enallagma* flights under various weather conditions. P o o r conditions are defined as: temperature = 24ºC, wind speed = 7m/s, light intensity = 200ft-c, and rain = 1; − A v e r a g e conditions are defined as tempterature = 29.7ºC, wind speed = 1.3m/s, light intensity = 344.0 ft-c, and rain = 0.2; − G o o d conditions are defined as temperature = 35ºC, wind speed = 0.5m/s, light intensity = 950ft-c, and rain = 0.

during my observations were due to increases in cloud cover. At those times, it was possible to see a distinct decrease in activity with a decrease in light intensity through casual observation alone, before running any statistical tests.

In the *Enallagma* species observed, flight activity was greatly reduced in the presence of rain. It rained heavily one day in June and no zygopterans were observed in the study area at all. Although I did not attempt to quantify it, there was an obvious decrease in the number of individuals in the study area if the rains lasted more than a few minutes and they were apparently leaving the pond altogether during extended periods of rain. These observations agree with others who have observed pond abandonment behaviour preceding or during periods of rain (KIAUTA, 1964; BELYSHEV, 1967). While some anisopterans will remain flying during light rain (SAMWAYS & CALDWELL, 1989) or stop only in heavy or prolonged rain (MOORE, 1993), zygopterans are usually smaller than anisopterans and are much weaker fliers. It is likely that the former show far less activity during periods of rain than their larger relatives. In fact, during the course of this study I witnessed only one zygopteran flight in rain, and it was during an insignificant rain while the sun was shining. This observation is not perfectly reflected in Figure 4 as there are several flights indicated during rain, but it can easily be explained by my data collection method. Conditions could, and sometimes did, change dramatically during a 5-minute time interval such that it would be raining at the beginning of the interval and not at the end. Any flights recorded during these time intervals were recorded as flights during rain regardless of whether they were actually flying during rain. I suspect that rain has a much more significant impact on flight activity than my data suggests and more observations should be made to determine whether this is the case.

Light rain may not have a considerable damaging affect on Zygoptera, though it could increase the evaporative cooling rate of the insects and hinder their escape as conditions deteriorate. Moderate to heavy rains, however, are probably dangerous to them. These could cause direct physical damage and can potentially

knock a resting individual from a perch onto the ground or into the water. The former could cause damage by direct physical contact, but the latter is probably particularly dangerous because the wings could easily become trapped in the surface film and expose the insect to drowning or predation.

If rain is in fact damaging, it is in a damselfly's best interest to leave the water in search of shelter before rain begins. In this case, it should be able to sense cues that storms are approaching and leave while conditions are still sufficiently acceptable to allow easy withdrawal from the pond. The use of cues to avoid damage by storms has been documented in other species (e.g. giant water bugs, LYTLE, 1999; hellgrammites, Carl Olsen, pers. comm.), so it is reasonable to suppose that zygopterans may employ a similar tactic toward the same end. The cues for pond abandonment are most likely the same weather factors that I measured during my study. In the area of Colorado where the study was undertaken, afternoon thunderstorms occur almost every day during the summer months. Storms usually approach and pass quickly, but can be incredibly violent. As a storm approaches, the light intensity decreases as the cloud cover becomes more extensive. The temperature begins to drop quickly and the wind usually becomes stronger. By the time rain begins, it is usually dark, cool, and windy, i.e. poor conditions for damselflies. As all four of these weather factors showed a significant association with their flight activity, changes in these factors likely act as cues for them, warning them of approaching storms. Indeed, as illustrated in Figure 5, the model predicts only about three *Enallagma* flights under poor conditions. Poor conditions in this figure represent typical rainy weather: low temperature, low light intensity, moderate wind, and rain. In contrast, much higher flight activity is predicted in good conditions (bright, warm, no wind or rain), suggesting that deteriorating weather conditions have a considerable impact on flight activity.

A drop in barometric pressure precedes the approach of storms and would act as an excellent advance warning system for odonates able to detect it. BELYSHEV (1967) suggests that barometric pressure affected the flight activity of *Leucorrhinia rubicunda*, so some odonates may use pressure as an abandonment cue. The *Enallagma* I studied did not. Because barometric pressure drops long before rain begins, damselflies using pressure as an abandonment cue may leave the pond too soon. An increase in mating activity has been observed in *Enallagma* immediately preceding or just after the start of storms (WHITE-CROSS, 1984), so leaving the pond before it becomes necessary would limit an odonate's chances to mate and may decrease its fitness.

While odonates appear to use abandonment cues to avoid approaching storms, it is possible that they do not abandon ponds as a protective measure. During the storms I witnessed, it became quite dark and cool before the rains began. This drop in light intensity and temperature may have prompted the odonates to seek their evening roosts. They are visual animals, using their remarkable vision to hunt, assess oviposition sites, protect their territories, and find mates (CORBET, 1999).

They are also known to use light and temperature to regulate their diel patterns (LUTZ & PITTMAN, 1970; WARINGER, 1982) and during pond abandonment (MILLER, 1964, 1983; BICK & BICK, 1961; OKAZAWA & UBUKATA, 1978). Studies of roosting behaviour in Anisoptera have found that roosting is closely correlated with light intensity (PARR & PARR, 1974; HASSAN, 1976; MILLER, 1989). Similar pond abandonment behaviours have been documented in response to solar eclipses (MITRA, 1996; KIAUTA & KIAUTA, 1999), suggesting that odonates may abandon ponds in response to drops in light intensity regardless of whether a storm follows or not. It is likely that a zygopteran returns to its roost before a storm simply because the conditions are similar to those that prompt a return to the roost at night. This is a simpler explanation of pond abandonment behaviour than the use of cues to avoid storms, though the data presented here do not lend credence to either hypothesis. Further studies are necessary to tease apart these two hypotheses and to determine whether light intensity and/or temperature are sufficient triggers for roosting and whether damselflies are able to detect changes in their environment to use cues to avoid storms.

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A SCANNING ELECTRON MICROSCOPE STUDY
OF THE ANTENNAL SENSILLA IN ADULT ZYGOPTERA

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Scanning electron microscope studies of the antennal flagella of *Coenagrion puella* and *Ischnura elegans* (Coenagrionidae), *Platycnemis pennipes* (Platycnemididae), *Lestes barbarus*, *L. viridis* (Lestidae), *Calopteryx virgo* and *C. haemorrhoidalis* (Calopterygidae) reveal the presence of pits containing sensilla on the latero-ventral side of the antenna. All these pits are the opening of deep cavities bearing the same sensilla previously described on Anisoptera antennae. These sensilla are represented by: (i) coeloconic porous sensilla, visible on the antennal surface, whose structure is in agreement with that reported for single walled olfactory receptors, and by (ii) two types of sensilla styloconica (type-1 and type-2), located at the bottom of the cavities and sharing common features typical of thermo-hygroreceptors. The present data allow us to extend previous considerations on the sensory role of the dragonfly antennae to the whole order Odonata, suggesting that olfaction, together with the ability to perceive temperature and humidity, are the main sensory functions of the antennae of these insects.

INTRODUCTION

An early overview of the sensory structures located on the antennal flagellum of Odonata reported the presence of coeloconic sensilla located in pits in both the suborders, Anisoptera and Zygoptera (SLIFER & SEKHON, 1972). Recently, more detailed fine structure (SEM, TEM) investigations on some Anisoptera species (REBORA et al., 2008; 2009a) revealed that these sensilla belong to three different types. One consists of single-walled, olfactory coeloconic sensilla (equipped with pores and pore tubules) visible on the antennal surface; the other two are sensilla styloconica (type-1 and type-2), sharing common features typi-

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cal of thermo-hygroreceptors and located at the bottom of cavities, which are evident as simple openings on the antennal surface.

On the basis of these data, the present research aims to investigate whether the sensilla described in Anisoptera are also present in Zygoptera. The results presented here are part of a research programme on the fine structure of the antennal sensilla in adult Odonata (REBORA et al., 2008; 2009a).

MATERIAL AND METHODS

Adults of both sexes of *Coenagrion puella* and *Ischnura elegans* (Coenagrionidae), *Platycnemis pennipes* (Platycnemidae), *Lestes barbarus* and *L. viridis* (Lestidae) and *Calopteryx virgo* and *C. haemorrhoidalis* (Calopterygidae) were collected in Umbria (central Italy) during summer 2008.

In the laboratory, antennal flagella were dissected from anaesthetised specimens and fixed for 12 hours in 2.5% glutaraldehyde in cacodylate buffer at pH 7.2. The fixed material, repeatedly rinsed in the same buffer, was then dehydrated by using a graded series of ethanols, followed by critical-point drying in a critical-point dryer CPD 030 Bal-Tec (Bal-Tec Union Ltd., Balzers, Liechtenstein). Specimens were mounted on stubs with silver conducting paint, sputter-coated with gold-palladium in a sputterer Emitech K550X (Emitech, Ashford, England), and observed with a Philips XL30 scanning electron microscope (Philips, Eindhoven, the Netherlands), at an accelerating voltage of 18kV.

For observations of the inner cuticular wall of the antenna, the dissected flagella were longitudinally sectioned with a razor blade and cleaned with KOH-solution. The flagellar cuticle was then dehydrated in a graded ethanol series, dried in an oven and mounted as above.

RESULTS

Zygoptera antennae consist of a scape, a pedicel and a monoarticulated flagellum. In all the analyzed species the latero-ventral side of the flagellum shows pits that represent the opening of cavities. On the edge of the pits coeloconic sensilla, characterized by a porous cuticle, are visible on the antennal surface while at the bottom of the cavities both types of deeply sunken sensilla styloconica are located. Type-1 sensilla have a cone with cuticular fingers in the distal portion and type-2 sensilla have a cone with an irregular rugged cuticular surface. No pore and no socket are present in either types. The pits are mostly concentrated on the proximal portion of the flagellum and differ in shape and abundance in the different families. No obvious differences were observed between the examined species belonging to the same family. No intra-specific differences have been observed between males and females.

COENAGRIONIDAE (*Coenagrion puella* and *Ischnura elegans*) − There are about five pits containing sensilla, located on small bulges arranged along the antennal surface (Fig 1a). Images of the inner cuticular wall reveal that the pits are the opening of wide and shallow cavities (about 30 μm in width and 10 μm in depth), which host sensilla coeloconica just inside the rim of the cavities (Figs 1b, d) and several deeply sunken type-1 and type-2 sensilla styloconica (Figs 1c, e, f).

PLATYCNEMIDIDAE (*Platycnemis pennipes*) − There are about five pits with

sensilla. They are the opening of narrow and deep convoluted cavities (about 5-10 μm in width and 30-40 μm in depth) (Figs 2a-b), bearing coeloconic sensilla (Figs 2b,c) and deeply sunken type-1 and type-2 sensilla styloconica (Fig. 2b) as above. Each cavity is parallel to the longitudinal axis of the antenna (Fig. 2a).

LESTIDAE (*Lestes barbarus* and *L. viridis*) − The arrangement is the same as in *P. pennipes* with four or five pits opening into narrow and deep convoluted cavities (about 5 μm in width and 30-40 μm in depth), which host coeloconic sensilla (Figs 2d, e) and both types of deeply sunken sensilla styloconica (Fig. 2f). Each cavity is parallel to the longitudinal axis of the antenna.

Fig. 1. Scanning electron micrographs of the antennal flagellum of *Coenagrion puella* (Coenagrionidae); (a) outer cuticular wall; arrows point to the pits located on small bulges. Scale bar = 50 μm; − (b) inner cuticular wall showing one of the cavity with coeloconic sensilla on its edge. Scale bar = 5 μm; − (c) view of a fractured cavity showing type-1 and type-2 deeply sunken sensilla styloconica. Scale bar = 10 μm; − (d) detail of a coeloconic sensillum showing pores on the peg surface. Scale bar = 1 μm; − (e) detail of type-1 deeply sunken sensilla styloconica showing the cuticular fingers at the apex of the cone. Scale bar = 2.5 μm; − (f) detail of type-2 deeply sunken sensillum showing the irregularly rugged surface of the cone. Scale bar = 2,5 μm. − [CF: cuticular fingers; − CS: coeloconic sensilla; − P: pores; − T1: type-1 deeply sunken sensilla styloconica; − T2: type-2 deeply sunken sensillum styloconicum]
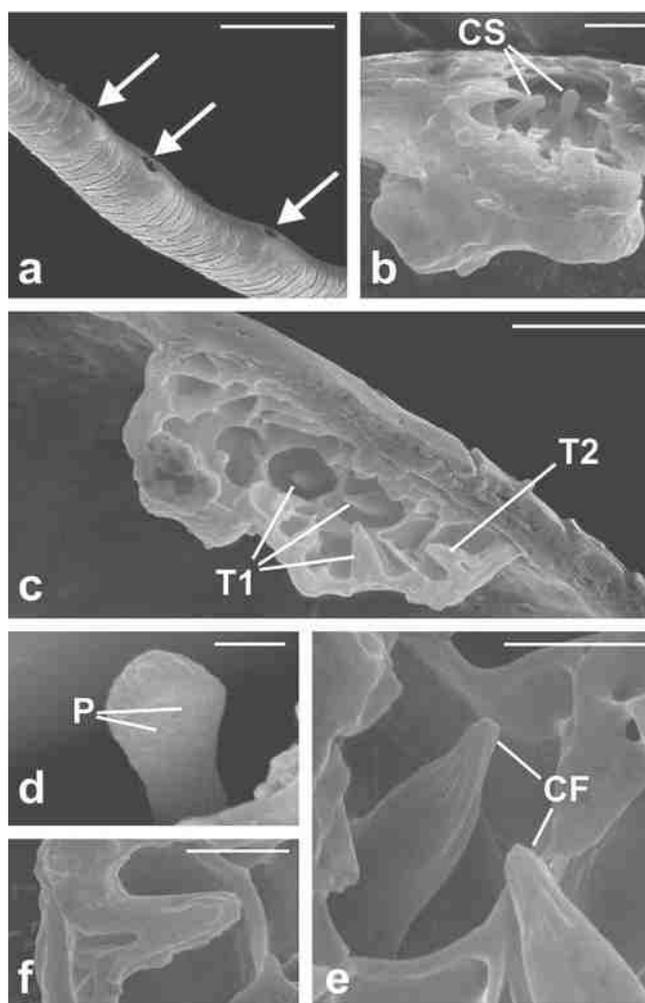
CALOPTERYGIDAE (*Calopteryx virgo* and *C. haemorrhoidalis*) − There are about 10 pits containing sensilla and they may be isolated or gathered to form small groups of two/three (Fig. 3a). These pits are the openings of narrow and shallow cavities (about 10-15 μm in width and 15-20 μm in depth) (Fig. 3b), which host coeloconic sensilla just inside the rim of the cavities (Fig. 3c) and deeply sunken type-1 and type-2 sensilla styloconica (Figs 3b, d, e).
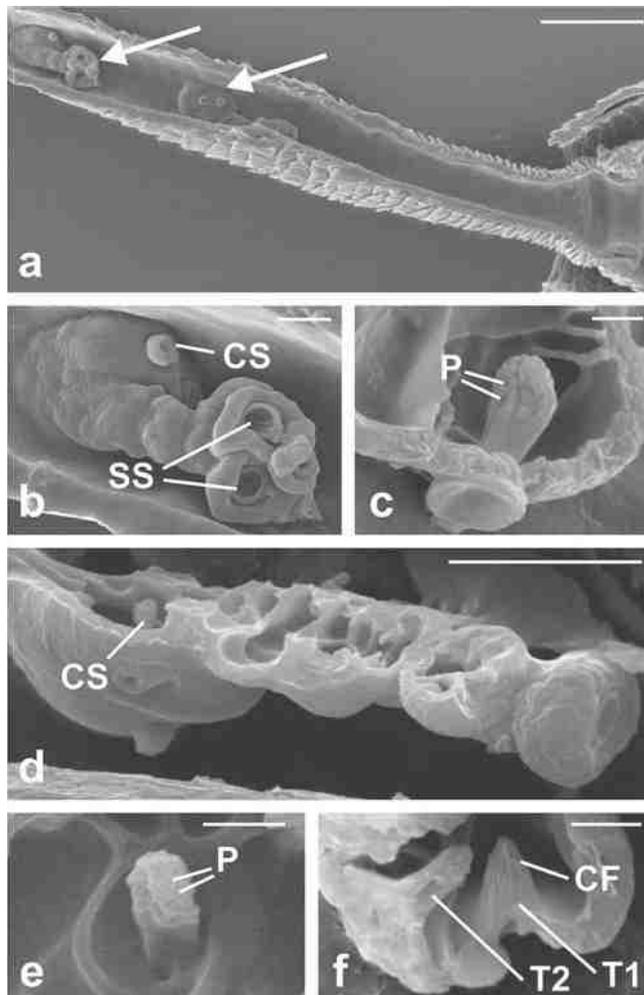

Fig. 2. Scanning electron micrographs of the antennal flagella of *Platycnemis pennipes* (Platycnemididae) (a-c) and *Lestes barbarus* (Lestidae) (d-f): (a) inner cuticular wall showing the cavities parallel to the longitudinal axis of the antenna (arrows). Scale bar = 30 μm; − (b) a cavity bearing a coeloconic sensillum on its edge and two sensilla styloconica at the bottom. Scale bar = 5 μm; − (c) detail of a coeloconic sensillum with pores on the cuticle. Scale bar = 2 μm; − (d) a longitudinally fractured cavity showing a coeloconic sensillum on its edge. Scale bar = 10 μm; − (e) detail of the coeloconic sensillum showing its porous cuticle. Scale bar = 2 μm; − (f) detail of type-1 and type-2 sensilla styloconica at the bottom of a cavity. Scale bar = 2 μm. − [CF: cuticular fingers; − CS: coeloconic sensillum; − P: pores; − SS: styloconic sensilla; − T1: type-1 deeply sunken sensillum styloconicum; − T2: type-2 deeply sunken sensillum styloconicum]

DISCUSSION

The present fine structural investigation on *Coenagrion puella* and *Ischnura elegans* (Coenagrionidae), *Platycnemis pennipes* (Platycnemididae), *Lestes barbarus* and *L. viridis* (Lestidae) and *Calopteryx virgo* and *C. haemorrhoidalis* (Calopterygidae), confirms the presence on the Zygoptera antennae of the same sensory structures already described in Anisoptera (REBORA et al., 2008; 2009a). Thus, damselfly flagella are equipped with porous sensilla coeloconica, already hypo-

Fig. 3. Scanning electron micrographs of the antennal flagella of *Calopteryx haemorrhoidalis* (a) and *C. virgo* (b-e) (Calopterygidae): (a) outer cuticular wall; arrows point out the pits with coeloconic sensilla visible on their edge. Scale bar = 50 μm; − (b) detail of a fractured cavity: type-1 and type-2 deeply sunken sensilla styloconica are visible on the bottom. Scale bar = 5 μm; − (c) detail of a coeloconic sensillum showing the cuticular pores. Scale bar = 2 μm; − (d) detail of type-1 deeply sunken sensilla styloconica showing the cuticular fingers at the apex of the cone. Scale bar = 2 μm; − (e) detail of type-2 deeply sunken styloconic sensillum showing the irregularly rugged cuticular surface (arrow). Scale bar = 3 μm. − [CF: cuticular fingers; − CS: coeloconic sensilla; − P: pores; − T1: type-1 deeply sunken sensillum styloconicum; − T2: type-2 deeply sunken sensillum styloconicum]
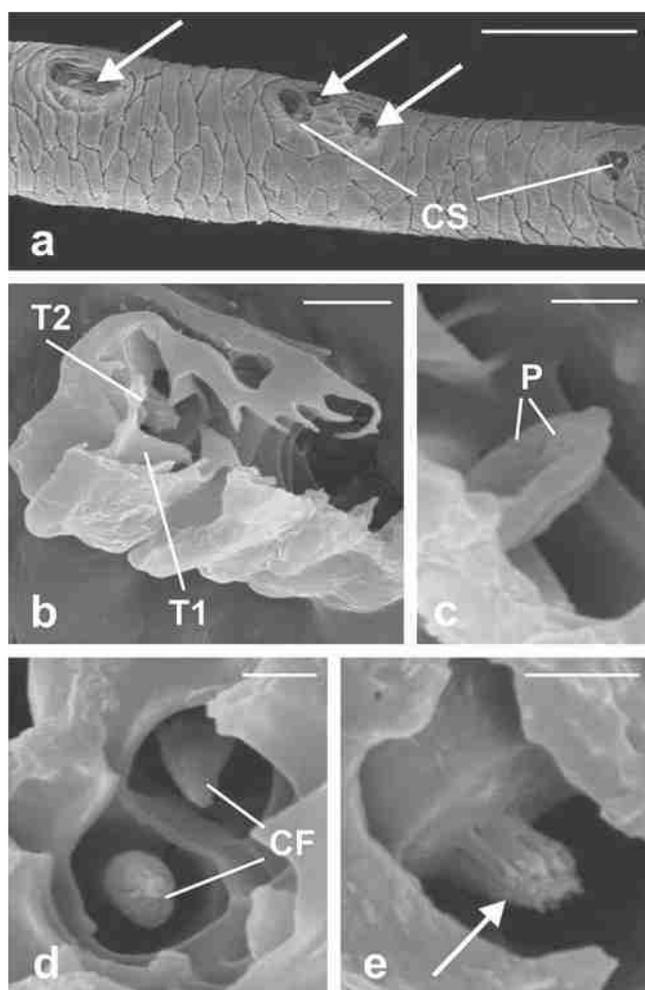
thesized to be olfactory receptors in Anisoptera (REBORA et al., 2008; 2009a), and two deeply sunken sensilla styloconica, namely type-1, characterized by cuticular fingers, and type-2, characterized by a rugged cuticular surface, hypothesized to be thermo-hygroreceptors in Anisoptera (REBORA et al., 2008; 2009a).

The distribution of these sensilla is very similar in all the zygopteran species analyzed whereas in Anisoptera some differences emerged among the families examined (REBORA et al., 2008; 2009a). In the Zygoptera the sensilla are located in pits mostly concentrated in the proximal portion of the flagellum, along its latero-ventral side; all the pits open into deep cavities hosting the porous coeloconic sensilla on their edge and both kinds of sensilla styloconica (type-1 and type-2) at their bottom. This morphological uniformity could be relevant when considering the debate about the zygopteran monophyletic/paraphyletic origin: the first hypothesis supported by morphological data (REHN, 2003), and the second one sustained by molecular investigations (HASEGAWA & KASUYA, 2006).

The present data reinforce some functional and phylogenetic considerations already proposed for the sensory role of the dragonfly antennae (REBORA et al., 2008; 2009a), which can be extended to the whole order Odonata. In particular:

− The small and setaceous antennae of damselflies and dragonflies seem to play a relevant role in environment perception. Notably, thermo-hygroreception and olfaction could be important sensory abilities in Odonata. Thermo-hygroreception is intuitively relevant for aquatic insects for which thermoregulation is very important (MAY, 1976; McKEY & HERMAN, 2008) but the role of olfaction is more difficult to hypothesize about. In both cases the biological significance of these abilities needs to be better investigated with behavioural and electrophysiological researches.

− The widespread presence of putative olfactory sensilla in Anisoptera (REBORA et al., 2009a) and Zygoptera, together with the description of similar sensory structures in the mayfly *Rhithrogena semicolorata* (REBORA et al., 2009b), raises relevant questions on the ability of Paleoptera (Odonata and Ephemeroptera) to perceive odours. Indeed, these insects have been traditionally considered anosmic, because their brains lack glomerular antennal lobes and mushroom body calyces, typically involved in Neoptera odour perception (STRAUSFELD et al, 1998; FARRIS, 2005). Recent neuroanatomical studies report that Odonata possess a remnant calyx but it is claimed that it is probably related to the visual ability of this group (SVIDERSKY & PLOTNIKOVA, 2004; STRAUSFELD et al., 2009). Because these taxa are considered to be the oldest pterygote insects, studies on Paleoptera olfaction could contribute significantly to trace evolutionary trends in insect odour perception and also be relevant for phylogenetic considerations.

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FIRST RECORD OF PARASITIZED
TRITHEMIS PALLIDINERVIS (KIRBY)
FROM TAMIL NADU, INDIA BY *ARRENURUS* LARVAE,
WITH A DESCRIPTION OF LARVAL MORPHOLOGY
(ANISOPTERA: LIBELLULIDAE; ACARI: HYDRACHNIDIA)

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Out of a total of 20 adult *T. pallidinervis* specimens (Odonata), collected in Tamil Nadu, India, 164 larvae of *Arrenurus* sp. were found; prevalence: 57.5%, intensity: 5-12. They were attached to the mesosternum and metasternum. Their morphology is very similar to that of *A. cuspidator* and *A. maculator*, but differs by the absence of Mp1 tripartite seta, V2 seta and secondary seta in PIII 1 and the presence of secondary setae on both sides of V3 setae. They also differ from *A. maculator* by the absence of hairbrush on the base of C1 seta.

INTRODUCTION

The genus *Arrenurus* has many species and is a particularly important group among the Hydracarina. Species of the genus live in almost all biotopes and in most zoogeographic regions. This genus, as with other freshwater mites, has been studied mostly from the point of view of the morphology and taxonomy of the adult stages. Larvae of most water mite species parasitize aquatic insects and this is how water mites disperse and colonize new water bodies (MITCHELL, 1970; BOHONAK, 1999; BOHONAK et al., 2004).

Water mites can be classified into two groups, depending on which insect order they parasitize: parasites of insects whose imagines stay under water or on

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Table I

Dimensions (in μm) of individual body parts of the larvae of *Arrenurus maculator*, *A. cuspidator* (ZAWAL 2006b) and *Arrenurus* sp. (N = 10)

Morphological characters	A. maculator			A. cuspidator			A. sp.		
	Range	Mean	Standard deviation	Range	Mean	Standard deviation	Range	Mean	Standard deviation
dorsal plate length	188-196	193.0	2.70	166-202	187.2	10.63	178-196	186.8	5.59
dorsal plate width	140-146	143.4	1.90	124-146	139.2	6.20	124-158	139.8	11.13
CpI medial margin length	60-62	61.3	0.94	61-67	63.5	2.27	54-60	56.6	1.77
CpII medial margin length	31-33	32.4	0.68	28-30	29.0	0.76	21-26	24.1	1.66
CpIII medial margin length	31-32	32.0	0.38	24-28	26.0	1.21	26-32	28.6	2.02
distance: Mp1-Mp1	58-61	59.7	1.14	52-61	56.2	3.46	55-64	57.7	2.54
distance: Lp1-Lp1	62-70	66.9	2.30	58-67	62.6	2.23	60-66	64.7	2.46
distance: Lp2-Lp2	77-93	85.2	4.70	80-84	81.1	1.13	80-89	84.5	2.70
distance: Mp2-Mp2	44-50	47.8	2.13	42-44	43.0	0.74	37-44	40.1	2.01
distance: Mh1-Mp2	35-44	39.8	2.82	34-44	38.8	2.56	3-41	35.8	2.39
distance: Mp1-Lp1	4-8	5.8	1.12	3-6	5.4	0.93	5-8	6.1	1.14
distance: Mp1-Lp2	30-36	33.4	2.20	34-42	37.0	2.72	26-33	30.1	1.93
distance: Mp1-Mp2	58-66	62.7	2.27	55-67	62.3	3.49	44-54	50.1	2.62
distance: Mp2-Mh1	27-30	28.8	1.07	19-29	25.0	3.30	22-30	25.0	2.45
distance between C1 and CpI median margin	19-22	20.4	0.68	13-18	15.4	1.36	16-22	18.1	2.75
distance between C4 and CpIII median margin	28-30	29.4	0.85	22-28	26.5	1.90	21-24	22.2	1.13
distance between C1 and C2	38-41	39.2	1.19	45-50	47.8	3.27	30-41	35.7	3.35
excretory pore plate length	20-22	20.6	0.63	19-24	21.2	1.52	22-26	22.9	1.32
excretory pore plate width	22-26	23.3	1.16	22-28	24.6	1.64	22-26	23.8	1.24
distance between Exp and Expp posterior margin	6-10	8.3	1.37	8-10	8.4	0.57	10-12	10.7	0.77
distance between E1 setae and Expp anterior margin	4-6	4.6	0.63	4-6	4.8	0.84	4-6	4.6	0.54
distance between E2 setae and Expp posterior margin	8-12	10.2	1.24	10-13	10.6	0.98	9-11	9.8	0.83
PIII length	26-30	27.1	1.38	22-26	24.0	1.19	22-26	23.4	1.25
length of PIV claw	26-29	27.6	0.86	26-28	27.1	0.80	31-38	33.9	1.93
length of PV 8 seta	115-130	122.2	4.44	88-102	92.4	4.25	111-116	113.8	1.51

its surface, leaving the water only sporadically (Coleoptera and Hemiptera) and those parasitizing insects whose imagines are terrestrial/aerial while only their pre-imaginal stages are aquatic (Odonata, Trichoptera, Diptera) (ZAWAL, 2006a). Different genera of water mites parasitize particular orders of aquatic insects. For example, *Hydrachna* and *Eylais* parasitize Coleoptera and Heteroptera, respectively; *Limnochares* parasitize Heteroptera (SMITH, 1988) and Odonata (SMITH & COOK, 1991) and *Arrenurus* parasitise Odonata, Coleoptera and Diptera (SMITH & COOK, 1991; BÖTTGER & MARTIN, 2003; ZAWAL, 2006a). Larvae from different *Arrenurus* subgenera are specific to insect orders: *Arrenurus* s. str. to Odonata adults and larvae (DAVIDS, 1997; ROLFF et al., 2001; BAKER et al., 2006). Regarding parasitism by water mite larvae, most papers are concerned with adult insects (MITCHELL, 1959; STECHMANN, 1977; ZAWAL, 2006a) and little attention has been paid to the relationship between the larvae of water mites and those of insects (ZAWAL, 2006a; BAKER & SMITH, 1997). Water mite larvae may influence Odonata populations, as indicated by mite larvae which remain on exuviae of Odonata which failed to moult from the final stage larvae to imagos (ZAWAL, 2006a). The larval morphology of the genus *Arrenurus* has been studied by IMAMURA & MITCHELL (1967), PRASAD & COOK (1972), STECHMANN (1977), VAJNŠTEJN (1980), SMITH (1990) and ZAWAL (2006b).

The aim of this paper is to present the first record of the parasitization of *Trithemis pallidinervis* by *Arrenurus* sp. larvae, together with a description of the larval morphology, paying particular attention to those features which differ from *A. cuspidator* and *A. maculator,* also to compare the last two species with the earlier description by ZAWAL (2006b).

MATERIAL AND METHODS

Twenty *Trithemis pallidinervis* (Kirby) adults collected from a marshy land area near a pond at Ariyalur (altitude: 75 m a.s.l., latitude: 1°8′ and longitude: 79°5′), Tamil Nadu, India, were examined under a stereo zoom microscope. The water mite larvae were loosely attached on the ventral side of the dragonflies, from where they were removed using a camel hair brush/forceps. They were mounted in Hoyer's medium and permanent slides were prepared. Measurements of the important taxonomic structures of 10 mites were made with the help of a calibrated ocular micrometer.

The material is deposited in the Department of Agricultural Entomology, Acarology Laboratory, Tamil Nadu Agricultural University, Coimbatore, India and in the Department of Invertebrate Zoology and Limnology, University of Szczecin, Szczecin, Poland.

The setal notation follows, with some modification, that of PRASAD & COOK (1972) (Lp1, Lp2, Mp1, Mp2, Mh1: setae on dorsal plate; − Hu, Mh2-Mh4 and Lh1-Lh3: setae on dorsal side outside of dorsal plate; − C1-C4: setae on coxal plates; − V1-V4: setae on ventral side outside of coxal plates; − E1, E2: setae on case excretory pore plate PII1; − PIII1-2, PIV1-3, PV1-8: setae on particular segments of pedipalp; − ITr1: setae on trochanter of leg I; − IFe1-7: setae on femur of leg I; − IGe1-5: setae on genu of leg I; − ITi1- 9: setae on tibia of leg I; − ITa1-14: setae on tarsus of leg I; − IITr1: setae on trochanter of leg II; − IIFe1-7: setae on femur of leg II; − IIGe1-5: setae of genu leg II; − IITi1-11: setae on tibia of leg II; − IITa1-14: setae on tarsus of leg II; − IIITr1: setae

Fig. 1. *Arrenurus* sp.: (A) dorsal plate; − (B) ventral side; − (C) pedipalp; − (D) excretory pore plate; − (E) leg I; − (F) leg II; − (G) leg III. − [Scale bars: A: 50 μm, − B: 100 μm, − C: 20 μm, − D: 10 μm, − E, F, G: 20 μm]

on trochanter of leg III; − IIIFe1-7: setae on femur of leg III; − IIIGe1-5: setae of genu of leg III; − IIITi1-11: setae on tibia of leg III; − IIITa3-14: setae on tarsus of leg III) (Fig. 1).

The measured characters based on 10 *Arrenurus* sp. larvae which were removed from particular hosts are reported with their ranges, mean values and standard deviations. The leg segments were measured along their distal margins. The measured characters of *A. maculator* and *A. cuspidator* came from ZAWAL (2006b) and are based on 10 individuals of each species.

In this paper, the following abbreviations are used: Cp: coxal plate, − Exp: excretory pore, − Expp: excretory pore plate.

RESULTS

On 20 specimens of adult *Trithemis pallidinervis,* 164 larvae of *Arrenurus* sp. were found: prevalence: 57.5%, intensity: 5-12. They occurred only on females and were attached to the ventral side of the body. The preferred areas were the mesosternum and metasternum. These larvae have not been named and described earlier. Therefore we add a short morphological description.

MORPHOLOGICAL DESCRIPTION

M a t e r i a l examined. − 5 larval slides, India: Tamil Nadu, Coimbatore, 12-VIII-2006, ex *Trithemis pallidinervis*. Coll. V. Radhakrishnan (No. 260/5).

The dorsal plate is egg-shaped, with a bend in the anterior lateral sides and a rounded posterior margin. The antero-lateral indents are relatively deep (Fig. 1A). The dorsal plate setae as Mp1, Mp2, Lp1, Lp2, Mh1 and Mh2 are thin, long and smooth. The dorsal plate length and width, the CpI medial margin length and the CpII medial margin length are all shorter than in *A. maculator* and *A. cuspidator*. The CpIII medial margin length and the distances between Mp1-Mp1, Lp1-Lp1 and Lp2-Lp2 are longer than in *A. cuspidator*. The distances between Mp2-Mp2, Mh1-Mp2, Mp1-Lp2 and Mp1-Mp2 are shorter than in *A. maculator* and *A. cuspidator* (Tab. I).

The C1, C2, C3 and C4 setae bear secondary setae on both sides. The brush of hairs on the base of C1 seat is not present. The distance between the C4 seta and

Table II
Number of setae on leg segments of *Arrenurus maculator*, *A. cuspidator* (ZAWAL 2006b) and *Arrenurus* sp.

Species	Legs	Trochanter	Femur	Genu	Tibia	Tarsus
Arrenurus maculator	I	1	7	5	9	14
and *A. cuspidator*	II	1	7	5	11	14
	III	1	6	5	10	11
Arrenurus sp.	I	1	7	5	9	14
	II	1	7	5	11	14
	III	1	6	5	10	12

Table III
Dimensions (in μm) of leg segments of *Arrenurus maculator*, *A. cuspidator* (ZAWAL 2006b) and *Arrenurus* sp.

Species	Legs	Trochanter			Femur			Genu			Tibia			Tarsus		
		range	mean	sd	range	mean	sd	range	mean	sd	range	mean	sd	range	mean	sd
A. maculator	I	16-18	17.5	0.70	24-28	26.6	1.17	21-26	24.9	1.66	41-45	42.7	1.37	58-61	59.6	0.68
	II	18-20	18.6	0.76	29-32	30.3	0.88	26-30	28.5	1.14	47-50	48.3	0.77	62-66	64	1.19
	III	18-21	19.3	0.80	28-32	30.2	1.45	28-31	29.4	1.07	45-50	47.0	1.92	59-66	63.8	2.26
A. cuspidator	I	16-20	18.0	1.02	24-31	27.2	1.85	23-27	25.0	1.25	36-42	40.7	2.01	50-58	55.5	2.30
	II	16-18	17.4	0.91	26-32	30.4	1.92	21-28	25.1	2.56	40-46	43.1	1.65	55-64	61.8	2.87
	III	16-21	18.7	1.32	22-32	27.6	3.31	21-29	26.6	1.95	41-48	45.4	2.00	54-64	62.3	3.17
Arrenurus sp.	I	22-26	23.8	1.00	32-36	33.6	1.41	29-31	29.8	0.93	45-46	45.3	0.56	56-60	58.2	1.20
	II	24-28	25.8	1.18	34-39	35.8	1.68	30-37	33.4	1.80	47-50	48.8	1.00	62-70	64.0	1.19
	III	26-30	27.1	1.43	36-38	36.6	0.74	30-37	34.1	2.00	48-53	50.3	1.58	65-70	67.4	1.60

sd = standard deviation

the median CpIII edge is longer that the distance between the C1 seta and the CpI margin. The distance between C1 and C2 setae is longer than the distance between the C4 seta and the median CpIII edge and the distance between the C1 seta and the CpI margin (Tab. I).

The dorsal and coxal plates feature a microrelief in the form of a regular porous reticulum (Fig. 1B). The excretory pore plate width and length are almost equal, the plate surface bearing two pairs (E1 and E2) of short setae (Fig. 1D). The palps have a pronounced tooth and three setae on segment IV. Segment V bears 8 setae. One seta (PV1) is a solenidion, another one (PV6) is relatively short and stout, PV7 is characteristically bent and bears secondary setae on one side and seta PV8 is very long (113.8) and bears secondary setae on both sides. The remaining setae (PV2, PV3, PV4 and PV5) are smooth. Segment III bears 2 smooth setae one of which is larger than the other. Segment II has a single smooth seta (Fig. 1C).

Each leg has five segments, the last segment bearing three claws (Figs 1E, F, G). The number of setae on each segment is given in Table II. The genu of each leg bears a single solenidion (IGe1, IIGe1, IIIGe1), tibia I and II feature two solenidia each (ITi1, ITi2, IITi1, IITi2), tibia III shows one solenidion (IIITi1) and the tarsi of legs I and II each bear one solenidion

(ITa1, IITa1). The tarsi of legs I and II each bear a single eupathidium (ITa2, IITa2). The femur of leg III lacks IIIFe2 seta. The setae of IGe5, ITi9, IIGe5, II Ti9, IITi11, IIIGe5, IIITi9 and IIITi11 bear characteristically long secondary setae on one side only, spaced widely apart which are a general character of *Arrenurus* larvae.

The proportions between the segments of each leg are more or less identical. The trochanter is clearly the shortest segment, its length being equal to about 2/3 of that of the femur and genu which are almost equal in length; the tibia and tarsus are 1.5 and 2 times longer, respectively than the genu (Tab. III). The ventral margins of the genu are clearly convex and show characteristic indents, the ventral margins of the tarsus being slightly concave. The remaining margins of all the segments are almost straight.

DISCUSSION

Although this is probably the first record of odonate parasitization by water mites from southern Asia, the phenomenon was reported from various other Asian regions, such as Kazakhstan (KLIMSHIN & PAVLYUK, 1972) and Japan (IMAMURA, 1951a, 1951b; IMAMURA & MITCHELL, 1967). Many authors have mentioned that Zygoptera are more frequently infected by *Arrenurus* larvae than Anisoptera (SMITH & COOK, 1991; CONROY & KUHN, 1997; DAVIDS, 1997; ZAWAL, 2004, 2006a, 2006c; BAKER *et al.*, 2006, 2007; ZAWAL & DYATLOVA, 2006, 2008). Therefore a new record of an infected anisopteran is of interest, particularly so as it concerns a new host species and genus. In the case of this and former records of *Arrenurus* larvae attached to dragonflies, they occur mainly on the ventral side of the thorax and abdomen (MÜNCHBERG, 1935, 1963; CASSAGNE-MÉJEAN, 1966; MITCHELL, 1959, 1961, 1965; FORBES *et al.*, 1999, 2002; ZAWAL, 2004, 2006a), although *A. papillator* and *A. postulator,* which infect *Sympetrum meridionale* and *S. fonscolombii* are attached to the wings (MÜNCHBERG, 1935, 1963, 1982; CASSAGNE-MÉJEAN, 1966; ZAWAL & JASKULA, 2008).

The description of the new *Arrenurus* sp. larval morphology given above is in general agreement with the earlier descriptions of congeneric larvae. The number of setae agrees with the data reported by PRASAD & COOK (1972), STECHMANN (1977) and SMITH (1978). VAJNŠTEJN (1980) and TUZOVSKIJ (1987) mentioned a higher number of eupathidia on the legs. The larval morphology of this new species is very closely related to that of *A. cuspidator* and *A. maculator* (ZAWAL, 2006b. The IGe5, ITi9, IIGe5, IITi9, IITi11, IIIGe5, IIITi9 and IIITi11 setae bear characteristically long secondary setae, spaced widely apart (Fig. 1) which are a general character of *Arrenurus* larvae.

According to ZAWAL (2006b), the larval stage of *Arrenurus* sp. is similar to *A. maculator* and *A. cuspidator* in most of the morphological characters but dif-

fers in a few, such as the shape of Expp, by the V2 seta and secondary seta in PIII 1 and by the presence of secondary setae on both the sides of V3setae. Also, the location of Exp in the *Arrenurus* sp. from India Exp is above the E2 setae, whereas in *A. maculator* and *A. cuspidator* it is below the E2 setae. Furthermore it differs from *A. maculator* by the absence of a hairbrush on the base of C1 seta. Its tarsal (III) leg setation was different from that of *A. maculator* and *A. cuspidator* (Tab. II). Secondary setae (IIITr1 and IIIFe7) were found on one side in *A. maculator* and *A. cuspidator* as against simple setae in the new *Arrenurus* sp. Similarly secondary setae (IIIFe4, IIIGe2, IIITi7 and IIITi8) occur on both sides in *A. maculator* and *A. cuspidator*, but only simple ones in the new species.

The larva of *Arrenurus* sp. is easily distinguished from that of *A. agrionicolus* Uchida and *A. mitoensis* Imamura described from Japan (IMAMURA & MITCHELL, 1967) by the shape of Expp and the locality of Exp (below the E2 setae) and by the number of setae on tarsus III.

It should be mentioned that many of the secondary setae were visible at 1250× magnification using the Nikon microscope, but could not be discerned with a lower resolution microscope (Jenaval).

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SPERM TRANSFER PROCESS IN THE NON-TERRITORIAL *ISCHNURA ASIATICA* (BRAUER) DURING COPULATION (ZYGOPTERA: COENAGRIONIDAE)[1]

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According to the movements of the ♂ abdomen, the copulation process in *I. asiatica* is divided into 3 stages (I, II and III). The mean duration of each stage was 75.8 ± 8.8 min, 6.4 ± 0.3 min and 15.8 ± 0.9 min for stage I, II and III, respectively (S.E.). No sperm transfer was found during stage I. The prolonged duration in stage I was related to the time of onset of copulation. Sperm was transferred into the bursa copulatrix during stage II. Although stage III was a phase without apparent abdominal movement, the sperm transfer was continued, following the sperm migration from the bursa copulatrix to the spermatheca. Immediately after copulation termination, the estimated number of sperm was 64,500 ± 4,425 in the bursa copulatrix and 43,143 ± 6,397 in the spermatheca (S.E.). The role of each stage in copulation will be discussed from the viewpoint of sperm competition.

INTRODUCTION

Sperm competition has resulted in the evolution of several male morphological and behavioral traits (PARKER, 1970). In Odonata, WAAGE (1979) demonstrated that *Calopteryx maculata* males use their specialized secondary genitalia to remove the sperm of rival males stored in the female before transferring their own sperm. Sperm removal is an efficient way to gain a high fertilization success for the male because the stored sperm is withdrawn from the female sperm storage organs. This mechanism has been repeatedly demonstrated in many zygopteran species (e.g., MILLER, 1987b; SIVA-JOTHY & TSUBAKI, 1989).

Studies of sperm competition in Odonata based on sperm volume but not on the number of spermatozoa have been reported (CÓRDOBA-AGUILAR et al., 2003). Because odonate sperm tend to clump into a dense, interwoven mass (WAAGE, 1979), it has been assumed that sperm number was homologous to sperm volume. However, little about the relationship between spermatozoa number and sperm volume has been clarified (REINHARDT, 2005). To gain more information about sperm competition, studies of the spermatozoa dynamics in the female during copulation and the total number of spermatozoa transferred in a single copulation are needed.

To clarify the sperm transfer process in *Ischnura asiatica*, we allowed virgin males and females to copulate in the laboratory. An experiment in which copulation was interrupted was conducted, and the number of spermatozoa transferred into the females' sperm storage organs was counted.

MATERIAL AND METHODS

Each larva that was captured in the field was kept individually in a bottle (φ 3.5cm, height 5.8cm) and fed with live *Tubifix* and brine shrimps. A twig 10cm in length was placed against the inner wall of the bottle for the final instar larva as a support for emergence.

All imagos were kept in a cage (40×40×50cm) with wooden frames covered by nylon mesh (1×1mm). They were fed on *Drosophila* spp. cultured.

We introduced each pair of virgin sexually matured males and females into a cage (30×30×30cm) with wooden frames covered by nylon mesh (1×1mm) in the morning (05:00-11:00), which is a time of day when many copulations in the fields were observed (NARAOKA, 1989). The cage was placed by a window with direct sunlight. According to the process of zygopteran copulation which has been divided into three stages by the male's abdominal movement (MILLER & MILLER, 1981), we divided the copulation of *I. asiatica* into three stages. In stage I, the males depressed and stretched the first and second abdominal segments. In stage II, the males thrust in the third abdominal segment. Stage III was a phase without apparent movement of the abdomen of either sex. After that, the pair separated.

The copulating pairs were interrupted 10 and 30 minutes from the onset of copulation, 0, 1, 2, 3 and 4 minutes from the onset of stage II, and 0, 2, 4, 6 and 8 minutes from the onset of stage III. The total number of spermatozoa transferred in a single copulation was also examined for five pairs.

Each female was decapitated and the abdomen dissected to detach the bursa copulatrix and the spermatheca. The number of spermatozoa was estimated according to a method described by SIVA-JOTHY (1987). That is, the bursa copulatrix and spermatheca were separately placed into a tissue-homogenizer containing a given volume of saline (stage I: 0.3ml, stage II: 0.5ml, stage III: 1ml) and ruptured with about 10 strokes of a pestle. The spermatozoa number was counted in a given volume by a blood-haemocytometer more than five times from the same sample, disregarding the volume of the bursa copulatrix and spermatheca, because they were much smaller than the volume of the saline.

RESULTS

Immediately after the encounter of both sexes in a cage, each female showed the mate refusal display, even though each female was virgin. The females opened their wings, raised and ventrally curled their abdomen when perching, or curled

their abdomen ventrally on the wing. After repeated approaches by the males, however, most females finally accepted copulation. Consequently, a total of 50 pairs successfully copulated.

The duration of stage I was 75.8 ± 8.8 min (n = 45, S.E.), varying with the time of day in which copulation began (Fig. 1). The longest duration of stage I was 188.5 min and the shortest was 20.1 min. The duration of stage I was negatively correlated with the time of day. Thus, when copulation began in the late morning, stage I was of shorter duration. The time of termination of stage I was estimated by the regression curve, indicating that stage I would last until around 08:30 or 09:00.

The frequency of male abdominal movements in stage I was 513 ± 186.3 (S.E., n = 7). Both the bursa copulatrix and spermatheca of the females during stage I was still flat, and no spermatozoa were found. Therefore, no sperm transferred during stage I.

The duration of stage II was 6.4 ± 0.3 min (n = 30, S.E.). The abdominal movement of the males during stage II became gradually slower compared to that of stage I. The frequency of abdominal movement was 24.4 ± 5.6 (n = 7, S.E.). Figure 2 shows that the number of spermatozoa increased in both the bursa copulatrix and spermatheca. The number of spermatozoa estimated to have been transferred into the bursa copulatrix and spermatheca during stage II was 39,333 ± 5,306 (S.E., n = 3) and 17,600 ± 15,673 (S.E., n = 3) respectively. Therefore, a male transferred about 47,000 spermatozoa in stage II.

The duration of stage III was 15.8 ± 0.9 min (n = 12, S.E.). The estimated number of spermatozoa increased in both the bursa copulatrix and spermatheca (Fig, 2). Just after copulation termination, the total estimated number of spermatozoa was 64,500 ± 4,425 (S.E., n = 4) in the former and 43,143 ± 6,397 (S.E., n = 4) in the latter, indicating that about 110,000 spermatozoa were transferred by males in a single copulation.
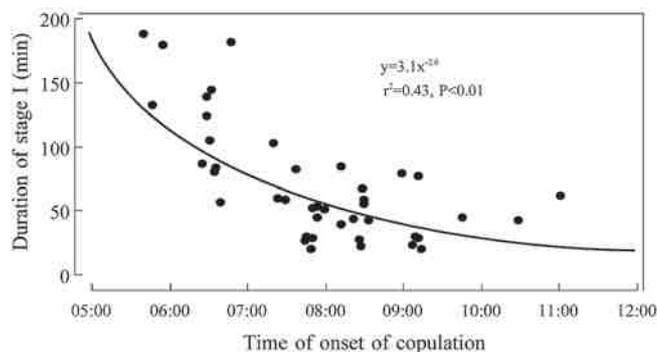

Fig. 1. The relationship between the duration of stage I and time of day in which copulation began. A regression curve was calculated by defining 00:00 as x = 0, 24:00 as x = 1.

DISCUSSION

Although many zygopteran species spend less than one hour in copulation (CORBET, 1999), ROBERTSON (1985) and MILLER (1987a) reported that *Ischnura* species spend several hours copulating. PARKER (1970) stated that prolonged copulation might be the consequence of sexual selection favouring male adaptations to avoid sperm competition. Prolonged copulation could cause the male body to act as a mating plug that prevents the female from remating before oviposition (ALCOCK, 1994), as well as enabling the removal of the sperm of rival males (SIVA-JOTHY, 1987). In the present study, since all females used were virgin, the males of *I. asiatica* did not require a long copulation in which to remove sperm. Therefore, the prolonged copulation of *I. asiatica* is likely to be mate guarding, as in case of *I. graellsii* (CORDERO, 1990) and *I. senegalensis* (SAWADA, 1999). Because most copulations of *I. asiatica* terminated around 08:30 to 09:00, females might not accept copulation after 09:00, though several females accepted copulation after 9:00 in the laboratory.
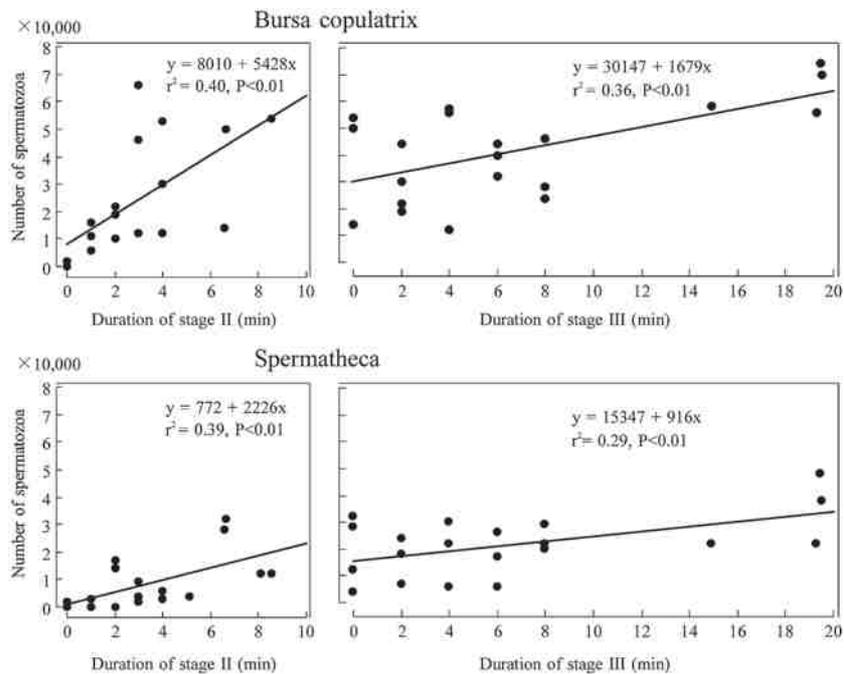
Fig. 2. Change in the number of spermatozoa stored in the bursa copulatrix and spermatheca during stage II and stage III.

Many odonate males remove the sperm of rival males stored in the female using abdominal movements before transferring their own sperm (e.g., WAAGE, 1979). Sperm volume reduction during stage I has been reported in *I. elegans* (MILLER, 1987b). SAWADA (1995) found sperm removal in *I. senegalensis* within 30 min after the onset of copulation. In *I. asiatica*, depressions and stretches of second and third abdominal segments of males were observed in stage I. In addition, at the end of the male genitalia in *Ischnura* species, there are two horn-like appendages, which are used to remove sperm (WAAGE, 1984). Sperm removal might occur during stage I in experienced females of *I. asiatica*.

An increase in sperm volume during stage II was reported in many *Ischnura* species (e.g., SAWADA, 1995). In the present study, stage II was a sperm transfer stage. Since the duration of stage II is 2–8 minutes in many *Ischnura* species (e.g., CORDERO, 1989; ROBERTSON, 1985), the duration of stage II and the form of abdominal movements in the males in *I. asiatica* were similar to that of other *Ischnura* species (e.g., MILLER, 1987a).

In *I. asiatica*, sperm transfer was continued during stage III, suggesting that stage III is also a sperm transfer stage, though there were no abdominal movements. Sperm transfer was previously believed to occur by the abdominal movement of males (SIVA-JOTHY & TSUBAKI, 1989). However, CORDERO & MILLER (1992) reported that both the duration and frequencies of the abdominal movements of males during stage II were not related to sperm volume in *I. graellsii*. A mechanism for sperm transfer without abdominal movements might exist in *I. graellsii* as well as *I. asiatica*.

A male of *I. asiatica* transferred about 110,000 spermatozoa to a female in a single copulation. There have been several studies on the spermatozoa number that are transferred in a single copulation. In many *Ischnura* species, the sperm transferred during a single copulation are sufficient to fertilize a female's lifetime reproduction (FINCKE, 1987; CORDERO, 1990; SIROT & BROCKMANN, 2001). In fact, 110,000 spermatozoa that transferred in a single copulation in *I. asiatica* could compare with 2,900 eggs loaded by a female (WATANABE & MATSU'URA, 2006).

Males remove sperm only in the bursa copulatrix using horn-like appendages on the genitalia of *I. senegalensis* and *I. elegans* (MILLER, 1987a; SAWADA, 1995). Since the spermatheca is bound to the bursa copulatrix by a long, narrow spermathecal duct in *I. asiatica*, males might be able to remove sperm in the bursa copulatrix but not in the spermatheca. Therefore, sperm competition will occur on 40% of spermatozoa transferred in the spermatheca, though NARAOKA (1994) has reported, by examining the change in the volume of the bursa copulatrix and spermatheca in the fields, that 61% of sperm in the bursa copulatrix and 71% in the spermatheca were removed.

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SHORT COMMUNICATION

THE LARVA OF *APANISAGRION LAIS* (BRAUER *IN* SELYS) (ZYGOPTERA: COENAGRIONIDAE)

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The larva is described and illustrated, based on material from Mexico. It is characterized by having 5+2 or 5+3 premental setae, 7 palpal setae, abdomen granular, caudal lamellae apically widened, female gonapophyses exceeding sternite 10, and male cerci sharply pointed.

INTRODUCTION

The New World genus *Apanisagrion* Kennedy comprises only one species known to date, *A. lais* (Brauer *in* Selys, 1876), ranging from USA (Arizona) to Honduras in Central America (WESTFALL & MAY, 1996). In Mexico it is widely distributed along an altitudinal gradient of approximately 1500 m (580 m a.s.l. at La Unión, Puebla state [GÓMEZ-ANAYA & NOVELO-GUTIÉRREZ, 1993] to 2050 m at Tuzanapa, Hidalgo state [NOVELO-GUTIÉRREZ & PEÑA--OLMEDO, 1991]). Although the larva of *A. lais* was previously keyed by WEST-FALL & MAY (1996) I formally describe it for the first time in this paper.

APANISAGRION LAIS (BRAUER *in* SELYS, 1876)
Figures 1-10

M a t e r i a l. − 2 exuviae (♂, reared), 6 F0 larvae (3 ♂, 3 ♀), 1 F1? (♀), 7 medium age larvae (4 ♂, 3 ♀). MEXICO: Veracruz: Municipality of Xico, Xico Viejo (19°25.920 N, 97°0.844 W, stream 1800 m), 27-VII-1997, R. Arce leg. (2 ♂). Municipality of Coatepec, Coatepec, Río Ahuacatlán at Los Tecajetes (19°28.356 N, 96°59.071 W, stream 1315 m), 20-III-1999, R. Novelo leg. (5 ♂, 2 ♀); at Colony Los Pinos (19°27.791 N, 96°58.310 W, stream 1227 m), 18-VII-2001, J.A. Gómez, R. Novelo

leg. (1 ♂). Michoacán: Municipality of Uruapan, El Sabino (19°24.684 N, 102°1.015 W, 1601 m), 15-V-2002, R. Novelo leg (2 ♀); Municipality of Chinicuila, La Nuez, El Colorín (ravine) (18°39.540 N, 103°24.057 W, 1050 m), 17-V-2002, R. Novelo, J.A. Gómez leg. (1 ♀); El Tejón (18°43.753 N, 103°14.101 W, 1315 m), 19-II-2005, R. Novelo, J.A. Gómez leg. (1 ♂). Chiapas: Municipality of Angel Albino Corzo, Reserve "El Triunfo" (15°39.510 N, 92°48.049 W, 1979 m), 14-V-2005, R. Novelo leg. (2 ♀). All deposited at Colección Entomológica del Instituto de Ecología, A.C., Xalapa (IEXA).

DESCRIPTION: Exuviae and larvae yellowish to light brown (alcohol specimens); larva stocky with broad head; abdomen short and robust, appearing granular on dorsal and ventral surfaces; caudal lamella densely tracheate.

H e a d. − Brown with yellow spots, mainly on anteclypeus and vertex (Fig. 1), almost twice as broad as long and wider than thorax and abdomen, occipital
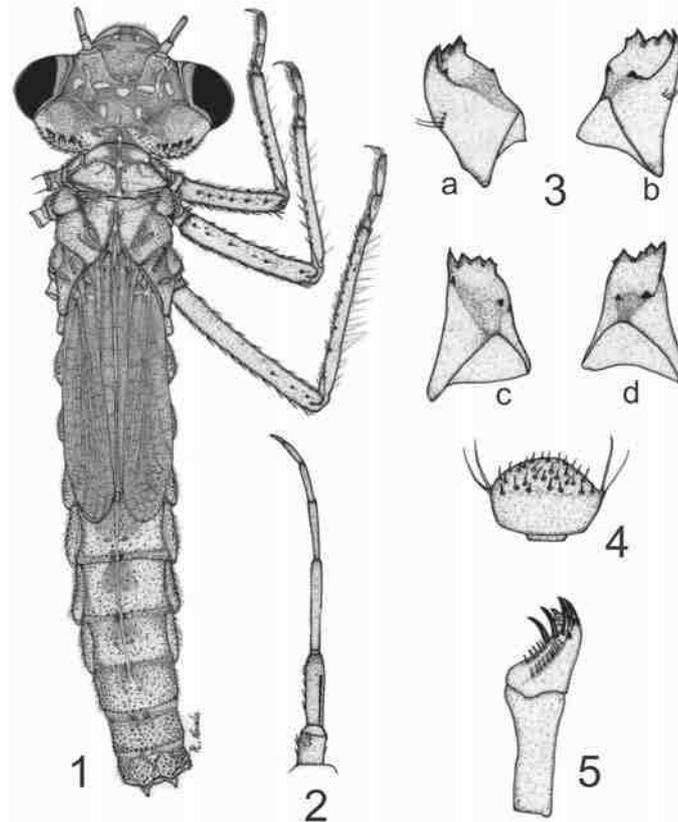
Figs 1-5. Larval morphology of *Apanisagrion lais*: (1) dorsal aspect of the F0 larva (male) (left legs, antennal flagellomeres and gills omitted); − (2) right antenna, dorsal view; − (3) mandibles: (a-b) ventrointernal view, − (c-d) internal view of right and left mandibles, respectively; − (4) ventral pad of hypopharynx; − (5) right maxilla, dorsal view.

margin widely concave, cephalic lobes rounded and covered with short, stout, stiff setae, remainder of head smooth; compound eyes prominent. Antennae 7-segmented (Fig. 2), the third segment the longest; relative length of antennomeres: 0.4, 0.8, 1.0, 0.6, 0.4, 0.3, 0.2; scape mostly creamy pale, pedicel light brown with a longitudinal, external, narrow, dark brown stripe (Fig. 2), remainder of antennomeres light brown; apex of flagellomeres 3-6 with long, white, delicate setae arranged in circle. Labrum mostly pale, with a large, central, brown, triangular spot, setose on apical margin. Mandibles (Fig. 3) with molar teeth but lacking molar crest, with following formula (*sensu* WATSON, 1956): L 1+2 3 4 5 0 a b, R 1+2 3 4 5 y a. Ventral pad of hypopharynx subrectangular (Fig. 4), anterior margin widely convex with numerous long, white setae and anterolateral corners
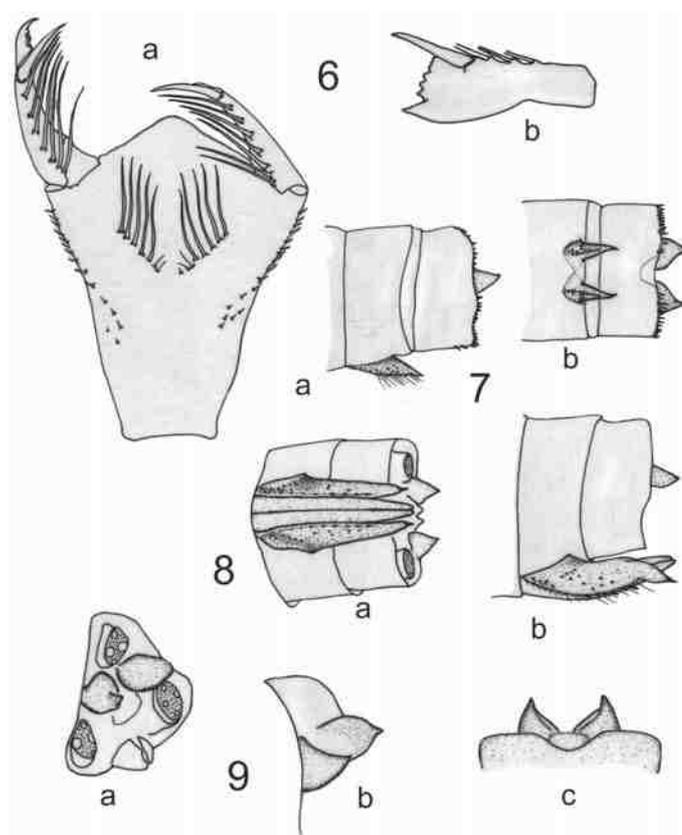
Figs 6-9. Details of the morphology of the larva of *Apanisagrion lais*: (6) labium: (a) prementum, dorsal view, − (b) detail of the left labial palp, frontal view; − (7) male gonapophyses: (a) lateral view, − (b) ventral view; − (8) female gonapophyses: (a) lateral view, − (b) ventral view; − (9) male cerci: (a) laterocaudal view, − (b) dorsolateral view, − (c) dorsal view.

with two long, stiff, light brown seta directed anteriorly. Maxilla: galeolacinia (Fig. 5) with six teeth, the three dorsal teeth long and moderately incurved, the ventroapical tooth the largest, the remaining two ventral teeth the smallest, the most internal one a mere spine, a row of stiff setae preceding both ventral and dorsal teeth; maxillary palp incurved, ending in a robust, obtuse spine, with some stiff, long setae on its external surface. Labium (Fig. 6): prementum-postmentum articulation reaching basal half of mesosternum; maximum width 0.8 its length (Fig. 6a), lateral margins smooth and moderately divergent on basal half, then strongly divergent at apical half with a row of 10-11 spiniform setae; premental setae 5+2 on the left side and 5+3 on the right side; ligula prominent, triangular, its border finely serrulate; labial palp (Figs 6a, b) with 7 long and stout setae, its apical lobe divided into a squarely truncated dorsal branch composed of 4 small teeth of which the dorsal one is obtuse and with minute denticles (Fig. 6b), and a ventral branch with a well-developed end hook; internal margin of palp finely serrated; movable hook long and sharply pointed.

T h o r a x. − Tan; pronotum trapezoidal, posterolateral angles moderately angular with a row of short robust setae, its posterior margin straight at middle. Anterior and posterior wing pads reaching 0.20 and 0.30 of abdominal segment 5, respectively. Legs pale, basal and apical borders of all segments, and dorsal carinae on femora and external carinae on tibiae with a narrow brown line (Fig.
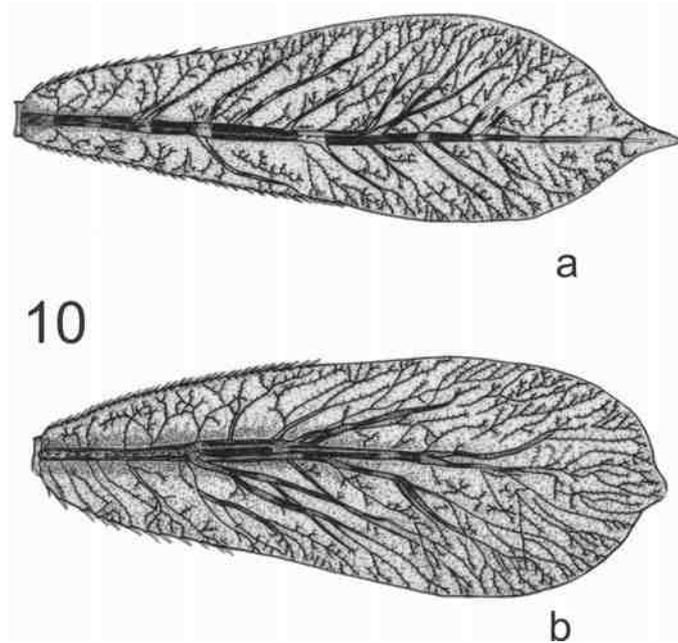

Fig. 10. Caudal lamellae: (a) left paraproct, external view, − (b) epiproct, left lateral view.

1); basal tarsomere, dorsal (external) surface of middle tarsomere and apical half of distal tarsomere brown, remainder pale. Femora and tibiae covered with spiniform setae mainly on dorsal (external) and ventral (internal) borders; tibiae with numerous tridentate setae on apicointernal surfaces; ventral surface of tarsi with a double row of stiff setae, claws simple with a pulvilliform empodium.

A b d o m e n. − Cylindric (Fig. 1), light brown, with narrow, pale, middorsal line on segments 3-7, gradually narrowing rearward, with a granular aspect on dorsal and ventral surfaces; lateral margin of segments 1-7 slightly convex, straight on 8-10, on 1-8 with a row of short, spiniform setae; posterior margin of segments 1-9 smooth, with a row of spiniform setae on 10. Male gonapophyses sharply pointed (Fig. 7), tips very slightly incurved in ventral view, reaching basal 0.30 of sternite 10, with a row of 9-10 small spiniform setae intermingled with long, white, delicate setae. Female gonapophyses exceeding posterior margin of sternite 10 (Fig. 8), lateral valvae sharply pointed with a ventral row of 4-6 robust spines on the middle third that increase in size and robustness posteriorly, basal third with 8-9 minute spiniform setae, apical third smooth. Male cerci globular basally, sharply pointed as in Figures 7 and 9; female cerci as in Figure 8. Caudal lamellae (epiproct and paraprocts) membranous (Fig. 10), profusely tracheate, widening gradually from base to apex reaching maximum width at basal 0.65 of their length, nodus absent; apex of paraproct (Fig. 10a) ending in a short tip which represents 0.10 of its total length, dorsal series of spiniform setae reaching basal 0.25, ventral series reaching basal 0.45, lateroexternal carina extending along basal 0.53 of the length of paraproct with numerous spiniform setae. Epiproct (Fig. 10b) widely rounded at apex, tip short and obtuse, dorsal series of spiniform setae reaching basal 0.45, ventral series reaching basal 0.30, lateral carinae extending along basal 0.55 the length of epiproct.

M e a s u r e m e n t s (in mm; average in square brackets). − Only F0 larvae: Total length (excluding caudal appendages) 10.8-14.1, [12] (N = 6); abdomen 7.0-9.6, [7.8] (N = 6); maximum width of head 3.2-3.4, [3.3] (N = 6); hind femur (dorsal) 2.7-3.1, [2.9] (N = 6); epiproct 3.2-5.7, [4.5] (N = 5); paraprocts 3.7-5.6, [4.8].

REMARKS. − *Apanisagrion lais* inhabits small bogs or swampy areas formed alongside streams, usually in more or less shaded conditions. It is also commonly found in eutrophized seepages. Larvae are associated to the emergent grasses or roots of herbaceous vegetation at the edge of these water bodies.

DISCUSSION

WESTFALL & MAY (1996) mentioned that the larvae of *Apanisagrion* "somewhat resemble those of *Telebasis* because of their unusually broad lateral gills". These authors also stated differences with *Telebasis* based upon the number of premental setae, 5 in *Apanisagrion* and 3 or fewer in *Telebasis*. Perhaps at first glance larvae of both genera could resemble each other, but a closer inspection reveals many differences (those of *Telebasis* in parentheses): the abdomen of

Apanisagrion lais appears densely granular, a condition resembling more that of an *Ischnura* (mostly smooth with some hair-like setae and sparse spiniform setae); lateral margins of abdominal segments 1-8 have a row of spiniform setae (lack spiniform setae); left mandible with formula L 1+2 3 4 5 0 a b (L 1+2 3 4 5 y a b); premental setae 5+2 or 5+3 (1-3); palpal setae 7 (6); the squarely truncate dorsal branch of apical lobe of palp is composed of 4 well differentiated small teeth (Fig. 6b) (dorsal branch just finely denticulated); male cerci sharply pointed (rounded); female gonapophyses clearly exceeding posterior margin of sternite 10 (slightly surpassing it); caudal lamellae lacking nodus (with nodus), not dotted (dotted).

ACKNOWLEDGEMENTS

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WATSON, M.C., 1956. The utilization of mandibular armature in taxonomic studies of anisopterous nymphs. *Trans. Am. ent. Soc.* 81: 155-202.

WESTFALL, M.J. & M.L. MAY, 1996. *Damselflies of North America*. Scient. Publishers, Gainesville/Florida.

ODONATOLOGICAL ABSTRACTS

2000

(17936)   BACH, L., 2000. Auswirkungen von Revitalisierungsmassnahmen an dem Heidebach Ise auf dessen Libellenfauna. *Angew. Landschaftsökol.* 37: 267-270. (With Engl. s.). − (Author's current address unknown).
Based on the 1991-1999 monitoring of the effects of various revitalisation measures on the odon. fauna of the Ise rivulet (Lüneburger Heide, Germany), it was noticed that particularly the typical stream spp. did profit from the revitalisation. Its effect on 15 spp. is shown in a graph.

(17937)   ZHOU, W.-b. & Z.-z. LI, 2000. Scalmogomphus guizhouensis sp. nov. and Lamelligomphus parvulus sp. nov., two new dragonflies from China (Anisoptera: Gomphidae) *Wuyi Sci. J.* 16: 18-21. (Chin., with Engl. s.). − (First Author: Dept Ent., Zheijang Mus. Nat. Hist., Gu-shan, Hanzhou-310012, China).
S. guizhouensis sp. n. (holotype ♂, allotype ♀: Guizhou, Huangguoshu, 18-VI-2000) and L. parvulus (holotype ♂, allotype ♀: Yunnan, Xiaguan, 10-VII-2000) are described and illustrated. The types are deposited at Zheijang Mus. Nat. Hist., Hanzhou).

2001

(17938)   FELLOWES, J.R. et al., [Eds], 2001. Report of rapid biodiversity assessments at Jianfengling Nature Reserve, Southwest Hainan, 1998 and 2001. *Sth China Forest Biodiv. Surv. Rep.* [Online Simplified Version] 3: ii + 26 pp. − (Kadoorie Farm & Bot. Garden Corp., Lam Kam Rd, Tai Po, N.T. Hong Kong, China).
27 odon. spp. are listed; − Ledong and Dongfang counties, China.

2002

(17939)   EIGENHEER, K., 2002. *Die Libellen an der Aare zwischen Büren a. A. und Rothrist (Schweiz)*. (With 1 p. Suppl., 2004). Eigenheer, Brügglen. 47 pp. − (Hofmatt 115, CH-4582 Brügglen).
A report on the odon. survey (1992-2001) along a 54 km stretch of the Aare river (cantons Berne, Solothurn, Aargau), Switzerland. Including the Supplement, 30 spp. were recorded. Annotations on their abundance, autochthony and ecology are provided.

2003

(17940)   BLACHUTA, J. & J. BLACHUTA, 2003. Ecological assessment of the Bug river based on its macrozoobenthos. *Proc. 6ᵗʰ Int. Conf. "Zagospodarowanie Zlewni Bugu […]"*, Warszawa-Popowo, pp. 147-155. (Pol., with Engl. s.). − (Inst. Meteorol. & Water Mngmt, Wroclaw, Poland).
From the Bug and its tributaries (Poland) 7 odon. spp. are listed.

(17941)   FELLOWES, J.R. et al., [Eds], 2003. Report of rapid biodiversity assessment at Nanling National Nature Reserve, Northwest Guangdong, China, June-July 2000. *Sth China Forest Biodiv. Surv. Rep.* [Online Simplified Version] 29: ii + 33 pp. − (Kadoorie Farm & Bot. Garden Corp., Lam Kam Rd, Tai Po, N.T. Hong Kong, China).
91 odon. taxa are listed, of which 5 spp. are new and undescribed; − Ruyuan co. (Shaoguan distr.), and Yangshan and Lianzhou counties (Qingyuan distr.).

(17942)　FERRERAS-ROMERO, M., F.J. CANO-
-VILLEGAS & J.C. SALAMANCA-OCANA,
2003. Valoración de la cuenca del rio Guadiamar
(sur de España), afectada por un vertido minero,
en base a su odonatofauna. *Limnetica* 22(3/4): 53-
62. (With Engl. s.). − (Depto Cien. Ambientales /
Zool., Univ. Pablo de Olavide, Ctra. de Utrera km
1, ES-41012 Sevilla).

The odon. community is analysed in the Guadiamar
catchment (S Spain), affected by a mining spill that
occurred in Apr. 1998. Compared to other Anda-
lusian catchments, the number of spp. (18) was not
particularly low, though 55.5% of them were libel-
lulids, and the absence of some typically rheophil-
ous Calopterygidae and Gomphidae spp. was sig-
nificant. This fact highlights the currently poor eco-
logical condition of that part of the catchment. In
addition, the biogeographical analysis showed that
a high proportion of spp. are of N African origin.

(17943)　SANFORD, M.R., J.B. KEIPER & W.E.
WALTON, 2003. The impact of wetland vegeta-
tion drying time on abundance of mosquitoes and
other invertebrates. *J. Am. Mosquito Contr. Ass.*
19(4): 361-366. − (First Author: Dept Ent., Univ.
California, Riverside, CA 92521, USA).

Vegetation management for constructed treatment
wetlands often involves knocking down emergent
vegetation and inundating the dead vegetation after
a period of drying. Such practices create favour-
able circumstances for larval mosquitoes and other
insects. Predators readily colonized the pools, al-
though more slowly than did most of the dipteran
taxa. Hydrophilid (Coleoptera) and aeshnid larvae
were the 2nd and the 3rd most abundant predator
colonizing the pools, respectively.

(17944)　STOKS, R. & M.A. McPEEK, 2003. Anti-
predator behavior and physiology determine Lestes
species turnover along the pond-permanence gra-
dient. *Ecology* 84(12) 3327-3338. − (First Author:
Lab. Aquat. Ecol., Univ. Leuven, Debériotstraat
32, B-3000 Leuven).

Identifying key traits that shape trade-offs that re-
strict spp. to only a subset of environmental gra-
dients is crucial to understanding and predicting
species turnover. Previous field experiments have
shown that Lestes larvae segregate along the entire
gradient of pond permanence and predator pres-
ence and that differential predation risk and life
history contraints together shape their distribu-
tion. Here, laboratory experiments are reported that
identify key differences in behaviour and physiology
among spp. that structure their distributions along
this gradient. The absence of adaptive antipreda-
tor behavioural responses against large dragonfly
larvae and fish of L. dryas, the only sp. to inhabit
predator-free vernal ponds that dry each year, is
consistent with its high vulnerability to predation
and probably the key trait that excludes it from
parts of the gradient with predators. The recipro-
cal dominance of 2 other Lestes spp. in permanent
waters dominated by either dragonflies or fish can
be explained by the lack of effective antipredator
behaviours against dragonflies and fish, reapec-
tively. Maximal growth rates did not differ among
Lestes along the gradient. However, in the natural
predator environment of vernal ponds (only conspe-
cific cannibals), the vernal-pond Lestes had higher
growth rates than the other Lestes suggesting that
this excludes other Lestes from vernal ponds. Simi-
larly, Lestes spp. that inhabit temporary ponds (i.e.,
ponds that dry intermittently every few years but
not every year) had a higher growth rate than the
fishless permanent-pond Lestes in the presence of
the syntopic dragonfly predator. These growth dif-
ferences among Lestes in predator treatments were
not due to differences in food intake, but due to
differences in physiology. The vernal-pond Lestes
converted more assimilated food into body mass
compared to the other Lestes in the presence of
conspecific larvae, and the temporary-pond Lestes
had a higher conversion efficiency than the fishless
permanent-pond Lestes in the presence of the syn-
topic dragonfly predators. In contrast, reductions
in growth rate within species in the presence of
syntopic predators were both physiologically and
behaviourally mediated. The interplay between be-
haviour and physiology may be a common feature
of the growth/predation-risk trade-off, and their
joint study is therefore critical to mechanistically
link phenotype, performance and, community as-
sembly along the freshwater habitat gradient.

(17945)　VERSTRAEL, T., J. BOUWMAN, R.
KLEUKERS, H. TURIN, R. VERHAGEN &
H. DE VRIES, 2003. Prioritiaire insecten en andere
ongewervelden in Noord-Brabant. − [Prioritary
insects and other invertebrates in Noord-Brabant].
Vlinderstichting Rapp. VS2003.022: 36 pp. (Dutch).
− (c/o De Vlinderstichting, P.O. Box 506, NL-6700
AM Wageningen).

In the provincial fauna of Noord-Brabant (the Netherlands), 17 odon. spp. are either nationally red-listed or they are included in the European Habitat Directive. Their status, habitat requirements and general location of their populations in the province are stated.

2004

(17946)   ESENKO, I., 2004. *Zaživimo z naravo!: ptice in ekološko vrtnarjenje*. − [*Let us revive with nature!: birds and ecological gardening*]. Didakta, Radovljica. 123 pp. ISBN 961-6463-89-6. (Slovene).
Coenagrion puella and Libellula depressa are among the most common inhabitants of garden ponds in Slovenia.

(17947)   JOBIN, L.-J. & J.-M. PERRON, 2004. Odonatofaune du parc écologique du mont Shefford, division de recensement de Shefford, Québec. *Naturaliste can.* 128(1): 27-30. − (Authors' addresses not stated).
A brief description of the Park, with a commented list of 42 spp.; − Quebec, Canada.

(17948)   MARTIN CASACUBERTA, R., 2004. Odonata of Catalonia: catalogue and geographic analysis. *Boln Asoc. esp. Ent.* 28(1/2): 55-69. (Span., with Engl. s.). − (C./Marti Juliá 19-23, 1° 1ª, ES-08911 Barcelona).
This is not a "critical catalogue" of the 65 spp. hitherto recorded from Catalonia (Spain), but these are said to be listed in a tab. However, most corduliids and all libellulids are missing there, therefore the utility of the paper is limited.

(17949)   PALMER, C.G., W.J. MULLER, A.K. GORDON, P.-A. SHERMAN, H.D. DAVIES-COLEMAN, L. PAKHOMOVA & E. DE KOCK, 2004. The development of a toxicity database using freshwater invertebrates, and its application to the protection of South African water resources. *Sth Afr. J. Sci.* 100: 643-650, tab 1 excl. − (First Author: Unilever Cent. Environ. Water Quality, UCEWQ, Inst. Water Res., Rhodes Univ., P.O. Box 95, Grahamstown-6140, Sth Afr.).
The UCEWQ has developed a toxicity database that, to date, records the responses of 21 Sth African freshwater taxa to 26 single-substance pollutants or mixtures, in which the odon. are represented by Enallagma sp. The database is reproduced here.

(17950)   PEÑALVER, E. & X. DELCLÒS, 2004. Insecto del Mioceno Inferior de Ribesalbes (Castellón, España): interacciones planta-insecto. *Trab. Mus. Geol. Barcelona* 12: 69-95. (With Engl. s.). − (First Author: Area Paleont., Inst. Cavanilles, Univ. València, Apartado Oficial 2085, ES-46071 Paterna, València).
The ichnofossils, originating from insects found in the Lower Miocene locality of "La Rinconada" near Ribesalbes (Castellón prov., Spain), are described, illustrated and discussed. The ovipositions on the leaves of Laurophyllum, Caesalpiniaceae and Populus show ovate to oblong eggs of 0.9-1.1 mm length and 0.2-0.3 mm width, occurring in eccentric archs, sometimes in a zigzag pattern. They are ascribed to coenagrionids.

(17951)   REASH, R.J., 2004. Dissolved and total copper in a coal ash effluent and receiving stream: assessment of in situ biological effects. *Envir. Monit. Assmt* 96: 203-220. − (Am. Electr. Power Water & Ecol. resour. Serv., Columbus, OH, USA).
The study was conducted adjacent to Ohio Power Company's Muskingum river power plant (SW Ohio, USA), which generates electric power by burning coal. Coal ash wastewater effluent is discharged to the river. The sites adjacent to effluent and 20 m downstream of it had the highest number (6) of odon. spp. The high water velocity of the discharge apparently creates a favourable microhabitat that, combined with Cu-complexing constituents in the discharge, supersedes potential effects of high Cu levels.

2005

(17952)   BECKEMEYER, R., 2005. Afrikaan Anisoptera and Zulu Zygoptera: a trip to South Africa [Newsl.] *Idalia Soc.* 16(2): 3-5. − (957 Perry Ave, Wichita, KS 67203-3141, USA).
A field trip report, with records (Feb. 2003).

(17953)   COLLAR, D.C., T.J. NEAR & P.C. WAINWRIGHT, 2005. Comparative analysis of morphological diversity: does disparity accumulate at the same rate in two lineages of centrarchid fishes? *Evolution* 59(8): 1783-1794. − (First Author: Sect. Evol. & Ecol., Univ. California, Davis, CA 95616, USA).
Odon. are reported in the diet of 5 N American (out of 12 examined) Lepomis (sunfish) spp. and in

1 (out of 8 examined) Micropterus (black basses) sp. − (*Abstractor's Note*: Odon. are not reported in the diet of L. [= Eupomotis] gibbosus, whereas in Slovenia the latter regularly preys on zygopteran larvae, if [rarely] occurring in its habitat.).

(17954)   JAKUBAS, D. & A. MIDUSZEWSKA, 2005. Diet omposition and food consumption in the grey heron (Ardea cinerea) from breeding colonies in northern Poland. *Eur. J. Wildl. Res.* 51: 191-198. − (Dept Vert. Ecol. & Zool., Univ. Gdansk, Legionów 9, PO-80-441 Gdansk.
The diet was investigated in 3 colonies. It was assessed during the breeding season on the base of pallets and regurgitated food. Odon. were represented in all colonies, but their numbers among the food items varied intercolonially (0-2%).

(17955)   NAKAMURA, S. & S. MATSUDA, 2005. The insects in the riversides of Takatsu river, Shimane prefecture: a result of survey in 2000. *Bull. Hoshizaki Green Found.* 8: 99-172. (Jap., with Engl. s.). − (First Author: Nishihon-machi 1-7-7, Shobara, Hiroshima, 727-0013, JA).
Includes an annotated list of 52 odon. spp., recorded from 5 localities along the river; − Japan.

(17956)   STOKS, R., J.L. NYSTROM, M.L. MAY & M.A. McPEEK, 2005. Parallel evolution in ecological and reproductive traits to produce cryptic damselfly species across the Holarctic. *Evolution* 59(9): 1976-1988. − (First Author: Lab. Aquat. Ecol., Univ. Leuven, Beriotstraat 32, B-3000 Leuven).
The zygopteran gen. Enallagma originated in the Nearctic, and 2 Nearctic lineages recently underwent radiations partly associated with multiple independent habitat shifts from lakes dominated by fish predators into lakes dominated by odon. predators. A previous molecular study of 4 Palearctic morpho-species and all representative Nearctic spp. identified the presence of 2 cryptic spp. sets, with each set having Palearctic and Nearctic representatives. However, the cryptic spp. within each set are not sibling spp. Here, are presented quantitative data on ecologically important larval morphologies and behaviours involved in predator avoidance and on adult ♂ morphological structures involved in mate recognition to quantify the phenotypic relationships among these cryptic spp. sets. For the adult stage, the data indicate strong parallel evolution of the structures involved in specific mate recognition,

the ♂ cerci. For the larval stage, morphometric analyses show that the Palearctic spp. evolved a nearly identical morphology to the sibling-clade members in the Nearctic that live in waters where dragonflies are the top predators. This implicates the importance of odon. predation in the history of the Palearctic clade. Behavioural analyses suggest population differentiation in response to the actual predator environment in the Palearctic clade consistent with the spp. differentiation seen in the Nearctic. The results suggest parallel evolution of adult traits that influence specific mate choice and larval traits that influence ecological performance underlie the striking similarity of Enallagma spp. across continents. This concurrent parallel evolution in both stages of a complex life cycle, especially when both stages do not share the same selective environment, may be a very unusual mechanism generating cryptic spp.

(17957)   WWF-US, Asia Program, 2005. *Ecosystem profile Eastern Himalayas region*. Critical Ecosystem Partnership Fund. ii + 97 pp. − (Publisher's address not stated).
Epiophlebia laidlawi is the only odon. sp. considered. The compilers of the present work were apparently not familiar with much of the literature pertaining to it, hence Nepal is stated as its sole distribution area and it is said that for E. laidlawi no biodiversity area ("site outcome") could be identified. − (For the currently known E. laidlawi distribution in India, Nepal and Bhutan, and for a comprehensive bibliography on the subject, see T. Brockhaus & A. Hartmann, 2009, *Odonatologica* 38: 203-215).

2006

(17958)   ABELLÁN, P., D. SANCHÉZ-FERN-ANDEZ, A. MILLÁN, F. BOTELLA, J.A. SÁNCHEZ-ZAPATA & A. GIMÉNEZ, 2006. Irrigation pools as macroinvertebrate habitat in a semi-arid agricultural landscape (SE Spain). *J. arid Envir.* 67: 255-269. − (First Author: Depto Ecol. & Hydrobiol., Univ. Murcia, Campus de Espinardo, ES-30100 Murcia).
A total of 8 odon. taxa (listed at gen. or sp. level) are recorded from 40 pools examined. Pools, constructed with low-density polyethylene covered with sand and stones, contained a significantly greater species richness, abundance and diversity than those constructed with high-density plastic materials. Sig-

nificant differences were also found in odon. species richness between pools with and without submerged vegetation. The presence of bank and emergent vegetation seemed to have the same effect.

(17959) KOUAMÉ, M.K., A. OUATTARA, M.Y. DIETOA & G. GOURENE, 2006. Alimentation du Clupeidae Pellonula leonensis dans le lac barrage de Buyo (Côte d'Ivoire). *Cybium* 30(2): 145-150. (With Engl. s.). − (Last Author: Lab. Environ. & Biol. aqaut., Univ. Abobo-Adjame, 02 BP 801, Abidjan-02, Ivory Coast).

In the P. leonensis diet in the Buyo reservoir on the Sassandra river (Ivory Coast), Phyllomacromia sp. and unidentified Coenagrionidae, Aeshnidae, Libellulidae and other odon. were found. Index of relative importance of the respective taxa was between 0.4 and 6.2%.

(17960) LAGUNOV, A.V., 2006. Chlenistonogie iz mezhdunarodnoy krasnoy knigi v faune Chelyabinskoy oblasti. − [Internationally red-listed arthropods in the fauna of the Chelyabinsk district]. *Izv. chelyabinsk. nauch. Cent.* 4(34): 96-100. (Russ.). − (Il'menskiy Gos. Zapovednik, OrO RAN, Miass, Russia).

Aeshna viridis, Ophiogomphus cecilia, Leucorrhinia albifrons and L. caudalis are listed.

(17961) MARQUES VIEIRA, M.E., 2006. *A comunidade de macroinvertebrados em dois trechos do Rio Morato (Guaraqueçaba, PR): estrutura, composição e ocupação especial*. Diss. Mestre Ecologia, Univ. Fed. Paraná, Curitiba. viii + 48 pp. (Port., with Engl. s.). − (Author's current address unknown).

The macroinvertebrate community of 2 similar stretches upstream and downstream of the Salto Morato Falls (Paraná, Brazil) is described. 9 odon. genera and "Calopterygidae" are listed, spp. names are not provided.

(17962) PATHANI, S.S. & K.K. UPADHYAY, 2006. An inventory of zooplankton, zoobenthos and fish fauna in the river Ramganga (W) of Uttaranchal, India. *ENVIS Bull. Himalayan Ecol.* 14(2): 37-46. − (Kumaon Univ., S.S.J. Campus, Almora-263601, Uttaranchal, India).

The information is presented on the occurrence and abundance of "Agrion", Rhinocypha and Matrona in a 45 km section of the river, at Gairsen, Chakhutia and Masi (alt. 1060-1650 m a.s.l.).

(17963) SAMWAYS, M., 2006. Astonishing recovery of rare and threatened dragonflies. *Newsl. Fac. AgriSci. Univ. Stellenbosch* 27: 1-2. − (Dept Conserv. Ecol. & Ent., Cent. Agric. Biodiv., Univ. Stellenbosch, P. Bag X1, Matieland-7602, SA).

The rich endemic odon. fauna of Sth Africa has been under threat from invasive alien trees, particularly eucalypts, wattles and pines. These shade out the habitat, making it unsuitable for the sun-loving endemic spp. The Biodiversity Recovery Index (BRI) is the ratio of the total odon. spp. score before alien tree removal to the score when they are removed. The highest recorded BRI so far is 6 (600% recovery), attained on the top of Table Mountain. Among the spp. that have made a come-back is Syncordulia venator (last recorded on the mountain is 1934). Ecchlorolestes peringueyi has also appeared.

(17964) TERMAAT, T. & D. GROENENDIJK, 2006. Witsnuitlibellen in de Groote en Deurnese Peel: onderzoek naar oorzaken van het verspreidingspatroon. − [Leucorrhinia dubia and L. rubicunda in the Groote Peel and the Deurnese Peel: inquire into factors controlling their distribution]. *Vlinderstichting Rapp.* VS2006.019: 31 pp. (Dutch). − (c/o De Vlinderstichting, P.O. Box 506, NL-6700 AM Wageningen).

These are large fens in the Noord-Brabant prov. (the Netherlands). Their vegetation structure appears very similar and the minute difference in pH is insignificant. The 2 spp. co-occur in the Deurnese Peel, whereas the nearby Groote Peel is populated solely by L. rubicunda. Under favourable and stable conditions L. dubia has larger populations than L. rubicunda, but the latter has larger ecological amplitude, it is more mobile and the adults and larvae are larger. Under stable conditions the 2 spp. are in balance, but even a slight disruption in the environment stability is likely to trigger a break-down of the balance: L. rubicunda will prevail and finally L. dubia completely disappear.

(17965) WHITE, D., D. WHITE & N. POWER, 2006. *Fauna survey report on the Burleigh Greenspace Conservation Reserve, Gold Coast City*. Gold Coast City Council, 56 pp. − (First Author: 32 Terrigal Crescent, Southport, Qld 4215, AU).

Includes a list of 20 odon. spp. recorded from the Reserve, Queensland, Australia.

2007

(17966)   BUIDIN, C. & Y. ROCHEPAULT, 2007. Inventaire des odonates de Minganie. *Naturaliste can.* 131(2): 10-16. − (First Author: 1 ch. du Grand Ruisseau, Rivière-Saint-Jean, QC, G0G 2N0, CA).

Commented lists of spp. known to occur in Minganie and on the island of Anticosti (32 spp. each), Quebec (Canada).

(17967)   CLOPTON, R.E., T.J. COOK & J.L. COOK, 2007. Revision of Geneiorhynchus Schneider, 1875 (Apicomplexa: Eugregarinida: Actinocephalidae: Acanthosporinae) with recognition of four new species of Geneiorhynchus and description of G. manifestus n. sp. parasitizing naiads of the green darner, Anax junius (Odonata: Aeshnidae) in the Texas Big Thicket. *Comp. Parasitol.* 74(2): 273-285. − (First Author: Dept Nat. Sci., Peru St. Coll., Peru, NE 68421 USA).

The 6 known spp. (G. monnieri, G. aeshnae, G. desportesi sp. n., G. baudoini sp. n., G. shteini sp. n., G. manifestus sp. n.) are intestine parasites in larval Anisoptera (Aeshna, Anax, Libellula).

(17968)   DE BLOCK, M., M.A. McPEEK & R. STOKS, 2007. Life-history evolution when Lestes damselflies invaded vernal ponds. *Evolution* 62(2): 485-493. − (Second Author: Dept Biol. Sci., Dartmouth Coll., Hanover, NH 03755, USA).

Little is known about the macroevolution of life-history traits along environmental gradients, especially with regard to the directionality compared to the ancestral states and the associated costs to other functions. Here it is examined how age and size at maturity evolved when Lestes damselflies shifted from their ancestral temporary pond habitat (i.e., ponds that may dry once every decade or so) to extremely ephemeral vernal ponds (ponds that routinely dry completely each year). Larvae of L. congener, L. dryas and L. forcipatus were reared from eggs until emergence under different levels of photoperiod and transient starvation stress. Compared to the 2 temporary-pond Lestes spp. the phylogenetically derived vernal-pond L. dryas developed more rapidly across photoperiod treatments until the final instar, and only expressed plasticity in development time in the final instar under photoperiod levels that simulated a later hatching date. The documented change in development rate can be considered adaptive and underlies the success of the derived species in vernal ponds. Results suggest associated costs of faster development are lower mass at maturity and lower immune function after transient starvation stress. These costs may not only have impeded further evolution of the routine development rate to what is physiologically maximal, but also maintained some degree of plasticity to time constraints when the habitat shift occurred.

(17969)   GOLUB, V.B. et al., [Eds], 2007. *Questions of aquatic entomology of Russia and adjacent lands.* (Materials of the 3rd All-Russia Symposium on amphibiotic and aquatic insects, Voronezh, 2007). 409 pp. ISBN 978-5-9273-1169-9. (Russ., with Engl. s's).

[Odonatological papers]: *Dombrovsky, K.O.*: Biotopic allocations and dynamics of the number of damselfly larvae (Odonata) of the Kakhovskoye water reservoir (pp. 96-100, 401); − *Dyatlova, E.S.*: Polymorphism of coenagrionid damselflies in the southwestern Ukraine (pp. 107-113, 401); − *Matushkina, N.A.*: The morpho-functional adaptations in Lestidae (Odonata, Zygoptera) to the oviposition into plant substrates of different stiffness (pp. 177-183, 403-404); − To the study of dragonflies (Odonata, Anisoptera) of Moscow and Moscow region (pp. 183-191; 404); − *Ryazanova, G.I.*: Reproduction tactics in the males of Lestes sponsa (Hansemann) (Odonata, Zygoptera): individual reproduction success or success of the population (pp. 287-292, 406); − *Semenova, V.A. & V.B. Golub*: Results of evaluating the condition of the benthic layer of the Voronezhkoye reservoir on the basis of stability of development index of the test-object, the damselfly Ischnura elegans (Odonata, Coenagrionidae) (pp. 296-302, 406-407); − *Silina, A. Ye.*: Substance and energy outflow from marsh ecosystem by insect emerging: the succession aspect (pp. 303-320, 407); − *Sluvko, A.A.*: The biological rhythms of the Odonata of the Astrakhan province (pp. 325-329, 407); − *Stain, V. Yu.*: Arealogical analysis of the Odonata fauna of the North Caucasus (pp. 335-342, 407-408); − *Sharapova, T.A.*: The Odonata larvae in the periphyton of West Siberia (pp. 374-376, 409).

(17970)   KARJALAINEN, S., 2007. New provincial records of Finnish dragonflies (Odonata) in 2002-2007. *Sahlbergia* 13: 13-25. (Finn., with

Engl. s.). − (Neidonpuistontie 6 D 8, FIN-02400 Kirkkonummi).

48 new provincial records are presented, incl. those of Sympecma paedisca and Aeshna mixta that were discovered during this period as new for the Finnish fauna. Also Coenagrion puella, Sympetrum sanguineum and Leucorrhinia pectoralis have become more common and are currently distributed in a wider area than before. An updated distribution tab. of Finnish Odon. by biogeographical provinces is appended.

(17971) KRELJ, Ž., 2007. *Ecological status of pond Tivoli*. Graduation thesis, Univ. Ljubljana. xi+76 pp. (Slovene, with Engl. s.).

The Tivoli pond is a shallow, eutrophic water body in the city park Tivoli on the NW margin of Ljubljana (Slovenia). Its plankton and macroinvertebrate communities were investigated from Oct. 2005 to June 2006. Larval Coenagrion puella and Enallagma cyathigerum are the sole odon. spp. recorded.

(17972) MACHIDA, K. & T. OIKAWA, 2007. Structure analyses of the wings of Anotogaster sieboldii and Hybris subjacens. *Key engineering Materials* 345/346: 1237-1240. − (Tokyo Univ. Sci., 2641 Yamazaki, Noda-shi, Chiba, 278-8510, JA).

Various 3-D models of A. sieboldii wing (Odon.) are analysed using the finite element method and compared with the model of H. subjacens wing (Neuroptera). It is concluded that the arch configuration of the odon. costal vein controls the bending and torsion of the wing. − For the Jap. version of this paper, see *OA* 17991.

(17973) MEURGEY, F., 2007. *Étude sur la repartition et l'écologie de Protoneura romanae (Odonata, Zygoptera, Protoneuridae) libellule endémique de Guadeloupe*. Parc National de Guadeloupe & Museum d'Histoire Naturelle, Nantes. 30 pp. − (Mus. Hist. Nat., 12 rue Voltaire, F-44000 Nantes).

The spatial and altitudinal distribution of P. romanae is outlined, and its larval habitat features and ecology are described.

(17974) RAMSEY, J.B., D.S. WHITE & H.-S. JIN, 2007. Spatial distribution of benthic macroinvertebrates in a sidearm embayment of Kentucky Lake. *J. Ky Acad. Sci.* 68(1): 50-58. − (First Author: Hancock Biol. Stn, 561 Emma Dr., Murray, KY 42071, USA).

The larvae of 4 odon. gen. (incl. Progomphus) are reported from Ledbetter Embayment (KY, USA). Enallagma, Lestes and Macromia were found primarily near the mouth of a spring inlet on the SW edge of the embayment.

(17975) RAVANELLO, C.T., 2007. *Abundance and diversity of Odonata larvae (Insecta) in rivers of the hydrographic basin of upper Uruguay river, Santa Catarina*. Diss. Mestre Ciências Ambientais Univ. Communitária Regional Chapecó. xii+43 pp. (Port., with Engl. s.). − (Author's current address unknown).

9 rivers were sampled (W of Santa Catarina, Brazil) with the objective to verify the influence of the abiotic variables on the community and to examine association patterns between the fauna and the substrate. 958 larvae were collected, pertaining to 36 gen. of Calopterygidae, Coenagrionidae, Megapodagrionidae, Aeshnidae, Gomphidae and Libellulidae.

(17976) ROUQUETTE, J.R. & D.J. THOMPSON, 2007. Patterns of movement and dispersal in an endangered damselfly and the consequences for its management. *J. appl. Ecol.* 44: 692-701. − (Pop. & Evol. Biol. Res. Gr., Sch. Biol. Sci., Univ. Liverpool, Crown St., Liverpool, L69 7ZB, UK).

A multisite mark-release-recapture project was carried out with Coenagrion mercuriale in the valley of the Itchen river in southern England to determine the extent of movement and the factors affecting movement of mature adults. A total of 8708 individuals was marked. The sp. was found to be extremely sedentary, with dispersal limited to an area of contiguous habitat. The median net lifetime movement was 31.9 m and 66% of individuals moved less than 50 m in their lifetime. Movements of greater than 500 m were rare and the longest recorded movement was 1.79 km. This makes it the most sedentary odon. that has been studied in the UK. The highest recapture rates and the lowest movement distances were recorded at the most isolated site. Time between capture and recapture, and day in season had an effect on movement, and individuals travelled further on their first than on subsequent moves. There was no consistent effect of age or sex on distance moved. There was strong evidence for inverse density-dependent movement, with individuals moving further in low-density than high-density populations. This is probably the first

time that inverse density-dependent movement has been observed in a natural population of odonates. Patterns of movement and dispersal are strongly affected by landscape structure and population density. This means that C. mercuriale is unable to recolonize isolated sites and requires 'stepping stone' habitats to improve its chances of survival in the medium and long term. Suitable habitat management between sites that are beyond the dispersal distance of individuals can be used to connect or reconnect populations. Within existing sites only small sections of habitat should be managed in any one year and new areas should be created close to existing populations. The long-term persistence of C. mercuriale requires a landscape approach to management, with connectivity an important part of management planning.

(17977)   SCHAEL, D.M., 2007. *Gamma-Grassridge 765kV transmission power lines (×2). Ecological and biodiversity assessment: wetland-specialist study*. Cent. Afr. Conserv. Ecol. viii+56 pp. − (Address not stated).
This report endeavours to investigate potential impacts to freshwater ecosystems that may be affected by the proposed development transmission line corridor from the Gamma substation outside of Victoria West to the Grassridge substation outside of Port Elisabeth, Sth Africa. It includes an annotated list of odon. spp. that could potentially occur in the proposed transmission line corridor.

(17978)   SCIBERRAS, A., J. SCIBERRAS & D. MAGRO, 2007. A celebration of dragonflies. *Malta Independent*, issue of 19 Nov., pp. 8-9. − (First Author: 131 'Arnest', Arcade St., Paola, Malta).
A feature article in a local newspaper; − Malta.

(17979)   SHARMA, G., R. SUNDARARAJ & L.R. KARIBASVARAJA, 2007. Species diversity of Odonata in the selected provenances of sandal in southern India. *Zoos' Print J.* 22(7): 2765-2767. − (Wood Biodegradation Div., Inst. Wood Sci. & Technol., 18th Cross Malleswaram, Bangalore, Karnataka-560003, India).
21 spp. are reported from sandal ecosystems of 6 localities in Karnataka, Tamil Nadu and Kerala, India.

(17980)   SMITH, J., M.J. SAMWAYS & S. TAYLOR, 2007. Assessing riparian quality using two complementary sets of bioindicators. *Biodiv. Conserv.* 16: 2695-2713. − (Second Author: Dept Conserv. Ecol. & Ent., Cent. Agric. Biodiv., Univ. Stellenbosch, P. Bag X1, Matieland-7602, SA).
Bioligical indicators are being increasingly used to rapidly monitor changing river quality. Among these bioindicators are macroinvertebrates. A short-changing river quality. Among these bioindicators are macroinvertebrates. A shortcoming of macroinvertebrate rapid assessments is that they use higher taxa, and therefore lack taxonomic resolution and species-specific responses. One subset of invertebrate taxa is the Odon., which as adults, are sensitive indicators of both riparian and river conditions. Yet adult Odon. are not necessarily an umbrella taxon for all other taxa. Therefore, it was investigated here whether the 2 metrics of aquatic macroinvertebrate higher taxa and adult odon. spp. might complement each other, and whether together they provide better clarity on river health and integrity than one subset alone. Results indicated that both metrics provide a similar portrait of large-scale, overall river conditions. At the smaller spatial scale of parts of rivers, Odon. were highly sensitive to riparian vegetation, and much more so than macroinvertebrate higher taxa. Odon. spp. were more sensitive to vegetation structure than they were to vegetation composition. Landscape context is also important, with the odon. assemblages at point localities being affected by the neighbouring dominant habitat type. Overall, benthic macroinvertebrates and adult Odon. spp. provide a highly complementary pair of metrics which together provide large spatial scale (river system) and small spatial scale (point localities) information on the impact of stressors such as riparian invasive alien trees. As adult Odon. are easy to sample and are sensitive to disturbance at both small and large spatial scales, they are valuable indicators for rapid assessment of river condition and riparian quality.

(17981)   SUBRAMANIAN, K.A. & K.G. SIVARA-MAKRISHNAN, 2007. *Aquatic insects of India: a field guide*. Ashoka Trust for Ecol. and Envir. (ATREE), Bangalore. 62 pp. ISBN none. − (First Author: Western Reg. Stn, Zool. Surv. India, Pune-411144, India).
An illustrated key to the families; the odon. are treated on pp. 26-29.

(17982)   VANAPPELGHEM, C., 2007. Les odonates de la région Nord – Pas-de-Calais: historique de

la connaissance et diversité. *Héron* 40(4): 149-154. (With Engl. s.). − (15 rue brûle-maison, F-59000 Lille).

An outline is presented of the history of odon. exploration in the region "Nord – Pas-de-Calais" (France), and a list is provided of the 53 hitherto recorded spp. The occurrence of Lestes barbarus, Onychogomphus forcipatus, Crocothemis erythraea, Sympetrum depressiusculum and S. meridionale is discussed.

2008

(17983)   ABBOTT, J.K. & E.I. SVENSSON, 2008. Ontogeny of sexual dimorphism and phenotypic integration in heritable morphs. *Evol. Ecol.* 22: 103-121. − (Sect. Anim. Ecol., Lund Univ., Ecol. Bldg, S-223-62-Lund).

The developmental basis of adult phenotypes is investigated in the polymorphic Ischnura elegans with 3 ♀ colour morphs. Larvae of different families were risen in individual enclosures in the laboratory and morphological changes during ontogeny were traced, using principal component analysis to examine the effects of sex, maternal morph and own morph on body size and shape. Also investigated were the larval fitness consequences of variation in size and shape by relating these factors to emergence success. ♀♀ grew faster than ♂♂ and were larger as adults and there was sexual dimorphism in body shape in both larval and adult stages. There were also significant effects of maternal morph and own morph on growth rate and body shape in the larval stage. There were significant differences in body shape but not in body size in the adult ♀ morphs, indicating phenotypic integration between colour, melanin patterning and body shape. Individuals that emerged successfully grew faster and had different body shape in the larval stage, indicating internal (non-ecological) selection on larval morphology. Overall, morphological differences between individuals in the larval stage carried over to the adult stage. Thus, selection in the larval stage can potentially result in correlated responses in adult phenotypes and vice versa.

(17984)   BARBIER, G., R. BÉCAN, J.-F. CLAUDE, C. DUSSAIX & C. KERIHUEL, 2008. Entomofaune sarthoise: nouvelles espèces apparues depuis ving ans. *Troglodyte* 21/22: 9-21. − (Last Author: 2 imp. Ravault, F-72190 Coulaines).

Ophiogomphus cecilia and Leucorrhinia caudalis are listed as new autochthonous spp. in the fauna of the dept of La Sarthe (France).

(17985)   BEDJANIČ, M., N. MICEVSKI & B. MICEVSKI, 2008. On the dragonfly collection in the Natural History Museum in Struga, Macedonia (Insecta: Odonata). *Biol. maced.* 61: 97-105. − (Last Author: Bul. ASNOMM br. 58-2/4, MK-1000 Skopje).

23 spp. are listed, most of them from Struga and its vicinity. Somatochlora flavomaculata is new for the fauna of Macedonia. Its occurrence in the Balkan is outlined and mapped. A checklist of the 37 spp. hitherto recorded from the Ohrid Lake is also provided.

(17986)   COSEWIC/COSEPAC, 2008. *Évaluation et rapport de situation […] sur le Gomphe de rapides, Gomphus quadricolor, au Canada*. Committee on the Status of Endangered Wildlife in Canada, Ottawa. vii+39 pp. ISBN 978-0-662-04071-2. − (An Engl. version is also available from: COSEWIC, Ottawa, ON, K1A 0H3, CA, titled: *Assessment and status report on the Rapids Clubtail Gomphus quadricolor in Canada*).

(17987)   DE BLOCK, M., S. SLOS, F. JOHANSSON & R. STOKS, 2008. Integrating life history and physiology to understand latitudinal size variation in a damselfly. *Ecography* 31: 115-123. − (First Author: Lab. Aquat. Ecol. & Evol. Biol., Univ. Leuven, Debériotstraat 32, B-3000 Leuven).

The understanding of latitudinal life history patterns may benefit by jointly considering age and mass at maturity and growth rate. Additional insight may be gained by exploring potential constraints through pushing growth rates to their maximum and scoring physiological cost-related variables. Therefore, Enallagma cyathigerum univoltine Spanish and Belgian populations and a semivoltine Swedish population (spanning a latitude gradient of ca 2350 km) were reared in a common environment from the eggs until adult emergence and exposed to a transient starvation period to induce compensatory growth. Besides age and mass at maturity and growth rate, body mass was greater in Spain and Sweden and lower in Belgium, suggesting a genetic component for the U-shaped latitudinal pattern that was found also in a previous study based on field-collected adults. The mass difference between univoltine populations can be explained by the shorter

development time in the Belgian population, and this despite a higher growth rate, a pattern consistent with undercompensating countergradient variation. In line with the assumed shorter growth seasons, Belgian and Swedish animals showed higher routine growth rates and compensatory growth after transient starvation. Despite a strong link with metabolic rates (as measured by oxygen consumption) populations with higher routine growth rates had no lower fat content and had higher immune function (i.e. immune function decreased from Sweden to Spain), which was unexpected. Rapid compensatory growth did, however, result in a lowered immune function. This may contribute to the absence of perfect compensating countergradient variation in the Belgian population and the lowest routine growth rates in the Spanish population. The results underscore the importance of integrating key life historical with physiological traits for understanding latitudinal population differentiation.

(17988)   [DE SILVA, M. (= team leader & principal investigator)], 2008. *The study of the faunal diversity in Galle district, southern Sri Lanka*. Wildlife Conserv. Soc., Galle. iii+44 pp. − (Publishers: Biodiv., Educ. & Res. Cent., Hiyare Reservoir, Hiyare, Galle, Sri Lanka).
Includes an annotated list of 62 odon. spp. (2 of which undescribed), recorded during a 6-month survey.

(17989)   EL HAISSOUFI, M., O. LMOHDI, N. BENNAS, A. MELLADO & A. MILLAN, 2008. Les odonates du basin versant Laou (Rif occidental, Maroc). *Trav. Inst. scient.*, Rabat (sér. gén.) 2008(5): 47-59. (With Engl. s.). − (Last 2 Authors: Depto Ecol. & Hidrol., Fac. Biol., Univ. Murcia, Murcia, Spain).
A detailed review is presented of the 32 spp. known to occur in the catchment area of the Oued Laou (W Rif, Morocco). Coenagrion scitulum, Pyrrhosoma n. nymphula and Onychogomphus costae are for the first time reported from the region. The habitats are described and the biogeographic composition of the fauna is analysed.

(17990)   ESENKO, I., 2008. *Sto vrtnih živali na Slovenskem*. − [*Hundred garden animals in Slovenia*]. Prešernova družba, Ljubljana. 244 pp. ISBN 978-961-6512-87-9. (Slovene). − (Publishers: Opekarska 4/A, SI-1000 Ljubljana).

The habitat requirements and behaviour of Coenagrion puella and Aeshna cyanea in garden ponds are outlined.

(17991)   MACHIDA, K., T. OIKAWA & J. SHIMANUKI, 2008. Structure analyses of the wings of Anotogaster sieboldii and Hybris subjacens. *J. jap. Soc. exp. Mech.* 8(2): 142-146. (Jap., with Engl. s.). − (First Author: Tokyo Univ. Sci., 2641 Yamazaki, Noda-shi, Chiba, 278-8510, JA).
A Jap. version of the paper listed in *OA* 17972. − Note the difference in authorship.

(17992)   MUGNAI, R., R.B. OLIVEIRA, A. DO LAGO CARVALHO & D.F. BAPTISTA, 2008. Adaptation of the Indice Biotico Esteso (IBE) for water quality assessment in rivers of Serra do Mar, Rio de Janeiro state, Brazil. *Trop. Zool.* 21: 57-74. − (First Author: Lab. Avaliação Saúde Ambiental, Fund. Oswaldo Cruz, Av. Brasil 4365, Manguinhos, BR-21-45-900 Rio de Janeiro, RJ).
Has a table showing odon. distribution (6 fam., 7 gen.) in the 4 RCE (= Riparian, Channel & Environment Inventory index) quality classes in the rivers of Serra dos Órgãos (RJ, Brazil).

(17993)   NIVEN, J.E., C.M. GRAHAM & M. BURROWS, 2008. Diversity and evolution of the insect ventral nerve cord. *A. Rev. Ent.* 53: 253-271. − (Dept Zool., Univ. Cambridge, Cambridge, CB2 3FJ, UK).
Most odon. spp. have 3 thoracic and 7 abdominal ganglia. 3 spp. diverge from this pattern, 2 spp. within the Libellulidae have 2 thoracic ganglia (the meso- and metathoracic ganglia are fused) and in Petalura gigantea A1 is not fused to T3 as it is in all other spp. − The ancestral insect ventral nerve cord probably consisted of a chain of 3 thoracic and 8 abdominal ganglia, though this pattern is rarely observed within the Pterygota.

(17994)   POLHEMUS, D.A., R.A. ENGLUND, G.R. ALLEN, D. BOSETO & J.T. POLHEMUS, 2008. Freshwater biotas of the Solomon Islands: analysis of richness, endemism and threats. *Bishop Mus. tech. Rep.* 45: iv+120 pp. − (First Author: Dept Nat. Sci., Bishop Mus., 1525 Bernice St., Honolulu, HI 96817, USA).
Presents lists of Odon. as recorded from 70 stations during the survey, and a complete checklist of spp. known from the archipelago. The latter includes 63

described spp., representing 37 gen. in 9 fam. Of these, 4 gen. and 28 spp. are endemic, representing a 11% rate of endemism at the generic level and a 44% rate at the species level. At least 1 undescribed, endemic Pseudagrion sp. was recorded during the survey.

(17995)   REECE, B.A. & N.E. McINTYRE, 2008. Dragonfly (Odonata: Anisoptera) holdings of the Museum of Texas Tech University. *Occ. Pap. Mus. Texas Tech Univ.* 279: 1-13. − (Dept Biol. Sci., Texas Tech Univ., Lubbock, TX 79409-3131, USA).
The Anisoptera specimens are reviewed. Most of these are from the state of Texas (54 new county records), some were collected from other states and countries. The holdings for Texas include some undersampled areas.

(17996)   SCIBERRAS, A., 2008. A contribution to the knowledge of Odonata in the Maltese islands. *Cent. Mediterr. Naturalist* 4(4): 275-288. − (131 'Arnest', Arcade St., Paola, Malta).
The observations are presented on the behaviour, prey and predators of 16 spp.

(17997)   SCIBERRAS, A. & M. SAMMUT, 2008. On the occurrence of Calopteryx virgo meridionalis (Selys, 1873) (Odonata: Calopterygidae) in the Maltese islands. *Cent. Mediterr. Naturalist* 4(4): 339-342. − (First Author: 131 'Arnest', Arcade St., Paola, Malta).
This sp. has never been seen alive in the Maltese islands, but 3 records exist of dead specimens, of which only that of a specimen collected from a rock pool at Marsascale (1987-1988) is reliable. It is assumed, C. v. meridionalis is not autochthonous in Malta; the specimens on record were either introduced through human-mediated transport (e.g. incidental introduction with plant shipments) or through strong wind drifts.

(17998)   SHEBL, M.A., S.M. KAMEL, T.A. ABU HASHESH & M.A. OSMAN, 2008. The most common insect species in alfalfa field in Egypt. *Acad. J. Ent.* 1(2): 27-31. − (Dept Plant Prot., Fac. Agric., Suez Canal Univ., Ismailia, Egypt).
The survey was carried out in alfalfa fields (Medicago sativa) in various areas, such as Ismailia, Suez, Swia Oasis etc. Ischnura senegalensis and Crocothemis erythraea are among the most common natural predators.

(17999)   ŠKORNIK, I. & A. GOGALA, 2008. *Spoznajmo soline.* − [*Let us make acquaintance with the salines*]. Soline, Portorož. 160 pp. ISBN 978-961-91550-0-4. (Slovene).
The shallow, warm and during spring and autumn brackish water of the salines in NW Istria (Slovenia) renders a rapid larval development of Sympetrum fonscolombii.

(18000)   TCHIBOZO, S., H.-P. ABERLENC, P. RYCKEWAER & P. LE GALL, 2008. Première evaluation de la biodiversité des odonates, des cétoines et des rhopalocères de la forêt marécageuse de Lokali (Sud Bénin). *Bull. Soc. ent. Fr.* 113(4): 497-509. (With Engl. s.). − (First Author: Cent. Rech. Gestion Biodiv. & du Terroir (Cerget), B.P. 04, BJ-0385 Cotonou, Benin).
24 odon. spp. are listed from the swampy rainforest of Lokali in southern Benin, of which 13 spp. are new for the country, including the rare Oxythemis phoenicosceles and the IUCN red listed Ceriagrion citrinum.

(18001)   WILLKOMMEN, J., 2008. The morphology of the pterothorax of Ephemeroptera, Odonata and Plecoptera (Insecta) and the homology of wing base sclerites and flight muscles. *Stuttgart. Beitr. Naturk.* (A) (N.S.) : 203-300. (With Germ. s.). − (Abt. Ent., Staat. Mus. Naturk., Rosenstein 1, D-70191 Stuttgart).
The aim of this PhD diss. is to homologise the wing base sclerites of Ephemeroptera, usually regarded as sister group of the remaining Pterygota, with that of other basal pterygote lineages and to reconstruct the ground plan of the wing base of Pterygota. The pterothoracic musculature of representatives of the three basal lineages of Pterygota (Ephemeroptera, Odon. and Neoptera) is also described and discussed. Contrary to previous hypotheses, it is shown that most elements of the neopteran wing base are also present in Ephemeroptera and Odon. The wing base in the ground plan of Pterygota is presumably composed of 3 axillary sclerites. The proximal median plate is probably also present in the ground plan of Pterygota. The first axillary is provided with 2 muscles. The third axillary is equiped with a short muscle that originates from the epimeron. This muscle is interpreted as another ground plan character of Pterygota. In Plecoptera a second muscle inserts at the third axillary sclerite. It originates from the episternum and is most likely

an autapomorphic character of Neoptera. The results imply that the wing base of the Plecoptera is close to the pterygote ground plan. It is assumed that the wing base of Ephemeroptera and Odon. is secondarily stiffened. The so-called basalare and its associated muscles in Ephemeroptera and Odon. are probably not homologous to the basalare and respective muscles in Neoptera. The enlarged subalare and associated muscles, the large dorsal longitudinal muscle, the small metathorax and shortened hindwings in Ephemeroptera suggest that mayflies have a derived flight apparatus in many respects. The Odon. on the other hand show different specialisations, namely a synthorax, large direct flight musculature, and a fusion of second and third axillary with the proximal median plate. Though the wing base in both taxa is secondarily stiffened, the specialisations of Ephemeroptera and Odon. may have evolved independently from each other.

(18002)   ZHANG, J.-J. W. WU & R.-X. HUANG, 2008. Investigation on beneficial insects in Xinjiang, 3: Predacious insects and insects for enjoy. *Xinjiang Agric. Sci.* 45(1): 98-101. (Chin., with Engl. s.). − (Coll. Life Sci. & Technol., Xinjiang Univ., Urumqi-830046, China).
9 odon. spp. are listed among the "insects to enjoy" in the Sinkiang Uighur Autonomous Region, China.

2009

(18003)   ABILHOA, V., H. BORNATOWSKI & G. OTTO, 2009. Temporal and ontogenetic variations in feeding habits of Hollandichthys multifasciatus (Teleostei: Characidae) on coastal Atlantic rainforest streams, southern Brazil. *Neotrop. Ichthyol.* 7(3): 415-420. (With Port. s.). − (GPIc, Mus. Hist. Nat. Capão da Imbuia, Rua Benedito Conceição 407, BR-82810-080 Curitiba, PR).
The characin is omnivorous, its diet is composed of autochthonous (mainly oligochaetes) and allochthonous (plants and terrestrial insects) material. Odon. larvae are among the 23 food items identified in the stomach contents of 191 specimens examined (March 2004-Febr. 2005).

(18004)   ALBERTI LUBERTAZZI, M.A. & H.S. GINSBERG, 2009. Persistence of dragonfly exuviae on vegetation and rock substrates. *NEast Nat.* 16(1): 141-147. − (First Author: Dept Plant Sci./

Ent., Univ. Rhode Island, Woodward Hall, Kingston, RI 02881, USA).
Surveys of Anisoptera exuviae have been used to assess rare spp. habitats, lake water quality status, and wetland restoration programs. Knowledge of the persistence of exuviae on various substrates is necessary to accurately interpret exuvial surveys. In 2006, exuvial persistence was recorded at defined areas in a variety of small freshwater wetlands in Rhode Island. Exuviae were field-identified, labelled with small daubs of nail polish, and observed every 3 weeks (June-Sept.). Overall, exuvial persistence displayed exponential decline, disappearing rapidly during the first few weeks, and more slowly thereafter. The initial rate of decline was similar for most spp., but differed in some taxa. There was no significant difference in exuvial retention on emergent vegetation vs. rock substrate.

(18005)   ALTAMIRANDA SAAVEDRA, M., 2009. Dragonfly (Insecta: Odonata) diversity in two use of soils in a tropical dry forest. *Revta Fac. nac. Agron. Medellin* 62(2): 5071-5079. (Span., with Engl. s.). − (Mus. Ent. Francisco Luis Gallego, Apto Aéro 3840, Medellin, Colombia).
The adult odon. were systematically sampled on 200×8 m plots in a secondary forest and in a Mango plantation (Mangifera indica) at Santafé de Antioquia (Colombia). 20 spp were recorded. In the forest, their abundance and diversity were higher. The list of spp. is provided and commented upon.

(18006)   BAKER, R.L. & M.E. McGUFFIN, 2009. Technique and observer presence affect reporting of behaviour of damselfly larvae. *Jl N. Am. benthol. Soc.* 26(1): 145-151. − (Dept Ecol. & Evol. Biol., Univ. Toronto, Toronto, ON, M5S 3B2, CA).
It is tested experimentally for systematic biases in techniques commonly used to study behaviour of larval aquatic insects and it is determined whether larval Zygoptera respond to the presence of an observer and whether live observation missed some behaviours. Significant differences were found between behaviours recorded during live observations and behaviours videotaped in the absence of an observer. All behaviours except Rotate, were exhibited less frequently in the presence of an observer. These results suggest that larvae respond to the presence of observers as if they were predators. Live observation also missed some behaviours. The duration of Crawl Forward, which can be very subtle, and the

frequency of Rotate, which can be very rapid and is easily missed, were greater when recorded from the videotape than by a live observer. Wherever possible, use of video recording systems is preferable over reliance on live observations.

(18007) BECKEMEYER, R.J., 2009. First record of the dragonfly Miathyria marcella (Selys) for Kansas (Odonata: Anisoptera: Libellulidae). *Trans. Kans. Acad. Sci.* 112(1/2): 130-132. − (957 Perry Ave, Wichita, KS 67203-3141, USA).

1 mature ♂ (Wichita St. Univ. Ninnescah Fld Stn, Sedgewick co., ca 35 mi SW Wichita, 26-IX-2008) is brought on record. The specimen was taken in prairie, perched on vegetation. The locality is approx. 200 mi from the previously recorded M. marcella range. Nevertheless, based on meteorological conditions, the record is considered to be an accidental occurrence of the sp. rather than an extension of its range.

(18008) BEDJANIČ, M., 2009. Kačji pastirji, letalski virtuosi. − [Dragonflies, great masters of the air]. *In*: Bedjanič, M., [Ed.], *Narava v občini Poljčane*, pp. 58-65, Občina Poljčane. ISBN 978-961-269-171-4. (Slovene). − (Kolodvorska 21/B, SI-2310 Slovenska Bistrica).

A visit to the dragonfly world of the municipality of Poljčane (Slovenia). Out of the over 30 local spp., only some selected taxa are dealt with, and short sections on biology and conservation are included. In view of the language and style, the book is almost a work of literary art rather than a traditional natural history publication.

(18009) BEDJANIČ, M., M. CULIBERG et al. [35 joint authors], 2009. *Okoljsko poročilo z dodatkom za širitev igrišča za golf v Lipici.* − [*Environmental report with a supplement on the extension of the golf playground in Lipica*]. ZRC SAZU, Ljubljana. 200 pp. ISBN 978-961-254-135-4. (Slovene). − (Publishers: Scient. Res. Cent., Slovenian Acad. Sci. Arts, Novi trg 2, SI-1000 Ljubljana).

From the Lipica area (Slovenia) 17 odon. spp. are reported; 12 of these occur on the Lipica Stud Farm territory. − See also *OA* 17176 and 17251.

(18010) BOTS, J., C.J. BREUKER, A. VAN KERK-HOVE, S. VAN DONGEN, L. DE BRUYN & H. VAN GOSSUM, 2009. Variation in flight morphology in a female polymorphic damselfly: intraspe-cific, intrasexual and seasonal differences. *Can. J. Zool.* 87: 86-94. (With Fr. s.). − (Evol. Ecol. Gr., Univ. Antwerp, Groenenborgerlaan 171, B-2020 Antwerpen).

In aerial animals, flight morphology needs to be designed to allow daily behavioural activities. Within species differences in behaviour can therefore be expected to relate to differences in flight morphology, not only between ♂♂ and ♀♀ but also between same-sex members when they use different behavioural strategies. In ♀ polymorphic Zygoptera, one ♀ morph is considered a ♂ mimic that resembles the ♂'s body colour and behaviour (andromorph), whereas the other is dissimilar (gynomorph). Here, it is questioned whether ♂♂, andromorphs and gynomorphs of Enallgama cyathigerum differ in flight morphology, with andromorphs being more similar to ♂♂ than gynomorphs. In addition, it is evaluated whether differences in flight morphology are consistent or whether some morphs are more plastic in response to seasonal environmental fluctuations. Most morphometrics showed similar seasonal plasticity for ♂♂ and both ♀ morphs, which could only partly be explained from allometry. Consistent with high manoeuvrability in flight, ♂♂ had broader wings and lower wing loading than ♀♀. Variation between ♀ morphs was less pronounced, with no consistent differences in length, aspect ratio, total surface, and wing loading. However, morph-specific differences were detected in shape and width, with andromorphs having broader wings than gynomorphs similarly to ♂♂.

(18011) BUCZYŃSKI, P., R. BERNARD & L. PIETRZAK, 2009. Dragonflies (Odonata) of selected dystrophic water bodies in the vicinity of Złocieniec (north-western Poland). *Chrońmy Przyr. ojcz.* 65(5): 353-364. (Pol., with Engl. s.). − (First Author: Dept Zool., MCSU, Akademicka 19, PO-20-033 Lublin).

The odon. fauna (27 spp.) was surveyed at 3 localities (all acid habitats). Species composition was mostly typical of the habitats: predominated by the tyrphobiontic (Aeshna subarctica elisabethae, Leucorrhinia dubia) and tyrphophilous spp. (Coenagrion hastulatum, Lestes virens, Leucorrhinia albifrons, L. rubicunda). Of interest is a large population of Nehalennia speciosa and the occurrence of some other red-listed spp.

(18012) CÓRDOBA-AGUILAR, A., 2009. A female

evolutionary response when survival is at risk: male harassment mediates early reallocation of resources to increase egg number and size. *Behav. Ecol. Sociobiol.* 63: 751-763. − (Depto Ecol. Evolutiva, Inst. Ecol., UNAM, Circuito esterior s/n, Apdo Postal 70-275, Ciudad Universitaria, MX-04510 México, DF).

One unexplored area in sexual conflict studies is the ♀ physiological costs and possible resource reallocation that accompany evolutionary costs due to ♂ harassment. Using Hetaerina americana ♀♀, it was first investigated whether ♂ harassment affected ♀ mating rate and survival and explored whether such effects induced a resource allocation from immunity (in the form of phenoloxidase activity) and muscular fat reserves to egg number and size. Using 2 seasons that differed in ♂ harassment, the fewer are the ♀ matings and the lower is the ♀ survival. These results were corroborated using an experimental approach in which a situation of high ♂ harassment was induced. It was also found that when the first mating takes place and at high ♂ harassment, ♀♀ had more reduced phenoloxidase activity and fat reserves and tended to lay most of the eggs they produce in their lifetime and these were considerably large. However, at low ♂ harassment, egg number and size were more equally produced across matings. ♀♀ under high ♂ harassment seemed to suffer the survival costs but may show a plastic evolutionary response of reallocating resources to egg traits to maximize fitness.

(18013)   CORDOBA-AGUILAR, A., M.A. SERRANO-MENESES & A. CORDERO-RIVERA, 2009. Copulation duration in nonterritorial odonate species lasts longer than in territorial species. *Ann. ent. Soc. Am.* 102(4): 694-701. − (First Author: Depto Ecol. Evolutiva, Inst. Ecol., UNAM, Circuito esterior s/n, Apdo Postal 70-275, Ciudad Universitaria, MX-04510 México, DF).

It was tested whether long copulation duration is more likely to have evolved in nonterritorial Odon. spp. than in territorial spp., given that nonterritorial ♂♂ do not incur the costs of territory defense. A phylogenetic comparative method that controls for the phylogenetic nonindependence of spp. was used to compare copulation duration among 46 spp. of Anisoptera and Zygoptera. Copulation duration of nonterritorial anisopteran spp. was longer than for territorial dragonflies; however, this relationship was not found for Zygoptera. Long copula-

tions in Anisoptera may be related to a ♂'s ability to manipulate a ♀'s stored sperm It is suggested that constraints that prevent a territorial ♂ from lengthening copulation do not seem to operate in Zygoptera. Other selective processes (i.e., cryptic ♀ choice and/or sexual conflict) may also be important determinants of copulation duration in the Zygoptera. This is probably the first exploration of the relation copulation duration and mating systems in insects.

(18014)   COUCEIRO, S.R.M., N. HAMADA, B.R. FORSBERG & C. PADOVESI-FONSECA, 2009. Effects of anthropogenic silt on aquatic macroinvertebrates and abiotic variables in streams in the Brazilian Amazon. *J. Soils Sediments* 2009: 15 pp.; − DOI: 10.1007/s11368-009-0148-z. − (First Author: Inst. Nac. Pasquisas Amazônia, Av. André Araújo 2936, CP 478, BR-69060-001 Manaus, Amazonas).

The impacts are evaluated of anthropogenic silt derived from the construction of roads, borrow pits and wells during the development of gas and oil on invertebrate communities in streams in the Urucu Petroleum Province in Central Brazilian Amazon. 10 impacted and 9 non-impacted streams were sampled. Anthropogenic suspended silt had a significant impact on aquatic macroinvertebrate diversity and density. 10 odon. fam. and 7 gen. were identified. Aeshnidae, Dicterias and Phyllogomphoides did not occur in impacted streams.

(18015)   DAVID, S. & M. ŠMIGA, 2009. Dragonflies (Insecta: Odonata) of Považské Podolie region in the vicinity of the town of Trenčin. *Folia faun. slovaca* 14(16): 107-112. (Slovak, with Engl. s.). − (Katedra Ecol. & Envir. Stud., Univ. Nitra, Hlinku 1, SK-94974 Nitra).

A commented list of 21 spp.; − Slovakia.

(18016)   DE SOUZA-FRANCO, G.M., I. de F. ANDRIAN & R.M. FRANCO, 2009. Community of aquatic insects associated with Eichhornia azurea (Schwartz) Kunth in a varzea lagoon in the floodplain of the High Paraná river, Mato Groso do Sul state, MS, Brazil. *Biológico* 71(1): 83-91. (Port., with Engl. s.). − (First Author: Cent. Ciênc. Agro-Ambientales, Univ. Comun. Regional Chapecó, Av. S.A. Fontana 591-E, BR-89809-000 Chapecó, SC).

Lists Coryphaeschna adnexa and 5 other odon. taxa (genera only).

(18017) DOMMANGET, J.-L., B. PRIOUL, A. GAJDOS & J.-P. BOUDOT, 2009. *Document préparatoire à une Liste Rouge des odonates de France métropolitaine complétée par la liste des espèces à suivi prioritaire*. Soc. fr. Odonatol., Bois-d'Arcy. 47 pp. − (Société française d'Odonatologie, 7 rue Lamartine, F-78390 Bois-d'Arcy).

(18018) DONOSO, D.A., F. SALAZAR, F. MAZA, R.E. CARDENAS & O. DANGLES, 2009. Diversity and distribution of type specimens deposited in the Invertebrate Section of the Museum of Zoology QCAZ, Quito, Ecuador. *Annls Soc. ent. Fr.* (NS) 45(4): 437-454, App. 1 incl., App. 2 (34 pp.) excl. (With Fr. s.). − (Second Author: Mus. Zool., Sch. Biol. Sci., Pontifical Catholic Univ. Ecuador, Apdo 17-01-2184, Quito, Ecuador).
1902 type specimens of 326 sp./spp. taxa are reviewed. The Odon. are represented by Lestes jerelly Tennessen, 1997 (2 paratypes), Oxyagrion tennesseni Mauffray, 1999 (paratype), and Aeshna (Marmaraeschna) brevicercia Muzón & von Ellenrieder, 2001 (holotype, paratype series). The text from the labels is reproduced and bibliographic references are provided.

(18019) EBRAHIMI, A., S.M. MADJDZADEH & H. MOHAMMADIAN, 2009. Dragonflies (Odonata) from south-eastern Iran. *Caspian J. envir. Sci.* 7(2): 107-112. − (First Author: Dept Biol., Fac. Sci., Shahid Bahonar Univ., Kerman, Iran).
The records (2006-2008) are presented of 27 spp. from 20 localities (alt. 429-2848 m a.s.l.) in the prov. of Kerman.

(18020) EROUKHMANOFF, F., D. OUTOMURO, F.J. OCHARAN & E.I. SVENSSON, 2009. Patterns of phenotypic divergence in wing covariance structure of calopterygid damselflies. *Evol. Biol.* 36: 214-224. − (First Athor: Sect. Anim. Ecol., Ecol. Bldg, Lund Univ., S-223-62 Lund).
Comparing species differences in covariance patterns of traits subject to divergent selection pressures can increase the understanding of the mechanisms of phenotypic divergence. Different calopterygid spp. have diverged in the melanised wing patch of ♂♂. This trait serves multiple ecological functions and has behavioural consequences in terms of sexual selection interspecific interactions and reproductive isolation. Here, the phenotypic variance-covariance matrices (P) of wing traits is compared among 9 populations of 4 European spp. A modest divergence in covariance structure was found among populations of the same sp., but strong divergence occurs between spp. Interestingly, the orientation of the first eigenvector of P (P_{max}) differed more between closely related than between distantly related spp., although this pattern was absent when overall covariance structures were compared. It was also found that distantly related but geographically closer spp. had converged towards a similar covariance structure. Finally, divergence in covariance structure was correlated with divergence in wing patch length, but not with other wing traits. This last finding suggests that divergent selection on wing patch length might have affected the stability of P. These results indicate that P might not only reflect ancestral developmental pathways but might also be influenced by current ecology.

(18021) *ERJAVECIA*. Bulletin of the Slovenian Odonatological Society (ISSN 1408-8185), No. 24 (31 Oct. 2009). (Slovene). − (c/o M. Bedjanič, Kolodvorska 21/B, SI2310 Slovenska Bistrica).
M. Bedjanič (pp. 1-14) is describing odon. inventory in the 9th vol. of J.W. Valvasor's graphic collection from 1684 (for that in the 18th vol., see *OA* 16079). Some local records and observations are provided by *D. Vinko* (pp. 14-16), *N. Erbida* (pp. 16-18) and *M. Bedjanič* (pp. 18-21). 3 anonymous notes deal with the novelties on dragonflies in the Slovenian arts (vine bottle labels, literature, architecture), whereas the 24th addition to the Slovenian odonatol. bibliography concludes the issue (*M. Bedjanič*, pp. 28-32, Nos 725-760).

(18022) FRANKOVIĆ, M. & T. BODANOVIĆ, 2009. *Vretenca. Priručnik za inventarizacijo i praćenje stanja*. − [*Dragonflies. A handbook for inventory and monitoring*], Državni zavod za zaštitu prirode, Zagreb. 43 pp. ISBN 978-953-7169-71-8. (Croatian). − (First Author: Oboj V, odvojak 10/1, HR-10000 Zagreb).
Includes a brief outline of dragonfly biology and illustrated family keys to larvae and adults. The address where the Croatian records and observations are to be sent is not provided. − From the list of species, it seems there appears in Croatia an undescribed Lindenia taxon, the Croatian vernacular name of which is different from that of L. tetraphylla.

(18023)   GONZÁLEZ-TOKMAN, D.M. & A. CÓRDOBA-AGUILAR, 2009. Survival after experimental manipulation in the territorial damselfly Hetaerina titia (Odonata: Calopterygidae): more ornamented males are not more pathogen resistant. *J. Ethol.* 2009: 5 pp.; − DOI: 10.1007/s10164-009-0151-2. − (Depto Ecol. Evolutiva, Inst. Ecol., UNAM, Apdo Postal 70-275, Ciudad Universitaria, MX-04510 México, DF).

It has been hypothesized that sexual ornaments communicate pathogen resistance ability. Here, the relationship between the expression of a ♂ ornamental trait (wing pigmentation) of H. titia and survival after a bacterial challenge is experimentally explored. ♂♂ were infected with Serratia marcescens (a Gram-negative bacteria typical of insects) and their survival compared against a group infected with dead bacteria and a non-infected group. Wing pigmentation was entered as a predictor of survival in this comparison. The study indicate: that wing pigmentation is not a good predictor of immune ability against bacteria. This contradicts previous findings in the same and other calopterygid spp. in which wing pigmentation intensity inversely correlated with gregarine infection levels. It also contradicts the general idea that ornaments are honest indicators of pathogen defense.

(18024)   HACET, N., 2009. The easternmost record of Somatochlora borisi Marinov, 2001 from Turkish Thrace, with a zoogeographic assessment on the distribution of the species (Odonata: Corduliidae). *J. ent. Res. Soc.* 11(2): 51-56. − (Dept Biol., Fac. Arts & ci., Trakya Univ., TR-22030 Edirne).

The easternmost known locality (Istanbul-Catalea, 1 ♂, 24-VI-1998) is brought on record, the distribution of the sp. is mapped, and its generic status is discussed.

(18025)   HENTZ, J.-L. & C. BERNIER, 2009. *Macromia splendens, une libellule remarquable dans le département du Gard. Synthèse des connaissances.* Gard Nature, Beaucaire. 16 pp. ISBN none. − (Publishers: Mas du Boschet Neuf, F-30300 Beaucaire).

The current knowledge on M. splendens in the department of Gard (France) is outlined. The adult and larva are briefly described, the maps of its distribution in France and of the known localities in the dépt are presented, notes are supplied on its biology and local status and a fairly exhaustive bibliography is appended.

(18026)   IDRIS, A.B., S. ISMAIL, Y. HARON & Y. SUHANA, 2009. Insects of Tasik Chini with special emphasis on ichneumonid wasps. *Sains malaysiana* 38(6): 813-816. (With Malay s.). − (Cent. Insect Syst., Fac. Sci. & Technol., Univ. Kebangsaan Malaysia, 43600 UKM Bangi, Selangor D.E., Malaysia).

Tasik Chini is the second largest natural lake in the state of Pahang (Malaysia). 9 odon. spp. are listed (Aeshnidae, Libellulidae).

(18027)   JOVIĆ, M., L. ANDJUS & S. SANTOVAC, 2009 New data on some rare and poorly known Odonata species in Serbia. *Bull. nat. Hist. Mus.* Belgrade 2: 95-108. (With Serb. s.). − (First Author: Nat. Hist. Mus., Njegoseva 51, RS-11000 Belgrade).

New information on the distribution of 10 spp. in Serbia is provided. All published records of Somatochlora metallica are actually referable to S. meridionalis, therefore the former sp. is to be deleted from the list of Serbian fauna.

(18028)   JOVIĆ, M. & B. MIHAJLOVA, 2009. Catalogue of the Odonata collection in the Macedonian Museum of Natural History. *Acta ent. serb.* 14(2): 133-146. (With Serb. s.). − (Second Author: Maced. Mus. Nat. Hist., Blvd Ilinden 86, MK-1000 Skopje).

1344 specimens, referable to 46 spp., are catalogued (with locality data and dates), almost all from Macedonia, a few specimens also from Bosnia and Herzegovina, Greece, Serbia and Turkey. Lestes parvidens is new for the fauna of Macedonia.

(18029)   KAIZE, J. & V. KALKMAN, 2009. Records of dragonflies from Kabupaten Maerauke, Papua, Indonesia collected in 2007 and 2008 (Odonata). *Suara Serangga Papua* 4(2): 40-45. (With Bahasa Indonesian s.). − (First Author: d/a Kelompok Entomologi Papua, Kotakpos 1078, Jayapura-99010, Indonesia).

Records of 37 spp.; − southern New Guinea.

(18030)   KALNINŠ, M., 2009. Lesser Emperor Anax parthenope (Selys, 1839) (Odonata: Aeshnidae): a new dragonfly species in Latvia. *Latv. Ent.* 47: 16-20. − (Nature Prot. Agency, Baznicas iela 7, LV-2150 Sigulda).

The sp. is brought on record from 5 localities (2008, 2009).

(18031) KHROKALO, L.A., V.V. SAVCHUK & E.S. DYATLOVA, 2009. New records of rare dragonflies (Insecta, Odonata) in Ukraine. *Vest. Zool.* 43(4): 378. (Russ.). − (First Author: Dept Envir. Biotechnol. & Bioenergy, Natn. Tech. Univ. Ukraine, Kyiv, Ukraine).

Records of Erythromma lindenii, Coenagrion scitulum and Selysiothemis nigra.

(18032) KORTELLO, A.D. & S.J. HAM, 2009. Movement and habitat selection by Argia vivida (Hagen) (Odonata, Coenagrionidae) in fuel-modified forest. *J. Insect Conserv.* 2009: 8 pp.; − DOI: 10.1007/s10841-009-9233-2. − (First Author: Banff Natn. Park, Fire & Vegetation Mngmt Program, Box 900, Banff, AB, T1L 1K2, CA).

Fuel management for wildfire protection is becoming increasingly common in the wildland-urban interface and may have conservation implications for spp. with restricted distributions and limited dispersal abilities. To evaluate the impact of forest fuel management on A. vivida at the northern margin of its range, terrestrial movements and habitat associations were examined using capture-mark-recapture and point count techniques. It was found that habitats away from the springs were particularly important for ♀♀. Most individuals travelled at least 50 m between capture and recapture and patches of cleared forest up to this size did not pose a barrier to movement. Although A. vivida typically roosts in trees at night, cleared fuel treatment areas were preferred over unmodified or thinned forest as daytime basking and foraging sites. Preferred sites were also characterized by heterogeneous canopy closure, i.e., a clearing adjacent to unmodified forest with a closed canopy. It is speculated that this behaviour derives from the species' thermoregulation requirements; the use of sunspots for thermal basking during the day and the use of forest cover at night to slow the radiant loss of heat. The findings demonstrate the scale of movements that define available habitat and the importance of both daytime and night time habitat requirements in considering terrestrial foraging and movement corridors. Consequently, conservation efforts for this sp. in fuel management areas should focus on maintaining unmodified stands of dense trees in association with cleared patches of appropriate dimension, rather than a uniformly thinned forest.

(18033) LANDMANN, A., 2009. Die Höhenverbreitung als Indikator der Gefährdung von Insekten in Alpenraum. *Contr. nat. Hist., Berne* 12: 829-856. (With Engl. s.). − (Inst. Zool., Univ. Innsbruck, Technikerstr. 25, A-6020 Innsbruck).

The listings of "valley, lowland", and "mountain" odon. spp. in the recent national (Austria, Switzerland) and regional (Tyrol, Carinthia, Lower Austria, Bavaria) Red Lists are analysed. Overall, the percentage of spp. regarded as "safe" (LC = Least concern) is significantly higher in the "mountain" species group than in that of the "lowland" taxa. The "lowland" and "mountain" groups also strongly differ in dimensions of threat, the former group exhibiting a much higher proportion of taxa within the highest categories (CR = Critically endangered, EN = Endangered). Differences between the "lowland" and "mountain" groups are higher in the central parts of the Alps than at their northern edge in Lower Austria and Bavaria (Germany).

(18034) LEVINE, T.D., B.K. LANG & D.J. BERG, 2009. Parasitism of mussel gills by dragonfly nymphs. *Am. Midl. Nat.* 162(1): 1-6. − (First Author: Hancock Biol. Stn, Murray St. Univ., 561 Emma Dr., Murray KY 42071, USA).

During a mark-recapture study of the critically endangered unionoid mussel Popenaias popeii, a Gomphus militaris larva was discovered eating the gills of a gravid mussel; larvae and gill material were found in the odon. gut. Many (15.2%) of the other mussels captured during a quantitative survey exhibited damage consistent with that inflicted by this dragonfly. Few non-gravid mussels were damaged and gravid mussels exhibited substantially more damage in gills used for brooding larvae than in gills not typically used for brooding. This previously unreported parasitic relationship may reflect a unique cost associated with reproduction and should be considered in the development of conservation strategies for P. popeii.

(18035) LI, Z.-x., W. SHEN, G.-s. TONG, J.-m. TIAN & L. VU-QUOC, 2009. On the vein-stiffening membrane structure of a dragonfly hind wing. *J. Zheijang Univ.* (Sci. A) 10(1): 72-81. − (First Author: Inst. Structural Engineering, Zhejiang Univ., Hangzhou-310058, China).

Aiming at exploring the excellent structural performance of the vein-stiffening membrane structure of dragonfly Pantala flavescens) hindwings, 2 planar computational models and three 3D computational

models with cambered corrugation were analyzed based on the finite element method. It is shown that the vein size in different zones is proportional to the magnitude of the vein internal force when the wing structure is subjected to uniform out-of-plane transverse loading. The membrane contributes little to the flexural stiffness of the planar wing models, while exerting an immense impact upon the stiffness of the 3D wing models with cambered corrugation. If a lumped mass of 10% of the wing is fixed on the leading edge close to the wing tip, the wing fundamental frequency decreases by 10.7-13.2%; if a lumped mass is connected to the wing via multiple springs, the wing fundamental frequency decreases by 16.0-18.0%. Such decrease in fundamental frequency explains the special function of the wing pterostigma in alleviating the wing quivering effect. These particular features of dragonfly wings can be mimicked in the design of new-style reticulately stiffening thin-walled roof systems and flapping wings in novel intelligent aerial vehicles.

(18036)   LOTZING, K., 2009. Kurzübersicht der seit 1980 nachgewiesenen Libellen (Insecta: Odonata) im Bereich der Bode und ihrer Nebenarme innerhalb des ehemaligen Landkreises Aschersleben-Stassfurt (Sachsen-Anhalt). *Halophila* 53: 15-18. − (Am Hollschen Bruch 4/c, D-39435 Unseburg).
5 wetland localities in the former district of Aschersleben-Stassfurt (Sachsen-Anhalt, Germany) are described in detail and their recorded odon. fauna (29 spp.) is listed.

(18037)   McPEEK, M.A., L. SHEN & H. FARID, 2009. The correlated evolution of three-dimensional reproductive structures between male and female damselflies. *Evolution* 63(1): 73-83. − (First Author: Dept Biol. Sci., Dortmouth Coll., Hanover, NH 03755, USA).
For many taxa, spp. are defined by the morphologies of reproductive structures. In many odon., these structures are the cerci of ♂♂ (used to hold ♀♀ during mating) and the thoracic plates of ♀♀ where the ♂ cerci contact the ♀ bodies. A previous study showed that the shapes of cerci of Enallagma ♂♂ are best explained by an evolutionary model of punctuated change at the time of speciation, with a homogeneous rate of change across the entire phylogeny of the genus. In the present study, the evolution of shape change in the corresponding ♀ plates is examined. It was found that,

like ♂ cerci, the shapes of Enallagma ♀ thoracic plates could best be explained by an evolutionary model of punctuated change at the time of speciation, with a homogeneous rate of change across the clade. Moreover, the evolutionary contrasts quantifying the rates of change in ♂ cerci and ♀ thoracic plates were positively related across the history of the clade, demonstrating that they evolve in a correlated fashion. This pattern of evolution suggests that these structures are primary signals of sp. identity during mating.

(18038)   MÜLLER, J. & R. STEGLICH, 2009. Fundort- und Artenliste eigener Libellen-Nachweise im Jahre 2008 in Sachsen-Anhalt: odonatologischer Jahresbericht 2008. *Halophila* 53: 7-13. − (First Author: Frankefelde 3, D-39116 Magdeburg).
The 2008 annual report on Odon. recorded in the federal state of Sachsen-Anhalt (Germany), with localities, dates and brief annotations where appropriate.

(18039)   MÜLLER, J. & R. STEGLICH, 2009. Zum Vorkommen der Scharlachlibelle Ceriagrion tenellum in Sachsen-Anhalt. *Halophila* 53: 14. − (Second Author: Zollstrasse 1/128, D-39104 Magdeburg).
The recent occurrence of C. tenellum in the federal state of Sachsen-Anhalt (Germany) is briefly reviewed and the expansion of its range in NE direction is confirmed.

(18040)   PAULSON, D.R., 2009. A new species of Leptobasis from Costa Rica (Odonata: Coenagrionidae). *Zootaxa* 2239: 62-68. − (Slater Mus. Nat. Hist., Univ. Puget Sound, Tacoma, WA 98416, USA).
L. guanacaste is described from seasonal wetlands in dry forest. Holotype ♂: Hacienda Taboga, Guanacaste prov., Costa Rica, 2-VIII-1967; deposited in FSCA). It is unique among the 5 spp. of the gen. in thoracic colour pattern and the structure of the ♂ terminal appendages and ♀ mesostigmal laminae and appears to be closest to L. candelaria through similarities in genital ligula, ♂ metafemur and ♀ ovipositor.

(18041)   PIRNAT, A., 2009. Inventarizacija kačjih pastirjev v glinokopu Pristava pri Mengšu. − [Dragonfly inventory of the Pristava clay-pit near Mengeš]. *In*: T. Gregorc & I. Nekrep, [Eds], *In-*

ventarizacija habitatnih tipov, kačjih pastirjev (Odo-nata), dvoživk (Amphibia), plazilcev (Reptilia) in ptic (Aves) na območju Jezera v Pristavi ter pred-log naravovarstveno pomembnih delov na območju raziskav, 8 pp., Lutra, Ljubljana. (Slovene). – (Pub-lishers: Opekarska 11, SI-1000 Ljubljana; − Au-thor: Groharjeva 18, SI-1241 Kamnik).

A commented list of 37 spp.; − central Slovenia. − See also *OA* 16599.

(18042)   QUADROS, G., G. GURAV, K. BHAGAT, A. CHORGHE, A. DHAMORIKAR, K. KHOT & M. NAGARKAR, 2009. *Report of the study of the biodiversity of Indian Institute of Technology Bombay Campus*. WWF-India, Maharashtra St. Office, Mumbai. v+158 pp., map & 44 pls excl. − (Publishers: World Wide Fund for Nature-India, Maharashtra State Office, Dr D.N. Rd, Fort Mum-bai-400 001, India).

36 odon. taxa were recorded, of which 30 spp. are identified and presented on pls 24-25.

(18043)   SCHULTZ, T.D., 2009. Diversity and habi-tats of a prairie assemblage of Odonata at Lost-wood National Wildlife Refuge, North Dakota. *J. Kans. ent. Soc.* 82(1): 91-102. − (Dept Biol., Deni-son Univ., Graville, OH 43023, USA).

26 spp. were recorded from 32 wetlands sites. The fauna consists primarily of widespread, common spp. that are adapted to fishless lentic communities and tolerant of alkaline and impermanent water re-gime. The odon. communities of semipermanent, oligosaline ponds are the most diverse. Long-term monitoring of odon. diversity and abundance may be useful in tracking the effects of climate change in the prairie pothole region but must take into ac-count yearly fluctuations due to variation in winter and summer precipitation.

(18044)   SHAALAN, E.A.-S. & D.V. CANYON, 2009. Aquatic insect predators and mosquito con-trol. *Trop. Biomed.* 26(3): 223-261. − (First Author: Zool. Dept, Aswan Fac. Sci., South Valley Univ., Aswan-81528, Egypt).

A review paper, including annotated odon. lists and their respective mosquito prey. Although odon. lar-vae have been investigated less compared to other predaceous aquatic insects, their long life cycle, predation capacity and sharing of habitats with mosquito immatures are advantageous for their being potential biological control agents.

(18045)   STEVENS, L.E. & R.A. BAILOWITZ, 2009. Odonata biogeography in the Great Canion ecoregion, southwestern USA. *Ann. ent. Soc. Am.* 102(2): 261-274. − (First Author: Mus. North-ern Arizona, 3101 N. Ft. Valley Rd, Flagstaff, AZ 80001, USA).

The odon. fauna of the Great Canion ecoregion (GCE) includes 89 spp. Three biogeographic hy-potheses account for the relatively high regional species richness: (i) faunal affinity (origin), (ii) el-evation effects on range, and (iii) landform impacts across spatial scale. The GCE odon. assemblage is the result of mixing of taxa from adjacent neotropi-cal and nearctic regions. Although no GCE odon. previously have been considered rare or at risk, 15 spp. are restricted to 3 or 4 localities, 4 spp. are known from a single locality, and 4 high-elevation nearctic spp. may be at risk of extirpation through climate change impacts on their habitats.

(18046)   WILLKOMMEN, J., 2009. The tergal and pleural wing base sclerites − homologous within the basal branches of Pterygota? *Aquat. Insects* 31 (Suppl. 1): 443-457. − (Abt. Ent., Staat. Mus. Naturk., Rosenstein 1, D-70191 Stuttgart).

The Ephemeroptera are usually regarded as the sis-ter group of the remaining Pterygota. Their wing base sclerites and pterothoracic musculature are compared with those of other basal pterygote line-ages. It is shown that most elements of the neopter-an wing base are also present in Ephemeroptera and Odon. The wing base in the ground plan of Ptery-gota is presumably composed of 3 axillaries and a proximal median plate. The first axillary is provided with 2 muscles. The third axillary is equipped with 1 short muscle in the ground plan of Pterygota. A second muscle, which inserts at the third axillary and originates from the episternum, is most likely an autapomorphic character of Neoptera. The re-sults imply that the wing base of Plecoptera is close to the pterygote ground plan. It is assumed that the wing bases of Ephemeroptera and Odon. are sec-ondarily stiffened. The so-called basalare and its associated muscles in Ephemeroptera and Odon. are probably not homologous to the basalare and respective muscles in Neoptera. Though the wing bases of both Ephemeroptera and Odon. show similar modifications their specialisations may have evolved independently from each other.

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(18047) ABBOTT, J.K. & E.I. SVENSSON, 2010. Morph-specific variation in an inter-specific mimicry system. *Evol. Ecol. Res.* 12: 105-118. − (First Author: Dept Anim. Ecol., Evol. Biol. Cent., Uppsala Univ., Norbyvägen 18D, SE-75236 Uppsala). Positive intersexual genetic correlations are typically viewed as constraining the evolution of sexual dimorphism, when traits are subject to sexually antagonistic selection. Here, Ischnura elegans was studied that has a ♀-limited colour polymorphism, with 3 ♀ colour morphs (♂♂ are monomorphic), one of which is considered a ♂ mimic. The question was whether there are morph-specific differences in the magnitude of intersexual genetic correlations, i.e. do androchromous ♀♀ have higher intersexual genetic correlations for morphological traits than non-mimic ♀♀. The offspring of in the field collected copulating pairs was risen in the laboratory, 5 morphological traits in parent and offspring generations were measured, and their heritabilities and genetic correlations were investigated. It was found a negative overall relationship between the degree of sexual dimorphism for a trait and its intersexual genetic correlation. But the magnitude and direction of intersexual genetic correlations depended on the ♀ morph. As expected, androchromous ♀♀ had higher intersexual genetic correlations. In addition, the genetic correlations between the morphs were in all cases significantly lower than unity. Androchromous ♀♀ had higher mother-son covariances than the non-mimic morph, and this difference is the proximate explanation for the difference in intersexual genetic correlations between the I. elegans morphs.

(18048) BERTI, J., J. GONZALEZ, E. NAVARRO--BUENO, E. ZOPPI, E. GORDON & L. DELGADO, 2010. Larval seasonality of the mosquito Anopheles aquasalis (Diptera: Culicidae) and other insects associated to its habitat in Suere, Venezuela. *Revta Biol. trop.* 58(2): 777-787. (Span., with Engl. s.). − (First Author: Inst. Altos Estudios 'dr A. Gabaldon', Lab. Ent. Malaria, Calle Dr A. Gabaldon, Las Delicias, Maracay, Venezuela). Familywise, monthly abundance is shown of larval Coenagrionidae, Aeshnidae and Libellulidae in the Rio Chiquito Abajo mangrove (Paria peninsula, Sucre, NE Venezuela).

(18049) *BULLETI d'OXYGASTRA*. Periodical of the Grup d'Estudi dels Odonats de Catalunya. (ISSN none). Nos 1 (Jan. 2007), 2 (Feb. 2007), 3 (March 2007), 4 (Oct., 2007), 5 (Feb. 2008), 6 (March 2008), 7 (Aug. 2008), 8 (March 2010). Catalan. − (c/o R. Martin, C./Marti Juliá 19-23, 1° 1a, ES-08911 Barcelona). The address of the publisher and that of the Editor are not stated in the journal. − [No. 8]: *Escolà, J.*: Odonata of the Õdena basin (pp. 1-8); − Odonata of Estany d'Ivars in Vila-sana (pp. 9-14); − *Martin, R.*: The description of Oxygastra curtisii (Dale, 1834) (pp. 15-17).

(18050) CHASE, J.M., A.A. BURGETT & E.G. BIRO, 2010. Habitat isolation moderates the strength of top-down control in experimental pond food webs. *Ecology* 91(3): 637-643. − (Dept Biol., Washington Univ., Saint Louis, MO 63130, USA). Habitat isolation is well known to alter patterns of spp. abundance, richness and the ratios of predator : prey. Less clear is, however, how isolation alters interactions within food webs. Here, the results are presented from an experiment performed in artificial ponds (mesocosms) manipulating habitat isolation crossed with a predator reduction treatment to disentangle how isolation mediates the top-down effect of predators. The 3 larger predator groups (Anisoptera, large diving beetles and hemipterans) were negatively affected by isolation, whereas Zygoptera and small beetles were positively affected.

(18051) ELTJON, H., P. ANILA, T. DRITAN & M. KASTRIOT, 2010. The impact of environmental conditions on the biodiversity of aquatic insects, Odonata, from aquatic ecosystems of Karavasta and Spillea in Albania. *BALWOIS*, Ohrid, 2010, pp. 1-6. − (Dept Biol., Fac. Nat. Sci., Univ. Tirana, Tirana, Albania). 26 spp. are recorded from Karavasta lagoon and from the delta of the Shkumbini river. The Albanian vernacular names of all the taxa are also provided.

(18052) *INTERNATIONAL JOURNAL OF ODONATOLOGY* (ISSN 1388-7890), Vol. 13, No. 1 (1 Apr. 2010). *Von Ellenrieder, N.*: Odonata biodiversity of the Argentine Chaco biome (pp. 1-25); − *Sánchez--Herrera, M. & E. Realpe*: Population structure of

Polythore procera at a Colombian stream (Odonata: Polythoridae) (pp. 27-37); − *Bernard, R. & B. Daraż*: Relict occurrence of East Palaearctic dragonflies in northern European Russia, with first records of Coenagrion glaciale in Europe (Odonata: Coenagrionidae) (pp. 39-62, pl. 1 excl.); − *Michalski, J. & S. Oppel*: Two new species of Argiolestes from Papua New Guinea (Odonata: Megapodagrionidae) (pp. 63-74); − *Kalkman, V.J., S.J. Richards & D.A. Polhemus*: Three new species of Argiolestes, with a key to the males of Argiolestes s. str. (Odonata: Megapodagrionidae) (pp. 75-88, pls 2-3a excl.); − *Tennessen, K.J. & J.T. Johnson*: Archaeopodagrion armatum sp. nov. from Ecuador (Odonata: Megapodagrionidae) (pp. 89-95, pl. 3b excl.); − *Kalkman, V.J. & K.D.P. Wilson*: Calilestes and Lestomima, junior synonyms of Rhipidolestes (Odonata: Megapodagrionidae) (pp. 97-102); − *Schütte, K.*: The larva of Nesolestes sp. from Madagascar (Odonata: Megapodagrionidae) (pp. 103-108); − *Choong, C.Y. & A.G. Orr*: The larva of Podolestes orientalis from West Malaysia, with notes on its habitat and biology (Odonata: Megapodagrionidae) (pp. 109-117, pl. 4 excl.); − *Kalkman, V.J., C.Y. Choong, A.G. Orr & K. Schütte*: Remarks on the taxonomy of Megapodagrionidae with emphasis on the larval gills (Odonata) (pp. 119-135); − *Muzón, J., S. Weigel Muñoz & R.E. Campos*: The larva of Mecistogaster amalia (Odonata: Pseudostigmatidae) (pp. 137-144); − *Xu, Q.*: The larvae of Macromia flavocolorata and M. septima from Fujian, China (Odonata: Macromiidae) (pp. 145-152).

(18053) KUTERA, M. & A. WOZNIAK, 2010. New locality of Common goldenring, Cordulegaster boltonii (Donovan, 1807) near Strochowice on the Kielce Upland. *Chrońmy Przyr. ojcz.* 66(2): 121-124. (Pol., with Engl. s.). − (First Author: Rudka 30, PO-27-415 Konów).

A ♂ was recorded (11-VII-2007) from a site populated by a beaver community, nr Lubienia (UTM EB15, Poland). The status of C. boltonii in Poland appears at present rather favourable, therefore the sp. was recently deleted from the Polish national Red List.

(18054) *ODONATRIX*. Bulletin of the Odonatological Section of the Polish Entomological Society (ISSN 1733-8239), Vol. 6, No. 1 (31 Jan. 2010). (Pol., with Engl. s's). − (c/o Dr P. Buczyński, Dept Zool., UMCS, Akademicka 1 9, PO-20-033 Lublin).

Buczyński, P. & E. Buczyńska: Another record of dragonflies (Odonata) in a light trap (pp. 1-2); − *Koleczek, D. & G. Tończyk*: Ischnura elegans (Zygoptera: Coenagrionidae) as a prey of Machimus sp. (Diptera: Asilidae) (p. 3); − *Tończyk, G.*: Area of Poland as locus typicus for some dragonfly species (pp. 4-6); − *Zawal, A.*: New locality of Crocothemis erythraea in western Poland (pp. 6-8); − *Tończyk, G. & K. Zemko*: Preliminary estimation of population total abundance of Leucorrhinia caudalis and L. pectoralis in 'Zdreczno Lake' nature reserve (Tuchola Forest, Poland) (pp. 9-14); − *Michalczuk, W. & P. Buczyński*: The second recent locality of Coenagrion ornatum (Odonata: Coenagrionidae) in the southeastern Poland (pp. 15-21); − *Tatarkiewicz, D.*: Sites of the emergence of Libellula fulva (Odonata: Libellulidae) in the forest of Puszcza Notecka (pp. 21-29); − *Zurawlew, P., S. Pawlak & P.T. Dolata*: Data on the occurrence of Sympetrum meridionale and S. pedemontanum in the southern Great Poland and in the Wieluń Land (pp. 30-32).

(18055) NESEMAN, H., R.D.T. SHAH, D.N. SHAH & S. SHARMA, 2010. First records of Rhicnoda natatrix and Rhicnoda rugosa (Blattodea: Blaberidae) from Nepal and India (Maharashtra) with notes on habitat quality. *J. threatened Taxa* 2(1): 648-652. − (First Author: Aquat. Ecol. Cent., Kathmandu Univ., Dhulikhel, Nepal).

Epiophlebia laidlawi and (familywise) the representatives of 9 other odon. fam. are reported from 5 habitats of the aquatic Rhicnoda cocroaches in Nepal. E. laidlawi is recorded from the metarhithron of the Sim Khola midstream and from epirithron of its first tributary.

(18056) PETRIN, Z., E.G. SCHILLING, C.S. LOFTIN & F. JOHANSSON, 2010. Predators shape distribution and diversification of morphological defenses in Leucorrhinia, Odonata. *Evol. Ecol.* 2010, 14 pp.; − DOI 10.1007/s10682-010-9361-x. − (First Author: Norw. Inst. Nature Res., N-7485 Trondheim).

Predators strongly influence species assemblages and shape morphological defences of prey. Adaptations that constitute effective defences against one type of predator may render the prey susceptible to other types of predators. Hence, prey may evolve different strategies to escape predation, which may

facilitate adaptive radiation of prey organisms. Larvae of different Leucorrhinia spp. have various morphological defences. The distribution of these larvae was studied in relation to the presence of predatory fish. The variation in morphological defences within species was examined with respect to the occurrence of fish. It was found that well-defended spp., those with more and longer spines, were more closely associated with habitats inhabited by predatory fish and that spp. with weakly developed morphological defences were more abundant in habitats without fish. The spp. predominantly connected to lakes with or without fish, respectively, were not restricted to a single clade in the phylogeny of the genus. The data is suggestive of phenotypic plasticity in morphological defence in 3 of the studied spp. since these showed longer spines in lakes with fish. It is suggested that adaptive phenotypic plasticity may have broadened the range of habitats.

(18057)   PINTO, A.P. & A.L. CARVALHO, 2010. A new species of Lauromacromia (Odonata: Corduliidae) from southwestern Brazil, with a cladistic analysis of the genus and comments on neotropical dragonfly biogeography. *Zootaxa* 2425: 45-68. (With Port. s.). − (Second Author: Depto Ent., Mus. Nac., UFRJ, Quinta de Boa Vista, São Cristóvão, BR-20940-040, Rio de Janeiro, JR).
L. melanica sp. n. is described and illustrated, based on 2 ♂. Holotype ♂: Brazil, Espirito Santo, Conceição da Barra, 1/6-XII-1969; deposited in MNRJ. It is similar to L. picinguaba. Cladistical analysis, encompassing 43 external morphological ♂ characters, is carried out. A key for ♂♂ of all known congeneric spp. is provided. A vacariance hypothesis is proposed to explain spatial evolution of Lauromacromia. Based on current biogeographical classification, Gomphomacromia and Rialla are considered apart from neotropical biota. Some aspects of Lauromacromia biology and ecology are also discussed.

(18058)   POPOVA, O.N. & Yu.A. SMIRNOVA, 2010. Community of aquatic insects in forest-steppe-lakes of Baraba (South of West Siberia). *Contemporary Probl. Ecol.* 3(1): 50-54. [Originally published in Russian in *Sibir. ekol. Zh.* (2010) 17(1): 69-74]. − (Inst. Anim. Syst. & Ecol., Russ. Akad. Sci., Frunze 11, Novosibirsk-630091, Russia).

The studies were conducted (2004-2006) on the drainage lake of Fadikha (Barabinsk region, Russia). At the lake and its vicinity, 41 odon. spp. were recorded. The composition of their larval communities in various habitats is thoroughly analysed.

(18059)   RANGNEKAR, P., M. BORKAR & O. DHARWADKAR, 2010. Additions to the Odonata (Insecta) of Goa. *J. threatened Taxa* 2(4): 805-814. − (First Author: Bldg 4, S-3, Technopark, Chogm Rd, Alto-Porvorim, Goa-403001, Tamil Nadu, India).
A report is presented of a 19-month odon. survey (2007-2008) of the state of Goa, India. 66 spp. are documented, with 34 new records for the state.

(18060)   SHAFROTH, P.B., A.C. WILCOX, D.A. LYTLE, J.T. HICKEY, D.C. ANDERSEN, V.B. BEAUCHAMP, A. HAUTZINGER, L.E. McMULLEN & A. WARNER, 2010. Ecosystem effects of environmental flows: modelling and experimental floods in a dryland river. *Freshw. Biol.* 55: 68-85. − (First Author: US Geol. Surv., Fort Collins Sci. Cent., 2150 Centre Ave, Bldg C, Fort Collins, CO 80526, USA).
The work was conducted on the Bill Williams River (Arizona, USA). After an experimental flood, Gomphidae experienced flood-induced mortality, but rebounded in numbers after 2 weeks. Their rapid return is attributed to their ability to move back to the active stream channel even when they were displaced into high flow channels that dried out postflood.

(18061)   THEISCHINGER, G., 2010. Der GSI-Clade (Odonata, Libelluloidea) in Australien: Systematik im Fluss. *Entomologica austriaca* 17: 49-66. (With Engl. s.). − NSW Dept Envir. & Climate Change, 480 Weeroona Rd, Lidcombe, NSW-2141, AU).
"Gomphomacromia-Synthemis-Idionyx" (GSI), a taxon recently established for a monophyletic group (clade) of higher Libelluloidea (see *OA* 17061), is discussed. Details are presented on the history of the discovery and systematic integration of the Australian members of the group. Information is also given on morphological characters of adults and larvae, distribution, biology, behaviour, conservation, collecting and preparation, and pressing research priorities are pointed out.

CONTENTS