Odonatologica 15(3): 335-345 *September 1, 1986*

A SURVEY OF SOME ODONATA FOR ULTRAVIOLET PATTERNS*

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Received May 8, 1985 / Revised and Accepted March 3, 1986

A series of museum specimens comprising 338 spp. in 118 genera and 16 families were photographed both with and without a Kodak 18-A ultraviolet (UV) filter. These photographs revealed that only *Euphaea amphicyana* reflected UV from its wings whereas all other spp. either did not absorb UV (e.g. 94.5% of the Coenagrionidae) or did so to varying degrees. In particular, spp. with flavescent, orange or brown wings (or wing patches) exhibited UV absorption for these same areas. However, other spp. with nearly transparent wings (especially certain Gomphidae) also had strong UV absorption. Pruinose body regions reflected UV but the standard acetone treatment for color preservation dissolves the wax particles of the pruinosity and destroys UV reflectivity. As is typical for arthropod cuticle, non-pruinose body regions absorbed UV and this obscured whatever color patterns might otherwise be visible without the camera's UV filter. Frequently there is sexual dimorphism in UV patterns (wings and body) and these differences may play a role in various aspects of mating behavior.

INTRODUCTION

Considerable attention has been paid to the various ultraviolet (UV) patterns exhibited by the Lepidoptera (e.g. SCOTT, 1973). Studies have shown (e.g. RUTOWSKI, 1981) that differing UV-reflectance patterns are frequently used as visual cues in various aspects of mating behavior. Although a few other insect groups have been investigated for the presence of UV patterns (HINTON, 1973; POPE & HINTON, 1977; SILBERGLIED, 1979), little information is available for the Odonata. ROBEY (1975) noted that pruinose areas on the bodies of male *Erythemis simplicicollis, Libellula cyanea, L. incesta* and *Pachydiplax longi-*

* Dedicated to Dr. M.J. Westfall, Jr, on the occasion of his 70th birthday.

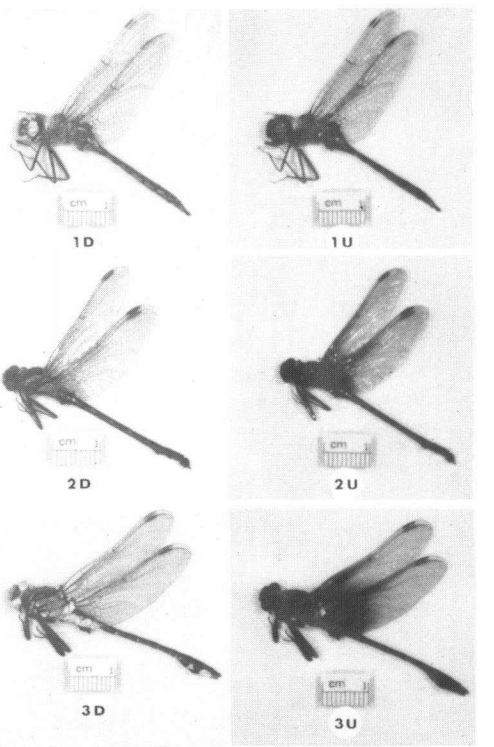
pennis reflected UV; so too did SILBERGLIED (1979) for *L. pulchella* and *Plathemis* (= *Libellula*) *lydia*, and ROBERTSON (1984) for *L. luctuosa, L. pulchella, Pachydiplax longipennis* and *Plathemis lydia*. In addition, SILBERGLIED (1979) observed UV reflection from the iridescent body regions of both sexes of *Argia fumipennis*. In contrast to these studies which recorded UV reflectance, SATO (1984) recorded UV absorbance in the wings of *Calopteryx cornelia, C. virgo japonica and Mnais pruinosa costalis*, as did FRANTSEVICH & MOKRUSHOV (1984) for certain species of *Sympetrum*.

Members of the Odonata are noted for their excellent vision, and those species which have been investigated are known to have UV receptors (MENZEL, 1979), especially in the ommatidia of the dorsal region of the eyes (EGUCHI, 1971; GOLDSMITH & BERNARD, 1974). For these reasons it seemed particularly important to survey the Odonata in order to determine the extent of UV patterns in these insects.

METHODS

Photographs were taken of preserved specimens in the Odonata collection at Bishop's University. These represented 338 species (plus 11 subspecies) in 118 genera and 16 families (Tab. I). All non-Canadian species were obtained from other odonatologists and I relied upon their determinations for species identification.

Photographic techniques were adapted from EGUCHI & MEYER-ROCHOW (1983), FERRIS (1972) and HILL (1977). The camera was a Pentax ME Super with a 50 mm Pentax-M 1:1.7 lens to which was attached (for the UV photographs) a Kodak 18-A ("Wratten") UV filter. The film was Tri-X Panchromatic 400 ASA.

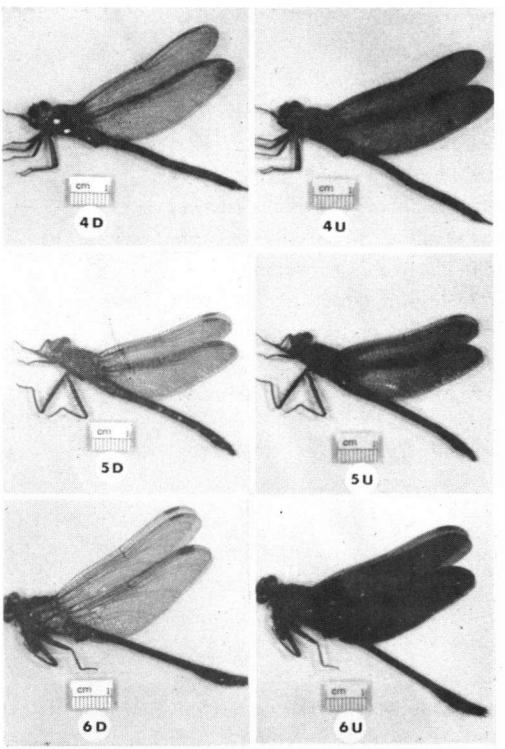


Figs 1-3. Daylight (D) and ultraviolet (U) patterns of: (1) *Tetragoneuria costalis* male (M); — (2) *Davidius nanus* (M); — (3) *Gomphurus fraternus* (M).

RESULTS

Fourteen response patterns to UV light have been determined in this survey (Figs 1-14) and each species in Table I has its UV pattern-type indicated by a number representing the Figure which most closely matches its own pattern. Pattern 1 (Fig. 1) has no UV absorbance or reflectance, patterns 2-13 (Figs 2-13) show varying degrees of UV absorbance, while pattern 14 (Fig. 14) shows UV reflectance.

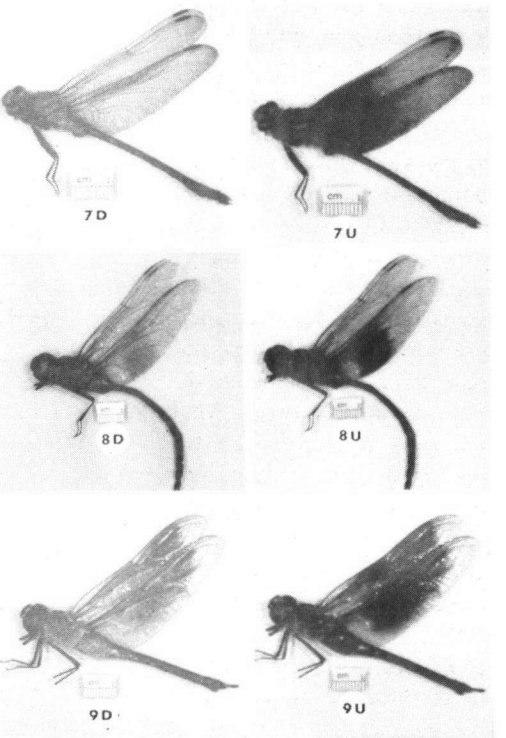
Certains trends can be seen. Almost all the Coenagrionidae [52/55 (94.5%)] did not show any UV patterns (like Fig. 1) and the same was true to a lesser extent for the Leucorrhiniinae [11/14 (78.6%)] and Libellulinae [14/21 (66.7%)]. In contrast, 10/12 (83.3%) of the Calopteryginae had a very dark UV-absorbing wing pattern (like Fig. 13), probably due to the dark pigment(s) typically present in their wings. The effect of wing pigment(s) as UV absorbers can be seen in species such as *Mnais pruinosa* in which dark-winged males had a very dark UV pattern while paler-winged females had only a slight wing darkening in UV. This tendency for wing pigment(s) to absorb UV was found in a number of species with flavescent, orange or brown wings or wing patches [e.g. *Lestes eurinus* (like Fig. 5), *Anax parthenope julius* (Fig. 9), *Nannophya pygmaea* (like Fig. 11), *Sympetrum semicinctum* (like Fig. 11) and *Tholymis tillarga* (Fig. 12)]. Species such as *Libellula lydia* or *Rhyothemis fuliginosa*, with very dark wing patches, undoubtedly also absorbed UV in these pigmented areas. However, they are already so dark in daylight that no change was evident in UV and thus are considered in Table I not to show UV patterns



Figs 4-6. Daylight (D) and ultraviolet (U) patterns of: (4) *Boyeria vinosa* (M); — (5) *Dromogomphus spinosus* female (F); — (6) *Gomphus melaenops* (M).

(like Fig. 1). Many Gomphidae had dark UV wing patterns, particularly at the basal one-quarter to one-half of the wings (Figs 2, 3 & 7), even though their wings were transparent in daylight. However, by holding the wings against a white background and looking very closely it was often possible to see a very faint flavescence which corresponded in position to the UV-absorbing regions of the wings. Sexual dimorphism in UV wing patterns was frequent. This might just be a small difference in wing darkening (e.g. *Polycanthagyna melanictera*) or one sex could have a dark wing pattern in UV while the other sex's wings remained transparent [e.g. *Gomphus hodgesi* (Fig. 10)].

Euphaea amphicyana was unusual because it was the only species to have wings that reflected UV. This occurred in the basal two-thirds of the hind wings (Fig. 14) and corresponded with a deep-purple reflective region which became visible against the very dark brown wing pigment(s) only when the wings were held at a particular angle.

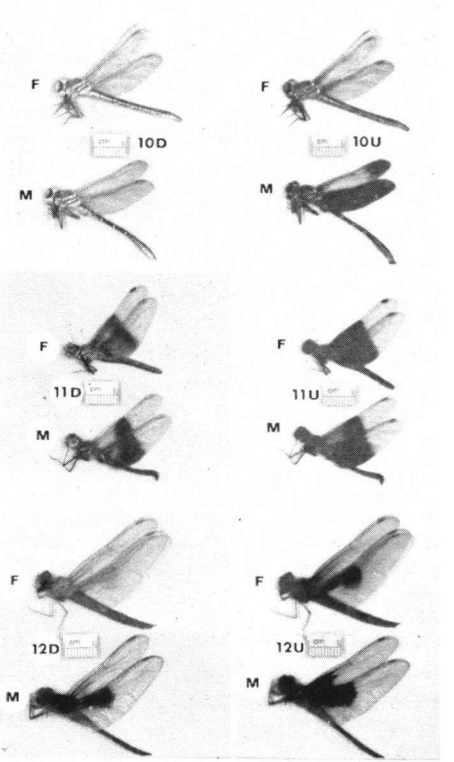


Figs 7-9. Daylight (D) and ultraviolet (U) patterns of: (7) *Gomphus pyeri* (M); (8) *Anax panybeus* (M); (9) *Anax parthenope julius* (F).

DISCUSSION

In contrast to many butterflies (e.g. SCOTT, 1973) (and except for *Euphaea amphicyana*) the Odonata listed in Table I did not show UV reflectance. GHIRADELLA (1984) and GHIRADELLA et al. (1972) have shown that UV reflectance in Lepidoptera is due to optical interference within the microscopic structure of wing scales. Certain Coleoptera (POPE & HINTON, 1977) have UV reflectance primarily caused by pigments contained within microtrichia and other setae but it may also be from dried cuticular secretions (some Tenebrionidae and Buprestidae) or subcuticular pigments (a few desert-dwelling Tenebrionidae). Because Odonata lack lepidopteran-type scales or the surface cuticular processes typical of some beetles,

this may be the reason why so few species reflect UV. The major exceptions are those species which exhibit pruinosity. ROBERTSON (1984), using a spectrophotometer, determined that pruinosity strongly reflected UV. BYERS (1975), ROBEY (1975) and SILBERGLIED (1979) recorded the tendency for white or bluish pruinose areas to have an enhanced whiteness when photographed through a UV filter. I also noticed this effect but did not designate it as a separate pattern-type in Table I. Both BYERS (1975) and SILBERGLIED (1979) suggested that UV reflectance of pruinose areas might be a Tyndall effect and BYERS (1975) observed that when the wax particles which comprise the pruinosity are removed by organic solvents the Tyndall effect is permanently destroyed. Due to the widespread practice by odonatologists of soaking captured Odonata in acetone for 24 hrs in order to preserve colors, many museum specimens will have lost their pruinosity and thus not reflect UV from these areas.



Figs 10-12. Daylight (D) and ultraviolet (U) patterns of: (10) *Gomphus hodgesi* (F + M); — (11) *Sympetrum occidentale fasciatum* (F + M); — (12) *Tholymis tillarga* (F + M).

It is not known what pigments are responsible for the flavescent, orange or brown wings (or wing patches) that strongly absorbed UV in many Odonata. However, in plants, BREHM & KRELL (1975) and THOMPSON et al. (1972) have determined that flavonoids in the nectar guides of some flowers are responsible for these regions absorbing UV.

As noted SILBERGLIED (1979), arthropod cuticle absorbs UV. This is why Odonata without pruinose regions had dark bodies in UV and their daylight color-patterns were obscured (Figs 1U-14U).

One cannot generalize about the role UV patterns play in odonate behavior. However, it obviously is not a species or sex recognition factor for some (e.g.

Table I
Species of Odonata which were examined for the presence of UV patterns

Species[1]	UV pattern type[2] ♂	♀	Species[1]	UV pattern type[2] ♂	♀
COENAGRIONIDAE			*E. hageni*	1	1
Amphicnemidinae			*Ischnura asiatica*	1	1
Antiagrion gayi	1	1	*I. cervula*		1
Pseudagrioninae			*I. elegans*	1	1
Ceriagrion latericum			*I. prognatha*	1	
ryukyuanum	1	1	*I. pumilio*	1	
C. melanurum	1	1	*I. ramburii*	1	
C. nipponicum	1		*I. senegalensis*	1	1
Pseudagrion p. pilidorsum	1	1	*I. verticalis*	1	1
Telebasis salva	1		*Oxyagrion terminale*	1	1
Coenagrioninae			Agriocnemidinae		
Cercion calamorum	1	1	*Agriocnemis femina oryzae*	1	1
C. hieroglyphicum	1	1	*Mortonagrion selenion*	1	1
C. plagiosum	1	1	Argiinae		
C. sexlineatum	1	1	*Argia moesta*	1	1
C. sieboldii	1	1	*A. oenea*	4	
Chromagrion conditum	1	1	*A. pulla*	1	
Coenagrion angulatum	1	1	*A. tezpi*	13	
C. armatum	1	1	*A. violacea*	1	1
C. concinnum	1	1	PLATYCNEMIDIDAE		
C. hastulatum	1	1	Calicnemidinae		
C. puella	1	1	*Coeliccia f. flavicauda*	1	
C. pulchellum	1	1	Platycnemidinae		
C. resolutum	1	1	*Copera annulata*		1
C. vernale	1	1	*C. marginipes*	1	
Erythromma najas	1	1	*C. tokyoensis*	2	
Nehalennia gracilis	1	1	*Platycnemis foliacea sasakii*	1	1
N. irene	1	1	*P. pennipes*	4	5
N. speciosa	1	1	PSEUDOSTIGMATIDAE		
Pyrrhosoma nymphula	1	1	*Mecistogaster linearis*		4
Ischnurinae			*Megaloprepus caerulatus*		1
Acanthagrion gracile	1		LESTIDAE		
Aciagrion hisopa	1		Lestinae		
A. migratum	1	1	*Archilestes grandis*	5	4
Amphiagrion saucium	1	1	*Chalcolestes viridis*	4	4
Cyanallagma interrupta	4	4	*Lestes congener*	1	1
Enallagma aspersum	1	1	*L. d. disjunctus*	1	1
E. boreale	1	1	*L. dryas*	1	1
E. carunculatum	1		*L. eurinus*	5	5
E. civile	1		*L. forcipatus*	1	1
E. cyathigerum	1		*L. japonicus*	4	
E. deserti yezoensis	1		*L. rectangularis*		1
E. ebrium	1	1	*L. sponsa*	4	4
E. exsulans	1		*L. temporalis*	4	4

[1] Genera and species are listed alphabetically; higher categories are according to Davies (1981).
[2] Numbers refer to the corresponding figures; a blank indicates this sex was not available for examination.

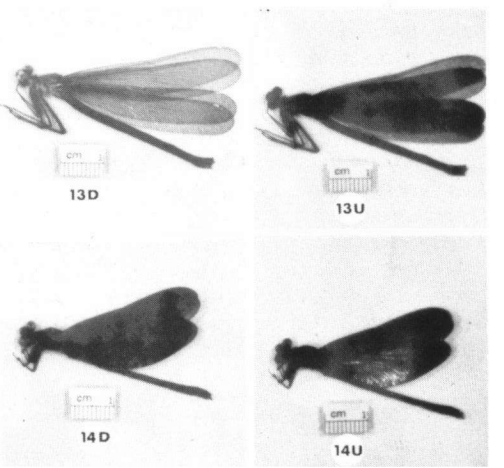
Species[1]	UV pattern type[2] ♂	♀	Species[1]	UV pattern type[2] ♂	♀
L. unguiculatus	1	1	*A. eremita*	1	1
L. virens	4	4	*A. cyanea*	4	4
L. viridis	1		*A. i. interrupta*	1	1
Sympecmatinae			*A. i. lineata*	1	9
Indolestes cyanea	4	4	*A. juncea*	1	4
I. peregrinus	1	4	*A. j. americana*	1	5
Sympecma paedisca	1	1	*A. multicolor*	1	
PSEUDOLESTIDAE			*A. nigroflava*	4	4
Hypolestinae			*A. palmata*	1	1
Rhipidolestes a. aculeata	4	1	*A. sitchensis*	1	
R. aculeata hiraoi	1	1	*A. subarctica*	1	1
R. okinawanus	4		*A. tuberculifera*	1	1
CALOPTERYGIDAE			*A. umbrosa occidentalis*	1	4
Calopteryginae			*A. u. umbrosa*	1	4
Calopteryx amatum		13	*A. verticalis*		1
C. atrata	13	13	*Anaciaeschna martini*	5	5
C. cornelia	13	13	*Anax junius*	5	5
C. maculatum	13	13	*A. longipes*	6	
C. splendens	13	13	*A. n. nigrofasciatus*	5	
C. virgo	13	13	*A. panybeus*	8	
Matrona basilaris	13	13	*A. parthenope julius*	9	9
M. basilaris japonica	13		*Gynacantha japonica*	4	5
Mnais costalis	13	13	*Polycanthagyna melanictera*	5	4
M. pruinosa nawai	13	4	Brachytroninae		
M. p. pruinosa	13	4	*Aeschnophlebia anisoptera*	13	1
Neurobasis c. chinensis	13	13	*A. longistigma*	5	
Psolodesmus mandarinus dorothea	1	4	*Basiaeschna janata*	4	
Vestalis apicalis	4	1	*Boyeria grafiana*	4	4
Hetaerininae			*B. maclachlani*	1	
Mnesarete pudica	1	1	*B. vinosa*	4	
CHLOROCYPHIDAE			*Gomphaeschna furcillata*	1	
Chlorocyphinae			*Oligoaeschna pryeri*	4	
Rhinocypha bisignata	13	4	GOMPHIDAE		
EUPHAEIDAE			Gomphinae		
Euphaea amphicyana	14		*Arigomphus maxwelli*	1	
E. formosa	13		*A. villosipes*	1	1
E. yayeyamana	13	13	*Davidius fujiama*		2
Bayadera h. brevicauda	4	4	*D. m. moiwanus*		2
EPIOPHLEBIIDAE			*D. nanus*	2	
Epiophlebia superstes	1	1	*Dromogomphus spinosus*		5
AESHNIDAE			*Erpetogomphus designatus*	4	
Aeshninae			*Gomphurus fraternus*	3	
Aeshna canadensis	1	4	*Gomphus australis*	3	
A. coerulea	1		*G. borealis*	2	
A. constricta	1	1	*G. brevis*	2	2

Species[1]	UV pattern type[2] ♂	♀	Species[1]	UV pattern type[2] ♂	♀
G. cavillaris	1		*Sieboldius albardae*	6	
G. crassus	2	2	Lindeniinae		
G. descriptus	5	4	*Ictinogomphus clavatus*	5	
G. diminutus	2		*I. pertinax*	6	
G. exilis	4	4	PETALURIDAE		
G. graslinellus	3	7	Petalurinae		
G. hodgesi	10	10	*Tachopteryx thoreyi*	2	
G. hybridus	2		Tanypteryginae		
G. ivae	1		*Tanypteryx pryeri*	2	
G. melaenops	6		CORDULEGASTRIDAE		
G. minutus	3	3	Chlorogomphinae		
G. oklahomensis	6		*Chlorogomphus b. brunneus*		13
G. ozarkensis	7	5	*C. brunneus costalis*	4	7
G. pallidus	1		*C. suzukii*	5	
G. plagiatus	1		Cordulegastrinae		
G. potulentus	1		*Anotogaster sieboldii*	5	7
G. pryeri	7		*Cordulegaster bidentatus*	5	
G. sandrius	4		*C. bilineata*	4	
G. septima	7		*C. boltoni*	5	
G. spicatus	1	1	*C. diastatops*	5	6
G. townesi	1		*C. erronea*	1	
G. vastus	3		*C. maculatus*	5	5
G. villosipes	1		*C. obliquus*	6	
G. vulgatissimus	4		*C. sayi*	1	
Hylogomphus abbreviatus	2		CORDULIIDAE		
H. geminatus	1		Corduliinae		
Lanthus albistylus	3	3	*Cordulia aenea amurensis*	4	
L. fujiacus	2		*C. shurtleffi*	1	1
L. parvulus	2		*Dorocordulia libera*	4	4
Nihonogomphus viridus	4		*Epicordulia princeps*	1	
Onychogomphus forcipatus	1		*Epitheca canis*	4	5
O. viridicostus	2		*E. cynosura*	1	1
Ophiogomphus carolus	4		*E. marginata*	5	
Sinogomphus flavolimbatus	2	2	*E. princeps*	1	1
Stylogomphus suzukii	7		*E. spinigera*		4
Stylurus oculatus	3		*Helocordulia selysia*	1	
Trigomphus citimus tabei	5	2	*H. uhleri*		1
T. interruptus	2		*Hemicordulia okinawensis*	5	2
T. melampus	4	4	*Neurocordulia alabamensis*		1
T. ogumai	2		*N. xanthosoma*	4	4
Gomphoidinae			*N. yamaskanensis*	5	4
Aphylla williamsoni	4		*Rialla villosa*	4	
Progomphus bellei	1		*Somatochlora alpestris*	5	
P. obscurus	1		*S. arctica*	4	
Hageniinae			*S. clavata*	4	
Hagenius brevistylus	6	6	*S. elongata*	1	

Species[1]	UV pattern type[2] ♂	♀	Species[1]	UV pattern type[2] ♂	♀
S. flavomaculata	4		*L. hudsonica*	1	1
S. forcipata	4		*L. intacta*	1	1
S. franklini	7		*L. proxima*	1	1
S. graeseri aureola	4	1	*L. rubicunda*		1
S. hudsonica	4	4	Libellulinae		
S. linearis	5		*Libellula angelina*	1	
S. metallica	4	4	*L. axilena*	1	
S. minor	1	1	*L. comanche*	1	
S. semicircularis	4	5	*L. fulva*	1	
S. tenebrosa	1	4	*L. julia*	1	1
S. uchidai	1		*L. luctuosa*		1
S. viridiaenea	4	4	*L. lydia*	1	1
Tetragoneuria costalis	1		*L. pulchella*	1	1
T. spinosa	1		*L. quadrimaculata*	1	1
Gomphomacromiinae			*L. q. asahinai*	1	1
Gomphomacromia paradoxa	4	2	*Lokia coryndoni*	1	1
MACROMIIDAE			*Lyriothemis elegantissima*	1	1
Didymops floridensis	1		*L. pachygastra*	2	2
D. transversa	1	1	*Orthemis ferruginae*	4	
Epophthalmia elegans	4		*Orthetrum albistylum speciosum*	1	4
Macromia a. amphigena		6	*O. cancellatum*	1	1
M. georgina	1		*O. coerulescens*		4
M. illinoiensis	1		*O. j. japonicum*	4	4
SYNTHEMISTIDAE			*O. luzonicum*	6	
Synthemis eustralacta	1	4	*O. pruinosum neglectum*	1	
LIBELLULIDAE			*O. s. sabina*	1	
Brachydiplacinae			*O. triangulare melania*	5	5
Brachydiplax chalybea flavobitta	5		Sympetrinae		
Chalcostephia flavifrons	1	1	*Acisoma p. panorpoides*	1	
Micrathyria hypodidyma	1		*Brachythemis contaminata*	9	4
Nannophya pygmaea	11	11	*Crocothemis servilia*	1	4
Uracis fastigiata	5	1	*Deielia phaon*		4
Leucorrhiniinae			*Diplacodes trivialis*	1	1
Cannacria batesi	4		*Erythemis simplicicollis*	1	4
Celithemis bertha	1		*Erythrodiplax funerea*		1
C. elisa	1		*E. fusca*	1	
C. eponina	13	13	*E. umbrata*	1	4
C. verna	1		*Lepthemis vesiculosa*	1	
Leucorrhinia albifrons	1	1	*Neurothemis r. ramburi*	1	1
L. borealis	1	1	*Pachydiplax longipennis*	4	4
L. dubia	1	1	*Sympetrum baccha matutinum*	1	1
L. d. orientalis	1		*S. costiferum*	4	4
L. frigida	1	2	*S. croceolum*	11	11
L. glacialis	1	1	*S. danae*	1	1

Species[1]	UV pattern type[2] ♂	♀	Species[1]	UV pattern type[2] ♂	♀
S. darwinianum	I	I	*S. uniforme*	5	
S. depressiusculum	4	I	*S. vicinum*	5	4
S. e. eroticum	I	2	*S. vulgatum*	4	I
S. flaveolum	II		Trithemistinae		
S. frequens	I	I	*Dythemis velox*	I	I
S. gracile	I	I	*Macrothemis imitans*	4	
S. infuscatum	I	4	*Pseudothemis zonata*	4	4
S. internum	4	4	*Trithemis aurora*	I	
S. kunckeli	I	2	Palpopleurinae		
S. maculatum	4	4	*Palpopleura lucia portia*	I	I
S. obtrusum	I	I	*Perithemis domitia*	13	
S. occidentale fasciatum	II	II	*P. seminole*	13	I
S. pallipes	I	I	Trameinae		
S. parvulum	2	2	*Miathyria marcella*	4	4
S. pedemontanum	I	I	*Pantala flavescens*	I	4
S. p. elatum	5	4	*Rhyothemis fuliginosa*	I	I
S. r. risi	5		*R. variegata imperatrix*	13	13
S. rubicundulum	I		*Tholymis tillarga*	12	12
S. sanguineum	I		Urothemistinae		
S. semicinctum	II	II	*Macrodiplax balteata*	I	I
S. s. speciosum	4	I	Zygonychinae		
S. striolatum	I	I	*Zygonyx takasago*	I	
S. s. imitoides	5	I			

most Coenagrionidae), whereas species like *Pachydiplax longipennis* and *Gomphus hodgesi* exhibit sexual dimorphism in body UV-reflectance and wing UV-absorbance, respectively. One would expect such species to utilize UV patterns in aspects of their mating behavior, just as ROBEY (1975) has shown for *Pachydiplax longipennis.*



Figs 13-14. Daylight (D) and ultraviolet (U) patterns of: (13) *Calopteryx amatum* (F); (14) *Euphaea amphicyana* (M).

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