Abstracts

ABBOTT, John C.

The status of *Cordulegaster sarracenia* Abbott & Hibbitts, 2011 with notes on its biology and a description of the final instar nymph (Odonata: Cordulegastridae)

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The range of *Cordulegaster sarracenia* Abbott & Hibbitts, 2011 is limited to *Sarracenia alata* pitcher plant bogs and small, mucky forest seepages, in southeast Texas and western Louisiana in the United States. The recent discovery, limited range, and poorly known biology of this species make it of potential conservation concern. The latest information about this species' nymphal and adult habitat, flight period and adult activity are described. The nymph of *C. sarracenia* is described and diagnosed from its closest relatives, *C. sayi* Selys, 1854, *C. talaria* Tennessen 2004, *C. bilineata* (Care, 1983) and *C. diastatops* (Selys, 1854) by a combination of characters. New facets of its life history are inferred from size and frequency data and DNA was collected to estimate population size, survivorship and gene flow.

AMAYA-VALLEJO, Vanessa

New Odonata species from Anchicayá (Valle del Cauca, Colombia): an integrative approach

Vanessa Amaya-Vallejo[1], Rodolfo Novelo-Gutiérrez[2], Emilio Realpe[1] & Heike Hadrys[3]
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Stenoecious odonates have specific ecologic requirements that can put them in a vulnerable condition if their habitat is degraded. As they belong mainly to tropical rainforests which are critically affected by mining and deforestation, knowledge of these species needs to be enriched in order to establish vulnerability diagnoses and conservation plans. The Anchicayá zone offers a great opportunity to do this as it is inside a protected area and is home to a rich and diverse assemblage of stenoecious odonates. Our research has focused on larvae because adults have been elusive and difficult to find. We aim to establish accurate relationships between life stages and to determine new species using taxonomic characters, ecological preferences and molecular barcoding. Taxonomic characters had yielded 3 new species so far, one of which was successfully reared in laboratory conditions. The biotic and abiotic factors which condition the presence of a species have been determined, setting habitat preferences for them. The last step is to establish molecular barcodes using CAOS algorithm [1]. Finally, all data will be collated according to the integrative methodology proposed by Damm *et al.* [2] in order to increase reliability in species determination, by basing determinations on an analytical rather than a descriptive approach.

[1] Rach, J., Desalle, R., Sarkar, I.N., Schierwater, B. & Hadrys, H., 2008. Character-based DNA barcoding allows discrimination of genera, species and populations in Odonata. Proceedings. Biological Science 7;275(1632):237–47.
[2] Damm, S., Schierwater, B. & Hadrys, H., 2010. An integrative approach to species discovery in odonates: from character-based DNA barcoding to ecology. Molecular Ecology 19(18):3881–93. doi: 10.1111/j.1365-294X.2010.04720.x.

BOGARÍN-TOPETE, Perla

Observations on a community of adult Odonata inhabiting a temporary water body in the tropical region of Chamela, Jalisco, Mexico

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The colonization of temporary freshwater habitats by adult Odonata is a poorly studied phenomenon, especially in tropical areas. In virtue of this, herein we present some observations on the manner in which the species composition of a community of adult Odonata changes over a year from the time when a tropical pond fills because of rains until the end when the same pond dries out in the region of Chamela, Jalisco, México. The study was realized during June, August – September, and October 2015, and ended by March 2016. We collected a total of 29 species, some of which seem to remain flying as adults for several months during the period (e. g. *Tramea onusta, Orthemis ferruginea, Lestes tikalus* and *Telebasis salva*). Among Anisoptera, Libellulidae contributed to the total with 15 species. Among the Zygoptera, Coenagrionidae with eight species were the most diverse family. *Mycrathyria hagenii, Ischnura ramburii, Erythrodiplax basifusca* and *Lestes tikalus* remained at the pond until it was almost completely dry.

BOMPHREY, Richard

Flight analysis, aerodynamics and flight modes

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The most modern scientific techniques allow us to examine the most ancient flying insect morphologies with unprecedented detail. In this talk I will give an overview of these methods and how they have contributed to our understanding of dragonfly and damselfly mechanics. I will investigate the aerodynamic consequences of corrugated wing profiles during gliding flight and the effects of variable wing planform on the energetics of flapping flight. I will show the fluid structures that appear over the wings of dragonflies as they explore a wind tunnel arena and how that flow topology varies with selected kinematic patterns. Conclusions are drawn from evidence built from field photography, scanning laser surface mapping, optical flow measurements and computational simulations. Finally, I will show the behavioural consequences of dragonflies' exquisite control over their aero-mechanics and how different flight modes can be distinguished by trajectory analysis

BOTA-SIERRA, Cornelio

Tropical mountain Odonata under climate change: the adult's thermal perspective

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Global warming is a critical change in the temperature that affects the dynamics of ecosystems around the world. The geographic distributions of populations are shaped by abiotic and biotic factors. When these factors change, organisms have three possible responses: migration, adaptation or extinction. Adaptability depends on the amount of variation present in the population. Populations in tropical mountain forests are vulnerable due to their complex communities and the ecophysiological constraints that limit migration. This makes it crucial to measure the variability in thermal resistance of the populations inhabiting these ecosystems.

Since June 2016, we have been working in the Colombian Western Andes, in the western slope of Tatamá National Park, covering an altitudinal gradient from 300 to 2600 metres. We measured minimum critical flight temperatures, voluntary temperatures of heat avoidance and maximum motor control temperature of adult dragonflies and damselflies. To date, we have measured 640 individuals from 59 different species. Preliminary analysis done on species with sample numbers higher than 10 have shown that variability in thermal resistance is high among the populations. This is good news for the future of tropical mountain dragonflies but raises several questions, such as: What variables constrain the altitudinal distribution of each species? Are biotic variables such as competition responsible for the distributional patterns? How important are the immature stages in determining altitudinal distribution; is it the immature stages that constrain distribution? We still have two more months of field sampling in which we expect to gather more data to complement what we already have in order to get results that are better supported.

BROOKS, Steve

Philip Corbet: his legacy

Stephen J. Brooks

Life Sciences, The Natural History Museum, Cromwell Road, London SW7 5BD, UK

Philip Corbet is a towering figure in world Odonatology. He has been a major influence on every aspect of the subject. His most important contribution has been the publication of thorough and ground-breaking syntheses which have provided a bench mark and a fount of knowledge on dragonfly biology and ecology to which all serious odonatologists turn before they embark on any enquiry or research project on dragonflies. Philip Corbet's significant contributions also include his meticulous research and clarity of writing which provide examples of best practice for other scientists. His excellent organisational abilities, encouragement of young scientists and passion for the conservation of dragonflies have all left important legacies too. In this presentation I will review this legacy and introduce the various strands of odonatological research which owe a debt to Philip and which will be covered in more detail in this special session celebrating Philip Corbet's immense contribution to the study of dragonflies.

BÜSSE, Sebastian

Material composition of mouthpart cuticle in Odonata and its possible biomechanical significance

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Odonata larvae are often key predators in their biotopes. They catch their prey with a unique and highly efficient apparatus, the so-called prehensile labial mask. The strong mandibles and extremely movable maxillae, however, play the lead in handling and crushing the food. The functional aspects of the prehensile labial mask were previously studied apart from the description of cuticular structures and muscle equipment of different mouthparts. However, the influence of the material composition of the dragonfly cuticle on the overall biomechanical system of mouthparts has not been studied so far.

We used confocal laser scanning microscopy (CLSM) to detect sclerotised, chitinous and membranous areas, as well as resilin-dominated areas of the cuticle by their different autofluorescence. Resilin is a visco-elastic protein, which is found in insect cuticle wherever high resilience, low fatigue, and/or strong damping are required. It is also often used for storing elastic energy for subsequent high-speed movements where muscles would not be able to move as fast as required.

Our results show the presence of resilin for example: i) at the transition of the labrum and anteclypeus where it increases movability and might provide shock absorption against mechanical impact; ii) at the base of the dentisetae (maxillae), where it serves as soft and elastic support of the strongly sclerotized structures of the tip of the dentisetae, representing most likely an adaptation against mechanical wear and damage; iii) at the t-rod (internal structure), where it might supplement – together with muscle 0hy7 – the hydraulic driving force of the prey-capturing process.

The interaction of the material composition, geometry of cuticular structures and the related musculature of the mouthparts determine their complex concerted movements. The material composition can influence the strength, movability and durability of single components of the mouthparts.

Plenary lecture: Seth Bybee, J. Abott, Adolfo Cordero, KD Dijkstra, Vincent Kalkman & Jessica Ware

BYBEE, Seth M.

Searching for strength in the backbone of Odonata phylogeny

Seth M. Bybee[1], John Abbott[2], Adolfo Cordero[3], K-D Dijkstra[4,5], Vincent Kalkman[4] & Jessica Ware[6]
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Odonate phylogeny has been heavily explored over the past two decades using modern methods of phylogenetic reconstruction for both morphological and molecular data. As a result, solid hypotheses of natural family-level groupings have largely come into focus, especially among the Anisoptera. Yet, a well-supported “backbone” or relationships

between the major family groupings has remained elusive within both suborders, but particularly among the Zygoptera. Herein we present two datasets derived from genome reduction methods, transcriptome (~85 taxa) and anchored hybrid enrichment data (~140 taxa) representing all major lineages except the genus *Rimanella*. We find greater support along the phylogenetic backbone of Odonata then ever before. However, we still find several difficult relationships to resolve with statistically significant support. This lack of support is likely due to extensive and rapid radiations that took place at multiple points throughout odonate evolutionary history.

CHELMICK, David

British Dragonfly Society - Philip Corbet's brainchild and still vital in today's world

David Chelmick
Macromia Scientific 31 High Beech Lane, Haywards Heath, West Sussex RH16 1SQ, UK

The BDS was formed in 1983 but its conception was back in the 1970s when a combination of circumstances conspired to bring the professional and amateur worlds of dragonflies together. From the first dragonfly recording meeting in 1979 and the field meeting at Thursley Common in 1980, the BDS with Philip Corbet as its first President, evolved; the rest as they say is history. The principle achievement of the Society must be the Recording Scheme and Atlas; however, there is so much more. The first example is a project in Dorset where one of the UK's red data book species, *Coenagrion mercuriale*, is in decline. The second concerns the rediscovery of the local damselfly, *Lestes dryas*, in the Weald of Southern England, where it was first found by Norman Moore in the 1940s.

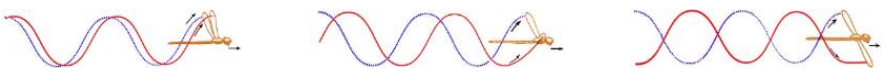
Without the work of BDS members neither of these projects could have been carried out and in a world where finances for research are becoming ever tighter, the role of the BDS in mapping, understanding and therefore conserving our dragonflies and their wetland habitats has never been more important. I like to think that Philip Corbet, to whom this talk is dedicated, would be justly proud of the continuing work that he started with the Society in 1983.

COMBES, Stacey

More than one way to capture prey: comparative flight biomechanics and capture strategies of hunting dragonflies

Stacey A. Combes, Susan F. Gagliardi, Mary K. Salcedo, Jay M. Iwasaki, Daniel E. Rundle & James D. Crall
Department of Neurobiology, Physiology and Behavior, University of California, Davis, USA

Dragonflies are highly successful aerial predators that pursue a variety of prey, engaging in complex, three-dimensional pursuits that are typically completed in less than a second. Because mechanistic studies of aerial predation are scarce, we do not yet know whether predators employ a general kinematic and behavioral strategy when pursuing most prey, or whether they tailor their pursuit to each prey type; nor do we know how widely prey species differ in their survival strategies and in their sensorimotor capabilities. To address these questions, we examined aerial interactions between dragonflies and dipteran prey, filming hundreds of encounters with high-speed video to reconstruct 3-d trajectories, quantifying flight biomechanics, and examining pursuit and escape strategies. We studied three species of libellulid dragonflies (*Libellula cyanea*, *Pachydiplax longipennis*, and *Sympetrum rubicundulum*) pursuing four species of dipteran prey. By analyzing large



numbers of encounters between different predator-prey pairs, we were able to identify common mechanical features of dragonfly predation, infer which prey species can sense and actively respond to approaching predators, and pinpoint key factors that help determine the outcome of predator-prey interactions. Surprisingly, we found that two of the dragonfly species achieve similar levels of capture success and expend similar amounts of power to capture prey, but they do so using very different capture strategies: slow, stealthy approaches that prey rarely detect vs. rapid, powerful approaches that prey try to evade but rarely can. These findings highlight the importance of examining complex flight behaviors such as predator-prey interactions in a natural, comparative context.

CONZE, Klaus-Jürgen

Dragonflies in Northrhine-Westfalia 1996–2016

Klaus-Jürgen Conze
Gesellschaft deutschprachiger Odonatologen (GdO) & Arbeitskreis Libellen Nordrhein-Westfalen (AK Libellen NRW), Hamburger Str. 92, D-45145 Essen, Germany

Twenty years after its foundation, the honorary working group produced this book *Dragonflies in Northrhine-Westfalia* in November 2016. More than 400 volunteers collected more than 175,000 datasets in the most densely populated federal state in Germany. Detailed maps and monographs of all 73 species so far known in the northwestern state are included in the heavy book. There are also articles about the long history of dragonfly research in this area and about the famous fossils from the ancient times of the Carboniferous as well as examples of important dragonfly habitats spread over the country. The talk will also deal with what is going on in the future regarding protection and further research, and how to modernize data collection and the efforts to stabilize the most endangered species.

CUÉLLAR-CARDOZO, J.

Odonate diversity and its relation with land uses along "La Avería" stream in tropical dry forest in Colombia

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Odonates are good indicators of ecosystem health as they provide a measure of the energetic balance of trophic webs. Tropical dry forests, their watersheds and biodiversity, are some of the most threatened ecosystems because land use changes have reduced their area. We estimated the relationship between odonate diversity and land uses along La Avería stream (Paicol, Huila) to determine how odonates respond to land use changes. We sampled physicochemical and land use variables along the stream during 2016 every three months. We captured 272 individuals (168 adults and 104 larvae) of 16 species. ANOVA analyses showed that there are no significant differences in odonate diversity, however there are differences in their abundance. The canonical correspondence analysis (CCA) for adults explained 59.1% for the data of the first axis and 91.1% for the second axis, showing that levels of ammonium and nitrate had significant effects. The CCA for larvae explained 47.1% for the data of the first axis and 94.8% for the second axis, showing that pH levels and levels of nitrate had significant effects. We also have

evidence signifying there is a relationship between land use and odonate abundance. We conclude that changes in odonate abundance are associated with changes in water physicochemical variables.

DENIS, Alice
Effects of water temperature on phenology and morphology of riverine Odonata
Alice Denis[1,2], Ophélie Payet[2], Samuel Danflous[1], Nicolas Gouix[1], Frédéric Santoul[2] & Laurent Pelozuelo[2]
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Habitat changes are major drivers of biodiversity loss and affect Odonata by causing fragmentation of populations. However, the manner in which these changes split populations is almost exclusively considered with respect to geographical isolation. Little attention is paid to changes in abiotic factors which potentially generate temporal segregation of populations. Here, we assessed the impacts of larval habitat temperature on emergence patterns and morphometric traits of dragonfly species. Five sites were equipped with water temperature loggers and were visited eleven times for exhaustive exuviae collection along 200 metres of river bank. All sites were close to each other: two were located on a large river, two on a tributary and one on an artificial pond fed by the tributary. Phenology shift was observed between lentic system (warmer) and lotic systems (cooler). Indeed, odonates which developed in the pond emerged about a month earlier than those that developed in rivers. These results support the hypothesis that warmer temperature drives the pond population to be segregated from the river population one. They also question whether warmer/cooler temperatures may drive local populations to a phenological mismatch with optimal conditions for the adults' life steps. Moreover, measurements of morphological traits on exuviae of *Gomphus graslinii* showed that temperature induced intraspecific variability.

Plenary lecture: K-D. Dijkstra
DIJKSTRA, K-D.
Africa, freshwater and dragonflies: natural history and conservation in the continent of change
K-D. Dijkstra
Biodiversity Discovery Group, Naturalis Biodiversity Center, PO Box 9517, 2300 RA Leiden, The Netherlands

Water is the source of life, the climate's essence, and probably humanity's most critical resource. The crises facing mankind collide in freshwater; nowhere is more biodiversity being lost. Freshwater conservation is not just another challenge, but embodies all environmental problems: as we disrupt the cycles that ensure its flow, we cannot expect one source to provide a sewer and a drink, energy and irrigation, and still sustain life forever. Dragonflies and damselflies are popular indicators of aquatic integrity and among its most powerful symbols. Found only but in all freshwater, they represent the majority of aquatic life, insects. As conspicuous members of a neglected majority, they emerge from a forgotten world into our lives on land. And, on the wing, they can return as quickly when things improve as they vanished when it got bad. Capturing nature's beauty, needs and resilience, dragonflies can become for healthy rivers and clean water what bees are for pollinators and food security. I will discuss how the growing interest, together with methodological innovations, can change the image and assessment of our

most valuable environments. I focus on Africa, perhaps the most changeable continent historically, but definitely where man-made change will be most dramatic this century.

DIJKSTRA, K-D.

Corbet's successes and Moore's successors: odonatology's metamorphosis from scientific society to conservation community

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A reflection.

FEINDT, Wiebke

Genomic research in *Megaloprepus caerulatus*: a non model system points towards the future of studying Neotropical Odonata

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During the last decade, although odonate research in the Neotropics is increasing exponentially, the transition towards 'state of the art conservation genetic approaches' is still lacking. Although fundamental biodiversity research, including the description of new species, species assemblages and species ranges under the light of changing environmental conditions will always be the essential backbone for studying evolution and ecology, promising new Next Generation Sequencing methods found their way into the detection of causal mechanisms underlying adaption and speciation.

One prominent taxon with a solid backbone of knowledge in (behavioral) ecology is the world's largest damselflies, belonging to the genus *Megaloprepus*. Recently we (re)discovered that the 'one-species-genus' *Megaloprepus* has radiated into three historical described and one newly described species accompanied by significant differences in taxonomy and genetics. Comparative larval transcriptome analyses using two of the species revealed local adaptation despite strong niche conservatism. Based on these results we further discuss adaption and speciation in *Megaloprepus* in comparison to its closely related sister genus *Mecistogaster*. Here adaption to different ecological niches resulted in the radiation of at least 12 species. Comparing adaptation and diversification between those genera may allow a detailed picture in how the environment shapes diversification on a genomic base.

FERRERAS-ROMERO, Manuel & SAMRAOUI, Boudjéma

Seasonality and life history of Mediterranean Odonata

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We reflect on Philip Corbet's influence in leading us to focus on the seasonal regulation of Mediterranean Odonata. In the early 1990s, Philip was instrumental in fostering odonatological studies in both Spain and Algeria. It involved two visits to Algeria, an extensive correspondence and joint papers dealing with topics concerning life history, adaptation to Mediterranean climate and seasonal regulation.

FINCKE, Ola M.

Visual versus non-visual cues in sex recognition and harassment of *Ischnura elegans* damselflies under field conditions

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[1]University of Perugia, Italy; [2]University of Oklahoma, USA

Odonates have long been assumed to use visual cues in locating potential mates. However, in the lab, males of the damselfly *Ischnura elegans* can discriminate between the sexes and female color morphs using only air-born cues from eight individuals [1]. In Italy, we tested how free-flying males under field conditions reacted to conspecifics in the absence of visual cues. 'Non-visual' treatments consisted of eight live conspecifics of a given type (male, blue or green female) attached to dowels, or empty control dowels. Each set was concealed under a muslin bag. 'Visual' (plus odor) treatments were the four uncovered dowel sets, each placed in the same area adjacent to water. Male reactions during 10 min were scored as non-sexual or sexual. In the non-visual treatments, male reactions towards live conspecifics did not differ from the controls. In contrast, in the visual treatments, male sexual responses were higher towards live conspecifics compared to controls. Results suggested that in nature, males cannot locate conspecifics without visual cues. Because sexual reactions were relatively low we also quantified natural male harassment rates of marked, free-flying females. We discuss the relevance of our findings for odonate behavior and sexual harassment more generally.

[1] Frati F., Piersanti, S., Conti, E., Rebora, M. & Salerno, G. 2015. Scent of a Dragonfly: Sex Recognition in a Polymorphic Coenagrionid. PLoS ONE 10(8): e0136697. https://doi.org/10.1371/journal.pone.0136697

FINCKE, Ola M.

Philip Corbet: mentor to a very green and grateful grad student

Ola Fincke
Department of Biology, University of Oklahoma, Norman, OK 73019, USA

A short reminiscence on the role Philip Corbet played in my graduate career and beyond. Included are ways he promoted collegiality and exploration of new topics of investigation at the biennial meetings.

FRATI, F.

Chemical cues in Odonata: laboratory investigations

F. Frati[1], S. Piersanti[2], M. Rebora[2] & G. Salerno[1]
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Odonata adults are mainly visually oriented insects which have been considered anosmic for a long time. Here, we summarize the results of a project on Odonata chemical ecology through laboratory investigations. In particular an electrophysiological screening showed that *Libellula depressa* and *Ischnura elegans* responded to the same 22 compounds encompassing mostly amines, carboxylic acids or aldehydes and belonging to green leaf volatiles, vertebrate related volatiles and volatiles emitted by bacteria found in standing water.

Laboratory bioassays, confirmed by electrophysiological recordings, showed that adults of *I. elegans* are attracted by olfactory cues emitted by prey, that males prefer female odour to male odour, and that females prefer to lay more eggs in water from larval rearing aquaria than in distilled or tap water.
Moreover, in single-cell recordings, antennal sensory neurons of *I. elegans* sensitive to different airborne odors were strongly inhibited by CO_2, with the magnitude of the off-response depending upon the CO_2 concentration. The biological role of carbon dioxide detection in Odonata is still unknown.

Further behavioural experiments are necessary to clarify Odonata chemical ecology in the field. Uncovering the sense of smell in Odonata is an important starting point for further molecular investigations on olfactory receptors in the more ancient winged insects.

FUTAHASHI, Ryo

Opsin gene diversity in dragonflies

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Dragonflies are colorful diurnal insects with large compound eyes. Because they visually recognize conspecific and heterospecific individuals, their body color plays essential roles in ecology and reproductive biology. We discovered an extraordinarily large number of visual opsin genes by RNA sequencing of 12 dragonfly species. Manual correction after *de novo* assembly was crucial for determining the exact number and sequence of opsin genes. Each opsin gene was differentially expressed between adult and larva, as well as between dorsal and ventral regions of adult compound eyes, highlighting the behavior, ecology and adaptation of aquatic larva to terrestrial adult. The repertoire of opsin genes differed among dragonfly species, plausibly involved in the diversity of the habitat and behavior of each species.

GOERTZEN, Diana
Large-scale impact of anthropogenic land-use on dragonfly fauna and diversity
Diana Goertzen & Frank Suhling
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Central European landscapes are mainly shaped by anthropogenic land-use resulting in either urban, agricultural, rural or forestal landscapes. This raises the question whether and how land-use affects the dragonfly fauna at the landscape-scale: Do anthropogenic landscapes have a specific dragonfly fauna? Are there species promoted by any kind of land-use? We analysed species composition and dragonfly diversity patterns using profound databases from dragonfly surveys all over Germany based on 10x10km^2 grids. For analysis we chose grids that were dominated by one kind of land-use. Results showed that species composition differed between grids of different land-use types. Although the range of species was similar, abundance patterns differed significantly. We could identify several species which indicated a certain kind of land-use, e.g. *Anax imperator* and *Sympetrum striolatum* in urban as well as *Cordulegaster boltonii* in forestal grids. Further analyses of different components of diversity will provide deeper insights into how land-use impacts dragonflies. In conclusion, our results indicate that land-use acts as an important driver for distribution and diversity patterns of dragonflies. Understanding these patterns helps to improve dragonfly conservation.

GONZALEZ-BELLIDO, Paloma
A deadly game of "tag": What are TSDNs and do they drive the dragonfly predatory attack?
Paloma Gonzalez-Bellido
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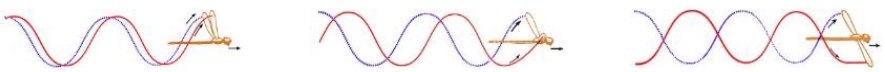
To ensure survival, animals must constantly make decisions and act upon them. The fluidity of such movements hides enormous complexity: How does an animal decide how to move, so that it arrives at the correct place at the right time? Although we understand much about the early visual system of insects, our understanding of how this is information is finally encoded to actuate goal driven actions (such as predation) is still limited. By understanding encoding of moving targets at such level, we will be have the input-outputs of the system, a fundamental step in making propositions about the neural underpinning of the predatory flight. In this presentation I will review our knowledge of target descending neurons and discuss whether, as originally proposed, they drive the predatory attack.

GORB, Stanislav
Structure and properties of dragonfly wings: composite structure of fibrous material supplemented by resilin
Esther Appel, Hamed Rajabi & Stanislav Gorb
Department of Functional Morphology and Biomechanics, Zoological Institute of the University of Kiel, Am Botanischen Garten 9, D-24118 Kiel, Germany

The exceptional aerodynamic performance and damage tolerance of dragonfly wings is due to the combination of their macro- and microscopic structure and material composition. This paper combines the approaches of bright-field light microscopy, wide-



field fluorescence microscopy, confocal laser-scanning microscopy, scanning electron microscopy and transmission electron microscopy and shows that wing veins consist of up to six different cuticle layers. Longitudinal and cross veins differ significantly in relative thickness of exo- and endocuticle, with cross veins showing a much thicker exocuticle. The presence of resilin in the unsclerotised endocuticle suggests its contribution to the increased energy storage and structural flexibility, thus to the prevention of vein damage. This is especially important in the highly stressed longitudinal veins, which should not fail when subjected to the applied forces during flight, as in cross veins. Morphological data have been used to develop a series of three-dimensional numerical models with different material properties and geometries. Finite element analysis has been employed to simulate the mechanical response of the models under different loading conditions. Numerical simulations suggest that although the presence of the resilin-dominated endocuticle layer results in a much higher flexibility of wing veins, the dumbbell-shaped cross section increases their bending rigidity. The rubber-like cuticle and material gradient-based design are expected to contribute to the higher damping capacity of veins.

GUILLERMO-FERREIRA, Rhainer
Neotropical Odonata
Rhainer Guillermo-Ferreira
Universidade Federal de São Carlos, Estado de Sao Paulo, Brazil

Abstract not available

GÜNTHER, André
Signalling with clear wings in African Chlorocyphidae
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The reproductive behaviour of different African chlorocyphids was filmed at 600 fps. Different flight styles were analysed with respect to changes in wing beat frequency and phase relationships of fore and hind wings. The analysis revealed significant differences in the flight style between non-escalated and escalated threat display as well as changes in the wing beat frequency of males during courtship dependant on the behaviour of the female. The behaviour fits very well with my results in narrow-winged Asiatic *Disparocypha, Heliocypha* and *Libellago* species. This is the first evidence suggesting that odonate species with clear wings can use specialized flight modes for intraspecific signalling. It is a reasonable conclusion that the evolution of the extraordinary wing displays of coloured-winged Odonata species was based on a simple display by frequency changes, which already occurs in species with clear wings.

HASSALL, Chris
The evolutionary ecology of urban dragonfly populations
Chris Hassall
School of Biology, University of Leeds, Leeds LS2 3JT, UK

Anthropogenic environmental change is a multifaceted problem facing biodiversity, and this problem is perhaps most acute in cities. Urbanisation leads to the loss of natural

habitats along with a reduction in the quality and connectivity of those habitat patches that remain. I will provide an overview of the ecological and evolutionary impacts of urbanisation on odonate populations, with a focus on the UK. I will begin by highlighting general trends in diversity in odonate richness and community structure across urban areas in the UK, with reference to other parts of Europe, using a dataset of 1,000 pond surveys. Focusing on London, I will discuss the relative impacts of the urban heat island and regional climate change on odonate phenology. For evolutionary consequences, I will first discuss the role of landscape type (from urban to rural) on wing morphometrics, as a proxy for selection on flight capacity. I will finish with a discussion of the capacity for evolution in polarotaxis, which represents a key response to novel urban stressors such as polarised light pollution.

HIGASHIKAWA, Wataru

Microhabitat use by an endangered dragonfly *Sympetrum pedemontanum elatum* (Selys) in Japan

Wataru Higashikawa[1], Mayumi Yoshimura[2] & Kao Maeto[1]
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Sympetrum pedemontanum (Allioni), which is distributed widely in the Eurasian continent and its neighboring islands, is facing regional extinction or is decreasing in several European countries and Japan. For the conservation of *S. p. elatum* (Selys) in Japan, we have studied its microhabitat use at the larval and adult stages.

Because *S. p. elatum* larvae cannot be morphologically discriminated from coexisting congeners, we first designed species specific PCR primers for molecular identification. In the field survey in Hyogo Prefecture, Japan, we found that *S. p. elatum* larvae preferred stagnant water immediately after hatching and subsequently advanced into weakly flowing water. Our results indicate that they seasonally change their microhabitat use during development, reflecting their need for a continuous spectrum of stagnant, transitional, and flowing water. Such a water spectrum has been disappearing with the modernization of water systems in rice paddy fields in rural Japan.

Meanwhile, previous studies had shown that *S. p. elatum* adults tended to fly on the flat surface of rice paddies. Thus, we hypothesized that they preferred short and flat grass. Our field experiments showed that the adults significantly preferred trimmed to untreated shaggy grass, implying the importance of grass management in the fluvial habitats for the conservation of this species.

ICHIKAWA, Yuta

Daily egg production in females of the wandering glider dragonfly, *Pantala flavescens*, in relation to food intake (Odonata: Libellulidae)

Yuta Ichikawa & Mamoru Watanabe
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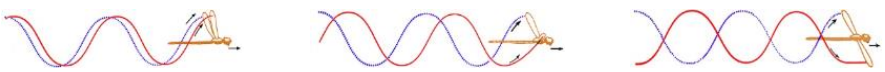
The wandering glider dragonfly, *Pantala flavescens*, arrives in Japan from tropical regions every spring. The population rapidly increases as autumn nears, but is followed by death in the winter cold. They often form foraging swarms above open grasslands for feeding on small insects, while the oviposition activity is observed at various open waters. Although egg production requires the nutrition from prey insects, there has been little consideration of the relationship between food intake and the number of eggs



produced. In the early morning, females of reproductive stage were captured in grasslands. Immediately after capture, an artificial oviposition technique was applied to each female to induce release of all mature eggs loaded. Then they were reared with water in the lab, and the dry weight of faeces excreted and the number of eggs produced were measured in each 24 h after capture. The estimated daily food intake was about 14 mg, corresponding to about 185 small prey insects. Females reared with water for 24 h released about 840 mature eggs, suggesting that when females take in a sufficient amount of daily food, they can oviposit a large number of eggs every day. The rapid egg production might enable the population of *P. flavescens* to grow.

JABLOTSCHKIN, Dominik

An approach for prioritizing dragonfly habitats on the basis of heterogeneous data

Dominik Jablotschkin
Institute of Geography, Ruhr University, Bochum, Germany

Efforts to protect and conserve dragonflies depend on a good data basis. Not least thanks to Citizen Science Projects there are big data collections in many places. These data often provide the potential for an analysis at the level of specific habitats. However, there is a lack of appropriate methods to assess the large number of dragonfly observations in a meaningful and comprehensive way. This paper presents a possible method to detect habitats of high importance to dragonflies and damselflies.

The presented methodology was designed with the intention to be flexible so that it could be used on data collections of different origins and any sizes. This was achieved by a high degree of automation, among other things. Challenges, especially those based on the heterogeneity of the used data, are discussed. The results of the procedure provide information about which biotopes are a constant reproduction site of a significant number of species or of endangered species. Furthermore those populations that are of high importance to the species' survival are highlighted. For demonstration purposes, the results of the approach for North Rhine-Westphalia are presented. Finally some relevant aspects for application using other databases are discussed.

JARZEMBOWSKI, Ed

Evolution of the odonate wing

Edmund A. Jarzembowski[1,2] & Daran Zheng[1,3]
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Dragonflies have an excellent fossil record on account of their large size and association with water-laid geological sedimentary deposits. Moreover, the ready preservation of the complex wing venation provides systematically useful features including the appearance of the pterostigma, nodus and arculus. Dragonflies *sensu lato* – in the broad, palaeontological sense or odonatopterans – date back to the earliest-known, late Palaeozoic radiation of the pterygotes (winged insects) in the mid-Carboniferous, circa 325 million years ago. The Carboniferous geropterans resemble some other contemporary insects that did not habitually fold their wings. The Carboniferous-Permian meganisopterans ('protodonatans', 'griffenflies'), by contrast, included the celebrated giant dragonflies which were the top aerial predators of their time in well-oxygenated, low-

latitude, coal-forming forests. Smaller, narrow-winged protozygopterans were, however, also present by the Late Carboniferous; these and other extinct lineages survived the Permo-Triassic crisis.

Modern dragonflies in the entomological sense made their debut in the Mesozoic Era (age of the dinosaurs). True (anisopteran) dragonflies arose in the Jurassic Period, accompanied by diverse anisozygopterans (damsel-dragonflies) unlike today. One of the most exciting discoveries of the past few years has been the recovery of numerous odonatans in mid-Cretaceous Burmese amber (circa 100 million years old). The inclusions, especially the true damselflies (zygopterans), were entrapped in a resinous, coniferous woodland amidst the burgeoning angiospermous flowering plants along the north-eastern fringe of the Tethyan ocean. Questions remain, however, such as what the earliest dragonfly larvae were really like.

JOHANSSON, Nathalie

Studying hidden diversity: *Aeshna grandis* from Sweden are highly genetically variable

Nathalie Johansson[1], Jessica L. Ware[2] & Göran Sahlén[1]
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[2]Department of Biological Sciences, Rutgers University, Newark, NJ, USA

Aeshna grandis is a species of "Least Concern" and the antithesis of a rare taxon. It occurs in a wide range of habitats and is in many areas of Europe considered very abundant. Here, we sequenced ~100 larval samples from Sweden, and reconstructed a phylogeny comprised of 11 Aeshnidae genera. We used cytochrome oxidase one (COI) to evaluate intrafamilial generic relationships, and relationships among *A. grandis* individuals from 13 populations. We reconstructed a phylogeny using maximum likelihood, and estimated a haplotype network using Popstar to generate a minimum spanning network.

The COI in *A. grandis* was found to be highly variable, forming three distinct clades, apparently existing in sympatry. Larvae from these clades were found to have no distinguishing morphological characters, and appear to be a single species. *A. grandis* shares COI haplotypes with North American and European *A. crenata*, *A. juncea*, *A. mixta*, *A. serrata*, *A. subarctica* and *A. umbrosa*, with the three clades differing in their patterns of haplotype in relation to other *Aeshna* species.

Our findings suggest that the observed genetic variation indicates a possible separation in habitat choice among groups, evidence for cryptic speciation or temporal separation due to long flight season.

KALNIŅŠ, Mārtiņš

Distribution and population size of Odonata in Latvia from 1778 till 2016: the role of forest management

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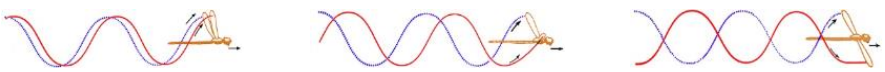
JSC "Latvijas valsts meži", Vaiņodes Str 1, Riga, LV-1004, Latvia

Dragonflies represent a faunistically well studied group of invertebrates in Latvia. Up to now, 62 dragonfly species in nine families have been recorded. Up to 2016 (inclusive), there were 12065 records in the database on the distribution of dragonflies in Latvia, covering the time period from 1778 to 2016. Since 2001, seven new species of dragonflies have been found in Latvia. The discovery of six species is related to the northward expansion of the species.



In 1923, wooded land comprised 25% of the territory of Latvia, but currently comprises 54%. Management of wooded land creates both direct and indirect impacts on the water bodies of forests: rivers, streams, ditches, lakes, ponds, bog pools, beaver dams, etc. Both physical and chemical parameters of water bodies, and the composition of vegetation species and structure both in the water bodies and an area 30–50 m from the shore are significant to dragonflies. The major factors associated with forest management that impact the distribution and population size of dragonflies are the following:

- felling (creation of new, open areas; formation of pools and other small water bodies during the logging process),
- renovation and maintenance of forest drainage system (draining of natural wetlands, formation of new migration corridors and habitats),
- construction of forest roads and the related elements (formation of new migration corridors and habitats),
- preparation of bogs for peat extraction, and peat extraction (drainage of natural habitats and modification of them).

These factors generally enhance the distribution and population size of dragonflies. Reconstruction of forest drainage systems have had a local negative impact on *Cordulegaster boltonii*, but preparation of bogs for peat extraction and peat extraction itself, negatively impact species, such as *Somatochlora arctica*, *Aeshna subarctica* and *Leucorrhinia albifrons*.

Impact of forest management activities on chemical composition and physical characteristics of small forest lakes that may affect, for example, populations of *Aeshna crenata* in Latvia, have not been explored sufficiently.

KOHLI, Manpreet Kaur

Genetic structure among different populations of *Aeshna juncea* in the Holarctic

Manpreet Kaur Kohli[1], Göran Sahlén[2] & Jessica L. Ware[1]
[1]Department of Biological Sciences, Rutgers University, Newark, NJ, USA; [2]Ecology and Environmental Science, Halmstad University, Halmstad, Sweden

A. juncea is one of only four known odonate species that has a Holarctic distribution; that is, its populations are found all across the continents of North America and Eurasia. A question that immediately comes to mind is, how does this species maintain such a large distribution across continents. Are individuals from different populations migrating across the continents thereby maintaining gene flow among them or are they starting to become genetically isolated? In this study we unravel some of these questions. Sequences from mitochondrial molecular marker cytochrome oxidase 1 (COI) were used to investigate the genetic structure of this species. Samples used in the analysis included populations from

Canada, Alaska, Germany, Russia, Japan and South Korea. Our results show that *A. juncea* has genetically distinct haplotypes in North America and Europe. However, populations from Japan seem to share genetic similarities with both North America and European populations. This indicates that North America populations and European populations are the two ends of the vast *A. juncea* range.

KOHLI, Manpreet Kaur

Low levels of genetic variation in the treeline emerald, *Somatochlora sahlbergi*

Manpreet K. Kohli[1], Göran Sahlén[2] & Jessica L. Ware[1]
[1]Biology department, Rutgers University, Newark, USA -07102; [2]Ecology and Environmental Science, Halmstad University, Halmstad, Sweden

Somatochlora sahlbergi is known as the northernmost breeding dragonfly. In this study we compared genetic and morphological variation as well as habitat choice between populations near the Arctic Circle in northern Europe and the Yukon. We found that despite geographic barriers across its vast arctic range, *S. sahlbergi* seems to be interbreeding between these areas and there is almost no variation among European and North American populations in their Cytochromes oxidase 1 (CO1) gene fragment or their D7 gene. We further found that characters thought to be diagnostic for the larvae of *S. sahlbergi* were absent in most of our European samples. The habitat occupied by the larvae sampled in northern Europe differs from what has been previously reported in the literature. These findings are discussed in the context of conservation measures, climate change, ecology and habitat choice and phylogeny of the genus *Somatochlora*.

KUHN, William R.

Automatic dragonfly identification with Odomatic and the Targeted Odonata Wing Digitization (TOWD) project

William R. Kuhn[1], Jessica L. Ware[2], John C. Abbott[3], Melissa Sanchez-Herrera[2] & Dirk Gassmann[2]
[1]University of Tennessee, Knoxville, TN, USA; [2]Rutgers University-Newark, NJ, USA; [3]University of Alabama Museums, University of Alabama, Tuscaloosa, AL, USA

Species identification underlies biological studies, informs management and conservation, and connects people with the natural world around them, but it's not always easy. New, game-changing smartphone "apps" like LeafSnap and Merlin Bird ID have made this task easier than ever, and the machine learning systems that power them have the potential to revolutionize the way we interact with life on Earth, but no system like this yet exists for identifying dragonflies and damselflies. Here, we present Odomatic, a system that accurately classifies Odonata from images of their wings, and the Targeted Odonata Wing Digitization (TOWD) initiative aimed at digitizing the wings of North American odonate taxa, as well as some Central and South American species. Odomatic, trained on the TOWD dataset, will be able to identify most of the Odonata of the New World, and the dataset will provide a unique, extensive resource for studying wing evolution in Odonata. Finally, we will introduce another exciting extension of Odomatic, currently under development, allowing it to identify Odonata from real-world photographs by leveraging the vast store of images in OdonataCentral.org. Funding provided by NSF grants 1611642 and 1564386.

LAUGHLIN, Simon

Why do dragonflies have the longest photoreceptors in the animal kingdom?

Simon Laughlin
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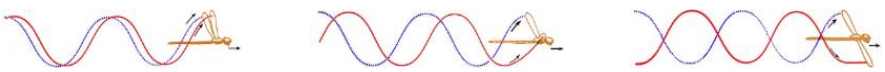
A longer photoreceptor catches a higher proportion of incident photons, so one might expect photon-starved deep sea fish or squid to have the world's longest photoreceptors. Indeed, compared with most animals their photoreceptors are long, with outer segments



of 280 µm and 600 µm respectively [1, 2], but the rhabdomeres of sun-drenched dragonflies are longer; 720 µm in *Hemicordulia tau*'s ventral eye and 800 µm in its dorsal [3]. The current world record holders are 1100 µm rhabdomeres in the dorsal eye of *Sympetrum*. These champions are in a zone that is specialised to detect small prey against the bright sky. Their exceptional length improves detection by increasing photon catch and providing sufficient transduction units (microvilli) to convert captured photons into electrical signals [4]. But why are photoreceptors in less overtly specialized regions of dragonflies' eyes longer than those of most animals? Dragonflies' long photoreceptors are especially costly; eye volume increases as (length × corneal surface area) and, because apposition optics provides spatial acuity inefficiently, surface areas are large. With a typical surface area of 25 mm^2 (from data in [5]) an extra 40 µm of length adds 1 mm^3 of eye volume.

We show that dragonflies' long photoreceptors optimize investment in spatial vision [6] by modelling how an eye's ability to code spatial information changes when a given investment of resources is redistributed among its components (e.g. by reducing the number of ommatidia and increasing photoreceptor length). Following [7], we calculate the bits of spatial information acquired from a daylit natural scene as a function of eye volume, number of ommatidia and, via number of transduction units, rhabdomere length. For every total investment in eye there is an investment in photoreceptor length that maximizes information. This optimum length increases with eye volume, and hence spatial acuity, to values seen in dragonflies. Thus long photoreceptors are the norm in dragonflies because they are an efficient investment in spatial vision. We confirm that dragonflies pay a high price for their visual acuity because they use inefficient apposition optics. A simple camera eye with more efficient optics gathers information at a fraction of the cost per bit and, because investment in optics is more efficient, has much shorter photoreceptors.

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LEHMANN, Fritz-Olaf

Wing phasing in dragonflies

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Insects are capable of a remarkable diversity of flight techniques. Dragonflies, in particular, are notable for their powerful aerial manoeuvres and endurance during prey catching. An extraordinary feature of dragonfly wing kinematics is wing phasing, the shift in flapping phase between the fore and hind wing periods. Despite efforts at understanding the implications of flapping flight with two pairs of wings, previous studies have generally painted a rather disappointing picture: interaction between fore and hind wings reduces the lift compared with two pairs of wings operating in isolation. However, wing phasing is effective in improving aerodynamic efficiency during flight by the removal of kinetic energy from the wake wasted as swirl in a manner analogous to coaxial contra-rotating helicopter rotors. We demonstrate that this increase in flight efficiency may save up to 22% aerodynamic power expenditure compared to insects flapping only two wings. The lecture provides a summary on power expenditures and aerodynamic efficiency in flapping tandem wings by investigating wing phasing in a dynamically-scaled robotic model of a hovering dragonfly.

LESCH, Velesia

First report of perfluoroalkyl substances in South African Odonata

Velesia Lesch[1], Hindrik Bouwman[1], Ayako Kinoshita[2] & Yasuyuki Shibata[2]
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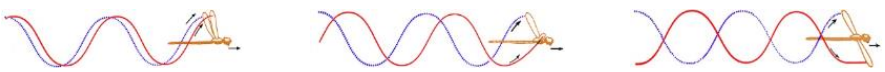
Perfluorinated substances (PFASs) are global and ubiquitous pollutants. Since perfluorooctane sulfonate (PFOS) appears to be the degradation product of many PFASs, its accumulation in wildlife dominates. Dragonflies play key roles in both terrestrial and freshwater aquatic habitats. They are both prey and predator to a variety of species; they are known indicators of biotope quality and biological health of aquatic habitats. In this study, adult male dragonflies from six sites in South Africa were collected and analysed to determine the concentration of PFOS to investigate their utility as environmental indicators. Quantifiable occurrences of PFASs were found, with PFOS dominating total PFASs concentrations in all samples. Samples obtained from the three northern sites located near agricultural areas had lower PFOS concentrations than the three southern sites located near industrialized areas (median total PFASs of 0.32 ng/g wm (wet mass) for north, and 9.3 ng/g wm for south). One of the southern sites (Bloemhof Dam) that is known to be a polluted area had the highest median concentration (total PFAS 21 ng/g wm). It is not likely that these substances are manufactured in South Africa and are most likely from imported products. Odonata are therefore excellent indicators of environmental pollution.



LESCH, Velesia

A potential identification technique to identify individual dragonflies using four, two-digit numbers

Velesia Lesch
Research Unit for Environmental Sciences and Management, North-West University, Potchefstroom, South Africa

The identification of individual dragonflies based on natural markings has not yet been established. We noted differences in the number of cells on the anterior edges of the left and right wings. We present a possible method using the number of cells between the costal and subcostal veins of the antenodal and postnodal regions of the left and right forewings, giving four, two-digit numbers. We counted the number of cells in the each region, starting from the humeral plate to the nodus, and from the nodus to the pterostigmatum, for both forewings. Four, two-digit numbers were then noted as a series starting from left outer to right outer, that serves as a numeric identity. Examples are 10-12-12-09 and 10-13-12-10, for *Orthetrum chryostigma*.

We found duplicate identities for three pairs of *O. chryostigma* (out of 21), and two pairs of *Trithemis arteriosa* (out of 13). In three cases, additional aberrations in the wing allowed separation. Additional options for refinement exist. We are now testing the practicality of this technique in the wild. By photographing dragonflies in the wild and using wing patterns to assign identities, we hope to improve our understanding of individual behaviour.

LIN, Huai-Ti

Wireless neural telemetry recording in freely flying dragonflies

Huai-Ti Lin
Department of Bioengineering, Imperial College, London, UK

The behaviors of dragonflies have intrigued generations of naturalists. What rules govern these behaviors and how does the sensorimotor system implement them? These questions are best answered by eavesdropping on the relevant neural circuits while the dragonfly is behaving. Recent developments of neural telemetry have allowed us to monitor neural activity (e.g. visual interneurons, flight motor neurons, muscle) in a freely flying dragonfly via a 50mg insect backpack. Here I will introduce two such projects. Firstly, a class of visual interneurons specifically tuned to small targets (TSDNs) are thought to drive the reactive flight steering during prey interception. However, there has been no direct evidence if and how they are involved. My wireless recordings of hunting dragonflies show that these neurons fire more prior to takeoff, suggesting a strong role in flight planning. Secondly, the structural properties of the dragonfly wings have been frequently linked to the flight mechanics. The wings are adorned with mechanosensors that could provide necessary feedback for flight control. I will share preliminary recordings of a group of campaniform sensilla from a flying dragonfly. This ongoing project links dragonfly flight to sensory encoding directly and will provide insights to the evolution of insect wings and flight.

LONTCHI, Judicael Fomekong

The diversity of the dragonfly fauna in Minko (South Cameroon)

Judicael Fomekong Lontchi[1], Jacques Anselme Massussi[2], Zéphirin Tadu[1], Stéphanie Kakam[1], Gertrude Tchoudjin[1], Syntiche Aymele Choungmo[1] & Champlain Djieto-Lordon[1]

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Odonata as larvae are beneficial insects and adults feed on harmful insects and are important components of aquatic food webs. Also, they are good indicators of overall habitat quality. Knowledge of the diversity and ecology of these insects is growing in Africa but little is known in Cameroon as most of the investigations have been done in the south-west part of the country. From August 2016 to February 2017, we conducted a monthly survey of adults in five different habitats situated in the locality of Minko (South region of Cameroon) between 8:00 a.m. to 6:00 p.m.

A total of 97 species belonging to 10 families were collected. The Libellulidae (47.69%) were the most abundant, followed by Coenagrionidae (28.39%) and Platycnemididae (15.69%). The Libellulidae included 51 species, the Coenagrionidae, 23 species and the Platycnemididae, 6 species. Open streams were the home of 55 species and were the most diversified of the 5 habitats (H' = 3.27, E = 0.82). The less diversified habitat was the river in the forest (H' = 2.26, E = 0.62).

This work helped to add many new records for Cameroon, notably *Gynacantha victoriae, Tetrathemi fraseri, Porpax sentipes, Tetrathemis longfieldae.*

LOZANO, F.

Description of the final instar larva of *Argia serva* Hagen in Selys, 1865 (Odonata: Coenagrionidae)

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Laboratorio de Biodiversidad y Genética Ambiental, CONICET – UNDAV, Buenos Aires, Mario Bravo 1460 esq. Isleta, Piñeyro, Argentina

The American genus *Argia*, with more than 100 species described, is the most speciose genus of Odonata in the world. In Argentina 11 species have been recorded; from these only the larvae of four have been described: *A. croceipennis*, *A. joergenseni*, *A. jujuya*, and *A. translata*. In this contribution the final stadium larvae of *Argia serva* is described based on reared material from Buenos Aires, Argentina. *Argia serva* is the southernmost distributed species of *Argia*, and is also recorded from Uruguay and Southern Brazil. The larva of this species can be easily separated from the other Argentinean *Argia* by the following combination of characters: sternum of S8 covered with spines (bare in *A. translata*); antennal segment 3 longer than 1+2 (equal to or shorter than 1+2 in *A. joergenseni* and *A. jujuya*); palpal setae absent (present in *A. croceipennis*). Larvae were collected in Martín García, an island with historical value found in the confluence of the Uruguay and Parana rivers (Rio de la Plata estuary), and since 1973 a Provincial Reserve for fauna and flora. The larvae were found in ponds connected to the shore of the river, under rocks.

MARTENS, Andreas

Ballistic defaecation as a widespread phenomenon in larval Anisoptera (Odonata)

Andreas Martens
Institute for Biology, University of Education Karlsruhe, Bismarckstrasse 10, 76133 Karlsruhe, Germany

Certain anisopteran larve eject their faecal pellets in a way that these can be propelled far away from the originator. The phenomenon termed as “ballistic defaecation” came into major focus when P.S. Corbet [1] drew special attention to it. Beside several other aspects Corbet addressed the question on the known spectrum of larval odonates which show ballistic defaecation.

So far, the majority of records of ballistic defaecation have been based on recording faeces outside the container, when anisopteran larvae which behave as claspers were held in captivity. By using transparent plastic containers with a lid the number of species known to show this behaviour could be enlarged significantly and included several species of Aeshnidae, Cordulegastridae and Libellulidae. In the case of Gomphidae the results have not been comprehensibly repeated so far. The anisopteran larve were kept at low water-level (1–1.5 cm), with sand, gravel or gauze as a substrate. They were held in the containers either just after collection in the field without any food supply or for longer periods and fed with ephemeropteran larvae (*Cloeon*), dipteran larvae (Chironomidae or Culicidae) or amphipods (*Gammarus* sp.). A clear indication for ballistic defaecation has been when the pellet stuck to the underside of the lid. In many cases the pellet has been within a large drop of water indicating that it was propelled away by jet propulsion which has been interpreted as escape or defence behaviour.

[1]. Corbet, P.S., 2004. Ballistic defaecation by anisopteran larvae (Odonata): a way to increase foraging success? International Journal of Odonatology 7(1): 25–32.

Plenary lecture: Mike May

MAY, Mike

Odonatology, 2017–2050

Mike May
Department of Entomology, Rutgers University, New Brunswick, NJ 08901, USA

Predictions (and hopes) for odonatology at mid-century:

- Odonata and odonatologists will still be extant, despite the best efforts of certain politicians.
- Alpha taxonomy will still be at the forefront of the discipline – we need to know what we have.
- We will finally figure out what “Calopterygoidea” and “Synthemistidae” are.
- The focus of research will be on the tropics, and will be carried out largely by indigenous scientists (as is increasingly true already).
- Detailed studies of larval ecology, using direct observation in the field and naturalistic laboratory environments that permit control of physical conditions, substrate, water quality, prey type and abundance, and predator pressure will provide new insight into habitat features required by immature stages and improve prospects for conservation.

- Imaging techniques will continue to improve in sophistication, ease of use, and affordability and will enable external and internal features to be recorded non-destructively, in living as well as dead individuals, opening up new possibilities in systematics, functional morphology, behavior, and physiology.
- It will become possible to track individual Odonata continuously for long periods and over great distances, leading to major advances in the study of behavior, population ecology, and conservation.

MAY, Mike

Catching up with migration

Michael L May
Department of Entomology, Rutgers University, New Brunswick, NJ 08901, USA

A recurrent objective of Philip Corbet's work, embodied very clearly in his early research at Cambridge, was to understand Odonata life histories, their environmental control, evolution, and adaptive features, including the role of migration in life history.

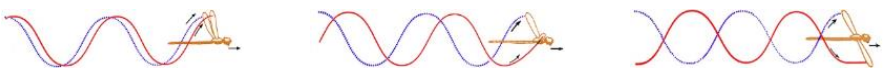
Recent work suggests that the best-known North American migrant, *Anax junius*, consists not of clear-cut migrant and resident cohorts but rather that individual responses of larvae to environmental cues may dictate whether an individual pursues a migrant or resident strategy. This may be because larval emergence success is unpredictable year to year in most breeding areas. Other species, e.g., *Pantala flavescens*, may be obligate migrants because they have not evolved larval diapause. This species probably undertakes the longest migrations of any insect; it is largely confined to the tropics but its ability to overwinter as a larva in northern temperate regions is still to be investigated. Some species may migrate to warm temperate or subtropical areas and diapause, or reproduce in permissive conditions, as adults. Others, e.g., *Libellula quadrimaculata*, are perhaps only occasional migrants, in which the behavior may not be adaptive. Among many unanswered questions is that of the effect of influxes of migrants on aquatic communities at their destination.

MORGHAD, F.

Environmental determinants of biodiversity of Odonata of two Mediterranean rivers in northeast Algeria

F. Morghad & B. Samraoui
Department of Biology, University of Annaba, Algeria

In our study, we were interested in the odonate communities of two Mediterranean rivers (wadis) in northeast Algeria. The first wadi, Bounamoussa, is 56 km long and was explored for the first time. We monitored 20 stations along its entire length. The second watercourse was wadi Bouaroug, which has not been studied since 1993. This is a small stream of about 3 km long, located within the El Kala National Park. We monitored 5 stations of this second wadi. All of the study stations were sampled monthly during a period of 9 months. The total odonatological species richness amounted to 31 species with 17 species common to both wadis. A total of 30 and 18 species were recorded in Bounamoussa and Bouaroug, respectively. Identified specimens belonged to 7 families with the Libellulidae, the most abundant (44% of all specimens), represented by 13 species followed by the Coenagrionidae (26%) represented by 3 species and the Platycnemididae (17%) represented by 1 species. Other families like the Lestidae (7%)



were represented by 4 species whereas the Calopterygidae (3%) had only one species, the Gomphidae (2%) 3 species and the Aeshnidae (1%), the least abundant taxon, had 5 species. Shannon-Wiener index of species diversity was 1.19 and 1.03 in Bounamoussa and Bouaroug, respectively. Multivariate and univariate analyses were performed to identify environmental determinants of species assemblages along these two wadis. The present study also contributed to a better knowledge of the status and distribution of North African endemics, threatened or data deficient (DD) species.

MUZÓN, Javier

The founding and future of the Sociedad(e) de Odonatología Latinoamericana (SOL)

Javier Muzón
Laboratorio de Biodiversidad y Genética Ambiental, CONICET – UNDAV, Buenos Aires, Mario Bravo 1460 esq. Isleta, Piñeyro, Argentina

Abstract not available.

MUZÓN, Javier

Decoupling positional and environmental variations from Gloger´s ecogeographical rule: an intraspecific case from the Patagonian damselfly *Cyanallagma interruptum*

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Phenotypic variation is one of the possible biotic responses to environmental fluctuations that allows the persistence of local populations. The aim of this contribution is to analyze intraspecific colour pattern variation and its relation to positional (elevation, latitude and longitude) and environmental (temperature and rainfall) variations in *Cyanallagma interruptum* the most abundant and widespread damselfly in Patagonia, South America

Specimens of *C. interruptum* were classified based on its pterothorax pigmentation into five morphotypes. A pigmentation index was calculated for each sex as a percentage of the total number of individuals of the population. Regression analyses were used to examine the relation between the pigmentation index (dependent variable) and different geographic variables. The Mean Difference test showed that females were significantly paler than males. Regression analyses showed a linear relation between pigmentation index and rainfall for both sexes. Females also showed a significant difference between the pigmentation index and longitude. Frequencies of darker morphotypes differ in Patagonia along a forest-steppe (east-west) gradient, following a longitudinally significant cline in dark individual frequencies. This cline is more related to humidity than to positional longitude, as the east-west rainfall variation pattern in Patagonia varies according to latitude. An increased capacity to avoid overheating in the hottest part of the day due to pale colour pattern in steppe populations is postulated as the underlying mechanism for this cline.

MUZÓN, Javier

A new genus and species of Coenagrionidae (Zygoptera) from South America

Javier Muzón & Federico Lozano,
Laboratorio de Biodiversidad y Genética Ambiental, CONICET – UNDAV, Buenos Aires, Mario Bravo 1460 esq. Isleta, Piñeyro, Argentina

A new genus and species of Coenagrionidae is described from 8 ♂ and 2♀ from Brazil and Argentina (Holotype and Allotype: Argentina, Corrientes, Santo Tomé, Ita Cuá stream on provincial route 94, 28°26'48.30"S – 56°00'33.11"W, 24.ii.2003, Muzón, J. & Pessacq, P. leg, deposited at MLP collection). General morphology places the new genus within Ischnurinae. Among the South American Ischnurinae the combination of a rounded frons, presence of pale postocular spots, a trilobate prothoracic posterior lobe, striped pterothorax, and male cerci armed with some kind of process is common to *Cyanallagma* Kennedy, *Homeoura* Kennedy, some species of *Ischnura* Charpentier, *Leptobasis* Selys, *Mesamphiagrion* Kennedy, *Oreiallagma* von Ellenrieder & Garrison, *Schistolobos* von Ellenrieder & Garrison, and *Telagrion* Selys. From these, the new genus and *Oreiallagma* are the only ones who share cerci which have dorsal and ventro-apical processes but lack a ventro-basal process. However, both genera can be easily separated by the morphology of male genital ligula (segment 2 with sclerotized latero-apical folds in *Oreiallagma*; without these folds in the new genus). Males of the new species are readily recognized by the morphology of the cerci: in lateral view with an acute apophysis directed dorsally located at 0.3 from base, tip rounded and pointing dorsally; in dorso-medial view widened distally, outer angle rounded, inner angle pointed and directed ventrally. Genital ligula with flexure short (distal segment longer than flexure); segment 3 slender, without lateral lobes; ental surface with a middle sub-rectangular lobe that reaches segment 2; distal margin with indentation; disto-lateral projections acutely pointed not surpassing segment 2. Females with mesostigmal plates wide (with medial margin approximately equal to anterior margin); without mesepisternal fossae; vulvar spine well developed. Holotype and allotype were collected in marshy area around a pine tree plantation which was crossed by a small creek.

NING, Xin

Rechecking the species group of *Coeliccia cyanomelas* (Zygoptera: Platycnemididae)

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Institute of Entomology, College of Life Sciences, Nankai University, Tianjin, China

Abstract not available

Plenary lecture: Ulf Norling

NORLING, Ulf

Proximate responses in the seasonal regulation of *Lestes sponsa*: egg diapause termination, hatching synchrony, and effects of photoperiod on larval development

Ulf Norling
Malmö University, Malmö, Sweden

After Corbet's pioneering studies, all appeared simple. After oviposition in late summer, eggs overwintered in an obligatory late-embryonic diapause, terminated during low temperatures. After synchronous hatching in spring, larvae grew fast, and metamorphosed in summer.

It was later shown that diapause termination also depended on long days and wetting, that larval development rate accelerates in a late photoperiodic regime, and that maturation can be delayed by a reproductive diapause.

In south-Swedish material, photoperiod and low temperatures interacted from the inception of diapause, like in many other insects. After transfer to 21°C and different photoperiods (12–24 hours), from 5°C treatments in darkness (0–21 weeks), very long days could override short cold treatments, but with slow responses and low synchrony, whereas longer cold treatments could override the diapause-maintaining effects of successively shorter days. Thus, wetted eggs in early-summer conditions gradually started to hatch, bringing delayed reproduction into perspective. Eggs from higher latitudes had the expected longer critical photoperiod and weaker diapause, but hatching performance appeared similar.

In larvae at 21.5°C, June photoperiods accelerated development compared to constant April/August photoperiods. However, larvae transferred from June to April/August photoperiods were the fastest, suggesting an ecologically relevant integration of absolute photoperiods and changes in photoperiod.

NORLING, Ulf

Some aspects of European *Coenagrion* life-histories and their regulation

Ulf Norling
Malmö University, Malmö, Sweden

A six year field study of a northern (58°N) population of *C. puella* revealed a mixed uni-semivoltinism, with a spring cohort split, where four overwintering stadia preceded emergence. In winter experiments a time-constraining summer photoperiod (LD 20:4, 20°C) mimicked the natural split, whereas the less time-constraining LD 16:8 made all larvae "univoltine" with a somewhat later emergence. Temperature optimum for active development may approach 30°C. In their last winter, semivoltines mostly peaked in F-1, and univoltines in F-2. In Europe, mixed voltinism with an autumn cohort split seems widespread, but some populations are univoltine with a winter peak in F-1.

Voltinism in a previously studied nearby population of *C. hastulatum* was also mixed, but with the cohort split starting in autumn. Three overwintering stadia preceded emergence, semivoltines peaking in F-0, and univoltines in F-1. Observations on *C. armatum* at 55°N indicated strict univoltinism and high synchrony, with all larvae overwintering in F-0.

Non-quantitative phenological observations agreed well with the larval studies. Size differences during the phenologically important last winter are probably correlated with differences in a diapause component in the development before the last winter. Latitudinal variation in voltinism and synchrony is further discussed.

NORLING, Ulf

A succession of response patterns in the control of larval development in temperate zone Odonata

Ulf Norling
Malmö University, Malmö, Sweden

Understanding responses to environmental cues such as photoperiod and temperature during different parts of larval development is important in any study involving environmental factors in development.

In most dragonflies which overwinter as larvae, larval development can be roughly subdivided into three modes of development, displaying different responses to photoperiod and temperature. These modes/response patterns have different seasonal outcomes, and are referred to with preliminary names. Although this model is supported by published and unpublished data, further confirmation is desirable.
Basic development: Small larvae, typically younger than F-3, do not yet predict the season of emergence, grow fast, may not react to photoperiod, but sometimes display a winter diapause. Ends in one of the following modes, or winter arrest.
Last-winter development: Emergence is predicted for the next season via environmental cues (excessive time-constraint), and is prevented. A diapause component is enhanced by extreme photoperiods and probably high temperatures. Ends in a suitable last-winter stadium. Often encountered in long-term constant conditions.
Pre-emergence development: Emergence is predicted for the present season. Typically fast development, enhanced by time-constraining photoperiods (usually long days) and high temperatures. Mainly in early season.
Examples from both field data and experiments are shown.

NUGRAHANINGRUM, Amelia
The Javanese endemic damselfly *Drepanosticta spatulifera*: distribution and fluctuating population in Petungkriyono Forest, Central Java
Amelia Nugrahaningrum[1,2] & R.C. Hidayat Soesilohadi[2]
[1]Indonesia Dragonfly Society, Jl. Plosokuning Raya no.15, RT11/RW04, Minomartani, Ngaglik, Sleman 55581, D.I.Yogyakarta, Indonesia; [2]Faculty of Biology, Universitas Gadjah Mada. Jl. Teknika Selatan, Sekip Utara, Yogyakarta 55281, Indonesia

The first study of *Drepanosticta spatulifera* distribution was in the forest near Baturaden [1]. After more than fifty years, *D. spatulifera* was recorded in Mount Ungaran, Central Java. In 2016, a large population was found in Sokokembang Forest, Central Java. This research aims to study the distribution and fluctuation of populations of *D. spatulifera* in Petungkriyono Forest. The research was conducted from July 2016 to March 2017 using the observation method. Sampling of populations was done at three locations of a small stream along a 100 m stretch. The results showed that *D. spatulifera* was found in five small streams that had a dense of canopy of the herb, *Colocasia esculenta*. The streams were at an altitude of 478–574 meters with the following characteristics: 30–1350 lux light intensity, DO 6.24–13.1 ppm, 50–100% soil moisture, and 7.3–7.8 pH of water. The peak population of *D. spatulifera* was recorded in February with 91 individuals, dominated by males; the daily air temperature was about 22.4–24.5◦C and the humidity was about 88–91%. It had a narrow home range and less potential to migrate due to low flight capability; the average flying distance was about 0.13–1.2 meters and individuals tended to return to a previous position.

[1] Lieftinck, M.A., 1934. Annotated list of the Odonata of Java, with notes on their distribution, habits, and life-history. Treubia 14 (4): 377–462.

O'CARROLL, David
Neural processing
David O'Carroll
Department of Biology, Lund University. Lund, Sweden

Abstract not available.

ORTEGA-SALAS, Héctor
Taxonomy and systematics of the Central American genus *Paraphlebia* Sèlys *in* Hagen, 1861
H. Ortega-Salas & E. González-Soriano
Instituto de Biología, UNAM, Depto. de Zoología 3er Circuito Exterior, Cd. Universitaria. Apdo. Postal 70-153, CP 04510, Ciudad de México, México

Paraphlebia has remained for years as an enigmatic genus restricted to Mexico and Guatemala. For over a hundred years only five species had been known. In this work we added 11 new species from México, Guatemala, Honduras and Nicaragua.
P .abrogata Calvert 1907 is shown to be a junior synonym of *P. quinta* Calvert 1901. A molecular phylogeny including 10 species is provided. Our data suggest that male polymorphisms have appeared more than once in the lineage, and support *Paraphlebia* as a monophyletic group, with *Thaumatoneura* McLachlan 1897 the sister group.

ORTEGA-SALAS, Héctor
Odonate endemism areas in México derived from species distribution models
Héctor Ortega-Salas
Instituto de Biología, UNAM, Depto. de Zoología 3er Circuito Exterior, Cd. Universitaria. Apdo. Postal 70-153, CP 04510, Ciudad de México, México

Abstract not available

OUTOMURO, David
Why do birds prey more often on large-spotted *Calopteryx* damselflies?
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[2]Department of Biology, Lund University, Lund, Sweden

European *Calopteryx* species are predated by white wagtails, and males of *C. virgo* experience a fourfold higher predation risk than *C. splendens*. Given that the conspicuousness of the wing coloration is similar between males of the two species, we asked whether the size of the male wing spot (much larger in *C. virgo*) can explain the differences in predation risk. In the lab, we used great tits as bird predators, and male *Calopteryx* with a piece of mealworm as rewarded targets. First, our results showed that naïve birds did not have any innate preference for large or small wing spots, or for wing spots with *C. splendens* or *C. virgo* coloration. Second, we trained birds to learn one wing phenotype (small or large wing spot). When the birds were presented with the alternative novel phenotype, the birds selected more frequently the large spots than the small spots, irrespective of their previous training. Thus, once birds have associated that a wing offers a reward, they tend to select more frequently the wing with more coloration, i.e. *C. virgo* rather than *C. splendens*. Our results offer a behavioural and cognitive explanation for predator choice on colourful prey targets.

OUTOMURO, David

Polythoridae damselflies avoid predation by mimicking the UV-reflective wing band of unpalatable glasswing butterflies

Alberto Corral-Lopez[1], Javier E. Varg[2], Yiselle P. Cano[3], Rafael Losada[3], Emilio Realpe[3] & David Outomuro[2]

[1]Department of Ethology/Zoology, Stockholm University, Stockholm, Sweden; [2]Animal Ecology, Evolutionary Biology Center, Uppsala University, Uppsala, Sweden; [3]Departamento de Ciencias Biológicas, Universidad de los Andes, Bogotá, Colombia

Previous studies have suggested that some Polythoridae damselflies in the Neotropics mimic unpalatable butterflies thereby reducing bird predation rates. The mimicry ring dominated by glasswing butterflies is characterized by the presence of a UV-reflective white wing band, i.e. the aposematic signal. We have previously shown that *Euthore fasciata* shows convergence of this white band within the bird visual space. We hypothesized that this aposematic signal confers reduced predation rates on *E. fasciata*. We studied bird predation rates on 1920 artificial models of *E. fasciata* and the glasswing butterfly *Greta andromica* in 64 replicated sites in central Colombia. The models were assigned to three possible treatments: with a UV-reflective white band, with a non-UV-reflective white band, and without a white band (control). Our results showed that bird predation was the highest on the control models, followed by the non-UV-reflective band and then by the UV-reflective band. Interestingly, bird predation was higher on the butterfly than on the damselfly models. Thus, our results suggest that *E. fasciata* reduces bird predation by mimicking the UV-reflective white band of glasswing butterflies. Interestingly, the white band comes from very different wing structures, namely scales on the butterfly wings, and high-density wax filaments on the damselfly wings. Our results have important implications on the evolution of imperfect mimicry in across-Order Batesian mimics.

PARR, Adrian

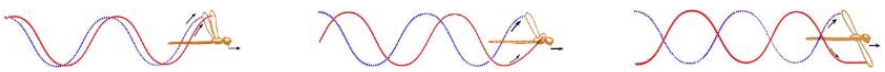
UK distribution mapping project

Adrian Parr

Odonata Records Committee, British Dragonfly Society c/o Natural England, Parkside Court, Hall Park Way, Telford TF3 4LR, UK

Britain has one of the best-studied insect faunas in the world. In 1960 Corbet *et al.*published the then-known distribution of all British and Irish Odonata. The British Dragonfly Society was formed in 1983 and recording of dragonflies has been well-established ever-since. A major distribution Atlas was published in 1996, based on almost complete coverage. A new Atlas was then published in 2014; this revealed major changes, many apparently linked to climatic warming.

In the last few years, dragonfly recording has seen a shift towards internet-based technologies and toward 'Citizen Science'. Data is now stored on iRecord (http://www.brc.ac.uk/irecord/), a web-based system for managing and sharing wildlife records. Information can be entered either 'in the field' via smartphones running the relevant app, or via the website either directly or by later uploading of spreadsheets. Data is verified online by accredited experts, and accepted records transferred to the main UK wildlife data-handling body, the National Biodiversity Network – whose online portal is currently being reformatted as the NBN Atlas (exploiting the Atlas of Living Australia infrastructure). Data is accessible to all to facilitate research and to inform and assist conservation and planning work. Information is also tied into a global context via the Global Biodiversity Information Facility.



PASKINS, Alison

Publishing your research — tips for success

Alison Paskins[1] & John Abbott[2]
[1]Taylor & Francis Group; [2]Editor-in-Chief, *International Journal of Odonatology*

This talk will guide new authors through the publishing process from selecting a journal, to preparing for submission, to navigating the peer review process. John Abbott will give you a valuable insight into the editorial process for the *International Journal of Odonatology*, including advice for successful publication. We will also cover essential tips for writing a review article, how to respond to reviewer comments, acting as a reviewer, plus more, giving a thorough understanding of the steps involved, the key information sources to be aware of, and what authors can be doing to help get their paper published.

PASS, Günther

Insect wings are not "dead" cuticular structures

Günther Pass
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Insect wings develop from lateral foldings of the integument with a small hemolymph filled space in-between. After wing expansion the epidermis is apoptotically dissolved and the resulting cell fragments are removed from the appendage together with the hemolymph. Thereby the dorsal and the ventral cuticular lamella come closer to one another and finally merge to form a functional wing blade. Living cells remain only in the wing veins, i.e. a few lining epidermis cells, tracheae, nerves which supply a number of sensilla located along the main longitudinal veins, and hemolymph. The latter circulates in a characteristic pattern through the tubular vein system. The motor of wing circulation is located in the thorax beneath the scutellum which forms the pump casing. The associated pulsatile part can be different in the various insect taxa. The plesiomorphic condition is a modification of the dorsal vessel. This is the case in Odonata where the aorta forms ampulla-like diverticles with incurrent ostia. In some other insect taxa separate organs evolved which represent completely autonomous auxiliary hearts. The origin of the latter demands particular interest since they are clear evolutionary novelties. This conclusion is supported by developmental studies in *Drosophila* whose wing-hearts originate from an independent pericardial cell lineage and are not individualized parts of the myocardium, as previously assumed. Remarkably, the regulatory gene network underlying wing-heart formation is unique, in that it is mainly somatic muscle-like, but also includes genes typical for cardiomyogenesis. Based on comparative analyses we conclude that the evolution of autonomous wing-hearts was triggered by spatial constraints inflicted by the rearrangement of the flight apparatus rather than by alterations in circulatory demands. Furthermore, we could demonstrate for the first time that the wing circulatory organs are mandatorily required during wing maturation in that they suck the apoptotic cell fragments together with hemolymph out of the wings. Although insects without functioning wing circulatory organs form full wings they cannot fly due to the higher weight of the uncleared wings.

PHAN, Quoc Toan

An introduction to dragonflies and damselflies of Vietnam

Quoc Toan Phan
Entomology & Parasitology Lab., Center for Molecular Biology, Institute of Research and Development, Duy Tan University, 3 Quang Trung, Da Nang, Vietnam

Vietnam is located on the eastern margin of the Indochinese peninsula and has one of the most biologically diverse faunas in the world. About 435 odonate species (202 species in 13 Zygoptera families and 233 species in 8 Anisoptera families) have been recorded in Vietnam (Phan, unpublished data). This is remarkable compared to other Southeast Asian countries. Moreover, several new species and new records for the country are awaiting being published in the near future.

Most odonate species of Vietnam are distributed separately in either the northern part of the country or the southern part with different climatic zones. The northern climatic zone has four seasons, one of which is a cold and humid winter, whereas the southern climatic zone is a typical tropical climate with only two seasons a year. Species in the northern part are species that are common in southern China, Laos and northern Thailand. The southern fauna, however, somewhat overlaps with that of peninsular Thailand and Maritime Southeast Asia. Moreover, the geographic topography of the north consists of highlands with several high mountain peaks in the northwest, whereas the Central highlands combine rugged mountain peaks of the Annamite range contrasting with the flatlands of the Mekong river delta. The variation and restriction of the habitat evolutionarily results in many endemic or near-endemic species to the country. However the knowledge of Vietnamese odonates is still inadequate since there is a lack of records in many localities within this region.

PIERSANTI, Silvana

The antennal sensilla in Odonata larvae

Silvana Piersanti[1], Stanislav Gorb[2] & Manuela Rebora[1]
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The larval antennal sensilla of two dragonfly species (*Libellula depressa* and *Onychogomphus forcipatus*) and two damselfly species (*Calopteryx haemorroidalis* and *Ischnura elegans*) belonging to four families (Libellulidae, Gomphidae, Calopterygidae, Coenagrionidae) have been investigated under scanning and transmission electron microscopy (SEM, TEM). These larvae show antennae with various shapes (short and flat, filiform, geniculate) and live in different environments (burrowing species, species living in lentic or lotic waters). A correlation between the different environments and the differences or similarities in the kind and distribution of sensilla in the four species has been outlined. Mechanoreceptors with various shapes in the form of filiform hairs and bristles, chemoreceptors, possible thermoreceptors have been observed in all the investigated species. A peculiar structure with an internal organization similar to that of a glandular unit has been observed in *Onychogomphus forcipatus*, *Calopteryx haemorroidalis* and *Ischnura elegans*. The possible function of this structure is at the moment unknown but it deserves further investigation owing to its wide presence in Odonata larvae.

PINKERT, Stefan

Evolutionary processes, dispersal limitations and climatic history shape current diversity patterns of European dragonflies

Stefan Pinkert[1], Klaas-Douwe B. Dijkstra[2], Dirk Zeuss[1], Christoph Reudenbach[3], Roland Brandl[1] & Christian Hof[4]
[1]Faculty of Biology, Department of Ecology – Animal Ecology, Philipps-Universität, Marburg, Germany; [2]Naturalis Biodiversity Center, Leiden, The Netherlands; [3]Faculty of Geography, Department of Environmental Geography, Philipps-Universität, Marburg, Germany; [4]Senckenberg Biodiversity and Climate Research Centre – BiK-F, Biodiversity and Area Dynamics of Vertebrates, Frankfurt (Main), Germany

We investigated the effects of contemporary and historical factors on the spatial variation of European dragonfly diversity. Specifically, we tested to what extent patterns of endemism (rarity) and phylogenetic diversity of European dragonfly assemblages are structured by (i) phylogenetic conservatism of thermal adaptations and (ii) differences in the ability of post-glacial recolonization by species adapted to lotic and lentic waters. We investigated patterns of dragonfly diversity using the distributions and phylogeny of 122 European species. Besides species richness and endemism, we used null model approaches to identify areas with higher or lower phylogenetic diversity than expected by chance. Dragonfly species richness peaked in central Europe, whereas endemism and phylogenetic diversity decreased from warm areas in the south-west to cold areas in the north-east and with an increasing proportion of lentic species. Except for species richness, all measures of diversity were consistently higher in formerly unglaciated areas south of the LGM 0°C isotherm than in formerly glaciated areas. Our findings highlight that phylogenetic conservatism of thermal adaptations and differences in recolonization ability after the last glacial maximum between lentic and lotic species in concert with the climatic history of the European continent shaped current diversity patterns of dragonflies in Europe.

POWNEY, Gary

Patterns of change in the Odonata of Britain

Gary D. Powney[1], Steve S.A. Cham[2], Dave Smallshire[2] & Nick J.B. Isaac[1]
[1]NERC Centre for Ecology and Hydrology, Wallingford, UK; [2]British Dragonfly Society, UK

National-scale metrics of change in species' status are vital for assessing the impacts of environmental change on biodiversity, for reporting on international biodiversity targets, and for the conservation of species. However, such measures of change tend to be taxonomically restricted with limited coverage of invertebrates (butterflies excluded). Here, we analysed over 350,000 odonate distribution records using recently developed hierarchical Bayesian occupancy-detection (hBOD) models to estimate reliable species-level trends. We examined these trends alongside species' traits in a comparative framework to shed light on the key drivers of distribution change in the Odonata of Britain.

RENNER, Samuel

Land cover and water body type shape the Odonata communities in the Brazilian Pampa

Samuel Renner[1], Eduardo Périco[1], Marina Schmidt Dalzochio[1] & Göran Sahlén[2]
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[2]Halmstad University, Environmental Sciences, Halmstad, Sweden

One of the less known biomes in Brazil is the Pampa, which occupies the southern portion of Rio Grande do Sul state. Originally this region was covered by open grasslands, with areas of higher vegetation around water bodies and rocky hills. Nowadays, human alteration of the biome is generating extreme pressure from activities such as agriculture, cattle farming and forestry. Studies developed in this region have proven that high diversity and endemism occurs. In this project, we aimed to increase the knowledge of dragonfly ecology of the Pampa, through sampling aquatic environments in its major ecological zones and comparing communities affiliated to different land cover and environmental variables. Our results revealed that the Pampa is a very rich biome (82 species registered), even when compared to Brazilian forest biomes. The most original forest and grassland dominated areas have shown more specific communities, hosting a larger number of rare and unique species (both with 54 species). Our analyses demonstrated that communities are directly related to environmental features, aggregating according to their ecological needs and habitat integrity. From the coming analyses, we expect to contribute to the conservation measures needed to protect this rich biome.

ROWE, Richard

Dragonfly vision: what they can do, what do they see?

Richard Rowe
Research School of Biology, Australian National University, Canberra, ACT 0200, Australia

Dragonflies have inherited compound eyes from their crustacean ancestors. Relative to camera eyes, compound eyes have advantages, and limitations. How dragonfly eyes have evolved to compensate for the limitations is reviewed. Sight is distinct from vision and the capacity for dragonflies to 'see' patterns is considered. The capacity to 'see' and respond to complex patterns is nearly as difficult as discussions of 'consciousness', so results are indicative, rather than based on science.

ROWE, Richard

Words – Philip: past, present, and future

Richard Rowe
Research School of Biology, Australian National University, Canberra, ACT 0200, Australia

Thirty and more years … and the future.

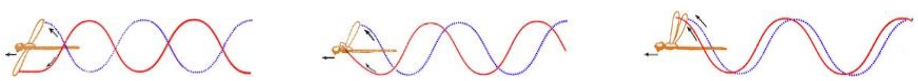
RÜPPELL, Georg
Kinematics of dragonfly flight
Georg Rüppell
Technical University Braunschweig, An der Wasserfurche 32 38162 Cremlingen, Germany

The different flight manoeuvres of odonates with clear wings are shown by slow motion videos slowed down to 20–40 times. Gliding flight is exhibited by larger damselflies and nearly all dragonflies. Damselflies then adjust their wings a little bit upwards, while dragonflies hold their wings in plane. Flapping flight includes many variations in wing movements such as changes of frequency, amplitude, phase-relationship, angles of attack and directions of wing-beats. To accelerate, stroke frequency and stroke amplitude are increased, while in braking angles of attack are increased and the stroke direction often is directed upwards. Sometimes the flight path is shifted upwards, too. Turning up and down is managed differently between damselflies and dragonflies. While damselflies shift their stroke direction upwards during upward turns and downwards during downward turns, some large dragonflies such as Aeshnidae can't do this. Their degree of freedom of stroke directions is restricted mainly going forward- downward [1, 2]. They bend their thorax upwards to get a more upward stroke direction for upward turns. Not that clear is a thorax- down turning when turning downwards. Flying turns around the vertical axis are managed by banking and asymmetric measures of the right and left wings. In fast flight, banking can reach more than 90° around the horizontal plane, especially in large dragonflies. The banking angle in damselflies is much smaller. Damselflies generate most of the turning moment by wing settings. In all odonates the turning moment is put in motion by the lower wings, fore stroking at higher angles of attack than the higher wings in the outside curve. In extreme flight situations as in aerial fights or in escape manoeuvres special kinematics occur. A common measure in all the situations of very fast and sudden flight manoeuvres is shifting from phase-shifted stroking to in-phase stroking, often with high-angles of attack. This can be done during fore- as well as during back-strokes. In fast backward flight this was the case in all filmed species, too.

[1] Pfau, H. K., 1986. Untersuchungen zur Konstruktion, Funktion und Evolution des Flugapparates der Libellen. Tijdschrift voor entomologie 129: 35–123.
[2] Rüppell, G., 1989. Kinematic Analysis of Symmetrical Flight Manoeuvres of Odonata. Journal of Experimental Biology 144: 13–42.

RÜPPELL, Georg
Flight variations in coloured-winged dragonflies
Dagmar Hilfert-Rüppell[1] & Georg Rüppell[2]
[1]Institut für Fachdidaktik der Naturwissenschaften, Bienroder Weg 82, 38106 Braunschweig, Germany; [2]Technical University Braunschweig, An der Wasserfurche 32 38162 Cremlingen, Germany

Dragonfly flight is generally described for the majority of species which have clear wings. But species with coloured wings do fly differently [1]. Their wings serve for flying as well as for communicating. The trade-off between these two objectives leads to very strange wing kinematics. Calopterygids beat their wings mostly in-phase; only in courting flight they use a species-specific beating pattern. This pattern can be counterstroking of the two wing pairs (*Calopteryx splendens*), or slightly phase-shifted (*Calopteryx virgo*), or with reduced amplitude of the hind-wings (*Calopteryx*



haemorrhoidalis). In the metalwings of East-Asia, belonging to Calopterygids as well, the hind-wings during male-female behaviour are held still and outstretched; they are signalling and are used only additionally as air foils [2]. Then the clear fore wings alone generate thrust and most of the lift. In contrast in male-male contests all four wings are beaten in-phase. During courting flight only medium and low velocities are reached while in phase-flight this can be increased to 5 m/s.

In dragonflies the modern group of Libelluldae owns many species with coloured wings. Here, too, the wings serve both functions, flight and communication. The wings of *Neurothemis fluctuans* are ornamented by broad brown patches. The males in front of a rival fly in an upright position and by in-phase stroking, remain motionless for some moments. From this performance an attacking flight can be started in the horizontal body position and with counter-stroking, high-frequent wing beats.

The main flight characteristics such as maximum speed, acceleration and turning velocities of the two modes, particularly the flight mode and the signalling mode are compared.

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[2] Günther, A., Hilfert-Rüppell, D. & Rüppell, G., 2014. Reproductive behaviour and the system of signalling in *Neurobasis chinensis* (Odonata, Calopterygidae) – a kinematic analysis. International Journal of Odonatology 17(1): 31–52. DOI:10.1080/13887890.2014.881305

Plenary lecture: **Göran Sahlén**

SAHLÉN, Göran

Forests and dragonflies revisited

Göran Sahlén
Ecology and Environmental Science, Halmstad University, Halmstad, Sweden

The term forest species has been in use for a few decades. In general, such species are considered to be less competent dispersers. They are also often smaller in size and tend to avoid open areas. Forest species are considered to be more specialized with narrower niches than open area (generalist) species. There are many factors affecting the occurrence of a species in a forest: land cover, patch size, landscape continuity, dispersal possibilities, temperature and water quality are some of them. Here I present data from species communities in boreal forest lakes in Sweden where variations in dispersal seem to shape only minor parts of the communities. Instead, species form ecological groups which have a different sensitivity from factors in the environment or those induced by humans. An example is intensive forestry where the direct effects develop over a few years' time but seem reversible over longer time periods. This can be the reason for the varied communities in today's forests, which in southern Sweden are only some 150 years old; the species pool 200 years ago would have been dominated by open area species. Adaptation and variation in niche occupancy have shifted species composition and distribution over time. In view of current climate change such an adaptive potential is promising.

SAMRAOUI, Boudjéma

An update of the odonate fauna of Saudi Arabia

Boudjéma Samraoui[1], Sami Al-Obaid[2], Jacob Thomas[2], Ahmed Al-Farhan[2], Hamed A. El-Serehy[3] & Wolfgang Schneider[4]

[1]Biology Department, University of Annaba, Annaba, Algeria; [2]Department of Botany and Microbiology, College of Science, King Saud University, P.O. Box-2455, Riyadh 11451, Saudi Arabia; [3]Department of Zoology, College of Science, King Saud University, Riyadh, Saudi Arabia; [4]Senckenberg Research Institute, Entomology II, Senckenberganlage 25, 60325 Frankfurt, Germany

The odonate fauna of the whole Arabian Peninsula was hardly known before the mid-twentieth century, but steady progress was made during the past century once the first specimens were collected by Bertram Thomas. A preliminary survey of major Saudi wetlands was carried out to fill some gaps in knowledge of the odonate fauna of that country. Twenty-five species, including *Trithemis dejouxi*, new to Saudi Arabia, were recorded during several expeditions (2009–2013). This survey represented a complementary step and a significant contribution to the elaboration of the IUCN Red List of the Odonata of the Arabian Peninsula. Finally, we will present and discuss an update of the odonate fauna of the Kingdom.

Plenary lecture: Michael Samways

SAMWAYS, Michael J.

The Cape of Good Hope for dragonflies in the Anthropocene

Michael J. Samways

Department of Conservation Ecology, Stellenbosch University, Cape Town, South Africa

Dragonflies are an ancient insect group with many species having long lineages. At the southern tip of Africa there are many endemic species with long lineages, the longest recorded being for *Syncordulia gracilis* at 59.6 million years. Appearance of the genus *Syncordulia* is estimated at 106.6 my, which coincides with the appearance of various families that characterize the open fynbos vegetation of the Cape Floristic Region. Despite these endemic species having survived the huge climatic changes through the Cenozoic, they have been particularly susceptible to shading effects of human-mediated alien invasive tree invasion, an impact to which they are not adapted. Yet these endemic species can recover well as soon as the alien trees are removed. Many other aquatic taxa also recover, making dragonflies a good surrogate taxon for much other aquatic diversity. Measuring anthropogenic impacts and success of restoration means knowing not just the traits of the species but also their particular sensitivities to various environmental conditions, including the adult's extraordinary ability to detect in-water chemistry in this ancient landscape. The Dragonfly Biotic Index, which uses a combination of geographical distribution, Red List status and sensitivity to disturbance, is a highly effective method for measuring recovery despite the overall devastating effects of the Anthropocene.

SAMWAYS, Michael J.

The evolution of dragonfly conservation

Michael J. Samways
Conservation Ecology & Entomology Department, Stellenbosch University, Stelenbosch, RSA

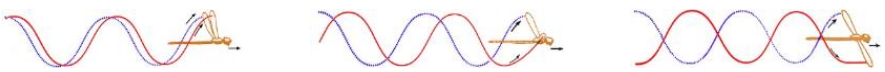
Dragonflies have been much appreciated by many historical cultures, and still are today. Their cultural conservation has been traditionally strong in Japan, especially through conversion of rice paddies into dragonfly reserves for aesthetic appreciation. With the arrival of the Anthropocene, pressures on dragonflies globally has been enormous, as it has for biodiversity overall. The Western world's first response to dragonfly decline was to form the Odonata Specialist Group of the IUCN/Species Survival Commission, which evolved into the Dragonfly SG, which is still highly active today. Early initiatives involved recognizing sites of special interest for dragonflies and conserving them, especially in Britain. This species-level approach also grew into regional assessments, with the African assessment being the first continental-size initiative. Meanwhile, there was an increasing awareness that aquatic systems are the most threatened ecosystems globally. Dragonflies have been at the forefront of insect conservation not only because they are sensitive to these threatened aquatic systems but also as they are iconic and highly appreciated by the public as well as being important subjects for conservation biologists. They are sensitive to both in-water and riparian conditions, making them excellent and effective bioindicators of water integrity and health. This has meant that today dragonflies have become integral to many landscape and sub-regional scale conservation initiatives worldwide.

SANCHEZ-HERRERA, Melissa

A biogeographical story of the Neotropical banner wing damselflies (Zygoptera : Polythoridae)

Melissa Sanchez-Herrera[1,3], Christopher Beatty[2], Camilo Salazar[1] & Jessica L. Ware[3]
[1]Biology Program, Faculty of Natural Sciences and Mathematics, Universidad del Rosario, Bogotá, D.C. 111221, Colombia; [2]Department of Ecology & Evolutionary Biology, Cornell University, Ithaca, NY, 14853, USA; [3]Department of Biological Sciences, Rutgers, The State University of New Jersey, Newark, New Jersey, USA

The Neotropics are a center for global diversity for many groups of organisms, including the dragonflies and damselflies. The family Polythoridae comprises fifty-seven species across seven genera: *Chalcothore*, *Chalcopteryx*, *Cora*, *Euthore*, *Miocora*, *Polythore* and *Stenocora*. Our recent molecular multi-locus phylogeny supports five monophyletic clades, not always congruent with the classical taxonomical classification. We propose new rearrangements of the species within the genera based on our molecular, morphological and geographical evidence, to generate a monophyletic classification of these Neotropical damselflies. Here we present the first divergence time analyses using fossil and biogeographical calibrations, in addition to an ancestral area reconstruction analysis to explore the biogeographical history of the banner wing damselflies. The recovered ages and diversification patterns strongly suggest a correlation with key geological events, including the Andes uplift, the Central America Seaway closure and the formation of the Amazon basin.



SANDALL, Emily L.
Importance of life stage capture in dragonfly specimen digitization
Emily L. Sandall & Andrew R. Deans
Frost Entomological Museum, Penn State University, University Park, PA 16802 USA

Life stage is apparently rarely captured during the digitization of natural history collections, but it can highlight sampling biases, life history changes, and gaps in taxonomy and systematics. Through the digitization of non-adult specimens of clubtail dragonflies, for example, it is possible to identify the taxa that lack diagnostic keys for all life stages. While likely only a small proportion of an entomological collection includes all life stages for a single taxon, the larvae/nymphs and exuviae (the skin shed upon emergence from the aquatic larval stage to the adult terrestrial stage) can provide a more comprehensive representation of morphological characters for species' identification and evolutionary questions. Furthermore, recording the life stage of dragonflies in the digitization process enables analysis of the distribution of a dragonfly taxon throughout its life history, which is both aquatic and terrestrial. By digitizing the Gomphidae specimens in the collection at the Frost Entomological Museum at Penn State University, proportions of life stages were compared to other digitized collections. This analysis reveals gaps in both keys and collections, as well as the need for increased diagnostic and natural history data for this family.

SHARKEY, Camilla R.
Exploring visual pigment evolution in odonates
Camilla R. Sharkey, Anton Suvorov & Seth M. Bybee
Department of Biology and Monte L. Bean Museum of Natural History, Brigham Young University, Provo UT, USA

Dragonflies and damselflies possess a surprisingly large number of visual pigment genes (opsins) that underpin sensitivity to different wavelengths of light within the visual system. Despite this recent finding, few studies have been carried out to explore this unexpected molecular complexity. It is widely accepted that the ancestor of insects possessed only three such opsin genes, conferring sensitivity to ultraviolet, blue and green wavelengths of light. However, within Odonata, opsins have undergone huge expansions with some species having as many as 30. Although dragonflies have a greater diversity of wavelength sensitivities than many insects (ultraviolet-, violet-, blue-, green- and red-sensitivity), this is not sufficient to explain the great diversity of opsin genes that we observe. To explore the patterns of opsin gene expansions in greater depth we have extended the range of species sampled, capturing considerably more of the diversity across the order. Additionally, we have investigated the possibility of sexual dimorphism within the visual genes and used bioinformatics techniques to investigate the evolutionary routes for these impressive but perplexing gene expansions.

SIVA JOTHY, Mike
Courtship and physiological traits – why are some males sexier than others?
Mike Siva Jothy
Department of Animal and Plant Science, University of Sheffield, Sheffield, UK

Abstract not available.

STANGE, Gert

Anatomy and physiology of the ocelli of the dragonfly, *Hemicordulia tau*

Gert Stange
Eccles Institute of Neuroscience, Australian National University, Canberra ACT, Australia

Many winged insects carry dual visual systems, namely a pair of compound eyes and three ocelli. The two lateral ocelli look sideways, and the median one looks forward. Each consists of a simple lens, followed by photoreceptor neurons, projecting upon a set of second order neurons. Usually, the images formed by the lenses are underfocussed and there is a large amount of convergence from many receptor neurons upon a few second order neurons. In this expression, ocelli are spatial low-pass filters, measuring the average light intensity over very wide fields of view. Together they would form an 'autopilot' that controls flight attitude, detecting the mean direction of incident light, which is usually vertical (dorsal light response).

However, the ocellar system of *Hemicordulia tau* is far more elaborate in several aspects. The median ocellar lens forms a focused but astigmatic image, and the lateral lenses are bifocal. At the level of the receptor neurons, the resolution can be as high as 15°. This is preserved at the second order neurons, albeit only in the vertical direction. Horizontally, the fields of view are much wider, and between a total of 17 median and lateral second order neurons, a range of more than 180° is covered.

Thus, this ocellar system is tuned to the detection of extended horizontal features, such as a shoreline, and it is suggested that it 'clamps' the head to a level attitude during hover, facilitating the detection of small moving objects by the compound eyes.

STAVENGA, Doekele

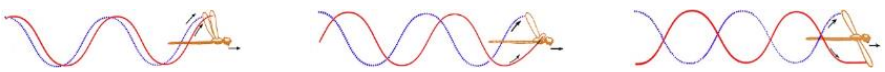
Odonate vision and coloration

Doekele G. Stavenga
Computational Physics, Zernike Institute for Advanced Materials, University of Groningen, NL-9747 AG Groningen, the Netherlands

The compound eyes of dragonflies and damselflies have a high acuity due to arranging the ommatidia by applying basic optical tools, both in the larvae and the adults [1–3]. The integrated optics of facet lens and crystalline cone focuses incident light into a fused rhabdom, consisting of rhabdomeres with different visual pigment types. The absorption spectra of the visual pigments principally determine the spectral sensitivities of the photoreceptors, but lateral and longitudinal filtering is also important.

Extreme optical specialisation is realized in the dorsal eyes of *Sympetrum* species, which are colored by yellow-orange screening pigment. This pigment plays a crucial role for the sensitivity of the UV and blue photoreceptors that populate the dorsal eyes. The photoproduct of the UV- and blue-absorbing rhodopsins, the metarhodopsins, predominantly absorb in the longer wavelength range. Long-wavelength stray light that has by-passed the distally-located orange screening pigment hence can photoreconvert the metarhodopsin molecules back to the native rhodopsin state, thus cheaply upgrading sensitivity. The ventral eyes contain a majority of green-sensitive photoreceptors. The photoproduct of their rhodopsin absorbs in the shorter wavelength range, and thus the ventral eyes have broad-band, strongly absorbing screening pigment [4, 5].

Odonate vision is naturally used for analysing the environment, particularly for navigation, and is specialized for detecting prey, but also for spotting conspecifics. Notably the coloration of males displays their identity. Body and wing coloration can be pigmentary, can have a structural basis, or can be a combination of both mechanisms.



The pigments encountered in odonates are melanins, ommochromes, and pterins [6–8]. Especially interesting are those cases where melanin pigment is arranged in nano-sized layers. For instance, male *Calopteryx japonica* have blue wing veins colored by melanin. Pterin pigment deposited in small granules can, when quasi-ordered, create blue or green body colors. We now are beginning to quantitatively understand the structural colors thanks to estimates of absorption-dependent refractive indices that are measured with a novel Jamin-Lebedeff interference microscopy method [6, 7]. Whether or not the body and wing colorations are tuned to the spectral properties of the visual system is a topic of continuous discussion.

[1] Sherk, T. E., 1977. Development of the compound eyes of dragonflies (Odonata). I. Larval compound eyes. Journal of Experimental Zoology A 201: 391–416.
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[7] Stavenga, D. G., Leertouwer, H. L., Hariyama, T., De Raedt, H. A. & Wilts, B. D., 2012. Sexual dichromatism of the damselfly *Calopteryx japonica* caused by a melanin-chitin multilayer in the male wing veins. PloS One 7: e49743.
[8] Futahashi, R., 2016. Color vision and color formation in dragonflies. Current Opinion in Insect Science 17: 32–39.

Plenary lecture: Frank Suhling

SUHLING, Frank

Life cycle and seasonality of African Odonata

Frank Suhling
Technische Universität Braunschweig, Institute of Geoecology, Landscape Ecology and Environmental Systems Analysis, An der Wasserfurche 32 38162 Cremlingen, Germany

The decoding of how life cycles have become appropriate to regional environmental conditions, especially with regard to latitude, and consequently how seasonal regulation has been achieved was one of Philip Corbet's core research topics. His main subject in his dissertation thesis was *Anax imperator*, which he studied in UK, thus in the temperate region. All other published data on voltinism of *A. imperator* are from the temperate zone, even though the species has its main distribution in the Afrotropics. This observation illustrates very well the knowledge situation about life cycles of African species. Comprehensive studies are rare and often the species have been studied outside the tropics, mostly in Europe and Mediterranean Africa. Best known are probably species from temporary habitats that are either multivoltine or that circumvent the drought in the adult stage. Thus, solid knowledge of African Odonata life cycles is limited and in particular information about tropical riverine species is lacking. The latter seem to be usually seasonally linked to the rainy season. In my presentation I aim to recapitulate what is known about voltinism, life cycle regulation and seasonality of African Odonata,

opening with the example of *A. imperator*. I will also present some examples of seasonality from well-surveyed localities based on the Odonata Database of Africa.

SUHLING, Frank

Corbet's contribution to the knowledge of African dragonfly larvae and their ecology

Frank Suhling
Technische Universität Braunschweig, Institute of Geoecology, Landscape Ecology and Environmental Systems Analysis, An der Wasserfurche 32 38162 Cremlingen, Germany

During the time Philip Corbet spent in Uganda he studied dragonfly larvae whenever possible. One of his aims was to form an adequate basis for an analytical key by describing all larvae he was able to properly identify. He reared larvae in the lab and observed emerging individuals in the field. He published those observations in a series of short papers in *The Entomologist*. His larval descriptions surely defined a standard, particularly concerning the style of drawings, which was later not always met. But, he also carefully reported all information on the larval microhabitats he could get and was relating this information to larval body shape. Surely these observations on often spectacular larval forms were an important basis to initiate many of the ideas he published in chapter 3 of his 1962 book, *A biology of dragonflies*. These ideas are still one of my main inspirations and should not be forgotten when memorializing Philip Corbet's contribution to science.

SUMANAPALA, Amila P.

The future of endemic Odonata in Sri Lanka under changing climatic patterns

Amila P. Sumanapala
Butterfly Conservation Society of Sri Lanka, 762/a, Yatihena, Malwana, Sri Lanka

Sri Lanka is a tropical, continental island nation in South Asia. It has a rich odonate fauna with 129 species of which 56 are endemic and 9 are endemic at subspecies level. Thirty-nine of these endemic odonates are under the threat of extinction. The distribution of 36 threatened endemic odonates and 4 recently discovered endemics were modeled for the current climatic conditions and conditions predicted for 2050 and 2080. Faunistic records from 2000 to 2016 were used as presence data. Modeling was performed in Maxent 3.3.3k version using the 19 Bioclimatic variables from Worldclim version 1.4 and slope and aspect layers with a resolution of 30 seconds. With a 50% probability of occurrence threshold, the majority of the species (67.5%) showed a range shrinkage by 2050 and their ranges continued to shrink, becoming even smaller by 2080. Other species showed an expansion in their ranges. Of these, 42.5% of the species showed a considerable climatic range shift towards the eastern parts of the island though the geographical barriers formed by the central highlands might not allow it in the real world situation. The endemics that are confined to the montane zone showed an alarming reduction in range and possibility of extinction by 2080 under the predicted climatic conditions.

SUPPLE, Jack
Descending sensorimotor control in dragonflies and damselflies
Jack Supple
Department of Physiology, Development and Neuroscience, University of Cambridge, Downing Street, Cambridge, UK

Dragonflies and damselflies perform complex visually guided aerial manoeuvres, but are distinct in their hunting strategies. Whilst dragonflies will intercept fast moving prey flying overhead, damselflies will often hover stealthily towards stationary prey before striking forward to pluck the prey away from the substrate. At the core of these behaviours is the information processing task of transforming visual representations of prey into motor commands. In dragonflies, a small set of 16 bilaterally symmetric target selective descending neurons efficiently encode prey position and direction of movement as a population vector. This system is thought to form a reactive control mechanism to stabilise the prey on the fovea for an interception course. In this talk I will present my recent findings aimed to elucidate whether a similar sensorimotor encoding strategy is present in damselflies.

Plenary lecture: Erik Svensson
SVENSSON, Erik
Odonates as a bridge between micro- and macroevolution
Erik Svensson
Department of Biology, Lund University, Lund, Sweden

There is a rich history of taxonomic and systematic research on odonates, and in recent years an increasing number of molecular phylogenies have been published. There is also a strong research tradition that focuses on sexual selection and behavioural ecology of odonate adults and to some extent also larval ecology. However, odonates remain largely underutilized as research models in macroevolution and phylogenetic comparative studies of trait evolution, in contrast to the situation in many other taxonomic groups like birds. Here I will argue that the time is now mature to improve this situation by utilizing and synthesizing the rich information about odonate ecology and evolution from various sub-fields and merge such information with molecular phylogenies and modern comparative methods. Odonates are extremely well-suited for such integrative evolutionary biology studies, given that they are fairly easy to study both in the field and the laboratory and they have a rich fossil history. In addition, molecular phylogenies are becoming increasingly available. In particular, I will argue that odonates can be used to bridge the gap between studies of microevolutionary processes in local populations with larger scale macroevolutionary patterns like speciation and diversification of phenotypic traits. I will present some results from my own research laboratory where we have initiated such studies. We have focused on the link between the micro- and macroevolution of female colour polymorphisms in pond damselflies (Coenagrionidae) and the evolution of wing pigmentation across all odonates in relation to latitude, temperature and other ecological factors, where we also compare trait evolution between temperate and tropical areas.

TSCHOL, Maximilian

Broad scale patterns in the evolution of wing pigmentation in Odonata: roles of geography, climate and sexual selection

Maximilian Tschol, John T. Waller & Erik I. Svensson
Evolutionary Ecology Unit, Lund University, Lund, Sweden

Wing pigmentation among dragonflies and damselflies is remarkably diverse. In some odonate species, pigmentation of the wing acts as a signal in mate choice, has been shown to be under sexual selection and mediates sexual isolation between congeneric (sympatric) species. Such within-species patterns in pigmentation and differences between males and females call for evolutionary explanations. While sexual selection is considered the major cause for this sexual dimorphism, natural selection may also operate on pigmentation, and may vary between different geographic areas, such as between temperate and tropical environments. This study aims to investigate how the interplay between natural and sexual selection shapes the evolution of wing pigmentation among Odonata. To infer the history of sexual dimorphism, we utilize ancestral state reconstruction to model the past state of male and female wing pigmentation. Additional phylogenetic comparative methods are employed to test for relationships between environmental factors and wing pigmentation, investigating how natural and sexual selection shapes the evolution of pigmentation. Our results support the assumption that the ancestral states of two main families, Libellulidae and Calopterygidae, were likely to be pigmented. Furthermore, losses of wing pigment following ancestral gain is a quite common pattern in this insect order, suggesting that natural selection opposes sexual selection, depending on local environmental conditions.

VEGA-SÁNCHEZ, Yesenia Margarita

Species recognition system in Rubyspots: morphometric and genetic patterns

Yesenia Margarita Vega-Sánchez[1], Andrés Rodríguez-Piña[2], Ayari Yazil Salgado-Equihua[2], Luis Felipe Mendoza-Cuenca[2] & Antonio González-Rodríguez[1]
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In odonates there are two main mechanisms related to species recognition: a visual system (related to coloration) and a mechanical-sensorial system. In the genus *Hetaerina*, males have characteristic red spots on the wings. These spots have evolved as a signal for male-male interactions and are not related to mate recognition. The caudal appendages are excellent candidates for this function because they show a highly diversified morphology in the genus and are the main characters used in the male for taxonomic recognition of species. To analyze the function of this character we analyzed the variation in the shape of superior caudal appendages of populations of four species of *Hetaerina* using geometric morphometric techniques. We also analyzed the genetic differentiation using nuclear microsatellites. In general, the variation in shape was greater among species than among populations. In *H. americana* and *H. cruentata*, however, we also observed an important variation among populations that corresponded to genetic differentiation patterns, suggesting reproductive isolation even within populations. We conclude that the shape of the caudal appendages is related to the species recognition system in this genus and possibly related to cryptic speciation.

VERSPUI, Karin

Puzzling illustrations of Selys' watercolour collection

Karin Verspui
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The watercolour collection of Edmond de Selys Longchamps depicting dragonflies and damselflies was created in the nineteenth century. This unpublished material is housed in the Royal Belgian Institute for Natural Sciences in Brussels. Marcel Wasscher and I set ourselves the task of making the illustrations and texts digitally available and making them more accessible in present times. As you can imagine bringing this information from the nineteenth century to the present presents problems, for example with understanding the names given to the depicted specimens by Selys. Helped by Matti Hämäläinen and Rosser Garrison, we attempted to associate the names Selys wrote on the illustration (Selys' names) with current species names. With references and the help of several odonate experts we were able to associate the majority of the Selys' names with current names and so facilitate the search for specific species in the watercolour collection by researchers. A number of odonate watercolours that are still puzzling will be presented in this workshop. We hope that a discussion with the participants will bring us closer to the identity of the depicted dragonflies and damselflies.

VERSPUI, Karin

Promoting Selys' watercolour collection with illustrations of damselflies and dragonflies as a source for research

Karin Verspui[1] & Marcel Wasscher[2]
[1]Lingedijk 104 4196HC Tricht, The Netherlands; [2]Minstraat 15 bis 3582 CA Utrecht, The Netherlands

In 2002 the watercolour collection of Edmond de Selys Longchamps was re-discovered in the Royal Belgian Institute for Natural Sciences (RBINS) in Brussels. The watercolours and drawings in this nineteenth century collection are largely based on the odonate collection of Selys in RBINS. To make the illustrations and texts digitally available, we catalogued and digitised sheets with illustrations and texts. To provide an overview of the watercolour collection, subject matter and characteristics of the sheets were analysed and we produced an interpretation of the handwritten notes of Selys. The majority of Selys' names from the nineteenth century were associated with current species names, using references and the opinions of odonate experts. The collection contains watercolours and drawings of damselfly and dragonfly species currently belonging to the superfamilies Lestoidea, Platystictoidea, Calopterygoidea, Coenagrionoidea, Epiophlebioidea, Aeshnoidea, Petaluroidea, Gomphoidea, Cordulegastroidea and Libelluloidea. The unpublished illustrations and texts of the collection will be presented on the website of RBINS, accompanied with the gathered information. Hopefully this valuable watercolour collection will be used more often as a source for taxonomic research of Odonata.

Plenary lecture: Jessica Ware

WARE, Jessica

Molecular phylogeny of Gomphidae

Jessica Ware
Department of Biological Sciences, Rutgers University, Newark, NJ, USA

Intrafamilial relationships among clubtail dragonflies (Gomphidae) have been the subject of many morphological studies, but have not yet been systematically evaluated using molecular data. Here we present the first molecular phylogeny of Gomphidae. We include six of the eight subfamilies previously suggested to be valid, and evaluate generic relationships within them. We have included examples of all genera reported from the Nearctic except *Phyllocycla*. This sample includes all North American species of *Ophiogomphus*, which has allowed us to explore intrageneric relationships in that genus. Our particular focus is on the closest relatives of the genus *Gomphus*, especially those North American species groups that have been commonly treated as subgenera of *Gomphus*. The *Gomphus* complex is split into additional genera, supported by molecular and morphological evidence: *Phanogomphus*, *Stenogomphurus*, *Gomphurus* and *Hylogomphus* are here considered to be valid genera. The genus *Gomphus*, in our restricted sense, does not occur in the western hemisphere; in addition, *G. flavipes* is transferred to *Stylurus*.

WARE, Jessica

***Pantala*: genetics suggest it really is a global wanderer**

Jessica Ware
Department of Biological Sciences, Rutgers University, Newark, NJ, USA

Among terrestrial arthropods, the dragonfly species *Pantala flavescens* is remarkable due to their nearly global distribution and extensive migratory ranges; the largest of any known insect. Capable of migrating across oceans, the potential for high rates of gene flow among geographically distant populations is significant. It has been hypothesized that *P. flavescens* may be a global panmictic population but no sufficient genetic evidence has been collected thus far. Through a population genetic analysis of *P. flavescens* samples from North America, South America, and Asia, the current study aimed to examine the extent at which gene flow is occurring on a global scale and discusses the implications of the genetic patterns we uncovered on population structure and genetic diversity of the species. This was accomplished using PCR-amplified cytochrome oxidase one (CO1) mitochondrial DNA data to reconstruct phylogenetic trees, a haplotype network, and perform molecular variance analyses. Our results suggested high rates of gene flow are occurring among all included geographic regions; providing the first significant evidence that *Pantala flavescens* should be considered a global panmictic population.

WASSCHER, Marcel

A few gleanings from the dawn of the history of odonatology from 1750–1850

Marcel Wasscher
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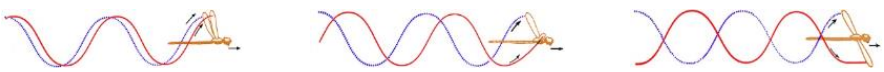
My presentation includes a few random snippets from the early history of the science of odonatology in reverse chronological order.



Some letters by Edmond de Selys Longchamps (1813–1900) kept at RBINS in Brussels, Belgium are discussed. The first item is a draft of a letter from Selys to Toussaint de Charpentier (1779–1847). Selys asks him for further information on two new odonate species, *Libellula* (now *Sympetrum*) *striolatum* and *L. ruficollis* (now a synonym of *Sympetrum striolatum*) and proposed an exchange of specimens. Two added notes by Selys show it was written in '1844(?)' and that the letter was not answered by Charpentier. Then follows an analysis of five letters sent by Pierre Rambur (1801–1870) to Selys between 1840 and 1849. Do these letters show how they co-operated?

Last year we discovered a watercolour of *Aeshna affinis* made by Pierre Vander Linden (1797–1831) in Selys' large portfolio of watercolour paintings. We then already knew that Vander Linden's collections, watercolours and other entomological legacy went to the 'Petit Séminaire de Malines' in Mechelen, Belgium. This is now a secondary school. I have recently seen an index of the school's library and had contact with the administrator of its archive and learned that there are no watercolour paintings or notes by Vander Linden presently kept in this school.

Finally I'll take you back to the years 1755–1756 when Daniel Rolander (1725–1793) visited Suriname for 9 months and collected plants, vertebrates and insects. Further details are known of his collecting activity in Suriname since the rediscovery by Jim Dobreff of Rolander's diary in 2007 in Copenhagen. Both Linnaeus (1758) and de Geer (1773) treated the Odonata in his material, the latter author introducing some synonymous names. Two species, *Libellula umbrata* (presently *Erythrodiplax umbrata*) and *L. dimidiata* (presently *Diastatops dimidiata*) were attributed to Rolander's material by Linnaeus (1758). Now also *Libellula fasciata* (presently *Zenithoptera fasciata*), originally erroneously stated to come from India, is proven to belong to Rolander's material from Suriname, as is De Geer's *Libellula unimaculata* (presently *Erythrodiplax unimaculata*).

WILLINK, Beatriz

A species phylogeny to study trait evolution in pond damselflies (Odonata: Coenagrionidae)

Beatriz Willink[1], Jessica Ware[2] & Erik Svensson[1]
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Damselflies and dragonflies are increasingly being used as model systems to study the evolution of ecologically relevant traits such as body size, thermal performance and colour patterns. These studies have been largely focused on how microevolutionary processes shape variation within species. Phylogenetic comparative methods complement those studies by providing a historical perspective and shedding light on the generality and large-scale consequences of such processes. However, modern comparative methods require time-constrained phylogenetic trees to investigate how shared ancestry contributes to trait distributions across present-day species. A key attribute of these phylogenies is dense taxon sampling, which is critical for the statistical power of comparative methods. Here, we present a species-level multilocus phylogeny of the species-diverse family of pond damselflies (Coenagrionidae), for which we have sampled over 30% of the species and nearly 70% of the genera currently recognized. This phylogeny is aimed to serve as a first roadmap to identify patterns of diversification and trait evolution across this ecologically diverse family, while clarifying the phylogenetic relations among genera. To illustrate the potential use of such a phylogeny we use an example of sex-limited colour traits and capitalize on Bayesian inference methods that are robust to phylogenetic uncertainty.

WOOTTON, Robin
The flight of Odonata: uniqueness and diversity, answers and questions
Robin Wootton
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The unique thoracic morphology of Odonata, and their uncoupled, independently operating wing pairs allow a quite remarkable range of flight skills and behaviours. Understanding the morphological diversity, particularly that of the wings, in terms of flight diversity is a major and fascinating challenge. The mechanical roles of many general characters are now clear: wing corrugation, the antenodal spar, the nodus, the basal complex, the resilin patches; but many questions relating to their variety, and to the adaptive significance of wing size, shapes, proportions and venational detail, still need answering.

XUE, Junli
A revised classification of the genus *Matrona* (Zygoptera, Calopterygidae) and further considerations about phylogeography
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Abstract not available

YU, Xin
The phoenix damselfly (*Pseudolestes mirabilis*), my love, from taxonomy to conservation
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The phoenix damselfly (*Pseudolestes mirabilis*) is an endemic damselfly of Hainan Island, China, that is the unique known island endemic odonate species which represents a whole family alone and has been treated as a logo of Hainan Island. I have been focused on researching this special damselfly since 2011. During this time I did many things for the first time: I found and described its enigmatic larva, recorded and confirmed the special biological feature of the retractable larvae gill tufts, used ecological niche modeling techniques to estimate the realized niches and to predict its potential distribution, and with my team, studied population ecology of this charming species and provided conservation suggestions. According to our work we argued for urgent conservation efforts for this species, not only for its indescribable beauty but also for its great potential value for systematic and evolutionary research.