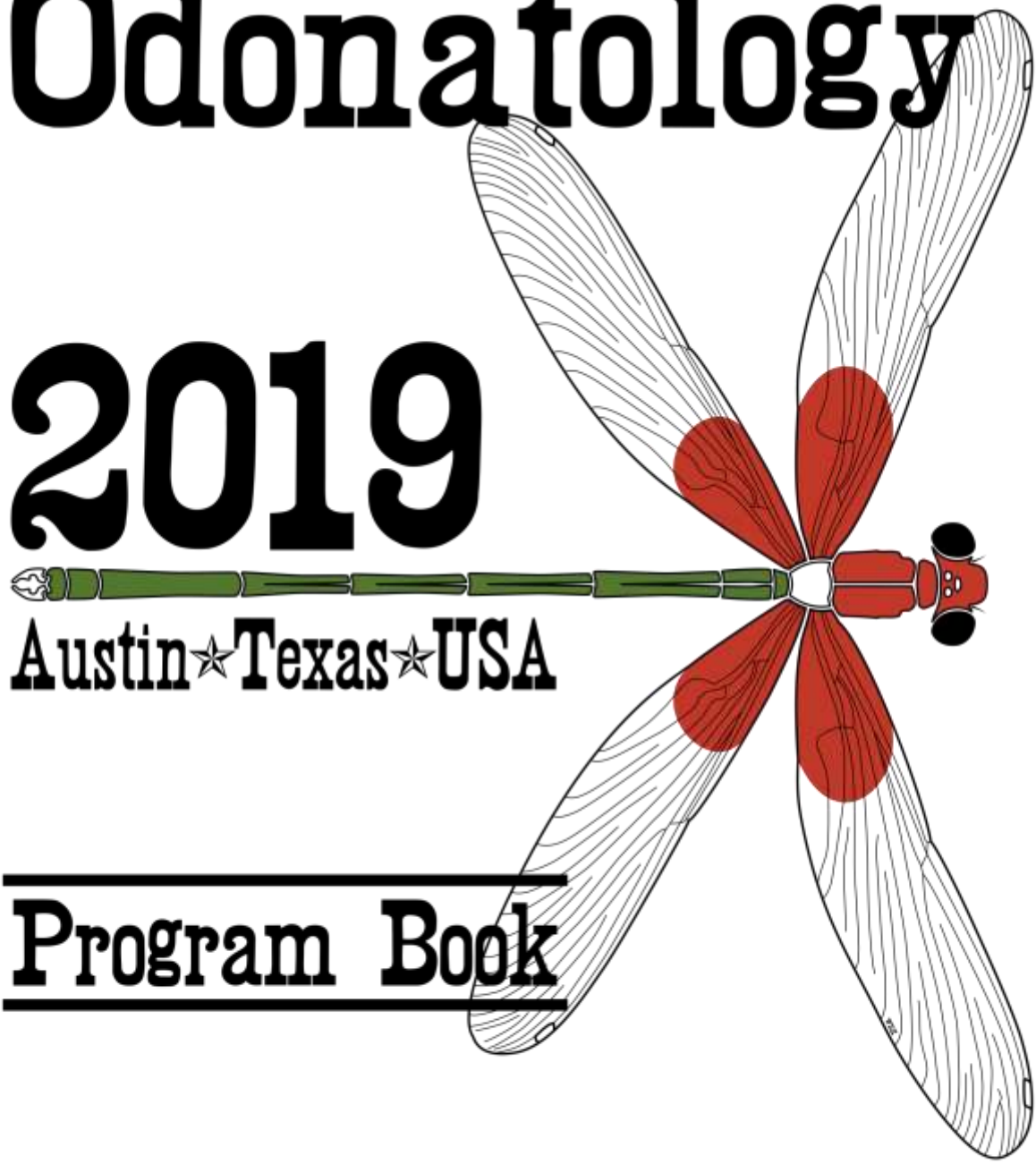
International Congress of Odonatology

2019



Austin ★ Texas ★ USA

Program Book

2019 International Congress of Odonatology
Austin, Texas, USA
14–19 July 2019

ICO 2019 has been organized in conjunction with the Worldwide Dragonfly Association (WDA).

ICO 2019 Book of Abstracts
Editors: John C. Abbott and Will Kuhn
Proofreading: Kendra Abbott and Manpreet Kohli
Design and layout: John C. Abbott
Congress logo design: Will Kuhn

Printed in July 2019

Congress Logo

The logo for ICO 2019 features the American Rubyspot, *Hetaerina americana*, a common species throughout the mainland United States. Both males and females of this damselfly species have brilliant metallic iridescent bodies, and males develop crimson patches on the basal fourth (or more) of their wings. You are sure to be greeted by the American Rubyspot along streams and rivers while you're in Austin, as well as the Smoky Rubyspot (*H. titia*), which is also found in these parts.

The logo also features the lone star of Texas. You'll find that among the citizens of the US, Texans are exceptionally (and perhaps inordinately) proud of their state. The lone star is an element of the Texas state flag, which decorates many homes and businesses throughout the state. Once you start looking for it, you'll never stop seeing it!

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2019 International Congress of Odonatology

International Congress Committee
Javier Muzón (Argentina), Richard Rowe (Australia), and Florian Weihrauch (Germany)

Congress Organization
John Abbott (co-convener), Kendra Abbott (co-convener), Ola Fincke, Manpreet Kohli, Will Kuhn, Nancy McIntyre, and Jessica Ware

Webmaster
Will Kuhn

Scientific Committee
Nancy McIntyre (chair), Seth Bybee, and Ola Fincke

Travel Awards Committee
Kendra Abbott (chair), John Abbott, Manpreet Kohli, and Will Kuhn

Travel Awards
Awards were provided to six young odonatologists to support their attendance at ICO 2019: Leocris Batucan, Jr (Taiwan), Cornelio Andrés Bota-Sierra (Colombia), Ashley C Mariani-Ríos (USA-Puerto Rico), Juliana Sandoval Hernandez (Colombia), Mónica Torres-Pachón (Mexico), and Yesenia M Vega-Sánchez (Mexico).

Financial Support
Financial support for student member attendance has been generously provided by the Dragonfly Society of the Americas (DSA), Gesellschaft deutschsprachiger Odonatologen (GdO), and Worldwide Dragonfly Association (WDA). In addition, the Texas Parks and Wildlife Department provided $1,000 in financial assistance to help with the Congress.

Venue, Accommodation & Registration

Congress Venue

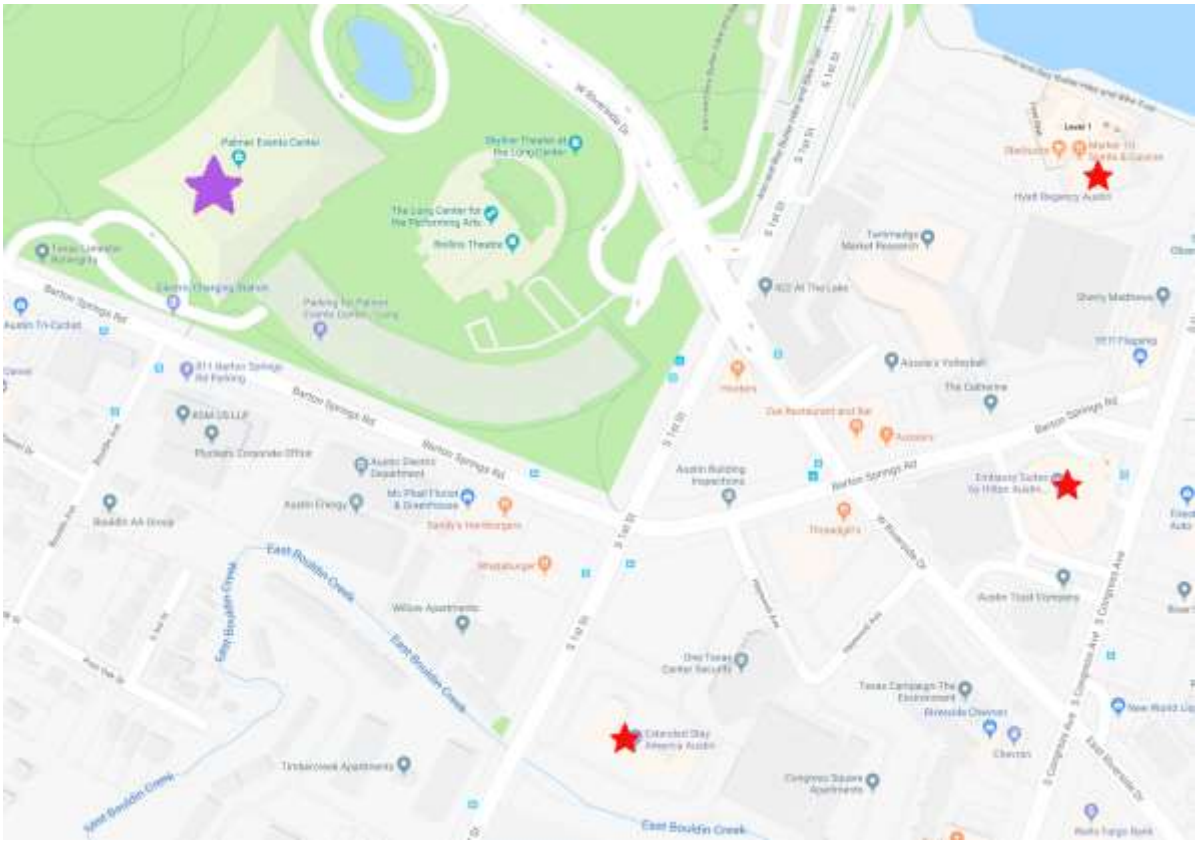
The Congress will take place at Palmer Events Center (900 Barton Springs Road, Austin, Texas 78704). All activities will take place the 2nd floor. Enter through the entrance on Riverside Drive near the pond.

Accommodations

- Hyatt Regency Austin, 208 Barton Springs Road, Austin, TX 78704 (+1 512 477 1234)
- Embassy Suites by Hilton Downtown Town Lake, 300 South Congress Avenue, Austin, TX 78704 (+1 512 469 9000)
- Extended Stay American, 507 South 1st Street, Austin, TX 78704 (+1 512 476 1818)

Registration

Late registration will be available during the Welcome Reception on the 2nd floor of the Palmer Events Center on Sunday, 14 July (7:00–9:00pm) and the morning of Monday, 15 July starting at 8:00am. Registrants can pick up their Congress bag and find general information at the registration table.



About Austin

Austin is the capital of Texas and the seat of Travis County, with portions extending into Hays and Williamson Counties. It is the 11th-most populous city in the United States and the 4th-most populous city in Texas. It is also the fastest growing large city in the United States, with a population of nearly 1 million. The city is the cultural and economic center of the Austin–Round Rock metropolitan statistical area, which had an estimated population of 2,168,316 as of 1 July 2018. Located in Central Texas within the greater Texas Hill Country, it is home to numerous lakes, rivers, and waterways, including Lady Bird Lake and Lake Travis on the Colorado River, Barton Springs, McKinney Falls, and Lake Walter E Long.

In the 1830s, pioneers began to settle the area in central Austin along the Colorado River. In 1839, the site was chosen to replace Houston as the capital of the Republic of Texas and was incorporated under the name "Waterloo". Shortly afterward, the name was changed to Austin in honor of Stephen F Austin, the "Father of Texas" and the republic's first secretary of state. The city grew throughout the 19th century and became a center for government and education with the construction of the Texas State Capitol and the University of Texas at Austin. After a severe lull in economic growth from the Great Depression, Austin resumed its steady development, and by the 1990s it emerged as a center for technology and business. A number of Fortune 500 companies have headquarters or regional offices in Austin including, 3M, Amazon.com, Apple Inc., Cisco, eBay, General Motors, Google, IBM, Intel, Oracle Corporation, PayPal, Texas Instruments, and Whole Foods Market. Dell's worldwide headquarters is located in a nearby suburb, Round Rock.

Texas is home to 247 species of dragonflies and damselflies (more than half of the US & Canada species list), and there are 117 species reported for Travis County.

Meals and Drinks

Breaks

Coffee, tea, water and light refreshments will be served at mid-morning and mid-afternoon breaks each day of the Congress.

Lunch

Lunch is on your own, but there will be an extended two-hour break and we encourage you to network with colleagues. There are numerous restaurants to choose from close to the Palmer Events Center.

There are 5 places directly across the street, listed below from least to most expensive. There are many additional places just up Barton Creek Road; these are also listed below. If you have never had Texas queso (cheese) dip, then you MUST try it! It’s AMAZING!

Vegetarian Note: Almost every restaurant in Austin (even BBQ restaurants) has vegetarian options. Beware: almost all green beans are cooked with bacon, thus not vegetarian-friendly!

Restaurants near Palmer Events Center

1. Sandy's Hamburger's - Local old-fashioned hamburgers and milkshakes
2. Whataburger – Texas' version of McDonalds, but 100x better with many burger options
3. Threadgill's – Local southern food
4. Terry Black's BBQ – Arguably the best BBQ in Texas. Certainly, one of the best!
5. El Alma – Very good Tex/Mex!

Restaurants along Barton Creek Road (10-min walk west of PEC across South Lamar Blvd)

1. Uncle Billy's Brewery and BBQ
2. Austin Java – Locally sourced food. Vegan friendly
3. Shady Grove – Comfort food and a local live music venue
4. Baby Acapulco – Tex-Mex
5. The Picnic (food truck park) – A little bit of everything, 15-min walk from PEC
6. Chuy's – Tex/Mex
7. Juliet Italian Kitchen – Upscale Italian

Congress Dinner (Wednesday, 17 July 6:45–9:00pm)

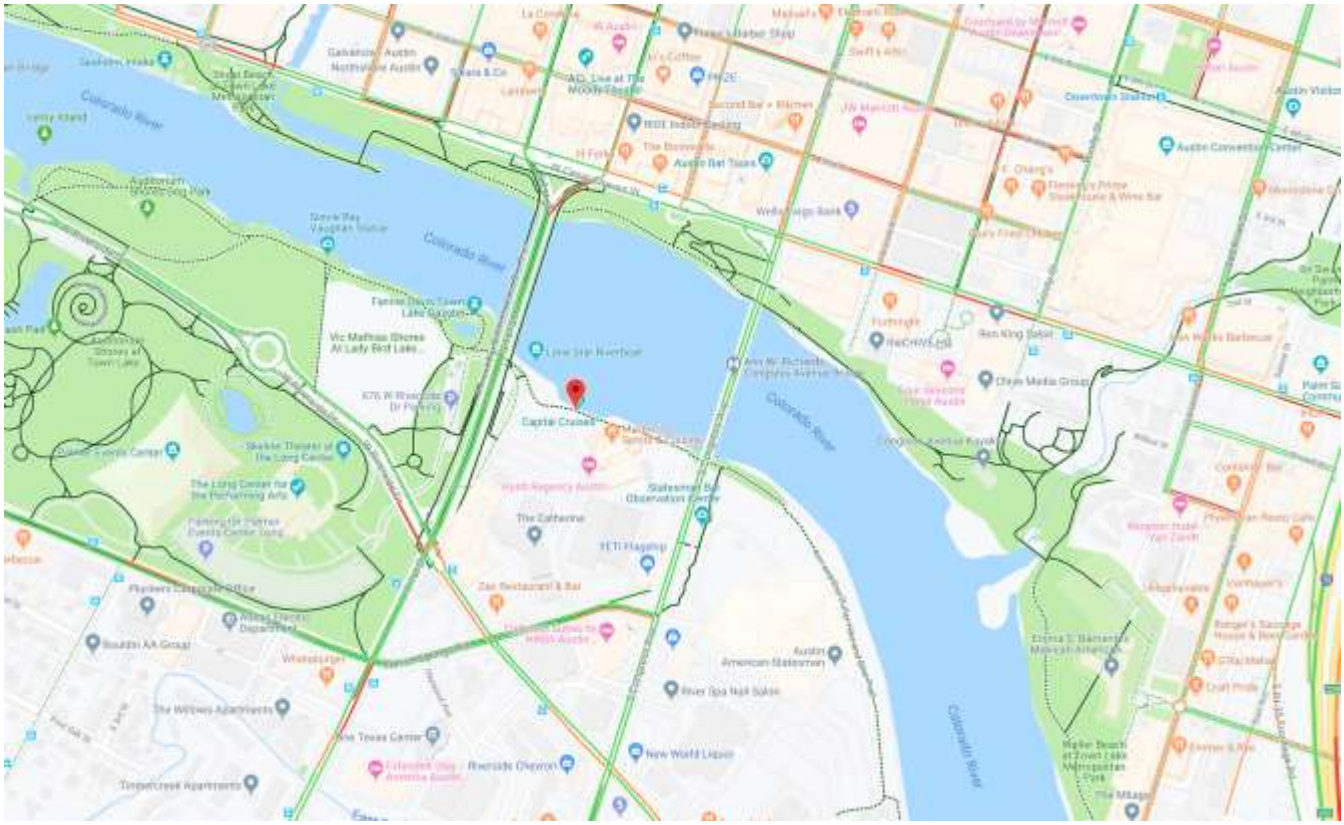
The Congress Dinner will be on a boat tour to see the bats emerging from the Congress Street Bridge on Lady Bird Lake. Texas-style fajitas will be served with local beer and wine, and vegetarian options will be available. We will board the *Capital Cruises* boat on the north side of the Hyatt Regency at 6:45pm.

Local Dragonflies Tour (Friday, 19 July 8:00am – 3:00pm)

During the tour, sandwich box lunches will be served from Austin Java who try and source their ingredients locally. Meet at the Hyatt Recency parking lot on Friday.

Congress Dinner

This year's Congress dinner is going to be super cool! It'll be held on Wednesday evening on a boat on Lady Bird Lake in Austin (walking distance from the Palmer Events Center). From the boat, we'll get to see the emergence of Mexican free-tailed bats from their harborage under the Congress Street Bridge, the largest metropolitan bat colony in the world. Price included Tex-Mex dinner and drinks available in the air-conditioned cabin of the boat or you can take your dinner to the top of the boat and enjoy the view and atmosphere of Austin. We will load up on the Capital Cruises boat located on the lake just north of the Hyatt Regency hotel at 6:45p.



About Bats in Austin

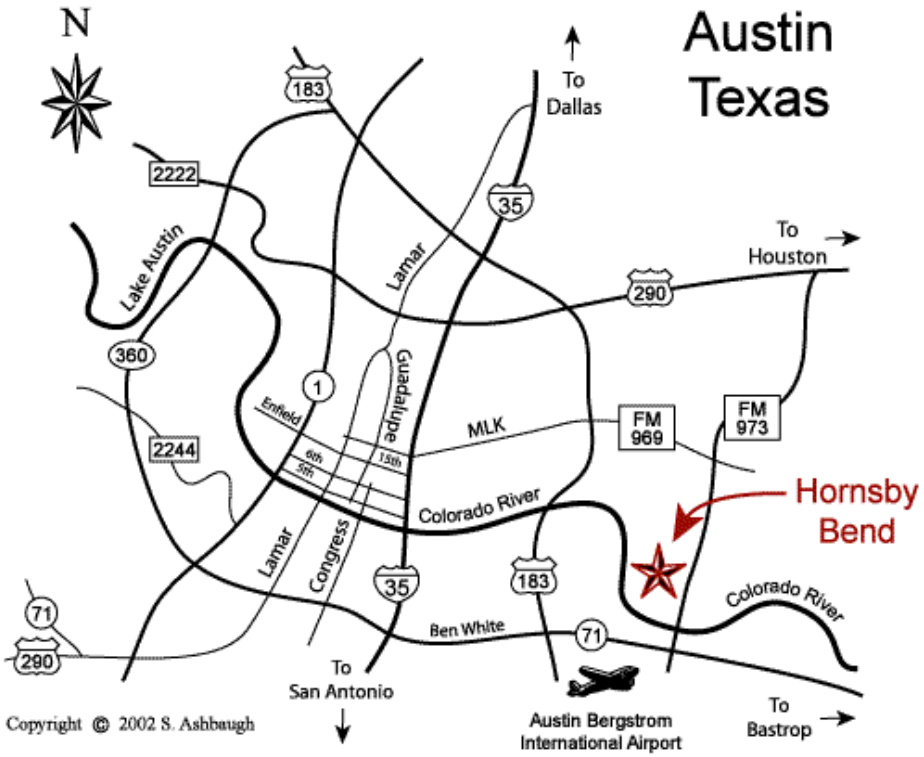
Whether a bat enthusiast or not, many just love to take in an evening view of bats in Austin as one of the many local Austin, Texas attractions. Simply put, people are batty for Austin's world-renowned Mexico free-tailed bats and their night flight of 60-plus miles per hour and 2-mile high flight patterns and feeding frenzy of Austin insects. Thanks to Lady Bird Lake, formerly Town Lake, circa 1980 renovations making a home for the bats in Austin, Texas, the South Congress Bridge, also known as the Ann W. Richards Congress Avenue Bridge, bats put on a nightly spectacular show of dynamic aerial flight typically lasting 45 to 60 minutes long. Whether attending the Austin Bat Festival, a visiting tourist, or a Keep Austin Weird local, bats in Austin under the South Congress Bridge entertain and amaze all walks of life, from the youngest to the oldest.

Local Dragonflies Tour

On Friday, we'll travel to Hornsby Bend Bird Observatory (https://www.hornsbybend.org/), which is home to 116 dragonfly and damselfly species! The tour includes travel by bus to Hornsby Bend. Lunch (included in price) will be catered by Austin Java, a locally owned restaurant that gets its ingredients locally. This event takes the place of the traditional mid-Congress tour. It's optional, but highly encouraged!

History of Birding at Hornsby Bend

The 1200-acre Hornsby Bend site is located in southeast Austin, Texas. The first birders found the "Platt" ponds at Hornsby Bend in 1959. Rob Fergus gives this account in his 1999 thesis on birds of Hornsby Bend, "G. Frank 'Pancho' Oatman, a young birder from Austin who was visiting relatives in Del Valle for the Thanksgiving Holiday, noticed ducks flying across the Colorado River. Guessing that there must be ponds nearby, Pancho explored the area and became the first birdwatcher to discover the sewage facilities at Hornsby Bend. On his initial visit, Pancho spotted waterfowl in large numbers-unusual for the Austin area-including four female common goldeneyes and a single Bonaparte's gull-both firsts for Travis County. Pancho excitedly phoned other birders with his news. Local experts Edgar Kincaid and Fred Webster joined Pancho at the ponds the next day with John and Rose Ann Rowlett. The rare birds were still there. Oatman and the Rowletts visited the facility again on 27 November and discovered two additional Travis County firsts-a dunlin and two lapland longspurs. Today, the Hornsby Bend Bird Observatory is a program of the Austin Water Utility's Center for Environmental Research at the Hornsby Bend Biosolids Management Plant.



ICO 2019 Program at a Glance

SUNDAY 14 JULY

7:00–9:00pm	Welcome Reception* (drinks & tapas will be served)

MONDAY 15 JULY

8:00	On-site Registration*
8:30	Housekeeping
8:45	Session 1: *The Future of Odonatology*
10:25	Coffee Break
11:00	Session 2
12:00	Lunch
2:00	Session 3
3:15	Coffee Break
3:45–5:00	Workshop: *Direction of WDA & IJO*
7:00–9:00	Student Mixer* (drinks & tapas will be served)

TUESDAY 16 JULY

8:30	Housekeeping*
8:45	Session 4: *Natural History of Odonata*
10:10	Coffee Break, set up posters
10:45	Session 4 continued
11:15	Poster Lightning Talks
12:00	Lunch
2:00	Session 5
3:15	Poster Viewing
5:00–5:30	WDA Outgoing Board Meeting
8:00–9:00	IJO Editorial Board Meeting*

WEDNESDAY 17 JULY

8:30	Housekeeping*
8:45	Session 6: *Morphology & Biomechanics of Odonata*
10:10	Coffee Break
10:45	Session 6 continued
11:15	Session 7
12:00	Lunch
2:00	Workshop: *Dragonfly Nymphs: Basic Anatomy & Identification*
4:00	Coffee Break
4:20–6:00	WDA Biennial Meeting
6:45–9:00	Congress Dinner (meet at Capital Cruises on north side of Hyatt Regency)

THURSDAY 18 JULY

8:30	Housekeeping*
8:45	Session 8: *Odonata Without Borders*
10:10	Coffee Break
11:00	Session 8 continued
11:30	Invitation to ICO 2021 in Cyprus
12:00	Lunch
2:00	Session 9: *Odonata Outreach*
3:25	Coffee Break
3:45	Workshop: *What is an acceptable record? Species richness and standardization of jurisdictional lists*
5:00–5:30	Concluding Remarks

FRIDAY 19 JULY

8:00–3:00	Local Dragonflies Tour (meet at Hyatt Regency parking lot)

*2nd floor of Palmer Events Center (use entrance on Riverside Drive, near pond). External doors will be locked (from outside) 15 minutes after the last scheduled event.

ICO 2019 Detailed Program

Presenting author is **bolded**.

SUNDAY 14 JULY

7:00–9:00 **WELCOME RECEPTION & REGISTRATION**
Palmer Event Center, 2nd floor; drinks & tapas will be served

MONDAY 15 JULY

8:00 **REGISTRATION**

8:30 Housekeeping
John Abbott

8:45 **SESSION 1**: The Future of Odonatology

8:45 Plenary talk: 1.1 An unexpected odonatological natural history journey: from species concepts to adaptations and moving towards conservation
Melissa Sánchez Herrera

9:10 1.2 Divergent agonistic behavior in two incipient damselflies species
Leocris Batucan, Jr (student travel award recipient)**,** Yu-Hsun Hsu*,* Chung-Ping Lin

9:25 1.3 Tropical mountain dragonflies and climate change: A look through the development of *Erythrodiplax fusca* (Rambur, 1842) (Odonata: Libellulidae) larvae in the altitudinal gradient of the Tatamá National Park, Colombia
Juliana Sandoval Hernandez (student travel award recipient)

9:40 1.4 The dragonflies of the Tatamá region (Colombia) as a path to conservation and peace in an extraordinarily rich biological region
Cornelio Andrés Bota-Sierra (student travel award recipient)

9:55 1.5 Differential evolution associated with absence or presence of color polymorphism in Odonata: A case study
Mónica Torres-Pachón (student travel award recipient), Jazmín Blaz-Sánchez, Enrique Ibarra-Laclette, Eduardo Ruiz-Sanchez, Camilo Salazar, Rodolfo Novelo-Gutiérrez

10:10 1.6 Phylogeography of three Rubyspot damselflies in Mexico
Yesenia M Vega-Sánchez (student travel award recipient), Luis F Mendoza-Cuenca, Antonio González-Rodríguez

10:25–11:00 Coffee Break

11:00	**SESSION 2**
11:00	2.1 Mythology and Science – how different are they? Discussing issues in dragonfly biogeography **Milen Marinov**
11:15	2.2 Odonates as models for ethodiversity studies **Adolfo Cordero-Rivera**
11:30	2.3 Hopping from “kreek” to “kreek” on the islands of Vanuatu: Current understanding of *Vanuatubasis* Ober and Staniczek (Odonata: Coenagrionidae) **Natalie A Saxton**, Gareth S Powell, Milen Marinov, Abigail M Dean, Seth M Bybee
11:45	2.4 Geographic variation of body size: combined effects of sexual selection, thermoregulation and reproductive interference in *Mnais* damselflies **Yoshitaka Tsubaki**
12:00–2:00	Lunch
2:00	**SESSION 3**
2:00	3.1 Population structure and genetic diversity of a rare dragonfly, *Cordulegaster sarracenia* (Odonata: Cordulegastridae) **Kendra Abbott**, John Abbott, Jeffrey Lozier
2:15	3.2 Comparative phylogeography uncovers evolutionary past of circumboreal dragonflies **Manpreet K Kohli**, Marie Djernæs, Melissa Sanchez-Herrera, Erik Pilgrim, Göran Sahlén, Thomas Simonsen, Kent Olsen, Jessica L Ware
2:30	3.3 Water quality parameters as indicators of odonate diversity and distribution in Lufasi and Omo Resort, Lekki, Lagos, Nigeria **Kehinde Kemabonta**, Rhema Uche-Dike
2:45	3.4 Odonata fauna as bioindicators of water quality and bioaccumulator of heavy metals in Kara (Ogun River) and Opa Stream, southwestern Nigeria Adetola Fadare**,** BA Jokanola, BW Adu, **KA Kemabonta**, SS Ogbogu
3:00	3.5 Odonata as indicators of tropical forest degradation **Aleš Dolný**, Hana Šigutová, Dan Bárta
3:15–3:45	Coffee Break
3:45–5:00	**WORKSHOP:** Future Direction of WDA and IJO
7:00–9:00	**STUDENT MIXER**

TUESDAY 16 JULY

8:30	Housekeeping **John Abbott**
8:45	**SESSION 4:** Natural History of Odonata
8:45	Plenary Talk: 4.1 Dragonfly coloration, as interesting as it gets **Dennis Paulson**
9:10	4.2 Spin-dry dragonflies: Nature's fastest spinners **James Walker**
9:25	4.3 ~~Non-invasive measuring of the duration of fights and copulation by individual territorial dragonfly males~~ ~~**Zandeleen Thygesen**, Velesia Lesch, Hindrik Bouwman~~ *cancelled*
9:40	4.4 Why Bluets are Blue, or not: Structure and function of coloration in *Enallagma* damselflies **Tom Schultz**
9:55	4.5 The evolution of color polymorphism in the genus *Ischnura* (Coenagrionidae) **Adolfo Cordero-Rivera**, Rosa A Sánchez-Guillén, Suman Neupane, Anais Rivas-Torres, Maren Wellenreuther, Seth Bybee, Bengt Hansson, María I Velásquez-Vélez, Emilio Realpe, Jesús R Chávez-Ríos, Fabricio Villalobos, Henri Dumont
10:10–10:45	Coffee Break; poster presenters: please set up your posters at this time
10:45	4.6 Egg-laying in Autumn Meadowhawks, *Sympetrum vicinum* (Hagen) **James Walker**
11:00	4.7 Test of male search image formation for color polymorphic females in the wild **Ola Fincke**, Silvana Piersanti, Viviana Di Pietro, Leonardo Giontella, Manuela Rebora, Gianandrea Salerno
11:15	**POSTER LIGHTNING TALKS** (1-min poster advertisements)
12:00–2:00	Lunch
2:00	**SESSION 5**
2:00	5.1 ~~Predatory dragonflies: Possible providers of ecosystem services for mosquito control~~ ~~**Maritza Monserrat San Miquel Rodríguez**, Alejandro Córdoba Aguilar~~ *cancelled, moved to poster P10*
2:15	5.2 Plants, water and landscape as drivers of Odonata assemblages in urban stormwater ponds **Mary Ann Perron**
2:30	5.3 Effects of different management types on dragonfly pond assemblages **Frank Suhling**, Diana Goertzen
2:45	5.4 Win–win urban ecology: Near-home fishing promotes diversity of Odonata **Michael Patten**, Emily Hjalmarson

3:00 5.5 Systematics of dragonfly genus *Aeshna* (Anisoptera: Aeshnidae)
Manpreet K Kohli**,** Marie Djernæs, **Ken Knapp**, Marie Djernæs, Göran Sahlén, Thomas Simonsen, Kent Olsen, Jessica L Ware

3:15 POSTER VIEWING

5:00–5:30 MEETING: WDA Outgoing Board Meeting

8:00–9:00 MEETING: IJO Editorial Board Meeting

WEDNESDAY 17 JULY

8:30 Housekeeping
John Abbott

8:45 SESSION 6: Morphology & Biomechanics of Odonatology

8:45 Plenary Talk: 6.1 The predatory strike of dragonfly larvae (Insecta: Odonata)
Sebastian Büsse, Alexander Köhnsen, Stanislav N Gorb

9:10 6.2 The flight apparatus of Odonata and the crucial role of resilin
Fabian Bäumler, Stanislav N Gorb, Sebastian Büsse

9:25 6.3 Holding on for dear life – the functional morphology of waterfall-dwelling damselflies in the Neotropics
Christopher Beatty, Sebastian Büsse, Melissa Sánchez Herrera, Esteban Saade Pelaez, Stanislav Gorb

9:40 6.4 Bringing morphology, molecules, fossils, and extant odonates together: How reliable is morphology in a phylogenetic context?
Robert Erickson, Seth Bybee

9:55 6.5 The dynamics of the predatory strike in Odonata larvae
Alexander Köhnsen, Stanislav N Gorb, Sebastian Büsse

10:10–10:45 Coffee Break

10:45 6.6 Automatically measuring dragonfly wings: an update on the Targeted Odonata Wing Digitization (TOWD) project
William R Kuhn, Jessica L Ware, John C Abbott, Melissa Sánchez Herrera, Dirk Gassmann

11:00 6.7 Precision 3D reconstruction of dragonfly flight paths and behavior as measured with GoPros and VSLAM software
Parrish Brady

11:15 SESSION 7

11:15 7.1 Differences in the critical thermal limits and thermal tolerance of males, females and larvae of *Hetaerina americana* (Fabricius) in three populations with contrasting environmental temperature conditions
Luisa Isarrarás-Hernández, Ignacio Castellanos-Sturemark, Luis Felipe Mendoza-Cuenca

11:30	7.2 Using Mixed Distribution Analysis to determine the instar of field-collected dragonfly nymphs **Ami Thompson**
11:45	7.3 Changes in the diversity of Odonata of University of Ibadan, Oyo State, Nigeria, using surveys and museum specimens **Kehinde Kemabonta**, Babashola Adu, Sylvester Ogbogu, Adebayo Omoloye, Winifred Makanjuola, Rhema Uche-Dike
12:00–2:00	Lunch
2:00	**WORKSHOP:** Dragonfly Nymphs: Basic Anatomy & Identification **Marla Garrison**
4:00–4:20	Coffee Break
4:20–6:00	**MEETING:** WDA Biennial Meeting **BIENNIAL MEETING**
6:45–9:00	CONGRESS DINNER (meet at Capital Cruises on north side of Hyatt Regency)

THURSDAY 18 JULY

8:30	Housekeeping **- John Abbott**
8:45	**SESSION 8:** Odonata Without Borders
8:45	Plenary Talk: 8.1 *Megaloprepus caerulatus* population genetics **Jessica L Ware**, Ola Fincke, Megan Wilson
9:10	8.2 Becoming Mx. Worldwide **Nene Kumashe Ugbah**, Jessica L Ware
9:25	8.3 Segregation structure in Odonata assemblages follows the latitudinal gradient **Francesco Cerini**, Luca Stellati, Leonardo Vignoli
9:40	8.4 Dragonflies prevail in the age of widespread insect decline **Göran Sahlén**, Marie Magnheden
9:55	8.5 Local movements and habitat selection of *Anax imperator* using radio-tracking **Marceau Minot**, Aurélie Husté
10:10–11:00	Coffee Break
11:00	8.6 Concept and realization of the World Odonata Manual Bastiaan Kiauta, Brij Kishore Tyagi, **Milen Marinov**
11:15	8.7 Geographic variation of body size and body shape in heliothermic damselflies along a latitudinal gradient in East Asia **Yoshitaka Tsubaki**
11:30	**INVITATION to ICO 2021 in Cyprus** **David and Rosalyn Sparrow**
12:00–2:00	Lunch
2:00	**SESSION 9:** Odonata Outreach

2:00	9.1 Promoting Youth Education and Research Through Dragonfly Citizen Science **Christine Goforth**
2:25	9.2 How difficult is it to turn an amateur into an “expert” in Odonata identification? **Stanislav Ožana**, Vojtěch Molek, Michal Hykel, Michal Burda, Marek Malina, Martin Prášek, Aleš Dolný
2:40	9.3 Odonata and the digital age - **John Abbott**
2:55	9.4 Damselfly population genetics as a CURE for science students at a small liberal arts university **Ryan Caesar**
3:10	9.5 Beyond dragonfly citizen science - **Ami Thompson**
3:25–3:45	Coffee Break
3:45	**WORKSHOP:** What is an acceptable record? Species richness and standardization of jurisdictional lists **Brenda Smith-Patten**
5:00	**CONCLUDING REMARKS**

FRIDAY 19 JULY

8:00–3:00 **LOCAL DRAGONFLIES TOUR** (meet at Hyatt Regency parking lot)

ICO 2019 Abstracts

Session 1: Future of Odonatology (Melissa Sánchez Herrera, plenary speaker)

1.1 Plenary talk: An unexpected odonatological natural history journey: from species concepts to adaptations and moving towards conservation

Melissa Sánchez Herrera (melsanc@gmail.com), Universidad del Rosario, Bogota, Colombia

The Anthropocene period is here: our planet is currently experiencing unprecedented changes and all life forms—including humanity—are being significantly affected. With this in mind, we must ask the question, how will our research of our beloved bugs address these challenges? Here I consider this while reviewing my work on the Neotropical damselflies in the genus *Polythore* Calvert. These damselflies are stunningly colorful, their wings displaying patterns of orange, black and/or white. The genus comprises 21 described morphospecies distributed along the eastern slopes of the Andes cordillera and the Amazon basin, through Colombia to northern Bolivia. The remarkable diversity of color in these damselflies has led my research questions to unexpected discoveries and an incredible journey. I will present an overview of the genus, from a macro to micro evolutionary scope. Moreover, I will portrait new research avenues to explore adaptive traits like wing coloration and larval functional morphology within the genus. Finally I will show how, by applying novel molecular techniques to odonate assessments, we can not only increase our knowledge of biodiversity at all scales, but also generate practical strategies that will promote the conservation of our most scarce resource for humans and our dragons—freshwater.

1.2 Divergent agonistic behavior in two incipient damselflies species

Leocris Batucan, Jr (student travel award recipient, leocrisjr@gmail.com), Department of Life Science, National Taiwan Normal University; Yu-Hsun Hsu, Biodiversity Program, Taiwan International Graduate Program, Academia Sinica; Chung-Ping Lin, Department of Life Science, National Cheng Kung University

Maintaining and defending a territory from rivals can be energetically costly and injury-prone. Thus, many strategies have arisen among territorial animals to maintain dominance, reduce costs, and deescalate fights. Here, we present two territorial subspecies of *Psolodesmus mandarinus* MacLachlan (*P. m. mandarinus* and *P. m. dorothea*) damselfly differing in their wing ornamentation and that utilize divergent strategies for territorial defense against consubspecific males. A unique agonistic behavior was observed in *P. m. mandarinus*, characterized by a perched four-stage escalating threat display, whereas only a direct aerial fight was recorded for *P. m. dorothea*. In *P. m. mandarinus*, contests that lead to aerial fights show increased wing beat frequency, threat-stage frequency, and shorter threat latency. Such divergent strategies in differently ornamented incipient species illustrate the various behaviors utilized by damselflies to settle costly territorial disputes and their potential role in speciation of the taxa.

1.3 Tropical mountain dragonflies and climate change: A look through the development of *Erythrodiplax fusca* (Rambur, 1842) (Odonata: Libellulidae) larvae in the altitudinal gradient of the Tatamá National Park, Colombia

Juliana Sandoval Hernandez (student travel award recipient, julisando@gmail.com), Instituto de Ecología A.C. (INECOL), Xalapa, Mexico

Although tropical mountains have constant temperature through the year, they can suffer of abrupt daily changes of temperature throughout the elevation gradient. Organisms living in these ecosystems are expected to tolerate small ranges of temperature, making them thermal specialists in small portions of the slopes. In particular, Colombia shows an incredible biodiversity that, together with the abovementioned factor, might be due to the presence of great physical barriers of the Andean range that cross the country and several rivers which flow through it. The temperature rise expected due to climate change make the tropical mountains some of the most endangered habitats in the planet. The red-face dragonlet, *Erythrodiplax fusca* (Rambur, 1842) has a large geographic distribution (U.S. to Argentina). Two larval populations occur at different elevations (350 and 1350 m) in the Tatamá NP elevational gradient (0 to 1400 m.a.s.l). We raised larvae in four different temperatures (15, 20, 25, and 28 °C) to determine their response to temperature changes. Our results will shed light on how these populations will deal with the expected rise in temperatures caused by climate change. If the response is plastic, they are expected to overcome this rise more easily than if the response shows some signs of adaptive selection to certain temperatures. The preliminary results show lower survival rates at the highest temperatures in both populations.

1.4 The dragonflies of the Tatamá region (Colombia) as a path to conservation and peace in an extraordinarily rich biological region.

Cornelio Andrés Bota-Sierra (student travel award recipient, corneliobota@gmail.com)

The Tatamá region is at the Western Andean Cordillera in Colombia and extends to the foothills and lowlands in the Biogeographic Chocó. There, two hotspots for biodiversity converge, making it one of the most diverse areas in the world. Until 2004, the access to the region was closed due to the cruel war going on there, since then the visit of researchers and the incomes from ecotourism have managed a positive transformation in the region. The mountains above 1100 m are protected inside a national park, which in the last ten years have become the most popular place for birdwatchers in Colombia. The foothills and lower areas, despite being part of the same biological system, are not protected and are seriously threatened by uncontrolled deforestation and mining. This results of special worry for organisms like odonates that are more diverse in the lowlands. During the last six years, several field trips intending to explore the odonates of this region, have revealed the presence of 14 families, 55 genera, and 120 species inhabiting the area, including 21 endemics, and 8 almost endemics, among them five species were recently described and five more are in the description process, including the emblematic *Cora verapax* devoted to the peace process going on in Colombia. With the aim to contribute to the peace and conservation of this region, we write a book in English and Spanish with 164 photographs of 104 species in the region that intend to show the great beauty this region harbors and invites you to visit, learn, and help the conservation of the Tatamá.

1.5 Differential evolution associated with absence or presence of color polymorphism in Odonata: A case study

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Color polymorphisms in nature are wonderful traits to study. Within the order Odonata there are multiple hypotheses about the evolution of presence or absence of this trait, but studies have been mainly focused at the population level. Comparative analysis in a phylogenetic context has not yet been evaluated. Our research questions is: Are there any signs of selection associated with the presence or absence of color polymorphism among lineages of Odonata? Transcriptomics of five species lacking color polymorphisms were sequenced for the

first time: *Phyllogomphides pacificus* (Selys, 1873), *P. pugnifer* Donnelly, 1979, *P. suasus* (Selys, 1859), *Phyllogomphides* sp. nov. and *Progomphus clendoni* Calvert, 1905 (Anisoptera: Gomphidae). Using Omics tools, these species were compared with the genomes and transcriptomes of 13 Odonata species, and 17 species of other insects available in GenBank. We identified orthologous genes within the species using GetORF. The rate of sequence evolution associated with binary trait was evaluated with TraitRateProp. For a test of positive selection, we used aBSREL and software Hyphy. The total identification of unigenes in each transcriptomes of the five species of gomphids, were between 11.000 and 29.000 unigenes. Likewise, the annotated proteins by homology-based inference were between 5.000 and 11.000 putative-proteins. 124 orthologous genes were found within Odonata species. The TraitRateProp test found no association between the phenotypic trait and rate of sequence evolution. More rRNA libraries of the five species will be sequenced to increase the depth in the sequences.

1.6 Phylogeography of three Rubyspot damselflies in Mexico

Yesenia M Vega-Sánchez (student travel award recipient, yvega@cieco.unam.mx), Universidad Nacional Autónoma de México; Luis F Mendoza-Cuenca, Universidad Michoacana de San Nicolás de Hidalgo; Antonio González-Rodríguez, Universidad Nacional Autónoma de México

Analyzing the phylogeographic patterns of species that are also closely related allow us to understand if there are common evolutionary events that have molded the geographic distribution of populations and identify those aspects that make the species differ in their distribution. *Hetaerina* is a group of 37 species of calopterygids that have a wide distribution in the neotropics and several species are usually found in sympatry. In addition, three species extend their distribution to the Nearctic; however, studies about the factors that restrict their distribution are scarce. To determine which evolutionary events have shaped the distribution of Neotropical species of the genus *Hetaerina* in Mexico, we analyzed genetically more than 150 individuals of the species *H. cruentata* Rambur, *H. occisa* Hagen and *H. titia* Drury using the mitochondrial region of barcoding (COI), as well as a nuclear region (ITS). Based on these data, we determined phylogenetic relationships, as well as historical demographic patterns and genetic differentiation among populations. For all species, there was incongruence between mitochondrial and nuclear patterns, which may be related to selection patterns on the mitochondrial genome or female philopatry. On the other hand, the patterns of nuclear genetic differentiation (F_{ST}> 0.90) show that the main barriers to gene flow are related to physical barriers and the dispersion patterns of the species. Finally, the limits of the distribution of strictly neotropical species seem to be associated with abiotic constraints rather than the dispersal capability of individuals.

Session 2

2.1 Mythology and Science – how different are they? Discussing issues in dragonfly biogeography

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This may sound like a ridiculous question; however, the talk will show that fundamentally mythology and science are not that different. Even with the best intentions to resolve an important scientific puzzle some researchers may easily fall into the trap of creating a myth.

The talk presents the author's view of what should be considered as a science. It applies the best scientific practices in some of already created myths in Odonata biogeography. Three study cases briefly touch base on unexplained so far phenomena in the distribution of *Anax ephippiger* (Burmeister, 1839), *Anax junius* (Drury, 1773) and *Pantala flavescens* (Fabricius, 1798). They challenge the widespread opinion of the high importance of the Long Distance Dispersal (LDD) in the oceanic island Odonata biogeography.

Topics covered will include: (1) the need for more plausible evidences on the LDD in dragonflies, (2) LDD alone cannot explain the origin and distribution of island biota, (3) contemporary species distribution is a result of a complex interactions between: dispersal, vicariance, human transport, and (4) *what's next?*

2.2 Odonates as models for ethodiversity studies

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The concept of ethodiversity has been proposed to highlight the need of appraising and preserving behavioral diversity as part of biodiversity. The concept of biodiversity is usually defined as the diversity of genes, species and ecosystems; however, I argue that a fourth level of biodiversity, never included in biodiversity studies, is of prominent relevance: ethological diversity. There is a growing number of studies showing that animal behavior is fine-tuned by natural and sexual selection. At the same time, many studies describe alternative behaviors, ethological plasticity and even personality, as characteristics of many animal populations. Behavior has profound ecological consequences, particularly in species interactions, and models that ignore ethological diversity, treating all individuals as equivalent, are unlikely to have good predictive power. Ethodiversity is important at the intraspecific, inter-population, and species level. Here I show that odonates are particularly useful subjects of study in this field, and discuss their diversity of reproductive behaviors. I will concentrate in the diversity of intra-male sperm translocation behavior, alternative tactics in males and females and postcopulatory sexual selection. Studies of tropical genera, particularly of Zygoptera, are urgently needed to gain an overall understanding of behavioral diversity in odonates.

2.3 Hopping from "kreek" to "kreek" on the islands of Vanuatu: Current understanding of *Vanuatubasis* Ober and Staniczek (Odonata: Coenagrionidae)

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Vanuatu is an island nation in the South Pacific composed of 82 islands. The island has on known endemic genus, *Vanuatubasis*. The genus was erected in 2009 by Ober and Staniczek. They included three species in the genus: *Vanuatubasis bidens* (Kimmins), *V. malekulana* (Kimmins), *V. santoensis* Ober and Staniczek 2009. Recent fieldwork from 2017-2019 in Vanuatu has expanded both our understanding of this genus and its distribution throughout the country. Here, we explore the habitat preference, ecological models, preliminary estimates of species diversity across Ambrym, Aneityum, Efate, Erromango, Espiritu Santo, Gaua, Malekula, Maewo, Pentecost, and Tanna. Future plans for the taxonomy, systematics and phylogenetics of the genus and also discussed. We will also outline general odonate diversity across Vanuatu as currently understood.

2.4 Geographic variation of body size: combined effects of sexual selection, thermoregulation and reproductive interference in *Mnais* damselflies

Yoshitaka Tsubaki (mnais.costalis@gmail.com), Center for Ecological Research, Kyoto University, Japan

Body sizes of animals often show geographic variation, and suggest various ecological and evolutionary implications such as developmental flexibility, climatic adaption, sexual selection and character displacement. As "body size" is difficult to define explicitly, body mass or a characteristic linear dimension, such as body length or wing length are often used interchangeably as measures of body size in insect. Although mass and linear dimensions may be strongly related, this need not always be so. Given constant linear dimensions, adult mass may vary depending on age, sex, morph and the feeding and reproductive status of an individual. Therefore, mass

is recommended to use in the analysis of ontogenetic change, while linear dimensions may be useful for describing individual variation in insects. I will report results and analyses of body size measurements on two Japanese broad-winged damselflies (*Mnais costalis* Selys and *M. pruinose* Selys). I found that the reproductive interference played an important role for the formulation of the geographic variation in this group.

Session 3

3.1 Population Structure and Genetic Diversity of a Rare Dragonfly, *Cordulegaster sarracenia* (Odonata: Cordulegastridae)

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We isolated and characterized a total of 13 microsatellite loci from *Cordulegaster sarracenia* (Odonata: Cordulegastridae). Loci were screened in 24 individuals from Louisiana and Texas. Within *C. sarracenia*, the number of alleles per locus ranged from 0 to 5, and observed and expected heterozygosities ranged from 0.000 to 0.556 and 0.000 to 0.613, respectively. Overall differentiation among study populations was very high (FST=0.423), suggesting significant geographic population structure with low diversity within populations. Twelve of the 13 primers amplified in *C. sayi*, *C. diastatops, C. maculata,* and *C. obliqua* and polymorphism levels are reported. These new genetic markers will provide tools for addressing a number of population genetic and demographic questions relating to conservation of this rare dragonfly species.

3.2 Comparative phylogeography uncovers evolutionary past of circumboreal dragonflies

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We investigate the evolutionary history of five northern dragonfly species and understand what role last glaciation period has played in their current distribution. We look at population structure and divergence time of populations of *Aeshna juncea*, *Aeshna subarctica*, *Sympetrum danae*, *Libellula quadrimaculata* and *Somatochlora shalbergi* across their Holarctic range. Our results present some common phylogeographic patterns across all the species except, *S. sahlbergi*. First, we find that North American and European populations are genetically distinct and perhaps have been separated for than 400,000 years before present. Second, our data also suggests that populations from Greater Beringian region (Beringia, Japan and China) don't have a geographic affinity and cluster with North America or Europe depending on the species. This is perhaps a result of fluctuating sea levels in during the Quaternary period. Third, we find that *Somatochlora sahlbergi* is an exception, and is different from all the other Holarctic species, and shows none of the geographic patterns presented in any other species. Lastly, we discuss *Sympetrum danae* as being a species complex of two species. Through this study we present a shared history among different species of dragonflies, which is influenced by the climatic fluctuations of the past.

3.3 Water quality parameters as indicators of odonate diversity and distribution in Lufasi and Omo Resort, Lekki, Lagos, Nigeria

Kehinde Kemabonta & Rhema Uche-Dike (rhemadike@gmail.com), University of Lagos, Department of Zoology, Akoka, Lagos, Nigeria

Dragonflies and damselflies are known to be excellent indicators of different biotypes and habitats and have been used as tools to assess the biological health of aquatic habitats. This study was conducted to compare the diversity of damselflies and dragonflies (Odonata: Insecta) in water bodies in Lekki Urban Forest and Animal Sanctuary Initiative (LUFASI) nature park and in Omu lake in Ibeju Lekki, Lagos, Nigeria. Samples of adult odonate specimens and water samples were collected from the lakes for a period of 9 months within January to September, 2018. A total of 700 individuals representing 26 species and 16 genera in two families, Libellulidae and Coenagrionidae, were collected and identified. Of the 700 individuals, Libellulidae had the higher percentage composition (79.18%) with 426 individuals, out of which *Chalcostephia flavifrons* (Kirby) had the highest number of individuals (253); Coenagrionidae had the lower percentage composition (20.81%) with 112 individuals. Omu lake had the highest species diversity (H'= 1.596) while Lake Moses, LUFASI had the least species diversity (H' = 1.055). Physico-chemical data and Margalef's water quality index showed that the Omu lake had the better water quality when compared with the other two sites, and this accounted for the highest species diversity found in that site. This finding explains and affirms the relationship between the quality of water and the diversity and abundance of Odonata. The distribution of odonate communities in relation to water quality could be a useful tool in classifying and comparing the water quality of aquatic ecosystems worldwide.

3.4 Odonata fauna as bioindicators of water quality and bioaccumulator of heavy metals in Kara (Ogun River) and Opa Stream, southwestern Nigeria

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Dragonflies and damselflies belong to order Odonata and are often used as bioindicators for the assessment for environmental health. This study compares the diversity of Odonata in Kara and Opa Stream in Ile-Ife, Nigeria. Samplings of specimens and water were conducted for a period of six months at the two locations. A total of 452 individuals belonging to 32 species from four families were identified at the stations. Only two families were found in Kara while all four families were represented at Opa stream. Of the total 32 species found, 18 occurred at Kara and 25 species occurred at Opa Stream. Most of the collected individuals (327) were from Kara while only 125 were from Opa Stream. Opa Stream had the higher species diversity (H' = 2.592). The physico-chemical properties of these freshwater ecosystems showed an absent of cadmium and the present of cobalt and lead (0.04 -1.67, and 0.003-0.007 respectively). These concentrations are in line with the standard limits set by WHO. However, cadmium and lead were present in detectable quantities in Odonate fauna analyzed in Kara (Cd = 0.738mg/kg and Pb= 7.375mg/kg) but only lead was present in Opa Stream odonates (Pb=4.167mg/kg). Diversity index values and the water quality index showed that Opa Stream had better water quality than Kara. This study shows that Odonates can be used as bioindicator of water quality and bio-accumulator of heavy metals.

3.5 Odonata as indicators of tropical forest degradation

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Odonata are frequently used as indicators of freshwater as well as terrestrial habitat conditions. Several studies have shown changes in odonate species richness and/or community composition in response to deforestation, suggesting their indication potential in tropics. However, former approaches were based on comparative samples from differently disturbed sites and/or knowledge of the focal species environmental specificity. We tested an adult-based, robust approach assuming that the level of tropical forest degradation reflects the proportions of the taxa above species. We used Web of Science, ScienceDirect, and Scopus databases to gather data from previously published studies linking odonate assemblages to human-mediated disturbances in tropical forests. These data were combined with our field samplings conducted in Borneo in 2008 and 2010, and French Guiana in 2012. We hypothesized that along a disturbance gradient (from primary forest to non-forest), (i) the proportion of the suborder Zygoptera (mostly sensitive habitat specialists) will decrease in favor of the suborder Anisoptera

(mostly generalists); and (ii) the proportions of largely generalist families Coenagrionidae and Libellulidae will increase at the expense of other Zygoptera and Anisoptera, respectively. We found that a ratio of Zygoptera/Anisoptera, previously considered as potentially good indicator of tropical forest conditions, is a poor indicator, probably due to ecological diversity within these groups. Nevertheless, the proportions of Coenagrionidae/other Zygoptera and Libellulidae/other Anisoptera suggested their potential to be a good indicator of degradation of forest habitats, as they significantly increased along a disturbance gradient. Our results support the practical use of Odonata in biological monitoring in tropics.

Session 4: Natural History of Odonata (Dennis Paulson, plenary speaker)

4.1 Plenary talk: Dragonfly coloration, as interesting as it gets

Dennis Paulson (dennispaulson@comcast.net), Seattle, US

The color patterns of adult odonates are infinitely variable, but there are patterns that can be teased out of this variation. I consider the patterns we understand and those we do not understand of equal interest. From my own research and over 50 years of studying odonates, I still have many questions, and I plan to discuss coloration by asking some of them. The ones asked here are just examples, as I have two more months to think about them.

How are the different color patterns in odonates, from dazzlingly bright to surpassingly cryptic, assorted phylogenetically, geographically, ecologically and behaviorally? Why is sexual dichromatism so common but not universal? Why do only certain groups have polymorphic females? What does the geographic variation in color patterns within species tell us? Why do different groups exhibit different arrays of colors? How does habitat affect coloration? What parallels are there between odonates and birds?

4.2 Spin-dry dragonflies: Nature’s fastest spinners

James Walker (jswphys@aol.com), Western Washington University, Bellingham, Washington, USA

Dragonflies exhibit a wide variety of behaviors, many involving their incredible flight abilities. A recently discovered suite of behaviors, referred to as the splash-dunk/spin-dry, is a case in point. Slow-motion videos show that many dragonfly species, especially darners, clean themselves by plunging headfirst into the water and coming to a complete stop. This behavior, which produces a prominent splash, is referred to as a splash-dunk. It typically takes about a second for a dragonfly to become airborne again after a splash-dunk, and the process is often repeated a number of times. Eventually, after a series of splash-dunks, the dragonfly gains altitude and performs a rapid head-over-heels tumbling motion about a horizontal axis—the spin-dry—to shed the water. Frame-by-frame analysis of slow-motion videos, filmed at 240 frames per second, shows that the spin-dry consists of 6 or 7 revolutions at a rate of approximately 1,000 rpm. This may make dragonflies the fastest spinning animals in nature. The spin-dry produces a centripetal acceleration of roughly 10 times the acceleration due to gravity, which has been shown to be effective at shedding water in many other animals, including wet dogs. The presentation includes slow-motion videos showing all aspects of the splash-dunk/spin-dry behavior, as well as a variety of other results obtained from 762 splash-dunk events observed to date.

4.3 Non-invasive measuring of the duration of fights and copulation by individual territorial dragonfly males

Zandeleen Thygesen (zandeleen@yahoo.com), Velesia Lesch & Hindrik Bouwman, North-West University, Potchefstroom, South Africa

Odonata are excellent candidates for behavioral studies due to small body and territory sizes, which make them relatively easy to observe. Behavioral studies involve invasive mark-release-and-recapture techniques that

interfere with reproductive, foraging, survival, and territorial behaviors. These techniques cause stress, damage, and in some cases, mortality to the individuals during capturing. I developed and tested a non-invasive technique to identify individual male dragonflies and combined it with a behavioral study to determine the duration of male-male fights and copulation. For this project, I used a camera to photograph the perching male (*Crocothemis erythraea*, Leach) dragonfly's wings and assign a wingprint ID. The unique number is obtained by counting the first row of cells from the pterostigmata to the nodus, and the nodus to the body, of all four wings with this resulting in an eight, two-digit number (e.g. 10-12-11-10-10-09-09-11). For this study, I managed to follow ten individuals in the field, without any capture disturbance. There were no statistical differences between how long each territory holder fought (160 events) or copulated (32 events). I also found that they were most active between 11:00 am and 12:00 pm, with the maximum fights and copulation events occurring at 28˚C, the least number of fights between 20-22˚C, and the least number of copulations at 25˚C. Territory retention following each fight was 94%. This technique shows that that it is possible to identify individual and follow the behavior of territorial males without having to capture and mark them.

4.4 Why Bluets are Blue, or not: Structure and function of coloration in *Enallagma* damselflies

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The diverse colorations of *Enallagma* damselflies arise from combinations of structural colors and diverse pigments. The blue colors of most males, which have been proposed as an intra-sexual aposematic signal, arise from coherent scattering by a 3D array of nanospheres of, as yet, undetermined material within the epidermal cells. Females of many species are polymorphic and exhibit the same structural color as their males or a cryptic coloration due to ommochrome pigments and a reduction in the density of nanospheres, as determined by transmission electron microscopy and cuticle histology. Pigment chromatography and TEM have revealed that in the *signatum* subclade of the genus, the colors of males result from vesicles of pterin pigments in place of nanospheres in the epidermis. These long-wavelength colorations are especially conspicuous in the ambient light conditions where the males, unlike males of blue species, exhibit quasi-territorial behavior and aggression towards conspecific males.

4.5 The evolution of color polymorphism in the genus *Ischnura* (Coenagrionidae)

Adolfo Cordero-Rivera (adolfo.cordero@uvigo.es), AC-R, Grupo ECOEVO, EE Forestal, Universidade de Vigo, Campus Universitario, Pontevedra, Spain; Rosa A Sánchez-Guillén, Suman Neupane, Anais Rivas-Torres, Maren Wellenreuther, Seth Bybee, Bengt Hansson, María I Velásquez-Vélez, Emilio Realpe, Jesús R Chávez-Ríos, Fabricio Villalobos, & Henri Dumont

The study of the origin(s) and evolutionary patterns of female-limited color polymorphism in damselflies, is a fascinating topic that may help is to understand how genetic and phenotypic variation is created and maintained. This polymorphism includes the presence of 2-3 color morphs: one androchrome morph with a coloration that is similar to the male, and 1-2 gynochrome morphs (*infuscans* and/or *aurantiaca*) with a female-specific coloration. The different morphs are likely employing alternative reproductive strategies. In fact, in ischnuran damselflies, sexual conflict over mating rates has been proposed as a key mechanism that has led to the diversity of color. In *Ischnura*, there is evidence that several life history traits are linked to color: mating system, fecundity, parasite resistance and behavior and resistance to male harassment. We documented the color and mating system of 44 of the approximately 75 taxa within the genus *Ischnura* to investigate: i) ancestral color state; ii) the correlated evolution of the color and mating system (monandry/polyandry); and iii) the directionality of trait-state transitions. Although we were not able to resolve the ancestral state of female color, our results showed that color polymorphism is more frequent among polyandric species, whereas monandric species tend to be monomorphic. We also found that being polymorphic and polyandric is the most persistent state. Our finding that the same phenotypic morphs have evolved multiple times (convergent evolution) suggests that several species in this genus might be experiencing similar selective pressures.

4.6 Egg-laying in Autumn Meadowhawks, *Sympetrum* vicinum (Hagen)

James Walker (jswphys@aol.com), Western Washington University, Bellingham, Washington, USA

Egg laying takes a variety of forms in dragonflies. In many species, the male and female fly in tandem as the tip of the female's abdomen is dipped repeatedly into the water. With each dip, one or more eggs is deposited. Slow-motion videos show that the situation is quite different for Autumn Meadowhawks, *Sympetrum vicinum* (Hagen). It is often stated that this species taps the female's abdomen alternately into the water and onto the damp shore of a pond. While this is broadly the case, it misses the essence of an egg-laying procedure that appears to be unique to this species—and it falsely implies that eggs are deposited in both locations. In Autumn Meadowhawks, egg laying begins with the female's abdomen being dipped into the water. No egg is laid at this time, however—the purpose of the dip is to acquire a drop of water which the female holds with her oversize "egg scoop," a prominent field mark that previously had no explanation. The pair hovers for a couple seconds as the female lays eggs into the drop. To dislodge the droplet, which is held firmly in place, the pair swoops downward vigorously and whacks a stem of vegetation. This results in the egg-laden droplet being deposited onto the damp shore. This presentation shows the egg-laying process with slow-motion videos, and also presents results for the sequencing of wingbeats in the hovering pair.

4.7 Test of male search image formation for color polymorphic females in the wild

Ola Fincke (fincke@ou.edu), University of Oklahoma, Norman, USA; Silvana Piersanti, University of Perugia, Italy; Viviana Di Pietro, University of Torino, Italy; Leonardo Giontella, Manuela Rebora & Gianandrea Salerno, University of Perugia

In female-specific color polymorphic species of Odonates with male mimics, learning to recognize females by mate-searching males is thought to lead to negative frequency-dependent selection in two explanatory models. We tested the ability of male *Ischnura elegans* (Vander Linden) to form a search image by quantifying encounter rates of males with females and conspecific distractors under natural conditions at our study site on Lago Trasimeno, Italy. This is the first test of search image formation under natural conditions for any organism. We individually marked each of 82 mature males with a small white dot on the thorax, and colored marks on the wing. A male was followed for as long as possible, and each encounter with a conspecific was recorded. Search image formation would be supported if 1) males encountered more than one mature female before mating on a given day, and 2) males that mated with a female had previously recognized that morph as 'female'. Some males formed tandems at the water before sunrise, when colors were not discernible by observers. Typically, males primarily encountered males and immature females, and only rarely encountered a mature female. Males reacted sexually with equal frequency towards males, mature and immature females. Males did not recognize conspecific females that they had encountered previously. Our results failed to support search image formation by males for either andromorphs (male mimics) or the two female heteromorphs, but were consistent with an alternative, signal apparency hypothesis.

Session 5

5.1 Moved to poster P10

5.2 Plants, water and landscape as drivers of Odonata assemblages in urban stormwater ponds

Mary Ann Perron (mperr058@uottawa.ca), University of Ottawa, Ontario, Canada

Urbanization poses a global risk to biodiversity through its impact on both the quantity and quality of wildlife habitat. Wetland ecosystems, in particular, are often scarce in cities as they have been heavily impacted in the past. In North America, stormwater management ponds are frequently constructed in cities to mimic the ecological services provided by natural wetlands in terms of flood attenuation and water filtration. However, species unavoidably colonize these systems, yet little is known about the quality of this habitat for wildlife. The objective of this study was to determine if stormwater ponds are providing habitat for Odonata and what are the major drivers of Odonata biodiversity. Adult and nymphal Odonata assemblages as well as plant, water and landscape features were studied at 41 stormwater ponds in the National Capital region of Canada and compared to ten natural ponds used as reference systems. There was a large variation in Odonata biodiversity between the stormwater ponds themselves, with some ponds having low diversity and others having comparable diversity to natural systems. Plant communities proved to be the most important driver of Odonata community structure, with water quality and surrounding land cover use being of lesser importance. In conclusion, stormwater ponds can be valuable habitat for Odonata in cities, if properly managed. As urbanization is expected to increase further, there is a need to incorporate sustainable ecosystems in cities as vital resources for the conservation of species.

5.3 Effects of different management types on dragonfly pond assemblages

Frank Suhling (f.suhling@tu-bs.de) & Diana Goertzen, Institut für Geoökologie, Technische Universität Braunschweig

Small pond ecosystems in the anthropogenically disturbed central European landscape undergo rapid succession without sufficient natural disturbances. Therefore, many early succession specialists are decreasing without management of these ecosystems. Typically, ever more such ponds are created for conservation purpose; for instance, more than 500 alone in the administrative area of Braunschweig (190 km^2), northern Germany, have been recently constructed. We sampled dragonfly larvae in 33 ponds in the suburban area of Braunschweig, which were treated in different ways in order to produce disturbance regimes. While 16 ponds were not treated at all, different modes of management were carried out at 17 ponds: regular ground clearing of vegetation (n=4, of which two were sampled multiple times after clearing), mowing of edges (n=3), or grazing by cattle, horses or Asian buffalo (N=10). The age and size of all ponds and dates of last management were noted. In addition, several environmental factors were measured, such as vegetation cover and composition, permanence, water quality, and presence of fish. In total 27 species were found, and species numbers per pond varied between 1 and 14, with one third of the ponds hosting 10 or more species. We used multivariate statistics for identifying principal factors responsible for the composition of the dragonfly assembles as well as for the abundance of species and the species diversity. Our main aim, however, was evaluating the different management-treatments, which will be a central part of my presentation.

5.4 Win–win urban ecology: Near-home fishing promotes diversity of Odonata

Michael Patten (mpatten@ou.edu) & Emily Hjalmarson, Oklahoma Biological Survey and Department of Biology, University of Oklahoma, Norman, USA

It is generally thought that increased human activity or infrastructure automatically translates to decreased wildlife activity or abundance. We surveyed dragonflies and damselflies (Odonata) at fourteen urban parks with water features to determine factors that promote or hinder species richness or overall abundance. We constructed basic decision trees with either richness or abundance as a response variable and a suite of park characteristics (e.g., size, footprint of the water feature(s), habitat heterogeneity, presence and extent of infrastructure) as predictors. We found that the key predictor of both higher odonate richness and higher odonate abundance was the presence and extent of fishing activities. Despite higher human use at parks that promoted angling, as well as more infrastructure and increased management at these parks—factors that typically are thought to be correlated negatively with biodiversity—odonates and humans benefit from maintaining them and, we suggest, ensuring proper water quality persists. If it is good for fish, it is good for aquatic insects.

5.5 Systematics of dragonfly genus *Aeshna* (Anisoptera: Aeshnidae)

Manpreet K. Kohli, Department of Biology, Rutgers University, Newark, New Jersey, USA; Marie Djernæs, Naturhistorisk Museum Aarhus, Aarhus University, Denmark; **Ken Knapp** (kbk46@rutgers.edu), Department of Biology, Rutgers University, Newark, New Jersey, USA; Göran Sahlén, Ecology and Environmental Science, RLAS, Halmstad University, Halmstad, Sweden; Thomas Simonsen & Kent Olsen, Naturhistorisk Museum Aarhus; Jessica L Ware, Rutgers University-Newark

We studied the relationships in the genus *Aeshna*. Out of the 29 recognized species we treated 24 in a phylogenetic context. We amplified the barcode gene, COI and D7 fragment to investigate the evolutionary relationships. Divergence time estimation analysis suggests an age of approximately 40 million years for this genus. *Aeshna affinis* is recovered as the oldest diverged species within the genus. We find that the North American and European species don't cluster according to their geographic affinities.

Session 6: Morphology/Biomechanics (Sebastian Büsse, plenary speaker)

6.1 Plenary talk: The predatory strike of dragonfly larvae (Insecta: Odonata)

Sebastian Büsse (sbuesse@zoologie.uni-kiel.de), Alexander Köhnsen & Stanislav N Gorb, Kiel University, Germany

Odonata larvae are often key predators in their aquatic biotopes. They catch their prey with a unique and highly efficient apparatus, the so-called prehensile labial mask, a strongly modified and extensible mouthpart. The main driving force and underpinning biomechanics of this movement remain questionable.

We used various techniques, such as micro computed tomography (µCT), scanning electron microscopy (SEM), confocal laser scanning microscopy (CLSM) and high-speed videography combined with manipulation experiments to gain insights into the biomechanics of the predatory strike of Odonata larvae.

Our results suggest a catapult system as the main driving force for this prey-capturing process. We could identify two resilin-dominated sclerites (T-rod and premental sclerite) and two accessory muscles 0la5 and 0hy7 responsible for the mechanism of fast extension. Here the resilin-containing structure is strained by slow muscle action and thereby energy is stored. To allow for this energy storage in spring-loaded catapult systems, a lock and a trigger is needed. Here a complex latch mechanism and a trigger muscle (0la15) is present.

Furthermore, the hypothesis that hydraulic pressures the driving force of the striking process, as suggested by former investigations, could be refuted by manipulation experiments. We suggest that hydraulic pressure is most likely used for recoil-preventing jet propulsion during the prey capturing process. Finally, we provide a proof of concept by a 3D-printed robotic system inspired by the odonate prehensile mask.

6.2 The flight apparatus of Odonata and the crucial role of resilin

Fabian Bäumler (fabian.baeumler@online.de), Stanislav N. Gorb & Sebastian Büsse, Kiel University, Germany

The unique flight mechanism in Odonata, especially direct flight musculature with specialized tendons, results in the ability to operate the wings independently and perform impressive flight maneuvers. Several components of the flight apparatus, such as wing base sclerites, wings and musculature are well studied, but the material composition, especially concerning the presence of the viscoelastic protein resilin in muscle associated cap tendons has gotten little attention. Resilin is found in regions of the insect exoskeleton, where high resilience, low fatigue or strong damping is required. Even though the first description of resilin was made from one tendon of *Aeshna cyanea* (Müller, 1764), no comprehensive study about its presence in various thoracic structures of Odonata has been done. We investigated the thorax musculature of adult Epiprocta and Zygoptera using µCT,

fluorescence microscopy and confocal laser-scanning microscopy (CLSM). Herewith, we present a complete mapping of the odonatan pterothorax, regarding the flight musculature and attached tendons, highlighting the presence of resilin. We identified 54 thoracic muscles, 20 of them with resilin dominated cap tendons (21 for Anisoptera) in the pterothorax. Resilin within the tendons might serve as shock absorber, to protect the flight apparatus from sustaining damage during flight maneuvers and collisions due to its pronounced damping characteristics. Additionally, resilin in tendons can absorb and return kinetic energy to maintain self-oscillation of the flight musculature. Our findings represent an important step towards understanding the complex structure-function relationships in the odonate flight apparatus.

6.3 Holding on for dear life – the functional morphology of waterfall-dwelling damselflies in the Neotropics

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Life in moving water habitats offers challenges in feeding, respiration, attachment and thermoregulation. The larvae of the damselflies of family Polythoridae are a paragon of this because they live in and around waterfalls in the Neotropics, where fast-flowing turbulent waters bring high oxygen concentrations and a ready food supply, but make movement and attachment difficult. For respiration, damselfly (Zygoptera) larvae normally possess caudal lamellae (tracheal gills): long, slender, feather-like structures that provide large surface areas for gas exchange. The polythorid damselflies, however, developed highly modified caudal lamellae, that are expanded and heavily sclerotized. These 'club-like' lamellae do not appear well suited for gas exchange, but interestingly, polythorid larvae also have external abdominal structures resembling the abdominal gills of mayflies, an extremely uncommon trait in odonates. We here present an in-depth exploration of these structures through comparative analysis of the larvae of *Polythore ornata* (Selys) and *P. procera* (Selys) with the more characteristic *Calopteryx splendens* (Harris). The lamellae of *Polythore* have developed a unique internal foam-like structure. Their external cuticle is also modified to be rigid throughout the dorsal surface, but with a convex ventral region that may be more flexible. Using X-ray microtomography, SEM, and CLSM, we examine the functional morphology and material properties of the caudal lamellae and abdominal gills. Paired with behavioral observations of larvae in experimental chambers we explore the hypothesis that the caudal lamellae of polythorids evolved for the novel function of attachment in extreme habitats, subsequently evolving abdominal gills to replace the diminished respiratory function.

6.4 Bringing morphology, molecules, fossils, and extant odonates together: How reliable is morphology in a phylogenetic context?

Robert Erickson (robert.j.erickson@byu.edu) & Seth Bybee, Brigham Young University, Provo, Utah, USA

Relationships along the backbone of extant Odonata have been difficult to resolve. Further, the relationships between both extant and fossil odonates, as well as closely related odonatoid fossils add additional complexity to odonate phylogenetic reconstruction. To date only one large-scale phylogenetic reconstruction of both extant and fossil odonates has been attempted. Including fossils allows for a rigorous test of the taxonomic classification for both fossil and extant Odonata, establishes hypotheses regarding the sister group to Odonata, and allows for an exploration of homoplasy among sets of morphological characters (e.g., wing venation) in the presence of molecular data.

We take the first steps by combining >250 morphological characters, encompassing major structural features in nymph and adults (head, thorax, abdomen, wings), and 478 molecular loci for >200 taxa (~75 fossil and ~125 extant) to reconstruct a phylogeny of Odonata that includes both fossil odonates and odonatoids. We identify

major structural features and sub-features in nymphs and adults that contribute to discordance between morphological and genomic datasets. As we continue to improve our morphological character matrix, insights from the odonate community are welcomed as we work together with the odonates we love to study.

6.5 The dynamics of the predatory strike in Odonata larvae

Alexander Köhnsen (alexander.koehnsen@outlook.com), Stanislav N Gorb & Sebastian Büsse, Kiel University, Germany

Odonata larvae are common limnic predators that show a unique biomechanical mechanism to capture prey. The labium is highly modified into a prehensile mask, allowing them to capture prey up to their own body size from an ambush. The prehensile labial mask is capable of stopping precisely at prey items and grasping them, using the hook-like labial palps. Powered by a dual catapult mechanism, rapid extensions at peak accelerations of up to 114.5 m/s^2 are possible. This is remarkable considering the challenges of high-speed movement in a dense fluid, where the motion due to the rather small size of the animal is dominated by viscous forces (comparably small Reynolds number). To further understand the underlying dynamics of the predatory strike, we analysed a series of feeding experiments using a combination of underwater force measurement techniques and high-speed videography. We assessed the influence of prey distance and temperature on the performance of the predatory strike, as well as the influence of differently shaped labial masks in *Sympetrum* sp. Newman, 1833 and *Anax imperator* Leach, 1815. The results provide evidence that the predatory strike adjusts to prey distance and that the maximum velocity is dependent on ambient temperature. The latter contradicts previous assumptions that catapult mechanisms are generally unaffected by temperature. These results can help to determine the power output of this unique mechanism under consideration of its challenging hydrodynamics.

6.6 Automatically measuring dragonfly wings: an update on the Targeted Odonata Wing Digitization (TOWD) project

William R. Kuhn (will@dlia.org), Discover Life in America, Gatlinburg, Tennessee, USA; Jessica L Ware, Rutgers University-Newark, New Jersey, USA; John C Abbott, University of Alabama Museums, University of Alabama, Tuscaloosa, AL, USA; Melissa Sanchez Herrera, Faculty of Natural Sciences and Mathematics, Universidad del Rosario, Bogotá, Colombia; Dirk Gassmann, Rutgers University-Newark

Here, I'll provide an update an effort to image wings of all North American Odonata species as well as to develop software for automatically making key measurements of them.

6.7 Precision 3D reconstruction of dragonfly flight paths and behavior as measured with GoPros and VSLAM software

Parrish Brady (scorpionjeger@hotmail.com), University of Texas at Austin, USA

High-resolution three-dimensional mapping and tracking of animals and environments is possible using visual simultaneous localization and mapping (VSLAM) software and two hand-held GoPro hero 5 cameras. The high resolution, high frame rate, and compact nature of the GoPro hero 5 camera make this camera system a valuable contribution to biological research. The VSLAM software, ORB_SLAM2, has been modified to use two video feeds with one map and to output the localization and mapping data in a usable format, where insect paths are found via triangulation. The system has a high degree of spatial and temporal resolution in tracking and mapping (~5.0 cm and ~4.0 ms scales, respectively). This mobile system allows for fine-resolution measurement and mapping characterization of the environment. The technology is not fixed in place, so the system can follow the animals being measured and be taken to remote locations. With this system I measured flight behavior of several dragonfly species from central Texas and compared species-level differences in the flight statistics of each species. I was able to measure flight velocities, path curvatures, and distances between individuals, water, and environmental

objects. Furthermore, I quantified flight interactions between males and females, and territorial behavior among males.

Session 7

7.1 Differences in the critical thermal limits and thermal tolerance of males, females and larvae of *Hetaerina americana* (Fabricius) in three populations with contrasting environmental temperature conditions

Luisa Isarrarás-Hernández (luizza.isa@gmail.com), Ignacio Castellanos-Sturemark & Luis Felipe Mendoza-Cuenca, Universidad Michoacana de San Nicolás de Hidalgo, Mexico

Temperature is a key environmental factor that significantly restricts the behavior, physiology and distribution of individuals. Insects in the Odonata order have limited thermal regulation capabilities so their ability to withstand unfavorable temperatures depends on their thermal tolerance limits. Knowing the plasticity in the thermal physiology of the species allows us to understand its geographical distribution and to predict the response capabilities in a climate change context. *Hetaerina americana* (Fabricius) is the North American species with the widest geographical distribution (Canada to Nicaragua), inhabiting a great diversity of habitats, experiencing a great variety of thermal conditions. We collected individuals of *H. americana* in 3 populations (in the warmest and coldest period) that cover the maximum thermal variation in Mexico: La Huacana (warmer site) and La Mintzita (temperate site), Michoacán; San Pedro Mártir, Baja California (colder site). In order to assess whether the environmental conditions experienced by individuals determine their thermal tolerance, we estimated high (CTmax) and low (CTmin) critical thermal limits for males, females and larvae, using electric thermos that increase/decrease temperature at 1°C/min rate. Our results showed sexual and ontogenetic variation in the critical thermal limits among the populations, which matches with the environmental temperature variation. The wider thermal tolerance of the larvae could promote the permanence of the species in periods of unfavorable temperature. This could explain the wide distribution of the species and provides information to make predictions on the distribution of the species in a climate change scenario.

7.2 Using Mixed Distribution Analysis to determine the instar of field-collected dragonfly nymphs

Ami Thompson (althomps@umn.edu), University of Minnesota, Minneapolis, USA

Determining the instars of field collected odonate nymphs is valuable for studying the growth, phenology, and ecology of dragonflies. However, it can be difficult to determine what instar a field collected nymph is in because we don't have established morphological size parameters for each instar for most species and because odonates can experience a variable number of molts. This is particularly challenging for younger instars. For this study, nearly 5,000 *Anax junius* (Drury) nymphs were collected from central Minnesota, USA over two years. Morphological parameters (head with and hind wing sheath length) were measured and plotted in histograms. Each peak in a histogram was assumed to represent an instar present in the sample. Nymph instars were determined with mixed distribution analysis using the *mixdist* package in R version 1.0.136. Mixed distributions of both head width (mm) and the ratio of hind wing sheath length (mm)/ head width (mm) were separately used to determine the number of instars present in the sample and to define the parameters of each instar's size distributions (mean and standard deviation). Furthermore, the amount of overlap in the instar distributions was quantified to determine the likelihood of misclassifying a nymph instar as one size too large or too small. This analysis was successful in determining the number of instars present in the field sample, determining the instar of a specific nymph (with a known error), and in noting when multiple development pathways may be present in a given sample.

7.3 Changes in the diversity of Odonata of University of Ibadan, Oyo State, Nigeria, using surveys and museum specimens

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Odonata are sensitive to habitat quality. This makes them very suitable for evaluating the health and quality of water in the short and long terms. The abundance and diversity of Odonata of the University of Ibadan, Oyo State, Nigeria, were evaluated in September 2018. Three sites--Awolowo Hall, fish pond, and botanical gardens--were surveyed within the campus for Odonata. The odonate species collected from the study were also compared with specimens from the University's Museum of Natural History that were collected between 1952 and 1971. A total of 495 individuals from 25 species (20 dragonflies and 5 damselflies) and 4 families (Coenagrionidae, Gomphidae, Libellulidae, and Platycnemididae) were collected in 2018. The family Libellulidae (75%) had the highest number of species (19), with *Trithemis arteriosa* (Burmeister, 1839) being the dominant species, followed by Coenagrionidae (23%) with 4 species and the dominant species was *Ceriagrion glabrum* (Burmeister, 1839). The University of Ibadan Museum of Natural History had more Odonata species (51) than the present survey (25). Of the 25 species surveyed in 2018, thirteen were generalists and not found in the museum collection. The absence of some museum Odonata species, especially those from the families Calopterygidae, Chlorocyphidae and Aeshnidae in the recent survey, may be an indication of severe alteration in the environment, resulting from a combination of habitat disruption and other factors.

Session 8: Odonata without Borders (Jessica Ware, plenary speaker)

8.1 Plenary talk: *Megaloprepus caerulatus* population genetics

Jessica L. Ware (jware42@newark.rutgers.edu), Rutgers University, Newark, New Jersey, USA; Ola Fincke, University of Oklahoma, Norman, USA; Megan Wilson, Rutgers University-Newark

Differences in sexual signaling may initiate speciation by limiting gene flow among diverging populations. The damselfly *Megaloprepus caerulatus* exhibits multiple wing pattern types across its range. Males from one subspecies have sexually 'dimorphic', white-banded wings, whereas males from other subspecies lack the sex-specific white wing band. Using mitochondrial (COI and 16S) and nuclear (H3) markers, we tested whether genetic differences in populations from Mexico to Panama varied consistently with morphology and behavior in demes of the two wing patterns. We quantified population density, resource defense, body size, wing shape and reflectance properties. To determine if wing patterns cued sex or deme identity, we noted the reaction of males lacking a white wing band to conspecifics with manipulated wings. Molecular trait variation revealed distinct monomorphic demes of two sub- species, and an ancestral state lacking white-banded males. Relative to 'wing monomorphic' demes, wing dimorphic ones exhibited relatively less molecular and morphological divergence, higher population density and male-male competition, and greater sexual dimorphism.

8.2 Becoming Mx. Worldwide

Nene Kumashe Ugbah (nu33@scarletmail.rutgers.edu) & Jessica L. Ware, Department of Biology, Rutgers University, Newark, New Jersey, USA

Pantala flavescens (Fabricius)—a common, nomadic dragonfly species—uses temporary water bodies as small and short-lived as rain puddles for breeding and development along their migratory path. Migrant dragonflies such

as *Pantala* are gaining attention as studies confirm that it undertakes transcontinental flights that rival that of the monarch butterfly. Although there is a growing interest in understanding dragonfly migration, it is still relatively understudied and there are many gaps in knowledge (e.g. the phenology of migrant dragonflies, the mechanistic reasons behind their migration, and the implications of impending climate change on their populations). One such gap concerns the embryogenesis of *Pantala* larvae. Here we tracked the stages of embryogenesis of *Pantala flavescens* from the initial egg laying event through larval emergence from the egg. We took high magnification pictures of egg clutches and videos of pre- and post-eclosion events with a Nikon stereomicroscope on the day of oviposition and each day afterward until hatching. Additionally, high magnification images and video were taken of early instar *Pantala* larvae. In the future, we aim to evaluate the variation in behavior among cohorts of *Pantala* to create a baseline ethology for this species and build upon existing larval characterizations.

8.3 Segregation structure in Odonata assemblages follows the latitudinal gradient

Francesco Cerini (francesco.cerini@uniroma3.it), Luca Stellati & Leonardo Vignoli, Università Roma Tre, Italy

Latitude is known to affect life, with effects generalizable into ecological rules; increasing species diversity toward tropics (LDG) is the most paradigmatic of these rules. Several hypotheses were formed to test patterns of the intensity of biotic interactions along latitude, but no patterns involving competition were uncovered. We tested Odonata assemblages (571 species) spanning a wide latitudinal range (87°) for co-occurrence structure (C-score index), and then correlated the occurrence of segregation pattern (intended as driven by competition) to latitude. Odonata showed an LDG at the regional scale (country scale) for a latitude range comparable with our analyzed assemblages, whereas local richness (community scale) did not correlate to latitude. Odonata assemblages structured in competitive fashion followed a latitudinal gradient with higher segregation towards the tropics, and were not influenced by local species richness. At lower latitudes, the high availability of resources and the higher number of species could determine higher probability of density-dependent interactions (predation, inter- and intra-specific competition) in such a strong way as to structure the communities. Since species diversity decreases toward higher latitude, the probability of occurrence and the intensity of the interactions (competition) is lower: high availability but low heterogeneity of resources could lead species to aggregate, thus mitigating the effect of competition (lack of segregation patterns), by keeping the populations below the threshold of strong biotic interactions. We speculated that the observed competition along the latitudinal gradient could have been primarily determined by LDG and then “coevolved” with it.

8.4 Dragonflies prevail in the age of widespread insect decline

Göran Sahlén (goran.sahlen@hh.se) & Marie Magnheden, Halmstad University, Sweden

During the last years there have been several alarming reports of a general insect decline, with biomass reduction of up to 75% reported also from protected areas in Central Europe. Pollinating insects are lower in the food web than the predatory dragonflies, and we therefore sought to compare the abovementioned reports to the biomass of dragonfly larvae collected over 21 years in Sweden. We used 330 samples from 162 lakes collected between 1996 and 2017. Larvae from 38 species occurred in the samples. Most of the species (n=21) were very restricted and appeared in less than 10% of the samples; only six species occurred in more than 30% of them. For comparisons we used the unit mg per netting effort, with a mean value of 160.6 ± 159.2 mg wet weight per netting effort over the period. Interestingly, our results showed stability both in the number of species per sample and the amount of biomass per netting effort. This stability was also observed looking at 16 of the 17 most abundant species. Biomass per netting effort has increased for the family Libellulidae and to some extent Corduliidae, but decreased for Aeshnidae. We conclude that that most Odonata at northern latitudes do not seem to be declining, contrary to other insect groups. We note, however, that biomass seems to vary over years and regions, and that there is a high species turnover. It is possible that top predators might have the adaptive potential needed to survive also severe anthropogenic ecosystem changes.

8.5 Local movements and habitat selection of *Anax imperator* using radio-tracking

Marceau Minot (marceau.minot1@univ-rouen.fr) & Aurélie Husté, Normandie University, UNIROUEN - ECODIV, France

Despite a large panel of studies on the activities of Odonates near the water bodies, only little is known about their movements between the ponds and their requirements in terrestrial habitats. In this study, we aimed to quantify local movements of the large dragonfly Anax imperator and identify preferred habitats via step selection models.

Field campaigns with two different marking methods were conducted simultaneously in the years 2017 and 2018. A radio-telemetry study was conducted on 64 individuals within a radius of 2 kilometers. A total of 87 individuals was also identified with a unique code on the wings and monitored on five ponds. Individuals equipped with radio-transmitters showed a lower survival compared to those that were wing-marked only. Nevertheless, radio-telemetry brought a unique dataset of terrestrial locations away from the water bodies. Females moved significantly further away from their releasing sites than males and had a larger 95 % Kernel home range. Through a step selection analysis, this study also highlighted a strong preference for high trees where individuals can rest, especially by low temperature. Overall, very few studies used radio-telemetry to track dragonflies and the present work is the first using such a large sample of equipped dragonflies to investigate their terrestrial ecology.

8.6 Concept and realization of the World Odonata Manual

Bastiaan Kiauta (mbkiauta@gmail.com), Siebengewald, The Netherlands; Brij Kishore Tyagi, Department of Zoology & Environment Science, Punjabi University, Patiala, Punjab, India; **Milen Marinov**, Plant Health & Environment Laboratory, Diagnostic and Surveillance Services, Ministry for Primary Industries, Auckland, New Zealand

Dragonflies are some of the more thoroughly studied creatures on global basis as a huge amount of literature is available on their natural history and biology, behavior and ecology in all stages of the life cycle for both physical and biotic environments, geographical distribution, catalogue, etc. During past nearly six decades the science of taxonomy and systematics too has undergone a remarkable change. Integrating molecular techniques with the classical morphological taxonomic studies had a considerable impact on the recent boost in phylogenetic research on the group. As a result, we now enjoy much improved taxonomy on higher taxa.

Therefore, we propose creating a Manual of World Odonata, which will be essentially a comprehensive and accessible overview of one of the world's most popular insect groups. It will be a unique guide which will help specialists and students in Odonata to assign specimens collected from any part of the world to a particular genus.

Three volumes are envisaged: General Introduction to the families (Vol. I), Zygoptera (Vol. II) and Anisozygoptera & Anisoptera (vol. III). The talk introduces the whole concept of realization with stages and expected outcome.

8.7 Geographic variation of body size and body shape in heliothermic damselflies along a latitudinal gradient in East Asia

Yoshitaka Tsubaki (mnais.costalis@gmail.com), Center for Ecological Research, Kyoto University, Japan

Inter-specific variation of body size and body shape among five *Mnais* damselfly species (Odonata; Calopterygidae) was studied using specimens collected from various locations of East Asia including Japan, Taiwan, Hongkong, Laos, Myammer and Thailand. Populations of each species consisted of two male forms and a female form: large orange-winged males and small clear-winged males and middle-sized females. In both male forms, there was an apparent body size increase with latitude. Body-length/body-mass ratio however, decreased with latitude. Such clinal variations in the body size and body shape are presented for the first time in Odonata. Geographic body-size variation in percher (heliothermic) damselflies may be adaptive because large-and-short

bodied individuals have higher ability of heat retention which activate territorial and reproductive behavior in cool environment, while small-and-long bodied individuals can avoid overheating in hot environments.

Session 9: Odonata Outreach (Chris Goforth, plenary speaker)

9.1 Promoting Youth Education and Research Through Dragonfly Citizen Science

Christine Goforth (chris.goforth@naturalsciences.org), North Carolina Museum of Natural Sciences, Raleigh, USA

Dragonfly Detectives is a multi-session educational program that engages children ages 9-13 in authentic odonate research. Through a series of data collection sessions interspersed with fun educational activities, participants explore how weather influences flight activity in the common whitetail (*Plathemis lydia*) by collecting real world data for the Dragonfly Detectives citizen science project. The children generate a hypothesis, collect data, analyze their results, and present their findings through a scientific poster at a large-scale public event over the length of the program. Data gathered by the students suggest that light intensity, temperature, and humidity are the most important weather parameters influencing flight activity in *Plathemis lydia* and that wind speed, wind direction, barometric pressure, and potentially the presence or absence of rain are of less consequence. Data were also collected about the effectiveness of the participants as accurate and precise data collectors and suggest that while children do not collect high quality data the first day, they improve rapidly and generate useable data by their third day in the field.

9.2 How difficult is it to turn an amateur into an “expert” in Odonata identification?

Stanislav Ožana (ozanastanislav@gmail.com), Department of Biology and Ecology, Faculty of Science, University of Ostrava, Ostrava, Czech Republic; Vojtěch Molek, Institute for Research and Applications of Fuzzy Modeling, University of Ostrava; Michal Hykel, Department of Biology and Ecology, University of Ostrava; Michal Burda, Institute for Research and Applications of Fuzzy Modeling, University of Ostrava; Marek Malina & Martin Prášek, Department of Informatics and Computers, Faculty of Science, University of Ostrava; Department of Informatics and Computers, Faculty of Science, University of Ostrava; Aleš Dolný, Department of Biology and Ecology, Faculty of Science, University of Ostrava

In many biological studies, the species identification of the organisms is a crucial element, which may not be easy even for experienced biologists. New technologies thus represent ideal tools for both simplification and acceleration of identification of organisms. In recent years, a lot of attention has been paid to mobile software applications, which can combine scientific disciplines such as mathematics, informatics and biology. Such software can work based on available species occurrence records in combination with their ecological and biogeographical characteristics, as well as photographs and distinctive sounds. In our case, we have focused on images, commonly taken by photographers or biological enthusiasts for many organisms and thus an easily accessible and usable source of information for professionals. Pilot research conducted on freely available online images of dragonflies and damselflies has shown promising results on both a mobile device-sized model and a standard, computationally more complex, model. We have achieved ~54%/~74% top-1/top-5 testing accuracy on the standard model and ~47%/~70% top-1/top-5 testing accuracy on the mobile model. This method for identifying species from the image is a very promising way how to make from an ordinary observer, when using appropriate tools, an “experienced” field biologist. The accuracy of the combination of a system using occurrence data with the species characteristics and recognition of image material can then be a breakthrough approach for species identification.

9.3 Odonata in the Digital Age

John Abbott (jabbott1@ua.edu), The University of Alabama, Tuscaloosa, USA

Odonates are continuing to grow in popularity among enthusiasts and arguably they are relying more and more on digital tools to learn about them. Enthusiasts and professionals alike are contributing to online resources at an astonishing rate. It is important that resources be devoted to making sure that this data is as clean and reliable as possible. I will discuss how some of these on-line, community-based resources can and are being utilized and demonstrate changes being made to www.OdonataCentral.org in an effort to build a more robust resource.

9.4 Damselfly population genetics as a CURE for science students at a small liberal arts university

Ryan Caesar (rmcaesar@schreiner.edu), Department of Life Sciences, Schreiner University, Kerrville, Texas, USA

Course undergraduate research experiences (CURE) have become a popular high-impact learning practice in science courses at American colleges and universities. In particular, they provide a way for students at small liberal arts institutions to get directly involved in research, when support for research is extremely limited. Provided a small amount of funding for supplies, equipment, and services is available, using damselflies (and other Odonata) as model study organisms can be highly productive and educational. This presentation will review a pilot of a CURE that focuses on population genetics using common of damselflies in central and south Texas. Within this framework, students are able to address questions such as: how much gene flow exists between putative populations?, how do these gene flow patterns compare between different species?, and to what extent does natural and human disturbance affect gene flow? The major benefit of this approach is that students (who often lack a strong interest in organismal biology) are exposed to an integrated approach that involves field work, ecology and behavior of Odonata, molecular lab techniques, data analysis, and bioinformatics. Such a CURE is therefore suitable for use in a variety of courses and can be expanded to span different courses over multiple semesters.

9.5 Beyond dragonfly citizen science

Ami Thompson (althomps@umn.edu), University of Minnesota, Minneapolis, USA

Most citizen science programs use public participants to crowd source data collection so academic scientists can get answers to larger, more expensive, and/or more complicated research questions. However, there is so much more to the process of science that the public can enjoy beyond data collection. The Driven to Discover Curriculum Series from the University of Minnesota-Extension uses citizen science programs as springboards for students and teachers to make observations about the natural world; develop and test their own research questions; read and interpret primary research; and analyze, interpret, and report on their own research results. Innovation components include primary adaptive literature lessons based on articles written by your colleagues re-written for middle schoolers and lessons that foster data and graph interpretation based on data directly from citizen science programs including Odonata Central.

Posters

P1 Systematics and biogeography of the superfamily Lestoidea

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Among Odonata, most lentic species are found in the largest and most recent (and thus most rapid) radiations, Coenagrionoidea and Libelluloidea. However, both suborders also have a small group, sister to the remainder, which is predominantly lentic: Aeshnoidea in Anisoptera and the 210 species of Lestoidea in Zygoptera. These small assemblages are still largely unstudied but must be understood to elucidate what constrains lentic diversification. Recent molecular and morphological studies do not agree in the relationships between and within the four accepted families of Lestoidea, while very few genera have ever been revised. The heterogeneous and cosmopolitan genus *Lestes* Leach, in particular, requires renewed study, being among the largest in the order with 83 species. We have assembled morphological and molecular data covering 20 and 19 of the 21 recognized genera respectively. The morphological matrix contains over 50 characters of which more than 30 have not been used before in a phylogenetic analysis. The project's main objectives are: to propose a molecular and morphological phylogenetic hypothesis and a reclassification of the superfamily; to perform a biogeographic analysis, calibrated by fossil data, to clarify the origin and survival of the relict taxa in Hemiphlebiidae, Synlestidae, and Perilestidae; and, finally, to carry out a generic revision and biogeographic analysis of *Lestes*.

P2 Dragonfly life history in El Yunque Rainforest, Puerto Rico: habitat use and temporal variability

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Variation in environmental factors throughout time can result in life history adaptations for species. Odonates are important components of stream ecosystems and play key roles in the functioning of stream food webs. Since they are present in both aquatic and terrestrial habitats, they are excellent model organisms to study these interactions. The objective of this study was to evaluate temporal and spatial (e.g. habitat) changes in Odonata assemblages in El Yunque National Forest and assess which environmental variables might be associated with the assemblages. We established a 100m transect in two first-order streams for larvae collection, divided into 5m meter segments. Each month, five segments were randomly chosen and sampled using hand nets in pools and riffles for 15 min per segment. Larvae were sorted from benthic material and preserved in ethanol. Temperature, canopy cover, stream width and type of substrate at each segment were also measured. Larval abundance was significantly higher in riffles than in pools in both streams. *Scapanea frontalis* Burmeister and *Macrothemis celeno* Selys in Sagra were the most abundant for both streams with 293 and 77 individuals, respectively. Analysis of size distribution resulted in a similar pattern for both streams with larvae with smaller head width (<1.5mm) being more abundant. We also did not find evidence of cohort development, as small and large larvae were present in the same months. Overall, Odonata assemblages favored flowing water habitats and had limited temporal variability in the study streams.

P3 Effect of urbanization on Odonata assemblage composition in a tropical island

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Urbanization is a major land-use type that has considerable impacts on stream ecosystems and their species richness and abundance. Streams in urban settings are affected by multiple stressors: flow modifications, changes in nutrient concentrations, and loss of riparian vegetation. Aquatic insect richness and abundance directly reflect

these alterations and can be used to assess urban impacts on streams. Odonates are important predators in aquatic environments, and they serve as links between aquatic and terrestrial environments. Unfortunately, the effects of urbanization on odonate richness and abundance in tropical island streams is poorly understood. The objective of this study was to determine the effects of urbanization on stream habitat quality and associated odonate assemblages in Puerto Rico. A total of 16 streams along a rural-urban gradient in the San Juan Metropolitan Area (SJMA) were characterized using the Stream Visual Assessment Protocol (SVAP) for Puerto Rico. A 100m reach of each stream was surveyed twice for 30min to assess adult odonate richness and abundance during the rainy (2018) and dry (2019) seasons. Adults were identified visually on the fly and their abundances were recorded. Odonate richness ranged from 2 to 9, and abundance from 5 to 382. Abundance positively correlated to the SVAP, but richness did not. Even though adult abundance and richness were higher in the dry season, these were not found to be statistically significant. Overall, our study indicates odonate assemblages are not diverse in the SJMA and are affected by changes in stream habitat condition associated with increasing urbanization.

P4 Predation is a major selective agent of freshwater community structure

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Prey has evolved multiple strategies to avoid predation by fish or invertebrates in fishless habitats (typically large predatory dragonflies). Here we report the results of our five studies focused on ability of Odonata to avoid predation, especially in the context of fish farming. Three field studies dealt with the ability of zygopteran and anisopteran adults and larvae to avoid habitats with fish top predators (i.e., behavioral defenses) and the subsequent larval survival, while two rearing experiments focused on larval regeneration and phenotypic plasticity (morphological defenses). Our field studies showed that ponds with adult fish stock negatively affected survival of odonate larvae, while the ability of adults to avoid them during oviposition was limited in generalists as well as in specialists. Moreover, larval ability to select microhabitats with limited fish predation was low. Intensive fish ponds, ubiquitous in the Central European landscape, thus act as ecological traps for most odonate species. Laboratory rearing experiment showed that larval *Anax imperator* Leach and *Leucorrhinia dubia* (Vander Linden) could lose some of their body structures, while the potential of their regeneration was affected mainly by the larval size and developmental stage. The other experiment provided evidence of morphological plasticity in a long-spined specialist dragonfly *Sympetrum depressiusculum* (Selys) under exposure to fish, invertebrate, and both predators combined. Our results indicate that despite the certain abilities of odonates to deal with predation, intensive fish farming may be destructive for larvae of most species. The research was funded by the Grant Agency of the Czech Republic (18-24425S).

P5 Species composition of Odonata in Badagry Area of Lagos state, Nigeria

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This study was conducted to determine the species composition of Odonata (damselflies and dragonflies) in eight sites within Badagry Central area of Lagos State, Nigeria, by assessing their abundance, diversity and distribution. Adult odonates as well as physicochemical properties of water samples were collected for a period of five months from eight sampling points. A total of 776 individuals belonging to 30 species from two families, Libellulidae and Coenagrionidae, were collected and identified during the sampling period. Libellulidae recorded the highest number of individuals (25), and the family Coenagrionidae had the lower number (5). *Ceriagrion glabrum* (Burmeister, 1839) had the highest number of individuals (151). Nigeria French language village had the highest species diversity (H'= 2.404) while Gberefu had the lowest species diversity (H' = 0.000). Analysis of the physicochemical properties and Margalef's water quality index showed that Nigeria French language village had the best water quality as compared with the other sites and this accounts for the high species diversity found in

that site. There was a strong positive correlation between pH and temperature, r = 0.9961 and dissolved oxygen (DO), r = 0.99851, hence sites with lower pH having higher diversity of species. This finding explains and affirms the relationship between the quality of water and the diversity and abundance of odonates.

P6 The complete phenome of *Perigomphus basicornis* sp. nov. (Amaya-Vallejo et al.) with a method for larval rearing under lab conditions

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The neotropical dragonfly genus *Perigomphus* (Gomphidae) included only two described species: *P. pallidistylus* Belle (complete phenome: adult male and female, and larvae) and *P. angularis* Tennessen (only the adult male). Here we present a third species of *Perigomphus* in the tropical sub-Andean forests of Anchicayá, Valle del Cauca, Colombia. The complete phenome of *Perigomphus basicornis* sp. nov. Amaya-Vallejo et. al. is described and illustrated based on adults obtained from mature larvae collected in field and reared at Universidad de Los Andes laboratory, Bogotá, Colombia. The adult male differs from the other species of *Perigomphus* in the shape of the cerci and the size of the epiproct; the adult female differs from that of *P. pallidistylus* in having the apical lobes of vulvar lamina wider, with divergent tips. The larva of *P. basicornis* differs from that of *P. pallidistylus* in having sternum 8 divided in five sclerites, abdominal segments 8 and 9 with small, low protuberances on the tergites and male's epiproct as long as its basal width. Adults are difficult to find in the field as they live high in the canopy and rarely descend; larvae are easy to collect but challenging to rear because of their particular habitat preferences. A rearing method was standardized under lab conditions, where an artificial habitat was prepared, resembling the natural one in the closest way possible; 80% of the collected larvae were successfully reared with this method, which is also useful for other gomphids with similar habitat requirements.

P7 Phylogenetic relationships between *Mecistogaster* Rambur, 1842 and *Platystigma* Kennedy, 1920 (Odonata: Pseudostigmatidae)

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In the last two years, three new species of *Mecistogaster* have been described and *Platystigma* has been revalidated with three new species included. Each genus is now composed of eight species. However, no phylogenetic analysis was generated in order to examine the relationship among these two genera and their species. Therefore, a morphological phylogenetic study was performed to test if *Mecistogaster* and *Platystigma* form monophyletic clades. For this, all known species of these two genera and the new described species of each of them were sampled. The species *Platystigma pronoti* Sjöstedt, known only by females, was not included in the analysis because it is in poor condition. *Microstigma*, *Megaloprepus* and *Anomisma* were used as outgroup taxa. Phylogenetic analyses were based on 51 morphological characters. Maximum Parsimony (MP) analyses were run in TNT 1.5 by exhaustive search. Two most parsimonious trees were found, with 103 steps. The result indicates *Mecistogaster* and *Platystigma* as polyphyletic. This suggests that *Platystigma* belongs to the genus *Mecistogaster*. Furthermore, the relationships between *Mecistogaster amalia* (Burmeister) and the three new species of this genus were not resolved. We believe that the Scanning Electron Microscopy (SEM) of the penis and eggs may show characteristics that may have phylogenetic relevance and can contribute to a better resolution in relationships between species of the studied groups.

P8 The Odonata of Queretaro state, Mexico

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For many years, central Mexico remained relatively understudied regarding its odonate fauna. To overcome this, several advances have been made recently in the states of Aguascalientes, Guanajuato and Hidalgo respectively. Some other studies on more local faunas have also improved the knowledge of this area. Until 2006 Queretaro had been considered as a little explored state with only 46 odonate species recorded. In 2007, additional studies increased the number of species to 50, although some of those species were misplaced and actually were recorded in the neighboring state of San Luis Potosí. Recent collections in the highly interesting area of Sierra Gorda Biosphere Preserve (SGBP) by EGS and HOS, gave us the opportunity of scanning more closely the odonato fauna from this area, discovering a very rich fauna.

In addition, collections made independently by one of us (RNG) and some records published elsewhere in the state increased its total to 97 species in 53 genera and 12 families of dragonflies. Platystictidae, Cordulegastridae and Macromiidae were recorded for the first time in Queretaro. Among the most outstanding records for the state are: *Palaemnema paulicoba* Calvert, *Macromia annulata* Hagen, *Remartinia secreta* (Calvert), *Oplonaeschna magna* González & Novelo and *Libellula gaigei* Gloyd. With this study, and those mentioned earlier for other states, we were able to generate a preliminary list of the odonate fauna existing in Central Mexico. The list shows a very complex and rich fauna of around 182 species belonging to a mixture of biogeographic origins.

P9 *Hetaerina calverti*, a new cryptic species of the American Rubyspot complex

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Hetaerina americana, Fabricius was described for the first time in 1798. Since then, several synonyms have been suggested (e.g., *H. californica* Hagen, *H. basalis* Hagen, *H. texana* Walsh, *H. scelerata* Walsh). These synonyms were related to the variation in the size of the wing spots as well as variation of the superior caudal appendages. However, in 1901, Calvert suggested that *H. americana* represents one variable species. Nevertheless, Vega-Sánchez (2016) through a genetic and morphological analysis suggested that *H. americana* represents a species complex. In the present work, we describe a new species that belongs to this complex: *H. calverti* sp. nov. The morphological characteristics of males and females of *H. calverti* are compared with those of *H. americana*. The most important character for differentiation between males is the shape of the superior caudal appendages and the size of the individuals (when species are in sympatry). In females, the main differences are related to the shape of the intersternites. Some generalities of the biology of the species, including genetic data and geographical distribution patterns are described.

P10 Predatory dragonflies: Possible providers of ecosystem services for mosquito control

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One of the main reasons odonates are considered providers of ecosystem services is because they control populations of insect vectors of human diseases. However, most of this research focused on their larval stages. In the present study, we evaluated the potential of adults *Hetaerina americana* (Fabricius) to regulate mosquito populations (which potentially carry diseases associated virus) in an Urban Park located in the city of Cuernavaca Morelos, Mexico. We made monthly samplings, where focal individuals were observed for 5 to 15 minutes to determine their foraging rate. Additionally, the individuals were captured during the predation event to identify their prey and determine the proportion of mosquitoes that are part of their diet. Finally, by method of human landing catch (HLC) mosquito vectors of dengue *Aedes aegypti* (Linnaeus) and *Aedes albopictus* (Skuse) were collected in order to analyze them for the presence of virus of medical importance. We found that the foraging rate is variable during the day, having its peak of activity from 9:00 to 10:00 in the morning. Insects from the Diptera order were the most consumed prey comprising 56% of the diet (mostly chironomids), whereas 20% of total prey

were hymenopterans (mostly wasps). Six *Aedes* prey were captured and those collected by HLC are currently being analyzed to determine the presence of virus (e.g., Zika, Chikungunya, Dengue). Finally, our data suggested that Odonata are predators that potentially control mosquito populations within the park, a finding that can be explored in other sites around the city.

P11 Changes in Odonata densities in Saga Plain, northern Kyushu, Japan before and after the application of fipronil in paddy fields

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Impacts of systemic pesticides on biodiversity are of recent global concern. In Japan, rapid population declines of *Sympertum* species (Odonata: Libellulidae) have been reported from 2000s in various localities. Several studies pointed out that the nursery-box application of fipronil in paddy fields cause severe negative impacts on *Sympetrum* larvae. Although several other Odonata species are suspected to have declined rapidly in recent decades, accurate evaluations of their population decline as well as clarification of its cause are difficult due to limited population density data before the declines. To evaluate the changes in Odonata densities during recent decades, we conducted line transect surveys of Odonata at a census cite along with Tafusegawa River in Saga Plain, northern Kyushu, Japan in 2000 and 2015-2016, i.e. before and after the application of fipronil in paddy fields. As a result, we detected that the abundance of *Asiagomphus pryeri* (Selys) (Gomphidae), *Macromia amphigena amphigena* Selys (Macromiidae) and *Sympetrum eroticum eroticum* (Selys) (Libellulidae) significantly decreased in recent years, while that of *Sieboldius albardae* Selys (Gomphidae), *Orthetrum melania melania* (Selys) and *Rhyothemis fuliginosa* Selys (Libellulidae) significantly increased. Because no apparent environmental changes were observed in and around the census site and similar tendencies are found for *A. pryeri*, *M. amphigena amphigena* and *S. eroticum eroticum* (Selys) (Libellulidae), in some other areas in Saga Plain, their population declines are considered not local events but general trends in Saga Plain. We discuss possible involvements of fipronil application in Odonata densities.

Workshops

Monday, 3:45-5:00 Direction of WDA and IJO

This will be a discussion led by the Executive Board of WDA on the future directions of both the Worldwide Dragonfly Association and the International Journal of Odonatology.

Wednesday, 2:00-4:00 Dragonfly Nymphs: Basic Anatomy & Identification
Marla Garrison

In order to become proficient in identifying odonate nymphs, one must first learn the basic anatomy by which they are characterized. Many of the structures in the nymph are to be found in the adult as well. Since most people begin observing and studying dragonflies through the adults of the species, many of the following terms will already be familiar. However, there are several unique nymphal structures which feature prominently in nymph identification. Therefore, it is imperative to learn the proper anatomical terminology and body parts of a nymph in order to diagnose with accuracy. With this in mind, the primary structures used to differentiate them are defined, described and labeled below. Any term in bold print is referenced in a corresponding diagram. Most terminology is consistent with that used by Ken Tennessen in Dragonfly Nymphs of North America: An Identification Guide (2019) which represents the most accurate and comprehensive published set of keys to date for species in our area.

Thursday, 3:45-5:00 What is an acceptable record? Species richness and standardization of jurisdictional lists
Brenda Smith-Patten

The basis of species richness analyses is an accurate accounting of which species occur in a given area. But without standardized methods for tallying those species (i.e., compiling species lists in the same way), we will continue to compare apples to oranges. In this open forum we will discuss comparing species richness across geographical space and jurisdictional borders and how best to determine what is or is not acceptable for a species' inclusion on local, regional, and national lists of odonate species.

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