The Odonate Phenotypic Database: a new open data resource for comparative studies of an old insect order

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Abstract

The Odonate Phenotypic Database is an online data resource for dragonfly and damselfly phenotypes (Insecta: Odonata). The database consists of a variety of morphological life-history behavioral traits, and biogeographical information collected from various sources in the literature. We see taxon-specific phenotypic databases as becoming an increasing valuable resource in comparative studies. Odonata is a relatively small insect order that currently consists of about 6400 species belonging to 32 families. Our database has at least some phenotypic records for 1011 of all 6400 known odonate species. The database is accessible at http://www.odonatephenotypicdatabase.org/.

Background & Summary

The Odonate Phenotypic Database is an online data resource for dragonfly and damselfly phenotypes (Insecta: Odonata). The database consists of a variety of morphological life-history behavioral traits, and bi-ogeographical information collected from various sources in the literature. The database is not intended for species identification, but for comparative analysis within this insect group or to be combined with data from other taxonomic groups. The database is provided along with a large phylogenetic tree (1322 taxa, 21% of known odonates): "The Odonate Super Tree". This phylogenetic tree was built using DNA-sequences from GenBank in combination with a traditional (morphologically-based) odonate taxonomy (see Waller and Svensson 2017).

Comparative analyses are becoming an increasing common part of evolutionary studies, as researches attempt to bridge the gap between microevolutionary processes and macroevolutionary patterns (Arnold et al. 2001, Estes et al. 2007; Uyeda et al. 2011; Arnold 2014). Almost all comparative analysis rely on high-quality phenotypic data collected from the literature, and often a large amount of time is spent collecting such data. Alternatively, a variable is obtained from live individuals or museum specimens, but an important covariate is often needed from the literature (such as behaviour, habitat, or body size). It seems in the best interest of those working in the field to collect and curate these phenotypic observations, so they can be used in the future and combined with other sources of phenotypic information.

Paradoxically, as a community we have been much more successful at storing and cataloguing genotypes, and DNA-sequences often exist in GenBank for many species, but not even simple phenotypic data (such as body size) exists in an easily accessible form for many organismal groups. This lack of information is likely due to there being no clear structure in which to store phenotypic data. Phenotypic databases, because of the high-dimensional nature of most phenotypes, are also very different from a genetic database such as GenBank. Phenomics, as it has been termed, will always have to prioritize what aspects of the phenotypes to measure (Houle et al. 2010).

From an evolutionary viewpoint, phenotypes are arguably just as important and interesting as genotypes, if not more so (Houle et al. 2010, Kühl et al. 2013, Laughlin and Messier 2015), as selection operates on phenotypes, regardless of their genetic basis (Lande and Arnold 1983). Moreover, the increasingly integrative research practices in evolutionary biology will need not only access to high-quality genomic, molecular and phylogenetic resources, but will also need high-quality phenotypic and biogeographic data, fossil information for time-calibration of phylogenetic trees and other general data provided by biodiversity informatics (Losos et al. 2013). Therefore, the difficulty of the task and the size of the project should not dictate the creation of structures needed to store the data.

One way forward is to create taxon-specific phenotypic databases, as we have done here. Having such databases available that focus on a certain taxonomic group, also allows the recorded phenotypes to be tailored to fit the needs of the specific group and have the advantages that trait definitions are less ambiguous (i.e., there is no need for a wing length variable in a mammal database).

Examples of such open taxon-specific databases with various forms of phenotypic, biogeographic and phylogenetic data include AmphiBIO for amphibian ecological traits (Oliveira et al. 2017), panTHERIA (Jones et al. 2009) and EltonTraits 1.0 (Wilman et al. 2014) for various mammalian traits, TRY for plants (Kattge et al. 2011) and birds (Dyer et al. 2017). However, in the case of animals, they are largely focused on vertebrate groups, while the most speciose animal group – the insects – do not have any such open database available, to our knowledge.

We see taxon-specific phenotypic databases as becoming an increasing valuable resource in comparative studies. Since our research background and expertise is in the order Odonata (dragonflies and damselflies), we have collected 34 phenotypic variables we see as useful to the research community (Table 1). Odonata is a relatively small insect order that currently consists of about 6400 species belonging to 32 families. Odonata are characterized morphologically highly conserved with respect to their overall external morphology (all representatives have six legs and four wings), but they also show considerable diversity in terms of wing and body colouration and shape (Fig. 1). Our database has at least some phenotypic records for 1011 of all 6400 known odonate species. The database is accessible at http://www.odonatephenotypicdatabase.org/.

Tabel 1.
Current approximate coverage of variables as of the publication of this document.

Table	Variables	Description	Coverage
Taxonomy	GenusSpecies Genus Species Family SubOrder	Taxonomy of record. Names are taken from the World Odonata List.	15%
Size	body_lengths forewing_lengths hind_wing_lengths	Body size in mm of species record.	13%
Body Colors	body_colors body_colortypes body_patterns		15%
Behaviour	mate_guarding flight_mode territoriality	Mating and flight behaviour of species in general.	15%
Location and Habitat	continents aquatic_habitats climates ecozones habitat_openness	Location and habitat climates taken from range maps usually.	15%
Morphisms	sex_polymorphisms sex_dimorphisms geo_polymorphisms	Polymorphisms and strength of sexual dimorphism.	15%
Wing Pigment or Color	has_wing_pigment wing_pigment_extent_discrete wing_pigment_extent_continuous wing_pigment_pattern wing_pigment_symmetry wing_pigment_dimorphism wing_pigment_color wing_pigment_placement wing_pigment_color_type	Wing color and pigment variables.	15%

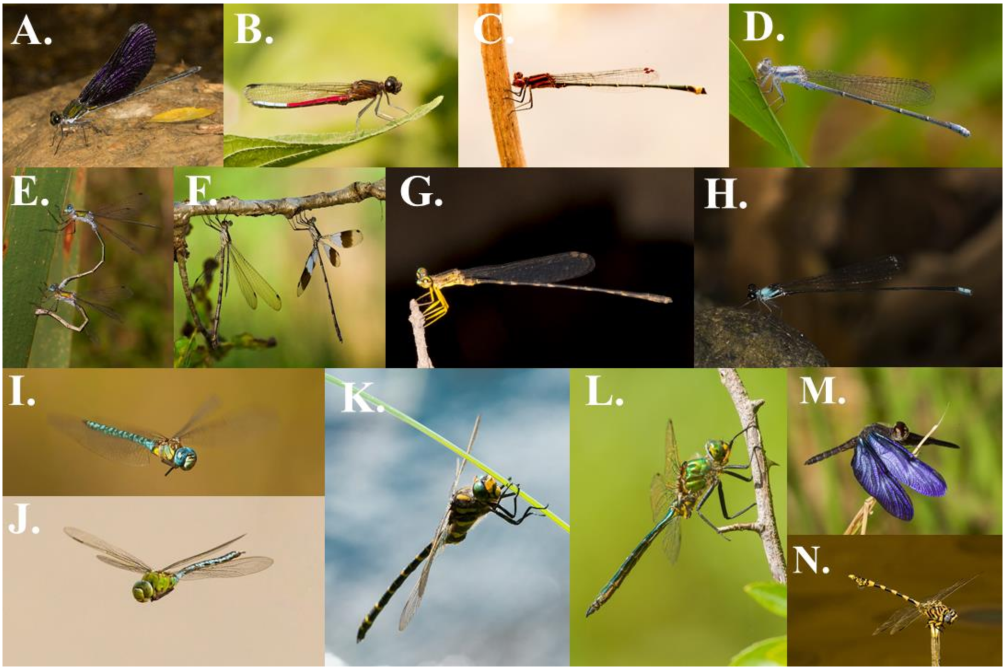

Figure 1 Phenotypic and taxonomic diversity
Phenotypic and taxonomic diversity of 12 representative families of Odonata, an insect order which currently encompasses c. a. 6400 species and a total of 32 families. All 32 odonate families are included in our molecular and time-calibrated phylogeny (Fig. 2; Waller and Svensson 2017). **A.** Family Calopterygidae: *Sapho orichalcea* (Cameroon, Africa, January 2017). **B.** Family Chlorocyphidae: *Chlorocypha curta* (Cameroon, Africa, January 2017). **C-D.** Family Coenagrionidae: **C.** *Acanthagrion adustum* (Guyana, South America, January 2015). **D.** *Argia moesta* (Texas, North America, April 2012). **E.** Family Lestidae: *Lestes sponsa* (Sweden, Europe, July 2010). **F.** Family Synlestidae: *Chlorolestes tessellatus* (Eastern Cape, South Africa, Africa, April 2010). **G.** Family Platycnemidae: *Copera congolensis* (Cameroon, Africa, February 2017). **H.** Family Protoneuridae: Elattoneura balli (Cameroon, Africa, January 2017). **I-J.** Family Aeshnidae: **I.** *Aeshna affinis* (Sweden, Europe, August 2010). **J.** *Anax imperator* (Sweden, Europe, August 2015). **K.** Family Cordulegasteridae: *Cordulegaster boltonii* (Sweden, Europe, July 2016). **L.** Family Corduliidae: *Somatochlora flavomaculata* (Sweden, Europe, June 2014). **M.** Family Libellulidae: *Zenithoptera fasciata* (Guyana, South America, January 2015). **N.** Family Gomphidae: *Ictinogomphus ferox* (Namibia, Africa, April 2017). All photographs by Erik Svensson.

Methods

Phenotypic data has been collected from the scientific literature and field guides. These literature sources are listed in Table 2. Phenotypes were scored by following a specific set of instructions for each variable. The descriptions of each variable can be found Data Records section below. The construction of the Odonate Super Tree has been described elsewhere (see Waller and Svensson 2017).

Table 2.
The primary references used to gather the data. Most of time these are field guides. Below is a list of resources that the database currently is based on.

Authors	Title and Publisher	Year
Theischinger and Hawking	Complete Field Guide to Dragonflies of Australia; CSIRO Publishing	2006
Kawashima and Futahashi	Dragonflies of Japan; Bunichi-Sogo Syuppan	2012
Dijkstra and Lewington	Field Guide to the Dragonflies of Britain and Europe; British Wildlife Publishing	2006
Paulson	Dragonflies and Damselflies of the West; Princeton University Press	2009
Samways	Dragonflies and Damselflies of South Africa; Penguin Random House South Africa	2008
Tarboton and Tarboton	A Fieldguide to the Dragonflies of South Africa; Warwick & Michèle Tarboton	2002
Heckman	Encyclopedia of South American Aquatic Insects: Odonata-Anisoptera; Springer	2006
Paulson	Dragonflies and Damselflies of the East; Princeton University Press	2011
Tang Hung Bun et al	A Photographic Guide to the Dragonflies of Singapore; Raffles Museum of Biodiversity Research	2010
Subramanian	Dragonflies and Damselflies of Peninsular India: A Field Guide; Indian academy of Sciences	2005
Hamalainen and Pinratana	Atlas of the Dragonflies of Thailand Distribution Maps by Provinces; Brothers of St. Gabriel in Thailand	1999
Esquivel	Dragonflies and damselflies of Middle America and the Caribbean; INBio	2006
Garrison et al	Dragonfly Genera of the New World An Illustrated and Annotated Key to the Anisoptera; John Hopkins University Press	2010
Nair	Dragonflies and Damselflies of Orissa and Eastern; Orissa Wildlife Organisation	2011
Tarboton and Tarboton	A Fieldguide to the Dragonflies of South Africa; Tarboton and Tarboton	2005
Okudaira et al	Dragonflies of the Japanese Archipelago in Color; Hokkaido UP	2001
Lencioni	Damselflies of Brazil: An illustrated identification guide 2 Coenagrionidae; F.A.A Lencioni	2006
Suhling and Martens	Dragonflies and Damselflies of Namibia; Gamsberg Macmillan	2007
Askew	The Dragonflies of Europe; Great Horkesley	1988
Dunkle	Dragonflies through Binoculars: A Field Guide to Dragonflies of North America (Butterflies Through Binoculars); Oxford University Press	2000
Manolis	Dragonflies and Damselflies of California; University of California Press	2003
Abbott	Dragonflies and Damselflies (Odonata) of Texas Volume 5; John C. Abbot	2011
Dijkstra and Clausnitzer	The Dragonflies and Damselflies of Eastern Africa; RMCA	2014
Tze-wai et al	The Dragonflies of Hong Kong; Cosmos	2011
Michalski	The Dragonflies and Damselflies of Trinidad and Tobago; Kanduanum Books	2015
Kompier	A Guide to the Dragonflies and Damselflies of the Serra dos Orgaos South-eastern Brazil; Regua publications	2015
Marinov and Waqa-Sakiti	An Illustrated Guide to Dragonflies of Viti Levu Fiji; The University of the South Pacific Institute of Applied Sciences	2013
Polhemus and Asquith	Hawaiian Damselflies: A Field Identification Guide; Bishop Museum	1996
Biggs	Common Dragonflies of California; Azalea Creek Publishing	2000

Code availability

All code used to generate the website and Odonate Super Tree are available in the supplementary material and on github (https://github.com/jhnwllr/shiny-server/tree/master/odonates).

Data Records

The following file have been deposited in Dryad. Additionally, up-to-date data can be explored and downloaded at: http://www.odonatephenotypicdatabase.org/.

1. opdb.csv
   - A flat data file 39 variables of all of the phenotypic data within the database. See Table 1 and Fig. 2 for a description and coverage of variables.
2. variable definitions.pdf A file that describes each of the variables within the opdb.csv and how they were collected.

Technical Validation

All of the phenotypic data were collected from published field guides or reliable internet sources. The field guides are listed in Table 2. All of the field guides have been published by respected odonatologists and experts on species identification. Our database is also not static, and additional data will be added as it becomes available. We encourage readers to contribute to this database by contacting the two authors for correspondence. We will accept data both from already published sources (e. g. scientific papers) even if it has already been deposited in other databases such as Dryad, as well as data that is not intended to be published elsewhere, as long as it can tailored to the format of the Odonate Phenotypic Database. Each species has a reference list, which lists the references from which the data was gathered, so it is possible to check each entry against these primary sources.

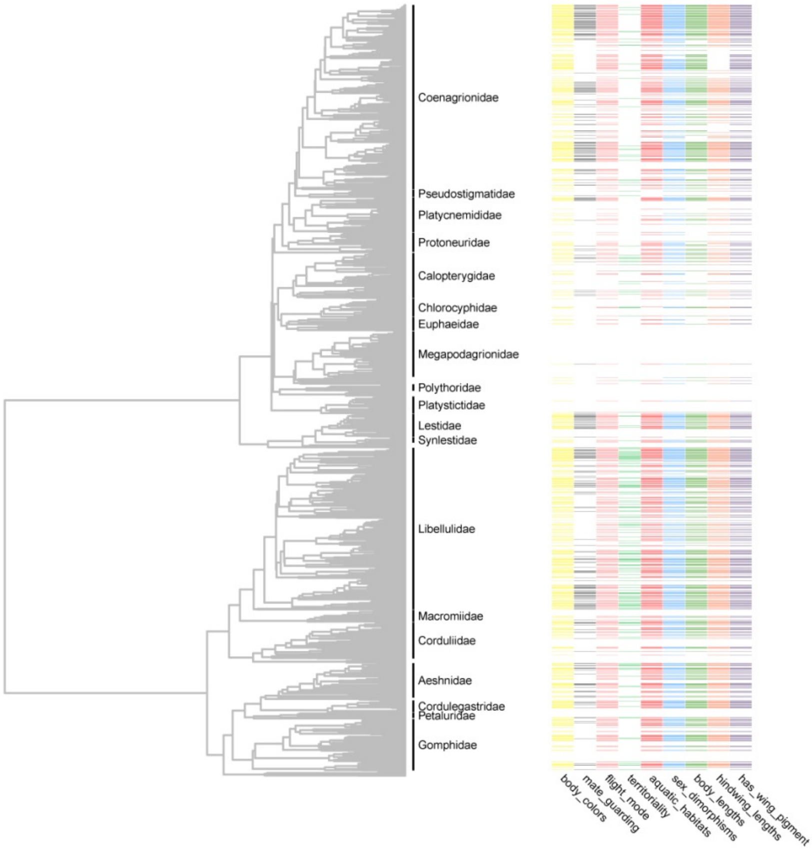

Figure 2
Our molecular time-calibrated phylogenetic tree, encompassing 1322 dragonfly and damselfly species (Waller and Svensson 2017a,b). Some representative data is annotated on the tree showing coverage of some of the variables in the database.

Usage Notes

The database is intended to be used in comparative analyses of odonate trait evolution. We therefore provide a previously published phylogenetic tree (Waller and Svensson 2017) along with the phenotypic data. Past problems that we have addressed using the phylogenetic comparative methods one these and similar data include the relationship between latitude and wing pigmentation (Svensson and Waller 2013) and macroevolutionary dynamics of body size (Waller and Svensson 2017). We have also investigated diversification dynamics (speciation and extinction rates) in relation to body size and wing pigmentation (Svensson and Waller 2013; Waller and Svensson 2017). Other potentially interesting future questions to pursue, include the evolutionary and ecological consequences of colour polymorphism in females (Svensson et al. 2005; Le Rouzic et al. 2015; Willink and Svensson 2017), biogeographical and ecological influences on various phenotypic traits such as body size and colouration and the role of climatic niche conservatism in the evolution and biogeography of odonates (Wiens et al. 2005; Wellenreuther et al. 2012).

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Author contributions

John Waller: constructed the website http://www.odonatephenotypicdatabase.org/ as part of his PhD-work, collected data, helped create variable definitions, wrote this manuscript.
Beatriz Willink: collected data, helped plan and organize data collection.
Maximilian Tschol: collected wing pigment data, created variable definitions.
Erik I. Svensson: created variable definitions, supervised data collection, came up with the original idea to create the database.

Competing interests

We declare no competing interests and the data published within this database is done so without bias.

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