Zootaxa 3856 (3): 349–365
www.mapress.com/zootaxa/

Article

ISSN 1175-5326 (print edition)
ZOOTAXA
ISSN 1175-5334 (online edition)

http://dx.doi.org/10.11646/zootaxa.3856.3.3
http://zoobank.org/urn:lsid:zoobank.org:pub:04B05A55-30E1-4A20-88F8-3974ACD8DC68

A Critically Endangered new dragonfly species from Morocco: *Onychogomphus boudoti* sp. nov. (Odonata: Gomphidae)

SÓNIA FERREIRA[1,2,3], GUILLERMO VELO-ANTÓN[1], CHRISTOPHE BROCHARD[4], CRISTIANA VIEIRA[1], PAULO CÉLIO ALVES[1,2,5], DAVID J. THOMPSON[3], PHILLIP C. WATTS[3,6] & JOSÉ CARLOS BRITO[1,2]

[1]*CIBIO – Centro de Investigação em Biodiversidade e Recursos Genéticos, InBIO Laboratório Associado, Universidade do Porto, Campus Agrário de Vairão, R. Padre Armando Quintas, 4485-661 Vairão, Portugal*
[2]*Departamento de Biologia da Faculdade de Ciências da Universidade do Porto, Porto 4169–007, Portugal.*
[3]*Institute of Integrative Biology, Biosciences Building, Crown Street, University of Liverpool, Liverpool, L69 7ZB, UK.*
[4]*Marsstraat 77, 9742EL Groningen, the Netherlands.*
[5]*Wildlife Biology Program, University of Montana, MT 59812, USA.*
[6]*Department of Biology, University of Oulu, PO Box 3000, FI–90014 Oulu, Finland.*
Corresponding author: Sónia Ferreira
SF—hiporame@gmail.com; GVA—guillermo.velo@cibio.up.pt
CB—info@cbrochard.com; CV—cristianavieira@cibio.up.pt
PCA—pcalves@fc.up.pt; DJT—d.j.thompson@liv.ac.uk
PCW—phillip.watts@oulu.fi; JCB—jcbrito@cibio.up.pt

Abstract

Both sexes of *Onychogomphus boudoti* sp. nov. Ferreira (Odonata: Anisoptera: Gomphidae) and exuviae are described and illustrated from a single locality in Morocco. This newly discovered species differs markedly from other *Onychogomphus* species by the morphology of the male epiproct and the female vulvar scale. It is genetically distinct in the mitochondrial DNA and the nuclear PRMT gene from all other Western Palaearctic *Onychogomphus* species. The known distribution of the new species is confined to a small stream with unusual habitat characteristics in the vicinity of Khenifra, in the Middle Atlas, where it experiences low population size and limited genetic diversity. We suggest listing this species both locally and globally as "Critically Endangered" [CR (B1, B2 + abiii)] following the IUCN Red List Categories and Criteria.

Key words: Anisoptera, endemic, Middle Atlas, North Africa, Palaearctic, phylogeny, mitochondrial DNA, nuclear DNA

Résumé

Onychogomphus boudoti sp. nov. Ferreira (Odonata: Anisoptera: Gomphidae) est décrit et illustré à partir de spécimens adultes des deux sexes et d'exuviae. Cette espèce, récemment découverte au Maroc, diffère nettement des autres *Onychogomphus* connus par la structure de l'appendice abdominal inférieur des mâles (épiprocte) et la morphologie de la lame vulvaire des femelles. Elle est génétiquement distincte des espèces ouest-Paléarctiques voisines par son ADN mitochondrial et son gène PRMT nucléaire. Cette espèce n'est jusqu'ici connue que d'une seule localité au voisinage de Khenifra, au Moyen Atlas, au niveau d'un habitat aux caractéristiques peu ordinaires pour le Maroc. Ne présentant qu'une faible population sur une surface réduite et une variabilité génétique limitée, cette espèce devra être classée "en danger critique d'extinction" [CR (B1, B2 + abiii)] au sein des listes rouges régionales et mondiales de l'IUCN.

Mots clés: Anisoptera, endémiques, Moyen Atlas, Afrique du Nord, Paléarctique, phylogénie, ADN mitochondrial, ADN nucléaire

Introduction

Members of the odonate family Gomphidae can be found on all continents (except Antarctica). Gomphids represent the third largest odonate family, comprising over 15% of all odonate species, and are classified in 95

Accepted by D. Paulson: 31 July 2014; published: 25 Aug. 2014

in each genetic marker. Further studies regarding its distribution, ecology and behaviour are needed to underpin a suitable conservation plan for this species. In the immediate term, we propose that local protection should be provided, focussing on limiting grazing and ensuring maintenance of the current hydrogeomorphologic characteristics of the area, especially regarding the natural drainage patterns.

Proposal and rationale for a Red List assessment

At present, *Onychogomphus boudoti* is known from just one locality in Morocco, being the species with the smallest known distribution range in the Western Palaearctic (Kalkman *et al.* 2010, Riservato *et al.* 2008). It was discovered in 2011, and, despite efforts to extend the known distribution of this species in two subsequent years, no individuals could be found other than at the type locality; indeed, we could not identify any location that had similar habitat to the type locality. The species qualifies for Critically Endangered IUCN threatened category based on its restricted geographic range and the inferred continuing decline of the quality of the habitat: B1, B2 + abiii (IUCN Standards and Petitions Subcommittee 2014). The extent of occurrence (EOO) is less than 1 km^2 as is the area of occupancy (AOO). There is a single known location and the area and quality of suitable habitat is likely declining and expected to do so in the future due to overgrazing, and agricultural practices (the habitat is surrounded by agricultural fields). Additionally, and based on criterion D: very small or restricted population, the species might also qualify cumulatively for IUCN category Endangered or also Critically Endangered, as very low numbers of individuals were seen in each visit (< 15); but further research is needed to ascertain population numbers.

Acknowledgements

The authors are grateful to our colleagues who sent samples for genetic analysis: Jean-Pierre Boudot, Andrea Corso, Klaas-Douwe B. Dijkstra, Sergei Drovetski, Lee Haines, Sönke Hardersen, Xavier Houard, Vincent Kalkman, Geert De Knijf and Elisa Riservato. The authors thank all colleagues that assisted us in the field: Pavel Bogdanov, Zbyszek Boratyński, João Campos, Sergei Drovetski, Despina Kitanova, Fernando Martínez-Freiría, Joana Marques, Albano Soares and Cândida Vale. Klaas-Douwe B. Dijkstra provided useful insights on the species description process. Vincent Kalkman and Frank Stokvis (Naturalis Biodiversity Center, Leiden—The Netherlands) and Joana Paupério (CIBIO, Portugal) provided crucial help with photography in the lab, and Lee Haines with image editing. Jean-Pierre Boudot kindly provided pictures of live specimens. A special thanks to Ewoud van der Ploeg for the valuable assistance in the exuviae study and to Arjen Van 't Hof for all the help in the lab. The collection of samples benefited from field work funded by the projects "Preserving Armenian biodiversity: Joint Portuguese—Armenian program for training in modern conservation biology" of Gulbenkian Fundation (Portugal), PTDC/BIA-BEC/103435/2008 of Fundação para a Ciência e a Tecnologia, FCT (Portugal), and "*Coenagrion mercuriale*: distribución, diversidad genética y estado de conservación" of Instituto de Estudios Ceutíes (Ceuta—Spain). Fieldwork took place under the permit of the Haut Commisariat aux Eaux and Forets of Morocco (HCEFLCD/DLCDPN/DPRN/CFF N°255/2012) S.F., G.V.-A., C.V., and J.C.B. are supported by Fundação para a Ciência e Tecnologia (SFRH/BD/65038/2009; SFRH/BPD/74834/2010; SFRH/BPD/63741/2009; IF/00459/2013, respectively).

References

Askew, R.R. (1988) *The Dragonflies of Europe.* Harley Books, Colchester, 291 pp.

Boudot, J.-P., Jacquemin, G. & Dumont, H.J. (1990) Revision of the subspecies of *Onychogomphus forcipatus* (Linnaeus, 1758) in Europe and Asia Minor, and the true distribution of *Onychogomphus forcipatus unguiculatus* (Vander Linden, 1823) (Odonata, Gomphidae). *Bulletin & Annales de la Société Entomologique de Belgique*, 126, 95–111.

Boudot, J.-P. & De Knijf, G. (2012) Nouvelles données sur les Odonates du Maroc oriental et méridional (Odonata). *Martinia*, 28 (1), 1–28.

Carle, F.L. (1986) The classification, phylogeny and biogeography of the Gomphidae (Anisoptera). *Odonatologica*, 15 (3), 275–326.

Conesa-García, M.A. (1995) Notes on infraspeciation in *Coenagrion caerulescens* (B. de Fonscolombe, 1839), with description of *C. c. isabelae* ssp. nov. from Morocco (Zygoptera: Coenagrionidae). *Odonatologica*, 24 (4), 425–440.

Darriba, D., Taboada G.L., Doallo, R. & Posada, D. (2012) jModelTest 2: more models, new heuristics and parallel computing. *Nature Methods*, 9 (8), 772.
http://dx.doi.org/10.1038/nmeth.2109

Dijkstra, K.-D.B. & Kalkman, V.J. (2012) Phylogeny, classification and taxonomy of European dragonflies and damselflies (Odonata): a review. *Organisms Diversity & Evolution*, 12 (3), 209–227.
http://dx.doi.org/10.1007/s13127-012-0080-8

Dijkstra, K.-D.B. & Lewington, R. (2006) *Field Guide to the Dragonflies of Britain and Europe*. British Wildlife Publishing, Dorset, 320 pp.

Drummond, A. & Rambaut, A. (2007) BEAST: Bayesian evolutionary analysis by sampling trees. *BMC Evolutionary Biology*, 7, 208–214.
http://dx.doi.org/10.1186/1471-2148-7-214

Dumont, H.J. (1972) Contribution a la connaissance des odonates du Maroc. *Bulletin de la Société des Sciences Naturelles et Physiques de Maroc*, 52, 14–179.

Edgar, R.C. (2004) MUSCLE: multiple sequence alignment with high accuracy and high throughput. *Nucleic Acids Research,* 32 (5), 1792–97.
http://dx.doi.org/10.1093/nar/gkh340

Ferreira, S., Lorenzo-Carballa, M.O., Torres-Cambas, Y., Cordero-Rivera, A., Thompson, D.J. & Watts, P.C. (in press). New EPIC nuclear DNA sequence markers to improve the resolution of phylogeographic studies of coenagrionids and other odonates. *International Journal of Odonatology.*
http://dx.doi.org/10.1080/13887890.2014.950698

Guindon, S. & Gascuel, O. (2003) A simple, fast and accurate algorithm to estimate large phylogenies by maximum likelihood. *Systematic Biology*, 52 (5), 696–704.

Huson, D.H. & Bryant, D. (2006) Application of phylogenetic networks in evolutionary studies. *Molecular Biology and Evolution*, 23, 254–267.
http://dx.doi.org/10.1093/molbev/msj030

IUCN Standards and Petitions Subcommittee (2014) Guidelines for Using the IUCN Red List Categories and Criteria. Version 11. Prepared by the Standards and Petitions Subcommittee.

Jacquemin, G. & Boudot, J.P. (1999) *Les Libellules (Odonates) du Maroc.* Société Française d'Odonatologie, Bois d'Arcy, France, 150 pp.

Kalkman, V.J., Boudot, J.-P., Bernard, R., Conze, K.-J., De Knijf, G., Dyatlova, E., Ferreira, S., Jović, M., Ott, J., Riservato, E. & Sahlén, G. (2010) *European Red List of Dragonflies.* Luxembourg: Publications Office of the European Union, viii + 28 pp.

Lee, E.M., Hong, M.Y., Kim, M.I., Kim, M.J., Park, H.C., Kim, K.Y., Lee, I.H., Bae, C.H., Jin, B.R. & Kim, I. (2009) The complete mitogenome sequences of the palaeopteran insects *Ephemera orientalis* (Ephemeroptera: Ephemeridae) and *Davidius lunatus* (Odonata: Gomphidae), *Genome*, 52 (9), 810–817.
http://dx.doi.org/10.1139/g09-055

Librado, P. & Rozas, J. (2009) DnaSP v5: a software for comprehensive analysis of DNA polymorphism data. *Bioinformatics*, 25 (11), 1451–1452.
http://dx.doi.org/10.1093/bioinformatics/btp187

Lieftinck, M.A. (1966) A survey of the dragonfly fauna of Morocco (Odonata). *Bulletin de l'Institut Royal des Sciences Naturelles de Belgique*, 42 (35), 1–63.

Lin, C.P., Chen, M.Y. & Huang, J.P. (2010) The complete mitochondrial genome and phylogenomics of a damselfly, *Euphaea formosa* support a basal Odonata within the Pterygota. *Gene*, 468 (1–2), 20–29.
http://dx.doi.org/10.1016/j.gene.2010.08.001

Lowe, C.D., Harvey, I.F., Thompson, D.J. & Watts, P.C. (2008) Strong genetic divergence indicates that congeneric damselflies *Coenagrion puella* and *C. pulchellum* (Odonata: Zygoptera: Coenagrionidae) do not hybridise. *Hydrobiologia*, 605 (1), 55–63.
http://dx.doi.org/10.1007/s10750-008-9300-9

Page, R.D.M. & Holmes E.C. (1998) *Molecular Evolution: A Phylogenetic Approach*. Blackwell Science, Oxford, U.K. 346 pp.

Riservato, E., Boudot, J-P., Ferreira, S., Jović, M., Kalkman, V.J., Schneider, W., Samraoui, B. & Cuttelod, A (2009) *The Status and Distribution of Dragonflies of the Mediterranean Basin*. IUCN, Gland, Switzerland and Malaga, Spain, vii + 33 pp.

Ronquist, F. & Huelsenbeck, J.P. (2003) MRBAYES 3: Bayesian phylogenetic inference under mixed models. *Bioinformatics*, 19, 1572–1574.
http://dx.doi.org/10.1093/bioinformatics/btg180

Sambrook, J. & Russell, D.W. (2001) *Molecular cloning: a laboratory manual.* 3rd edition. Cold Spring Harbor Laboratory Press, Cold Spring Harbor, New York, 346 pp.

Schorr, M. & Paulson, D. (2013) *World List of Odonata*. Available from: http://www.pugetsound.edu/academics/academic-resources/slater-museum/biodiversity-resources/dragonflies/world-odonata-list2/ (accessed 22 July 2013)

Stephens, M. & Donnelly, P. (2003) A comparison of Bayesian methods for haplotype reconstruction from population genotype data. *American Journal of Human Genetics*, 73 (5), 1162–1169.
http://dx.doi.org/10.1086/379378

Stephens, M., Smith, N. & Donnelly, P. (2001) A new statistical method for haplotype reconstruction from population data. *American Journal of Human Genetics*, 68 (4), 978–989.
http://dx.doi.org/10.1086/319501

Suhling, F. & Müller, O. (1996) *Die Flußjungfern Europas (Gomphidae)*. Die Neue Brehm-Bücherei 628, Westarp, Magdeburg & Spektrum, Heidelberg, 237 pp.

Tamura, K., Peterson, D., Peterson, N., Stecher, G., Nei, M. & Kumar, S. (2011). MEGA5: Molecular Evolutionary Genetics Analysis using Maximum Likelihood, Evolutionary Distance, and Maximum Parsimony Methods. *Molecular Biology and Evolution*, 28 (10), 2731–2739.
http://dx.doi.org/10.1093/molbev/msr121

Yamauchi, M.M., Miya, M. & Nishida, M. (2004) Use of a PCR-based approach for sequencing whole mitochondrial genomes of insects: two examples (cockroach and dragonfly) based on the method developed for decapod crustaceans. *Insect Molecular Biology*, 13 (4), 435–442.
http://dx.doi.org/10.1111/j.0962-1075.2004.00505.x