

USE OF GENETIC DIVERGENCE IN WATER FROGS TO CONSTRAIN GEODYNAMICS AND LANDSCAPE DEVELOPMENT IN THE EASTERN MEDITERRANEAN REGION

Çiğdem Akin^{1,2*}, C. Can Bilgin¹, Hansjürg Hotz^{2,5}, Peter Beerli³, Rob Westaway⁴, Torsten Ohst², Gaston-Denis Guex⁵, Spartak N. Litvinchuk⁶, Thomas Uzzell⁷, Metin Bilgin⁸, Jörg Plötner²

¹ Biodiversity and Conservation Laboratory, Department of Biology, Middle East Technical University, 06531 Ankara, Turkey

² Museum für Naturkunde, Leibniz-Institut für Evolutions- und Biodiversitätsforschung an der Humboldt-Universität zu Berlin, Invalidenstraße 43, 10115 Berlin, Germany

³ Laboratory for Molecular Systematics and Ecology, Academy of Natural Sciences, 1900 B. F. Parkway, Philadelphia, Pennsylvania 19103, USA

⁴ Faculty of Mathematics, Computing and Technology, The Open University, Abbots Hill, Gateshead NE8 3DF, UK and IRES, Newcastle University, Newcastle-upon-Tyne NE1 7RU, UK.

⁵ Zoologisches Institut, Universität Zürich-Irchel, Winterthurerstrasse 190, CH-8057 Zurich, Switzerland

⁶ Institute of Cytology, Russian Academy of Sciences, Tikhoretsky pr. 4, 194064 St. Petersburg, Russia

⁷ School of Computational Science and Department of Biological Science, Florida State University, Tallahassee, Florida 32306-4120, USA

⁸ Edward R. Madigan Laboratory, Department of Cell and Developmental Biology, University of Illinois at Urbana Champaign, Urbana, IL 61801, USA

Water frogs occupy many habitats but their dependence on fresh water makes them highly susceptible to effects of climate change, crustal deformation, and regional-scale vertical crustal motions. They can therefore be used to study effects of geological processes and climate changes on speciation. Genus *Pelohylax* occurs throughout the Mediterranean and Middle Eastern regions as a series of species (main haplogroups or MHGs) and subspecies (subgroups or SGs), all descended from a common ancestral population. Based on two mitochondrial genes (ND2 and ND3), the different lineages (MHGs) have been identified and the timings of their genetic divergence have been resolved; the rate of divergence is estimated as ~1.7% per million years. The results are in accord with the timings of a number of geodynamic events and environmental changes known independently from the geological record and provide a means of confirming the timings of other events that are not constrained with confidence using the geological record. For example, the closure in the Middle Miocene (~15-14 Ma) of the former west-east Tethyan Seaway across northern Syria, resulting in the creation of a north-south land bridge (between the Mediterranean Sea to the west and the still submerged Mesopotamian Basin to the east), led to the migration of members of this ancestral Eurasian frog population into Arabia and North Africa and the start of its subsequent isolation as the modern North African species *P. saharicus*. Subsequently, the ‘Lago-Mare’ phase of the Messinian salinity crisis resulted in wetland environments across much of the Eastern Mediterranean region, which facilitated the spread of a frog

population that became subdivided into isolated groups by the marine transgression at the start of the Pliocene (at ~5.4-5.3 Ma). Thus, the frog species now found in SW Syria and the Jordan Valley, *P. bedriagae* (MHG2), became isolated from its counterparts *P. cypriensis* (MHG3) in Cyprus and *P. cf. bedriagae* (MHG6) in Anatolia, from two MHGs that currently lack formal species names, now found in Cilicia (MHG4) and the Karasu Valley / Narlı plain (MHG5) in southern Turkey (i.e., west and east of the Amanos Mountains), from *P. ridibundus* (MHG1) in the Black Sea region and Europe, and from MHGs 7-9 in central Asia. These two southern Turkey haplogroups in turn became isolated from each other at ~2.8-2.7 Ma, an event that is attributed to the initiation at ~3.7-3.6 Ma of the modern geometry of faulting within the northern Dead Sea Fault Zone, which has created the Amanos mountain range through transpression. The Amanos Mountains thus became an effective topographic barrier within a million years of the initiation of this geometry of faulting. Finally, the Anatolian species *P. cf. bedriagae* (MHG6) began to differentiate into its present four SGs around the start of Pleistocene, a succession of events that is attributed to the increase in relief due to the progressive uplift of Anatolia; one of these (the Euphrates SG) now inhabits the Euphrates valley in NE Syria, having evidently spread downstream in response to the lengthening of this river that has accompanied the uplift of the Mesopotamian Basin. Work on this topic continues; it will involve the study of other genetic markers and the collection of data from hitherto unstudied localities across the Middle East.