Zootaxa 2690: 43–52 (2010)
www.mapress.com/zootaxa/

Article

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

A new species of *Danakilia* (Teleostei, Cichlidae) from Lake Abaeded in the Danakil Depression of Eritrea (East Africa)

MELANIE L. J. STIASSNY[1], GIUSEPPE DE MARCHI[2] & ANTON LAMBOJ[3]

[1]*Division of Vertebrate Zoology, Department of Ichthyology, American Museum of Natural History, Central Park West at 79th Street, New York, NY 10024. E-mail: mljs@amnh.org*

[2]*Museo Civico di Storia Naturale di Milano, Corso Venezia 55, 20121 Milano, Italy. E-mail: dromasardeola@gmail.com*

[3]*Universität Wien, Fakultät für Lebenswissenschaften, Department für Evolutionsbiologie, Althanstrasse 14, A - 1090 Wien, Austria. E-mail: anton.lamboj@univie.ac.at*

Abstract

A new species of cichlid fish is described from a small, endorheic lake (Lake Abaeded), situated some 30 m below sea level in the Danakil Depression of Eritrea (East Africa). *Danakilia dinicolai* is readily distinguished from its congener, *D. franchettii*, on the basis of body proportions and in the possession of markedly longer pectoral fins at all sizes. Additionally, oral dentition is more robust than that of its congener, and the lower pharyngeal jaw is markedly hypertrophied and covered with considerably finer and more densely implanted teeth on the posterior field of the jaw.

Key words: Eritrea, East Africa, *Danakilia*, Cichlidae

Introduction

Danakilia, originally described by Vinciguerra (1931) for *D. franchettii*, is a small tilapiine cichlid endemic to Lake Afdera (=Afrera or Giulietti) in the Danakil Depression of northern Ethiopia. Trewavas (1983) provided a list of generic attributes of *Danakilia* including, most notably, the presence of an exclusively tricuspid oral dentition. With the exception of the distantly related *Oreochromis tanganicae* (Schwarzer *et al.*, 2009), outer row oral dentition in tilapiine cichlids is invariably bicuspid, and the tricuspid dentition of *Danakilia* is herein considered diagnostic for the genus. Trewavas (1983) hypothesized a sister group relationship between *D. franchettii* and the geographically disjunct Iranian cichlid, *Iranocichla hormuzensis* Coad, 1982 and suggested a possible relationship between these two and *Tristramella*, a genus from the Jordan Valley. Subsequent phylogenetic analysis, based on molecular markers, has confirmed a close relationship between *Iranocichla* and *Tristramella*, but was unable to clarify the placement of *Danakilia* due to lack of material for DNA extraction (Schwarzer *et al.*, 2009).

Exploration of Lake Abaeded, an isolated crater lake located in the Danakil Depression of Eritrea, revealed the presence there of two fish species in this otherwise hyper-arid landscape: *Lebias dispar* Rüppell, 1829, a cyprinodontid widespread throughout the scattered water bodies of the region (Getahun & Lazara, 2001), and a cichlid that was initially considered to represent a population of *Danakilia franchettii*, previously known only from Lake Adfera, in the Danakil of Ethiopia some 160 km to the southeast. On closer examination, and after comparison with preserved material of *D. franchettii* including syntypes of the latter, numerous morphometric and morphological differences between the Lake Abaeded specimens and *D. franchettii* were identified. The Lake Abaeded cichlid is herein recognized as diagnosably distinct from its only known congener, *D. franchettii*, and is described below.

Accepted by J. Friel: 12 Nov. 2010; published: 29 Nov. 2010

Material and methods

Description of the new *Danakilia* species is based on examination of the type series and comparative materials housed in the collections of the American Museum of Natural History, New York (AMNH), the Museo Civico di Storia Naturale, Milano (MSNM) and the Museo Civico di Storia Naturale, Genoa (MSNG). Description of live specimens is based on field observations and on photographs of wild caught individuals held in aquaria by of one of us (G.M.). Fishes and environmental data were collected during three expeditions to the Lake Abaeded in January 1998, April 1998 and March 2001. Counts and measurements follow Barel *et al.* (1977). All measurements were taken on the left side with digital callipers with an accuracy of +/- 0.03 mm. Specimens were cleared and stained (C&S) using a modified protocol based on Taylor and Van Dyke (1985). Abbreviations used throughout the text are: ex.: example(s); SL: standard length; HL: head length.

Comparative materials examined in this study, arranged alphabetically by genus and species are: *Danakilia franchettii*: MSNG 31294, syntypes, 12 ex., 20.0–73.7 mm SL, Ethiopia: Lake Adfera. AMNH 227324, 10 ex., 4 C&S, 53.5–72.0 mm SL, Ethiopia: Lake Afdera, 280 km northwest of Asaita, Afar Region. 13˚ 10' N, 40˚ 50' E, Abebe Getahun, 19 June, 1997. AMNH 223754, 15 ex., 15.770.3 mm SL, Ethiopia: Lake Adfera. AMNH 227324, 10 ex., 4 C&S, 53.5–72.0 mm SL, Ethiopia: Lake Afdera, 280 km northwest of Asaita, Afar Region. 13˚ 10' N, 40˚ 50' E, Abebe Getahun, 19 June, 1997. *Iranocichla hormuzensis*: AMNH 97876, 1ex., 89.2 mm SL, Iran: Hormozogan, Sarzeh River, 46 km by road north of Bandar Abbas, Laristan. 27˚ 30.33' N, 56˚ 15.30' E, B.W. Coad, 29 November, 1976. AMNH 97875, 3 ex., 1 C&S, 39.5–52.7 mm SL, Iran: Kul River, Laristan. 27˚ 14.00' N, 55˚ 46.30' E, B.W. Coad, 26 November, 1976. *Tristramella simonis*: AMNH 225653, 4 ex., 142.7–151.40 mm SL, Israel: Lake Kinereth, A Ben-Tuvia, January 1991.

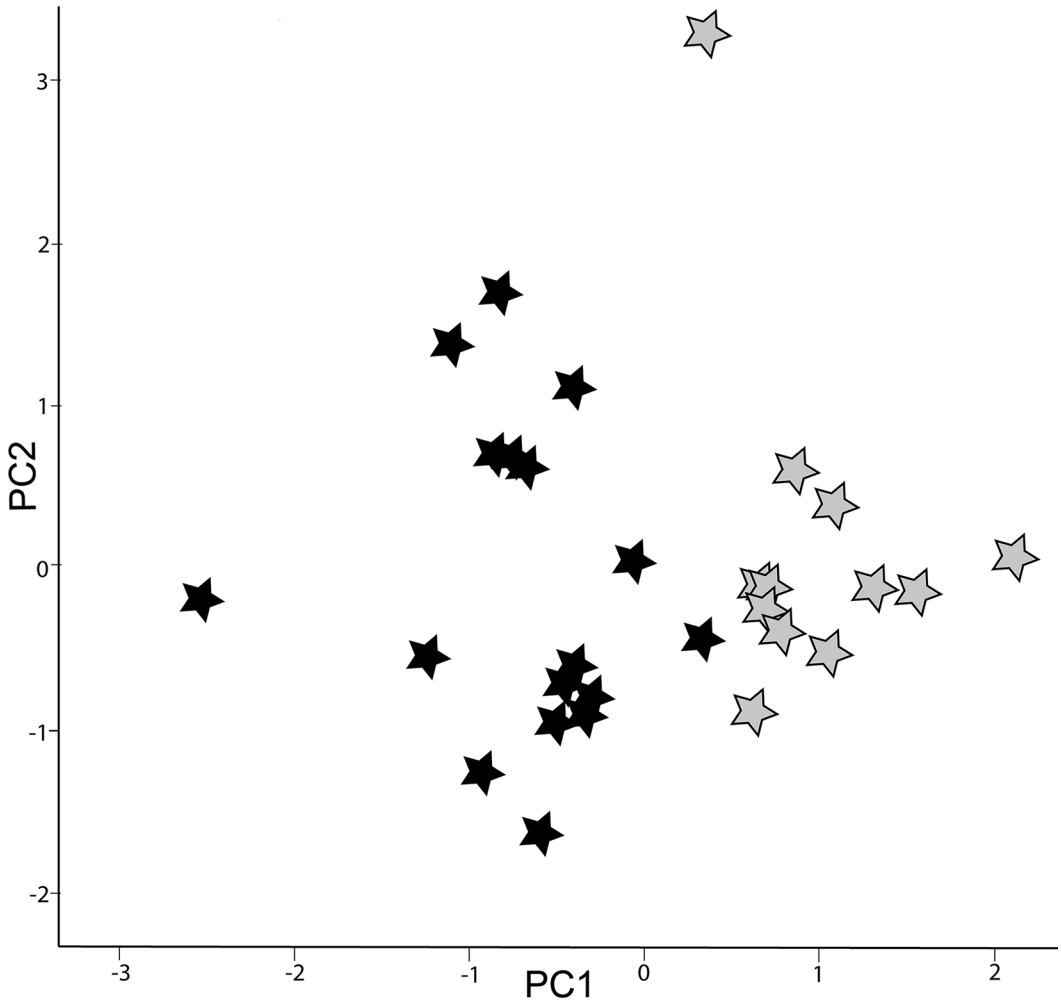

FIGURE 1. Scatter plot of PC1 vs. PC2. *Danakilia franchettii* (black stars), *Danakilia dinicolai* (grey stars).

Principal components analysis. Statistical analyses were performed using SPSS for Windows, Version 11.5 and all morphometric measurements were subjected to a Principal Components Analysis (PCA) using correlation matrix and varimax rotation options. Analysis of the dataset of 26 linear measurements (Table 1) separates the two species (Fig. 1) with PC I strongly correlated with size, explaining 89.60% of observed variance; PC II explains 3.98% (Table 1). PC I loadings are high for eye orbit diameter (EOD), predorsal length (DSD), length of longest pelvic fin-ray (PRL), prepelvic length (DSP) and prepectoral length (DSV), whereas highest PC II are for length of longest dorsal fin-ray (DRL), caudal peduncle depth (CPD), length of longest pectoral fin-ray (VRL), head depth (HD) and length of longest anal fin-ray (ARL). A small overlap involves a single specimen of *D. franchettii*. Based on the PCA results and examination of morphological features of the oral and lower pharyngeal jaws we herein recognize two diagnosably distinct *Danakilia* species and provide a formal description of the new Lake Abaeded taxon.

TABLE 1. Component matrix for PC I and PC II.

	PC I	PC II
TL (total length)	0.788	0.611
SL (standard length)	0.786	0.611
BD (body depth)	0.697	0.692
HL (head length)	0.818	0.566
HD (head depth)	0.594	0.772
SNL (snout length)	0.751	0.622
EOD (eye diameter)	0.934	0.265
POL (postorbital length)	0.799	0.595
MW (mouth width)	0.718	0.602
IOD (interorbital width)	0.680	0.707
PMX (premaxillary length)	0.737	0.632
LJL (lower jaw length)	0.743	0.569
CHEEK (cheek depth)	0.754	0.626
PROD (preobital length)	0.807	0.571
CPL (caudal peduncle length)	0.771	0.592
CPD (caudal peduncle depth)	0.253	0.847
DSD (predorsal length)	0.884	0.418
DSA (preanal length)	0.789	0.597
DSP (prepectoral length)	0.824	0.552
DSV (prepelvic length)	0.820	0.553
DL (dorsal fin-base)	0.655	0.723
AL (anal fin-base)	0.544	0.745
DRL (longest dorsal fin-ray)	0.355	0.866
ARL (longest anal fin-ray)	0.531	0.754
PRL (longest pectoral fin-ray)	0.880	0.341
VRL (longest pelvic fin-ray)	0.544	0.808

***Danakilia dinicolai*, new species**
Figs. 2–4; Table 2

Holotype. MSNM 4888, male, 96.4 mm SL, Eritrea: Lake Abaeded. 14˚ 35' 17" N, 40˚ 05' 04" E., G. De Marchi, January 1998.

Paratypes. MSNM 4889, male, 72.9 mm SL, same data as holotype. MSNM 4890, female, 63.9 mm SL, same data as holotype. MSNM 4891, male, 56.7 mm SL, same data as holotype. AMNH 248881, 5 ex., 3 males, 2 females, 69.9–82.9 mm SL, Eritrea: Lake Abaeded, G. De Marchi, March 2001. AMNH 251633 4 ex. (1C&S), 1 male, 3 females, 63.6–76.5 mm SL, Eritrea: Lake Abaeded, G. De Marchi, March 2001. MSNG 55210, 1 female, 73.0 mm SL, Eritrea: Lake Abaeded. 14˚ 35' 17" N, 40˚ 05' 04", E., G. De Marchi, March 2001.

Diagnosis. Differs from its only congener, *Danakilia franchettii*, in the possession of longer pectoral fins (31.1–38.7% SL vs. 21.7–30.6% SL). Outer row teeth in both oral jaws composed of stout tricuspids, considerably more robust and fewer in number than those of *D. franchettii*. Lower pharyngeal bone relatively massive, longer than wide, length 30–32% HL (vs. small, only slightly longer than wide, length 25–27% HL in *D. franchettii*), with 40–48 teeth in posterior row (vs. 26–36 in *D. franchettii*).

Description. Based on holotype and 13 paratypes. Maximum size 96.4 mm SL. Counts and proportional measurements are given in Table 2. Snout acute, mouth terminal, lips thickened but not fleshy. Head large, snout conical with straight profile, head smoothly convex behind nape to dorsal fin, except in largest males with a bulbous frontal gibbosity, particularly evident in life (Figs. 2 & 4B). Greatest body depth between insertion of dorsal and pelvic fins. Caudal peduncle always longer than deep. Caudal fin truncate. Dorsal XIII–XIV 9–11. Anal III 7 or 8. Pectoral fin long, reaching to anal fin origin or beyond. First pelvic ray longer in males than females but pelvic fin always reaching anus, and often beyond anal origin.

FIGURE 2. *Danakilia dinicolai*, holotype, MSNM 4888, male, 96.4 mm SL, Lake Abaeded, Eritrea.

Jaws isognathous, both with 2–4 rows of tricuspid teeth. Outer row teeth in both jaws stout tricuspids with small, symmetrically rounded lateral cusps and larger medial cusp (Fig. 3A), considerably more robust and fewer in number than in *D. franchettii* (Fig. 3B). Lower pharyngeal bone relatively massive, longer than wide (Fig. 3A), length 30–32% HL (versus small, only slightly longer than wide, length 25–27% HL in *D. franchettii* (Fig. 3B). Pharyngeal teeth in anterior field of jaw, robust unicuspids, sparsely implanted, becoming increasingly elongate, recurved and spatulate posteriorly, densely implanted over posterior field of jaw, 40–48 teeth in posterior row (Fig. 3A). Pharyngeal teeth in *D. franchettii* are similarly arrayed, but coarser and less densely implanted in posterior field of jaw, 26–36 teeth in posterior row (Fig. 3B).

Eleven to 14 small, moderately tuberculate gill rakers along lower limb of first arch (including raker at angle), 2 or 3 pointed epibranchial rakers. Microbranchiospines absent.

Scales cycloid, 2 or 3 rows on cheek, 2–4 horizontal rows on opercle. Dark scaleless spot on outer edge of opercle. Chest and belly scales deeply embedded, markedly smaller than on flank, 4 or 5 scales between pectoral and pelvic fins. Upper lateral line separated from dorsal fin anteriorly by 3 or 4 scale rows, at 8th pored scale by 2 scale rows, at last pored scale by 1–1.5 scale rows. End of upper lateral line separated from lower lateral line by 1 or 2 scale rows. Basal $^{1}/_{3}$ of caudal fin covered with scales; other fins unscaled.

TABLE 2. Morphometric and meristic data for the holotype and 13 paratypes of *Danakilia dinicolai*.

	holotype	mean	SD	Range
Standard length	96.4	77.9		63.6–96.4
% SL				
Body depth	41.0	39.4	1.2	37.2–41.3
Head length	39.2	38.9	1.2	37.0–40.9
Caudal peduncle length	14.2	14.2	0.9	12.5–15.2
Caudal peduncle depth	11.8	11.9	0.5	11.4–13.4
Dorsal-fin base	49.2	48.7	1.3	46.8–51.0
Anal-fin base	13.7	13.5	1.0	12.0–14.9
Predorsal distance	39.2	40.0	1.0	38.7–41.7
Preanal distance	75.7	73.3	2.6	69.5–76.3
Prepectoral distance	44.5	42.1	1.0	40.8–44.5
Prepelvic distance	47.4	45.3	1.3	43.5–47.4
Longest dorsal-fin ray	28.3	17.1	3.9	13.2–28.3
Longest anal-fin ray	25.4	16.1	3.1	13.8–25.4
Longest pectoral-fin ray	31.1	33.6	2.5	31.1–38.7
Longest pelvic-fin ray	32.6	24.0	2.9	21.2–32.6
% HL				
Head depth	96.0	70.0	8.8	61.7–96.0
Snout length	42.2	36.5	2.5	31.7–42.2
Eye diameter	19.2	24.1	2.0	19.2–27.0
Postorbital distance	38.6	39.4	1.8	37.0–41.9
Interorbital distance	31.5	29.5	1.7	25.6–31.5
Cheek depth	32.2	31.7	1.4	28.9–34.8
Lower jaw length	32.7	32.2	1.9	29.9–37.2
Preorbital distance	25.9	25.6	1.5	23.2–27.6
Caudal peduncle length % as of depth	120.2	118.7	8.3	102.8–128.8
		median		
Upper lateral-line scales	16	17		16–18
Lower lateral-line scales	9	9		8–11
Total lateral-line scales	27	27		27–29
Circumpeduncular scales	16	16		
Dorsal-fin spines	14	14		13–14
Dorsal-fin rays	10	10		9–11
Anal-fin spines	3	3		
Anal-fin rays	7	8		7 or 8
Pectoral-fin rays	13	12		11–13
Gill rakers on lower limb of first arch	12	12		11–14
Total gill rakers on first arch	14	14		13–17

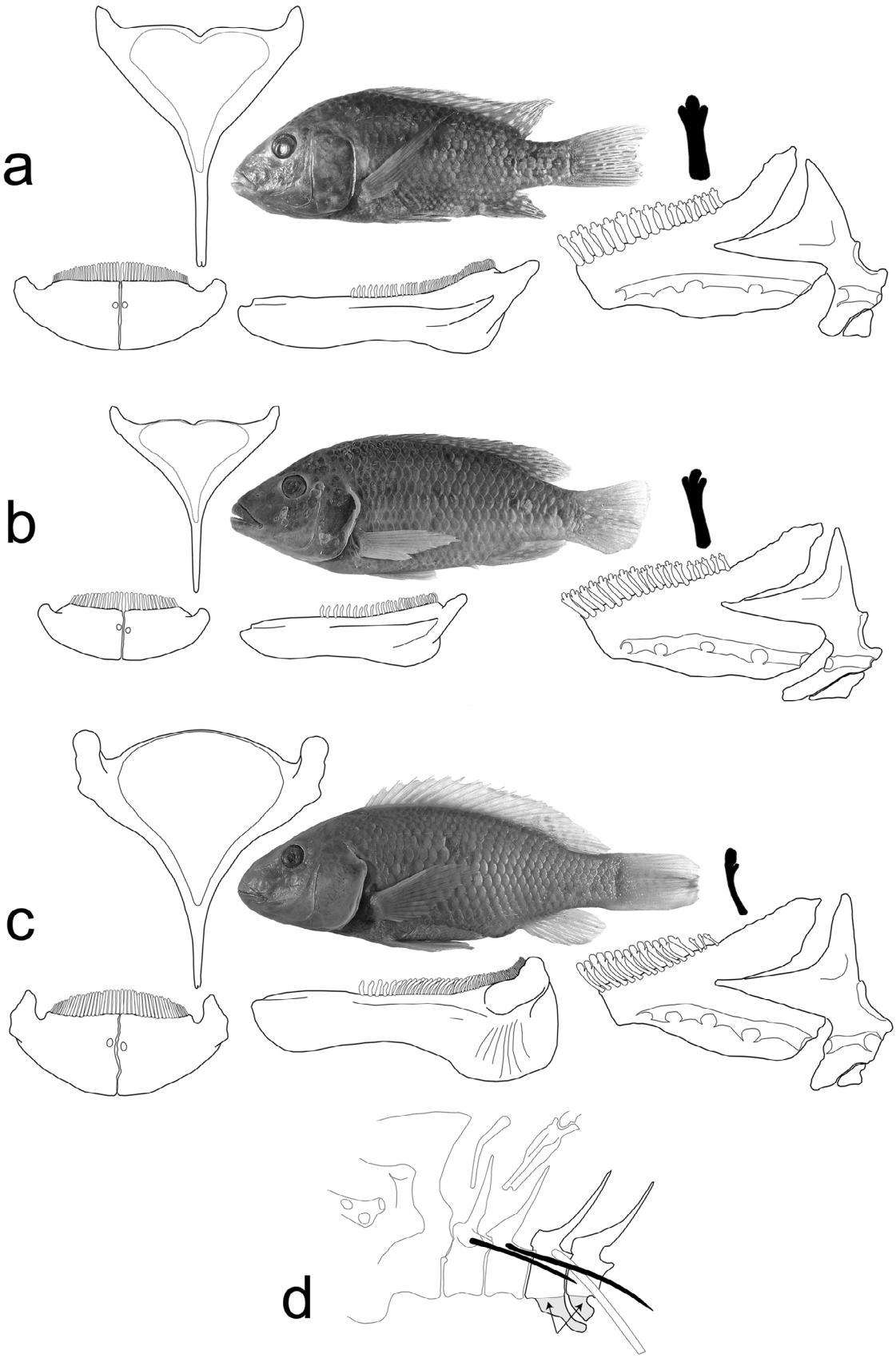

FIGURE 3. Lower pharyngeal jaw (dorsal, posterior and lateral views), left mandible and isolated tooth in (a) *Danakilia dinicolai*, (b) *Danakilia franchettii*, (c) *Iranocichla hormuzensis*. Elements drawn in corresponding scale for each species. Posterior neurocranium and anterior vertebral elements, arrows indicate inferior vertebral apophysis of (d) *Iranocichla hormuzensis*.

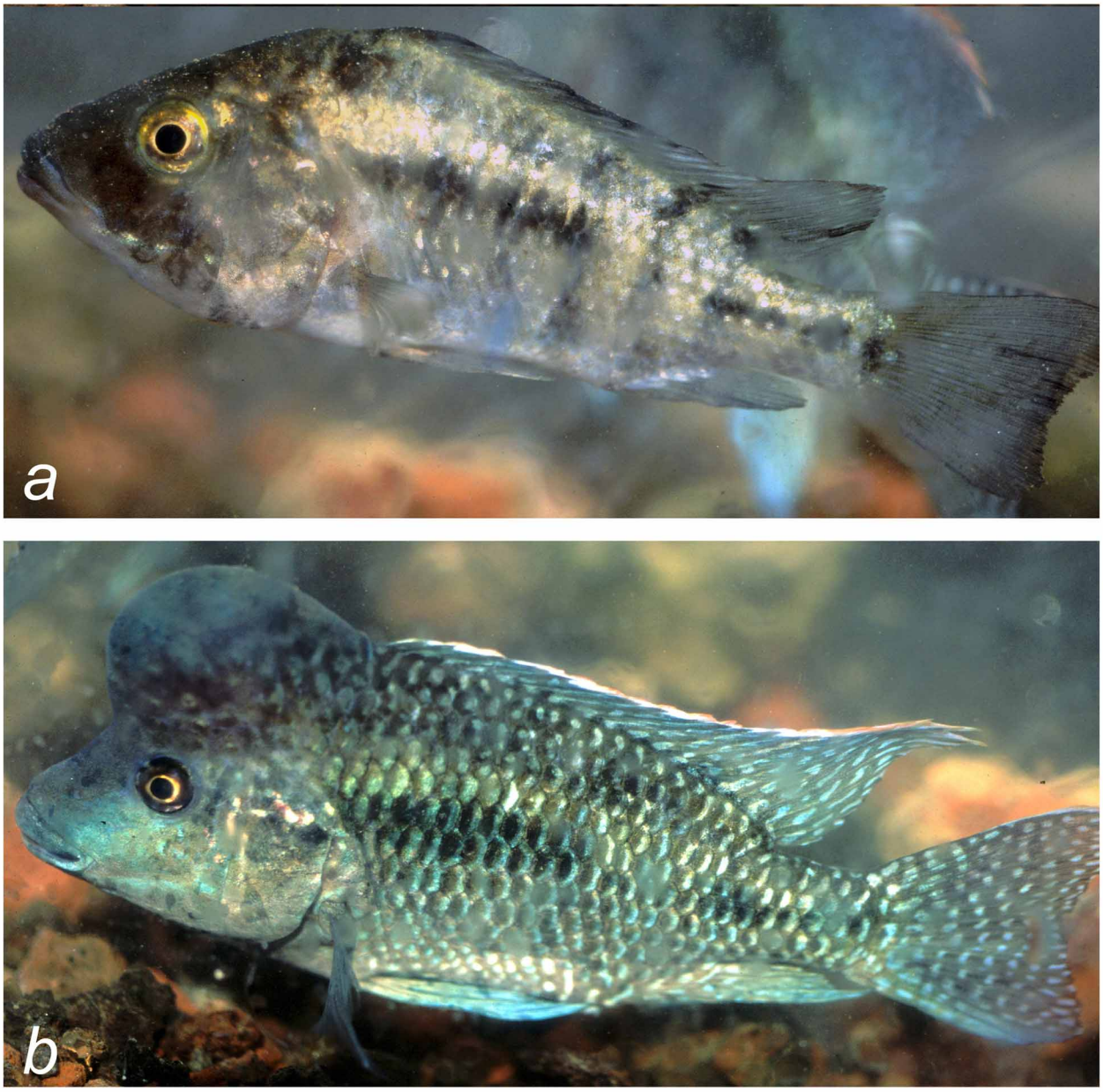

FIGURE 4. *Danakilia dinicolai* (a) wild caught female and (b) wild caught male. Specimens not preserved or measured.

Miscellaneous osteology. Infraorbital series complete, with lachrymal (first infraorbital) and four tubular infraorbitals, lachrymal with five openings of laterosensory system. Total of 25 or 26 vertebrae, 11–13 precaudal and 12–14 caudal. Inferior vertebral apophysis (spondylophysial apophysis) supporting anterior end of gas bladder composed of elongate ventro-posteriorly directed process on 3rd vertebral centrum which abuts a stout ventro-posteriorly directed process on 4th centrum; similar in form and composition to that of *Iranocichla* (Fig. 3D).

Coloration in life. Females and non-dominant males (Fig. 4A). Opercule and body pale silvery-grey, snout and nape dark brownish-black. Dark scaleless spot on outer edge of opercle variously intense, but always present. Upper lip with bluish cast, lower lip grey. Throat and branchiostegal membranes pale silver-grey. Two dark longitudinal stripes sometimes visible on flanks, upper stripe at level of upper lateral line, passing to end of dorsal-fin base, lower stripe from edge of opercle to caudal base, not extending into caudal fin. Sometimes 5–7 dark vertical bars on body from dorsal-fin base to ventrum. Eye golden-yellow to brownish-black. Dominant males (Fig. 4B). Dorsal, caudal and anal fins pale blue, with numerous paler blue

dots. White margin of dorsal fin flushed pale red-orange distally. Thin white margin on upper caudal lobe. Pelvics blue, paler distally. Body scales with iridescent, pale blue posterior margins, centrally grey to greyish-black. Scales on chest and belly silvery grey, with darker grey margins. Prominent frontal gibbosity blackish-blue to greyish-blue. Snout and lips pale blue.

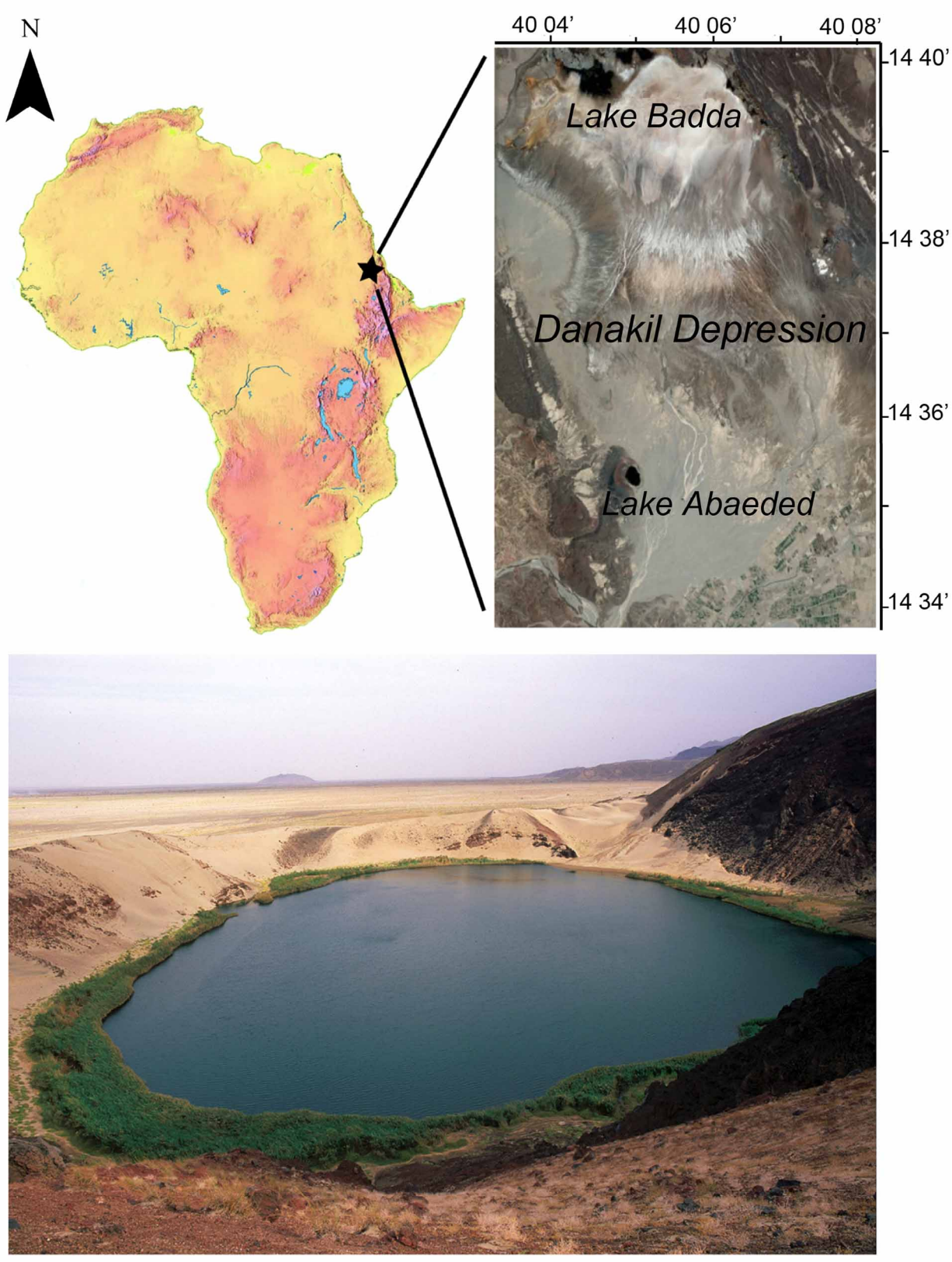

FIGURE 5. Geographic location and photograph of type locality, Lake Abaeded, Eritrea.

Coloration in preservation (Fig. 2). Both sexes with head and body brown, darker dorsally, with dark lines or bars often visible as described in living specimens. Dorsal, anal and caudal fins heavily spotted in males, less so in females.

Feeding behaviour. No field observations made, but gut morphology and contents suggests a diet primarily consisting of algae grazed from the surface of plants and rocks. Guts are highly coiled, and extend to 7.6 times SL, most are filled with floculent algae with some sand grains and vegetable debris. However, it is likely that this species is an opportunistic feeder, as individuals were caught on lines baited with grasshoppers.

Breeding behaviour. Unknown, but large males guarding pits over sand were observed in the field.

Distribution and habitat (Fig. 5). Lake Abaeded occupies a small oval depression (maximum width of 450 m, maximum depth 10 m) in a volcanic crater at the northwestern border of the Danakil Depression in Eritrea, 132 km southeast of the coastal town of Massawa. Lake surface is about 30 m below sea level. Sand from dunes along the eastern and southern rim is frequently blown into the lake. The lake is fed by many hot springs at surface level and underwater, and as there is no surface outlet evaporation in this hyper arid region (rainfall of ~5 m/year) probably fully compensates for the input from springs to maintain a stable lake level year round. In April 1998 water temperature was 29°C but reached 45°C close to the hot springs. Total salinity was 14.5 gr/l. The most abundant ions were Na^+ (111 EPM), Ca^{++} (99 EPM), Mg^{++} (18 EPM), Cl^- (217 EPM) and SO_4^- (41 EPM). Ph was 7.46 and EC was 23100. High concentrations of Na^+, Ca^{++}, Cl^- and SO_4^- are certainly the result of circulation of water heated at depth through layers of gypsum and halite that cover the bottom of the northern part of the Danakil Depression (Gasse & Street 1978). The lakeshore is almost completely encircled by reeds (*Phragmites australis*) and stands of tamarisk (*Tamarix aphylla*), but is free of vegetation in the proximity of hot springs. A single non-piscine vertebrate inhabiting the lake is a frog, probably *Ptychadena anchietae*. Fishes are abundant in the lake and concentrate among the reeds, but are found also on sandy substrate near the shore, where temperature is not too high. The bottom of the sandy areas is covered with crater-like nests dug and defended by large colourful males. The species has been found so far only in Lake Abaeded, but no research has yet been conducted in the nearby Lake Badda, a variable surface reed-fringed lake only 8 km north of Lake Abaeded (Fig. 5).

Etymology. Named in memory of Ernesto Di Nicola, a member of the 2001 expedition to Lake Abaeded who died in a car accident while returning from the lake.

Discussion. The discovery of a second species of *Danakilia* in a small lake currently isolated by some 160 km of hyper-arid desert from its congener, *Danakilia franchettii*, raises the question of the age and origin of these two isolated species. The geological history of the region indicates that the Danakil Depression formed as a result of tectonic movements related to the Afro-Arabian Rift (Beyene & Abdelsalam 2005). It was an intermittent marine basin (at least in the northern region) during the late Pleistocene, and with the formation of volcanic structures at the northern end it is thought to have separated from the Red Sea sometime around 32,000–25,000 years ago (Bonatti 1971, Barberi *et al.* 1972). Separation of the two species of *Danakilia* might therefore date back to the Pleistocene to the time of the formation of the Alayta e Tat'Ale shield volcanoes that surround Lake Afdera (Barberi *et al.* 1972). Alternatively, their separation may be considerably younger having occurred after the drying of extensive saline lakes that occupied the bottom of the Danakil Depression during a major arid phase that started about 9,000–5,000 years ago (Gasse 1974, Gasse & Street 1978). Unfortunately, despite considerable effort all attempts to extract DNA from either species have so far failed, and molecular divergence time estimates cannot be made until additional material becomes available.

Acknowledgements

We thank the following for help in the field, loan of material and/or discussion of the manuscript: Samson Tsegay, Yassin Adem, Dania Avallone (Eritrean Ministry of Fisheries, Massawa, Eritrea), Guido Traverso (Liceo Marconi, Asmara, Eritrea), Ernesto Abbate (Universitá di Firenze, Firenze, Italy), Giorgio Chiozzi (MSNM), G. Doria (MSGN), Norbert Milasowszky (University of Vienna, Austria).

References

Barel, C.D.N., van Ojen, M.J.P., Witte, F. & Witte-Maas, E.L.M. (1977) An introduction to the taxonomy and morphology of the haplochromine Cichlidae from Lake Victoria. *Netherlands Journal of Zoology*, 27, 333–389.

Beyene, A. & Abdelsalam, M.G. (2005) Tectonics of the Afar depression: A review and synthesis. *Journal of African Earth Sciences*, 41, 41–59.

Barberi, F., Borsi, S., Ferrara, G., Marinelli, G., Santacroce, R., Tazieff, H. & Varet, J. (1972) Evolution of the Danakil Depression (Afar, Ethiopia) in Light of Radiometric Age. *Journal of Geology*, 80, 720–729.

Bonatti, E., Emiliani, C., Ostlund, G. & Rydell, H. (1971) Final desiccation of the Afar Rift. *Science*, 172, 468–469.

Gasse, F. (1974) Les Diatomées des Sédiments Holocènes du Bassin du Lac Afrera (Giulietti) (Afar Septentrional, Ethiopie). Essai de Reconstitution de l'Évolution du Milieu. *Internationale Revue der gesamten Hydrobiologie und Hydrographie*, 59, 95–122.

Gasse, F. & Street, F.A. (1978). Late Quaternary lake level fluctuations and environments of the Northern Rift Valley and Afar Region (Ethiopia and Djibouti). *Paleogeography, Paleoclimatology, Paleoecology*, 24, 279– 325.

Getahun, A. & Lazara, K.J. (2001) *Lebias stiassnyae*: A new species of killifish from Lake Adfera, Ethiopia (Teleostei: Cyprinodontidae). *Copeia* 2001, 1, 150–153.

Schwarzer, J., Misof, B., Tautz, D. & Schliewen, U.K. (2009) The root of the East African cichlid radiations. *BMC Evolutionary Biology* 2009, 9, 186.

Taylor, W.R. & Van Dyke, G.C. (1985) Revised procedures for staining and clearing small fishes and other vertebrates for bone and cartilage study. *Cybium*, 9, 107–119.

Trewavas, E. (1983) Tilapiine Fishes of the genera *Sarotherodon*, *Oreochromis* and *Danakilia*. Trustees of the British Museum (Natural History), London, 583 pp.

Vinciguerra, D. (1931) Spedizione del Barone Raimondo Franchetti in Dancalia. *Annali del Museo Civico di Storia Naturale "Giacomo Doria"*, 55, 96108.