Nothobranchius streltsovi, a new species of annual killifish with two male colour morphs from the Malagarasi drainage, central Tanzania (Teleostei: Cyprinodontiformes: Nothobranchiidae)

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Nothobranchius streltsovi, new species, is described from specimens collected in pools associated with seasonal streams in upper catchments of the Ugalla River, Malagarasi drainage, central Tanzania. It belongs to the N. ugandensis species group based on male diagnostic characters comprising light blue scales with a broad, irregular reticulated pattern on the body, vivid red or orange oblique bars on the head and dorsum, yellow or blue anal fin, large vivid red spots on dorsal and anal fins, rounded head with a slightly concave to nearly straight dorsal profile, predorsal profile convex from nape to posterior extremity of dorsal-fin base, and variable cephalic squamation. Nothobranchius streltsovi has two sympatric colour morphs and is distinguished from all other members of the N. ugandensis group by the following combination of characters: scale margins orange; caudal fin orange, spotted proximally; pectoral fin spotted proximally; anal and pelvic fins with red dots, light blue proximally, yellow or creamy white distally; seven branchiostegal rays; 31–34 longitudinal, 14–16 transverse, and 15–16 circumpeduncular scales; supraorbital neuromast formula 2+3+4.

Introduction

The genus Nothobranchius comprises a group of small fishes inhabiting temporary savannah pools in Eastern Africa. The genus currently contains about 70 valid species distributed from Sudan to South Africa, and from Chad to Zanzibar and the Mafia islands in Tanzania (Wildekamp, 2004). All Nothobranchius species are annual; the adults die when the ephemeral habitat dries out and the next generation survives in the form of desiccation-resistant eggs encased in dry mud (Watters, 2009). The eggs hatch after the onset of the rainy season, develop and grow rapidly, and some species can reach sexual maturity in less than three weeks (Blažek et al., 2013).


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that occurs in the Lake Victoria basin, Bahi swamp, Ruaha river drainage, and Lake Rukwa watershed (\textit{N. ugandensis} species group sensu Wildekamp, 1990; Seegers, 1997, Neumann, 2008, Rosenstock, 2011, Shidlovsky, 2010, Valdesalici, 2012). In addition, genetic analyses suggest that \textit{N. robustus} Ahl, 1935 is closely related to \textit{N. taeniopygus}, and \textit{N. steinforti} Wildekamp, 1977, known from two localities belonging to the Wami river in eastern Tanzania, represents the basal form of all the above taxa (Dorn et al., 2014).

Within the known populations of \textit{N. sp.} ‘Lake Victoria’, a form has been referred to as \textit{N. sp.} ‘Limba Limba’. It was first collected by L. Seegers in 1994 near the Limba Limba river (L. Seegers pers. comm.). It was depicted in a colour photograph in Seegers (1997), and as an undescribed \textit{Nothobranchius} species in De Vos et al. (2001), but no material was previously available for study. In April 2010, 2012 and 2014, specimens apparently corresponding to \textit{N. sp.} ‘Limba Limba’ were collected from small pools associated with the Nkululu river in central Tanzania (Shidlovsky, 2010), close to the Limba Limba river, and are herein described as \textit{N. streltsovi}, new species.

\section*{Material and methods}

Measurements follow Amiet (1987) with the addition of caudal peduncle length, measured from the posterior extremity of the anal-fin base to the posterior end of the hypural plate, eye diameter measured between the anterior and posterior

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{fig1.jpg}
\caption{\textit{Nothobranchius streltsovi}, MSNG 57812, male, holotype, white morph, 51.2 mm SL; Tanzania: Ugalla River drainage.}
\end{figure}

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{fig2.jpg}
\caption{\textit{Nothobranchius streltsovi}, wild male, white morph, about 45 mm SL; Tanzania: Ugalla River drainage; collected in 2014, after several months in captivity, not preserved. (Photograph by Sergey Torgashev).}
\end{figure}
orbital rims, snout length measured from the anterior tip of the lower jaw to the anterior edge of the orbital rim, and interorbital width which is the shortest distance between the orbits across the top of the head. Measurements were taken with a digital calliper (to the nearest 0.1 mm), partly under a dissection microscope. All measurements and counts were taken from the left side. All visible rays of the dorsal and anal fins were counted. Scale counts as per Huber (2000). Unless stated otherwise, measurements are presented as percentages of standard length (SL), except for eye diameter, snout length and interorbital width, which are given as percentages of head length (HL). Nomenclature follows Scheel (1968), Huber (2000) and Costa (2001) for the neuromast system on the head, and Hoedeman (1958) for frontal squamation. A principal component analysis (PCA) was conducted using log-transformed measurements to one tenth of a millimeter in a covariance matrix and without rotation, using the software package PAST (Hammer et al., 2001). Cleared and stained (c&s) specimens were prepared following Taylor & Van Dyke (1985). Type and comparative material is deposited in the following institutions: MSNG, Museo Civico

Fig. 3. *Nothobranchius streptosovi*, wild male, yellow morph, about 45 mm SL; Tanzania: Ugalla River drainage; collected in 2014, after several months in captivity, not preserved; reversed. (Photograph by Sergey Torgashev).

Fig. 4. *Nothobranchius streptosovi*, female, about 30 mm SL; Tanzania: Ugalla River drainage; collected in 2014, after several months in captivity, not preserved; reversed. (Photographed by Sergey Torgashev).
Nothobranchius streltsovi, new species
(Figs. 1–4)


Holotype. MSNG 57812, male, 51.2 mm SL; Tanzania: Malagarasi River basin, Ugalla River drainage: temporary pool in Nkululu River (6°40’52” S 33°41’00” E); S. Torgashev & A. Niki- forov, 22 Apr 2014.

Paratypes. MSNG 57654, male, 47.6 mm SL; same locality as holotype; S. Streltsov et al., 27 Apr 2010. – MSNG 57655, 2 males 38.3–42.6 mm SL, 3 females 31.3–33.8 mm SL, 1 male 38.8 mm SL c&s; aquarium stock (about six months old, parents collected at type locality in 2010).

Diagnosis. Nothobranchius streltsovi males are similar to other members of the N. ugandensis species group in possessing light blue scales with a broad, irregular, reticulated pattern on the body, oblique red or orange bars on the head and dor- sum, yellow or blue anal fin, large vivid red spots on the dorsal and anal fins, rounded head with slightly concave to nearly straight dorsal profile, convex predorsal profile from nape to posterior extremity of dorsal-fin base, and variable cephalic squamation. Males can be distinguished from all other species of this species group by the following combination of characters: scale margins orange; caudal fin orange, spotted proximally; pectoral fin spotted proximally; anal and pelvic fins with a pattern of red dots, light blue proximally, yellow or creamy white distally; seven branchiostegal rays; 31–34 longitudinal scales; 14–16 transverse scales; 15–16 circumpeduncular scales; supraorbital neuromast formula 2 + 3 + 4.

Description. General body features are illustrated in Figures 1–4, and morphometric characters are summarised in Table 1. Maximum observed length in male 51.2 mm SL. Dorsal profile of head straight to slightly concave anteriorly, convex from nape to posterior extremity of dorsal-fin base. Ventral profile convex, slightly concave to nearly straight on caudal peduncle posterior to anal fin. Snout slightly pointed, mouth superior, lower jaw longer than upper, posterior end of

| Table 1. Morphometric data of Nothobranchius streltsovi. Holotype MSNG 57812 and paratype MSNG 57654 preserved in the field; paratypes MSNG 57655 born in captivity, about 6 months old. |
|-----------------|-----------------|-----------------|-----------------|
|                 | MSNG 57812 | MSNG 57654 | MSNG 57655 |
| **Standard length (mm)** | | | |
| Depth at pelvic fin | 28.3 | 32.9 | 38.3–42.6 |
| Predorsal length | 60.3 | 60.7 | 58.9–65.4 |
| Length of dorsal-fin base | 26.3 | 29.6 | 23.7–25.0 |
| Preanal length | 59.9 | 61.3 | 61.0–63.6 |
| Length of anal-fin base | 22.0 | 21.2 | 18.3–20.6 |
| Prepelvic length | 49.8 | 52.5 | 49.0–53.3 |
| Length of caudal peduncle | 17.7 | 21.2 | 18.5–26.0 |
| Depth of caudal peduncle | 13.2 | 14.4 | 11.7–12.2 |
| Head length | 30.2 | 33.6 | 27.4–29.6 |
| **Percentage of standard length** | | | |
| Snout length | 30 | 26 | 25–29 |
| Eye diameter | 25 | 27 | 30–34 |
| Interorbital width | 45 | 39 | 35–39 |

Valdesalici: Nothobranchius streltsovi
strictus at same level or slightly above centre of eye. Branchiostegal membrane projecting posteriorly from opercle.


Frontal neuromast (Fig. 5) pattern ‘open’ type (as per Scheel, 1968). Anterior supraorbital neuromast series in a shallow groove with 3 neuromasts; posterior supraorbital neuromast series curved with 4 neuromasts (as per Huber, 2000). Cephalic neuromasts: supraorbital 2+3+4 (as per Costa, 2001). Preopercular neuromast series in an open groove, distal ridge slightly overlapping opercle. One neuromast on each scale of midlateral longitudinal series.

Basihyal bone sub-triangular, basihyal cartilage spatulate. Seven branchiostegal rays. Three vomerine teeth in a small patch. Lateral process of post-temporal short. Urohyal, with a single antero-dorsal process. Second pharyngobranchial with one tooth. Total number of vertebrae 32. Premaxilla and dentary with many irregularly distributed, unicuspid, slightly curved teeth of variable size, a small number of larger teeth on outer row in both jaws.

Female. Maximum observed length 33.8 mm SL. Anal fin triangular with rounded tip. Pelvic fin short, tip not reaching anus. Branchiostegal membrane not projecting from opercle. Urogenital papilla surrounded by an expanded membrane forming a pocket shaped structure overlapping anterior portion of anal fin.

**Colour in life.** Males exist in two sympatric colour morphs (Figs. 2–3). Flank light blue with orange reticulations; side of head light blue with orange reticulations; anterior, superior portion of head, dentary, and lower jaw orange. Iris silvery with golden sheen, a faint black vertical bar through centre of eye. Branchiostegal membrane orange with white rim. Dorsal fin light blue with dark red spots and dots, larger basally, smaller distally. In white morph anal fin light blue with rows of red spots and dots on basal portion, creamy white with red tip on distal half. In yellow morph anal fin light blue with rows of red spots and dots on basal portion, elongate over median rays, yellow on distal half. Dorsal and anal fins with dark brown to black margin. Caudal fin orange, light blue with red spots on basal portion. Pectoral fin hyaline orange with dark orange to red dots on basal portion, light blue posterior margin. In white morph pelvic fin light blue with elongate red spots, distal portion creamy white. In yellow morph pelvic fin light blue with elongate spots, distal portion yellow.

Female (Fig. 4). Body and head scales light brown-grey, ventrally whitish. Posterior scale margins darker, forming a reticulated pattern. Opercular region whitish with light blue reflection. Scales on dorsal surface and upper part of flank reflective light blue posteriorly. Fins hyaline. Iris silvery.

**Distribution** (Fig. 6). *Nothobranchius streltsovi* is currently known only from a single locality associated with the Nkululu River, a tributary of the Ugalla River, Malagarasi River basin, central Tanzania.
Habitat notes. At time of collection in 2014 the type locality comprised an ephemeral pool located near a culvert measuring approximately 6 m × 6 m, less than 50 cm deep, and without aquatic vegetation. The water was light clay grey and slightly turbid with low conductivity (approximately 150 µS·cm⁻¹), pH 7.9 and temperature approximately 26 °C. *Nothobranchius seegersi* was the only other fish species present.

Etymology. The species is named in honour of Sergey Streltsov, who collected the type specimens.

Discussion

The chromatic polymorphism present in *N. streltsovi* is different to that exhibited by other *Nothobranchius* species. In *N. streltsovi* differences in colour pattern are limited to the anal and pelvic fins, whereas other *Nothobranchius* species tend to display variation in caudal-fin colouration. The evolutionary processes driving the existence of multiple sympatric or allopatric colour morphs in *Nothobranchius* species are currently unknown (Reichard et al., 2009). *Nothobranchius streltsovi* occurs in two clearly separated but sympatric colour morphs differing in colour pattern of the pelvic and anal fins. These differences are not related to stress (e.g. pale colouration in subdued males) but represent a stable character that can also be recognised in preserved specimens. The white morph seems more abundant although no statistical analysis was performed. Chromatic polymorphism has been observed in members of almost all known *Nothobranchius* lineages with the exception of the basal *N. virgatus* and *N. microlepis* species groups, and probably reflects a derived condition (Dorn et al., 2014).
Nothobranchius streitsovi is comparable to the sympatric *N. seegersi* in terms of morphology and meristics, but differs by the existence of two (vs. one) colour morphs, possession of orange scale margins forming a broad, irregular, reticulated pattern on the body and head (vs. red scale margins forming a thin reticulated pattern), pectoral fin spotted (vs. hyaline), anal fin spotted (vs. striped), caudal fin spotted proximally (vs. plain red), and caudal fin plain orange distally (vs. red with blue bar and black distal margin).

*Nothobranchius streitsovi* belongs to the *N. ugandensis* species group, defined by Valdesalici et al. (2009) and modified by Valdesalici (2012), by the following combination of characters: male colour pattern consisting of light blue scales and a broad, irregular reticulated pattern on the body; vivid red or orange oblique bars on the head and dorsum; yellow or blue anal fin; large vivid red spots on the dorsal and anal fins; head rounded with slightly concave to nearly straight dorsal profile, predorsal profile convex from the nape to the posterior extremity of the dorsal-fin base; cephalic squamation variable. This putative assemblage currently includes *N. ugandensis* Wildekamp 1994, *N. nubaensis*, *N. kardashevi* and the undescribed *N. sp*. ‘Lake Victoria’. The group is widely-distributed, ranging southwards from Sudan (seasonal rivers around the Nuba mountains) as far as the Lake Rukwa drainage system in Tanzania.

Males of *N. streitsovi* are distinguished from those of *N. ugandensis*, known from the basins of Lakes Victoria, Albert and Kioga in Uganda plus the neighbouring area in Lake Victoria basin of western Kenya, by possession of orange (vs. grey brown in the yellow morph and red in the red morph of *N. ugandensis*) scale margins, a spotted (vs. hyaline) pectoral fin, spotted (vs. unspotted or pattern reduced to a few dots) anal fin, spotted (vs. unspotted or pattern reduced to faint dots on yellow morph) caudal-fin base, and absence (vs. presence) of a black marginal stripe on the caudal fin. Examination of the available data also indicated that there are no marked differences in proportional measurements with value overlap. Males of *N. streitsovi* differ from those of *N. ugandensis* by possessing greater numbers of circumpeduncular (15–16 vs. 14) and transverse (14–16 vs. 12–13) scales, plus a different cephalic neuromast supraorbital pattern (2+3+4 vs. 3+4+5).

Male individuals of *N. streitsovi* differ from those of *N. nubaensis*, known from foothills of the Nuba Mountains in Sudan and the Gambella Region in Ethiopia, by the existence of two (vs. one) colour morphs, possession of spotted (vs. plain) pectoral fins, spotted dorsal fin (vs. fused vermiculate markings forming irregular horizontal stripes), anal fin with spots reduced to dots or absent distally (vs. large blotches always present), dark margins present (vs. absent) on the dorsal and anal fins, and caudal fin spotted proximally (vs. plain red). Males of *N. streitsovi* are morphologically similar to those of *N. nubaensis*, but *N. streitsovi* possesses a greater number of scales in the longitudinal series (31–34 vs. 29–30), greater numbers of circumpeduncular and transverse scales (15–16 vs. 14, and 14–16 vs. 12, respectively), and a different cephalic neuromast supraorbital pattern (2+3+4 vs. 2+3+3).

Males of *N. streitsovi* are distinguished from those of *N. kardashevi*, known from the Katuma river drainage in Tanzania, by the existence of two (vs. one) colour morphs, regular thin reticulations (vs. irregular broad margins) on the scales, a spotted (vs. hyaline) pectoral fin, anal and pelvic fins creamy white or yellow (vs. blue) distally, a uniformly-coloured pattern of dots on the dorsal and anal fins (vs. dots present in two colours), and dark margins present (vs. absent) on the dorsal and anal fins. *Nothobranchius streitsovi* males also possess a greater number of circumpeduncular and transverse scales (15–16 vs. 12, and 14–16 vs. 12, respectively), a different cephalic neuromast supraorbital pattern (2+3+4 vs. 2+2+3), the dorsal-fin origin located more posteriorly (predorsal distance 60.3–60.7 % SL vs. 57.8–60.2), and a deeper caudal peduncle (13.2–14.4 % SL vs. 12.1–13.0).

*Nothobranchius streitsovi* appears to be related to an unidentified taxon referred to as *N. sp*. ‘Lake Victoria’ that clearly belongs to the *N. ugandensis* group, but may comprise an assemblage of several species based on aspects of its geographic distribution and colour pattern (Wildekamp, 1990; Seegers, 1997; Neumann, 2008; Shidlovsky, 2010; Rosenstock, 2011). A population of *N. sp*. ‘Lake Victoria’ from the Rungwa river drainage, which has been referred to as *N. sp*. ‘Piti River’ (Shidlovsky, 2010) is located most closely to habitats of *N. streitsovi*, but inhabits a separate drainage system. Males of *N. streitsovi* differ from those of *N. sp*. ‘Piti River’ by the existence of two (vs. one) colour morphs, possession of orange (vs. red brown) scale margins, spotted anal fin colour pattern absent distally (vs. spots present on the
whole fin), and a spotted (vs. unspotted) caudal-fin base.

Morphometric comparisons between males of *N. streltsovi* and other members of the *N. ugandensis* group were conducted by principal component analysis on the variance-covariance matrix of log-transformed morphometric data. In the principal component analysis conducted on the variance-covariance matrix of log-transformed morphometric data show *N. streltsovi* males separated from *N. ugandensis*, *N. kardashevi* and *N. sp. ‘Lake Victoria’ along PCI and from *N. nubaensis* along PCII. The highest loadings on PCI were dorsal-fin base length, body depth, and pre-anal length. The highest loadings on PCII were head length and snout length (Table 2; Fig. 7).

As reported by Stewart (2001), rifting at the end of the Miocene led the formation of a shallow lake basin known as Lake Manonga located about 150–200 km south-east of modern Lake Victoria. At its greatest extent this Pliocene paleo-lake probably encompassed 10000 km², and may have represented the centre of origin for the *N. ugandensis* species group.

The discovery of this new species increases the distribution of the *N. ugandensis* group in Tanzania. Sampling on floodplains of tributaries along the Malagarasi River and other remote areas in Tanzania is expected to result in the discovery of additional members of this species group.

**Comparative material.** *Nothobranchius ugandensis*:
MRAC 93-159-P-25-33, 6 males, 31.5–46.2 mm SL, 3 females, 31.6–42.0 mm SL; Uganda: Lake Albert basin, 0°51’00”N 32°29’00”E. – CSV 1021, 1 male, 47.3 mm SL; Uganda: Lake Albert basin, 1°47’16”N 31°19’39”E. – CSV 1022, 1 male, 43.7 mm SL; Uganda: Lake Victoria basin, 0°37’21”N 33°36’53”E. Data from Wildekamp (1994) were used for comparison.

*N. nubaensis*:
MRAC 2008-05-P-1, holotype, male, 42.9 mm SL; MRAC 2008-05-P-2–4, paratypes, 1 male, 43.9 mm SL; 2 females, 28.1–33.2 mm SL; MSNG 54286, 1 paratype, male, 40.8 mm SL; MNHN 2008-1140, 2008-1141, 2008-1179, 3 paratypes, males, 38.4–45.8 mm SL; SAIAB 80410, 1 patatype, male, 36.5 mm SL; BMNH 2008.4.2.11–12, 2 paratypes, 1 male, 45.1 mm SL; 1 female, 33.1 mm SL; Sudan: Khor Abu Habil system, 11°53’05”N 29°42’31”E. – SAIAB 80411, 1 male, 49.0 mm SL; SAIAB 80412, 1 female, 40.8 mm SL; BMNH 2008.4.2.13–14, 1 male, 47.1 mm SL, 1 female, 39.8 mm SL; Sudan: Wadi Al Ghallah system, 11°42’05”N 32°32’55”E.

*N. kardashevi*:
MRAC B2-09-P-1, holotype, male, 37.7 mm SL; MRAC B2-09-P-2–5, 4 paratypes, 1 male, 36.1 mm SL c&s, 3 females, 29.3–33.6 mm SL; MSNG 56889, 1 paratype, male, 31.2 mm SL; Tanzania: Katuma river drainage, 6°22’03”S 30°56’09”E.

*Nothobranchius* sp. ‘Lake Victoria’:
CSV 1024, 1 male, 40.2 mm SL, 2 females, 29.6–31.8 mm SL; Tanzania: Rungwa river drainage, Piti River, 7°18’51”S 33°29’31”E. – CSV 1026, 5 males, 21.8–30.7 mm SL, 5 females, 25.1–26.4 mm SL; Kenya: Nyando river drainage, 0°09’00”S 35°00’30”E.

**Table 2.** Factor loadings for PCA carried out on 12 log-transformed measurements of *Nothobranchius streltsovi* (n = 2), *N. ugandensis* (n = 4), *N. kardashevi* (n = 3), *N. nubaensis* (n = 10) and ‘Lake Victoria’ (n = 6).

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<th>Morphometric characters</th>
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Literature cited