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New records of *Pseudophoxinus firati* from Turkey (Teleostei: Leuciscidae)

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Summary

Pseudophoxinus firati was described from one spring in the upper Euphrates River drainage in Turkey. Here we record this species from seven additional sites, three in the upper Euphrates drainage, one in the upper Seyhan and three in the upper Ceyhan River drainages. These findings largely expand the distribution area of the species and its habitats are discussed.

1 | INTRODUCTION

Spring minnows of the genus *Pseudophoxinus* are widespread and species rich from Central Anatolia east to the upper Euphrates River drainage and south to the Dead Sea basin. Many *Pseudophoxinus* species have very limited distribution ranges, espacially in the Central Anatolian endorheic basins as well as in the small coastal rivers in the eastern Mediterranean basin (Bogutskaya, Küçük, & Atalay, 2006; Freyhof & Özuluğ, 2009a; Küçük, Gülle, Güçlü, Çiftçi, & Erdoğan, 2013).

Pseudophoxinus firati was described from a headwater spring in the Tohma River, a tributary of the upper Euphrates (Bogutskaya et al., 2006). This spring is isolated from adjacent streams, but the area is shallow and it is hard to imagine that the species might have been long isolated in the area. Actually, there is a channel that connects the spring with the Tohma River at very high water levels. Therefore, already Freyhof (2014) suspected, that *P. firati* might be more widespread. But until now, only one additional record of the species has been published (Freyhof, 2014) but no details had been mentioned.

The aim of this study is to report additional populations of *P. firati* found in the meanwhile. These new records largely expand the distribution area of the species and we also discuss the highly isolated findings of *P. firati* in the relatively well-studied area.

2 | MATERIALS AND METHODS

Pseudophoxinus firati specimens were collected by electrofishing device and released. Few voucher individuals were killed by an overdose of anaesthesia, fixed in 5% formaldehyde and stored in 70% ethanol. Measurements were made with a dial caliper and recorded to the nearest 0.1 mm. All measurements were made point to point (never by projections). Methods for counts and measurements

follow Kottelat and Freyhof (2007). Scales along the lateral line are counted from the first one just behind the pectoral girdle to the last one at the end of the hypural complex; scales on the caudal-fin base are excluded. Standard length (SL) is measured from the tip of the snout to the end of the hypural complex. The length of the caudal peduncle is measured from behind the base of the last anal-fin ray to the end of the hypural complex, at mid-height of the caudal-fin base. The last two branched rays articulating on a single pterygiophore in the dorsal and anal fins are counted as "1½."

Abbreviations used: HL, lateral head length excluding the skin flap; SL, standard length. Collection codes: FSJF, Fischsammlung J. Freyhof, Berlin; IUSHM, Istanbul University, Science Faculty, Hydrobiology Museum, İstanbul; FCME, Fish Collection of Mahmut Elp; FCMG, Fish Collection of Muhammet Gaffaroğlu; FFR, Recep Tayyip Erdogan University Zoology Museum of the Faculty of Fisheries, Rize.

3 | RESULTS

3.1 | New records

Pseudophoxinus firati was identified based on the characters given by Bogutskaya et al. (2006). The identification of the population from the spring Karahalka was also confirmed by unpublished molecular data (COI) made available by Matthias Geiger (pers. com, 2018). *Pseudophoxinus firati* was found at totally eight sites (Figure 1):

1. A spring south of Yazyurdu (uppermost part of Tohma River) in the upper Euphrates drainage. Voucher materials: IUSHM 37600-229, 20, 33–57 mm SL; FSJF 2493, 34, 32–89 mm SL; Sivas prov.: spring south of Yazyurdu, uppermost part of Tohma River about 30 km west of Gürün, 38.7977333°N, 36.9179833°E (Figure 2).
2. The uppermost stream Tohma east of Yazyurdu in the upper Euphrates drainage. Voucher materials: FFR 03296, 6, 44–83 mm SL; Sivas prov.: uppermost part of stream Tohma at Yazyurdu, 38.806190°N, 36.933042°E.
3. The stream Süt Kaynağı in the uppermost drainage of the Murat River, a tributary of the Euphrates. Voucher materials: FCME 2008–03, 14, 48–105 mm SL; FSJF 4000, 5, 55–95 mm SL; Bitlis prov.: stream Süt Kaynağı 3 km north of Güroymak, 38.5973056°N, 42.0061722°E (Figures 2 & 3).
4. The upper stream Balıklıtohma is a tributary of the stream Tohma in the upper Euphrates drainage. Voucher materials: FFR 03307, 6, 43–62 mm SL; Sivas prov.: stream Balıklıtohma about 5 km northwestern of Kocakurt, 39.207449°N, 37.201188°E.
5. The stream Çağlayan (38.033776°N, 36.468079°E), a tributary of the Göksun River in the Ceyhan River drainge. This population has been reported by Bostancı (2006) as *Pseudophoxinus fahirae* (=

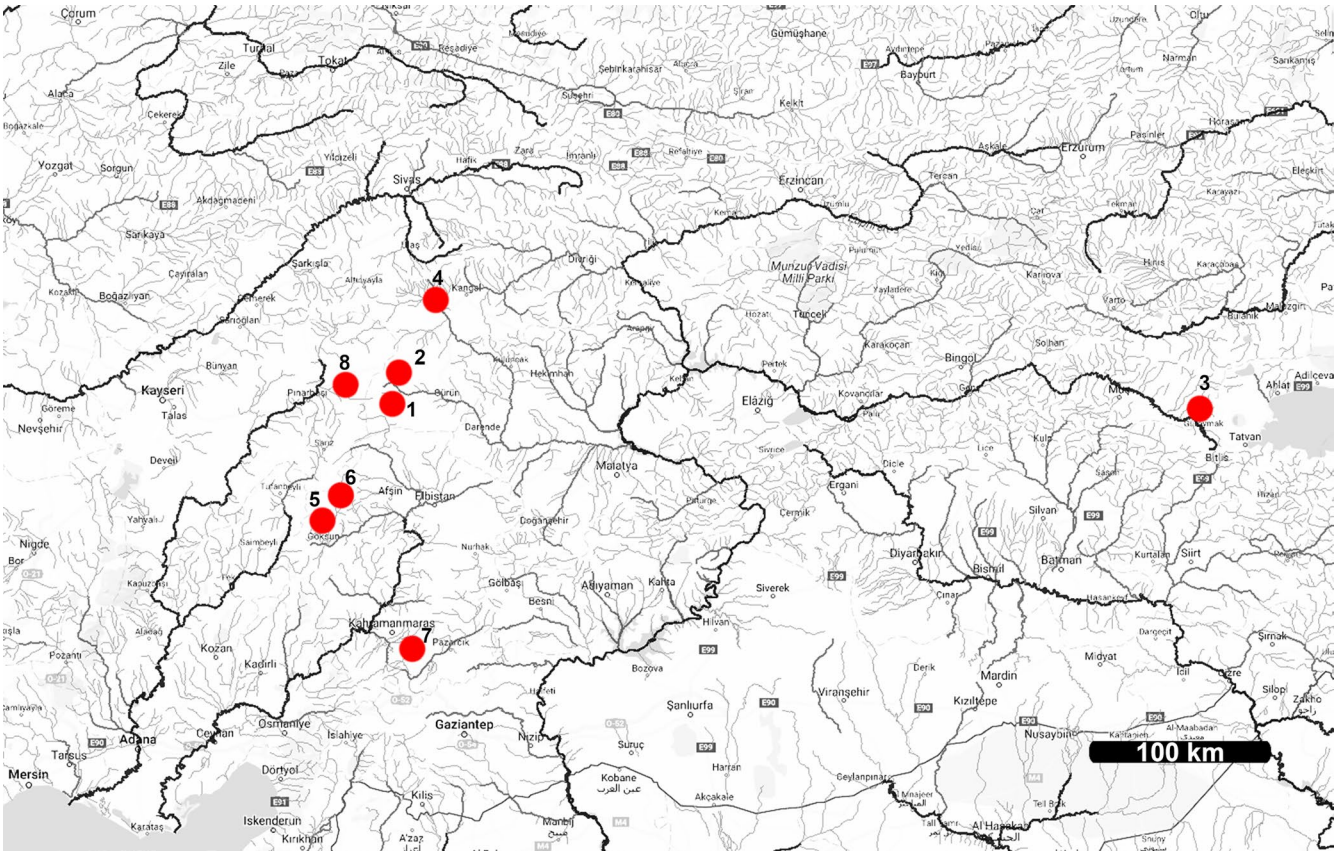

FIGURE 1 Records of *Pseudophoxinus firati* (1- spring Yazyurdu (type locality); 2- Tohma River; 3- stream Süt Kaynağı; 4- stream Balıklıtohma; 5- stream Çağlayan; 6- spring Göz; 7- stream Aksu; 8- spring Karahalka)

Chondrostoma fahirae) and the species has been confirmed from the Göksun River itself by CK in 2018, just 400 m below the stream Çağlayan. *C. fahirae* is endemic to the upper Dalaman River drainge and the Lake Burdur basin in western Anatolia (Freyhof & Özuluğ, 2009b). Voucher materials: FFR 03283, 26, 31–61 mm SL; Kahramanmaraş prov.: Göksun River at northwestern of Göksun, 38.032240°N, 36.472357°E

6. The spring Göz at Mehmetbey (Kahramanmaraş prov.: Spring Göz, 38.090450°N, 36.465992°E) in the upper the Ceyhan River drainge which is about 6 km north of the stream Çağlayan. No voucher material (Figure 3).
7. The stream Aksu, in the upper Ceyhan River drainage, a second place where *P. firati* has been recorded by Bostancı (2006) as *P. fahirae*. Voucher materials: FSJF 5052, 4, 56–74 mm SL; Kahramanmaraş prov.: Aksu River, 37.445261°N, 37.020691°E.
8. The spring Karahalka in the upper Seyhan River drainage. Voucher materials: FCMG 2015-08, 5, 59–95 mm SL; FFR 03308, 1, 59 mm SL; Kayseri prov.: spring Karahalka at Karahalka, Pınarbaşı, 38.885699°N, 36.819408°E (Figures 2 & 3).

See Table 1 and Table 2 for morphometric and meristic data of three populations examined in detail. Davut Turan (Rize) made materials from Bostancı's collection available (FSJF 4052) which fully agrees with other populations of *P. firati* examined for this study.

3.2 | Habitat description

We expect that more populations of this species to be discovered, especially in the area, where the watersheds of the Euphrates, Ceyhan and Seyhan are close to each other and the majority of the records had been made. Still, the finding of *P. firati* in the eastern Murat River is much isolated from the main distribution area and we expect undiscovered populations of *P. firati* waiting for discovery in small headwater streams of the Murat. Ichthyological studies in the Euphrates, Seyhan and Ceyhan drainages are generally made in large rivers. If more small springs and small streams would be studied, additional populations of *P. firati* are expected to be found. Indeed, all populations of *P. firati* were found in springs and small creeks and it is worthwhile to shortly describe the habitats of the species.

Spring south of Yazyurdu: This is a small spring lake. The shape of the lake is almost round and the shores are shallow and covered with reeds. The water of the spring is clear. There are several rainbow trout established in the lake (Figure 4).

Tohma River: The uppermost part of the Tohma River is situated just 1.5 km northeastern of the spring Yazyurdu. The Yazyurdu spring flows just one km south to the Tohma River from where *P. firati* was found. It is a small, shallow and clear stream with flow slowly. No pollution was observed.

FIGURE 2 *Pseudophoxinus firati*, from above: IUSHM 37600-229, 52 mm standard length (SL), spring Yazyurdu; FCMG 2015-08, 80 mm SL, spring Karahalka; FCME 2008-03, 98 mm SL, stream Süt Kaynağı

FIGURE 3 *Pseudophoxinus firati*, from above: male, 75 mm standard length (SL), female, 80 mm SL, spring Yazyurdu; about 40 mm SL, spring Göz; about 55 mm SL, spring Karahalka

TABLE 1 Morphometric data of *Pseudophoxinus firati*

	Yazyurdu (*n*: 8)		Süt Kaynağı (*n*: 8)		Karahalka (*n*: 3)	
Metric characteristics	**Mean ± *SD***	**Range**	**Mean ± *SD***	**Range**	**Mean ± *SD***	**Range**
SL (mm)	53.24 ± 2.69	50.25–58.21	91.65 ± 8.31	76.65–99.63	73.62 ± 5.56	69.78–80.00
In percent of SL						
Head length	27.4 ± 0.6	26.0–27.9	24.9 ± 1.0	23.2–26.0	23.9 ± 1.1	22.7–24.9
Body depth at dorsal-fin origin	26.0 ± 1.1	24.5–27.8	27.3 ± 1.3	25.0–28.6	25.0 ± 0.7	24.5–25.5
Body width at dorsal-fin origin	14.9 ± 1.1	13.5–16.5	17.9 ± 1.5	15.3–19.4	15.0 ± 1.0	14.4–16.1
Predorsal length	56.9 ± 1.3	55.0–58.7	53.5 ± 0.9	52.5–55.1	54.4 ± 1.4	53.6–56.1
Postdorsal length	35.9 ± 0.7	35.1–37.0	38.0 ± 1.2	36.0–39.3	37.7 ± 0.2	37.5–37.8
Prepelvic length	53.0 ± 1.3	51.2–54.8	51.2 ± 0.8	50.3–53.0	52.2 ± 0.9	51.5–53.2
Preanal length	73.0 ± 1.2	70.6–74.1	72.9 ± 1.0	71.2–74.4	72.4 ± 2.0	70.3–74.4
Distance between pectoral and pelvic fin origin	26.1 ± 1.2	24.1–27.8	27.3 ± 0.7	25.9–28.1	28.4 ± 1.2	27.1–29.4
Distance between pelvic and anal fin origin	20.7 ± 0.5	19.8–21.4	23.6 ± 0.7	22.6–24.8	21.8 ± 1.0	20.7–22.6
Depth of caudal peduncle	12.4 ± 0.5	11.6–13.0	12.0 ± 0.9	10.7–13.2	12.2 ± 0.3	11.9–12.4
Length of caudal peduncle	20.0 ± 0.9	18.2–20.9	20.6 ± 0.8	19.3–21.5	21.6 ± 0.6	21.0–22.3
Pectoral fin length	19.8 ± 0.8	18.6–20.9	16.9 ± 0.7	16.0–17.8	18.5 ± 0.6	17.8–18.9
Pelvic fin length	17.1 ± 0.5	16.4–17.8	16.2 ± 0.9	14.7–17.0	16.9 ± 0.6	16.5–17.6
In percent of head length						
Head depth at nape	75.6 ± 1.9	73–79	78.9 ± 2.8	74–82	80.0 ± 2.5	77–82
Head depth at eye	58.5 ± 1.1	57–60	60.8 ± 2.0	56–63	60.1 ± 1.2	59–61
Snout length	28.1 ± 0.6	27–29	28.2 ± 2.0	26–32	28.3 ± 1.0	28–29
Eye diameter	27.0 ± 1.1	25–29	23.4 ± 0.8	22–24	24.1 ± 1.8	22–26
Postorbital distance	48.8 ± 1.4	47–51	50.8 ± 1.2	49–53	52.3 ± 0.6	52–53
Maximum head width	55.7 ± 1.1	54–57	64.5 ± 2.0	62–67	55.6 ± 1.1	54–57
Interorbital width	30.2 ± 1.3	28–32	32.4 ± 1.3	31–34	33.8 ± 1.4	33–35

SL: standard length.

Stream Süt Kaynağı: *Pseudophoxinus firati* was collected close to the source of the stream. No pollution was observed. The stream is shallow, less than 50 cm deep. The current velocity of the stream was high and there are small waterfalls.

Stream Balıklıtohma: The species was found in habitats with very shallow water (10–50 cm water depth) and 50–150 cm stream width during the middle November when the water level is the lowest. The river bed was destroyed in the lower and middle parts of the stream and domestic waste was observed in the upper part.

Spring Göz: Spring Göz sources from Mahmutbey and crosses over the Mehmetbey. The spring creates a short stream (just three km) which flows to the Göksu River. The water was clean and deep, more than 150 cm in some parts (Figure 4).

Spring Karahalka: The water at the site was slow-flowing and clean and there had been dense stands of submerged vegetation. The water depth was about 25–30 cm. In 2018, the species was very rare and the place was much impacted by human activities (Figure 4).

Bostancı (2006) has reported the species (as *P. fahirae*) to occur together with *Salmo* species in cold, clean and fast-flowing streams with stony and gravel substrate.

4 | DISCUSSION

Not unexpected, there are some small differences in the morphometrics and meristics of our materials examined from the type locality of *P. firati* and the data given by Bogutskaya et al. (2006). The postdorsal length in our materials is 35%–37% SL (vs. 32–36 in Bogutskaya et al., 2006), the caudal peduncle length is18%–20% SL (vs. 17–18), the eye diameter is 25%–29% HL (vs. 23–24) and the interorbital width is 28%–32% HL (vs. 35–36). These differences are likely to be the result of differences in measuring fish, larger variations in morphometrics or seasonal variations. This results point to the difficulties of using small differences in morphemetric characters in taxonomy, especially if small numbers of fish are examined. The

TABLE 2 Frequency of occurrence of meristic characters in *Pseudophoxinus firati*

	Lateral series scales														
	n	43	46	47	48	49	50	Mode							
Spring south of Yazyurdu	6	–	1	1	3	1	–	48							
Spring Süt Kaynağı	6	–	1	2	1	1	1	47							
Spring Karahalka	5	1	1	2	1	–	–	47							
	Lateral line scales														
	n	13	21	25	29	27	31	35	36	38	41	43	44	45	Mode
Spring south of Yazyurdu	6	–	–	–	–	1	–	1	1	3					38
Spring Süt Kaynağı	6	1	1	2	1	–	1	–	–	–	–	–	–	–	25
Spring Karahalka	5	–	–	–	–	–	–	–	–	–	1	1	1	2	45
	Scale rows between dorsal fin origin and lateral line									Scale rows between anal fin origin and lateral line					
	n	8	9	10	Mode					*n*	4	5	Mode		
Spring south of Yazyurdu	6	–	3	3	9					6	2	4	5		
Spring Süt Kaynağı	5	1	4	–	9					**5**	–	5	5		
Spring Karahalka	5	2	3	–	9					5	–	5	5		
	Branched dorsal fin rays									Branched anal fin rays					
	n	7	8	Mode						*n*	6	7	Mode		
Spring south of Yazyurdu	6	6	–	7						6	6	–	6		
Spring Süt Kaynağı	7	6	1	7						7	6	1	6		
Spring Karahalka	5	5	–	7						5	5	–	6		
	Gill rakers														
	n	5	6	7	8	Mode									
Spring south of Yazyurdu	6	–	1	3	2	7									
Spring Süt Kaynağı	7	1	3	3	–	7									
Spring Karahalka	5	–	1	2	2	8									

fishes from Karahalka and Süt Kaynağı have a larger SL and a slightly smaller head than reported by Bogutskaya et al. (2006) (the largest individual 100 mm SL vs. 58 mm SL) (head length in Karahalka: 23%–25% SL; Sütkaynağı 23%–26% SL vs. 27%–89% SL). We measure head length without the skin flap, in contrast to Bogutskaya et al. (2006), who measured the head length with the skin flap.

Bogutskaya et al. (2006) described *P. firati* as having 6½ branched anal-fin rays, 15–44 scales in the lateral line, 45–51 scales in the lateral series, 6–7, rarely eight gill rakers and a wide lateral stripe in live individuals. We examined six specimens from the type locality of *P. firati* and 12 specimens from the spring Karahalka and the stream Sütkaynağı for meristic data. We found one individual with 7½ branched anal-fin rays while others have 6½ branched anal-fin rays. In our materials, *P. firati* has 13–45 lateral line scales, 43–50 scales in the lateral series, 6–8 gill rakers (Table 2).

4.1 | Pseudophoxinus firati, a threatened species?

Freyhof (2014) assessed *P. firati* Endangered following the IUCN Red List Criteria. These times, only two populations (Yazyurdu & Süt

FIGURE 4 Habitats of *Pseudophoxinus firati*, from above: spring Yazyurdu, spring Göz, spring Karahalka

Kaynağı) were known and the species was believed to decline. The enhanced information on the distribution of *P. firati* offers the opportunity for a re-assessment of the conservation status following the IUCN criteria. The extent of occurrence (EOO) of the species is estimated to be at least 37.100 km^2 and the species is now known from eight independent populations. All these eight populations inhabit very small areas and the area of occurrence (AOO) is believed to be smaller than 40 km^2. However, it might be more widespread in the Göksun River drainage, which is a tributary of the Ceyhan. More populations are expected to be found in the future and the species might qualify as Least Concerned, but still it qualifies as Vulnerable following the IUCN Red List Criteria (https://cmsdata.iucn.org/downloads/redlistguidelines.pdf). There are many threats in the area and the population in the stream Süt Kaynağı could not be found again during a research done in 2017 (C.K. & J.F.) and the spring Karahalka was in a very bad situation and only one individual could be found in 2018 (C.K.). Also, the uncontrolled rainbow trout farming and irrigation pump in Yazyurdu are the threats. Therefore, we expect the species to be slowly declining.

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