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Actual Distributions and Validity of *Petroleuciscus* spp., with the Range Extension and Length-Weight Relationship Data in Case of *Petroleuciscus ninae*

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Abstract

The genus *Petroleuciscus* was known from the Marmara, Aegean, and Black Sea drainages, as well as southeast Anatolia and Iran. However, studies conducted in recent years have suggested that the species described in southeast Anatolia and Iran belong to different genera. The results and recommendations of these studies were evaluated. On the other hand, in the scope of this study, the taxonomic status and length-weight relationship of several *Petroleuciscus ninae* populations in Western Anatolia were evaluated. The morphological comparisons revealed that Tahtalı Reservoir, Küçük Menderes and Sarıçay rivers, and Acıgöl Lake`s *Petroleuciscus* populations recorded as *Petroleuciscus smyrnaeus* in all previous studies belong to *P. ninae* which was known only from the type locality Akçay Stream. In addition, the length-weight relationship of *P. ninae* in the lakes Akgöl and Belevi, Lake Acıgöl, stream Akçay, Sarıçay River, an inflow of Yenişehir Reservoir and inflow of Tahtalı Reservoir were studied. The following research considers some first records and comprehensive information on the length-weight relationship of *P. ninae* in the Western Anatolia water resources. In study, the constant *b* changed from 3.101 to 3.389 (Akçay Stream) in all the sampling locations. It is expected that the results of this research might support the conservation of this species and contribute knowledge of its taxonomic status.

Introduction

The genus *Petroleuciscus* is distributed in the western and North Sea sea basins (Bogutskaya, 2002). The genus is represented by four valid species (Turan *et al*. 2018; Freyhof *et al*. 2018; Sheraliev and Peng, 2021). *P. borysthenicus* is the most widespread member of the genus that inhabits the Aegean, Marmara, Azov, and Black Sea basins (Ağdamar and Saç, 2022). The second species is endemic *P. aphipsi* which inhabits Kuban River drainages, Black Sea Basin (Kalaycı, 2022). *P. smyrnaeus* is known from between the rivers Bakırçay and Gediz. It was an endemic species to Turkish Aegean Sea drainages; however, it was also recorded on Lesbos Island in Greece (Stoumboudi *et al*., 2006). Endemic *P. ninae* was described in Akçay Stream (Büyük Menderes River drainage) by Turan *et al*. (2018). Analysis enlightens that *P. ninae* has diagnostic nucleotide substitutions based on the mtDNA barcode region (Kalaycı, 2022).

Besides these valid species mentioned above, five additional species of the genus were recognized from Iran, south-eastern Anatolia, and Tajikistan. The first one was *Pseudophoxinus persidis* Coad 1981 which was

moved to the genus *Leuciscus* (Coad, 1998), *Squalius* (Doadrio and Carmona, 2006), and *Petroleuciscus* (Bogutskaya, 2002), respectively. However molecular data demonstrate that the species belongs to the genus *Acanthobrama* (Perea *et al.*, 2010). The second one was *Petroleuciscus esfahani* Coad and Bogutskaya 2010, which was treated as a synonym of *Alburnus doriae* based on the examined material from the Zayandehrud River, Esfahan basin (the type locality), as well as from Namak and Tigris drainages (Mohammadian-Kalat *et al.*, 2017). The third one was *Leuciscus kurui* Bogutskaya 1995 which was described from the Yüksekova wetland in upper Great Zap, later moved to the genus *Petroleuciscus* (Bogutskaya, 2002). However, the molecular and morphological data show that the species belongs to the genus *Alburnus* (Freyhof *et al.*, 2018). The fourth one, *Leuciscus ulanus* Günther 1899, was described from Ula on the Zola Chai (Lake Urmia basin) (Jouladeh-Roudbar *et al.* 2020). The species was moved to the genus *Squalius* (Doadrio and Carmona, 2006) and then to the *Petroleuciscus* (Bogutskaya, 2002). Recently, Jouladeh-Roudbar *et al.* (2020) emphasized that the species may belong to the genus *Alburnus*. Despite further study needed to confirm this assertion, transferring the species to the genus *Alburnus* will make the distribution range of the genus *Petroleuciscus* meaningful. Because *P. ulanus* is the last species that represents the genus in the Middle East, and probably it does not belong to the genus such as the other species mentioned above. The last species was *P. squaliusculus* which was known from Syr Darya drainage in Kazakhstan, Kyrgyzstan, and Tajikistan (Kalaycı, 2022). It was emphasized that the molecular characters of this species had not been studied and their systematic positions still require clarification. Finally, a recent study revealed that the molecular data included *P. squaliusculus* in the genus *Leuciscus* (Sheraliev & Peng, 2021).

Petroleuciscus ninae has been recently described from a single locality (Stream Akçay, drainage of Büyük Menderes River) (Turan *et al.*, 2018). It was reported as *P. smyrnaeus* in previous studies (from Beydağ Reservoir, Yerli *et al*., 2016; from Sarıçay River, Top *et al.*, 2016) and sooner studies (from Küçük Menderes River, İlhan *et al.,* 2021; *Saç et al.*, 2021). However, considering the similarities between the geographical isolations, and river drainages in some other freshwater fish groups (e.g., *Capoeta*, *Chondrostoma*) in the region, it is expected that the *Petroleuciscus* populations living in the southern parts of the Boz Mountains running parallel to İzmir belong to the *P. ninae*.

Length-weight relationships (LWRs) are fundamental for a value that is used for any kind of fisheries research, such as determining age structures, presenting growth rates, and many other population parameters. The LWRs provide basic information for every kind of fisheries research (Sparre & Venema, 1998; Froese, 2006). These data can be applied in several execution research areas. One important point, these morphological data provide the opportunity to compare the histories of the population in an ecological area and give some clues for the morphological structures of populations which live in different areas (Moutopoulos & Stergiou, 2002). More than this, it is possible to make comparisons between the populations of the same species habiting in various habitats (Sangun *et al.*, 2007). There are many resent studies investigating the relationship between length and weight in Türkiye (e.g. Kurtul & Sarı 2020a, 2020b, İlhan *et al*. 2020a, Ofluoğlu *et al*. 2021, Çiçek *et al*. 2022a, 2022b; Sungur *et al*. 2022).

Türkiye is a superlative area for natural life, and most of the freshwater fish species are known as endemic within the freshwater fish fauna members of Türkiye (Freyhof *et al*., 2014; Çiçek *et al.*, 2018). The invasion stories of the fish species have been increasing day by day and this invasion has also had many effects on freshwater life distributed in Anatolian freshwaters (Freyhof *et al.*, 2014; Tarkan *et al.*, 2015). The best way to effective conservation decisions for native/endemic fishes from both invaders and pollution effects is to increase the number of scientific studies on the fishes. Hence, the research on the fish population characteristics of the species should be increased, and the similarities and differences between the population characteristics of other species should be investigated. In the literature related to *Petroleuciscus*, studies could be found about which are focusing mostly on their systematic features (Bogutskaya, 1995, 1996, 2002; Coad & Bogutskaya, 2010). To the best knowledge of the authors, only information is available on the LWRs of *P. ninae* (in all studies they are given as *P. smyrnaeus*) have been found in water resources in western Anatolia (Özcan, 2008; Tarkan *et al.*, 2009; Yerli *et al.*, 2016; Güçlü & Küçük, 2021).

To confirm the range extension of *P. ninae*, and clarify the distribution range of *P. smyrnaeus,* it was aimed to reveal the taxonomic positions of these populations by examining the diagnostic features of Turan *et al.* (2018) as the first hypothesis of the present study. Hence, it is believed that there is a deficiency in basic parameters that represent populations the second aim of the present research is to present some of the growth parameters for *P. ninae* from several streams and several lakes in Western Anatolia. With this aim, we recorded *P. ninae* length-weight relationship of the species for the first time from some Western Anatolia water resources in the meantime with its evaluated taxonomic status.

Materials and Methods

Study Area

To range extension of *Petroleuciscus* populations (4 lentic and 3 lotic habitats) in Western Anatolia were investigated. Samplings were carried out at 7 different locations Akgöl and Belevi lakes (Selçuk/İzmir; Küçük

Menderes River drainage), Acıgöl Lake (Basmakçı/Denizli-Afyonkarahisar; closed basin), Akçay Stream (Beğerli/Aydın; Büyük Menderes River drainage), Tahtalı Reservoir (Menderes/İzmir; on Gümüldür Stream: a coastal Aegean drainage), Sarıçay River (Milas/Muğla; a coastal Aegean drainage) and inflow of Yenişehir Reservoir (Yenişehir/İzmir; Küçük Menderes River drainage) during the years between 2011 and 2019. These lotic and lentic locations show typical Mediterranean climate characteristics with considerable seasonal variation (Peel *et al.*, 2007).

Sampling Procedure

In the sampling carried out in seasonal periods, "Samus 1000" model electro-shocker was used in lotic habitats, multi-mesh gillnets, and standard nets in accordance with the criteria of "TS-EN 14757 Water Quality-Taking fish samples with dense mesh nets with changing meshes" in lentic habitats during 2011–2019. After anaesthesia, fishes were fixed in 5% formaldehyde and stored in 70% ethanol or directly fixed in 99% ethanol. The collection materials have been used in this study, and as the samples belong to enclosed projects, there is no need for an ethical statement.

Laboratory Process and Analysis

Identification of the Species

It followed diagnostic characteristics provided by Turan *et al*. (2018). According to Turan *et al.* (2018), *P. ninae* was identified by using some morphological features which are compared in detail in the section 'Results'.

Morphological Analyses

Measurements were made with a dial calliper, recorded to 0.1 mm, from a precise point-to-point approach, never by projections. Methods for measurements followed Kottelat and Freyhof (2007) and Turan *et al*. (2018). Standard length is measured from the tip of the snout to the posterior extremity of the hypural complex. The length of the caudal peduncle is measured from behind the base of the last anal-fin ray to the posterior extremity of the hypural complex, at mid-height of the caudal-fin base.

Morphological data of *P. smyrnaeus* and type specimens of *P. ninae* were taken from Turan *et al*. (2018).

Material Examined

All materials from Türkiye: See the type specimens and materials examined listed in Turan *et al.* (2018). The materials examined other than Turan *et al.* (2018) are listed below:

Petroleuciscus ninae: FFR 3845, 24 individuals, range is between 54-95 mm SL; Muğla Prov.: stream Sarıçay, 5 km west of Milas, 23 April 2011, coordinates are 37.3287N, 27.7127E. —FFR 3861, 8, 28-50 mm SL; İzmir Prov.: inflow of Tahtalı Reservoir at Cumaovasi, 14 July 2018, 38.1990N, 27.1705E. —FFR 3860, 11, 56-78 mm SL; İzmir Prov.: inflow of Yenişehir Reservoir 2 km east Yenişehir, 29 March 2019, 38.0760N, 27.9274E. —FFR 3859, 1, 34 mm SL; İzmir Prov.: stream Balaban 2 km west of Küner, Tahtalı Reservoir drainage, 15 November 2018, 38.2139N, 27.1015E. —FFR 3854, 23, 37-78 mm SL; Denizli Prov.: spring Gemiş, Lake Acı basin, 22 March 2014, 37.7730, 29.8450E. —FFR 3837, 54, 35-65 mm SL; Aydın Prov.: Akçay stream, 3 km west of Beğerli Büyük Menderes River drainage, 25 August 2014, 37.7594N, 28.3353E. —Not preserved 2, 50-60 mm SL; Aydın Prov.: stream Akçay at 1 km east of Alamut, 22 March 2014, 37.8098N, 28.3152E. —FFR 3853, 2, 53-72 mm SL; Denizli Prov.: Yenicekent DSİ pump station, Büyük Menderes River, 11 km east of Buldan, between Yenicekent and Mahmutlu, 19 May 2011, 38.0373N, 28.9636E. —EFSM/PISI 2018-243, 70, 30-81 mm SL; Türkiye: İzmir Prov.: Lake Belevi at Belevi, 38.0168N, 27.4653E. —ESFM/PISI 2018-042, 56, 33-82 mm SL; İzmir Prov.: Lake Kocagöl at 3 km west of Selçuk, 14 June 2018, 37.9427N, 27.3299E. —ESFM/PISI 2018-058, 8, 41-67 mm SL; İzmir Prov.: Lake Gebekirse at Zeytinköy, 15 June 2018, 37.9880N, 27.3015E. —ESFM/PISI 2018-195, 42, 37-86 mm SL; ESFM/PISI 2018-191, 50, 46-90 mm SL; ESFM/PISI 2018-046, 246, 37-106 mm SL; İzmir Prov.: Lake Akgöl (Çatal) at Barutçu, 15 June 2018, 37.9937N, 27.3230E.

Petroleuciscus smyrnaeus: FFR 3857, 7, 47-88 mm SL; İzmir Prov.: stream Koca, 4 km northeast of Aliağa, 15 November 2018, 38.8102N, 27.0301E. —FFR 3858, 30, 40-78 mm SL; İzmir Prov.: stream Karadere, drainage of Bakırçay, 4 km north of Kınık, 16 July 2018, 39.1299N, 27.3723E. (In addition, see material examined by İlhan *et al*. (2020b) for *P. smyrnaeus*).

For the LWRs Part of the study

The total length (TL) of each *P. ninae* specimen was measured with a vernier calliper to the nearest 0.05 mm, and weighed with a digital scale to the nearest 0.01 g. As the species does not represent sexual dimorphism, male and female individuals were evaluated altogether. Regression analysis was used to determine the relationship between the total length and weight of the *P. ninae* individuals. For the regression, the equation $W=aL^b$ was used (Ricker, 1973). In the present formula, *W* shows the total weight (g), *L* shows the total length (cm), and *a* (intercept) and *b* (slope) are known as regression constants (Zar, 1999). Before determination of the LWRs equality, the correlation coefficient (r^2) was calculated (Zar, 1999) and a correlation coefficient significance control test was applied. The student t-test was applied to data to determine the growth types of the individuals (Pajuelo & Lorenzo, 1998).

Abbreviations Used

Collection codes: 1. FFR: Recep Tayyip Erdogan University Zoology Collection of the Faculty of Fisheries (Recep Tayyip Erdogan University, Rize) 2. ESFM: Collection of Ege University Faculty of Fisheries (Ege University, İzmir). SL: Standard Length.

Results

Taxonomic Part of the Study

Four valid *Petroleuciscus* species remained, and their distribution is shown in Figure 1. *P. borysthenicus* is known as rare in Anatolian Black Sea drainages, although it is widespread in the rivers around the Black Sea (missing in the Don River) (Kottelat & Freyhof, 2007). The species was not recorded by faunistic studies conducted in the Black Sea drainages in western and mid-western (İlhan & Balık, 2008; Yoğurtçuoğlu *et al.*, 2020) and eastern (Turan 2003; Bayçelebi *et al*., 2015, 2017) Anatolia, except two recent records from Samsun (Miliç River at Terme [Saygun *et al.*, 2017], and Simenlik-Akgöl Lagoon [Özpiçak *et al.*, 2022]). *P. borysthenicus* was recorded in Sakarya drainage by Van Neer *et al.* (2008). However, this species has not been recorded again in the area.

Turan *et al.* (2018) described *P. ninae* from a single locality, stream Akçay (Büyük Menderes River drainage). The specimens were obtained during the surveys in this study from the Sarıçay and Küçük Menderes rivers, Tahtalı Reservoir, and Acıgöl Lake (Figure 2) superficially like type specimens of the *P. ninae* (Figures 3-5).

According to Turan *et al.* (2018) "*P. ninae* is distinguished from *P. smyrnaeus* by having a black stripe on flank extending from head to base of the caudal fin, stripe wider than eye diameter (vs. equal to or smaller than eye diameter) (stripe absent in life), numerous black pigments on anal-fin rays in life (vs. pigments absent or very few orange pigments in life); a deeper body (body depth at dorsal-fin origin 27–30% SL vs. 24–27) and a wider head (head width at posterior eye margin 16–19% SL vs. 14–16). Also, *P. ninae* has an eye diameter that is smaller than snout length (vs. eye diameter approximately equal to snout length)."

We have examined and compared diagnostic characteristics provided by Turan *et al.* (2018) for *P. ninae* against Küçük Menderes and Sarıçay rivers, and Tahtalı Reservoir and Acıgöl Lake`s *Petroleuciscus* populations to test if our samples belong to *P. ninae* or *P. smyrnaeus*. All of our individuals match with *P. ninae* against the "presence of a black stripe wider than eye diameter on flank extending from head to base of caudal fin", "having a smaller eye diameter than snout length" and "numerous black pigments on anal-fin rays in life (Figures. 3–5)". Besides, "body depth at dorsal-fin origin" of our new populations completely overlapped with *P. ninae* and was measured always larger than 27% mm SL (27–31% SL in Küçük Menderes; 27–31% SL in Tahtalı Reservoir; 27–32% SL in Sarıçay River; 27–30% SL in Lake Acıgöl) (Table 1). However, according to our data, the head width at the posterior eye margin is not separate *P. ninae* and *P. smyrnaeus.* Our measurements were highly variable (14–15% SL in Küçük Menderes; 14–15% SL in Tahtalı Reservoir; 13–16% SL in Sarıçay River; 15–19% SL in Lake Acıgöl). Even our additional measurements from the type locality of *P. ninae* demonstrated that the lower value of "head width at posterior eye" is 15% SL, not 16 as mentioned in its original diagnosis. Therefore, we concluded that "head width at posterior eye margin" is not a diagnostic characteristic as provided by Turan *et al.* (2018) to distinguish it from *P. smyrnaeus*.

Based on the data mentioned above, we accepted these new populations as *P. ninae*. These new populations of the species (Teleostesi, Leuciscidae)

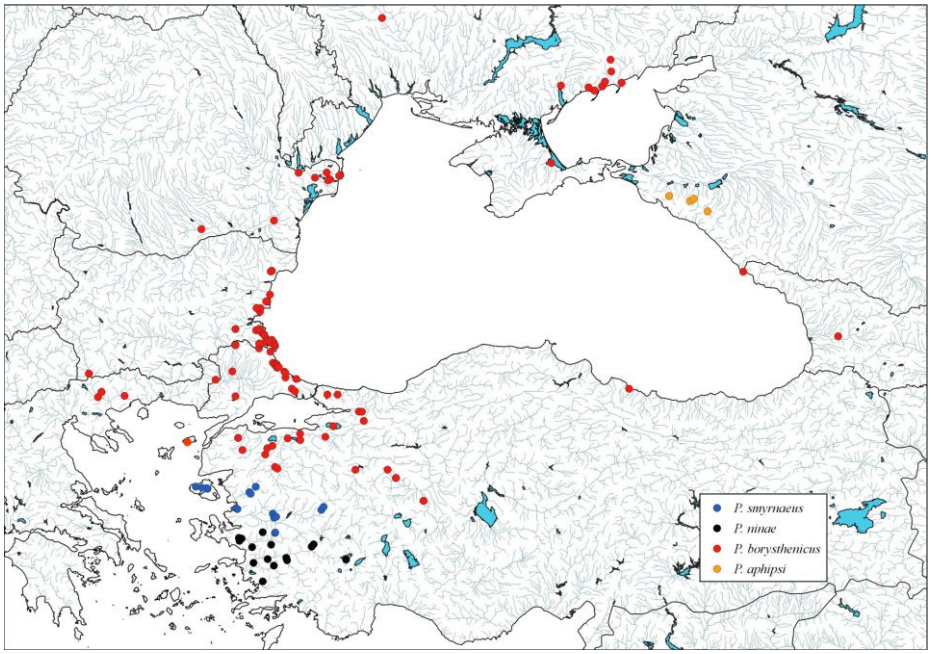

Figure 1. Distribution of *Petroleuciscus* species.

reveal the scarce biogeographic knowledge of *P. ninae* in Western Anatolia. Inherently, the presence of *Petroleuciscus* in Sarıçay River and Küçük Menderes rivers mentioned by previous authors as *P. smyrnaeus* (Top *et al.*, 2016; Yerli *et al.*, 2016; İlhan *et al.*, 2021; Saç *et al.*, 2021) also belongs to *P. ninae*. *Petroleuciscus smyrnaeus* was described from İzmir (Smyrna) by Boulenger (1896), and it is already known from between the rivers Bakırçay and Gediz rivers (Figure 1).

LWRs Analysis Part of the Study

Due to unespied sexual dimorphism in *P. ninae* the LWRs parameters were calculated for all specimens. A total of 418 specimens were measured for determining their length and weight distribution, and their LWRs from Western Anatolia water resources. The specimens` length and weight data and their standard error were given for the study areas (Table 2). *Petroleuciscus ninae*`s sample size (n) estimated parameters of the (*b* with standard errors), coefficient of regressions, *r* with standard error, t-test results, and growth types are given in Table 3.

The maximum length and weight were found for the species from Akgöl Lake (L_{max}=13.00 cm, W_{max}=35.52 g), and the minimum length was found for the species from Belevi Lake (L_{min}=3.40 cm, W_{max}=3,97 g).

According to the current study, the correlation coefficient results in all study areas were highly correlated (in all the sampling localities *r* changed between 0.911-0.996). The constant *b* varied *between* 3.101-3.389 in all the sampling locations, and the highest *b* constant was found in Akçay Stream. After finding the results for LWRs in the present study, the t-test was applied to between Akçay Stream (the sampling area which shows the highest b value) and Kemer Reservoir (Özcan, 2008) (a previous study at the same drainage) to understand is there any differences or not. With this test, it was controlled the *b* values differences between the Kemer Reservoir and Akçay Stream (t_{cal} = 3.533 > $t_{0.05,\ n\ =\ 65}$ = 2.00).

The growth type of the *P. ninae* specimens was found as isometric growth in many sampling areas except the three localities, Akçay Stream, Akgöl, and Acıgöl lakes. In these sampling areas, positive allometric growth was found for the species (Table 3).

Discussion

The zoogeographic distribution of *Petroleuciscus ninae* and *P. smyrnaeus* in the Turkish Aegean Sea drainages, with *P. smyrnaeus* inhabiting between the rivers Bakırçay and Gediz (around İzmir), and *P. ninae* inhabiting Tahtalı Reservoir basin to the north and Sarıçay River to the south, nested within the range of the *Capoeta* and *Chondrostoma* species in the same region. *Capoeta aydinensis* and *Chondrostoma turnai* distributed in Büyük Menderes River and southern

Figure 2. Habitat of *Petroleuciscus ninae*: a, Stream Akçay; b, Yenicekent DSİ pom station, Büyük Menderes River; c, inflow of Yenişehir Pond, Küçük Menderes Drainage; d, Stream Balaban, Tahtalı Reservoir Drainage; e, Spring Gemiş, Lake Acı Basin; f, Sarıçay River.

Figure 3. *Petroleuciscus ninae*, from the top: FFR 3845, 82 mm SL; 78 mm SL; Türkiye: stream Sarıçay; FFR 3854, 74 mm SL; 71 mm SL; Türkiye: Lake Acıgöl.

Figure 4. *Petroleuciscus ninae*, from the top: FFR 3860, 71 mm SL; 66 mm SL; Türkiye: inflow of Yenişehir pond, Küçük Menderes drainage; FFR 3861, 50 mm SL; 40 mm SL; Türkiye: a northeastern drainage of Tahtalı Reservoir.

Figure 5. *Petroleuciscus ninae*, from the top: FFR 3860, 71 mm SL; 64 mm SL; inflow of Yenişehir Pond, Küçük Menderes Drainage; FFR 3861, 50 mm SL; a north-eastern drainage of Tahtalı Reservoir; FFR 3853, 72 mm SL; Yenicekent DSİ pomps, Büyük Menderes River; not preserved, about 60 mm SL, Stream Akçay Büyük Menderes drainage.

Table 1. Morphometry of four new populations of *Petroleuciscus ninae*.

Drainage	Küçük Menderes		Lake Acı		Stream Sarıçay		Tahtalı Dam	
Collection codes	FFR 3860		FFR 3854		FFR 3845		FFR 3861	
Number of measured individuals	n=11		n=20		n=14		n=5	
Standard length (mm)	Range (mean)	SD	Range (mean)	SD	Range (mean)	SD	Range (mean)	SD
In percent of standard length	76–78 (65.1)	6.4	51–77 (63.4)	6.5	69–95 (78.7)	6.3	32–50 (38.7)	7.2
Head length	26.4–29.0 (28.0)	0.8	26.8–30.7 (28.2)	1.0	26.5–28.8 (27.6)	0.6	28.0–29.7 (29.1)	0.7
Body depth at dorsal-fin origin	27.1–30.8 (28.7)	1.4	26.3–30.0 (28.1)	1.0	27.0–31.9 (29.2)	1.5	27.2–31.1 (29.2)	1.6
Caudal peduncle depth	11.2–12.6 (12.0)	0.5	11.9–13.4 (12.6)	0.4	11.6–12.9 (12.3)	0.4	11.7–13.8 (13.3)	0.4
Head width at anterior eye margin	10.2–11.4 (10.7)	0.4	10.5–12.8 (11.6)	0.6	10.1–12.0 (11.0)	0.6	9.8–10.8 (10.5)	0.4
Head width at posterior eye margin	13.4–15.3 (14.2)	0.5	14.6–18.7 (16.4)	1.0	13.4–15.7 (14.4)	0.7	13.7–15.2 (14.5)	0.6
Head width at nape	15.2–16.7 (15.8)	0.5	15.7–18.2 (16.9)	0.8	15.7–17.6 (16.6)	0.7	15.1–16.9 (16.2)	0.7
Head depth at interorbital region	14.9–15.9 (15.5)	0.3	14.0–17.4 (15.4)	0.9	14.1–15.7 (14.9)	0.5	14.2–16.3 (15.3)	0.8
Head depth at nape	19.0–20.7 (19.9)	0.5	19.0–23.1 (20.9)	1.1	19.5–21.6 (20.7)	0.6	20.2–22.8 (21.2)	1.0
Eye diameter	7.5–8.8 (7.9)	0.4	6.7–9.4 (7.7)	0.8	6.5–8.1 (7.4)	0.4	7.3–9.0 (8.4)	0.6
Snout length	7.1–8.4 (7.7)	0.4	7.5–9.7 (8.7)	0.7	7.0–8.4 (7.8)	0.4	7.7–8.3 (7.9)	0.2
Interorbital width	9.0–10.7 (10.2)	0.5	10.2–13.2 (11.2)	0.8	9.1–11.3 (10.6)	0.6	8.4–10.0 (9.2)	0.7
Snout width at nostrils	9.6–11.0 (10.4)	0.5	9.6–12.4 (10.9)	0.8	9.5–10.8 (10.3)	0.4	8.9–10.4 (9.7)	0.6
Snout depth at nostrils	10.5–11.6 (11.0)	0.3	9.4–12.5 (10.8)	1.0	10.0–13.3 (11.0)	0.8	10.1–11.5 (10.6)	0.6
Width of mouth gape	6.3-7.3 (6.9)	0.3	7.1-11.4 (8.7)	1.2	6.3-8.7 (7.0)	0.6	6.5-7.4 (6.8)	0.4
Length of mouth gape	6.2-8.1 (7.2)	0.5	7.9-11.1 (9.2)	0.9	6.5-8.0 (7.1)	0.5	7.0-8.0 (7.6)	0.4
Predorsal length	56.0–59.0 (56.9)	0.9	57.2–60.5 (59.1)	1.0	57.2–60.3 (58.5)	1.0	55.8–57.9 (56.9)	0.8
Prepelvic length	50.6–53.3 (51.9)	0.9	50.4–55.6 (52.6)	1.3	50.0–52.8 (51.6)	0.8	50.4–53.2 (52.1)	1.2
Preanal length	73.1–75.2 (74.0)	0.6	72.6–77.7 (74.7)	1.3	72.9–75.6 (74.4)	0.8	69.5–74.3 (71.6)	1.9
Pectoral-fin origin to anal-fin origin	46.7–50.0 (48.7)	1.0	47.1–52.6 (49.3)	1.5	46.6–50.4 (48.8)	1.1	43.1–47.0 (45.3)	1.5
Pectoral-fin origin to pelvic-fin origin	25.2–27.7 (26.3)	0.8	24.2–28.1 (26.3)	1.2	24.2–27.1 (26.1)	1.0	22.6–25.9 (24.1)	1.2
Pelvic-fin origin to anal-fin origin	21.5–24.1 (22.5)	0.9	20.8–25.5 (23.2)	1.2	21.5–24.6 (23.4)	1.0	19.5–23.1 (21.4)	1.5
Caudal-peduncle length	16.1–18.4 (17.4)	0.8	14.3–18.5 (16.5)	1.1	16.2–18.7 (17.3)	0.7	16.7–18.7 (17.8)	0.9
Dorsal-fin depth	19.9–23.3 (21.4)	0.9	21.2–24.0 (22.8)	1.0	18.1–24.0 (20.1)	1.6	19.5–21.4 (20.6)	0.7
Pectoral-fin length	19.1–21.5 (20.4)	0.8	18.8–23.8 (21.4)	1.3	17.3–21.6 (19.5)	1.3	17.2–18.8 (18.0)	0.6
Pelvic-fin length	15.6–17.9 (16.7)	0.8	15.6–19.3 (17.9)	1.0	15.3–19.9 (17.2)	1.4	14.5–17.2 (16.2)	1.0
Anal-fin length	14.3–16.9 (15.4)	0.8	14.8–18.2 (16.5)	1.1	13.3–16.8 (15.0)	1.1	15.6–16.6 (16.1)	0.5
Length of upper caudal-fin lobe	25.6–27.6 (26.8)	0.6	24.1–27.8 (25.4)	1.1	24.2–26.9 (25.2)	0.8	23.8–25.8 (24.7)	0.8
Length of middle caudal-fin ray	13.7–16.5 (15.1)	0.9	14.5–17.5 (16.0)	1.0	11.1–15.6 (13.9)	1.0	14.0–16.1 (14.9)	0.8

drainages while *C. bergamae* and *C. holmwoodi* distributed in Gediz River and northern drainages (Turan *et al.*, 2017; Güçlü *et al.*, 2018). Apparently, the Boz Mountains lying vertically to the Aegean Sea in the east of İzmir serve an important role in the isolation mechanism.

According to the reports (Arslan *et al.*, 2016), among the rivers in the western part of Türkiye, Küçük Menderes River needs more attention in terms of anthropogenic pressure, especially water abstraction. The findings on both physicochemical variables and macrozoobenthic organisms demonstrated that the water quality in the Küçük Menderes River is highly polluted. It is observed that the richness of biodiversity decreases dramatically with the increasing pollution, especially in the lower parts of the river (İlhan *et al*., 2021). Moreover, there are more than ten thousand wells in the Küçük Menderes basin that have been drilled for various purposes by official and informal institutions and organizations. Apart from this excessive use of groundwater, there are 6 dams in the basin (Şahin *et al.*, 2018). Fortunately, the situation of some drainage and reservoirs in the upper part of the river has not yet been highly polluted (Figure 2c).

According to Froese (2006), the regression constant *b* should normally be between 2.5 and 3.5. In the present study, the *b* constant was within the expected range. Further, the correlation coefficients were found different, but meantime higher than b>3 in all sampling localities. The highest b value was found from Akçay Stream as *b*=3.389. It is accepted information that the *b* constant value might be different because of various factors. The geographical location, environmental factors, fish health, reproduction, sex, age, and stomach ingredients are the most effective features (Bagenal & Tesch, 1978). If the sampling procedure was standardized, differences between the LWR values might be related to habitat differences (Tesch, 1971). Thus, the differences in the *b* constant may have been related to one or more factors mentioned above. According to personal observations, Akçay Stream was comparatively an unpolluted area, and it saves its natural habitat structure. This may be the main reason for having the highest *b* value of the study.

Up to date, the length-length relationship and LWRs of *Petroleuciscus* population from Beydağ Reservoirs (from Küçük Menderes drainage) was found as *b*=2.760, for *a*=0.0258 by Yerli *et al.* (2016); as *b*=2.802, for *a*=0.0191 from Kemer Reservoir on Akçay Stream by Özcan (2008); as *b*=3.284, for *a*=0.0091 from Marmara Lake on Gediz River Basin by İlhan and Sarı (2015), and as *b*=3.159, for *a*=0.0011 from Gediz River Basin by Güçlü and Küçük (2021) as *P. smyrnaeus*. The number of previous studies conducted for the species` LWRs parameters are changed as for *b*=2.760-3.284, for *a*=0.0011-0.0258.

To understand if there are any differences or not between this study's results and the previous studies, the t-test was applied to the data. With this test, it was controlled the *b* values differences between the Kemer Reservoir (Özcan, 2008) and Akçay Stream (this study). According to the t-test results (as $t_{cal}=3.533>t_{table}$; $p<0.05$), meaningful differences were found in growth in terms of the different sampling areas. The differences that are observed with *b* values obtained in the other research might be due to factors such as water quality

Table 2. The length and weight distribution, mean length (cm) and weight (g) and their standard errors of *P. ninae* in some Western Anatolia water resources (ESFM/PISI 2018-046; EFSM/PISI 2018-243; FFR 3837; FFR 3854; FFR 3845; FFR 3860; FFR 3861, respectively).

River Basin	Locality	n	L_{min}	L_{max}	L_{mean}±SE	W_{min}	W_{max}	W_{mean}±SE
Küçük Menderes	Akgöl Lake	246	4.50	13.00	7.53±0.069	1.02	35.52	6.14±0.227
Küçük Menderes	Belevi Lake	70	4.00	10.00	5.37±0.119	0.86	20.68	2.60±0.296
Büyük Menderes	Akçay Stream	49	4.40	9.40	5.24±0.104	1.01	16.01	2.32±0.294
Closed	Acıgöl Lake	23	4.80	9.90	7.81±0.218	1.40	15.51	7.88±0.648
Coastal (Aegean)	Sarıçay River	11	6.60	11.60	8.98±0.255	4.73	25.86	12.04±1.100
Küçük Menderes	Yenişehir Res (IF)	11	7.10	9.60	8.17±0.226	5.21	14.53	8.56±0.789
Coastal (Aegean)	Tahtalı Res	8	3.40	6.20	4.33±0.311	0.61	3.97	1.45±0.371

Res: Reservoir, IF: Inflow of water, SE: Standard error.

Table 3. LWRs parameters of *P. ninae* in some Western Anatolia water resources. (ESFM/PISI 2018-046; EFSM/PISI 2018-243; FFR 3837; FFR 3854; FFR 3845; FFR 3860; FFR 3861, respectively).

Locality	n	a	b	SE_b	r	SE_r	t_{test}	GT
Akgöl Lake	246	0.009	3.181	0.046	0.976	0.043	$t_{cal} = 3.935 > t_{0.05,\ n = 245} = 1.65$	A(+)
Belevi Lake	70	0.010	3.191	0.120	0.955	0.076	$t_{cal} = 1.592 < t_{0.05,\ n = 69} = 1.68$	I
Akçay Stream	49	0.007	3.389	0.098	0.981	0.034	$t_{cal} = 3.969 > t_{0.05,\ n = 48} = 1.68$	A(+)
Acıgöl Lake	23	0.008	3.316	0.097	0.911	0.029	$t_{cal} = 3.258 > t_{0.05,\ n = 22} = 1.72$	A(+)
Sarıçay Stream	11	0.011	3.142	0.123	0.983	0.038	$t_{cal} = 1.154 < t_{0.05,\ n = 10} = 1.71$	I
Yenişehir Res (IF)	11	0.010	3.190	0.238	0.976	0.031	$t_{cal} = 0.798 < t_{0.05,\ n = 10} = 1.72$	I
Tahtalı Res	8	0.013	3.101	0.120	0.996	0.028	$t_{cal} = 0.842 < t_{0.05,\ n = 7} = 1.90$	I

GT: Growth type, Res: Reservoir, IF: Inflow of water, SE: Standard error, A(+): Positive allometric growth, I: Isometric growth.

and nutrient availability (Sparre *et al.*, 1989). This indication is highly probable the results that reservoirs are less efficient than natural aquatic resources. More than this, the number of samples, sampling period, and sampling methods for the species might be the reasons for the differences. In the meaning time, according to previous studies the minimum *b* constants were found for Beydağ Reservoir, with Kemer Reservoir. This situation supports the hypothesis natural habitats create more sufficient areas for the fish fauna.

Isometric growth was determined for all specimens at the four sampling localities. As the isometric growth has been observed in the related sampling areas (Belevi Lake, Sarıçay Stream, Yenişehir, and Tahtalı reservoirs) it might be considered that the fish have serious competition with other species. Also, it was observed that especially the fish populations of the Belevi Lake are under high pressure because of the anthropogenic effects. More than this, Yenişehir and Kemer localities are reservoirs, and because of this reason highly probably their habitat characters are different from the natural lakes.

The Akgöl, Acıgöl lakes, and Akçay Stream populations` which show positive allometric growth, are natural habitats and they are rich areas in terms of food. One important point, according to the current knowledge, it is accepted that the genus *Petroleuciscus* just lives in the areas which are connected to the sea directly. So, it is estimated that Acıgöl Lake`s *P. ninae* populations do not belong to the lake's natural fauna, and it is an introduced population for the lake. Because it is an introduced species for the lake, it would be better to follow the population of it with regular studies.

Conclusion

Within the actual study, *Petroleuciscus* specimens were investigated in large frequency in the water resources of the western part of Türkiye, and it has had a wider range extension. The current study showed that, due to taxonomic investigations populations of the genus *Petroleuciscus*, *P. ninae* were recorded for the Küçük Menderes drainages (Akgöl, and Belevi lakes, and Yenişehir Reservoir), Acıgöl Lake, Tahtalı Reservoir, and Sarıçay River for the first time. More than this, it is the first wide research that provides the basic information on the LWRs of *P. ninae* inhabiting various water resources of the western part of Anatolia. The present study considered basic information on the LWRs for an established population which would be useful for fish biologists in the region. The genus *Petroleuciscus* is a very important part of Türkiye`s ichthyofauna with their status. They should be monitoring in freshwater resources regularly as the genus is under threat because of different factors such as pollution, habitat loss, and rising invasive species in the freshwaters. As a further study, the ecological requirements should be investigated for the genus.

Ethical Statement

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Author Contribution

Cüneyt Kaya: Conceptualization, writing – review & editing, formal analysis, identification of taxonomic status, writing – original draft, visualization. Irmak Kurtul: Conceptualization, Formal analysis, writing, – original draft, visualization. Esra Bayçelebi: Identification of taxonomic status, writing – original draft. Ali İlhan: Formal analysis, writing – original draft. Hasan M. Sarı: Writing – review & editing.

Conflict of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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