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

Cüneyt Kaya¹,* , Irmak Kurtul²,³ , Esra Bayçelebi¹, Ali İlhan² , Hasan Musa Sarı²

¹Recep Tayyip Erdogan University, Faculty of Fisheries, Department of Inland Waters Biology, Rize, Türkiye  
²Ege University, Faculty of Fisheries, Marine and Inland Waters Sciences and Technology Department Izmir, Türkiye  
³Bournemouth University, Department of Life and Environmental Sciences, Poole/ Bournemouth, United Kingdom

**How to Cite**

**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 Kaban 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 kurni* Bogutskaya 1995 which was described from the Yükselkova 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 ul anus* 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* (Seraliev & 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. smyrnæus* in previous studies (from Beydağ Reservoir, Yerli et al., 2016; from Sarıçay River, Top et al., 2016) and sooner studies (from Küçük Menderes River, Ilhan 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 almost every 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 recent studies investigating the relationship between length and weight in Türkiye (e.g. Kurtul & San 2020a, 2020b, Ilhan et al. 2020a, Ofuuoğlu 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. smyrnæus*) have been found in water resources in western Anatolia (Özcan, 2008; Tarkan et al., 2009; Yerli et al., 2016; Guclü & Kucuk, 2021).

To confirm the range extension of *P. ninae*, and clarify the distribution range of *P. smyrnæus*, 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 Akgol and Belevi lakes (Selçuk/Izmir; Küçük...
Menderes River drainage), Aşağı (Basmakç/Denizli-Ayvatlar); closed basin), Akçay Stream (Büşerli/Aydın; Büyük Menderes River drainage), Tahtalı Reservoir (Menderes/Izmir; on Gümüldür Stream: a coastal Aegean drainage, Sarıçay River (Mzla/Muğla; a coastal Aegean drainage) and inflow of Yenisehir Reservoir (Yenisehir/Izmir; Kçük 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 lentic 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 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 Kink, 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 \( W=at^b \) 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, Izmir). 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 (Teleostei, Leuciscidae)
reveal the scarce biogeographic knowledge of *P. ninae* in Western Anatolia. Inherently, the presence of *Petroleuciscus* in Sariçay River and Küçük Menderes rivers mentioned by previous authors as *P. smyrnaeus* (Top et al., 2016; Yerli et al., 2016; Ilhan 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<sub>max</sub>=13.00 cm, W<sub>max</sub>=35.52 g), and the minimum length was found for the species from Belevi Lake (L<sub>min</sub>=3.40 cm, W<sub>min</sub>=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<sub>cal</sub> = 3.533 > t<sub>0.05</sub>, 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 Açıgöl 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 Sariçay 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

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*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, Sariçay 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 pumps, Büyük Menderes River; not preserved, about 60 mm SL, Stream Akçay Büyük Menderes drainage.

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

<table>
<thead>
<tr>
<th>Drainage</th>
<th>Küçük Menderes</th>
<th>Lake Acı</th>
<th>Stream Sançay</th>
<th>Tahtalı Dam</th>
</tr>
</thead>
<tbody>
<tr>
<td>Collection codes</td>
<td>FFR 3860</td>
<td>FFR 3854</td>
<td>FFR 3845</td>
<td>FFR 3861</td>
</tr>
<tr>
<td>Number of measured individuals</td>
<td>n=11</td>
<td>n=20</td>
<td>n=14</td>
<td>n=5</td>
</tr>
<tr>
<td>Standard length (mm)</td>
<td>76–78 (65.1)</td>
<td>51–77 (63.4)</td>
<td>69–95 (78.7)</td>
<td>32–50 (38.7)</td>
</tr>
<tr>
<td>In percent of standard length</td>
<td>Range (mean)</td>
<td>SD</td>
<td>Range (mean)</td>
<td>SD</td>
</tr>
<tr>
<td>Head length</td>
<td>26.4–29.0 (28.0)</td>
<td>0.8</td>
<td>26.8–30.7 (28.2)</td>
<td>1.0</td>
</tr>
<tr>
<td>Body depth at dorsal-fin origin</td>
<td>27.1–30.8 (28.7)</td>
<td>1.4</td>
<td>26.3–30.0 (28.1)</td>
<td>1.0</td>
</tr>
<tr>
<td>Caudal peduncle depth</td>
<td>11.2–12.6 (12.0)</td>
<td>0.5</td>
<td>11.9–13.4 (12.6)</td>
<td>0.4</td>
</tr>
<tr>
<td>Head width at anterior eye margin</td>
<td>10.2–11.4 (10.7)</td>
<td>0.4</td>
<td>10.5–12.8 (11.6)</td>
<td>0.6</td>
</tr>
<tr>
<td>Head width at posterior eye margin</td>
<td>13.4–15.3 (14.2)</td>
<td>0.5</td>
<td>14.6–18.7 (16.4)</td>
<td>1.0</td>
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<tr>
<td>Head width at nape</td>
<td>15.2–16.7 (15.8)</td>
<td>0.5</td>
<td>15.7–18.2 (16.9)</td>
<td>0.8</td>
</tr>
<tr>
<td>Head depth at interorbital region</td>
<td>14.9–15.9 (15.5)</td>
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<td>14.0–17.4 (15.4)</td>
<td>0.9</td>
</tr>
<tr>
<td>Head depth at nape</td>
<td>19.0–20.7 (19.9)</td>
<td>0.5</td>
<td>19.0–23.1 (20.9)</td>
<td>1.1</td>
</tr>
<tr>
<td>Eye diameter</td>
<td>7.5–8.8 (7.9)</td>
<td>0.4</td>
<td>6.7–9.4 (7.7)</td>
<td>0.8</td>
</tr>
<tr>
<td>Snout length</td>
<td>7.1–8.4 (7.7)</td>
<td>0.4</td>
<td>7.5–9.7 (8.7)</td>
<td>0.7</td>
</tr>
<tr>
<td>Interorbital width</td>
<td>9.0–10.7 (10.2)</td>
<td>0.5</td>
<td>10.2–13.2 (11.2)</td>
<td>0.8</td>
</tr>
<tr>
<td>Snout width at nostrils</td>
<td>9.6–11.0 (10.4)</td>
<td>0.5</td>
<td>9.6–12.4 (10.9)</td>
<td>0.8</td>
</tr>
<tr>
<td>Snout depth at nostrils</td>
<td>10.5–11.6 (11.0)</td>
<td>0.3</td>
<td>9.4–12.5 (10.8)</td>
<td>1.0</td>
</tr>
<tr>
<td>Width of mouth gape</td>
<td>6.3–7.3 (6.9)</td>
<td>0.3</td>
<td>7.1–11.4 (8.7)</td>
<td>1.2</td>
</tr>
<tr>
<td>Length of mouth gape</td>
<td>6.2–8.1 (7.2)</td>
<td>0.5</td>
<td>7.9–11.1 (9.2)</td>
<td>0.9</td>
</tr>
<tr>
<td>Predorsal length</td>
<td>56.0–59.0 (56.9)</td>
<td>0.9</td>
<td>57.2–60.5 (59.1)</td>
<td>1.0</td>
</tr>
<tr>
<td>Prepelvic length</td>
<td>50.6–53.3 (51.9)</td>
<td>0.9</td>
<td>50.4–55.6 (52.6)</td>
<td>1.3</td>
</tr>
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<td>Preanal length</td>
<td>73.1–75.2 (74.0)</td>
<td>0.6</td>
<td>72.6–77.7 (74.7)</td>
<td>1.3</td>
</tr>
<tr>
<td>Pectoral-fin origin to anal-fin origin</td>
<td>46.7–50.0 (48.7)</td>
<td>1.0</td>
<td>47.1–52.6 (49.3)</td>
<td>1.5</td>
</tr>
<tr>
<td>Pectoral-fin origin to pelvic-fin origin</td>
<td>25.2–27.7 (26.3)</td>
<td>0.8</td>
<td>24.2–28.1 (26.3)</td>
<td>1.2</td>
</tr>
<tr>
<td>Pelvic-fin origin to anal-fin origin</td>
<td>21.5–24.1 (22.5)</td>
<td>0.9</td>
<td>20.8–25.5 (23.2)</td>
<td>1.2</td>
</tr>
<tr>
<td>Caudal-peduncle length</td>
<td>16.1–18.4 (17.4)</td>
<td>0.8</td>
<td>14.3–18.5 (16.5)</td>
<td>1.1</td>
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<tr>
<td>Dorsal-fin depth</td>
<td>19.9–23.3 (21.4)</td>
<td>0.9</td>
<td>21.2–24.0 (22.8)</td>
<td>1.0</td>
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<td>19.1–21.5 (20.4)</td>
<td>0.8</td>
<td>18.8–23.8 (21.4)</td>
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<td>Pelvic-fin length</td>
<td>15.6–17.9 (16.7)</td>
<td>0.8</td>
<td>15.6–19.3 (17.9)</td>
<td>1.0</td>
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<tr>
<td>Anal-fin length</td>
<td>14.3–16.9 (15.4)</td>
<td>0.8</td>
<td>14.8–18.2 (16.5)</td>
<td>1.1</td>
</tr>
<tr>
<td>Length of upper caudal-fin lobe</td>
<td>25.6–27.6 (26.8)</td>
<td>0.6</td>
<td>24.1–27.8 (25.4)</td>
<td>1.1</td>
</tr>
<tr>
<td>Length of middle caudal-fin ray</td>
<td>13.7–16.5 (15.1)</td>
<td>0.9</td>
<td>14.5–17.5 (16.0)</td>
<td>1.0</td>
</tr>
</tbody>
</table>
drainage 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, Kıcık 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 Kıcık 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 Kıcık 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 (Saĥin 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 Akçağ 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, Akçağ 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 Kıcık 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 Akçağ 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 Kıcık (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 Akçağ Stream (this study). According to the t-test results (as t<sub>cal</sub>=3.533>t<sub>table</sub>; 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 features (Bagenal & Tesch, 1978). If the sampling

<table>
<thead>
<tr>
<th>River Basin</th>
<th>Locality</th>
<th>n</th>
<th>l&lt;sub&gt;min&lt;/sub&gt;</th>
<th>l&lt;sub&gt;max&lt;/sub&gt;</th>
<th>l&lt;sub&gt;mean±SE&lt;/sub&gt;</th>
<th>W&lt;sub&gt;min&lt;/sub&gt;</th>
<th>W&lt;sub&gt;max&lt;/sub&gt;</th>
<th>W&lt;sub&gt;mean±SE&lt;/sub&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kıcık Menderes</td>
<td>Akgöl Lake</td>
<td>246</td>
<td>4.50</td>
<td>13.00</td>
<td>7.53±0.069</td>
<td>1.02</td>
<td>35.52</td>
<td>6.14±0.277</td>
</tr>
<tr>
<td>Kıcık Menderes</td>
<td>Belevi Lake</td>
<td>70</td>
<td>4.00</td>
<td>10.00</td>
<td>5.37±0.119</td>
<td>0.86</td>
<td>20.68</td>
<td>2.60±0.296</td>
</tr>
<tr>
<td>Büyük Menderes</td>
<td>Akçağ Stream</td>
<td>49</td>
<td>4.40</td>
<td>9.40</td>
<td>5.24±0.104</td>
<td>1.01</td>
<td>16.01</td>
<td>2.32±0.294</td>
</tr>
<tr>
<td>Closed</td>
<td>Açıgoğlu Lake</td>
<td>23</td>
<td>4.80</td>
<td>9.90</td>
<td>7.81±0.218</td>
<td>1.40</td>
<td>15.51</td>
<td>7.88±0.648</td>
</tr>
<tr>
<td>Coastal (Aegean)</td>
<td>Sarıçay River</td>
<td>11</td>
<td>6.60</td>
<td>11.60</td>
<td>8.98±0.255</td>
<td>4.73</td>
<td>25.86</td>
<td>12.04±1.100</td>
</tr>
<tr>
<td>Kıcık Menderes</td>
<td>Yenisehir Res(IF)</td>
<td>11</td>
<td>7.10</td>
<td>9.60</td>
<td>8.17±0.226</td>
<td>5.21</td>
<td>14.53</td>
<td>8.56±0.789</td>
</tr>
<tr>
<td>Coastal (Aegean)</td>
<td>Tahtalı Res</td>
<td>8</td>
<td>3.40</td>
<td>6.20</td>
<td>4.33±0.311</td>
<td>0.61</td>
<td>3.97</td>
<td>1.45±0.371</td>
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</tbody>
</table>


<table>
<thead>
<tr>
<th>Locality</th>
<th>n</th>
<th>a</th>
<th>b</th>
<th>SE&lt;sub&gt;b&lt;/sub&gt;</th>
<th>r</th>
<th>SE&lt;sub&gt;r&lt;/sub&gt;</th>
<th>t&lt;sub&gt;cal&lt;/sub&gt;</th>
<th>GT</th>
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<tbody>
<tr>
<td>Akgöl Lake</td>
<td>246</td>
<td>0.009</td>
<td>3.181</td>
<td>0.046</td>
<td>0.976</td>
<td>0.043</td>
<td>t&lt;sub&gt;cal&lt;/sub&gt;=3.935 &gt; t&lt;sub&gt;0.05, n = 245&lt;/sub&gt;= 1.65</td>
<td>A(+)</td>
</tr>
<tr>
<td>Belevi Lake</td>
<td>70</td>
<td>0.010</td>
<td>3.191</td>
<td>0.120</td>
<td>0.955</td>
<td>0.076</td>
<td>t&lt;sub&gt;cal&lt;/sub&gt;=1.592 &lt; t&lt;sub&gt;0.05, n = 69&lt;/sub&gt;= 1.68</td>
<td>l</td>
</tr>
<tr>
<td>Akçağ Stream</td>
<td>49</td>
<td>0.007</td>
<td>3.389</td>
<td>0.098</td>
<td>0.981</td>
<td>0.034</td>
<td>t&lt;sub&gt;cal&lt;/sub&gt;=3.969 &gt; t&lt;sub&gt;0.05, n = 48&lt;/sub&gt;= 1.68</td>
<td>A(+)</td>
</tr>
<tr>
<td>Açıgoğlu Lake</td>
<td>23</td>
<td>0.008</td>
<td>3.316</td>
<td>0.097</td>
<td>0.911</td>
<td>0.029</td>
<td>t&lt;sub&gt;cal&lt;/sub&gt;=3.258 &gt; t&lt;sub&gt;0.05, n = 22&lt;/sub&gt;= 1.72</td>
<td>A(+)</td>
</tr>
<tr>
<td>Sarıçay River</td>
<td>11</td>
<td>0.011</td>
<td>3.142</td>
<td>0.123</td>
<td>0.983</td>
<td>0.038</td>
<td>t&lt;sub&gt;cal&lt;/sub&gt;=1.154 &lt; t&lt;sub&gt;0.05, n = 10&lt;/sub&gt;= 1.71</td>
<td>l</td>
</tr>
<tr>
<td>Yenisehir Res (IF)</td>
<td>11</td>
<td>0.010</td>
<td>3.190</td>
<td>0.238</td>
<td>0.976</td>
<td>0.031</td>
<td>t&lt;sub&gt;cal&lt;/sub&gt;=0.798 &lt; t&lt;sub&gt;0.05, n = 10&lt;/sub&gt;= 1.72</td>
<td>l</td>
</tr>
<tr>
<td>Tahtalı Res</td>
<td>8</td>
<td>0.013</td>
<td>3.101</td>
<td>0.120</td>
<td>0.996</td>
<td>0.028</td>
<td>t&lt;sub&gt;cal&lt;/sub&gt;=0.842 &lt; t&lt;sub&gt;0.05, n = 7&lt;/sub&gt;= 1.90</td>
<td>l</td>
</tr>
</tbody>
</table>

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 biomass 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), Akgöl 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

Not applicable.

Funding Information

This study was not funded.

Author Contribution


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.

Acknowledgements

The second author gave her contributes to this manuscript while she was at the Bournemouth University, so we would like to thank to Bournemouth University for providing their facilities, and TÜBİTAK BİDEB (2219 Program) which supported İrmak Kurtul with one-year scholarships during her post-doctor research at the United Kingdom. We are grateful to Züleyha Akpinar (Rize), and Dr. Salim Serkan Güçlü (Isparta) for their help during the field works. A special thanks to Dr. Baran Yoğurtçuoğlu (Ankara) for sharing examined material and producing the map, and Dr. Jörg Freyhof (Berlin) for his remarkable comments on the earlier version of this manuscript.

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