Morphology, Feeding, and Reproduction of the Round Goby, Neogobius melanostomus (Pallas), in the Danube River Basin, Yugoslavia

Predrag Simonović1,*, Momir Paunović2, and Srdja Popović1

1Institute of Zoology, Faculty of Biology
University of Belgrade
Studentski trg 16
11001 Belgrade, Yugoslavia
2Department of Hydrobiology
Institute for Biological Research
29 November 142
11000 Belgrade, Yugoslavia

ABSTRACT. The round goby Neogobius melanostomus was the last Ponto-Caspian goby species to enter in the Danube River bordered by Serbia and Yugoslavia. There are five Ponto-Caspian goby species in the waters of Serbia including the sand goby Neogobius fluviatilis, the round goby Neogobius melanostomus, the racer goby Neogobius gymnotrachelus, the bighead goby Neogobius kessleri, and the tubenose goby Proterorhinus marmoratus. The sand, bighead, and tubenose gobies occur along the Yugoslav Danube and in the lower reach of the Danube’s tributaries; the racer goby is found both upstream and downstream of the Djerdap II dam; and, the round goby has been collected only downstream of the Djerdap II dam. Investigations on the continuous morphological characters of the round goby revealed neither sexual dimorphism, nor significant differences in adult size-classes, although some suggestions of sexual dimorphism were found in cranial skeletal analyses. Analysis of external continuous characters revealed a west-east cline along the distribution range of the round goby in the Black Sea basin. Molluscivory for the round goby was corroborated along the Danube. Standard length of each age class for the round goby in the Danube was less than populations in the Caspian and Azov seas.

INDEX WORDS: Round goby, distribution, morphology, feeding, Danube, Yugoslavia.

INTRODUCTION

Information on the distribution of Ponto-Caspian gobies in Yugoslav section of the Danube from the literature is scarce and out-of-date (Vuković and Ivanović 1971, Ristić 1972, Ristić 1977). The discovery of the round goby Neogobius (Apollonia Iljin 1927) melanostomus (Pallas 1811), as a new gobid species, for the fauna of Serbia and Yugoslavia (Simonović et al. 1998) completed the knowledge on the distribution of Ponto-Caspian gobies in the Danube. The recent records on the dispersal of Ponto-Caspian gobies in the Yugoslav

*Corresponding author: E-mail: pedja@bf.bio.bg.ac.yu
stretch of the Danube, and also in the Danube basin, are of interest because gobids also are expanding their distribution in other regions including in the Ukraine, e.g., Dniepr, Dniestr, Don rivers (Smirnov 1986), the River Moscow (Sokolov et al. 1989, 1994), the Baltic Sea (Skora and Stolarski 1993) and the Laurentian Great Lakes in North America (Jude et al. 1992). The round and tubenose *Proterorhinus marmoratus* (Pallas 1811) gobies, have naturally surpassed their original limits of distribution in the Ponto-Caspian area (Smirnov 1986; Miller 1986, 1990; Economidis and Miller 1990; Ahnelt et al. 1998).

The appearance of the round goby as a new species in the Yugoslav section of the Danube River is noteworthy. The objective of this study was to document the presence of gobids in the Danube River and to determine the relationship between the round goby and other fishes. Also examined were the morphology, feeding habits, size of age-classes, and maturity of the round goby.

**METHODS**

The neogobiids were caught by float and legger angling, by using an “umbrella” fishnet (of the size 1 × 1 m and mesh size 0.8 × 10⁻² m) and by electrofishing (220 VAC transformed to 220 V DC, 2.1 KW) at sites of the River Danube basin during 1993 to 1998 (Fig. 1). Sampling locations for the River Danube basin in Serbia are given in distance from Sulina, i.e., from the mouth into the Black Sea (Jude et al. 1991) (Table 1). Fish were preserved in 70% ethanol and transferred to the laboratory for processing. They were identified using taxonomic keys from Banarescu (1964), Smirnov (1986), and Miller (1986). Most specimens are still stored in the collection of the Institute of Zoology, Faculty of Biology, University of Belgrade.

Using a binocular microscope, age was determined on scales taken from the left flank at the level of the first dorsal fin. Fish stomachs were analyzed and sex and stage of gonad ripeness were

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**FIG. 1.** Position of the sampling sites in the Danube drainage in Serbia (Sample sites correspond to numbers in Table 1).
recorded. Non-mollusc food items were identified mainly to order and family levels (Kerovec 1986), and molluscs were identified to the genus and species levels (Ložek 1956). Items related to specific aspects of feeding patterns were analyzed by χ² Frequency Analysis, with the Yate’s correction applied (Petz 1985). Correspondence Analysis was used to examine overall food partitioning.

Meristic traits of round goby were counted on a reduced character set (Smirnov 1986) using a dissection microscope (×6). Calipers (0.1 mm), were used to measure 15 continuous external morphological characters conforming to the character set given in Holčík (1989) (hmax—maximal body height; hmin—minimal body height; aD1—predorsal length; pD2—postdorsal length; aP—prepectoral length; aV—preventral length; aA—preanal length; lD1—first dorsal fin base length; hD1—first dorsal fin height; lD2—second dorsal fin base length; hD2—second dorsal fin height; lA—analfin base length; hA—analfin height; IP—pectoral fin length; lV—pelvic disk length). Measures were transformed to indices of standard length. Round goby populations from the Serbian section of the Danube were compared with those from the Azov and Black seas and the River Dniepr (Smirnov 1986). Squared Euclidean distance (Sokal and Rohlf 1981) between means of external continuous characters was used as a measure of (dis)similarity between the sample from Prahovo (Fig. 1) and others from the literature (Smirnov 1986). The relationships between analyzed samples were derived from the obtained distance matrix using an agglomerative UPGMA clustering method (Sokal and Rohlf 1981).

A multivariate analysis of round goby from the Baltic Sea (the Gulf of Gdansk) was used to examine external morphology (using the truss network scheme, i.e., a set of longitudinal, vertical, and diagonal distances between homologous points of

### TABLE 1. Authors’ and others data on recent (since 1986) records of gobies in the Danube and its tributaries on the territory of Serbia and Yugoslavia: localities, sampling dates, and sizes of both saved and unpreserved samples.

<table>
<thead>
<tr>
<th>Species</th>
<th>Fig. 1 No.</th>
<th>River</th>
<th>Sampling locality</th>
<th>Date (in ‘d/m/y’, or ‘y’ format)</th>
<th>Sample size</th>
<th>Status in collection or source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neogobius melanostomus</td>
<td>1</td>
<td>Danube</td>
<td>Prahovo (km 861)</td>
<td>13-15/09/1997</td>
<td>13</td>
<td>+ (on loan)</td>
</tr>
<tr>
<td>Round goby</td>
<td>2</td>
<td>Danube</td>
<td>Prahovo (km 861)</td>
<td>01/10/1998</td>
<td>30</td>
<td>+ (on loan)</td>
</tr>
<tr>
<td>Neogobius fluviatilis</td>
<td>3</td>
<td>Danube</td>
<td>Zemun (km 1172)</td>
<td>19/09/1993</td>
<td>85</td>
<td>+ (in 70% alc.)</td>
</tr>
<tr>
<td>sand goby</td>
<td>4</td>
<td>Danube</td>
<td>Orešac (km 1124)</td>
<td>04/06/1994</td>
<td>3</td>
<td>In 70% alc.</td>
</tr>
<tr>
<td>5</td>
<td>Danube</td>
<td>Bezdány (km 1426)</td>
<td>13/07/1996</td>
<td>1</td>
<td>—</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Danube</td>
<td>Prahovo (km 861)</td>
<td>15/09/1997</td>
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<tr>
<td>7</td>
<td>Danube</td>
<td>Begeč (km 1276)</td>
<td>??/??/1986</td>
<td>12</td>
<td>Janković et al.</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Danube</td>
<td>Prahovo (km 861)</td>
<td>01/10/1998</td>
<td>10</td>
<td>+ (in 70% alc.)</td>
<td></td>
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<tr>
<td>9</td>
<td>Sava</td>
<td>Novi Beograd</td>
<td>15/05/1994</td>
<td>16</td>
<td>+ (in skeleton)</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>V. Morava</td>
<td>Velika Planina</td>
<td>06/09/1998</td>
<td>9</td>
<td>+ (in 70% alc.)</td>
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<tr>
<td>11</td>
<td>Sava</td>
<td>Šabac (121 km)</td>
<td>24/09/1998</td>
<td>12</td>
<td>+ (in 70% alc.)</td>
<td></td>
</tr>
<tr>
<td>Neogobius gymnotrachelus</td>
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<td>Danube</td>
<td>Prahovo (km 861)</td>
<td>13-15/09/1997</td>
<td>1</td>
<td>+ (in 70% alc.)</td>
</tr>
<tr>
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<td>Bezdán (km 1425)</td>
<td>15/10/1996</td>
<td>1</td>
<td>Hegedíš et al.</td>
</tr>
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<td>13-15/09/1997</td>
<td>3</td>
<td>+ (in 70% alc.)</td>
</tr>
<tr>
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<td>Belgrade (km 1173)</td>
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<td>45</td>
<td>+ (in 70% alc.)</td>
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<td>29/11/1993</td>
<td>12</td>
<td>—</td>
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<tr>
<td>18</td>
<td>Danube</td>
<td>Golubac (km 1042)</td>
<td>30/11/1992</td>
<td>16</td>
<td>+ (in 70% alc.)</td>
<td></td>
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<tr>
<td>19</td>
<td>Danube</td>
<td>Orešac (km 1124)</td>
<td>04/06/1994</td>
<td>2</td>
<td>+ (in 70% alc.)</td>
<td></td>
</tr>
<tr>
<td>21</td>
<td>Sava</td>
<td>Šabac (121 km)</td>
<td>09/10/1998</td>
<td>2</td>
<td>+ (in 70% alc.)</td>
<td></td>
</tr>
<tr>
<td>Proterorhinus marmoratus</td>
<td>22</td>
<td>Danube</td>
<td>Zemun (km 1172)</td>
<td>1993, 1994</td>
<td>33</td>
<td>+ (on loan)</td>
</tr>
<tr>
<td>Tubenose goby</td>
<td>23</td>
<td>Sava</td>
<td>Novi Beograd</td>
<td>24/05/1995</td>
<td>16</td>
<td>+ (in skeleton)</td>
</tr>
<tr>
<td>24</td>
<td>Tamiš</td>
<td>Tomasevac</td>
<td>21/10/1998</td>
<td>3</td>
<td>+ (in 70% alc.)</td>
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</table>

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particular body regions; Bookstein et al. 1985), continuous osteological characters and karyological characters. These analyses used different techniques, explained in detail in Simonović and Nikolić (1995/1996), Simonović (1996a, b, 1999), and Simonović et al. (1996). Intraspecific variability of gobids was examined to determine phylogenetic relationships among the five Ponto-Caspian gobiid species occurring in Yugoslav waters.

RESULTS AND DISCUSSION
Ponto-Caspian Gobies in Yugoslav Waters

Records were established for the occurrence of sand *Neogobius (Apollonia) fluviatilis* (Pallas 1811), bighead *Neogobius (Ponticola) kessleri* (Günther 1861), and tubenose gobies in the Yugoslav section of the River Danube. Sand and bighead gobies occur along the entire Yugoslav section of the River Sava. The occurrences were verified of the tubenose goby (upstream from the mouth of the River Tamis into the Danube), and the sand goby (upstream from the mouth of the River Velika Morava into the Danube) (Table 1, Fig. 1). There is unconfirmed information, obtained from anglers, that sand, bighead, and tubenose gobies occur in tributaries of the Danube (V. Morava, Sava, Tamis) upstream of the sampling locations (River Tisa in the vicinity of city Žabaloj) (Table 1). The tadpole goby *Bentophilus stellatus* (Sauvage 1874), has been reported in the one of Djerdap reservoirs (Nalbant in Ahnelt et al. 1998) and may represent the sixth Ponto-Caspian goby species in the Yugoslav section of the Danube.

In addition to the round goby, three other gobiid species were caught in the Danube River near the city of Prahovo: sand goby, racer goby *Neogobius (Babka) gymnotrachelus* (Kessler 1857), and bighead goby. According to the catch data from the River Danube at Prahovo (Simonović et al. 1998), the syntopic gobiid community in the inshore zone is rather uniform. After repeated sampling in October 1998, it was observed that gobids (sand, bighead, and round goby; the racer goby was not caught) share the same littoral habitat with the common gudgeon *Gobio gobio*, a small, native, rheophilic, bottom-dwelling cyprinid. The finding of round and tadpole gobies in the lowermost section of the Danube in Serbia, i.e., downstream from the Đerdap II dam, was expected, since Smirnov (1986) documented their occurrence in the Romanian section of the Danube up to Vidin (km 790), approximately 71 km downstream from the Prahovo.

THE ROUND GOBY

Morphology

The values for discrete traits (lateral rows of scales, number of rays in fins, etc.) given in the literature (Berg 1949, Svetovidov 1964, Georgiev 1966, Smirnov 1986) for the round goby were within the range of values obtained for the round goby from the Danube at Prahovo.

Although sample sizes for males and females were small, analysis on continuous morphometric characters (Table 2) did not reveal sexual dimorphism, corroborating the results derived form the multivariate analysis of the “truss box network” scheme of characters in the round goby from Baltic Sea (Simonović and Mesaros 1998). The results of intraspecific analysis of cranial skeletons in large adult round goby (up to 19 cm TL) from the Baltic Sea revealed no difference between four size classes (< 14 cm TL; 14–15 cm TL; 15–16 cm TL; > 16 cm TL), judging from the comparison of their ontogenetic trajectories ($b_1 = 0.036 \pm 0.243$; $b_2 = -1.241 \pm 0.287$; $b_3 = 0.149 \pm 0.308$; $b_4 = -0.239 \pm 0.144$) by q test ($q_{1.2} = 2.438$; $q_{2.3} = 2.531$; $q_{3.4} = 1.576$; $k = 4$; $n = 18$; df = 10). These results agree with the lack of allometric growth in cranial skeleton elements in large specimens. However, the comparison of ontogenetic trajectory of males

<table>
<thead>
<tr>
<th>TABLE 2. Sexual dimorphism of continuous characters (in % of standard length) of the round goby from the Danube at Prahovo (M—mean, SE—standard error of mean; values were not significantly different).</th>
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<tr>
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<tr>
<td></td>
</tr>
<tr>
<td>Hmax</td>
</tr>
<tr>
<td>Hmin</td>
</tr>
<tr>
<td>aD1</td>
</tr>
<tr>
<td>pD2</td>
</tr>
<tr>
<td>AP</td>
</tr>
<tr>
<td>AV</td>
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<tr>
<td>AA</td>
</tr>
<tr>
<td>ID1</td>
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<td>hD1</td>
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<tr>
<td>ID2</td>
</tr>
<tr>
<td>hD2</td>
</tr>
<tr>
<td>LA</td>
</tr>
<tr>
<td>HA</td>
</tr>
<tr>
<td>LP</td>
</tr>
<tr>
<td>LV</td>
</tr>
</tbody>
</table>
Round Goby in the Danube

(b_m = −0.108 ± 0.068) with that of females (b_f = 0.090 ± 0.052) for cranial skeleton characters was close to significance for sexual dimorphism (q_m-f = 3.207; k=2; n=18; df-14; p < 0.05). The slight sexual dimorphism, both on the Principal Component Analysis loadings (regardless of size-component), and on the ANOVA tests, was due mainly to significant differences for articular plate (p < 0.01) in the lower jaw, premaxillar height (p < 0.02) in the upper jaw and supracleithrum—posttemporal bridge (p < 0.01) in the pectoral girdle (Simonović 1996c).

Comparison of 15 characters (Smirnov 1986) between the round goby from the River Danube at Prahovo and those from the localities at the River Dniepr, Danube Delta, Sevastopolis region (all from the Black Sea basin), and at Berdyansk (from the Azov Sea) revealed statistically significant differences (Table 3). Round gobies in riverine habitats have retained similar proportions of predorsal (aD1), postdorsal (pD2), and preanal (aA) distances and first dorsal fin base (lD1) and ventral disk (lV) length (Table 3). Few of these characters seem to be stable in the samples compared, e.g., aD1, aA, and ID1. The remaining characters revealed great variability, corroborating the findings of Smirnov (1986), who found differences between his samples for various continuous traits. The sample from Prahovo differs from all others in minimal body height (hmin), prepectoral distance (aP), first dorsal fin height (hD1), second dorsal fin base length (ID2), and anal fin base length (lA) (Table 3). The similarity between the Prahovo and Danube Delta Region samples in a few characters (hmax, aV, aA) may be due to the general stability of those traits. The sample from Prahovo is closer to the sample from the Danube Delta Region for most of characters for which a statistical difference was found, implying some sort of clinal variability for these continuous traits (aP, hD1, lD2, hD2, lA, and hA). Cluster analysis (Fig. 2) illustrated the assumption, but it needs to be tested.

Feeding

In late summer, the round goby fed mainly on mollusks, especially Dreissena polymorpha (Dreissenidae) and followed by Pisidium (Spheriidae) and Anodonta sp. (Unionidae), the last. Other prey included two species of snails, Lymnaea peregra and Theodoxus danubialis, an amphipod (Gammarus sp.), one Oligochaeta and three insects (Diptera and Plecoptera). Gammarids dominated the non-mollusk prey items. Apparently, the round goby selects mollusks and gammarids. Mollusks were the favored prey item over the non-mollusks in all age-
classes. The selectivity for mussels over the snails did not occur in age- and size-classes (Simonović et al. 1998). The molluscivory of the Danubian round goby confirmed the findings of Svetovidov (1964). Also, Smirnov (1986) concluded that “in general, the diet of the round goby in different regions is consisted mainly on mollusks;” Ray and Corkum (1997) stated that zebra mussels *Dreissena polymorpha* were the dominant prey of large (> 7 cm) round gobies.

The diet of round goby from the River Danube at Prahovo is similar to those reported from other localities with some differences in the taxa of particular food items in round goby samples from marine or oligohaline environments. In comparison to the reports dealing with the riverine round gobies, the molluscan taxa, specific to the Pontic region (*Dreissena polymorpha, Pisidium*), were the same as the diet of the round goby in the Danube.

### Food Partitioning Among Gobies

Apart from the extensive data on prey items of neogobiids (Smirnov 1986), other studies have not examined partitioning of prey items among species that share the same habitat. Knowledge on the utilization of food resources by neogobiids would be useful for predicting the outcome of the recently introduced round goby in the Yugoslav section of the Danube. On the basis of the neogobiid samples (n=105) from several localities (1, 3, 4, 9, 11, 16, 18, 19, 24, and 21; Table 1), the round goby may feed in the nearshore areas of the Danube (unpublished data). Unlike the round goby, other gobiids fed on larvae of different insect groups (Chironomidae, non-chironomid Diptera, Trichoptera, Ephemeroptera, Hemiptera, Coleoptera, and Odonata), Oligochaeta, goby fry and insect eggs (Fig. 3) in all seasons (sand goby $\chi^2 = 1.76; \text{df} = 7$; bighead goby $\chi^2 = 6.44; \text{df} = 14$). However, a clear distinction among goby species based on their diet did not occur ($\chi^2 = 296.74; \text{df} = 1560$) because bivalves and gammarids were found in all fishes. On the pairwise testing between species, the significant partitioning for prey occurred among the round goby and sand ($\chi^2 = 14.33, \text{df} = 7, p < 0.05$) and tubenose ($\chi^2 = 13.19, \text{df} = 7, p < 0.1$) gobies. A similarity in diets between round and bighead gobies ($\chi^2 = 5.86, \text{df} = 7$) was attributed to the presence of gammarids. The similarity in feeding found between all other gobies ($\chi^2$ ranging from 3.19 to 10.93, $\text{df} = 7$) was mainly due to their mutual feeding on larvae of different insect groups (among which chironomids dominated), gammarids, and Oligochaeta.

### Reproduction

In late September 1998, the gonads of male and female round goby were tiny, and firmly attached on the dorsal wall of the body cavity, corresponding to II stage of maturity (Moiseev et al. 1981). The stage II development of gonads in early fall is in agreement with the reports of Kulikova and Fandeeva (1975) and Moiseeva and Rudenko (1978), who reported that II and III stages overwinter. In the other regions, the round goby spawns repeatedly from the end of April to the end of August (Vinogradov 1948; Il’in 1949). Spawning episodes per year vary from 2 (Trifonov 1955, Kostyuchenko 1960), 3 to 4 and 4 (Bil’ko 1968, Kalinina 1976), to 5 to 6 (Kulikova and Fandeeva 1975). Neither fecundity, nor the extent of the spawning season of round goby in the middle Danube River is known.

### Size-at-age

The standard length of round goby from the Prahovo is up to 42 mm (year 0), 77 mm (year 1), and 93 mm (year 2). These size-at-age values are somewhat less than those reported from the Azov, Black, and Caspian seas (Fig. 4). According to Berg (1949), the Caspian Sea round goby achieves 45 mm and 95 mm in age-classes 0 and 1, respectively, and the Azov Sea values are 70 mm, 120 mm, and 140 mm in age classes 0, 1, and 2, respectively.
FIG. 3. UPGMA clustered correspondent scores on Euclidean distances (small insert) between goby species from the Yugoslav section of the Danube and its tributaries, presenting feeding pattern, with its most prominent determinants from the Correspondence Analysis applied.

FIG. 4. Growth-in-length (SL) of round goby from Danube, Prahovo compared with those from Azov and Caspian Seas (taken from the literature; see text).
cording to Smirnov (1986), the Azov Sea round goby grows up to 50 mm, 99 mm, 116 mm, and 123 mm in age classes 0 to 3, respectively.

Small intraspecific variability found for the adult round goby is concordant with the pattern found for other neogobiids (sand and bighead) (Simonovic et al. 1995/1996, Simonovic 1996a). Results obtained for the round goby from the Yugoslav section of the Danube River suggested a sort ofcline for its morphology, and confirmed the molluscivory of that species. A study of resource partitioning between the round goby and small-sized native cyprinids in different seasons may help to determine the impact of the round goby on the well-established fish communities in the inshore areas of the Danube.

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