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Population dynamics and feeding ecology of the western tubenose goby (*Proterorhinus semilunaris*) in the Stugna River, Dnieper River basin, Ukraine

by

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Abstract

The study investigated the inter-annual and seasonal population dynamics, as well as the feeding habits of the western tubenose goby *Proterorhinus semilunaris* in an invaded river close to its natural range (Dnieper River basin). Material was collected monthly in 2015–2016 and 2018 at one sampling site located in the Stugna River, at a distance of 1100 m from the point where it enters the Kaniv reservoir. Catch-per-unit-efforts (CPUE) of this species at the sampling site varied considerably, both between different months within a given year and between the analyzed years, from 1.1 to 127.1 fish 100 m^{-2}. Peak abundances were observed in July in both 2015 and 2018, and then dropped sharply in the following months. The western tubenose goby is characterized by a protracted spawning season, lasting from April to July. A total of 50 prey taxa were recorded in the diet of the western tubenose goby at the sampling site, among which chironomids were the most abundant and most frequently encountered, followed by cladocerans. This gobiid at the sampling site preyed mainly among submerged vegetation, where phytophilous chironomids were the most important prey.

Key words: Gobiidae, invasive species, alien species, fish diet, Ponto-Caspian

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1. Introduction

The western tubenose goby, *Proterorhinus semilunaris* (Pallas, 1814), is a freshwater gobiid of Ponto-Caspian origin, the native range of which covers waterways of the northern Black Sea (e.g. the Danube River up to nearly Vienna), as well as the Maritza and Struma drainage basins in the eastern Aegean basin (Kottelat & Freyhof 2007) and some inland waters in Turkey (Saç 2019; Özuluğ et al. 2023). In recent decades, the species showed a rapid expansion of its range and established itself in various European freshwaters, including the Morava River in the Czech Republic (Prášek & Jurajda 2005), the Moselle River in Germany (von Landwüst 2006), the Pripyat River in Belarus (Rizevsky et al. 2007), the Rhine in the territories of France, Germany and the Netherlands (Manné & Poulet 2008; Borcherding et al. 2013; Roche et al. 2013), and the Meuse River in the Netherlands and Belgium (Cammaerts et al. 2012; Mombaerts et al. 2014). In addition, it arrived in North America in 1990 in ballast water and has successfully established itself there (Jude et al. 1992). It is believed that one of the factors facilitating and accelerating the spread of this goby is transport in the ballast water of ships, as well as the canalization of main rivers and the creation of reservoirs or slow-flowing waters (Ahnelt et al. 1998; Wonham et al. 2000).

In Ukraine, the western tubenose goby is considered to be native to the Dnieper River, as it has been reported to have long inhabited the lower and middle reaches of the river. However, it has not been reported in the reach of the Dnieper River, where the Kaniv Reservoir is currently located. For example, according to Beling (1914), the species occurred in the middle reaches of the Dnieper River, as well as in some of its tributaries, such as the Vorskla and Psel rivers. It was later reported further upstream in the Ros and Trubizh rivers (Beling 1937). As for the Stugna River, little information is available, but it is known that this species was absent there in the 1970s (Poltavchuk 1976), and its presence was first reported in 1999–2004 (Sabodash & Tsyba 2006). Nevertheless, the western tubenose goby has been recorded in some other tributaries of the middle reaches of the Dnieper River downstream of the Stugna River, including the Ros, Olshanka, Trubizh, and Supiy rivers (Poltavchuk 1976).

The feeding ecology of the western tubenose goby has been investigated in a number of studies in invaded (e.g. Adámek et al. 2010; Vašek et al. 2014; Všetičková et al. 2014; Dawson et al. 2020) and native waters (Adámek et al. 2007; Saç 2019). Less information is available on the population dynamics of this species (Valová et al. 2015). Knowledge of the feeding ecology and population dynamics of this goby is important for predicting its possible impact on co-occurring aquatic organisms, as well as on entire invaded ecosystems. Therefore, the aim of the study was to investigate the inter-annual and seasonal population dynamics, as well as the feeding habits of the western tubenose goby in an invaded river very close to its natural range.

2. Materials and methods

2.1. Fish sampling

Fish sampling was carried out in the littoral zone of the right bank of the lower Stugna River (50°08′57.16″N; 30°43′55.05″E) at a single sampling site approximately 70 m long, which was located approximately 1100 m from the inflow of the river into the Kaniv reservoir. The substrate at the sampling site was sand and muddy sand with patches of submerged aquatic vegetation (mainly *Myriophyllum* sp., *Ceratophyllum* sp., and *Potamogeton* spp.), which covered approximately 40% of the sampling site area. The width of the sampled river reach was approximately 85 m. Sampling was carried out monthly from March 2015 to February 2016 and from March 2018 to November 2018, usually between the 15th and 20th of the month and usually between 9.00 and 12.00 (noon).

Fish were collected by hauling a beach seine (10 m long × 1 m high with a mesh size of 1.0 mm) along the river bank. A total of three hauls were carried out on each sampling day, each covering approximately 30 m^2. The maximum depth within the hauling area did not exceed 1.2 m. Fish from all hauls carried out during one sampling day were pooled, identified, and counted. A total of 30 to 40 specimens (if available) of the western tubenose goby were randomly selected and preserved in 4% formaldehyde solution to be processed in the laboratory. The remaining fish were measured in the field to the nearest 1 mm (total length, TL) and then released into the sampled river reach. Fish caught in 2015–2016 were used for both population dynamics and diet analysis, while those caught in 2018 were used only for population dynamics. Water temperature at the sampling site was measured on each sampling day with a digital thermometer at a depth of 0.5 m below the surface.

In the laboratory, fish preserved in 4% formaldehyde solution were measured (standard length, SL, and total length, TL) to the nearest 1 mm and then eviscerated. The entire fish gut contents were removed and examined under a binocular microscope at magnifications ranging from 8x to 32x. The prey items found in the gut contents were identified to the lowest possible taxon and counted. Macrozoobenthic prey was measured under an ocular micrometer. Furthermore, up to ten gobies (if available) were taken randomly from each sample and chironomid larvae from their gut contents were picked and preserved in 4% formaldehyde solution in Eppendorf tubes for later identification to the lowest possible taxon (Didenko et al. 2021). As for zooplankters, the lengths of at least 20 specimens of each identified taxon were measured with an ocular micrometer. The measured lengths of benthic and zooplanktic prey were used to calculate the dry weight of zooplanktic and benthic organisms using published length–dry weight relationships (McCauley 1984; Culver et al. 1985; Benke et al. 1999; Watkins et al. 2011). The obtained dry weights of prey organisms were then transformed into wet weight values assuming a water content of 85.0% for zooplankton and 76.0% for benthic organisms (USEPA 2010).

2.2. Data analysis

To analyze the dynamics of fish abundance at the sampling site in different months, the catch-per-unit-effort (CPUE) was used as the number of fish caught per 100 m^2 of a seine haul. For the diet analysis, fish were arbitrarily divided into three length groups: < 30 mm, 30 – 49 mm, and ≥ 50 mm TL. Fish with no food in their guts were not used for the diet analysis, however, they were used to calculate the average vacuity index (%VI), which corresponds to the percentage of empty stomachs relative to all analyzed stomachs. Diet composition by month (length groups pooled) and by length group (all months pooled) were described using the following indices: frequency of occurrence, %F; relative abundance, %N; percentage of biomass, %W; and percent index of relative importance, %IRI. Only %N and %W were used to analyze different chironomid taxa.

Linear regression was used to find the relationship between CPUEs of the western tubenose goby and water temperature, as well as to determine length–length relationships (SL vs. TL and TL vs. SL), which can be used to compare data from different literature sources.

3. Results

3.1. Population dynamics

A total of 340 individuals of the western tubenose goby were sampled during the study and 154 of them were taken for the diet analysis. The total lengths of the sampled fish ranged from 12 mm to 77 mm, with an average length of 36.98 ± 0.82SE mm.

CPUEs of the western tubenose goby at the sampling site substantially varied both between different months within a year and between the analyzed years, from 1.1 to 127.1 fish 100 m^{-2} (Fig. 1). No specimens of this species were recorded in catches in March and April of 2015, as well as in October and

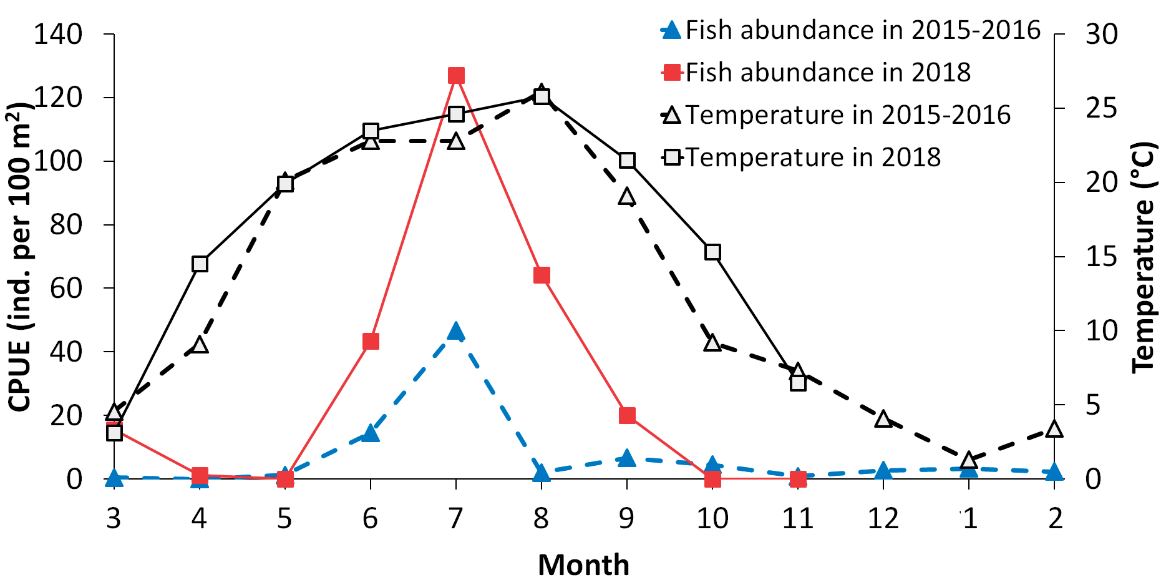

Figure 1

Seasonal and inter-annual dynamics of the western tubenose goby abundance (CPUE) and water temperature in the Stugna River.

November 2018. Peak abundances were observed in July in both 2015 and 2018, and they dropped sharply in the following months. The overall abundance of gobies in the samples was almost three times higher in 2018 compared to 2015. Water temperatures during sampling events in 2018 were usually higher than those in 2015, but no significant relationships were found between the CPUE of the western tubenose goby and water temperature ($p > 0.05$).

The average lengths of the western tubenose goby in catches varied throughout the year, with the smallest fish observed in the summer months (Fig. 2). New young-of-the-year (YOY) specimens of 12 to 27 mm TL started appearing in catches in June. The length–frequency distribution in the summer months showed multimodal patterns. A clear gap in the length frequency distribution was observed between YOYs and adult fish in June, but this gap was not apparent for the following months.

The following length–length relationships were determined:

$$TL = 1.20 + 1.18SL, r^2 = 0.99;$$

$$SL = -0.77 + 0.84TL, r^2 = 0.99.$$

3.2. Diet

The average vacuity index of the investigated western tubenose goby for the entire year was 1.91%, with only three specimens of this species found with empty guts and all in August.

A total of 50 prey taxa were recorded in the diet of the western tubenose goby at the sampling site (Table 1), with chironomid larvae being the most abundant and most frequently encountered, followed by cladocerans. Chironomids recorded in the gut contents of this goby included 20 taxa, among which

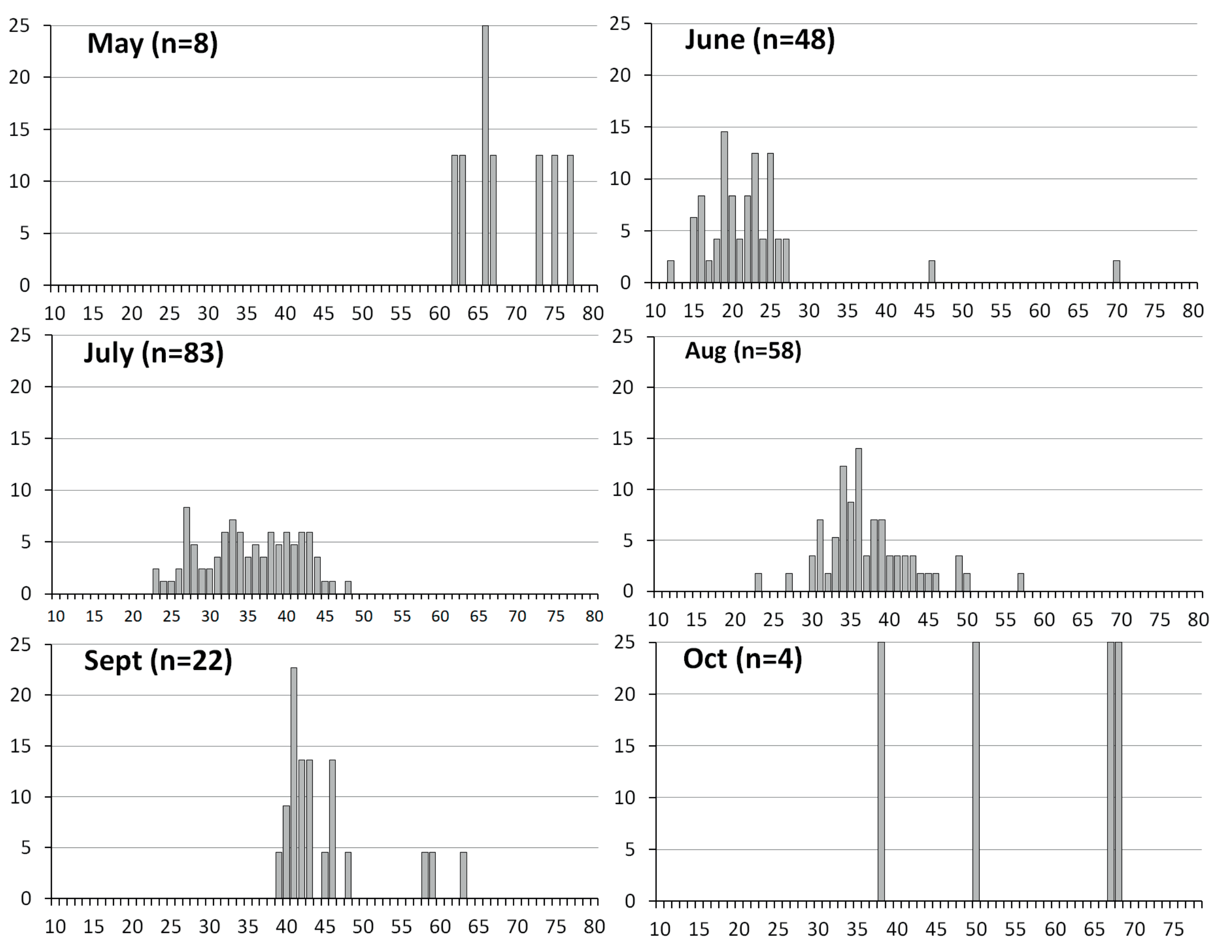

Figure 2

Length–frequency histograms for the western tubenose goby sampled in the Stugna River in May–October in 2015 (n = number of sampled fish).

Table 1

Diet composition of the western tubenose goby from the Stugna River (all length groups and seasons pooled, n = 154) in 2015, where %N = relative abundance of prey items, %W = percentage of biomass, %F = frequency of occurrence, %IRI = percent index of relative importance. Bold font indicates the corresponding pooled taxa.

	N%	W%	F%	%IRI
Bryozoa statoblasts	0.25	0.35	1.30	< 0.01
Dreissena sp. veligers	0.10	0.02	0.65	< 0.01
Gastropoda	0.05	0.03	0.65	< 0.01
Cladocera	**31.70**	**7.73**	**62.34**	**8.73**
Chydorus sphaericus	4.91	0.52	27.27	0.53
Ceriodaphnia sp.	0.05	0.01	0.65	< 0.00
Alona affinis	6.83	2.17	21.43	0.68
Alona sp.	0.64	0.12	5.84	0.02
Pseudochydorus globosus	4.32	0.91	22.73	0.42
Pleuroxus aduncus	0.05	0.01	0.65	< 0.01
Disparalona rostrata	0.64	0.13	5.19	0.01
Graptoleberis testudinaria	0.20	0.05	2.60	< 0.01
Camptocercus sp.	1.18	0.36	5.84	0.03
Acroperus harpae	6.88	0.77	12.99	0.35
Eurycercus lamellatus	2.01	1.18	13.64	0.15
Diaphanosoma sp.	0.05	-	0.65	< 0.01
Simocephalus sp.	2.31	1.05	4.55	0.05
Copepods	**4.82**	**1.24**	**20.13**	**0.43**
Cyclopoida	4.37	1.22	20.13	0.40
Harpacticoida	0.44	0.02	3.90	0.01
Ostracoda	2.21	0.77	17.53	0.19
Mysidae	0.05	0.38	0.65	< 0.01
Dikerogammarus villosus	1.38	6.73	12.34	0.36
Hydrachnidia	0.10	0.14	1.30	< 0.01
Insects	**59.36**	**82.60**	**95.45**	**48.11**
Ephemeroptera larvae	**1.97**	**6.82**	**15.58**	**0.49**
Caenis sp.	1.72	6.57	12.34	0.36
Baetis sp.	0.25	0.25	3.25	0.01
Trichoptera larvae	**1.82**	**9.84**	**13.64**	**0.56**
Orthotrichia sp.	1.18	0.60	5.84	0.04
Other Trichoptera	0.64	9.24	7.79	0.27
Zygoptera larvae	0.20	2.80	2.60	0.03
Chironomidae larvae	**52.19**	**58.45**	**94.16**	**36.99**
Chironomus sp.	0.36	0.02	-	-
Corynoneura celeripes	0.22	0.02	-	-
Cricotopus sylvestris gr.	15.05	11.43	-	-
Dicrotendipes nervosus	4.54	3.42	-	-
Dicrotendipes tritomus	0.36	1.32	-	-
Endochironomus albipennis	11.35	13.64	-	-
Glyptotendipes sp.	9.79	18.83	-	-
Parachironomus vitiosus	0.99	0.75	-	-
Parachironomus sp.	0.22	0.12	-	-
Paratanytarsus lauterborni	0.71	0.35	-	-
Paratendipes sp.	1.43	0.43	-	-
Polypedilum sordens	1.06	1.25	-	-
Polypedilum sp.	1.08	2.00	-	-
Psectrocladius psilopterus	0.85	0.86	-	-
Rheotanytarsus exiguus	0.36	0.12	-	-
Stictochironomus histrio	0.53	0.52	-	-
Tanytarsus gregarius	1.19	0.24	-	-
Trissocladius potamophilus	1.08	2.26	-	-
Tribe Chironomini	0.36	0.74	-	-
Tribe Tanytarsini	0.66	0.13	-	-
Chironomidae pupae	**3.19**	**4.69**	**27.92**	**0.78**

Cricotopus sylvestris was the most abundant, followed by *Endochironomus albipennis* and *Glyptotendipes* spp. They accounted for 28.8%, 21.8% and 18.8% of all chironomids found, respectively. A total of 14 cladoceran taxa were identified in the diet of the western tubenose goby at the sampling site, among which *Acroperus harpae* and *Alona affinis* were the most abundant, accounting for 21.7% and 21.6% of all detected cladocerans, respectively.

Chironomid larvae significantly dominated in the diet of all length groups of the western tubenose goby caught at the sampling site (Table 2), while cladocerans were the second most important prey organisms. The lowest proportion of cladocerans in the gut contents was found in the medium length group (30–49 mm). Zooplankters such as *Chydorus sphaericus* and

Table 2

Diet composition of different length groups (TL) of the western tubenose goby from the Stugna River in 2015 (%IRI). Bold font indicates the corresponding pooled taxa.

	Length group		
	< 30 mm n = 45	30–49 mm n = 78	≥ 50 mm n = 31
Bryozoa statoblasts	-	0.02	-
Dreissena sp. veligers	0.04	-	-
Gastropoda	-	-	0.01
Cladocera	**10.58**	**5.50**	**10.33**
Chydorus sphaericus	7.06	1.39	0.03
Ceriodaphnia sp.	-	< 0.01	-
Alona affinis	-	1.69	3.38
Alona sp.	0.58	0.02	0.01
Pseudochydorus globosus	0.10	0.36	0.14
Pleuroxus aduncus	2.32	1.39	0.10
Disparalona rostrata	0.22	0.02	0.01
Graptoleberis testudinaria	0.02	0.01	-
Camptocercus sp.	0.05	0.01	0.52
Acroperus harpae	0.07	0.24	4.49
Eurycercus lamellatus	0.15	0.35	0.60
Diaphanosoma sp.	-	< 0.01	-
Simocephalus sp.	-	0.02	1.05
Copepods	**2.45**	**0.94**	**0.55**
Cyclopoida	2.26	0.93	0.55
Harpacticoida	0.19	0.01	-
Ostracoda	-	0.26	1.87
Mysidae	-	0.01	-
Dikerogammarus villosus	-	0.41	3.38
Hydrachnidia	-	< 0.01	< 0.01
Insects	**86.93**	**92.86**	**83.84**
Ephemeroptera larvae	**-**	**1.79**	**0.29**
Caenis sp.	-	1.76	0.29
Baetis sp.	-	0.04	-
Trichoptera larvae	**-**	**0.84**	**0.73**
Orthotrichia sp.	-	0.07	0.23
Other Trichoptera	-	0.77	0.50
Zygoptera larvae	-	0.06	0.16
Chironomidae larvae	**86.61**	**88.61**	**78.98**
Chironomidae pupae	**0.32**	**1.56**	**3.69**

Pleuroxus aduncus were more important in the diet of the smallest goby length group, while *Acroperus harpae* and *Alona affinis* were more important in the diet of the largest length group. The smallest gobies consumed more copepods than the largest ones. On the other hand, the largest fish also consumed more chironomid pupae compared to fish from the smaller length groups.

Prey composition in the gut contents of the western tubenose goby showed certain seasonal differences (Fig. 3). However, chironomid larvae significantly dominated throughout the year, except in September, when cladocerans accounted for almost half of the prey organisms. Very few cladocerans were consumed in May and August compared to other months.

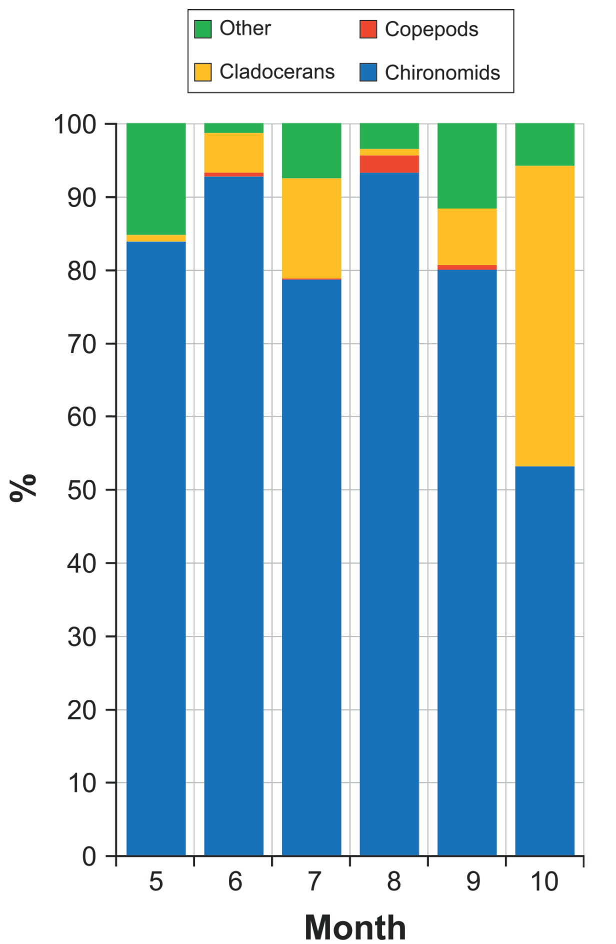

Figure 3

Seasonal dynamics of the diet composition of the western tubenose goby from the Stugna River based on the percent index of relative importance (%IRI) in May–October 2015.

4. Discussion

4.1. Population dynamics

The seasonal variation in abundance of the western tubenose goby in the Stugna River was similar to that observed in the invaded Dyje River in the Czech Republic (Valová et al. 2015). In both cases, very low CPUEs of this goby were recorded during the winter months, suggesting that most of the fish wintered in deeper waters. The abundance of the western tubenose goby began to increase sharply in June, when first YOYs appeared in samples (Table 2). Given the incubation period of this species of 7 – 8 days, the size at hatching of 4 – 6 mm, and the overall daily growth rate of 0.618 mm day^{-1} (Leslie et al. 2002; Dawson et al. 2020), as well as the wide size range of YOYs in June samples (12 mm to 27 mm TL), its spawning in the Stugna River likely occurred in April–May.

The pattern of the length frequency distribution and monthly population dynamics of the western tubenose goby from the Stugna River were in many ways similar to that observed in the Dyje River in the Czech Republic (Valová et al. 2015). For example, in both rivers the first YOYs appeared in June. The minimum and maximum lengths of YOYs in June samples were 12 mm and 27 mm TL, respectively, with the highest peak of 19 mm TL fish in the Stugna River, and these values were 11 mm SL (14 mm TL), 23 mm SL (28 mm TL), and 15 mm SL (19 mm TL), respectively, in the Dyje River. In both the Stugna and Dyje rivers, a distinct gap in length frequency between YOYs and older fish was observed only in June and this gap became indistinct in the following months, i.e. the first YOYs reach the size of adult fish as early as in July. According to Smirnov (1986), the western tubenose goby reaches sexual maturity at a length of 27 – 29 mm SL (which corresponds to 33-35 mm TL) and weight of 0.4 – 0.5 g, and this size was reached by some individuals in July.

The peak abundance observed in the Stugna River in July clearly reflected the recruitment of new YOYs, which was similar to that observed in the Dyje River (Valová et al. 2015). The presence of small YOYs of the same size (e.g. 23 mm) recorded in samples from the Stugna River in all three summer months may suggest batch spawning, as observed and confirmed in the Dyje River (Valová et al. 2015). If batch spawning also occurred in the Stugna River, the last spawning event probably occurred at least in July. A protracted spawning season of the western tubenose goby was also observed from April to late June in the Dyje River, where 16 – 17 mm SL (20 – 21 mm TL) YOYs were observed in samples in July and August (Valová et al. 2015), from late April to July in the Vistula River in Poland (Grabowska et al. 2019) and in the Istranca River in Turkey (Saç 2019), and from June to July in the Lake Superior Basin in the USA (Dawson et al. 2020). A longer spawning season lasting until August was recorded in Lake Tisa in Hungary (Harka & Farkas 2006).

The decrease in the abundance of adult western tubenose gobies in June compared to May can be related to the end of their spawning activity. Such a drop in the abundance of gobiids after their spawning may be due to post-spawning mortality of large fish caused by physical stress incurred during their reproductive season (Lynch & Mensinger 2012). Moreover, female gobies can move after spawning to deeper waters, while males remain near nests to guard them (Grabowska 2005). A decrease in the abundance of adult tubenose gobies in samples in June and July compared to May was also observed in the Dyje River (Valová et al. 2015).

An overall sharp decline in the abundance of the western tubenose goby after July was observed in both the Stugna and Dyje rivers (Valová et al. 2015), but it was more drastic in the Stugna River. Such a sharp decrease in fish abundance is probably due to a very high mortality rate within the first year of life typical of this species, which can reach 3.50% per day (Dawson et al. 2020). The sharp decrease in fish abundance observed in August and following autumn months can be related to the mortality caused by predation by other fish species and seasonal migrations to deeper offshore areas in response to a decrease in water temperature, which was also observed in the Dyje River (Valová et al. 2015) and Laurentian Great Lakes (Kocovsky et al. 2011) and which was typical of other gobiids inhabiting temperate freshwaters (Lynch & Mensinger 2012; Blair et al. 2019).

The inter-annual variability in the abundance of the western tubenose goby in the Stugna River probably depended on some environmental factors affecting fish spawning success and survivability rates of juveniles. For example, spawning conditions were probably better in spring of 2018 than in 2015, resulting in significantly higher abundance of YOY gobies in July 2018 compared to 2015. For example, water temperature at the sampling site in April 2018 was considerably higher compared to April 2015.

4.2. Dietary habits

The obtained vacuity index of the western tubenose goby in the Stugna River was very low compared to that observed in the Istranca River in Turkey (Saç 2019), which may indicate high feeding activity of this species in the former river throughout the year.

The western tubenose goby diet in the Stugna River was characterized by a broad spectrum and consisted mainly of benthic prey, as has also been observed in other studies (e.g. Adámek et al. 2007; Adámek et al. 2010; Vašek et al. 2014; Všetičková et al. 2014; Endrizalova et al. 2020). However, the composition of benthic prey taxa can vary in different water bodies. For example, the most important group in the gut contents of the western tubenose goby in the Stugna River were chironomid larvae, which was also observed in the confluence of the Danube and Hron Rivers in Slovakia (Adámek et al. 2007), many Moravian waters in the Czech Republic (Adámek et al. 2010; Ondračková et al. 2019), and some Turkish streams (Saç 2019). However, Trichoptera predominated in the diet of this goby in the Dyje River in the Czech Republic (Všetičková et al. 2014), while benthic macro-Crustacea dominated in the St. Louis River estuary of Lake Superior (Dawson et al. 2020). The western tubenose goby was found to be a food generalist with an opportunistic feeding strategy (Adámek et al. 2010; Všetičková et al. 2014; Saç 2019), which can switch to other food items under specific conditions (e.g. high macrozoobenthos density) (Ondračková et al. 2019).

It should be noted that the most abundant chironomid taxa in the diet of the western tubenose goby at the sampling site (*C. sylvestris* and *E. albipennis*) are phytophilous, associated with macrophytes, but can also occur in bottom sediments (Menzie 1981; Kornijów 1992). Another abundant chironomids were *Glyptotendipes* spp., which are usually also associated with macrophytes and are often leaf miners (Koperski 1998). However, they can also live on other substrates, including plant tissues, plant detritus, wood debris, and mud (Kornijów 1986; Özkan et al. 2010). Consequently, this gobiid in the Stugna River probably preyed mainly among macrophytes. Previous observations in the Kamianske Reservoir (Dnieper River) showed an association between the aquatic vegetation density and the abundance of the western tubenose goby, where the highest abundance of this species was recorded among dense vegetation (Didenko 2013). The presence of this goby also increased in habitats with more vegetation in some rivers of the Danube basin (Janáč et al. 2012).

A comparison of the diet composition of different length groups of the western tubenose goby did not reveal significant differences between them, i.e. the ontogenetic diet shift in this species is not pronounced, which can be due to the relatively narrow size range observed in this gobiid. However, some differences were still observed, e.g. the smallest gobies consumed more small cladocerans (such as *Ch. sphaericus*) and copepods and fewer aquatic insect larvae except chironomids compared to larger fish, which, on the contrary, were more likely to consume larger cladocerans (such as *A. affinis* and *Simocephalus* sp.) and various aquatic insect larvae, as well as amphipods. However, distinct differences between the diets of small (YOYs) and large (age ≥ 1) western tubenose gobies were observed in the Dyje River (Všetičková et al. 2014), where smaller fish consumed significantly more chironomids than larger ones. As for the predominance of *A. harpae* in the diet of the largest gobies, they were observed in their gut contents mainly in the fall months, when this zooplankter was probably more abundant in the environment and when no small fish were sampled, because all YOYs reached adult size.

Western tubenose gobies showed some seasonal differences in their diet composition observed in the months studied, which may be related to the varying availability of their prey in the environment and the growth of the fish, when gobies of different sizes consuming slightly different prey dominate in the population in different months. Seasonal shifts in the diet compositions of freshwater gobiids are typical and usually reflect the biological cycles of their insect prey (Brandner et al. 2013; Vašek et al. 2014). Nevertheless, chironomids usually remained the most important prey at the sampling site throughout the seasons. However, as demonstrated by previous studies, the composition of chironomid taxa in gut contents of the western tubenose goby at the sampling site varied throughout the seasons, depending on their availability in the environment (Didenko et al. 2021). A significant increase in the proportion of zooplanktic prey in the diet of the western tubenose goby during fall months compared to summer recorded in the Stugna River was also observed in the Mušov Reservoir (Adámek et al. 2010) and the Dyje River (Všetičková et al. 2014). This shift to zooplankton in fall can be due to a decrease in the abundance of macrozoobenthic prey in the environment associated with a decrease in water temperature and the die-off of aquatic vegetation, which serves as an important habitat for phytophilous chironomids.

Thus, the western tubenose goby has successfully established itself in the Stugna River and has became a common component of the local fish fauna. It is characterized by a protracted spawning season, which lasts from April to July. The species consumes a relatively wide range of invertebrates and preys mainly among submerged vegetation, with the most important prey being phytophilous chironomids, which were probably the most abundant and therefore easily available in a given season. The western tubenose goby may also compete for food with small native fish species, especially with those occurring in the same habitats. However, additional research is needed to confirm this. The specifics of reproduction and feeding can facilitate the successive establishment of this species in new environments and contribute to its widespread distribution.

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Availability of data and materials

The datasets generated and analyzed during the current study are available from the corresponding author upon reasonable request.

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