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THE HABITAT USE AND SELECTIVITY BY TOPMOUTH GUDGEON (*PSEUDORASBORA PARVA*)

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The topmouth gudgeon is an invasive species of the European fish fauna that causes problems not only as a competitor of native fishes in natural waters but also generates damages in pond fish farming. The behaviour of topmouth gudgeon has already been studied from a number of aspects, however, complex investigations on the habitat use of the species in invaded regions were not carried out yet. Here the habitat use of the fish in a close-to-nature pond system was examined with special, non-selective minnow traps and observations were subsequently complemented by aquarium experiments. Our findings revealed that in a pond inhabited by predator fish, topmouth gudgeon preferred the pelagial region, while in a pond free of predator fish, they preferred the littoral zone. The examined abiotic parameters had no effect on the habitat use of the fish. In a simplified artificial environment experiments have yielded the same results. The findings showed that topmouth gudgeon is rather flexible in adapting to the environmental conditions, the available nutrition base, but from the aspect of habitat use the most significant factor is probably the presence of predatory fish. The results can establish an effective suppression method of topmouth gudgeon populations with predator fishes.

Keywords: aquarium, habitat use, pond, predator, topmouth gudgeon.

INTRODUCTION

The occurrence of invasive species is one of the major reasons for a significant decrease in fresh water ecosystem biodiversity to date (among others, Moyle *et al.* 1986, Mack *et al.* 2000). In addition to competition, another reason for that is that together with the invasive species new diseases and parasites also arrive to the newly acquired habitat (Kennedy 2008). Besides decreasing genetic diversity and increasing biological homogeneity, the tremendous economic loss caused by newcomer fish species like the topmouth gudgeon is a further concern (*Pseudorasbora parva* Temminck et Schlegel, 1846) (Rahel 2000). The topmouth gudgeon, a small-sized cyprinid originally native to the Far East was introduced to Europe and to continents outside its original area of distribution, together with fish species farmed and transferred from Asia like the grass carp (*Ctenopharygodon idella* Valenciennes, 1844), the silver carp

(*Hypophthalmichthys molitrix* Valenciennes, 1844) and the bighead carp (*Hypophthalmichthys nobilis* Valenciennes, 1844) (Gozlan *et al.* 2010). The impact generated by topmouth gudgeon can be summarised as follows: it plays an important role in the spread of diseases and parasites (among others Galli *et al.* 2007, Czeczuga *et al.* 2002, Pinder *et al.* 2005, Gozlan *et al.* 2010), it competes for food with native small size cyprinids (Adámek *et al.* 1996, Hliwa *et al.* 2002), and also adversely affects the success of reproduction rate of certain species (Gozlan *et al.* 2005).

The investigation of the behaviour and habitat use of different fish species is extensively covered by technical literature. The group of species examined is rather broad: covering a range from the tiger shark (*Galeocerdo cuvier* Peron et Lesueur, 1822 (Heithaus *et al.* 2002)) to the guppy (*Poecilia reticulate* Peters, 1859 (Fraser & Gilliam 1987)). The most important factors are abiotic parameters, habitat complexity, food supply and the presence of predators but the choice of habitat by different fish species can also be affected by the presence of parasites (Poulin & Fitzgerald 1989). Most research probably focused on the correlations within the predator-prey-hiding place system. Observations showed that the habitat use by prey fish changed in the presence of predatory fish irrespective of whether the observation was conducted in nature (He & Kitchell 1990) or under laboratory circumstances (Snickars *et al.* 2004). In most cases prey fishes avoided areas with no hiding places (among others Gotceitas & Colgan 1987), and there are also examples where the prey, adapting to the behaviour of the predatory species, clearly chose open water spaces (Savino & Stein 2002). Habitat use is greatly affected by food supply and the intensity of metabolism of the fish: hungrier fish takes larger risks (Damsgard & Dill 1998, Pettersson & Brönmark 1993), but experiments showed, one after the other, that significant difference was needed in food supply to make the fish take risk (Abrahams & Dill 1989, Cerri & Fraser 1983). Experiments also showed that the behaviour of fish was also affected by whether predators lived in their original habitat or not (Fraser & Gilliam 1987).

The behaviour of topmouth gudgeon has already been examined from a number of aspects. Researchers revealed that, in addition to abiotic factors such as temperature, the swimming and feeding speed of the species was also affected, among others, by satiety, the prey and the density of the flora (Asaeda *et al.* 2001, Priyadarshana *et al.* 2000, Priyadarshana & Asaeda 2007). Topmouth gudgeon's physiological responses to sensed predators and to water flow were also examined in laboratory circumstances (Sunardi *et al.* 2007). Furthermore, in a natural environment topmouth gudgeon either showed no preference among the different habitats (Ye *et al.* 2006, Beyer *et al.* 2007), or the species used the aquatic vegetation covered areas (Kapusta *et al.*

2008). Acknowledging previous results, the aim was to investigate the habitat use of topmouth gudgeon on an invaded territory by a complex study and then prove the findings in a simplified artificial environment. The results of current research can contribute to future eradication programmes with different predator fish species meaning a feasible, sustainable and cost effective method to decrease topmouth gudgeon infection.

MATERIAL AND METHODS

Experiment series I

The experiments were carried out in Babat Valley, where topmouth gudgeon lives in two ponds of the pond system (Fig. 1; 47°36′48″ N 19°24′00″ E and surroundings). The pond system consists of artificial lakes established with barrage dams in the 1930s (Ángyán *et al.* 1999). Initially, fish farming was intensive in the ponds but later, due to eutrophication and the change of ownership, no deliberate fish management was carried out for decades. Observations were made at Babat pond I and Babat pond III. Both ponds are hypertrophic, with significant macro vegetation in the littoral zone (reeds, lesser bulrush and also submerged vegetation), with approximately 50% open water surface owing to the relatively significant water depth (2–2.5 m) and the turbidity caused by the floating algae (NTU > 5). The fish fauna of Babat pond I consisted of only six fish species at the time of the research. Prussian carp (*Carassius gibelio* Bloch, 1782), topmouth gudgeon, European perch (*Perca fluviatilis* Linneaus, 1758; standard length (SL) was 0–200 mm) were present in a large number, while carp (*Cyprinus carpio carpio* Linneaus, 1758), pike-perch (*Sander lucioperca* Linneaus, 1758; SL was 0–350 mm) and common rudd (*Scardinius erythrophthalmus* Linneaus, 1758) were present in small numbers in the pond.

The fish fauna of Babat pond III was very similar to Babat pond I; only the predator species were missing. The density of the topmouth gudgeon population was rather significant in fact, as preliminary research showed, very similar, in both lakes.

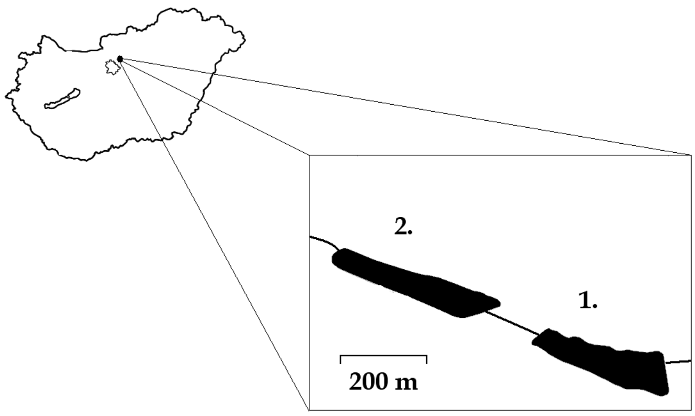

Fig. 1. Sampling site 1. Babat pond I and sampling site 2. Babat pond III (47°36′48″N 19°24′00″E and surroundings).

For sampling, home-made uniform minnow traps were used: with 20 mm diameter entrance, 1.5 dm^3 volume, transparent perforated sidewalls, an emptying hole, 200 g weight and a float that enabled the submerging of the minnow trap into the water at the desired depth. 5 g feed was placed in each minnow trap. During the experiment, exclusively topmouth gudgeon was caught. Size selectivity of the minnow trap was also examined (this preliminary experiment was conducted on Babat pond I). Size distribution of year 1+ age groups of topmouth gudgeon caught in the minnow traps by a method not considered selective on the basis of technical literature data (using a lift net of 1 × 1 × 1 m of a mesh size of 1mm, Morgan *et al.* (1988)) was tested. Since the distribution of the received value was unnatural, Mann-Whitney test was conducted. Preliminary experiment was also conducted on Babat pond III in order to determine the appropriate exposure time. Impact of the exposure time of 15, 30, 60 minutes on the probability of a catch and the number of fish caught was also examined (exposure time exceeding 60 minutes was rejected as too many fish were caught in the minnow trap, which, due to local shortage of oxygen, could lead to the death of the fish individuals). Research was carried out in two series of measurements with three minnow traps in each; results were examined with Kruskal-Wallis test. Finally, on Babat pond III, mark and recapture method was used to identify the optimal distance between the minnow traps in order to achieve independent sampling. As a result, three sampling points were identified at a distance of 25 metres from each other, where fish were caught by minnow traps and were marked differently at each sampling points; followed by a release into the water at the point where they were caught. Trapping was repeated 1 day, 1 week and 2 weeks later, when the number of unmarked and marked fish and, for the latter, the location of the original catch was recorded.

On the basis of the results of the above experiments, a 24-hour examination was conducted at both sampling sites in July, in sunny weather conditions, free of weather fronts. Perpendicular to the longitudinal axis of the pond, 5 separate sampling sites were identified. On each sampling point one minnow trap was placed in the shore vegetation at half of the water column, one in the open water 0.5 m below the surface and one in the open water 0.25 m above the bottom (later referred to as littoral, pelagial and benthal). In the course of the day four measurements were conducted with one hour exposure time each (at 6:00, 12:00, 18:00, 24:00). The number of fish caught, the water temperature and the oxygen level at the point of the catch were all recorded. The distribution of the data were analysed by chi-squared statistic. In case of significant ($p < 0.05$) results, Bonferroni 95% confidence intervals were constructed around the used sample proportion for each habitat (Márton 2014, Neu *et al.* 1974, Byers *et al.* 1984). The relationship among the abiotic parameters and number of fish in the trap was analysed with correlation analysis.

Experiment series II

The result of the first experiment led to the null hypotheses: on the basis of the examined parameters, habitat use of topmouth gudgeon was determined by the presence of predatory fish. To provide evidence, a simplified aquarium test system was established. The size of the aquarium was 0.6 × 0.6 × 1.2 m, from which a 0.3 m band was separated in order to have sufficient depth clarity for making photos. The aquarium was illuminated from above for 12 hours a day. Temperature of the water remained 25°C during the trials. Vegetation was imitated by eight 5 cm wide and 35 cm long rachel nets. Photos were used to examine the position of the fish individuals. The photos were made with a Canon EOS

300 camera, fixed on a stand, to prevent fish from seeing the movement of the cameraman. Fish were taken from two sites: Kincsem fish pond in Hatvan and Babat pond VII. The former pond is inhabited by carp, small cyprinid fishes (*Abramis* spp., *Rutilus rutilus, Carassius gibelio),* and a small number of large catfish *(Silurus glanis* Linneaus, 1758; SL: 600 mm+*)* (which typically does not feed on topmouth gudgeon) while the latter contained carp, Prussian carp, regular topmouth gudgeon eater bullhead (*Ameiurus* spp; SL: 0–200 mm.) and pike-perch (SL: 0–400 mm). Fish were caught with a 1 × 1 m lift net and selected randomly for the experiment from the year 1+ age group (SL of fish was 36±9 mm in Babat pond VII and 39.4±5 mm in Hatvan pond). In both populations four experimental settings were conducted three times repeatedly. In each setting, 35 photos were taken at 2 minutes' intervals and only those were evaluated in which the position of each fish in the aquarium could be identified. In the first setting, only topmouth gudgeon were placed in the aquarium. The findings were immediately analysed and the experiment was continued only when no statistically verifiable difference was found in preference of between the right and the left side of the aquarium, i.e., the fish verifiably did not have any preference for any side of the aquarium (chi-squared statistics). Subsequently to this, artificial vegetation was positioned differently in the experiment series (either on the right or on the left side), and after adaptation, photos were made. After that a 150 mm long (SL) European perch was placed in the water, and following a 24-hour adaptation period, new photos were taken. In the final setting, the perch was left in the aquarium, but the artificial vegetation was removed. This predatory fish species was selected because under natural circumstances the habitat use of the topmouth gudgeon was presumably affected by this fish. Moreover, European perch feeds on fish (Pavlović *et al.* 2013, Heermann 2008, and specially in Hungary Guti 1992) and, according to literary data, presence of a predator fish individual can induce the most natural response from the topmouth gudgeon (Rowland 1999). The perch typically stayed among the artificial vegetation, close to the bottom. The photos were analysed by computer, by dividing the space of the aquarium into four parts (right and left from the middle line, and above and below the middle line) and number of fish items was recorded in the different sections. Data were analysed by chi-squared statistic. In case of significant ($p < 0.05$) results, Bonferroni 95% confidence intervals were constructed around the used sample proportion for each habitat (Márton 2014, Neu *et al.* 1974, Byers *et al.* 1984). For statistical analysis Graphpad Prism 4.0 was used.

RESULTS

Experiment series I

In the examinations verifying the non-selective nature of the minnow trap a total of 379 fish (of which 329 specimens were caught by minnow trap and 50 were caught by using a lift) were caught and each was measured to the preciseness of 1 mm (in the first case the mean of the SL was 48.85±4.34 mm, in the second case the mean of the SL was 50.1±3.85 mm). Statistics pointed out no significant deviation between the two samples ($p = 0.309$). Non-selectivity of the traps was stated based on the method applied by Morgan *et al.* (1988).

During the examination of the exposure time, a total of 224 and 388 fish were trapped from ponds in two replicate, respectively. By adjusting the relevant figures to 60 minutes, 6.6 fish were caught in a 15 minutes interval on average, while in the 30 minutes interval resulted in 8.9 on average; and in the 60 minutes examination 10.25 fish were caught ($p < 0.001$). Data led to the declaration that the largest number of fish can be collected during the 60 minutes interval, giving presumably the most precise picture about the distribution of the fish. Furthermore, effectiveness of the traps was also measured. Results showed that 91.6% of the minnow traps of 60 minute intervals contained fish, while it resulted 79.17% and 56.25% for the 30 and 15 minutes interval, respectively. Effect of subsequent catches on trapping success at the same place was also investigated resulting in no difference among the occasions($p > 0.05$), therefore, it can be stated that in the ponds under examination topmouth gudgeon lives in such a density that low number of trapping occasions (< 8) on an identical site would not affect the probability of catching.

In the mark-recapture experiments, a total of 995 fish were caught (467, 237 and 291 on different sites), including 18 earlier marked fish of which 17 were caught at the site where previously were marked and 1 was caught at an adjacent sampling site, therefore, the sampling sites being at a distance of 50 m from each other could be considered independent for the purposes of our experiment.

During the habitat use experiment, a total of 461 fish from the two ponds (369 fish from Babat pond I and 91 from Babat pond III) were caught. The average SL (±SD) of the fish age 1+ year was 44.31±9.25 mm in Babat pond I and 50.34±11.6 mm in Babat pond III (Fig. 2). In Babat pond I, the largest number of fish was caught in the pelagial minnow trap in each sample. In the case of Babat pond III, however, the largest number of fish was caught in in the benthal minnow traps in two cases and in the littoral minnow traps in other two cases. In Babat pond I the chi squared test showed inhomogeneous habitat use ($p < 0.001$), as fish preferred the pelagial region and avoided the littoral region ($p < 0.05$) at all the time. Disregarding of one, probably accidental mid-

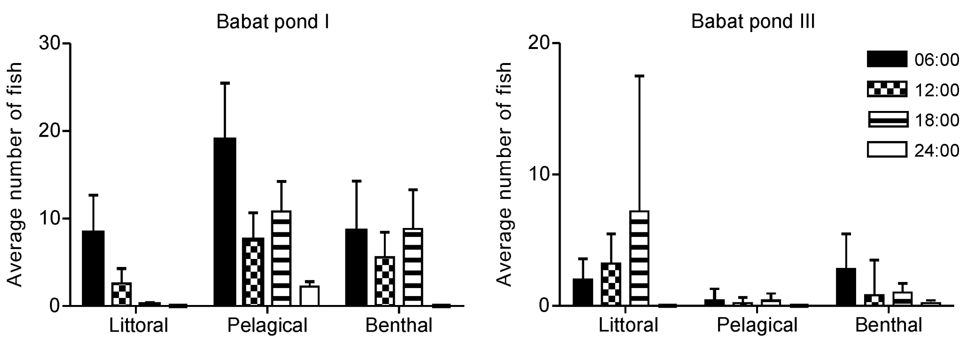

Fig. 2. Number of fish caught by minnow trap from Babat pond I and pond III.

Table 1. Average values of abiotic parameters a(±SD) during trapping.

		Temperature (C°)	Dissolved oxygen (mg/dm³)
Babat I	Littoral	26.52±1.11	10.76±5.47
	Pelagial	26.49±1.05	12.9±57.01
	Benthal	25.04±0.18	1.45±0.89
Babat III	Littoral	29.02±2.18	9.88±2.93
	Pelagial	28.79±2.19	10.91±1.61
	Benthal	25.75±0.75	2.56±1.01

night catch, the alternative hypothesis proved to be true ($p < 0.05$) for all the time in Babat pond III. Post test showed that fish avoided the pelagial region in all the cases, and two times they definitely preferred the littoral region. Temperature and oxygen content were also measured in the environment of the minnow traps and the values in both parameters showed significant differences at the different sampling sites, showed in Table 1. The position of the fish individuals, however, did not show any verifiable correlation with the two measured parameters (correlation analysis, Spearman test: Babat pond I: oxygen level $p = 0.91$, temperature $p = 0.2879$, Babat pond III: oxygen level $p = 0.7025$, temperature $p = 0.8437$)

Experiment series II

The results of the analysis of the 571 photos, suitable for evaluation, showed that in the first setting (no artificial vegetation, no predatory fish) the fish essentially used the sides randomly. The impact of the sides did not show a significant value ($p < 0.05$), and in respect of water depth, the fish used the lower layer of the water. In the case of the second setting (presence of artificial vegetation), the choice of the fish was obvious both in terms of water depth and side preference: it was statistically verifiable that their choice fell on the vegetation side and they chose the bottom of the water in every case. In the third setting (presence of predatory fish and vegetation), the habitat use of fish fundamentally changed: they avoided the previously preferred bottom with vegetation and chose the area close to the water surface in a statistically verifiable manner. Setting number 4 (presence of predatory fish without artificial vegetation) also showed significant difference compared to the first setting: there was a clear preference for the surface water area irrespectively of the sides of the aquariums (Table 2).

Table 2. Results of the aquarium experiments (result of Bonferroni test $p < 0.05$).

		Without plant	With plant	With plant and predator	Predator only
Hatvan	top	NS	NS	*avoid	*preference
	top with plant (if plant is present)	*avoid	NS	*preference	*preference
	bottom	NS	NS	*avoid	*avoid
	bottom with plant (if plant is present)	*preference	*preference	*avoid	*avoid
Babat	top	NS	*avoid	*preference	*preference.
	top with plant (if plant is present)	NS	NS	*preference	*preference
	bottom	NS	NS	NS	*avoid
	bottom with plant (if plant is present)	NS	*preference	*avoid	*avoid

DISCUSSION

This series of examinations investigated the habitat use of topmouth gudgeon from a number of aspects. Preliminary experiments served as a base to elaborate a non-selective sampling procedure for the year 1+ age group that allowed the investigation of up-to-date density of the fish individuals and, as a result, their habitat preference. The results showed significant difference in the case of two ponds where the environmental conditions were very similar (abiotic factors, vegetation, food supply) and only one difference was noticeable: the predator of the topmouth gudgeon (European perch) was present in Babat pond I in a large number, while in Babat pond III, there was no presence of predator fish (the frequency of other predators was presumably similar at both sampling sites, as the vegetation and the disturbance of the ponds were very similar and the two ponds were situated close to each other). While in the first case topmouth gudgeon avoided the areas close to the shore covered by vegetation, in the second case fish showed a definite preference for littoral regions. These observations make the statements of the Polish researchers (Kapusta *et al.* 2008) more sophisticated. In their opinion, the topmouth gudgeon gave a clear preference to areas covered by aquatic vegetation in the summer, but this investigation was conducted on a pond where predatory fish (chub (*Squalius cephalus*) and pike-perch) were present only in a rather limited number. In contrast with the current research, however, Ye *et al.* (2006)

pointed out that at a habitat in China in a complex fish community with a large number of predator fish, topmouth gudgeon showed no preference for any single habitat and was found in all three areas of the examined fish pond community. British researchers arrived at very similar results in a river ecosystem (Beyer *et al.* 2007) and Onikura and Nakajima (2013) found that in irrigation ditches the species exhibited r-selected characteristics and habitat use was unaffected by structural factors (including vegetation). On the other hand, our results are in correlation with findings of researchers focused on different fish species where the prey changed their habitat use as an effect of predator presence (Gotceitas & Colgan 1987, He & Kitchell 1990, Snickars *et al.* 2004). This was deliberately true for fathead minnows (*Pimephales promelas*) (Savino & Stein 2002), a fish species of very similar characteristics like topmouth gudgeon, which moved to the open area in the presence of predator fish hiding in weeded areas. Finally, in the past decades researchers often suggested to reduce the amount of invasive species with the use of predator species (among others Hein *et al.* 2006, Santos *et al.* 2009, Mumby *et al.* 2011) and especially the results of Lemmens *et al.* (2014) provided evidence that management directed to the enhancement of pike (*Esox lucius* Linneaus) populations could strongly contribute to the effective suppression of invasive topmouth gudgeon populations.

On the basis of the above results and formerly cited authors, the zero hypotheses that the habitat use of topmouth gudgeon is determined by the presence of predatory fish is most likely. The experiments conducted in an artificial and, in many respects, simplified environment clearly confirmed the presumption. Irrespective of whether they had previous negative experiences or came from different habitats, topmouth gudgeon responded in an identical manner: by changing their habitat use in the presence of a predatory fish.

The above statement may be interesting from a number of aspects. On one hand, it is essential that a predator using one single habitat is not suitable for the regulation of the topmouth gudgeon population as, owing to its broad feed range and fast adaptation ability, this species can easily avoid the predator. This presumption of Lemmens *et al.* (2014) was proved by our investigation. On the other hand, in a native community, the role of the topmouth gudgeon may change greatly depending on the presence of predator species and the habitat they use. It may be interesting in particular from the aspect that the predator species, introduced for the purpose of limiting the topmouth gudgeon population, may force the topmouth gudgeon into an environment where it was previously not present at all or occurred only in a small number and, by doing that, we may force protected species or those of economic significance to compete with this invasive fish species.

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