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## THE SIGNIFICANCE OF STONE MOROKO, *PSEUDORASBORA PARVA* (TEMMINCK AND SCHLEGEL), IN THE SMALL-SIZED FISH ASSEMBLAGES IN THE LITTORAL ZONE OF THE HEATED LAKE LICHEŃSKIE

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**ABSTRACT.** The aim of the study was to determine changes in the seasonal abundance of stone moroko, *Pseudorasbora parva* (Temminck and Schlegel), and to identify the role this alien species plays in the littoral zone of a heated lake. This study also aimed at defining the habitat preferences of this species and describing the relations between the relative abundance of stone moroko and the occurrence of submerged vegetation. A significant dependence was determined of the degree to which the lake bottom is covered with macrophytes and the occurrence of stone moroko. The fish caught belonged to 14 species and 2 families. Stone moroko preferred habitats that were abundantly overgrown with submerged vegetation and avoided areas devoid of macrophytes. Thus, as the bottom cover increased, so did the relative number of this fish. In light of habitat availability and its food preferences, the abundant occurrence of this species poses a serious threat to the endemic ichthyofauna.

**Key words:** *PSEUDORASBORA PARVA*, INTRODUCED SPECIES, INVASION, HEATED LAKES, MACROPHYTES

## INTRODUCTION

Stone moroko, *Pseudorasbora parva* (Temminck and Schlegel), is one of the most effective invasive species to have inhabited European inland waters in recent years (Caiola and De Sostoa 2002, Gozlan et al. 2002, Cakic et al. 2004, Pinder et al. 2005, Pollux and Korosi 2006). In the waters where it has settled, it prefers shallow, abundantly overgrown areas, where plentiful food resources, a spatially varied environment, and the occurrence of submerged vegetation provide advantageous living conditions. Aspects of the life history of this species that

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predispose it to settling in new aquatic basins include a wide tolerance of environmental conditions, reaching sexual maturity in the first year of life, batch spawning, and nest guarding (Pinder et al. 2005).

Lakes that are connected with a system of canals are a convenient distribution route for alien species of ichthyofauna. The most common sources of alien species introduction include aquaculture, the ornamental fish trade, controlling selected elements of biocenoses, scientific research, the use of such species as bait, and the accidental or natural movement of organisms (Bartley and Subasinghe 1996). By the end of the 1980s, 74 species of fish originating from other continents had been introduced in Europe, while another 60 fish and lamprey species were moved from their natural range of occurrence (Holčík 1991). By the mid 1990s in Poland, 23 alien species were confirmed to occur either periodically or permanently in inland waters (Witkowski 1996).

The stone moroko, a small fish of the family Cyprinidae that naturally inhabits the waters of east Asia (Gozlan et al. 2002), was first confirmed in Europe in 1960 in Romania, and was noted in Poland in 1990 at the Stawno farm near Milicz (Oder River catchment in southwest Poland). Most probably it was introduced along with stocking material of herbivorous fish that had been imported from Hungary several years earlier (Witkowski 1991). By the end of the 1990s, this fish had spread throughout all the regions of Poland inhabiting lakes, ponds, and rivers (Kotusz and Witkowski 1998). The first sighting of stone moroko in Lake Licheńskie was in 2002 (Kapusta 2004), and in subsequent years increases were noted in its abundance and its inhabiting subsequent lakes (Kapusta et al. 2006).

The aim of the current study was to determine the habitat preferences of this alien ichthyofauna species and to follow changes in its abundance throughout one year in a heated lake.

## MATERIALS AND METHODS

### STUDY AREA

Lake Licheńskie (147.6 ha) is located in central Poland near Konin in the Wielkopolsko-Kujawskie Lakeland (52°19'N-18°21'E) (Kondracki 2001). Its trough shape extends from the north to the southwest. Along with four neighboring lakes, Lake Licheńskie is part of a complex connected by a canals network that serves as the

cooling system for the Konin and Pątnów power plants. The high water temperature and its continual exchange throughout the year (at an average of every five days), substantial industrial and communal pollution, and the stocking of the lakes with herbivorous fish species alien to the endemic ichthyofauna have caused a range of disadvantageous changes in Lake Licheńskie. In the 1970s *Najas marina* L. and in the 1990s *Vallisneria spiralis* L. were noted in place of naturally occurring native submerged littoral plants (Hutorowicz 2006).

### FISH CATCHES AND DATA ANALYSIS

Fish were caught in the littoral zone of Lake Licheńskie in April, June, July, August, and September 2004 with an experimental net (length 5 m, depth 0.8 m, mesh size 1.0 mm). Catches were made in the shore zone at six sites (Fig. 1). Fish

from different sampling sites were placed in separate containers and then preserved in a 4% formaldehyde solution. The fixed fish were identified (Pinder 2001, 2005) and measured (body weight to the nearest 0.001 g and total length to the nearest 0.01 mm). A total of 329 stone moroko specimens were analyzed (Table 1).

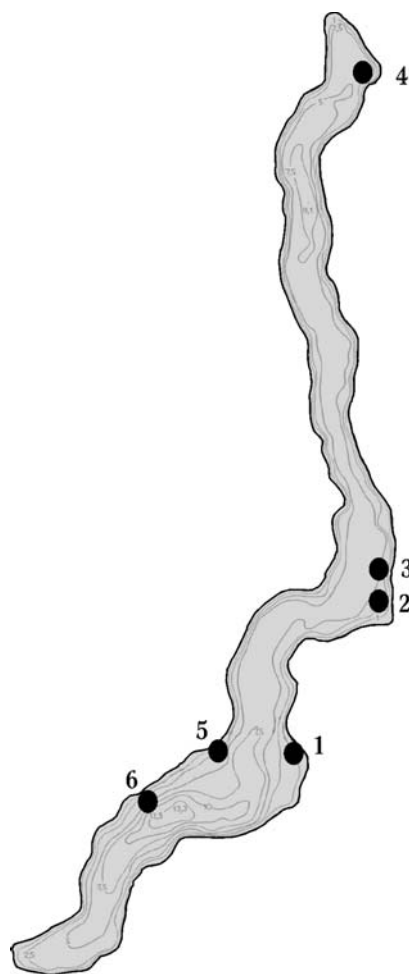


Fig. 1. Location of study stations in Lake Licheńskie.

TABLE 1

Number (N), length and body weight of stone moroko, *Pseudorasbora parva* from Lake Licheńskie

Date	N	Mean total length (mm)	Total length range (mm)	Mean body weight (g)	Body weight range (g)
30 June 2004	17	40.98	19.6-53.6	1.45	0.145-2.840
27 July 2004	90	15.40	6.9-40.9	0.10	0.002-1.350
30 August 2004	120	20.24	7.0-53.2	0.21	0.003-2.500
30 September 2004	165	18.78	8.5-66.2	0.19	0.007-5.340

Physicochemical conditions at the sampling sites were registered when the fish were caught. Oxygen content was measured with a DO meter (HI 9142, Hanna Instruments), while water temperature and pH were measured with a pH meter with a microprocessor (HI 991001, Hanna Instruments). The dependence between the occurrence of submerged vegetation and the relative density of stone moroko was determined by dividing the collected samples based on the quantity of macrophytes occurring at a given fishing site. At each sampling stations the total cover of macrophytes was expressed by the sum of the covers of all plant species. Macrophytes cover was estimated by visual observations of percent cover. Five-degree scale vegetation were used: I – no vegetation; II – 1-25%; III – 25-50%; IV – 50-75%; V – exceeding 75% macrophytes bottom cover.

The analysis of the material was based on determining the relative density (D) and the frequency of occurrence of given species. The evaluation of the frequency of occurrence of fish species was expressed as the frequency index (V), which is the quotient of the number of samples in which a given species occurred and the number of all samples collected. Grouping the samples confirmed in the littoral zone of Lake Licheńskie was performed with cluster analysis. Ward's method was used to perform agglomerations based on the permanence of occurrence and domination of particular species. Euclidean distance was used as the measure of distance, which permitted categorizing the confirmed species into sensible structures known as guilds. Relations between the bottom macrophytes cover and the relative number of stone moroko was determined with nonparametric analysis of variance (ANOVA Kruskal-Wallis) and Spearman rank correlation. Comparing total length of stone moroko in subsequent fishing periods was performed with the Kruskal-Wallis test. Relations between weight and total length were described with polynomial functions. All of the statistical analyses were performed with Statistica 7.1 (StatSoft Inc.).

## RESULTS

### CHARACTERISTICS OF HABITAT CONDITIONS

Environmental conditions (water temperature, oxygen content, pH) did not differ significantly statistically among the sampling sites (Kruskal-Wallis test,  $P > 0.05$ ). Among the designated sampling sites, only station 2 was significantly shallower than the others (Kruskal-Wallis test:  $H = 12.758$ ,  $P = 0.026$ ). Water temperature in the littoral zone of Lake Licheńskie during the study period fluctuated from 16.1 (on 30.09) to 29.2°C (on 27.07), while the dissolved oxygen content ranged from 5.6 (on 01.06) to 20.0 mgO<sub>2</sub> dm<sup>-1</sup> (on 27.07). The water pH in Lake Licheńskie during the study period was slightly basic within the range of 8.14 (on 26.04) to 9.26 (on 29.07). The percentage of bottom area overgrown with macrophytes at the study sites in the littoral zone of Lake Licheńskie ranged from 0 to 100%. The least bottom cover was noted at the study stations in April (0-10%). In subsequent months, the amount of bottom cover increased and was at its maximum in September, when it fluctuated from 65 to 100% (mean 76%). The only exception was station 2, located on the beach, at which vegetation density was similar in each month (from 0 to 20%).

### FISH ASSEMBLAGES

A total of 3122 fish belonging to 14 species and 2 families (Table 2) were noted. Among the species identified, the majority were obligatory or facultative phytophils. Stone moroko comprised 32.6% of all the fish caught, and its permanence of occurrence in the samples was 60%. The other dominant species included bleak, *Alburnus alburnus* (L.), at 31.8% and roach, *Rutilus rutilus* (L.), at 15.3%. Although the number share of roach in the catches was lower than that of bleak, it did occur in the catches more frequently (frequency indices were 50.0 and 36.7%, respectively). The frequency of occurrence of other phytophil species (tench, *Tinca tinca* (L.), rudd, *Scardinius erythrophthalmus* (L.), Prussian carp, *Carassius gibelio* (Bloch)) was high ( $\geq 30\%$ ), but relative density was low. The share of the remaining fish species did not exceed 10%. The rarest (3.3%) and least abundant ( $< 0.1\%$ ) species in the catches included sunbleak, *Leucaspis delineatus* (Heck.), ruffe, *Gymnocephalus cernuus* (L.), and chub, *Leuciscus cephalus* (L.).

TABLE 2

List of species caught in the littoral zone of Lake Licheńskie divided into reproductive groups  
(D – dominant, V – frequency of occurrence)

Ecological reproductive group		Species name	D	V
Non-guarding and open substratum egg scattering				
Lithophil	Chub	<i>Leuciscus cephalus</i> (L.)	< 0.1	3.3
Phyto-lithophils	Roach	<i>Rutilus rutilus</i> (L.)	15.3	50.0
	Bleak	<i>Alburnus alburnus</i> (L.)	31.8	36.7
	White bream	<i>Abramis bjoerkna</i> (L.)	1.8	23.3
	Bream	<i>Abramis brama</i> (L.)	0.1	6.7
	Ruffe	<i>Gymnocephalus cernuus</i> (L.)	<0.1	3.3
Phytophils	Rudd	<i>Scardinius erythrophthalmus</i> (L.)	6.4	46.7
	Tench	<i>Tinca tinca</i> (L.)	3.5	50.0
	Prussian carp	<i>Carassius gibelio</i> (Bloch)	4.1	30.0
	Carp	<i>Cyprinus carpio</i> L.	0.2	10.0
Nonguarders, brood hiders				
Ostracophil	Bitterling	<i>Rhodeus sericeus</i> (Bloch)	3.7	13.3
Guarding nesters				
Phytophils	Pikeperch	<i>Sander lucioperca</i> (L.)	0.3	6.7
	Sunbleak	<i>Leucaspis delineatus</i> (Heck.)	<0.1	3.3
Phyto-lithophil	Stone moroko	<i>Pseudorasbora parva</i> (Temminck and Schlegel)	32.6	60.0

The species that occurred in the catches at fairly high frequencies and numerous (stone moroko, bleak) or fairly numerous (roach, rudd, tench) were divided into separate branches of the classification tree (Fig. 2). Another guild was comprised of species that occurred infrequently or in very small numbers. Of these fish, those with fairly high frequency of occurrence were grouped on a separate branch of the classification tree (Prussian carp, bitterling, *Rhodeus sericeus* (Bloch), white bream, *Abramis bjoerkna* (L.)). A third group was comprised of species that occurred in the catches very rarely and in very small numbers (pikeperch, *Sander lucioperca* (L.), bream, *Abramis brama* (L.), carp, *Cyprinus carpio* L., chub, ruffe, sunbleak).

## STONE MOROKO POPULATION

The density of stone moroko in the littoral zone of Lake Licheńskie increased in each subsequent month of the study (Fig. 3). In April, 497 fish were caught, but there were no stone moroko noted. In June, however, 17 of these fish were caught, which was less than 3% of all the fish caught in this month. The most fish were caught in July (968), but stone moroko comprised barely 11% of the fish caught. A distinct increase in

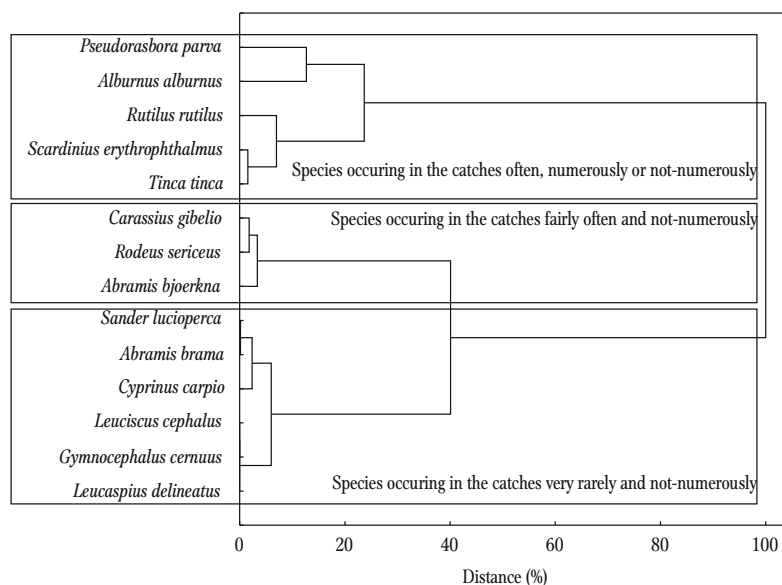


Fig. 2. Hierarchical classification of fish species occurring in the catches made in Lake Licheńskie.

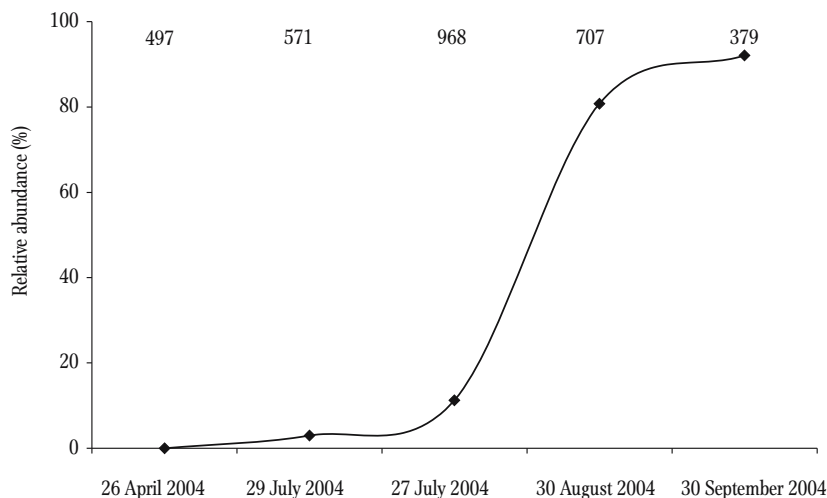


Fig. 3. Relative stone moroko density in the littoral of Lake Licheńskie (at the top the total number of fish caught is given).

the density of stone moroko in the littoral zone of Lake Licheńskie was not noted until August and September (at 80 and 92%, respectively).

The relative density of stone moroko increased along with the development of submerged vegetation (Fig. 4). A significant dependence between the degree of bottom

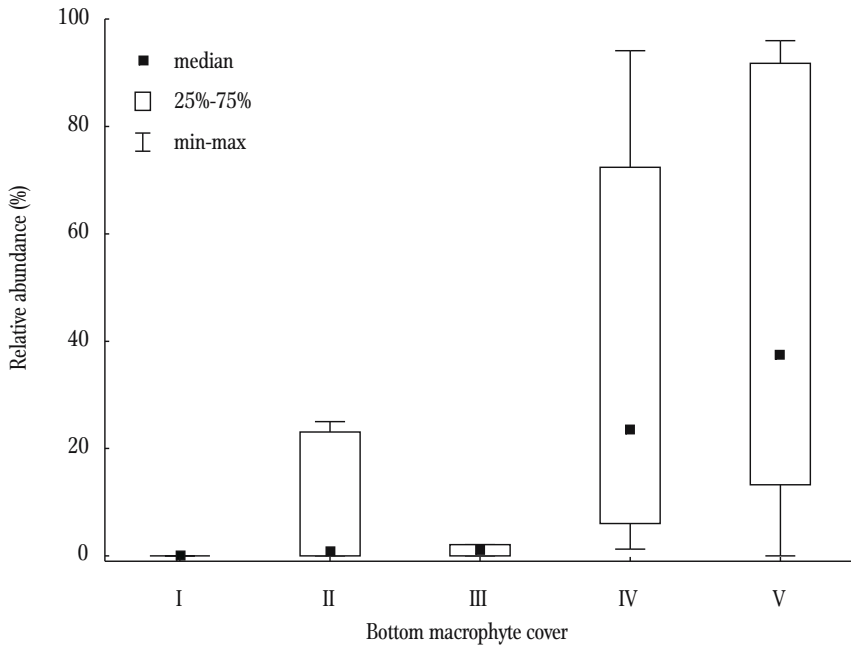


Fig. 4. Comparison of degree of macrophyte bottom cover and the abundance of stone moroko in the littoral zone of Lake Licheńskie. Macrophyte bottom cover: I – no vegetation. II – 1-25%, III – 25-50%, IV – 50-75%, V – over 75%.

macrophyte cover and the occurrence of stone moroko was confirmed (Kruskal-Wallis test:  $H = 11.276$ ,  $P = 0.024$ ). The results of correlation analysis confirm that as bottom macrophyte cover increased, so too did the relative number of stone moroko (Spearman correlation,  $r = 0.537$ ,  $P < 0.05$ ).

The specimens caught in June had the greatest mean total length (Fig. 5). In subsequent months, the mean TL of the fish caught was lower, even if specimens occurred in the catches that were of a maximum body size larger than that in June. This resulted from the appearance in the littoral zone of a large quantity of stone moroko larvae and fry that followed spawning. The largest specimen (66.2 mm in length) was caught on 30.09. The dependence between length (TL) and body weight in stone moroko was described with a polynomial function (Fig. 6). Specimens of a total length of 30-33 mm attain a weight of approximately 0.5 g, while after exceeding a length of 38 mm, they achieve a weight of 1.0 g.



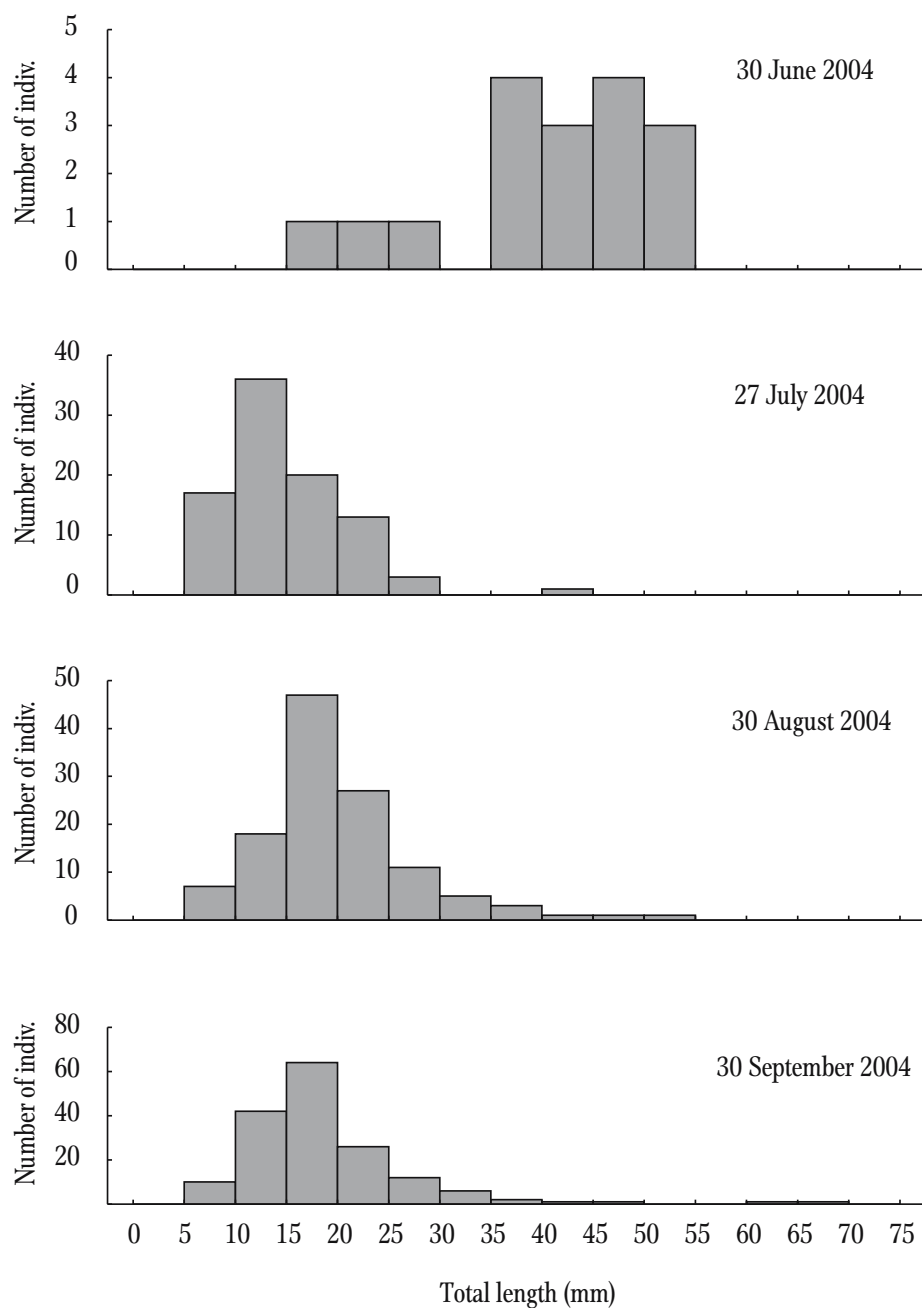


Fig. 5. Total length distribution of stone moroko in the littoral zone of Lake Licheńskie.

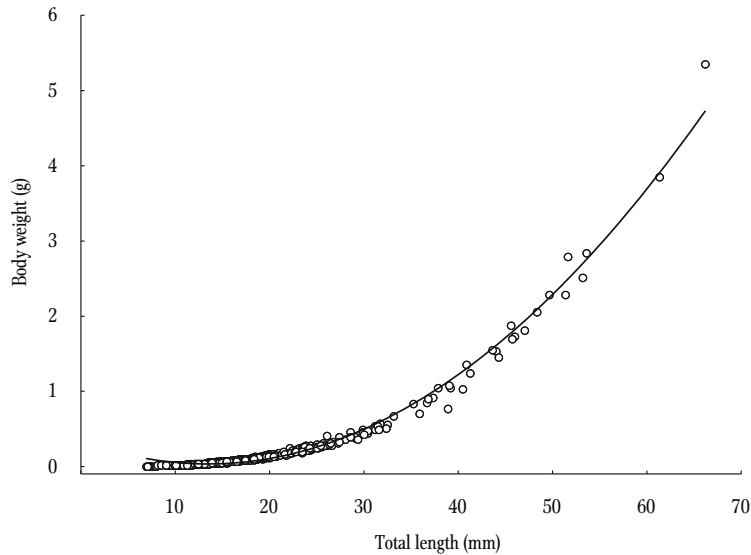


Fig. 6. Dependence between weight and total length of stone moroko.

## DISCUSSION

The analysis of the structure of the ichthyofauna and archival data on the abundance of predatory fish (Wilkońska and Żuromska 1983, Ciepielewski and Dominiak 2004) indicate their impact on the stone moroko population in Lake Licheńskie is minimal. During the current study, the abiotic conditions (water temperature, oxygen content, pH) did not differ significantly. The factors that did differ significantly among the study sites in the littoral zone of Lake Licheńskie were the area of lake bottom cover with macrophytes and the abundance of invertebrate fauna. Spatial differentiation in the occurrence of stone moroko was likely linked to the occurrence of vegetation. The spatial differentiation in the structure of the bottom of the littoral zone in Lake Licheńskie is not significant, and the majority of this bottom zone is sandy or sand covered with a small quantity of organic detritus. Areas with gravel and stones occupy a very small area of the littoral zone. Water temperature, oxygen content, and pH were not factors that differed significantly among the sampling stations during the study. The only factor that was significantly different among the sampling stations was the degree to which the bottom was overgrown with vegetation. The occurrence of macrophytes in lakes in the temperate zone is seasonal. In Lake Licheńskie the dominating species of

submerged vegetation is *V. spiralis*, which grows in over 90% of the shallow littoral (Hutorowicz and Dziedzic 2003). The results of the current study confirm that there is a significant dependence between the share of stone moroko in the fish groups and the occurrence of macrophytes – overwhelmingly *V. spiralis*. Increasing bottom cover with submerged vegetation corresponded to an increased share of stone moroko in the fish groups. Pollux and Korosi (2006) presented similar observations from their work in Holland; greater stone moroko frequency was noted in floodplain lakes with dense vegetation than in rivers devoid of macrophytes.

The occurrence of stone moroko has been confirmed in the inland waters of many European countries (Bianco 1988, Marković and Simović 1997, Caiola and De Sostoa 2002, Cakic et al. 2004), although some incidences of its accidental introduction have not been permanent (Copp et al. 2007). This species was first noted in the Konin lakes in 2002 (Kapusta et al. 2006) when the first specimens of it were caught in Lake Licheńskie. In subsequent years this species was noted at increasing density in this lake and it began the gradual colonization of the neighboring lakes. The dispersal of this species has occurred through the system of canals that connect the lakes. The results of catches made in the littoral zones of the Konin lakes in the 2002-2006 period (Kapusta et al. 2006) suggest that locks and cascades and other constructions as well as strong water flow hamper this species in its settlement of other lakes. Of the five lakes comprising the power plant water cooling system, stone moroko has been noted in four. Only in Lake Gośławskie, located to the west of the system and isolated by a series of locks, a pumping station and the direction of water flow in the canals, has stone moroko not been noted. As in Lake Licheńskie, in the other lakes this species prefers littoral zones overgrown with macrophytes.

Stone moroko occurred in the lake littoral zone seasonally. This phenomenon might also be explained by the occurrence of macrophytes. In April, when the littoral zone was nearly devoid of macrophytes, no stone moroko were caught. In subsequent months, however, more and more specimens of this species were caught as the submerged vegetation developed. Length analysis indicates that the majority of these were juveniles from the 2004 spawning. Only in June, did specimens from older age classes (> 0+) dominate the catches. This raises the question of which parts of Lake Licheńskie did these specimens inhabit prior to the development of submerged plants in the shallow littoral zone? Due to the lake's thermal regime (year-round water heating, no ice

cover), submerged vegetation does occur in winter, but only in the deeper parts of the littoral zone ( $> 2$  m, Hutorowicz unpublished data). Decreases in water temperature, which are most apparent in the shallow littoral zone ( $< 1$  m), and the occurrence of submerged vegetation in the deeper zones of the lake are the likely causes for the stone moroko to change its place of occurrence. This hypothesis needs to be confirmed with the appropriate research.

The results presented here regard fish caught with selective gear; and since larval fish occurred even in September it was impossible to use any other type of gear. Bearing in mind this limitation, it is tempting to propose that stone moroko plays a significant role in the lake littoral zone. This is confirmed by the analysis of the fish groupings in the littoral zone of Lake Licheńskie. The abundant occurrence of macrophytes in the littoral zone of the lake (Hutorowicz and Dziedzic 2003), offer excellent conditions for phytophils. However, the domination in the catches of the accidentally introduced stone moroko, indicates that *V. spiralis*, an equally exotic species to Polish waters, offers particularly good conditions for *P. parva*. In 2004, it was the most abundant and most frequently occurring species. In terms of numbers, only the bleak stock matched its abundance. The consequences of the dispersal of stone moroko are not difficult to predict. The juveniles of this species are planktivorous (Hliwa et al. 2002), thus, they compete for food with other species subsequently impacting abundance. Additionally, parasites carried by alien ichthyofauna species can lead to declining abundance or even the dying out of other species in a given area (Gozlan et al. 2005, Pinder et al. 2005).

The results of the study showed that the spatial and temporal variation in the occurrence of stone moroko corresponded with the occurrence of macrophytes, and that this fish species finds good feeding and reproductive conditions in this aquatic vegetation. As the area of bottom covered with submerged vegetation increased, so too did the relative density of this fish species. The stone moroko's preferences for inhabiting littoral areas with abundant submerged vegetation suggests that the endemic species of phytophils will be under the greatest impact from *P. parva*.

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## STRESZCZENIE

ZNACZENIE CZEBACZKA AMURSKIEGO, *PSEUDORASBORA PARVA* (TEMMINCK AND SCHLEGEL) W ZESPOLE RYB NIEWIELKICH ROZMIARÓW W LITORALU PODGRZEWANEGO JEZIORA LICHEŃSKIEGO

Celem badań było określenie sezonowych zmian liczebności czebaczka amurskiego, *Pseudorasbora parva* (Temminck and Schlegel) oraz roli tego obcego gatunku w litoralu podgrzewanego jeziora (rys. 1). W pracy podjęto próbę określenia preferencji siedliskowych oraz scharakteryzowano relacje pomiędzy względną liczebnością czebaczka amurskiego a występowaniem roślinności zanurzonej. Analizie poddano łącznie 329 osobników czebaczka amurskiego (tab. 1). Złowiono ryby należące do 14 gatunków i 2 rodzin (tab. 2, rys. 2). Stwierdzono sezonową zmienność występowania czebaczka amurskiego w litoralu jeziora (rys. 3) oraz istotną zależność pomiędzy stopniem pokrycia dna hydrofitami a jego względnym zagęszczeniem (rys. 4). Czebaczek amurski preferował siedliska obficie porośnięte roślinnością zanurzoną, a unikał siedlisk pozbawionych hydrofitów. Wraz ze wzrostem pokrycia dna hydrofitami wzrastała względna liczebność czebaczka amurskiego. Największą średnią długością całkowitą charakteryzowały się osobniki złowione w czerwcu (rys. 5). W kolejnych miesiącach średnia długość całkowita łowionych ryb była niższa, nawet jeśli w odłowach występowały osobniki o maksymalnych rozmiarach ciała większych niż w czerwcu. Zależność pomiędzy długością a masą ciała opisano za pomocą funkcji wielomianowej (rys. 6). Obfite występowanie tego gatunku w powiązaniu z dostępnością siedlisk i preferencjami pokarmowymi wskazują na duże zagrożenie dla rodzimej ichtiofauny.