Electronic Journal of Ichthyology
March, 2007 **1**: 1-14

NEW PATTERNS IN DANUBIAN DISTRIBUTION OF PONTO-CASPIAN GOBIES – A RESULT OF GLOBAL CLIMATIC CHANGE AND/OR CANALIZATION?

Ákos Harka[1] and Péter Bíró[2]

[1] Lajos Kossuth Secondary School, H-5350 Tiszafüred, Táncsics str. 1., Hungary; [2] Balaton Limnological Research Institute, Hungarian Academy of Sciences, H-8237 Tihany, Kuno Klebelsberg str. 3., Hungary,
Corresponding author:
[2] P. Bíró, Balaton Limnological Research Institute, Hungarian Academy of Sciences, H-8237 Tihany, Kuno Klebelsberg str. 3., Hungary, Tel.: 36-87-448-244; Fax: 36-87-448-006; e-mail: **biro@tres.blki.hu**

Abstract: Since the 1970's, dispersion of several Ponto-Caspian fish species in Central Europe, mainly along the Danube-valley, has been registered. Especially certain gobies have reached long distances, two of them (*Proterorhinus marmoratus, Neogobius kessleri*) have already been distributed in Germany. In parallel with this horizontal distribution, an upstream vertical migration can also be observed into the mountain zones of lowland and hilly country rivers. Horizontal and vertical expansions substancially do not differ from each other, because fish species in both cases have an upstream-oriented migration.

Explanations concerning expansions cleared up only the modes of distribution. However, for widening of areas, the permanent settling of species is also required. In their acclimatization, some factor may play significant role. The first is probably the rising temperature of waters, the second is possibly the canalization resulting in a series of dammed river sections. As the local warming of certain river sections and construction of further reservoirs continue, the westward-migration of more warmwater fish species and further distribution of already present ones are highly probable.

Key words: Ponto-Caspian gobies, distribution, global climate change

Introduction

A number of fish species of Ponto-Caspian origin occur in Central Europe, which migrated upstream from the area of Black Sea along the Danube water regime, and became distributed at the central areas of the continent (Bănărescu 1992). A part of them is postglacial immigrant and „native" at that area since thousands of years (following the Würm Glacial Period), however, there are recent ones, mainly among gobies. The area of distribution of species in the last group expands rapidly.

Beside horizontal spreading, a migration in vertical direction can also be observed in recent times. In mountain zones of rivers, species, earlier known only from lower sections, occur more often. This paper provides a draft of these processes and attempts to reveal the main reasons of this phenomenon.

Materials and Methods

During the last decades, we participated in several fish faunistic expeditions at the drainage area of River Danube, mainly in the Carpathian Basin. Data were collected with international cooperations from rivers Ondava and Laborec (Slovakia), from rivers Uz and Latorica (Ukraine) during 1999 (Harka et al. 2000). Collections were made in Rumanian territories from R. Barcau in 1998 (Harka et al. 1998), from R. Crasna in 2000, from rivers Viseu, Iza and Sapanta, the side rivers of Tisza, in 2001 (Harka et al., 2002), respectively. During 2002, the fish fauna of R. Tur was studied (Harka et al. 2002). With the exception of Tisza, all rivers were studied from their source up to estuary. Direct measurements proved the occurrence of unusually high water temperatures in the mountain sections of these rivers. During the systematic fish collections, alterations of species composition and appearance of alien species in the mountain zones have also been observed.

Expansions of gobies in Hungarian standing and running waters, e.g. in rivers Tisza, Drava, Raba, Körös, Zala, as well as in Lake Balaton and Kis-Balaton Water Reservoir were experienced (Harka 1988, 1992a, 1992b, 1993, 1996b; Bíró & Paulovits 1994; Harka & Juhász 1996; Bíró et al. 2002; Harka & Szepesi 2004). Since 2002, fishes were collected from characteristic biotopes from rivers Sebes-Körös, Berettyó and Zagyva, all belonging to the drainage area of R. Tisza.

During faunistic collections, usually a 3x2 m bag seine with two marginal rods was operated. Its knot-to-knot mesh size of 6x6 mm allowed the capture of Y-O-Y specimens. Lift nets and hand nets were also used for samplings in peculiar habitats. The last ones could be used effectively in densely vegetated areas. Identification of species were made according to Bănărescu (1964), Berinkey (1966), Harka (1997), Holčik (2002), Lelek (1987), Pintér (2002).

Besides own investigations, personal communications and unpublished data of some colleague provided more information. A picture was drawn on the expansion processes of species according to the time and topograhy of their observations. However, systematic monitoring was carried out only in a few places, and pilot-scale studies showed different intensities in various water bodies (Table 1).

The species expansions were evaluated in context of long-time data set of air- and water temperatures. Data on air temperature formations were provided by National Meteorogical Survey (Szalai & Szentimrey 2001). Water temperature changes were based on measurements of Water Research Institute for Water Resources (VITUKI), Budapest, and of Transtiscian Environmental Protection and Water Authority, Debrecen. Daily surface temperature data of rivers for the period from 1 January 1954 to 31 December 2003 were used, which were measured in a 5-10 cm depth at 7 o'clock a.m. each day. Accordingly, monthly and annual averages were calculated with the Microsoft Excel Computer software. Trends in the temperature changes were then determined.

Results

A systematic survey of the more significant faunistic data, documenting recent immigration and spreading of Ponto-Caspian elements, has been given as follows.

Tube-nosed goby – *Proterorhinus marmoratus* (Pallas 1814)

The first representative of gobies in Central-Europe was the tube-nosed goby. This small-sized fish, which was described from the littoral waters of the Black Sea at the beginning of the 19th century, was found later in freshwaters, too. Probably it was present in the lower stretch of R. Danube, because it was discovered at Budapest, 2000 kilometers off the estuary, in 1872 (Kriesch 1873). Soon after, it was observed at the vicinity of Bratislava (Koelbel 1874), then in Lake Balaton, the largest shallow lake in Hungary (Vutskits 1895), as well as from Neusidler See (Lake Fertő), partly belonging to Austria and Hungary (Mika & Breuer 1928).

Table 1. List of rivers studied

Name of the rivers	Countries in which the river flows through	Flows into	Approximative geographic coordinates of the estuary
Barcau (Berettyó)	Rumania (RO), Hungary (H)	Sebes-Körös	21^{o} 07' - 46^{o} 59'
Bodrog	Slovakia (SK), Hungary (H)	Tisza	48^{o} 08' - 21^{o} 25'
Crasna (Kraszna)	Rumania (RO), Hungary (H)	Tisza	22^{o} 19' - 48^{o} 09'
Drava (Drau, Dráva)	Austria (A), Hungary (H), Croatia (HR)	Duna	18^{o} 54' - 45^{o} 32'
Dyje (Thaya)	Austria (A), Czech Republic (CZ)	Morava	16^{o} 57' - 48^{o} 36'
Eger Stream	Hungary (H)	Tisza	20^{o} 43' - 47^{o} 41'
Hron	Slovakia (SK)	Danube	18^{o} 45' - 47^{o} 49'
Ipel (Ipoly)	Slovakia (SK), Hungary (H)	Danube	18^{o} 52' - 47^{o} 49'
Iza	Rumania (RO)	Tisza	23^{o} 51' - 47^{o} 56'
Körös (Cris)	Rumania (RO), Hungary (H)	Tisza	20^{o} 11' - 46^{o} 43'
Laborec	Slovakia (SK)	Latorica	21^{o} 55' - 48^{o} 31'
Latorica	Ukraine (UA), Slovakia (SK)	Bodrog	21^{o} 52' - 48^{o} 32'
Marcal	Hungary (H)	Raba	17^{o} 35' - 47^{o} 40'
Morava	Czech Republic (CZ), Slovakia (SK)	Danube	16^{o} 59' - 48^{o} 11'
Mur (Mura)	Austria (A), Hungary (H)	Drava	16^{o} 53' - 46^{o} 19'
Ondava	Slovakia (SK)	Bodrog	21^{o} 49' - 48^{o} 28'
Porecka	Serbia–Montenegro (SC)	Danube	22^{o} 17' - 44^{o} 29'
Raba (Raab, Rába)	Austria (A), Hungary (H)	Danube	17^{o} 40' - 47^{o} 42'
Sajó (Slaná)	Slovakia (SK), Hungary (H)	Tisza	21^{o} 07' - 47^{o} 57'
Sapanta	Rumania (RO)	Tisza	23^{o} 40' - 47^{o} 59'
Sebes-Körös (Cris Repede)	Rumania (RO), Hungary (H)	Körös	20^{o} 59' - 46^{o} 56'
Tisa (Tisza, Theiss)	Ukraine (UA), Rumania RO), Slovakia (SK), Hungary (H), Serbia–Montenegro (SC)	Danube	20^{o} 16' - 45^{o} 08'
Tur (Túr)	Rumania (RO), Hungary (H)	Tisza	22^{o} 36' - 48^{o} 06'
Uz (Uh)	Ukraine (UA), Slovakia (SK)	Laborec	21^{o} 59' - 48^{o} 38'
Váh (Vág)	Slovakia (SK)	Danube	18^{o} 08' - 47^{o} 45'
Viseu (Visó)	Rumania (RO)	Tisza	24^{o} 09' - 47^{o} 55'
Zagyva	Hungary (H)	Tisza	20^{o} 13' - 47^{o} 10'
Zala	Hungary (H)	Lake Bala-ton	17^{o} 16' - 46^{o} 43'

Areas of occurrence of *P. marmoratus* completed in 1957, when the species was collected from River Tisza at Szeged (Southern Hungary), 170 km from R. Danube (Berinkey 1972). Its occurrence here was confirmed by Sterbetz (1963), who discovered new specimens 10 km upstream in 1960.

In Slovakia, during 1947-1968, besides the inundation areas and side arms of River Danube, the species was observed in downstream near to estuaries of northern rivers Morava, Váh, Nitra, Hron, Ipel and in their adjacent canals (Hensel 1995; Holčik 2002). These findings did not modify significantly the borders of areas registered until the end of the 19th century. The area of distribution of the tube-nosed goby in the Danube basin remained essentially unchanged in accordance with a map scheduled by Bíró (1972), which was accepted also by Lelek (1987) without any modification (Figure 1A).

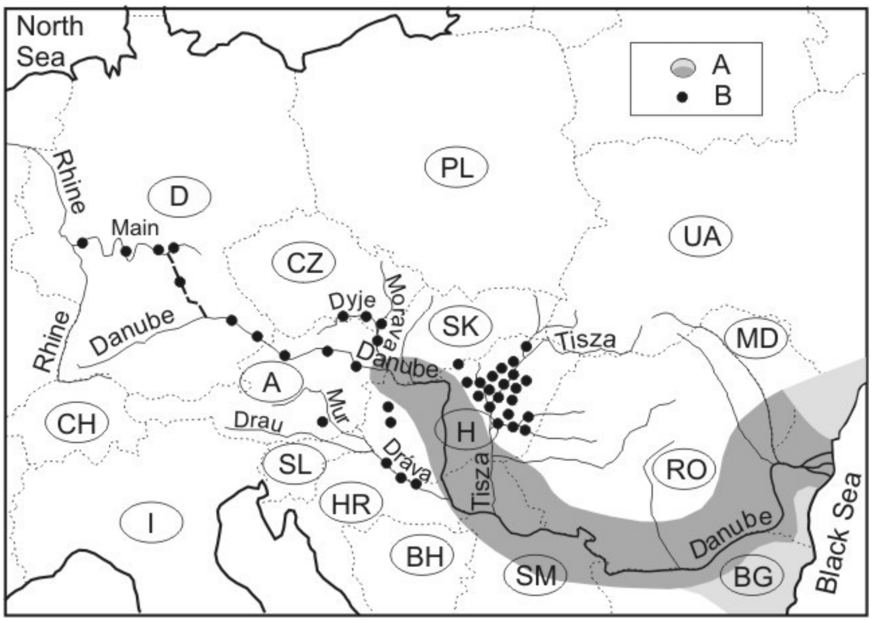


Figure 1. Alterations in area of distribution of the tube-nosed goby (*Proterorhinus marmoratus*) A: earlier area of distribution (darker colour refers to the system of R. Danube) after Lelek (1987), B: significant, recent findings

The first signs of its spreading appeared as early as in the 1970's, when its area of occurrence has moved away with 200 km upstream of the Austrian stretch of Danube from Wienna to Linz (Ahnelt 1988). However, it should be noted that Balon (1967) described the species in the river up to Linz already a decade earlier.

During the successive years tubenose goby penetrated forward upstream along the main river and side arms. Within River Danube, it reached Germany in 1985, where the first capture took place at Passau, and after a few years 100 km further up it was found at Regensburg (Reinartz et al. 2000).

Since the 1980's, its intensive expansion along the Hungarian rivers of second order was observed. First it was found in River Tisza 200 km upstream as compared to earlier findings (Harka 1988), then the species was collected from R. Körös running into Tisza from Rumania, and then came up from the lower reach of R. Drava, forming the Croatian-Hungarian border, as well. (Harka 1990, 1992a). Its insignificant expansion in West-Hungarian rivers e.g. Marcal, Rába (Harka 1991, 1992b) and Ipoly (Ipel) has also been observed, the last one forming the border between Slovakia and Hungary (K. Györe personal communication).

The tube-nosed goby appeared in Czech Republic in 1994 (Hensel 1995). Its first finding was a lowland reservoir near the city Musov in River Dyje flowing into River Morava (Lusk & Halacka 1995), where from it spread away up to the Austrian border during the following years. An insignificant upstream distribution was observed in northern side-rivers of R. Dyje and R. Morava (Lusk et al. 2000; Prásek & Jurajda 2000). The rapid expansion of the species neither was interrupted at the turn of this century, nor during 1997-2003. Although, a relatively less upstream penetration was registered along R. Drava (Sallai 2002), it was discovered in the vicinity of Graz, 200 km further up in the Mura-valley (Friedl & Sampl, 2000). In Eastern Hungary, it has mainly been distributed along the middle reach of R. Tisza (Harka & Szepesi 2004). However, its upstream spreading distance is also significant, because it reached R. Bodrog, a side river, in 2003 (Z. Sallai personal communication). This goby becomes more and more common even in the drainage area of R. Körös, flowing into R. Tisza from East and was collected in 2003 near to the Hungarian-Rumanian border (Harka 1996b).

In 1997, related to its expansion, a significant breaking-through happened in Germany. The tube-nosed goby, probably via R. Danube and shipping canal constructed in 1992, reached River Main (Reinartz et al., 2000), and accordingly, a free way opens for its migration in the direction of the North Sea. During the last years, *Proterorhinus marmoratus* became fairly common in the middle stretch of R. Main and some specimens were caught from the lower section of Rhein-Main-Danube canal (O. Born personal communication).

Monkey goby – *Neogobius fluviatilis* (Pallas 1814)

Originally it was also a downstream fish of rivers running into the Black Sea. During the 1960's, it was known in R. Danube only below Orsova (Bănărescu, 1964), downwards the estuary of R. Porečka (Ristić 1977). Therefore, its sudden appearance in Lake Balaton in 1970, proved to be an ichthyological sensation (Bíró 1971, 1972). At the new biotop it seemed isolated, but in 1984, the species was collected from the lower Hungarian stretch of R. Danube (Pintér 1989), which is reflected by the map of distribution according to Lelek (1987) (Figure 2A).

In successive years its expansion seemingly stopped, but in 1993 its explosion-like propagation was observed in a reservoir constructed at the middle section of River Tisza („Tisza-tó" reservoir), as earlier in Lake Balaton (Harka 1993), respectively. That time this appeared as isolated habitat, but later on it was discovered that the species was present in both the lower and middle reaches of the river in Serbia and Hungary (Guelmino 1994, Györe et al. 2001).

During the last decade the monkey goby expands in rivulets flowing into L. Balaton (Bíró & Paulovits 1994, Bíró et al. 2002), in the Hungarian-Croatian border-section and in River Tisza and its side rivers (Sallai 2002). In River Danube, the species moves upstream: in 2001 it was collected at the Hungarian-Slovak section (Stráňai & Andreji 2001; Sallai 2003; Holčík et al. 2003), and in 2003 it was caught at the lower section of R. Raba, near to R. Danube and the Austrian border (G. Guti personal communication).

Bighead goby – *Neogobius kessleri* (Günther 1861)

A fairly ancient inhabitant in the lower Danube was caught from above the Iron Gate in 1910, at Banatska Palanka settlement (Vutskits 1911). According to Bănărescu (1964) it penetrated in the Danube up to Moldova Noua, and according to Ristić (1977), up to the mouth of R. Tisza (Figure 3A).

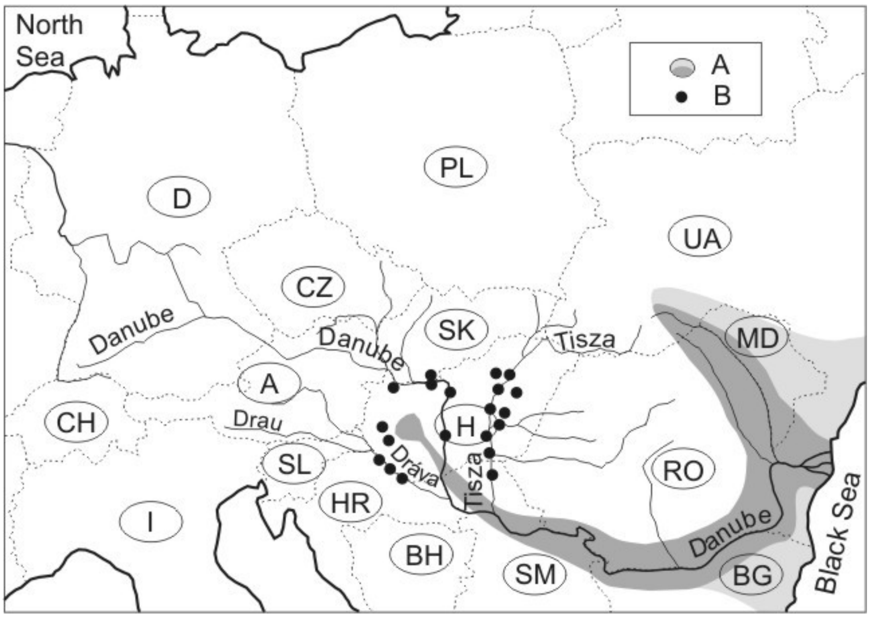
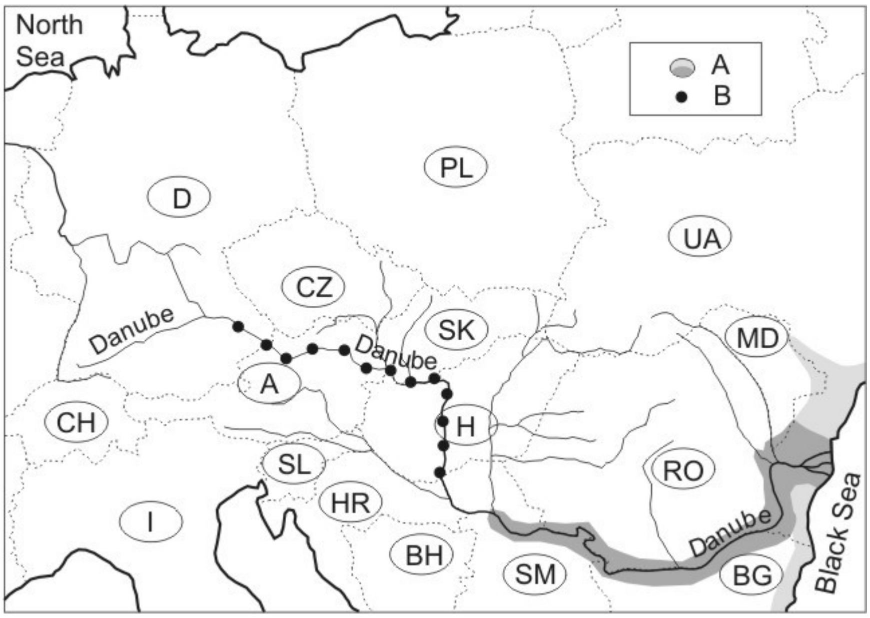


Figure 2. Changes in area of distribution of the monkey goby (*Neogobius fluviatilis*). A: earlier area of distribution of the species (darker at the drainage of R. Danube) (after Bíró 1972), B: significant new findings.



Figuer 3. Changes in area of occurrence of bighead goby (*Neogobius kessleri*) A: earlier area of distribution (darker at the drainage area of R. Danube) (according to Bănărescu (1964) and Ristic (1977)), B: significant new findings

Distribution maps of Blanc et al. (1971), as well as Terofal (1984) represent the whole Hungarian section of R. Tisza as locality, however, no bighead goby has been collected from the Hungarian section of this river yet.

The presence of this species was supposed in the Danube section between Serbia and Budapest already in the early 1990's (Pintér, 2002). Verifying samples were found only in 1996 (Erős & Guti 1997), nearly in the same time of its Slovakian discovery (Kautman 2000; Stránai 1997). In Austria, it was identified even earlier (Zweimüller et al. 1996), and explosion-like distribution was then registered. During a few year, the bighead goby became common along the whole Austrian stretch of R. Danube (Wiesner 2003) and appeared at Straubing city in Germany as early as in 1999 (Seifert & Hartmann 2000). New findings along its migration route are shown in Figure 3.

Round goby – *Neogobius melanostomus* (Pallas 1814)

Contrary to the previous species, the round goby was reluctant to invade flowing waters. Its original habitat in the Danube valley was concentrated only to the estuary and the littoral zone of Black Sea (Bănărescu 1964, Blanc et al. 1971; Müller 1982) (Figure 4A). Upstream distribution was observed in 1997, when they caught in Serbia over Prahovo (Simonović & Nikolić 1996; Simonović et al. 1998), and in 3 years they described at Vienna, Austria (Wiesner et al. 2000). From the Hungarian section of R. Danube, it was found above Budapest in 2001 (Guti et al. 2003), and in 2003 the species was collected at South of Budapest (Sallai Z. personal communication). In Slovakia, the species appeared at the Slovak-Hungarian section of R. Danube and in the estuary of R. Hron in 2003, respectively (Stránai & Bitter, 2003). In Austria, it expands upstream and has already been observed at Krems in recent past (Wiesner 2003). Its distribution in East-Europe is more spectacular, where *N. melanostomus* reached from the Caspian to the Baltic Sea, probably with help of ships.

Racer goby – *Neogobius gymnotrachelus* (Kessler 1857)

According to Bănărescu (1964), the racer goby earlier has reached the estuaries of rivers Mostistea and Calmatui along R. Danube, similarly to the picture drawn by Blanc et al. (1971) (Figure 5A). Its spreading in Serbia was noted below the section of Iron Gate, where it was collected first at Brza Palanka (Hegedis et al. 1991), then at Prahovo settlement (Simonović et al. 1998). Following its discovery here, its upstream distribution in R. Danube seemed to be stopped, however, in 1999 it was found upstream by 1000 km at Bratislava and Viena. In the next year, even new specimens were caught nearby (Kautman 2000, 2001; Ahnelt et. al. 2001).

Finally, two other Gobiids can be mentioned from the Black Sea. One of them is the Ginger goby – *Neogobius eurycephalus* (Kessler 1874) –, which inhabits the area of Danube Delta (Otel et al. 1994), and the other is the Syrman goby – *Neogobius syrman* Nordmann 1840 –, which is very sporadic in the rivers, and is even rare in the vicinity of the Sea. In 1997 it was discovered in the River Danube at Baja, Southern Hungary (Guti 1999).

Discussion

There are several explanations for the spreading of Ponto-Caspian gobies. Beside active and spontaneous immigration, the illegal introduction by aquarists, the introduction by chance with ballast-water

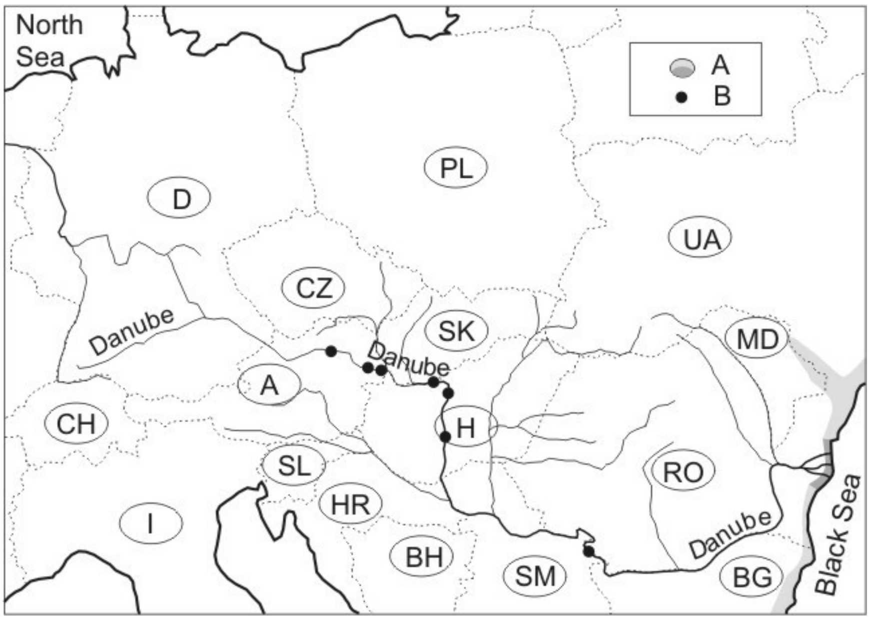


Figure 4. Modifications in area of distribution of round goby (*Neogobius melanostomus*). A: previous area of distribution of the species (darker at the drainage area of R. Danube) (after Müller 1982), B: significant new findings.

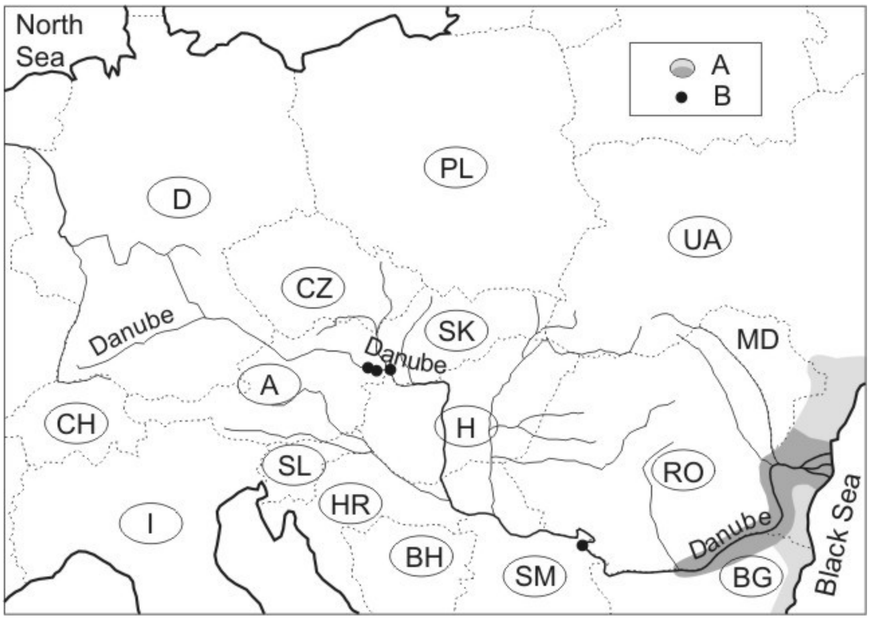


Figure 5. Changes in the area of distribution of the racer goby (Neogobius gymnotrachelus) A: earlier area of distribution (darker tone refers to the Danube system) (after Blanc et al. 1971), B: new findings

of ships, or by eggs sticking to the outer surface of ships are also possible (Bíró 1972; Ahnelt et al. 1998; Guti 1999, 2000; Lusk et al. 2000; Holcík et al. 2003). Probably it is a complex process, in which all the above reasons may play some role, however, there is no explicit answer, why this process became speeded up during the last couple of decades. First it must be cleared up what reasons allow the accomodation of fish species appearing in new areas. Analyzing the spreading of gobies, it is striking that their pioneer specimens were usually found in those water bodies, where the water temperature was higher as compared to the surrounding water regimes. These habitats, in some cases, are connected to hot springs, and in most cases, they occur in temperate shallow lakes, reservoirs or in dammed river sections.

The first sample of the *Proterorhinus marmoratus* was caught in a hot-spring canal running into River Danube at Budapest, or in the outlet of Hévíz-spa at Keszthely (Lake Balaton), and not from the River Danube itself. Dense populations were formed in the warmer „Tisza-tó" reservoir, or in the dammed section of River Körös, or lately in the reservoirs of River Dyje. The present pioneer specimens reached the drainage area of River Rhein through the connected and dammed sections of the upper-Danube and the Danube-Main-Rhein canal. The invasion-like mass appearance of *Neogobius fluviatilis* was observed in Hungary first in Lake Balaton with significantly higher water temperature as compared to R. Danube. Later its presence was noticed in the „Tisza-tó" reservoir of even higher water temperature as compared to L. Balaton. Pioneer populations of *Neogobius kessleri*, *N. melanostomus* and *N. gymnotrachelus* were also described under similar conditions first in Djerdap reservoirs in the vicinity of Iron Gate and then, along the dammed sections of R. Danube at Vienna. Such small-sized fishes have usually been captured in their densely inhabited areas, or where intensive research takes place, because they are not the objects of commercial or recreational fisheries.

Contrary to Ahnelt et al. (1998), Guti's (2000) statement is opposed that *N. fluviatilis* was present earlier in Lake Balaton than in the route leading there. At the beginning, the population discovered in „Tisza-tó" reservoir, 400 km off R. Danube, seemed to be isolated, however, the species was soon collected, when they started to search for it (Guelmino 1994). In case of *N. kessleri* it seemed that an isolated population inhabits the Danube section between Vienna and Bratislava (Zweimüller et al. 1996; Ahnelt et al. 1998), however, it became soon evident that it was present in the whole Hungarian river section (Guti 2000). The situation is nearly the same in the case of *N. melanostomus,* which species was observed in the dammed section of R. Danube over Vienna, than in the more rapid Slovak and Hungarian sections. The species even occurs in the Baltic Sea under comparatively cooler conditions (Sapota 2004).

Based on statements shown above, the continuous expansion is more probable (Bíró 1972; Harka 1993; Guti 2000) than the discontinuous one. The lack of systematic investigations and the rare populations are the reasons of later observations of alien species in lakes, reservoirs and dammed river sections. In addition, gobies are characterized by secreted way of life. Due to their small size and life manner, they become evident following their mass propagation.

Several examples are available indicating the expansion of Ponto-Caspian species along the Danube valley. During the 1980's, distribution and propagation of white-finned gudgeon (*Gobio albipinnatus* Lukasch 1933) was observed in lowland rivers at the Hungarian Great Plain. As a result, *G. albipinnatus* became the most common Gobio species, while *Gobio gobio* (Linnaeus 1758) nearly disappeared from those habitats (Harka 1996a, 1997). At the South-Eastern part of the Czech Republic, in parallel with tube-nosed goby (*Proterorhinus marmoratus*), two other species, the Volga pikeperch (*Sander volgensis* Gmelin 1788) and the Balon ruffe (*Gymnocephalus baloni* Holčík & Hensel 1974) appeared as new species there during the 1990's (Lusk et al. 2000), respectively.

The expansion of the above mentioned species is considered of horizontal feature characterized by the covered distance, while the rising level is insignificant. At the mountainous sections of rivers, a vertical migration can also be observed, when certain lowland and hilly zone species penetrate into the mountain stretches. In the West-Rumanian River Barcau, for example, the ablette (*Leucaspius delineatus* Heckel 1843), in the rivers Tisza and Iza, the roach, *Rutilus rutilus* (Linnaeus 1758) and perch (*Perca fluviatilis* Linnaeus 1758), in R. Latorica the roach and bream, *Abramis brama* (Linnaeus 1758) were collected from the upstream regions, respectively. In the same time, the brown trout (*Salmo trutta* Linnaeus 1758) even extended near to the spring-zone (Harka et al. 1998, 1999, 2000, 2002). Such changes were earlier observed in those rivers, where they constructed reservoirs at their upper stretches. However, such human impacts did not occur in cases mentioned above.

Ardelean et al. (2000) referred to similar phenomena in the uppermost sections of montain rivers of North-Rumania, where they even observed the distribution of common carp (*Cyprinus carpio* Linnaeus 1758), crucian carp, *Carassius carassius* (Linnaeus 1758), pike (*Esox lucius* Linnaeus 1758), common bream, *Abramis brama (*Linnaeus 1758), brown bullhead (*Amiurus nebulosus* Lesueur 1819), chub, *Leuciscus cephalus* (Linnaeus 1758), as well as the undermouth, *Chondrostoma nasus* (Linnaeus 1758), respectively.

Searching for the reasons of vertical migration, one explanation may be the difference in water temperature. In the nose (Chondrostoma) zone of River Iza running into the upper Tisza, e.g. 6 August 2001, the water temperature was as high as 25 ^{o}C, that is with 5 degrees higher than the usual maximum in this zone. Similarly, instead of 13, the water temperature was 17.3 ^{o}C in the trout zone of Sapanța brook, although, both running waters protect natural close conditions (Harka et al., 2002). Certain warming up can be detected even at river sections without any influence of damming. According to measurements of Water Research Institute for Water Resources (VITUKI), it can be established that the annual mean water temperature of River Danube at Budapest increased from 10.2 to 11.5 ^{o}C during the past 50 years. Due to relatively smaller amount, the mean water temperature in River Tisza increased from 11.1 to 12.2 ^{o}C during the last 50 years, exhibiting the same tendency taking place in River Danube.

There are several reasons of warming of rivers. This, e.g. may be casused by reservoirs, of which the water retention and increased surface allow them to accumulate more heat energy. The canalization of rivers may have a stronger effect on the water temperature, when in the final stage, they become a chain of dammed river sections. Water power stations may also play a role, where the cooling-waters are released back as heated by some degrees (heat-pollution), and the communal sewage discharged to the river may also slightly contribute to the warming up.

According to data sets of the National Meteorological Service, the surface temperature in Hungary increased by 0.67 ^{o}C, during the 20th century (Szalai & Szentimrey, 2001). In the central part of the Danube-Basin, 12 % higher temperature increase has taken place over the average. This warming up became striking during the last 30 years, and from 1991 to 2000 became the hottest decade not only of this century, but of the millenium. Similar tendencies can be established from data on water temperatures, however, only 50 years data sets are available.

It is not by chance that the dispersions of tube-nosed goby and monkey goby became evident, and that the other four goby species started their upstream migration during the last 10-15 years. The series of events show significant relationships between the expansion of species and the warming up of certain river sections. On the other hand, it cannot be stated that the expansion of the Ponto-Caspian gobies in Central Europe has been exclusively the result of the increased water temperature. There are many other reasons playing role in the temperature increase of waters, e.g. the consequences of canalization. Alterations in the flow rate of water, in the compositions of stream deposits, in the trophic level, in the building of waterworks may all influence the survival and propagation of the new immigrants. It is highly probable that elevated water temperature and canalization promote significantly the dispersion of species.

Based on the above processes, it can be predicted that other new thermophyll species will probably immigrate into Central Europe from the vicinity of the Black Sea during the next years, causing further changes in the fish communities in various river sections. The other route of migration of West European elements are the Danube-Rhein-Maine canal system.

Acknowledgements

The paper was presented at the 11th European Congress of Ichthyology (6-10 September 2004, Tallin, Estonia) and at the „Ecology of Stream Fish: State of the Art and Future Prospects II. (12-16 June 2006, Léon, Spain). Unpublished data for new findings were provided by Gábor Guti (Hungarian Danube Research Station, Göd), Károly Györe and Zoltán Sallai (Research Institute for Fisheries, Aquaculture and Irrigation, Szarvas). Water temperature data-sets were provided by Béla Csányi and Pál Gulyás (Water Research Institute for Water Resources, Budapest). Literature data and various information were obtained from Harald Ahnelt, Pavol Balázs, Oliver Born, Juraj Holčík. We are very thankful for their help.

This work forms part of National Scientific Research and Development (NKFP) # 3B/0014/2002 and of National Research Fund (OTKA) # T 042622.

References

Ahnelt, H. (1988). Zum Vorkommen der Marmorierten Grundel (*Proterorhinus marmoratus* (Pallas), Pisces: Gobiidae) in Österreich. Annalen des Naturhistorischen Museums in Wien **90(B)**: 31-42.

Ahnelt, H., Bănărescu, P., Spolwind, R., Harka, Á. & Waidbacher, H. (1998). Occurence and distribution of three gobiid species (Pisces: Gobiidae) in the middle and upper Danube region - example of different dispersal patterns? Biologia Bratislava **53(5)**: 665-678.

Ahnelt, H., Duchkowitsch, M., Scattolin, G., Zweimüller, I. & Weissenbacher, A. (2001). *Neogobius gymnotrachelus* (Kessler, 1857) (Teleostei: Gobiidae), die Nackthals-Grundel in Österreich. Österreichs Fischerei **54**: 262-266.

Ardelean, G., Béres I. & Dehelean, I. (2000). [Penetration of certain limnophyll fish species into the Máramaros mountain range]. Acta Biologica Debrecina - Supplementum Oecologica Hungarica **11(1)**: 29. (In Hungarian)

Balon, E. K. (1967). [Evolution of the Danube fishfauna, its recent state and an attempt for the prognosis of further changes after the hidro-electric powers building]. Biologické Práce **13(1)**: 3-121. (In Slovakian).

Bănărescu, P. (1964). Pisces – Osteichthyes. Fauna R. P. Romine, Vol 13. Academiei Republicii Populare Romine, Bucuresti. p. 959. (In Rumanian).

Bănărescu P. (1992). Zoogeography of Fresh Waters Vol. 2. Distribution and Dispersal of Freshwater Animals in North America and Eurasia. AULA-Verl. Wiesbaden. p. 1091.

Berinkey, L. (1966). [Halak – Pisces]. Fauna Hungariae 79. Akadémiai Kiadó, Budapest, p.139.

Berinkey, L. (1972). [Freswater fishes of Hungary and adjacent regions in the collection of the Museum of Natural History]. Vertebrata Hungarica **13**: 3-24. (In Hungarian).

Bíró, P. (1971). [A new goby (*Neogobius fluviatilis* Pallas) from Lake Balaton]. Halászat **64(1)**: 22-23. (In Hungarian).

Bíró, P. (1972). *Neogobius fluviatilis* in Lake Balaton – a Ponto-Caspian goby new to the fauna of Central Europe. Journal of Fish Biology **4**: 249-255.

Bíró, P. & Paulovits, G. (1994). Evolution of fish fauna in Little Balaton Water Reservoir. Verhandlungen der Internationale Vereinigung für Theoretische und Angewandte Limnologie **25**: 2164-2168.

Bíró, P.; Specziár, A.; Keresztessy K., (2002): Fish species assemblages in inflowing waters of Lake Balaton. Verh. Int. Ver. Limnol. **28**: 273-278.

Blanc, M., Bănărescu, P., Gaudet, J.-L. & Hureau, J.-C. (1971). European Inland Water Fish. A multilingual catalogue. FAO, Fishing News (Books) Ltd, London p. 24+393+XIX.

Erős, T. & Guti, G. (1997). [The first record of *Neogobius kessleri* Günther, 1861 in the Hungarian section of the Danube]. Halászat **90(2)**: 83-84. (In Hungarian).

Friedl, T. & Sampl, H. (2000). Erstnachweis der Marmorierten Grundel (*Proterorhinus marmoratus* PALLAS) in der Steiermark (The first record of *Proterorhinus marmoratus* PALLAS in Styria (Austria)). Österreichs Fischerei **53**: 189-191.

Guelmino, J. (1994). [Gobies in the lower section of River Tisa]. Halászat **87(3)**: 133. (In Hungarian).

Guti, G. (1999). [*Neogobius syrman* (Nordmann 1840) in the Hungarian section of the Danube]. Halászat **92(1)**: 30-33. (In Hungarian).

Guti, G. (2000). [Dispersion of Ponto-Caspian gobiid fish (Gobiidae) in the middle Danubian basin]. Hidrológiai Közlemények **80(5)**: 303-305. (In Hungarian with English summary)

Guti, G., Erős, T., Szalóky, Z. & Tóth, B. (2003). [Round goby, *Neogobius melanostomus* (Pallas, 1811) in the Hungarian section of the Danube]. – Halászat **96(3)**: 116-119. (In Hungarian).

Györe, K., Józsa, V., Specziár, A. & Turcsányi, B. (2001). [Fish census in rivers Szamos and Tisza in context of cyanid pollution originating from Rumania]. Halászatfejlesztés **26**: 110-152. (In Hungarian).

Harka, Á. (1988). [Expansion and East-Hungarian appearance of tubenose goby (*Proterorhinus marmoratus*)]. Halászat **81(3)**: 94-95. (In Hungarian).

Harka, Á. (1990). Zusätzliche Verbreitungsgebiete der Marmorierten Grundel (*Proterorhinus marmoratus* Pallas) in Mitteleuropa. Österreichs Fischerei **43**: 262-265.

Harka, Á. (1991). [Additional distribution areas of *Proterorhinus marmoratus* Pallas in Central Europe]. A Természet **42(4)**: 64-65. (In Hungarian)

Harka, Á. (1992a). [Fish fauna of River Drava]. Halászat **85(1)**: 9-12. (In Hungarian).

Harka, Á. (1992b). [Fish fauna of River Raba]. – Halászat **85(4)**: 154-158. (In Hungarian)

Harka, Á. (1993). [Invasion of the *Neogobius fluviatilis*]. Halászat **86(4)**: 180-181. (In Hungarian).

Harka, Á. (1996a). [The distribution of the Gobio species in Hungary]. Halászat **89**: 95-98. (In Hungarian).

Harka, Á. (1996b). [Fish fauna of River Körös]. – Halászat **89(4)**: 144-148. (In Hungarian)

Harka, Á. & Juhász, L. (1996). [Fish Fauna of the Zala River]. – Halászat **89(1)**: 8-10. (In Hungarian)

Harka, Á. (1997). [Fishes of Hungary]. Természet- és Környezetvédő Tanárok Egyesülete, Budapest, p. 175. (In Hungarian).

Harka, Á., Bănărescu, P. & Telcean, I. (1999). Fish fauna of the Upper Tisza. Tiscia monograph series, In Hamar, J. & Sárkány-Kiss, A. (ed.): The Upper Tisa Valley. Szolnok–Szeged–Tirgu Mures, pp. 439-454.

Harka, Á., Györe K., Sallai Z. & Wilhelm, S. (1998). [Fish fauna of the River Berettyó/Barcau]. Halászat **91(2)**: 68-74. (In Hungarian).

Harka, Á., Kosco J., Wilhelm, S. (2000). [Fish fauna of River Bodrog and its tributaries]. Halászat **93(3)**: 130-134., 93(4): 182-184. (In Hungarian).

Harka, Á. Sallai, Z. & Wilhelm, S. (2002). Effects of water pollution and global warming on the fish fauna of the Rumanian tributaries of the River Tisza. Tiscia **33**, 51-58.

Harka, Á. & Szepesi, Zs. (2004). [Appearance and spreading of tubenose goby (*Proterorhinus marmoratus* Pallas, 1811) in the watershed of River Zagyva]. Halászat, **97(1)**: 38-40. (In Hungarian).

Hegediš, A., Nikcevič, M., Mickovič, B., Jankovič, D. & Andjus, R. K. (1991). Discovery of the goby *Neogobius gymnotrachelus* in Yugoslav fresh waters. Arhiv Bioloških Nauka, Beograd, **43(3-4)**: 39-40.

Hensel, K. (1995). *Proterorhinus marmoratus* (Pallas, 1814). – in Barus, V. & Oliva, O. (ed): Mihulovci (Petromyzones) a ryby (Osteichthyes). Fauna ČR a SR **28(2)**: 431-434. Academia, Praha, (In Slovakian).

Holčík, J. (2002). [Our gobies and how to distinguish them]. Biodiverzita ichtyofauny České Republíky **(IV)**: 73-78. (In Slovakian).

Holčík, J. (2003). Changes in the fish fauna and fisheries in the Slovak section of the Danube River: a rewiew. Annales de Limnologie – International Journal of Limnology **39(3)**: 177-195.

Holčík, J., Stránai, I. & Andreji, J. (2003). The further advance of *Neogobius fluviatilis* (Pallas, 1814) (Pisces, Gobiidae) upstream of the Danube. Biologia Bratislava **58(5)**: 967-973.

Kautman, J. (2000). [Three new fish species of Slovakia]. Biodiverzita ichtyofauny České Republiky **3**: 29-36. (In Slovakian)

Kautman, J. (2001). The first occurence of *Neogobius gymnotrachelus* in the Slovak Danube. Folia Zoologica (Brno) **50(1)**: 79-80.

Koelbel, C. (1874). Über die Identität der *Gobius semilunaris* Heck. und *G. rubromaculatus* Kriesch mit *G. marmoratus* Pallas. Verh. Kais.-K. Zool. – Bot. Ges. Wien, **24(2)**, 569-574.

Kriesch, J. (1873): Ein neuer Gobius. Verhandlungen der Kaiserlich-Königlichen Zoologisch-Botanischen Gesellschaft in Wien, **23**: 369-376.

Lelek, A. (1987). The Freshwater Fishes of Europe vol. 9. Threatened Fishes of Europe. Aula.Verlag Wiesbaden, p. 343.

Lusk, S. & Halačka, K. (1995). The first finding of the Tubenose Goby, *Proterorhinus marmoratus*, in the Czech Republic. Folia Zoologica (Brno) **44(1)**: 90-92.

Lusk, S. Lusková, V., Halačka, K. & Lojkásek, B. (2000). [Changes in the species composition of the ichthyofauna in the territory of Czech Republic after 1990]. Biodiverzitá ichtiofauny České Republiky **(III)**: 21-28. (In Slovakian).

Mika, F. & Breuer, G. (1928). Die Fische und Fischerei des ungarischen Fertő (Neusiedlersees). Archivum Balatoni-cum (Tihany) **2**: 116-131.

Müller, H. (1982). Fische Europas. Neumann Verlag, Leipzig–Radebeul, p. 320.

Oțel, V., Nalbant, T. & Bănărescu, P. (1994). [*Neogobius eurycephalus* (Kessler, 1874) (Pisces, Gobiidae), a new species for the fauna of Romania]. An. Stiint. Inst. Cercet. Proiect Delta Dunarii, Tulcea/Romania **III/1**: 181-184. (In Rumanian).

Pintér, K. (1989). [Fishes of Hungary]. Akadémiai Kiadó, Budapest, p. 202. (In Hungarian).

Pintér, K. (2002). [Fishes of Hungary] Second edition. Akadémiai Kiadó, Budapest, p. 222. (In Hungarian).

Prásek, V. & Jurajda, P. (2000). [Expansion of tubenose goby (*Proterorhinus marmoratus*) in the Czech Republic].

Biodiverzita ichtyofauny České Republiky **3**: 127-129. (In Slovakian).

Reinartz, R., Hilbrich, T. & Born, O. (2000). Nachweis der Marmorierten Grundel (*Proterorhinus marmoratus* PALLAS, 1811) im unterfränkischen Main bei Eltmann (Rheineinzugsgebiet) [Finding of the tubenose goby (*Proterorhinus marmoratus* PALLAS, 1811) in the Main-River in lower Franconia near Eltmann (Rhine catchment area)]. Österreichs Fischerei **53**: 192-194.

Ristić, M. (1977). [Freshwater Fishes and Fishing]. – Nolit, Beograd, p. 332. (In Serbian).

Sallai, Z. (1995). [Fish fauna of the River Hortobágy–Berettyó]. A Puszta **13**: 58-72. (In Hungarian).

Sallai, Z. (2002). [Investigation of the fish fauna of the Drava–Mura river system. II. List of species, conclusions]. Halászat **95(3)**: 119-140. (In Hungarian).

Sallai, Z. (2003). [Data on fish fauna of River Danube in the section between Neszmély and Süttő]. A Puszta 2001, **18**: 57-76. (In Hungarian).

Sapota, M.R. (2004). The round goby (*Neogobius melanostomus*) in the Gulf of Gdansk – a species introduction into the Baltic Sea. Hydrobiologia **514**: 219-224.

Seifert, K. & Hartmann, F. (2000). Die Kesslergrundel (*Neogobius kessleri* Günther, 1861), eine neue Fischart in der deutschen Donau. Lauterbornia **38**: 105-108.

Simonović, P. D. & Nikolic, V. P. (1996). Freshwater fish of Serbia: an annotated check list with some faunistic and zoogeographical considerations. Bios (Macedonia, Greece) **4**: 137-156.

Simonović, P., Valković, B. & Paunovic, M. (1998). Round goby *Neogobius melanostomus*, a new Ponto-Caspian element for Yugoslavia. Folia Zoologia (Brno) **47(4)**: 305-312.

.

Sterbetz, I. (1963). [Data on the distribution of hundfish (*Umbra krameri* Walbaum) and tubenose goby (*Proterorhinus marmoratus* Pall.)]. Vertebrata Hungarica **5**: 15-18. (In Hungarian).

Stránai, I. & Andreji, J. (2001). [Monkey goby – (so far) the last invasing species from the gobiids family]. Polovnictvo a rybárstvo Bratislava **53(11)**: 44-45. (In Slovakian).

Stránai, I. & Bitter, P. (2003). [Round goby – sequentially the fourth goby from the genus Neogobius – in the waters of Slovakia]. Polovníctvo a rybárstvo Bratislava **55(10)**: 52. (In Slovakian).

Stránai, I. (1997). [*Neogobius kessleri* in the Danube River]. Polovníctvo a rybárstvo, Bratislava **49(8)**: 33. (In Slovakian).

Szalai, S. & Szentimrey, T. (2001). [Did Hungarian climate warm up?]. Országos Meteorológiai Szolgálat, Budapest, p. 22. (In Hungarian).

Terofal, F. (1984). Süsswasserfische. Hungarian translation Schmidt Egon: Édesvízi halak, 1997. Magyar Könyvklub, Budapest, p. 288 (In Hungarian).

Vutskits, Gy. (1895). [Data to the fish fauna of Balaton and „Hévíz” at Keszt-hely]. Természettudományi Közle-mények **27**: 15-18. (In Hungarian).

Vutskits, Gy. (1911). [A new fish species of our fauna]. Állattani Közlemények, 31-44.

Wiesner, C. (2003). Eingeschleppte Meeresgrundeln in der Österreichischen Donau – Gefahren und Potenziale. Am Fischwasser **2**: 29-31.

Wiesner, C., Spolwind, R., Waidbacher, H., Guttmann, S. & Doblinger, A. (2000). Erstnachweis der Schwatzmundgrundel *Neogobius melanostomus* (Pallas, 1814) in Österreich. Österreichs Fischerei **53**: 330-331.

Zweimüller, I., Moidl, S. & Nimmervoll, H. (1996). A new species for the Austrian Danube, Neogobius kessleri. Acta Universitatis Carolinae. Biologica **40**: 213-218