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SPATIO-TEMPORAL PATTERN OF THE SMALL-SIZED MUSSEL FAUNA IN THE DANUBE ABOVE BUDAPEST

E. BÓDIS

HAS Hungarian Danube Research Station, Jávorka S. u. 14., H-2131 Göd, Hungary, bodler@freemail.hu

A KISTESTŰ KAGYLÓFAUNA TÉR- ÉS IDŐBELI MINTÁZATA A BUDAPEST FELETTI DUNA-SZAKASZON

BÓDIS ERIKA

MTA ÖBKI Magyar Dunakutató Állomás, 2131 Göd, Jávorka S. u. 14.

KIVONAT: A magyarországi kistestű kagylófajokról csak kevés faunisztikai munka készült, mennyiségi adatok egyáltalán nem léteznek, ezért a kistestű kagylófauna mennyiségi vizsgálatai szükségesek. A kutatás célja a kistestű kagylófauna tér- és időbeli mintázatának leírása, valamint az abundancia változások feltárása a Duna eróziós és depozíciós partszakaszain. Mintavételek 2005-ben történtek 4 alkalommal (június, augusztus, szeptember, november) és összesen 4 különböző helyszínen Kismarosnál és Gödnél. A kagylófauna minél pontosabb felméréséhez különböző gyűjtési módszereket használtunk: Surber mintavevőt (0,25 x 0,25 x 0,05 m), valamint 4 és 19 cm-es átmérőjű core mintavevőt. Az összes mintavételi helyet tekintve 14 faj került elő 3 családból, ami a magyar Duna-szakasz kagylófaunájának 82,4%-t, az országos kagylófaunának pedig 63,6%-t teszi ki. Az előfordult fajok között szerepel két invazív faj (*Corbicula fluminea*, *Dreissena polymorpha polymorpha*) és 3 országosan ritka faj (*Pisidium amnicum*, *Sphaerium rivicola*, *Sphaerium solidum*). A leggyakoribb 5 kagyló fajnév szerinti sorrendben: *Corbicula fluminea*, *Pisidium amnicum*, *Pisidium henslowanum*, *Pisidium supinum*, *Sphaerium solidum*. A legmagasabb denzitás értékek a *Pisidium supinum* (1088 egyed m^{-2}) és a *Corbicula fluminea* (736 egyed m^{-2}) fajnál jelentek meg a kismarosi mintavételi helyen novemberben. A denzitás értékek 1 m^2 felületű és 5 cm vastagságú alzatrétegre vonatkoznak. A legnagyobb diverzitással és abundanciával jellemezhető időpont november volt, egy jelentős vízállás csökkenés után. A legkisebb diverzitás és abundancia értékek júniusban, 3 hónapos magas vízállás után, valamint szeptemberben, időszakos áradások után adódtak. A kismarosi mintavételi hely, iszap és homok alzatösszetétellel a legalkalmasabb élőhely a kagylófajok többsége számára, a legmagasabb összesített abundancia értékek itt figyelhetőek meg. A gödi kavics és homok alzatösszetétellel leírható mintavételi hely csak néhány kagylófaj számára alkalmas, amit a legalacsonyabb összesített fajszám is jelez. Az összesített fajszám és denzitás összehasonlításakor a core mintavevő bizonyult eredményesebbnek, egyes fajok gyűjtésénél azonban a két mintavételi módszer eltérő hatékonyságú volt. A nagy core mintavevő használatakor a *Sphaerium rivicola* is előkerült, ami egy ritka faj Magyarországon, populációinak száma és denzitása folyamatosan csökken a *Corbicula fluminea* megjelenése óta. A kis core mintavevővel vett minták egyedszám adatai folyamatosan csökkentek a mélyebb alzatrétegek irányába, ami mutatja, hogy az ideális élőhely a kagylók számára a legfelső 5 cm-es alzatréteg.

ABSTRACT: Only some faunistical studies were written about the small-sized mussel fauna in Hungary, but there are not any quantitative data about these species. For this reason the quantitative aspects of their research is necessary. The aim of our investigation was the description of the spatial and temporal changes and also the abundance variations of the small-sized mussel fauna in the erosion and deposition zones of the River Danube. Samples were taken 4 times in 2005 (June, August, September, November) at 4 different sampling sites. To reveal the abundance of mussel fauna as accurate as possible several sampling techniques were used such as Surber sampler (0,25 x 0,25 x 0,05 m), large core sampler (19 cm in diameter) and small core sampler (4 cm in diameter). Regarding all of the sampling sites altogether 14 small-sized mussel species of 3 families were found, which presents 82,4% of the small-sized mussel fauna of the Hungarian Danube section and 63,6% of that of the nationwide fauna. Two of them (*Corbicula fluminea*, *Dreissena polymorpha polymorpha*) are invasive and three species (*Pisidium amnicum, Sphaerium rivicola, Sphaerium solidum*) are rare in Hungary. The most abundant 5 species were in alphabetical order: *Corbicula fluminea, Pisidium amnicum, Pisidium henslowanum, Pisidium supinum, Sphaerium solidum.* The highest density was detected in the case of *Pisidium supinum* (1088 ind. m^{-2}) and *Corbicula fluminea* (736 ind. m^{-2}) in November at Kismaros. The density values refer to 1 m^2 surface area of the 5 cm depth upper layer of the sediment. The most diverse and most abundant assemblages were found in November after a period of decreasing water level. The least diverse and abundant samples characterized June after a three-month long period of high water, and September after intermittent floods. Kismaros with a bottom texture of mud and sand is the most suitable place for the majority of mussels, so the highest total abundance was observed here. The sampling site at Göd with the bed sediment of pebbles, cobbles and sand is suitable only for some species, so the number of species was the lowest at this spot. Comparing the total species number and the density of mussels, large core sampler proved to be more effective, but concerning each species, the efficiency of the two sampling methods was different. With the use of large core sampler *Sphaerium rivicola* was also recorded, which is a rare species in Hungary, and the number and density of its populations has been decreasing since the appearance of *Corbicula fluminea.* In general the number of individuals sampled by small core sampler gradually decreased in the direction of deeper sediment layers, which means that the ideal environment for the mussels is the upper 5 cm layer of the sediment.

Key words: Corbiculidae, Dreissenidae, Sphaeriidae, spatio-temporal pattern

Introduction

Much of the hydrobiological studies on freshwater molluscs have been directed at those groups that are best known ecologically, larger bivalves and snails. In comparison, the ecology of small-sized but abundant mussels, especially in large rivers, is poorly known. These species of Hungarian mussels belong to three families: Corbiculidae, Dreissenidae and Sphaeriidae. The first two families are represented by only three species in Hungary, while the family Sphaeriidae („pea" mussels or „fingernail" clams) has higher species richness (19 species). Data about these mussels are insufficient because their identification is problematic due to their tiny body and simple shell architecture.

The investigation of small-sized mussels has a considerable importance in many fields. As filter-feeding organisms they have significant role in the flux of matter and energy of detritus and they are a connecting link between the primary production and the detritus chain. They contribute to the selfpurification of water due to their organic matter filtration effect. They have a significant function in the nutrient dynamics of waters and in the aquatic food web as important food sources for fishes, birds and insects.

Only some faunistical studies were written about the small-sized mussel fauna in Hungary (VARGA et al. 1998-99, PINTÉR and SUARA 2004, BÓDIS and OERTEL 2005, BÓDIS 2006, BÓDIS et al. 2006), and there are not any quantitative data about these species. For this reason the quantitative aspects of their research is necessary. The aim of our investigation was the description of the spatial and temporal changes and also the abundance variations of small-sized mussel fauna in the erosion and deposition zones of the River Danube.

The exploration of quantitative aspects of the small-sized mussel fauna can clarify their functional role in the flux of matter and energy of detritus as well as about the effects of human impacts (dams, fragmentation, catastrophic pollution). This knowledge could be useful in the practice of European Water Frame Directive, in the assessment of ecological status of the considerably modified river sections and in the following rehabilitation.

This study, the survey of quantitative aspects and spatio-temporal pattern of small-sized mussel fauna in a Hungarian Danube section was made on the basis of samples collected in the framework of investigation called : „The structural and functional role of macro- and meiobenthos in a detritus food-chain of the River Danube" in the HAS Hungarian Danube Research Station.

Methods and materials

Investigations were performed in the main arm of the Danube, upstream of Budapest. The sampling sites were different both in the respect of hydrological characteristics and composition of sediment. Deposition zones were studied at two sections of the river. At Kismaros (1688 river km) the riverside sampling place (KIM1) had low velocity of water (0.1 m s^{-1}), bed sediment of mud and sand. The other deposition site was at the lower end of the island at Göd (1669 river km). At the outlet of the side arm (GOD1) low velocity and bed sediment of mud and sand were characteristic. The sampling place at the outer shoreline of the island (GOD2) was characterized by high velocity (0.8 m s^{-1}), sand and fine-sand dominated bed sediment. Erosion zone was sampled at Göd (1668 river km), where the riverside of the Danube (GOD3) was characterized by fast velocity of water (0.75 m s^{-1}) and very coarse bed sediment, which consists of pebbles, cobbles and sand.

To reveal the abundance of mussel fauna as accurate as possible several sampling techniques were used such as Surber sampler (S, 0,25 x 0,25 x 0,05 m), large core sampler (B, 19 cm in diameter) and small core sampler (C, 4 cm in diameter).

Bed sediment samples were collected by large core sampler to depth of 5 cm and by Surber sampler at KIM1, GOD2 and GOD3. 5 parallel samples were collected by Surber sampler at each sampling sites and dates. Two deposition sites (KIM1, GOD1) were sampled to depth of 15 cm by small core sampler. Three sediment layers were separated in each core by depth (0-5 cm, 5-10 cm 10-15 cm, respectively). Small and large core samplers were used twice for the sake of reliability.

Samples were taken four times in 2005: on 21st of June after three-month long period of high water, on 15th of August and on 23rd of September after intermittent floods, and on 08th of November after a period of decreasing water level.

Samples taken by large core sampler were frozen. Samples collected by Surber sampler were fixed in-situ in 4 % formaldehyde solution. Samples gathered by small core sampler were separated immediately after sampling. Simultaneously several environmental parameters (bottom texture, current velocity) were recorded. After separation mussels were preserved in 70% ethanol. Only the living individuals were identified, empty shells were omitted.

Identification of the *Pisidium* and *Sphaerium* genus was made after RICHNOVSZKY and PINTÉR (1979), SOÓS (1957), ELLIS (1962), GLÖER and MEIER-BROOK (1998). The density values refer to 1 m^2 surface area of the 5 cm depth upper layer of the sediment.

Results

Faunistical investigation

Regarding all of the sampling sites altogether 14 small-sized mussel species of 3 families were found (Table 1), which presents 82,35% of the small-sized mussel fauna of the Hungarian Danube section and 63,64% of that of the nationwide fauna. Two of them (*Corbicula fluminea*, *Dreissena polymorpha polymorpha*) are invasive mussels and three species (*Pisidium amnicum, Sphaerium rivicola, Sphaerium solidum*) are rare in Hungary (FEHÉR et al. 2004).

In comparison of the species lists given by different sampling techniques, there is difference among the occurrence of species and the number of species.

With the help of Surber sampler 13 species were collected, and two species (*Musculium lacustre, Sphaerium corneum*) occurred only with the use of this method.

With the help of large core sampler 12 species were collected, and one species (*Sphaerium rivicola*) appeared only with the use of this method. The species number of each sampling place and date was higher with the application of large core sampler method (Figure 1).

Table 1. The list of small-sized mussel fauna in Hungary and their occurence in different sampling sites, dates and with application of different sampling methods. The appearence of *Pisidium obtusale* and *P. pseudosphaerium* in the Hungarian Danube section is presented by FRANK et al. (1990). Legends: S – Surber sampler, B – large core sampler.

Small-sized mussel fauna of Hungary	Codes	Hungarian Danube section	Hungarian Danube section (data from literature)	Hungarian Danube section at Kismaros and Göd																							
				June						August						September						November					
				S			B			S			B			S			B			S			B		
				KIM1	GOD1	GOD2	KIM1	GOD1	GOD2	KIM1	GOD1	GOD2	KIM1	GOD1	GOD2	KIM1	GOD1	GOD2	KIM1	GOD1	GOD2	KIM1	GOD1	GOD2	KIM1	GOD1	GOD2
CORBICULA																											
Corbicula fluminea (O.F. Müller, 1771)	Cflu	+		+	+	+	+	+	+	+	+	+	+	+	+	+	+	+		+	+	+	+	+	+	+	+
Corbicula fluminalis (O.F. Müller, 1771)		+																									
DREISSENA																											
Dreissena polymorpha polymorpha (Pallas, 1771)	Dpol	+								+												+	+	+	+		
SPHAERIUM																											
Musculium lacustre (O.F. Müller, 1774)	Mlac	+			+					+							+										
Sphaerium corneum (Linnaeus, 1758)	Scor	+								+																	
Sphaerium nucleus (S. Struder,1820)																											
Sphaerium rivicola (Lamarck, 1818)	Sriv	+																							+		
Sphaerium solidum (Normand, 1844)	Ssol	+			+					+									+			+	+		+		
PISIDIUM																											
Pisidium amnicum (O.F. Müller, 1774)	Pamn	+		+	+		+				+		+	+		+	+	+					+		+		
Pisidium casertanum (Poli, 1791)	Pcas	+						+									+						+				
Pisidium casertanum var. ponderosum (Stelfox, 1918)	Pcap	+							+									+				+		+			
Pisidium henslowanum (Sheppard, 1823)	Phen	+			+		+		+		+			+									+		+	+	
Pisidium milium Held, 1836	Pmil	+																									
Pisidium moitesserianum Paladilhe, 1866	Pmoi	+																					+		+		
Pisidium nitidum (Jenyns, 1832)	Pnit	+							+	+	+											+	+	+			
Pisidium obtusale (Lamarck, 1818)	Pobt		+																								
Pisidium personatum (Malm, 1855)	Pper	+																									
Pisidium pseudosphaerium J. Favre, 1927			+																								
Pisidium pulchellum Jenyns, 1832																											
Pisidium subtruncatum Malm, 1855	Psub	+			+					+			+					+					+	+	+	+	+
Pisidium supinum A. Schmidt, 1851	Psup	+		+	+	+				++	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Pisidum tenuilineatum Stelfox, 1918																											

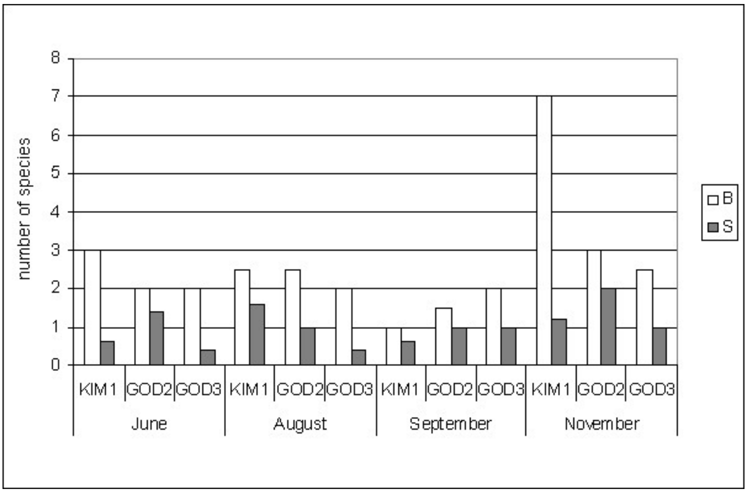

Figure 1. Number of species collected by different sampling methods. Legends: S – Surber sampler, B – large core sampler.

Abundance

The most abundant 5 species were in alphabetical order: *Corbicula fluminea, Pisidium amnicum, Pisidium henslowanum, Pisidium supinum, Sphaerium solidum.* Regarding the different sampling methods difference can be detected in the abundance of each mussel species.

With the use of Surber sampler the most abundant 5 species were in order: *Pisidium supinum, C. fluminea, S. solidum, P. amnicum, P. henslowanum* (Figure 2). With the use of large core sampler the most abundant 5 species were in order: *C. fluminea, P. supinum, P. amnicum, P. henslowanum, S. solidum* (Figure 3).

Density

The highest values of density was in order: 1088 ind. m^{-2} (*Pisidium supinum,* KIM1, November, Surber sampler), 736 ind. m^{-2} (*Corbicula fluminea*, KIM1, November, Surber sampler), 735,19 ind. m^{-2} (*Corbicula fluminea*, GOD3, November, large core sampler), 716,81 ind. m^{-2} (*Pisidium supinum*, GOD3, August, large core sampler).

Regarding the different sampling sites and dates, the highest values of density were found at KIM1 and GOD3 in November (Figure 6).

Distribution of number of species and individuals in different sediment layers

The number of individuals sampled by small core sampler gradually decreased in the direction of deeper sediment layers (Figure 7). The number of species decreased at Göd in the deeper sediment layers, however at Kismaros the highest species number was detected in the layer between 5-10 cm (Figure 8).

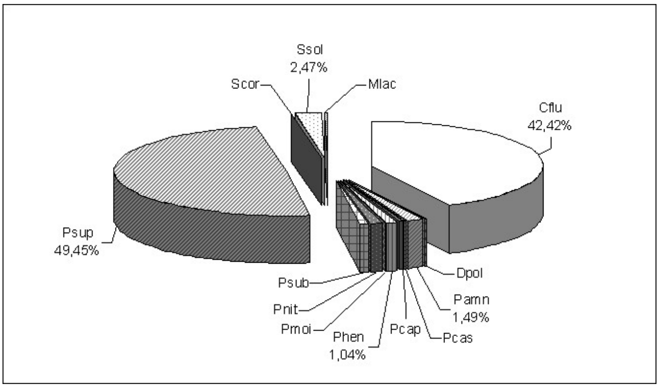

Figure 2. Relative abundance of mussel species collected by Surber sampler. Legends: see Table 1.

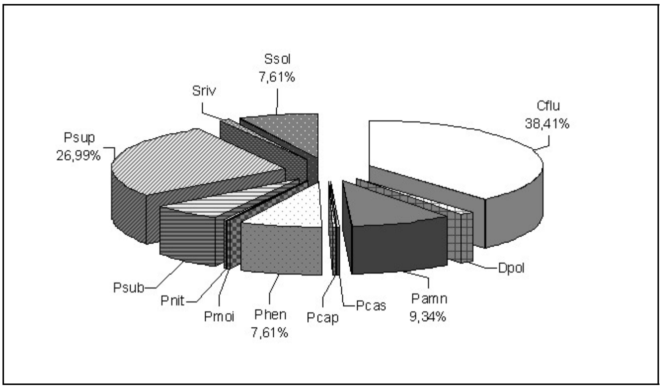

Figure 3. Relative abundance of mussel species collected by large core sampler. Legends: see Table 1.

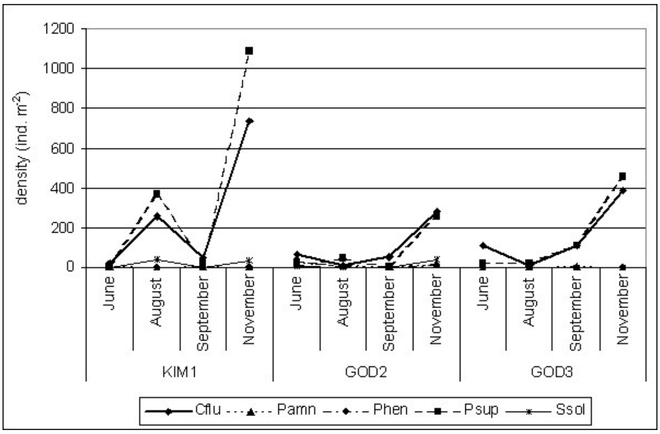

Figure 4. Density of mussel species collected by Surber sampler. Legends: see Table 1.

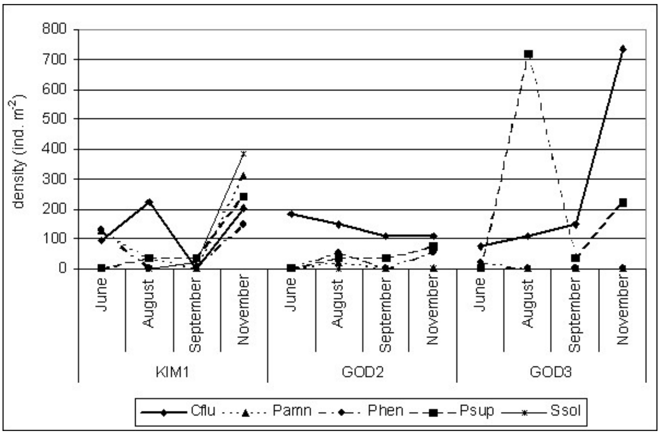

Figure 5. Density of mussel species collected by large core sampler. Legends: see Table 1.

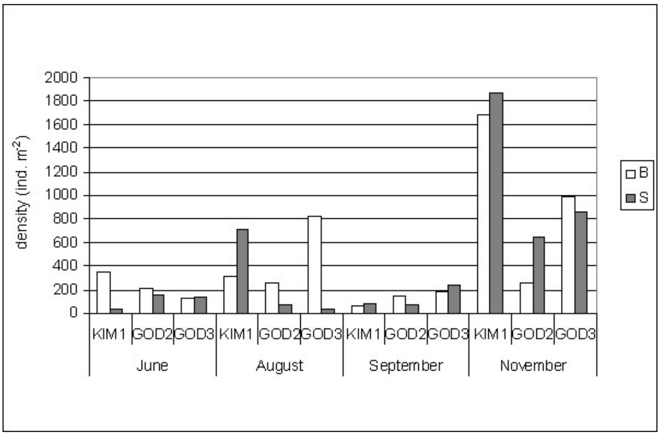

Figure 6. Density of mussels collected by different sampling methods. Legends: S – Surber sampler, B – large core sampler.

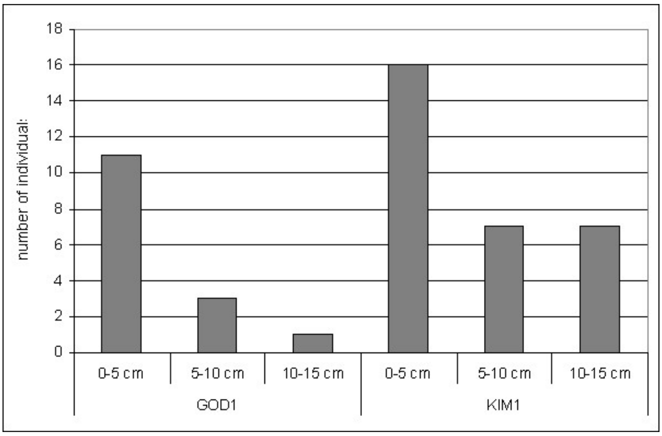

Figure 7. Number of individuals in the different sediment layers.

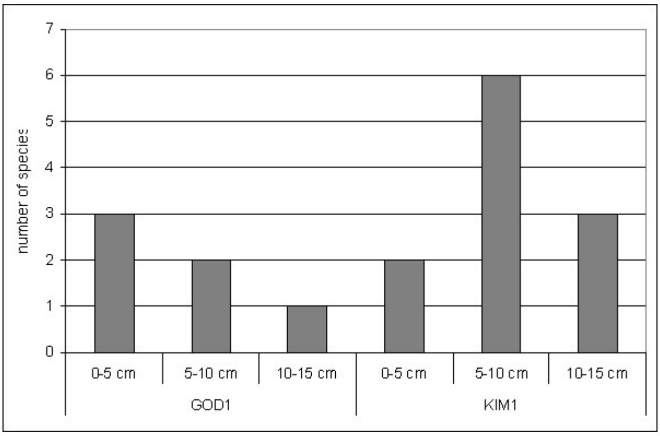

Figure 8. Number of species in the different sediment layers.

Sampling sites and dates

In comparison of the samping sites the highest total species number appeared at GOD2 with the application of Surber sampler and at KIM1 with the use of large core sampler. The lowest total species number can be indicated at GOD3 with both sampling tecniques, which means that the least diverse site was GOD3 from the point of view of mussels. The most abundant sampling site was KIM1, while the lowest total number of individuals was detected at GOD2 (Table 2).

Regarding the sampling dates the most diverse and most abundant assemblages were found in November after a period of decreasing water level. The least diverse and abundant samples characterized June after a three-month long period of high water, and September after intermittent floods (Table 3).

Table 2. Total number of species and total abundance at different sampling sites. Legends: S – Surber sampler, B – large core sampler.

	KIM1	GOD2	GOD3
total number of species (S)	1.6	2.0	1.0
total number of species (B)	7.0	3.0	2.5
total number of individuals (S)	169.0	58.6	79.8
total number of individuals (B)	65.5	24.0	58.0

Table 3. Total number of species and total abundance in different sampling dates. Legends: S – Surber sampler, B – large core sampler.

	June	August	September	November
total number of species (S)	1.4	1.6	1.0	2.0
total number of species (B)	3.0	2.5	2.0	7.0
total number of individuals (S)	20.4	51.8	23.8	211.4
total number of individuals (B)	19.0	38.0	10.5	80.0

Discussion

14 small-sized mussel species were recorded in the investigated Hungarian Danube section, which presents 82,35% of the small-sized mussel fauna of the Hungarian Danube section (only 3 species were absent: *Corbicula fluminalis, Pisidium milium, Pisidium personatum,* which require special environmental conditions).

The most abundant 5 species were in alphabetical order: *Corbicula fluminea, Pisidium amnicum, Pisidium henslowanum, Pisidium supinum, Sphaerium solidum.*

In the last years small-sized mussel fauna was enriched by 3 species (*Corbicula fluminea, Corbicula fluminalis, Sphaerium solidum*). The appearance of *Sphaerium solidum* in the Hungarian Danube section was published at first by VARGA and JUHÁSZ (2002), and further occurences was revealed (VARGA et al. 2003), too. Nowadays *Sphaerium solidum*, which is regarded as a rare species in Hungary, is one of the most abundant species in the Hungarian Danube section at Kismaros and Göd. The *Corbicula fluminea* and *Corbicula fluminalis* invasive mussels appeared at first in the lower part of the Hungarian Danube section (CSÁNYI 1998-99). Nowadays due to the rapid expansion, *Corbicula fluminea* is one of the most abundant mussel species in the whole Hungarian Danube section.

Regarding the sampling dates mussels occurred in November with the highest density, which can be explained by the lower water level and by the outstanding high abundance of *Corbicula fluminea* and *Pisidium supinum*. The highest density of species can be detected in the case of *Pisidium supinum* (1088 ind. m^{-2}) and *Corbicula fluminea* (736 ind. m^{-2}) in November at Kismaros. The least diverse and abundant assemblages were found in June and in September. In June samples were collected after a three-month long period of high water, and the samplings in September was performed after intermittent floods. In the period of floods the high current velocity disarranges the bottom of rivers, and carries the sediment in different distances. Among the animals living in the sediment, the small-sized clams are especially endangered, because they can get damaged and die dashing on pebbles, cobbles and against each other.

Considering the sampling sites Kismaros with bottom texture of mud and sand is the most suitable place for the majority of mussels, so the highest total abundance was observed here. The sampling place at GOD3 with the bed sediment of pebbles, cobbles and sand is ideal only for some species, so the number of species was the lowest at this station.

In summary the species number and the density of mussels was higher with the application of large core sampler, but concerning each species, the achievement of the two sampling methods was different. With the use of large core sampler *Sphaerium rivicola* could be recorded, which is a rare species in Hungary, and the number and density of its population has been decreasing since the appearance of *Corbicula fluminea.* This native mussel became endangered, because the invasive competitor *Corbicula fluminea* could replace it to a final disappearance, so the occurrence of *Sphaerium rivicola* at Kismaros is an important data.

With the use of large core sampler in the sediment with 1 m^2 surface and 5 cm depth most of the mussel species could be found in multiple amount.

With the use of Surber sampler *Sphaerium corneum* and *Musculium lacustre* also occured in the samples, and the *Pisidium nitidum* appeared with more abundance in the sediment with 1 m^2 surface and 5 cm depth.

In general the number of individuals sampled by small core sampler gradually decreased in the direction of deeper sediment layer, which means that the ideal environment for the mussels is the upper 5 cm layer of the sediment.

Some species could be found in every sediment layers, but other species occured only in one layer (*Pisidium amnicum, Pisidium subtruncatum, Pisidium nitidum, Musculium lacustre). P. amnicum* and *P. subtruncatum* was recorded in the middle layer (5-10 cm) at Kismaros, while *P. nitidum* appeared only in the upper layer (0-5 cm) at Göd. *Musculium lacustre* was found in the lowest layer (10-15 cm) at Kismaros.

Horizontal and vertical substrate relations in some *Pisidium* species (*P. lilljeborgii, P. hibernicum, P. nitidum*) were investigated by experiments in laboratory and by observations on distribution of the three species in Lake Titisee (MEIER-BROOK, 1969). In experiments *P. nitidum*, which occurred in our samples, too, tended to avoid the fine-grained fraction and migrated into the coarse sediment. In field *P. nitidum* had its greatest abundance in the zone of coarse organic sediment and dense vegetation and its abundance rapidly decreased below this layer. Summarizing the results *P. nitidum* is strongly restricted to biotopes below the sediment surface, but prefers the coarse organic sediment with large-pored interstitial spaces which enable the animal to provide itself with water sufficiently rich in oxigen. Comparing these observations to our results relationship can be shown, because *P.nitidum* appeared only in the upper 5 cm layer of the sediment, which is still well-oxigenated.

At Kismaros many species lived in the middle and lowest sediment layer, which can be explained by the quality of the bottom texture. Both at KIM1 and GOD1 the dominant bed sediment was mud and sand, but at GOD1 the bottom texture was denser, and the current velocity of water was lower, than at KIM1. Probably the deeper sediment layers at KIM1 have higher oxygen content and therefore some mussel species can live there.

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