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Spread and distribution pattern of *Sinanodonta woodiana* in Lake Balaton

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ABSTRACT

Key-words: *Lake Balaton,* Sinanodonta woodiana*,* *biodiversity,* *biological invasion*

The exotic Chinese pond mussel (*Sinanodonta woodiana*) is the biggest bivalve in Europe, it was first reported from Lake Balaton in 2006. In 2011 summer relative abundance and biomass of *S. woodiana* and native unionids were recorded at 21 sampling sites, in order to analyse the speed of dispersion of the Chinese pond mussel and to reveal its possible ecological impacts on native unionids. GPS coordinates of the sampling sites were recorded, spatial distribution of the data shows that high abundances and biomass are characteristic along the northern shore of the lake. In the western part of the lake, in the Keszthely Basin, its biomass may amount to as much as 50–80% of the total unionid biomass. In this basin, comparing these data to the distribution of unionids measured in 1992/93, the impact of *S. woodiana* seems high, as *A. cygnea* has been replaced by *S. woodiana* and the ratio of *A. anatina* reduced from 17.8% to 8.6%. Taking into consideration that *S. woodiana* has so rapidly developed high relative abundance and biomass close to the supposed source of introduction and it has a high spread potential in the lake, future increase in population size (and dominance) can be expected.

RÉSUMÉ

Schéma de propagation et distribution de *Sinanodonta woodiana* dans le lac Balaton

Mots-clés : *lac Balaton,* Sinanodonta woodiana*,* *biodiversité,* *invasion biologique*

L'anodonte chinoise (*Sinanodonta woodiana*) est le plus grand bivalve en Europe, elle a été signalée dans le lac Balaton en 2006. En été 2011, l'abondance relative et la biomasse de *S. woodiana* et des Unionidés indigènes ont été estimées dans 21 sites d'échantillonnage, afin d'analyser la vitesse de dispersion de l'anodonte chinoise et de révéler ses impacts écologiques possibles sur les Unionidés indigènes. Les coordonnées GPS des sites d'échantillonnage ont été enregistrées, la distribution spatiale des données montre que les fortes densités et biomasses sont rencontrées le long de la rive nord du lac. Dans la partie ouest du lac, dans le bassin de Keszthely, sa biomasse peut s'élever jusqu'à 50–80% de la biomasse totale des Unionidés. Dans ce bassin, en comparant ces données à la distribution des Unionidés mesurée en 1992/93, l'impact de *S. woodiana* semble élevé, *A. cygnea* a été remplacée par *S. woodiana* et le ratio de *A. anatina* réduit de 17,8%

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à 8,6%. Prenant en considération le fait que *S. woodiana* a si rapidement développé une grande abondance relative et une forte biomasse à proximité de la source supposée de l'introduction et qu'elle a une grande capacité de dispersion dans le lac, l'augmentation future de la taille de la population (et sa prépondérance) peut être attendue.

Chinese pond mussel, *Sinanodonta* (*Anodonta*) *woodiana* (Lea, 1834) has been reported as being invasive worldwide. The species is native to South-East Asia, and the Amur Basin in Eastern Russia (Graf, 2007; Watters, 1997). It has been accidentally imported to Europe along with Chinese white carp stocks. It is the biggest freshwater mussel in Europe, and has been observed in different habitats (rivers, lakes, channels, reservoirs) in Hungary and Europe since 1960. Its first occurrence in Hungary was reported by Petró (1984). It has been reported from other European countries as well, among others from Austria (Reischutz, 1998); Czech Republic (Beran, 1997), France (Girardi and Ledoux, 1989), Germany (Glöer and Zeittler, 2005), Italy (Manganelli *et al.*, 1998), Poland (Bohme, 1998), Romania (Sárkány-Kiss, 1986) and from Slovakia (Košel, 1995).

Its invasion success is attributed to its parasitic larvae, termed glochidia. These larvae are incubated in the female's modified gill chambers. Ripe glochidia of *S. woodiana* are released mainly in June−August. They are parasiting host fish, spending 7−10 days on it in 20−22 °C. Host specificity is low and European native fish species might serve as potential hosts (Douda *et al.*, 2012). It has been experimentally proven that glochidia might attach to juvenile fish, causing direct mortality (Báskay *et al.*, 1996), resulting in economic loss in fish hatcheries.

Due to its high growth ratio and reproductive potential, *S. woodiana* can become a serious competitor of native bivalves (Pou-Rovira *et al.*, 2009), which are a highly threatened group showing serious decline worldwide in the last decades (Bogan, 2008).

The species is quite tolerant to high siltation rates and relatively high water temperatures (Zettler and Jueg, 2006; Paunovic *et al.*, 2006; Kraszewski and Zdanowski, 2007). It was experimentally shown that filtration rate of *S. woodiana* is higher in comparison to *Unio douglasiae* at higher temperature (Kim *et al.*, 2011). Competition of *S. woodiana* is most possibly favoured by its overall stress-tolerance, assessed by biochemical markers such as cholinesterase enzyme activity (Corsi *et al.*, 2007).

Lake Balaton is the largest shallow freshwater lake in Central Europe. In addition to being a unique water body, it is also a multi-purpose lake which performs both economic and ecosystem services, these functions are most likely to be threatened by biological invasions. In the lake, *S. woodiana* was first reported in 2006 (Majoros, 2006). A detailed survey was carried out in 2011, to map its distribution, to describe its growth rate and spread potential and to make some conclusions about its ecological impact experienced so far.

In 2011 summer, between 22–24 June, 21 sampling sites were investigated around the lake (Figure 1). The collection of the molluscs was done by scuba-diving method. With every dive, a 40 × 40 cm surface was sampled, specimens (including native unionids) were collected by hand. Each sample consisted of 5 sub-samples, individual numbers and biomass data were summed to derive data given for each sampling site. After identification, the following parameters were recorded: length, width, height, (with 0.1 mm accuracy), living weight, wet weight, shell weight (with 0.1 g accuracy). No mussels were found at site 21, from the other 20 sampling sites, altogether 775 specimens were collected.

Figures 2 and 3 show relative abundances and relative biomass of unionids recorded in the 21 sampling sites. The highest *S. woodiana* ratio (in living weight) was found in site 6 (84.3%), and in sites 11, 12 (61.9 and 68%, respectively). Considering relative abundances, also site 6 seems the most 'infected', with 51.6%. Relatively high abundances were found at sites 11, 12 and 13: 38.0%, 31.5% and 28.6%, respectively.

Figure 4 shows the distribution of size classes. The population has the biggest specimens in the Western Basin, a specimen with the maximum length (130 mm) was also found here in the Western Basin, at site 12.

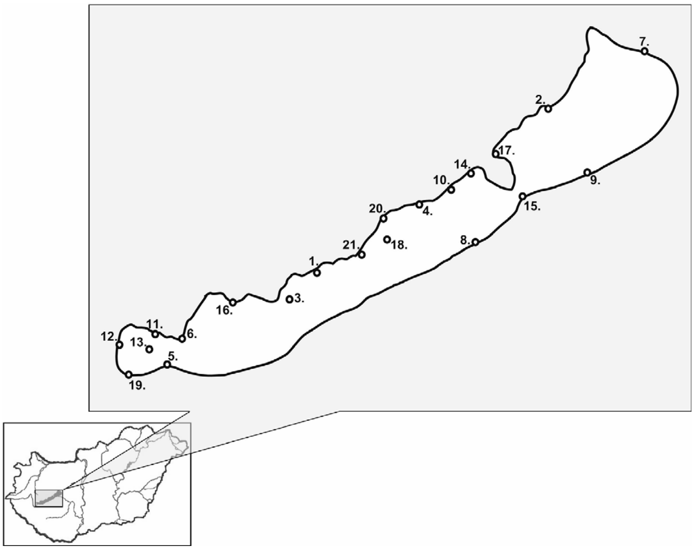

Figure 1
Location of sampling sites.

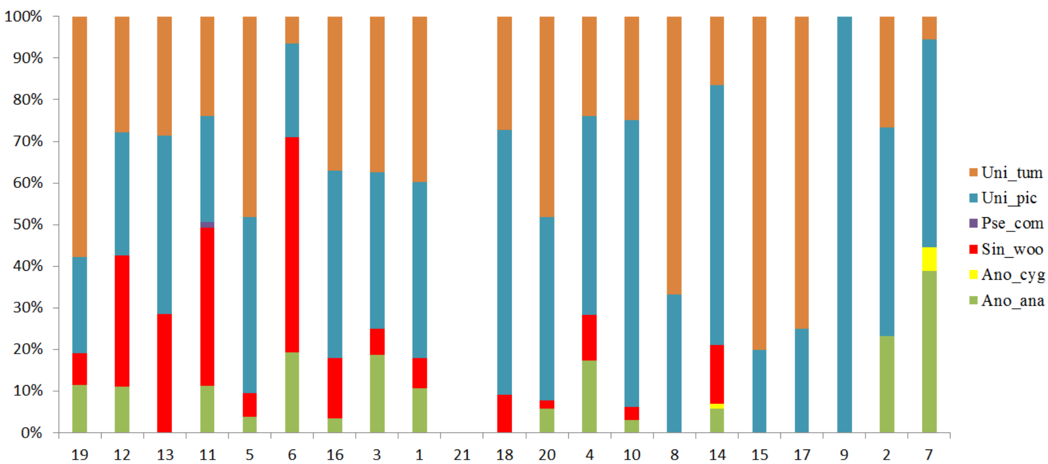

Figure 2
Relative abundances of native unionids vs. Sinanodonta woodiana *in the sampling sites (abbreviations were constructed from the Latin names of the species, using the first 3 characters of genus and species names, like Sin_woo=* Sinanodonta woodiana*).*

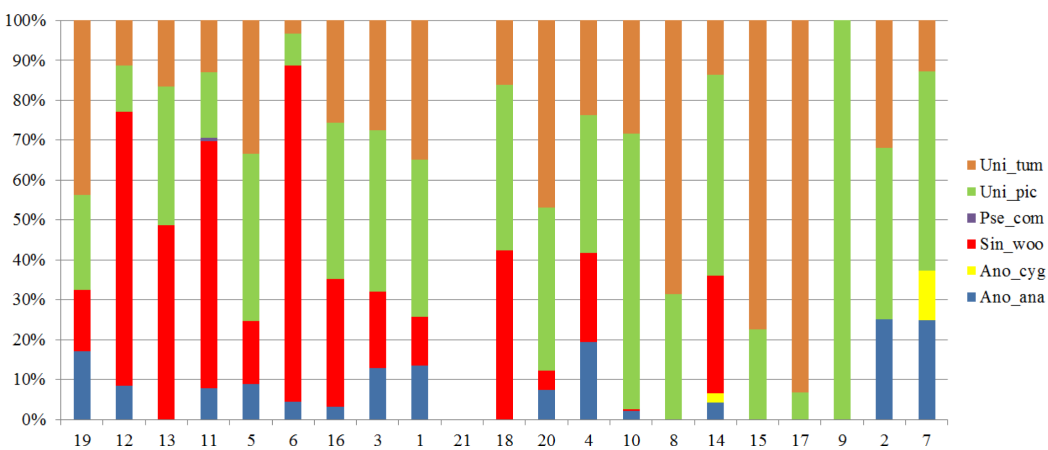

Figure 3
Relative biomass of native unionids vs. Sinanodonta woodiana *in the sampling sites.*

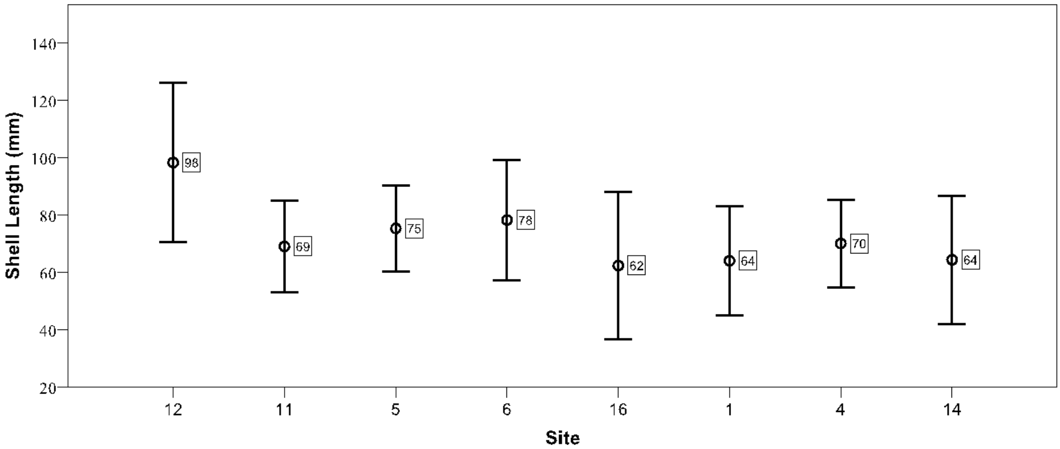

Figure 4
Size distribution of Sinanodonta woodiana *specimens in the sampling sites. (Only those sites are depicted where at least 3 specimens were found).*

The distribution pattern clearly shows that the centre of introduction must have been on the west side of the lake. Most probably, *Sinanodonta woodiana* was introduced to the western basin along with vector fish from fishponds. It is generally agreed that exports of fish for commercial purposes (mainly carp species from East Asia) can be the main pathway of human-mediated dispersal (Watters, 1997).

S. woodiana has developed an increasing population since the first observation (2006) in Lake Balaton. The biggest relative abundances and biomass could be found in the south part of the lake (Keszthely Basin), in some sites reaching 50–80% of the total unionid biomass. The experiences gained in other Hungarian areas (Tisza River, Körös River and ponds in the Southern region) showed, that the species might reach 80–90% of total biomass of unionid mussels in a few years (unpublished data). At this moment, this is not the case in Lake Balaton, however, the presence and biomass of *S. woodiana* will most likely increase in the future. Virtually, its impact on biodiversity is high but two possibilities have to be taken into consideration: (1) individual number/biomass of *S. woodiana* increase total number/biomass of unionids without disturbing native species' populations or (2) *S. woodiana* replaces native unionids.

In 1992–1993, a comprehensive study was conducted in Lake Balaton (Kiss, 1994), aiming at getting a general overview about community structure of unionids in the lake. Though this study used less sampling sites (only 11), in case of Keszthely Basin, where highest abundances of *S. woodiana* were detected during the 2011' survey, a good match was found between location of sampling sites. Means of relative abundance data of different sampling years (1992/93 and 2011) were compared using Mann-Whitney U-test. Analyses have been performed using R statistical environment (R Development Core Team, 2009). Using the 1992/93' survey as an indicative baseline dataset, it can be hypothesised that in the Keszthely Basin appearance of *S. woodiana* negatively influenced two native *Anodonta* species: *Anodonta cygnea* seems to be replaced by *Sinanodonta woodiana* and the ratio of *Anodonta anatina* reduced from 17.8% to 8.6% Although the decrease in the relative abundance ratio of *A. anatina* was obvious, the change is not significant (Mann-Whitney U test, $U = -0.731$; $P = 0.548$). As *S. woodiana* usually grows bigger than other unionids, the decrease of *A. anatina* in biomass is more significant: from 14.9 to 7.5% (Mann-Whitney-test: $U = -2.173$; $P = 0.0317$) (Figure 5). However, we have to stress that no direct relationship is proven between *S. woodiana* and the two species: it is also possible that *A. cygnea* has disappeared due to other environmental factors, and *S. woodiana* has just taken the 'empty' niche. Nevertheless, the fact that two native species have been negatively influenced, raises the likelihood of direct impact. *S. woodiana* exerts its ecological impact on native unionid community especially by competition: in Italy it has almost completely replaced *A. anatina* in some channels in North-Italy (Fabbri and Landi, 1999) or in Venezia province (Niero, 2003). Other authors

Table I
Sampling sites, relative abundances (RA) and relative biomasses (RB) of mussels in Lake Balaton (2011).

Site	Site name	Latitude (N)	Longitude (E)	*Anodonta anatina* (Held, 1836)		*Anodonta cygnea* (Held, 1839)		*Sinanodonta woodiana* (Lea, 1834)		*Pseudanodonta complanata* (Rossmasler, 1835)		*Unio pictorum* (Küstler, 1853)		*Unio tumidus* (Zelebor, 1851)	
				RB	RA	RB	RA	RB	RA	RB	RA	RB	RA	RB	RA
1.	Ábrahámhegy	46.810641	17.57176	13.4	10.8	0.0	0.0	12.3	7.2	0.0	0.0	39.4	42.2	34.9	39.8
2.	Alsóörs	46.973873	17.95716	25.1	23.3	0.0	0.0	0.0	0.0	0.0	0.0	43.0	50.0	31.9	26.7
3.	Badacsonytomaj	46.782852	17.527174	12.8	18.8	0.0	0.0	19.3	6.3	0.0	0.0	40.4	37.5	27.5	37.5
4.	Balatonakali	46.87874	17.742505	19.3	17.4	0.0	0.0	22.4	10.9	0.0	0.0	34.5	47.8	23.8	23.9
5.	Balatonberény	46.716508	17.326661	8.8	3.8	0.0	0.0	15.9	5.8	0.0	0.0	41.9	42.3	33.4	48.1
6.	Balatongyörök	46.74912	17.351489	4.4	19.4	0.0	0.0	84.3	51.6	0.0	0.0	8.1	22.6	3.2	6.5
7.	Balatonkenese	47.03068	18.116910	24.8	38.9	12.4	5.6	0.0	0.0	0.0	0.0	50.1	49.9	12.7	5.6
8.	Balatonszárszó	46.833407	17.829145	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	31.5	33.3	68.5	66.7
9.	Balatonszéplak	46.902585	18.015319	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	100.0	0.0	0.0
10.	Fövenyes	46.89295	17.792319	2.2	3.1	0.0	0.0	0.3	3.1	0.0	0.0	69.1	68.8	28.4	25.0
11.	Gyenesdiás	46.75336	17.308602	7.9	11.3	0.0	0.0	61.9	38.0	0.9	1.4	16.4	25.4	12.9	23.9
12.	Keszthely	46.745392	17.247483	8.4	11.1	0.0	0.0	68.8	31.5	0.0	0.0	11.6	29.6	11.2	27.8
13.	Keszthely2	46.737139	17.298264	0.0	0.0	0.0	0.0	48.7	28.6	0.0	0.0	34.7	42.9	16.6	28.6
14.	Örvényes	46.910510	17.827091	4.3	5.9	2.3	1.2	29.5	14.1	0.0	0.0	50.2	62.4	13.7	16.5
15.	Szántód	46.881250	17.9082	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	22.6	20.0	77.4	80.0
16.	Szigliget	46.78485	17.436252	3.1	3.4	0.0	0.0	32.2	14.6	0.0	0.0	39.1	44.9	25.6	37.1
17.	Tihany	46.927223	17.863019	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.7	25.0	93.3	75.0
18.	Szepezd	46.841323	17.687876	0.0	0.0	0.0	0.0	42.3	9.1	0.0	0.0	41.6	63.6	16.1	27.3
19.	Zala-torok	46.710050	17.263342	17.0	11.5	0.0	0.0	15.5	7.7	0.0	0.0	23.8	23.1	43.7	57.7
20.	Zánka	46.866367	17.683226	7.4	5.8	0.0	0.0	4.8	1.9	0.0	0.0	41.0	44.2	46.9	48.1
21.	Révfülöp	46.82809	17.643801	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Mean (%)			7.6	8.8	0.7	0.3	21.8	11.0	0.0	0.1	35.5	41.7	29.6	33.4

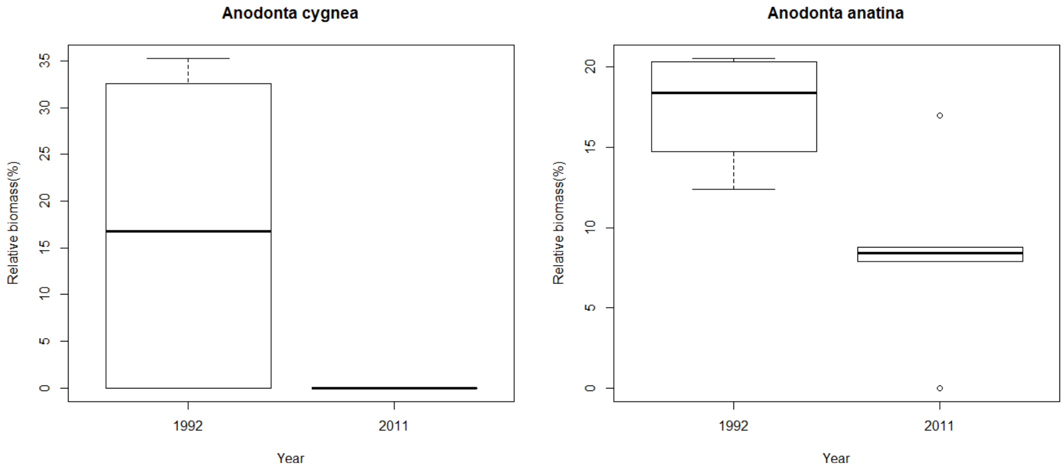

Figure 5
Decrease in biomass of A. cygnea *and* A. anatina *in the Keszthely Basin, comparing 1992/93' and 2011' data.*

(Paunovic *et al.*, 2006) also suggest that dominance of *S. woodiana* over native species can be a result of competition.

As concluding remarks, taking into consideration that *Sinanodonta woodiana* has so rapidly developed high relative abundance and biomass close to the supposed source of introduction and it has a high spread potential in the lake, future increase in population size (and dominance) can be expected in areas where the bottom is suitable for establishment.

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