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Abundant prey or optimal microhabitat? *Natrix tessellata* stays hidden in safe areas in a diverse floodplain along the Danube at Göd, Hungary

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Abstract. *Natrix tessellata* (Laurenti, 1768) is a diurnal piscivorous Eurasian snake species with a large distribution area. Along the River Danube it is present in the floodplain and along the lower stretch of tributaries. The distribution of *N. tessellata* among the different microhabitats along the River Danube at Göd (1669-1671 rkm) and its relationship with environmental parameters and fish presence/absence, species composition, size distribution and abundance was studied at eight selected sections. Samples were collected twice a month from March to October in 2008-2009; *N. tessellata* was found between May and early October. Altogether 26 *N. tessellata* sightings were recorded together with 497 individuals of 21 fish species along the same sections, while another 5,547 individuals belonging to 28 fish species were caught in snake-free areas. Microhabitat characteristics were more important than the presence of fish in determining along which section *N. tessellata* stays. It favoured slow-flowing sections with aquatic macrophytes and a sandy or muddy bottom. In spite of their suitability, artificial habitats were not much used maybe due to increased risk of disturbance and predation/persecution. The habitat preference of *N. tessellata* changed less between the two studied years with different water level fluctuations than those of fishes and it was not identical with that of any of the fish species caught. However, fish 15-30 mm and longer may influence the distribution of *N. tessellata*.

Key words: *Natrix tessellata*, Reptilia, juvenile fish, environmental parameters, habitat preferences, Middle-Danube.

Introduction

The dice snake (*Natrix tessellata* Laurenti, 1768) is a diurnal piscivorous Eurasian snake species ranging from Germany and Switzerland to China and Egypt (Gasc et al. 1997, Ibrahim 2012), well adapted to the aquatic environment (Lahav & Dmi'el 1996) with an ability to react to climate change relatively fast if provided with opportunities to enlarge its distribution area (Marosi et al. 2012). It occurs in aquatic or marshy habitats, including brackish water (Gruschwitz et al. 1999, Tuniyev et al. 2011) occasionally even inhabiting cities such as Rome and Prague (Velensky et al. 2011, Vignoli et al. 2009).

N. tessellata is listed on Annex II of the Bern Convention (1999) and it also appears on Annex IV of the Habitats Directive 92/43/ECC but due to its wide distribution and presumably large population it is categorised as least concern (IUCN 2012). However, it is considered to be threatened in a number of western and central European states, with low genetic variation in some populations (Gautschi et al. 2002, Guicking et al. 2004) and its world population was also assessed as declining by IUCN (2012). As such, conservation measures should still be undertaken for this species as habitat destruction, pollution, road traffic, collection and persecution are listed as possible threats.

Habitat alteration and destruction is a main threat for *N. tessellata* along running waters, which can be compensated by protection and restoration (Schiemer et al. 2004). However, the habitat preference of *N. tessellata* has rarely been investigated in the floodplains of large rivers, which serve as corridors as well as habitats, where hiding places and prey can be abundant and diverse (Sloboda 2010). Along the River Danube this snake species has been suggested to occur in the floodplain along the Romanian – Bulgarian stretch (Iftime 2005). In Hungary, the River Danube is a main axis of *N. tessellata* distribution with a number of observations in tributaries as well as in the main arm (Puky et al. 2005).

The feeding spectrum of *Natrix tessellata* is relatively well-studied (see e.g. Filippi et al. 1996, Luiselli et al. 2007) but much less information is available on how it selects areas for foraging and what effect potential prey may have on it in large rivers.

The aim of the present study was to determine

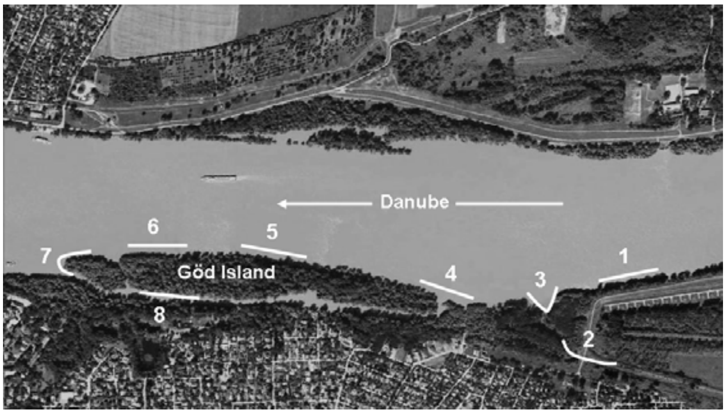

Figure 1. Sampling sites along the Danube at Göd (1671 – 1669 rkm).

the distribution of *N. tessellata* among the different microhabitats along the River Danube at Göd and its relationship with environmental parameters. A second aim was to determine how the presence/absence, species composition, size distribution and abundance of its commonest prey item, fish, influences this spatial pattern.

Material and methods

The Göd section of the Danube is in the middle stretch of the river, where the river bed is stable and several islands have been formed. As a first water engineering activity in the Danube at Göd, a barrier was built in the 1930s in the side arm along Göd Island, which led to its gradual filling up. To overcome difficulties in navigation caused by fords in the region, longitudinal dikes and further barriers were built in the 1950s. These interventions resulted in the development of diverse microhabitats; natural (sand and gravel) and artificial banks (ripraps, barriers) also characterise this river section. Göd Island is a part of the Danube – Ipoly National Park since 1997, and the adjacent floodplain was designated as a NATURA 2000 site in 2004. However, as it is near the Hungarian capital of 2 million people and just at the edge of a town, Göd, of 15,000 people, recreational pressure and both point and non-point source pollution is present in the area, especially between June and August.

Eight 120-150 m long sampling sections were selected at Göd Island between river km 1671 and 1669: 1) rockfilling over the mouth of Ilka stream, 2) Ilka stream over the flood protection dike, 3) mouth of Ilka stream with a steep clay bank, 4), gravel bank over Göd Island, 5), shallow gravel bank between two dikes on the outer side of Göd Island, 6), shallow, sandy bank under the lower dike on the outer side of Göd Island, 7) sandy lower tip of Göd Island, 8) sandy gravelly lower part of the side arm at Göd Island (Fig. 1.). Sampling sites were characterised by eight environmental variables: distance from the bank, current velocity, aquatic and terrestrial plant cover (0%, <10%, 10-50%, >50%), woody debris, coverage of shading trees (0%, <10%, 10-50%, >50%), water depth, sediment composition (rocks, boulders >10 cm, pebble 10-0.2 cm, sand-mud 2-0.004 mm, clay 0.004-0.00024 mm) (Bogárdi 1971) and fish present. As the size distribution of fish is also of importance for *N. tesselata* (Ghira et al. 2009), fish individuals were put into three size classes in the statistical analysis, as in the larval stage (0-15 mm) most species can hardly swim due to undeveloped fins, while 15-30 mm fish can avoid predators by their partly or fully developed fins but they are still unable to move against strong currents for longer periods, which they can usually manage over 30 mm (Pinder 2001).

Five hour surveys were carried out twice a month during the active period for dice snakes (March – October) in 2008 and 2009, while in 2008 fish communities were monitored till December (Gaebele & Guti 2009, 2010). *N. tessellata* individuals were detected by two methods, visual encounter surveys and electrofishing. Their length was measured in the field. Juvenile fish assemblages were sampled by electrofishing using the "point abundant" sampling method (Copp 1989) with a portable electrofishing equipment (DEKA 3000) collecting 30-30 point-samples.

N. tessellata and fish determined on the site were released immediately after measurements were made. Fish too small to determine properly in the field were preserved in 4% formaldehyde and taken to the laboratory for microscopic examination and measurements.

Statistical analysis was made using SYN-TAX 2000 (Podani 2001) and CANOCO (Lepš & Šmilauer 2003). Redundancy analyses (RDA) were used to identify the habitat characteristics explaining the distribution of dice snakes (Podani 1997). We used presence-absence data of snakes and log10 transformed data of explanatory variables. Series of daily water level data in the period of study and local water level fluctuation calculations were gathered from the internet (www.hydroinfo.hu/Html/archivum/archiv_tabla.html, http://dunaiszigetek.blogspot.hu).

Table 1. Date and locality of *N. tessellata* sightings in the floodplain of the river Danube at Göd in 2008 and 2009 together with fish species present and their individual numbers along the same section [*N.t.=Natrix tessellata*].

Date	Section	No. of *N. t.* individuals	Fish species and individual number (in brackets)
2008.06.20	2	1	*Abramis bjoerkna* (15), *Alburnus alburnus* (15), *Squalius cephalus* (2), *Rutilus rutilus* (7), *Leuciscus idus* (1), *Scardinius erythrophthalmus* (1)
2008.07.25	8	1	*Abramis bjoerkna* (1)
2008.07.25	4	1	*Abramis bjoerkna* (1), *Aspius aspius* (1), *Lepomis gibbosus* (1)
2008.08.08	8	1	*Abramis bjoerkna* (3), *Lepomis gibbosus* (3), *Neogobius melanostomus* (2), *Scardinius erythrophthalmus* (1), *Ponticola kessleri* (1)
2008.08.08	5	1	*Abramis bjoerkna* (2), *Condrostoma nasus* (1), *Leuciscus idus* (1), *Neogobius melanostomus* (1)
2008.08.12	4	1	*Condrostoma nasus* (2), *Aspius aspius* (1), *Ponticola kessleri* (1)
2008.08.19	4	1	*Romanogobio albipinnatus* (1)
2008.08.19	2	1	*Alburnus alburnus* (2), *Barbus barbus* (1), *Squalius cephalus* (1), *Vimba vimba* (1)
2008.09.09	8	1	*Alburnus alburnus* (3), *Neogobius fluviatilis* (1), *Neogobius melanostomus* (6)
2008.09.09	2	1	*Squalius cephalus* (21), *Alburnus alburnus* (15), *Neogobius fluviatils* (4), *Babka gymnotrachelus* (3), *Barbus barbus* (3), *Leuciscus idus* (3), *Chondrostoma nasus* (2)
2008.09.24	8	1	*Alburnus alburnus* (9), *Neogobius melanostomus* (6), *Neogobius fluviatilis* (2), *Squalius cephalus* (1)
2008.09.24	3	1	*Neogobius melanostomus* (2), *Neogobius fluviatilis* (1)
2008.09.24	5	1	*Neogobius melanostomus* (8), *Alburnus alburnus* (1), *Ponticola kessleri* (1)
2008.09.24	2	2	*Squalius cephalus* (32), *Alburnus alburnus* (13), *Chondrostoma nasus* (2), *Lepomis gibbosus* (2), *Abramis brama* (1), *Barbus barbus* (1), *Cobitis elongatoides* (1), *Rhodeus amarus* (1), *Ponticola kessleri* (1)
2008.10.08	3	1	*Squalius cephalus* (32), *Alburnus alburnus* (2), *Condrostoma nasus* (1)
2008.10.08	2	1	*Abramis bjoerkna* (5), *Alburnus alburnus* (3), *Vimba vimba* (1)
2009.05.12	2	1	*Squalius cephalus* (32), *Lepomis gibbosus* (11), *Rhodeus amarus* (2) *Lota lota* (1)
2009.05.27	2	1	*Alburnus alburnus* (1), *Abramis brama* (2), *Squalius cephalus* (4), *Cobitis elongatoides* (1)
2009.06.10	8	1	*Rutilus rutilus* (2), *Leuciscus cephalus* (2), *Aspius aspius* (2)
2009.08.12	3	1	*Alburnus alburnus* (44), *Abramis bjoerkna* (3), *Ponticola kessleri* (3), *Leuciscus idus* (1)
2009.08.12	2	1	*Alburnus alburnus* (7), *Abramis bjoerkna* (4), *Abramis brama* (3)
2009.08.19	6	1	*Alburnus alburnus* (31), *Abramis bjoerkna* (3), *Neogobius fluviatilis* (1), *Ponticola kessleri* (1)
2009.09.16	2	3	*Squalius cephalus* (69)

Results

Distribution of *N. tessellata* among different microhabitats

Altogether 26 *N. tessellata* and 6,044 individuals of 28 fish species were sampled over the two year study period, with 497 individuals of 21 fish species being caught in the vicinity of snakes. Date and river section where *N. tessellata* was found together with the species and individual number of fish collected along the same section can be seen in Table 1.

Effect of environmental parameters on the distribution of *N. tessellata*

The effect of environmental variables on the habitat use of *N. tessellata* and fish size classes at Göd Island in 2008 and 2009 can be seen in Fig. 2. In 2008 the first two axes explained 51 and 31% of the total variance; in 2009 they explained 74 and 19% of the total variance, respectively.

Co-occurrence of *N. tessellata* and fish species

The effect of environmental variables on the habitat use of *N. tessellata* and potential prey at Göd Island in 2008 and 2009 can be seen in Fig. 3. In 2008 the first two axes explained 34 and 30% of the total variance; in 2009 they explained 48 and 22% of the total variance, respectively.

Discussion

Distribution of *N. tessellata* among different microhabitats

The habitat use of dice snakes is determined by the basic needs of the species. In its active period it predominantly occurs in the close vicinity of suitable waters with abundant fish communities (see e.g. Lenz & Gruschwitz 1993, Filippi et al. 1996, Covaciu-Marcov et al. 2006). Žagar et al. (2011) found that relatively open banks overgrown by grass, shrubs or, to a moderate extent, trees are

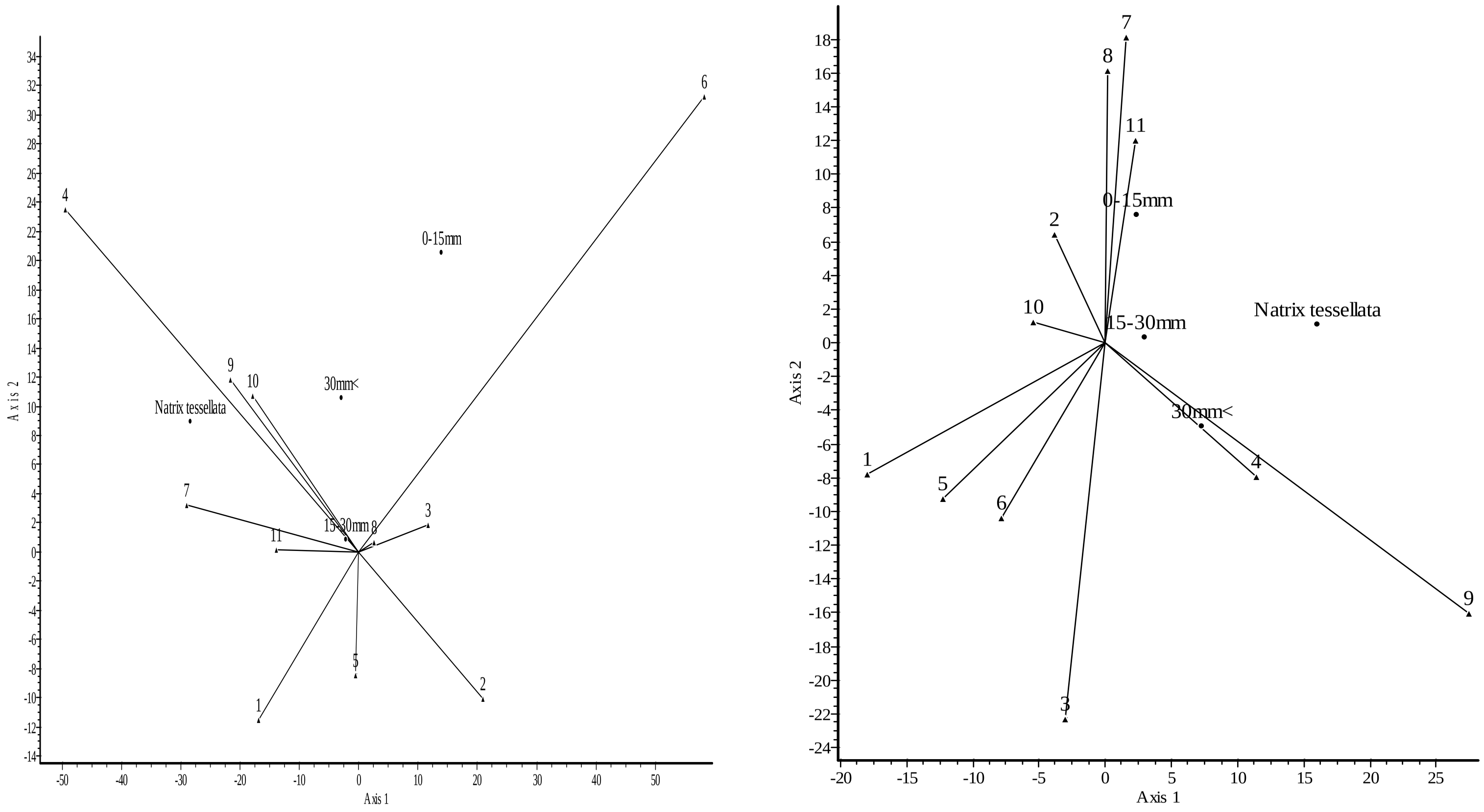

Figure 2. Effect of environmental variables on the habitat use of *N. tessellata* and its potential prey (juvenile fish species) at Göd Island in 2008 and 2009 (RDA). Legend: 1= distance from the bank (m), 2= water depth (m), 3= current velocity (zero, slow, medium, fast), 4= mud-sand, 5= pebbles, 6= rocks, boulders, 7= clay, 8= woody debris, 9= aquatic macrophytes, 10= terrestrial plants, 11= shading trees, 0-15 mm= 0-15 mm fish larvae, 15-30 mm= 15-30 mm fish larvae, 30 mm<= fish over 30 mm.

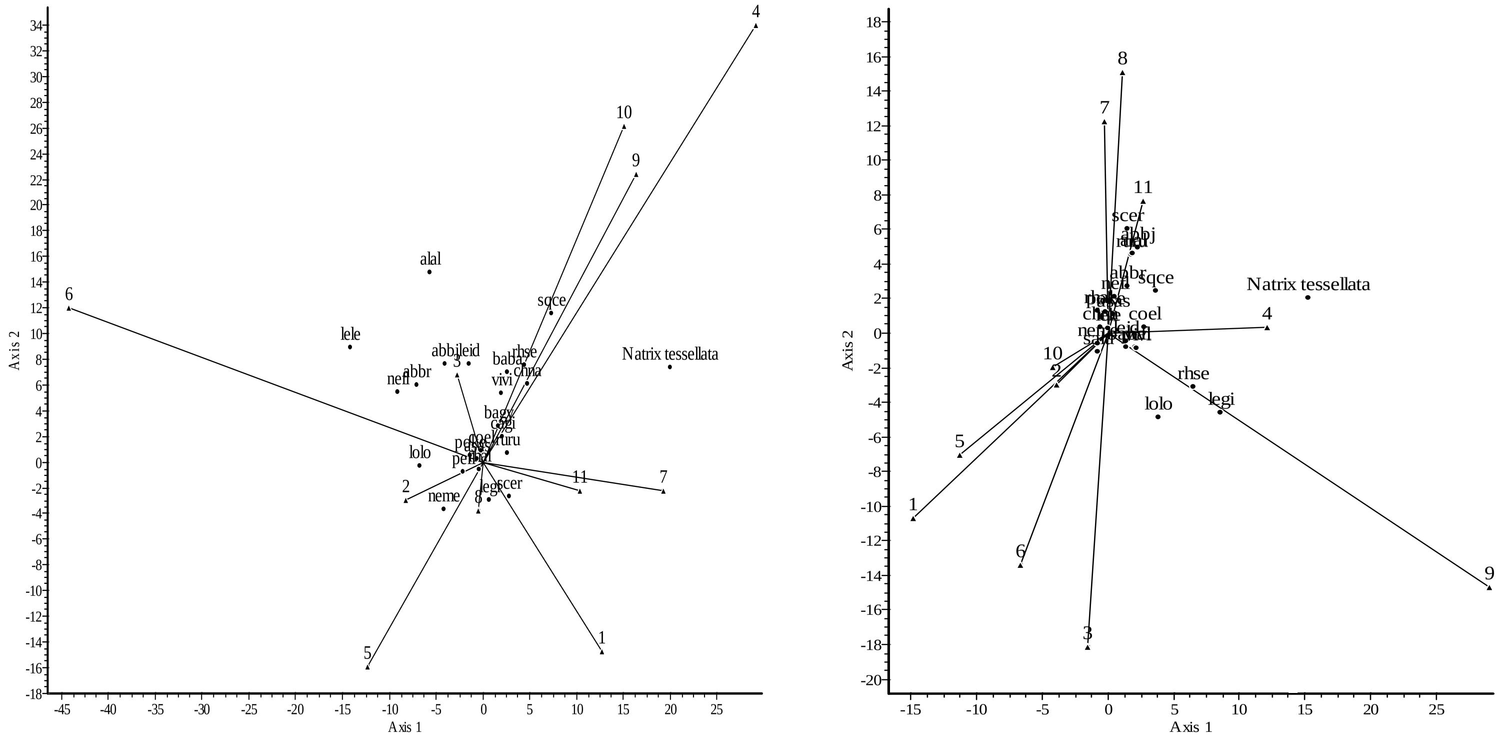

Figure 3. Effect of environmental variables on the habitat use of *N. tessellata* and its potential prey (juvenile fish species) at Göd Island in 2008 and 2009 (RDA). Legend: 1= distance from the bank (m), 2= water depth (m), 3= current velocity (zero, slow, medium, fast), 4= mud-sand, 5= pebbles, 6= rocks, boulders, 7= clay, 8= woody debris, 9= aquatic macrophytes, 10= terrestrial plants, 11= shading trees. Code of fish species: *Rutilus rutilus* (ruru), *Scardinius erythrophthalmus* (scer), *Leuciscus leuciscus* (lele), *Squalius cephalus* (sqce), *Leuciscus idus* (leid), *Aspius aspius* (asas), *Alburnus alburnus* (alal), *Abramis bjoerkna* (abbj), *Abramis brama* (abbr), *Vimba vimba* (vivi), *Chondrostoma nasus* (chna), *Barbus barbus* (baba), *Romanogobio albipinnatus* (rhal), *Rhodues sericeus* (rhse), *Carassius gibelio* (cagi), *Cobitis elongatoides* (coel), *Lota lota* (lolo), *Lepomis gibbosus* (legi), *Perca fluviatilis* (pefl), *Sander lucioperca* (salu), *Babka gymnotrachelus* (bagy), *Neogobius fluviatilis* (nefl), *Neogobius melanostomus* (neme), *Ponticola kessleri* (poke).

preferred though some individuals also live in urban areas. Our microhabitat survey showed marked differences in the presence of *N. tessellata* at the different sections. Most animals were found in the slow flowing section of Ilka stream, followed by the side arm. Much less frequent encounters were recorded in the main arm of the Danube. In certain sections with mainly man-made banks (no. 1. and 7.) no *N. tessellata* was recorded over the two year sampling period even if Mebert et al. (2011) described the detection probability of *N. tessellata* increasing with the artificiality of the banks and increase of vegetation cover of the 20 m riparian strip. What is more, Conelli et al. (2011) found most *N. tessellata* individuals in that habitat type in a survey in southern Switzerland. One of the reasons for this difference may be the frequent visits of humans and domestic animals, primarily dogs in such areas at Göd. Even if *N. tessellata* is known to use man-made structures, e.g. dikes along the river, which provide easy access to solar radiation as well as hiding places and foraging opportunities that may outweigh the negative effect of increased human presence. As also suggested by Kammel and Mebert (2011) and Mebert et al. (2011), disturbance can be too intensive for the local *N. tessellata* population along the main arm of the Danube at Göd, which can also generate increased predation by dogs and persecution by humans. The recorded snake length distribution is similar to what Herczeg et al. (2005) described at Mád, with a high ratio of young individuals. However, the fact that there are more juveniles in the population than usual (Carlsson et al. 2011, Werner & Shapira 2011), may also lead to a shift in microhabitat use.

<u>Effect of environmental parameters on the distribution of *N. tessellata*</u>

Along the Göd section of the River Danube *N. tessellata* favoured slow-flowing or still sections with aquatic macrophytes and a sandy or muddy bottom (Fig. 2). This is in harmony with those observations from both lowlands and highlands, which described a sit and wait strategy of this snake after the aquatic vegetation has grown dense enough to be hidden in it (Acipaner et al. 2006, Filippi et al. 1996, Ghira et al. 2009, Göcmen et al. 2011, Luiselli et al. 2007, Zimmerman & Fachbach 1996) unrelated to the life strategy of the predominant prey. Luiselli et al. (2007) indicated fish not using mud as the preferred substratum as the commonest prey selected by *N. tessellata*. Under riparian conditions at Göd, where *N. tessellata* was also found on mud, this preference may be outweighed by the importance of safe areas with the presence of vegetation (Fig. 2). As discussed earlier, unlike our results with aquatic vegetation, artificial habitats such as ripraps were also observed as frequently used *N. tessellata* habitats elsewhere (e.g. by Kärvemo et al. 2011), also in other habitats in Hungary (Puky and Weiperth unpublished data from Lake Balaton). However, in spite of their general suitability, artificial habitats were not much used by *N. tessellata* along the Danube at Göd, which may be related to increased risk of disturbance and predation/persecution due to a high number of recreational tourists in the area in summer.

Fish 15-30 mm and longer positively influenced the presence of *N. tessellata*, as it occurred more frequently at sections where such optimal prey size fish was present (Fig. 2). Strong correlation between fish over 30 mm and slow-flowing or still sections with aquatic macrophytes and a sandy or muddy bottom was especially evident in 2009. Again, it is related to the sit and wait hunting strategy of *N. tessellata* under such conditions (Filippi et al. 1996, Luiselli et al 2007, Zimmerman & Fachbach 1996) and also its head morphology and the hydrodynamic constraints on its prey-capture performance (Wassenbergh et al. 2009).

<u>Co-occurrence of *N. tessellata* and fish species</u>

With a very low number of exceptions developed under special conditions with low fish availability (Beshkov & Dushkov 1981, Frotzler et al. 2011), fishes accounted for most of the dice snake diet. In Italy it was over 90% occasionally even reaching 97% (Filippi et al 1996, Luiselli et al. 2007), with reptiles, tadpoles and frogs as other food items (Bilckle et al. 2006, 2007, Filippi et al 1996, Luiselli et al. 2011, Luiselli & Rugiero 1991) while in Turkey this ratio was 72.4% for fish, 14.9% for amphibians, 7.9% for insects, 2.9% for molluscs and 1.3% for reptiles and small mammals (Göcmen et al. 2011). Along Austrian running waters from mountain streams to rivers, fish characteristic of the given stretch represented 98% in the diet of *N. tessellata* (Zimmerman & Fachbach 1996). What is more, there is no apparent ontogenetic change in dietary composition, except that the immature individuals of this species preyed on fry and small fish, while the adults tended to prey on larger fish (Filippi et al. 1996).

N. tessellata adapts its hunting strategy to the

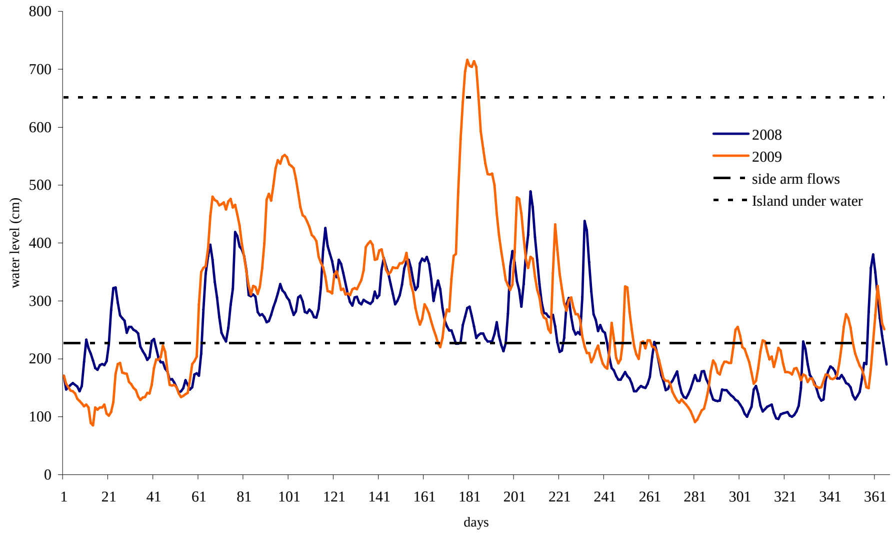

Figure 4. Change of average daily water level at Budapest. 227 cm is the lowest water level when the Danube overflows into the side arm at Göd. 652 cm is the lowest water level when Göd Island is completely overflooded.

environmental conditions. In many cases it is an active forager (Marosi et al. 2011, Sloboda et al. 2010). They can hunt for cyprinid or bottom-dwelling gobiid species (Sloboda et al. 2010) as well as for pelagic species (Acipaner et al. 2006, Gruschwitz et al. 1999). However, Ghira et al. (2009) recorded a shift on the active floodplain from spring to summer, from active foraging to sit and wait tactics, which is also recorded elsewhere (Gruschwitz et al. 1999).

In our study the habitat preference of *N. tessellata* was not identical to that of any of the fish species recorded. Also, it changed less than those of fishes due to water level fluctuations in the Danube (Fig. 4), which rather indicates more site fidelity and possible shifts in selecting potential prey. It is in harmony with the fact that *N. tessellata* eats prey with diverse reproductive strategies (Balon 1975, 1981, Erős 2005) including species living in eu- and parapotamon habitats, as adults also move into spawning grounds with a reduced current velocity in side arms and effluents, where their fry can stay for a whole year (Gaebele & Guti 2010). Another factor enlarging the prey spectrum and thus leading to smaller overlap of the predator and any of the prey species is that several invasive gobiid species have recently colonised the Göd section of the River Danube (Bódis et al. 2012) providing a new food source for *N. tessellata*, which supports its survival in the region.

Our statistical analysis emphasises the importance of the investigated environmental variables (including prey size) on the presence of *N. tessellata* over the spatial and temporal distribution of potential prey species. However, the juveniles and young individuals of potential prey also influences the the spatial and temporal distribution of *N. tessellata*, as in 2008, the year with a low Danube water discharge, it occurred more frequently along the main arm of the Danube, where juvenile fish were more abundant than in 2009 (Table 1.).

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