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Risk assessment of non-native fishes in the catchment of the largest Central-European shallow lake (Lake Balaton, Hungary)

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Abstract

The Fish Invasiveness Screening Kit (FISK) has proved to be a useful tool for assessing and screening the risk posed by potentially invasive fish species in larger risk assessment (RA) areas (i.e. country or multi-country level). In the present study, non-native freshwater fishes were screened for a smaller RA area, the closed and vulnerable but economically important drainage basin of Lake Balaton (Hungary). Receiver operator characteristic analysis of FISK scores for 26 fish species screened by four assessors identified 21 species with scores of ≥ 11.4 to pose a 'high risk' of being invasive, with five species ranked as 'medium risk' and none as 'low risk'. The highest scoring species were gibel carp *Carassius gibelio* and black bullhead *Ameiurus melas*, with three Ponto-Caspian Gobiidae identified as amongst the species posing the potentially greatest threat to the catchment. The results of the present study indicate that FISK can be applied to risk assessment areas of smaller geographical scale.

Keywords: FISK, shallow lakes, invasibility, hazard identification, biological invasions

Introduction

Lake Balaton is the largest shallow lake in Central Europe. The lake and its catchment are considered to be one of the most economically important regions of Hungary, providing essential ecosystem services such as angling tourism, which has increased continuously across the catchment. The populations of target native species, i.e. common carp *Cyprinus carpio* and pikeperch *Sander lucioperca*, are strongly dependent upon the stocking of non-native species (Specziár and Turcsányi 2014). Also, the opening of the Sió Canal in the 1860s connected the Balaton basin with that of the River Danube (Korponai et al. 2010; Zlinszky and Tímár 2013), resulting in several biological invasions (Bíró 1972; Muskó et al. 2008; Benkő-Kiss et al. 2013).

Based on the list of native species given in Herman (1887), the first non-native fish to have invaded the Balaton basin (via the Sió Canal) was tubenosed goby *Proterorhinus semilunaris*, which is native to the lower Danube, followed by introductions in the late 19th century of three North American fishes, pumpkinseed *Lepomis gibbosus*, rainbow trout *Oncorhynchus mykiss* and mosquitofish *Gambusia affinis*, and also European eel *Anguilla anguilla*. These species were introduced for aquaculture (rainbow trout, eel), ornamental purposes (pumpkinseed) and mosquito control (Herman 1890; Vutskits 1897; Györe 1995). Being intolerant to colder temperatures, the mosquitofish has not dispersed from its original introduction site, the thermal lake at Héviz (Specziár 2004). The next wave of introductions to Lake Balaton occurred in the 1960s and involved several species of Far-Eastern origin. At present, 12 of the 42 fish species (29%) in the Balaton catchment are non-native (Takács et al. 2011), which is amongst the highest in Europe (Economidis et al. 2000; Copp et al. 2005a; Povz and Sumer 2006; Koščo et al. 2010; Lusk et al 2010; Almeida et al. 2013).

The distribution, abundance and related impact on the native ecosystem by these non-native species varies strongly even at local geographical scales (Erős et al. 2009; Sály et al. 2011;

Ferincz et al. 2012, 2014; Paulovits et al. 2014), and the possibility of further introductions is still high. For this reason, there is an urgent need to identify those species that are likely to pose a high risk to the Balaton catchment. The aims of the present study were therefore to: 1) undertake a risk screening of non-native species using version 2 (Lawson et al. 2013) of the Fish Invasiveness Screening Kit (FISK; Copp et al. 2009) so as to inform environmental managers of which non-native species pose the greatest risk of being invasive in the Balaton catchment; and 2) evaluate the applicability of FISK to smaller risk assessment (RA) areas than those (country or regional scales) for which it has been used in the past (Copp 2013).

Material and Methods

The RA area, the Lake Balaton catchment (Fig. 1), is located in West Hungary (Transdanubia), has an area of 5775 km² and is characterized by a humid continental climate (Köppen-Geiger type Dfb; Peel et al. 2007). The Balaton catchment supports stable populations of several species listed in the Bern Convention (Annexes II and III) and Habitats Directive (Annexes II, IV and V), such as razorfish *Pelecus cultratus*, asp *Aspius aspius*, Volga pikeperch *Sander volgensis* and the endemic European mudminnow *Umbra krameri* (Specziár et al. 2010, Takács et al. 2015).

Altogether, 26 non-native species were assessed for their potential to represent a threat for the RA area using FISK v2 (Lawson et al. 2013), and their selection was based on the following two criteria: 1) the species has already been reported from the Balaton catchment (Takács et al. 2011); and 2) the species occurs within the territory of Hungary (Harka and Sallai 2004; Halasi-Kovács et al. 2011), which is taken to represent the primary donor area. Of the species assessed, 12 (46%) corresponded to criterion 1 and 14 (54%) to criterion 2 (Table 1).

FISK v2 (Lawson et al. 2013) was chosen because of its widespread usage, relative simplicity and ‘policy-maker friendly’ output (Copp 2013). Briefly, FISK v2 relies on 49 questions in

total that assess the potential risk of a species being invasive and are arranged according to eight topics: domestication/cultivation, climate and distribution, invasive elsewhere, undesirable traits, feeding guild, reproduction, dispersal mechanism, and persistence attributes. Importantly, in this study definition of the RA area (the Lake Balaton catchment) was based on biogeography considerations instead of political boundaries (as done for most previous FISK applications), and this is consistent with non-native species risk analysis guidelines (e.g. EPPO 2002) and more generally agrees with the non-native species concept (Copp et al. 2005b).

Assessments of the 26 species were carried out independently by four assessors (AF, AS, AW and PT), who have knowledge of the distribution and ecology of fishes within the risk assessment area. Receiver operating characteristic (ROC) curves analysis was used to assess the predictive ability of the FISK tool, with the final objective to determine a threshold score for discriminating between non-invasive and invasive species. Since *a priori* categorization of the species is needed for this test, FishBase (<http://www.fishbase.org/home.htm>) and the database of Invasive Species Specialist Group (<http://www.issg.org/>) were used to categorise the species *a priori* as 'invasive' or 'non-invasive'. Four independent ROC curves were then constructed for the four assessors, and differences between these curves were statistically assessed using the Venkatraman (2000) method. Following between-curve comparison, a global ROC curve was computed on the mean scores from all 26 species evaluated.

Statistically, a ROC curve is a graph of sensitivity versus 1 minus specificity (1 - specificity), and in the present context the sensitivity of the FISK test will be the proportion of invasive fish species that are correctly identified by the test, whereas specificity refers to the proportion of non-invasive species that are correctly identified as such. An important measure of the accuracy of the calibration analysis is the area under the ROC curve. If this area is equal to 1.0, then the ROC curve consists of two straight lines, one vertical from 0.0 to 0.1 and the

next horizontal from 0.1 to 1.1. In such cases, the test is 100% accurate because both the sensitivity and specificity are 1.0, so there are no false positives or false negatives. On the other hand, a test is not accurate if the ROC curve is a diagonal line from 0.0 to 1.1. The ROC area for this line is 0.5, with ROC curve areas typically being between 0.5 and 1.0 (Copp et al. 2009). The best FISK threshold (cut-off) value that maximizes the true positive rate (true invasive classified as invasive) and minimizes the false positive rate (true non-invasive classified as invasive) was determined using a combination of Youden's J statistic (Youden 1950) and the point closest to the top-left part of the plot with perfect sensitivity or specificity. For the global (mean) ROC curve, a smoothed mean ROC curve was also generated and bootstrapped confidence intervals of specificities computed along the entire range of sensitivity points (0 to 1, at 0.1 intervals).

As each response of FISK for a given species is allocated a certainty score (1 = very uncertain; 2 = mostly uncertain; 3 = mostly certain; 4 = very certain), a 'certainty factor' (CF) was computed as:

$$\Sigma(CQ_i)/(4 \times 49) \ (i = 1, \dots, 49)$$

where CQ_i is the certainty for question i , 4 is the maximum achievable value for certainty (i.e. 'very certain') and 49 is the total number of questions comprising the FISK tool. The CF therefore ranges from a minimum of 0.25 (i.e. all 49 questions with certainty score equal to 1) to a maximum of 1 (i.e. all 49 questions with certainty score equal to 4). Analyses were carried out with package pROC for R statistical environment (R Development Core Team 2015, Robin et al. 2011) and 2000 bootstrap replicates were used.

Results

There were no statistical differences between the four assessor-specific ROC curves and corresponding AUCs (Venkatraman permutation tests: Table 1, Fig 2a). As a result, a global ROC curve could be computed based on mean FISK scores, which resulted in an AUC of

0.7005 (0.5226–0.9224 95% CI), hence above 0.5 (Fig. 2b). This indicated that FISK was able to discriminate reliably between invasive and non-invasive species for the Balaton catchment. Since Youden’s J and closest top-left statistics provided slightly different values (i.e. ≈ 11.4 and ≈ 11.9 , respectively), the smallest one was chosen as calibration threshold of the FISK risk outcomes for the Balaton catchment (Table 2). Based on this threshold, ‘medium risk’ species were regarded as those with scores within the interval $[1; 11.4[$ and ‘high risk *sensu lato*’ species those with scores within the interval $[11.4; 57]$, with the latter further categorised as per Britton et al. (2010a) into ‘moderately high risk’ (interval $[11.4, 25[$), ‘high risk’ (interval $[25, 30[$), and ‘very high risk’ (interval $[30, 57]$). Species categorised as ‘low risk’ were those attributed a FISK score within the interval $[-15, 1[$ (NB: open square brackets indicate an open interval).

Based on the 11.4 threshold score and corresponding intervals, none of the mean scores for the 26 species fell into the ‘low risk’ category, whereas five (19.2%) were categorized as ‘medium risk’, and the remaining 21 (80.7%) as ‘high risk’ *sensu lato* of which 18 (85.7%, 69.2%; of total) as ‘moderately high risk’, two (9.5%; 7.4% of total) as ‘high risk’ (topmouth gudgeon *Pseudorasbora parva* and black bullhead *Ameiurus melas*), and one (4.8%; 3.7% of the total) as ‘very high risk’ (gibel carp *Carassius gibelio*; Table 2). The lowest-scoring species was the rainbow chichlid *Archrocentrus multispinosus*.

Mean and median scores according to the different selection criteria showed significant differences ($t = -3.48$, $df = 99.9$, $P = 0.0007$), with non-native species already inhabiting the catchment scoring higher. Amongst the Criterion 1 species, the highest scoring were the round goby *Neogobius melanostomus*, bighead goby *Ponticola kessleri*, and the racer goby *Babka gymnotracheus*. The median FISK score in each group (i.e. criteria 1 and 2) was higher than the 11.4 threshold (Fig. 3). Mean scores for all species classified *a priori* as invasive were ranked as ‘high risk *sensu lato*’ and fell into the ‘moderately high risk’ sub-category.

However, the mean scores for non-invasive species both of least concern and vulnerable threat status also were ranked as ‘moderately high risk’, with only the non-invasive endangered Siberian sturgeon *Acipenser baeri* classified as ‘medium risk’ (Fig. 4).

Mean certainty in response for all species was 3.36 ± 0.3 SE (i.e. above the category “mostly certain”) and CF was 0.84 ± 0.09 SE, and ranged from a minimum of 2.52 ± 0.1 SE (CF: 0.63 ± 0.01 SE) for channel catfish *Ictalurus punctatus* and rainbow trout to a maximum of 3.88 ± 0.4 SE (CF: 0.97 ± 0.08 SE) for monkey goby *Neogobius fluviatilis* and round goby (Table 1).

Discussion

The threshold value of 11.4 obtained in the present study was overall consistent with those for previous FISK-based assessments in neighbouring areas, namely the southern (threshold = 9.5: Simonović et al. 2013) and northern (threshold = 11.8: Piria et al. 2015) Balkans countries. Conversely, the Lake Balaton FISK threshold value was lower than those obtained for RA areas elsewhere worldwide, ranging from 15.3 to 24 (Copp et al. 2009; Verreycken et al. 2009; Onikura et al. 2011; Vilizzi and Copp 2012; Almeida et al. 2013; Puntila et al. 2013; Tarkan et al. 2014; Perdikaris et al. 2015; Mendoza et al. 2015). The lower threshold values in the Balkans region, where within-region and/or between-catchment translocations have occurred, has been attributed to the elevated proportion of endemic species (Simonović et al. 2013; Piria et al. 2015). Locally translocated species (those native to one part of the RA area and introduced outside their native range within the RA area) tend to be less invasive than more exotic species (those from other continents), and this is likely the reason for the lower threshold values. The reason for the low score threshold in the Balaton catchment could be attributed to a scale-dependent effect, given that this RA area is much smaller than the RA areas of previous FISK applications, where entire countries, regions, or very large river catchments were considered (Copp 2013).

The taxonomic profiles of the highest scoring species showed overall similarities to previous studies, with cyprinids and ictalurid catfishes being ranked as high risk (Mastitsky et al. 2010; Almeida et al. 2013; Puntila et al. 2013; Tarkan et al. 2014; Perdikaris et al. 2015; Piria et al. 2015). Gibel carp received the highest score, similar to FISK assessments elsewhere in Europe and Asia Minor. This species, native to the Far East (Bănărescu 1990), has a long history of invasiveness and its establishment in the Danube system could have occurred in two ways. Firstly, Holčík (1980) hypothesised that gibel carp expand across Romania by natural dispersal, but (secondly) stocks were also known to have been imported previously from Bulgaria to Szarvas (Eastern Hungary) for aquaculture (Szalay 1954). The first report of gibel carp for the Hungarian section of the Danube was in 1975 (Tóth 1975), with its introduction to Lake Balaton occurred in the same period (Bíró 1997), and the species is currently present virtually throughout the Balaton catchment, with extremely high abundances in wetlands, angling ponds and canals (Ferincz et al. 2016).

Black bullhead scored second highest in the present study. With the exception of Finland (Puntila et al. 2013), this high risk ranking is consistent with FISK assessments elsewhere, including Europe (Copp et al. 2009; Verreycken et al. 2009; Mastitsky et al. 2010; Almeida et al. 2013; Perdikaris et al. 2015; Piria et al. 2015), Asia Minor (Tarkan et al. 2014) and the Murray-Darling basin, Australia (Vilizzi and Copp 2012). Tolerant of harsh water conditions (e.g. pollution, low dissolved oxygen levels), this nest-guarding species is omnivorous and aggressive (Braig and Johnson 2003; Novomenská and Kováč 2009). Black bullhead was first reported in Europe, in France, in 1871, where it was imported for aquaculture (Couchérousset et al. 2006), and it has since expanded its invasive range to become the most widespread North American ictalurid catfish of Europe (Pedicillo et al. 2008). The species' expansion has been human mediated and fast in some cases (e.g. to Hungary from Italy in 1980: Harka 1997). In other European locations, however, dispersal has been slower, such as in Spain (first

record in 1984: Elvira 1984), Portugal (first record in 2002; Gante and Santos 2002), and England, where the only recently confirmed population has been present for >50 years (Wheeler et al. 2004) but was eradicated in 2014 (GB Non-native Species Secretariat 2014). Yeű, despite achieving a high score, its abundance and frequency of occurrence is still generally low across the Balaton catchment (Erűs et al. 2009; Sály et al. 2011; Paulovits et al. 2014; Ferincz et al. 2015).

Topmouth gudgeon was also categorised as ‘high risk’, similar to all other European and Asia Minor assessments. This small, mainly planktivorous fish, which is regarded as the most invasive species in Europe (Gozlan et al. 2005, 2010), is native to the Far East (i.e. China, Korea and western regions of Japan, and its introduction to Europe (including Hungary) and Middle Asia occurred accidentally in 1960–1962 as a contaminant of larvae of large herbivorous cyprinids (i.e. *Hyphophthalmichtys* sp. and grass carp *Ctenopharyngodon idella*) imported to Romania from China (Bănărescu 1964). A continental-scale invasion then took place in the 1970–80s, and currently the species is widespread throughout Europe (Gozlan et al. 2010). Extremely high abundances are often found in small angling ponds, nursing ponds and canals of pond aquaculture facilities (Adamek and Siddiqui 1997; Rosecchi et al. 2001; Britton et al. 2010b), and there is increasing evidence of its impacts on native fishes (e.g. Britton et al. 2007, 2009, 2011; Gozlan et al. 2005, 2010). For example, competition for spawning grounds with the endangered *Pseudorasbora pumila* has been observed in Japan (Konishi and Takata 2004) and trophic overlaps with roach *Rutilus rutilus* and rudd *Scardinius erythrophthalmus* have been reported (Britton et al. 2010c). Specific to the Balaton catchment, topmouth gudgeon is found in every habitat with the highest abundances recorded in angling and fish ponds (Sály et al. 2011; Paulovits et al. 2014; Ferincz et al. 2015).

According to current assessment, the Amur sleeper *Percottus glenii* was categorised as ‘moderately high risk’, in spite of recent studies having highlighted this species as the most

threatening for the native fish communities of the Carpathian Basin (Kati et al. 2015; Takács et al. 2015). Currently, the status of this species is confusing, as it is classed as 'Vulnerable' in its native range, but also considered to be the most invasive species in Central Europe. The invasion of this small odontobutid (Perciformes: *Odontobutidae*) species is well documented (Terlecki and Palka 1999; Harka and Sallai 1999; Koščo et al. 2003; Nalbant et al. 2004; Reshetnikov 2004; Simonović et al. 2006; Jurajda et al. 2006; Nowak et al. 2008), and its native range is the Russian Far East and the northern part of the Korean Peninsula and the potential Holarctic distribution was modelled by Reshetnikov and Ficetola (2011). The introduction and expansion of Amur sleeper in Europe started with two introduction events, namely in St. Petersburg in 1912 and Moscow in 1948, both as releases from aquaria (Koščo et al. 2003). The first Hungarian specimen of the Amur sleeper was collected in 1997 in the middle section of the River Tisza (Harka 1998), and the species has since invaded the highly-vegetated irrigation canals, oxbow lakes and other lentic habitats of the river catchment (Harka and Sallai 1999). At the time, the species was expected to require decades to reach the Transdanubian region (Erős et al. 2008). However, the first specimens were caught in the Balaton-catchment in 2008 (Erős et al. 2008) and reached the mouth of the main inflow of River Zala in 2012 (Takács et al. 2012). As the Amur sleeper has been known to extirpate populations of the endemic, strictly-protected European mudminnow (Kati et al. 2015, Takács et al. 2015) and amphibians, aquatic macroinvertebrates (Reshetnikov 2003, 2008). Therefore, the effective risk posed by this non-native species is considered to be higher than indicated by the current risk assessment.

Similarly to Turkey (Tarkan et al. 2014), the Iberian Peninsula (Almeida et al. 2013), Greece (Perdikaris et al. 2015) and Northern Balkan countries (Piria et al. 2015), no species in the present study were categorised as at 'low risk' of being invasive. This finding is in agreement with the 'invasion sensitivity' of this small and closed catchment (Bíró 1972;

Muskó et al. 2008; Benkő-Kiss et al. 2013). The significantly higher scores of the species already present in the catchment indicated that species with higher invasive potential are already present in the RA area. In this respect, the potentially most threatening species were those from Criterion 2, and included three Ponto-Caspian gobies (i.e. round goby, racer goby, bighead goby). These species have a long invasion history throughout Europe and North America (Kornis et al. 2012; Roche et al. 2013), and the Sió Canal may represent an important invasion corridor from river Danube. For this reason, appropriate management measures are required of the Sió floodgate to prevent the passage of this species into Lake Balaton.

In conclusion, a successful risk screening was carried out for the small and isolated catchment of Lake Balaton. The most threatening non-native species were identified using FISK v2. These results pointed out the necessity and possibility of damming further invasions and might be a basis of planning the further fish stock management issues of the RA area.

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References

- Adamek, Z. & M. A. Siddiqui, 1997. Reproduction parametres in a natural population of topmouth gudgeon, *Pseudorasbora parva*, and its condition and food characteristics with respect to sex dissimilarities. Polish Archives of Hydrobiology 44: 145–152.
- Almeida, D., F. Ribeiro, P. M. Leunda, L. Vilizzi & G. H. Copp, 2013. Effectiveness of FISK, an invasiveness screening tool for non-native freshwater fishes, to perform risk identification assessments in the Iberian Peninsula. Risk Analysis 33: 1404–1413.

285 Bănărescu, P., 1964. Pisces – Osteichthyes. Fauna Republicii Populare Romine, 13th edn.
 286 Acad. RPR, Bucuresti, 959 pp. [In Romanian]

287 Bănărescu P., 1990. Distribution and dispersal of freshwater animals in North America and
 288 Eurasia. Wiesbaden: Aula-Verlag, Zoogeography of Freshwaters: 91–92.

289 Benkő-Kiss, Á., Á. Ferincz, N. Kováts & G. Paulovits, 2013. Spread and distribution pattern
 290 of *Sinanodonta woodiana* in Lake Balaton. Knowledge and Management of Aquatic
 291 Ecosystems 408: 1–7.

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

294 Bíró, P., 1997. Temporal variation in Lake Balaton and its fish population. Ecology Of
 295 Freshwater Fish 6: 196–216.

296 Braig, E. C. & D. L. Johnson, 2003. Impact of black bullhead (*Ameiurus melas*) on turbidity
 297 in a diked wetland. Hydrobiologia 490: 11–21.

298 Britton, J. R., G. D. Davies, M. Brazier & A. C. Pinder, 2007. A case study on the population
 299 ecology of a topmouth gudgeon *Pseudorasbora parva* population in the UK and the
 300 implications for native fish communities. Aquatic Conservation 17: 749–759.

301 Britton, J. R., G. D. Davies & C. Harrod, 2009. Trophic interactions and consequent impacts
 302 of the invasive fish *Pseudorasbora parva* in a native aquatic foodweb: a field
 303 investigation in the UK. Biological Invasions 12: 1533–1542.

304 Britton J. R., J. Cucherousset, G. D. Davies, M. J. Godard & G. H. Copp, 2010a. Non-native
 305 fishes and climate change: predicting species responses to warming temperatures in a
 306 temperate region. Freshwater Biology 55: 1130–1141.

307 Britton, J. R., J. Cucherousset, J. Grey & R. E. Gozlan, 2011. Determining the strength of
 308 exploitative competition from an introduced fish: roles of density, biomass and body size.
 309 Ecology of Freshwater Fish 20: 74–79.

- Britton, J. R., G. D. Davies & M. Brazier, 2010b. Towards the successful control of the invasive *Pseudorasbora parva* in the UK. *Biological Invasions* 12: 125–131.
- Britton, J. R., G. D. Davies & C. Harrod, 2010c. Trophic interactions and consequent impacts of the invasive fish *Pseudorasbora parva* in a native aquatic foodweb: a field investigation in the UK. *Biological Invasions* 12: 1533–1542.
- Copp, G. H., 2013. The Fish Invasiveness Screening Kit (FISK) for non-native freshwater fishes – a summary of current applications. *Risk Analysis* 33: 1394–1396.
- Copp, G. H., P. G. Bianco, N. G. Bogutskaya, T. Erős, I. Falka, M. T. Ferreira, M. G. Fox, J. Freyhof, R. E. Gozlan, J. Grabowska, V. Kováč, R. Moreno-Amich, A. M. Naseka, M. Peñáz, M. Povž, M. Przybylski, M. Robillard, I. C. Rusell, S. Stakėnas, S. Šumer, A. Vila-Gispert & C. Wiesner, 2005a. To be or not to be, a non-native freshwater fish? *Journal of Applied Ichthyology* 21: 242–262.
- Copp, G. H., R. Garthwaite & R. E. Gozlan, 2005b. Risk identification and assessment of non-native freshwater fishes: concepts and perspectives on protocols for the UK. Cefas Science Technical Report. Cefas, Lowestoft, 36 pp.
(<http://www.cefas.co.uk/publications/techrep/tech129.pdf>) (accessed: 11 Jan. 2016)
- Copp, G. H., S. Stakėnas & P. I. Davison, 2006. The incidence of nonnative fishes in water courses: Example of the United Kingdom. *Aquatic Invasions* 1: 72–75.
- Copp, G. H., L. Vilizzi, J. Mumford, G. V. Fenwick, M. J. Godard & R. E. Gozlan, 2009. Calibration of FISK, an invasiveness screening tool for non-native freshwater fishes. *Risk Analysis* 29: 457–467.
- Coucherosset, J., J. M. Paillisson, A. Carpentier, M. C. Eybert & J. D. Olden, 2006. Habitat use of an artificial wetland by the invasive catfish *Ameiurus melas*. *Ecology of Freshwater Fish* 15: 589–596.

334 Economidis, P. S., E. Dimitriou, R. Pagoni, E. Michaloudi & L. Natsis, 2000. Introduced and
 335 translocated fish species in the inland waters of Greece. *Fisheries Management and*
 336 *Ecology* 7: 239–250.

337 Elvira, B., 1984. First record of the North American catfish *Ictalurus melas* (Rafinesque,
 338 1820) (Pisces, Ictaluridae) in Spanish waters. *Cybiurn* 8: 96–98.

339 EPPO, 2002. EPPO Standards. Pest Risk Analysis. PM 5/2 (revised). EPPO Bulletin 32: 231–
 340 233.

341 Erős, T., A. Specziár & P. Bíró, 2009. Assessing fish assemblages in reed habitats of a large
 342 shallow lake—A comparison between gillnetting and electric fishing. *Fisheries Research*
 343 96: 70–76.

344 Erős, T., P. Takács, P. Sály, A. Specziár, Á. I. György & P. Bíró, 2008. Az amurgéb
 345 (*Percottus glenii* Dybowski, 1877) megjelenése a Balaton vízgyűjtőjén. [First occurrence
 346 of Amur sleeper (*Percottus glenii* Dybowski, 1877) in the Balaton-catchment] *Halászat*
 347 101: 75–77. (in Hungarian)

348 Ferincz Á, Zs. Horváth, Á. Staszny, A. Ács, N. Kováts, C. F. Vad, J. Csaba, S. Sütő & G.
 349 Paulovits, 2016. Desiccation frequency drives local invasions of non-native gibel carp
 350 (*Carassius gibelio*) in the catchment of a large, shallow lake (Lake Balaton, Hungary).
 351 *Fisheries Research* 173: 37–44.

352 Ferincz, Á., Á. Staszny, A. Ács, A. Weiperth, I. Tátrai & G. Paulovits, 2012. Long-term
 353 development of fish assemblage in Lake Fenéki (Kis-Balaton Water Protection System,
 354 Hungary): succession, invasion and stabilization. *Acta Zoologica Scientarum Academiae*
 355 *Hungarica* 58 (Supplementum 1): 3–18.

356 Ferincz, Á., Á. Staszny, A. Weiperth, S. Sütő, G. Soczó, A. Ács, N. Kováts & G. Paulovits,
 357 2014. Adatok a Dél-Balatoni berekterületek halfaunájához. [Data to the fish fauna of

southern wetlands of Lake Balaton] *Natura Somogyiensis* 24: 279-286. (in Hungarian with English summary)

Gante, H. F. & C. D. Santos, 2002. First records of North American catfish *Ictalurus melas* (Rafinesque, 1820) in Portugal. *Journal of Fish Biology* 61: 1643–1646.

GB Non-native Species Secretariat, (2014) High risk species eradicated from GB: Black bullhead catfish *Ameiurus melas*. (www.nonnativespecies.org/news/index.cfm?id=151) (last accessed: 22/07/2014)

Gozlan, R. E., D. Andreou, T. Asaeda, K. Beyer, R. Bouhadad, D. Burnard, N. Caiola, P. Cakic, V. Djikanovic, H. R. Esmaeili, I. Falka, D. Golicher, A. Harka, G. Jeney, V. Kováč, J. Musil, A. Nocita, M. Povž, N. Poulet, T. Virbickas, C. Wolter, A. S. Tarkan, E. Tricarico, T. Trichkova, H. Verreycken, A. Witkowski, C-g. Zhang, I. Zweimueller & J. R. Britton, 2010. Pan-continental invasion of *Pseudorasbora parva*: towards a better understanding of freshwater fish invasions. *Fish & Fisheries* 11: 315–340.

Gozlan, R. E., S. St-Hilaire, S. W. Feist, P. Martin & M. L. Kent, 2005. An emergent infectious disease threatens European fish biodiversity. *Nature* 435: 1046.

Györe, K., 1995. Magyarország természetesvízi halai. [Freshwater fishes of Hungary] Környezetgazdálkodási Intézet, pp.1–339. (in Hungarian)

Halasi-Kovács, B., L. Antal, S. A. Nagy, 2011. First record of a Ponto-caspian *Knipowitschia* species (Gobiidae) in the Carpathian basin, Hungary *Cybum* 35: 257–258.

Harka, Á., 1997. Terjed vizeinkben a fekete törpeharcsa. [The spreadnig of black bullhead of Hungarian waters] *Halászat* 90 (3): 109–110. (in Hungarian)

Harka, Á. 1998. Magyarország faunájának új halfaja: az amurgéb (*Perccottus glehni* Dybowski, 1877). [New species for Hungarian ichthyofauna: the Amur sleeper (*Perccottus glehni* Dybowski, 1877)] *Halászat* 91 (1): 32–33. (in Hungarian)

382 Harka, Á. & Z. Sallai, 1999. Az amurgéb (*Perccottus glenii* Dybowski, 1877) morfológiai
383 jellemzése, élőhelye és terjedése Magyarországon. [Morphological characterization, habitat
384 and spread of Amur sleeper (*Perccottus glenii* Dybowski, 1877) in Hungary] Halászat 92
385 (1), 33–36. (in Hungarian)

386 Harka, Á. & Z. Sallai, 2004. Magyarország halfaunája. [The fish fauna of Hungary] Nimfea
387 Természetvédelmi Egyesület, Szarvas, 269 pp. (in Hungarian)

388 Harka, Á. & Zs. Szepesi, 2010. How many stickleback species (*Gasterosteus* sp.) Exist in
389 Hungary? Pisces Hungarici 4: 101–103.

390 Herman, O., 1887. A magyar halászat könyve. [The book of Hungarian fisheries] Magyar
391 Természettudományi Társulat Budapest, reprint 2008, Homonnai kiadó, 642 pp. (in
392 Hungarian)

393 Herman, O., 1890. Ángolna a Balatonban és a Velencei-tóban. [Eel in Lake Balaton and
394 Lake Velencei] Természettudományi Közlöny 255: 603–604. (in Hungarian)

395 Holčík, J., 1980. *Carassius auratus* (Pisces) in the Danube River. Acta Scientiarum Naturale
396 Brno 14 (11): 1–43.

397 Jurajda, P., M. Vassilev, M. Polačik & T. Trichkova, 2006. A first record of *Perccottus glenii*
398 (Perciformes: Odontobutidae) in the Danube River in Bulgaria. Acta Zoologica Bulgarica
399 58: 279–282.

400 Kati, S., A. Mozsár, D. Árvai, J. N. Cozma, I. Czeglédi, L. Antal, S. A. Nagy & T. Erős, 2015.
401 Feeding ecology of the invasive Amur sleeper (*Perccottus glenii* Dybowski, 1877) in
402 Central Europe. International Review of Hydrobiology 100: 116–128.

403 Konishi, M. & K. Takata, 2004. Size-dependent male–male competition for a spawning
404 substrate between *Pseudorasbora parva* and *Pseudorasbora pumila*. Ichthyological
405 Research 51: 184–187.

- Kornis, M. S., N. Mercado-Silva & M. J. Van der Zanden, 2012. Twenty years of invasion: a review of round goby *Neogobius melanostomus* biology, spread and ecological implications. *Journal of Fish Biology* 80: 235–285.
- Korponai, J., M. Braun, K. Buczkó, I. Gyulai, L. Forró, J. Nédli & I. Papp, 2010. Transition from shallow lake to a wetland: a multi-proxy case study in Zalavári Pond, Lake Balaton, Hungary. *Hydrobiologia* 641: 225–244.
- Koščo, J., L. Košuthová, P. Košuth & L. Pekárik, 2010. Non-native fish species in Slovak waters: origins and present status. *Biologia* 65: 1057–1063.
- Koščo, J., S. Lusk, K. Halačka & V. Lusková, 2003. The expansion and occurrence of the Amur sleeper (*Perccottus glenii*) in eastern Slovakia. *Folia Zoologica* 52: 329–336.
- Lawson, L. L., J. E. Hill, L. Vilizzi, S. Hardin & G. H. Copp, 2013. Revisions of the Fish Invasiveness Scoring Kit (FISK) for its application in warmer climatic zones, with particular reference to Peninsular Florida. *Risk Analysis* 33: 1414–1431.
- Lusk, S., V. Lusková & L. Hanel, 2010. Alien fish species in the Czech Republic and their impact on the native fish fauna. *Folia Zoologica* 59: 57–72.
- Mastitsky, S. E., A. Y. Karatayev, L. E. Burlakova, B. V. Adamovich, 2010. Non-native fishes of Belarus: diversity, distribution, and risk classification using the Fish Invasiveness Screening Kit (FISK). *Aquatic Invasions* 5: 103–114.
- Mendoza, R., S. Luna, S. & C. Aguilera, 2015. Risk assessment of the ornamental fish trade in Mexico: analysis of freshwater species and effectiveness of the FISK (Fish Invasiveness Screening Kit). *Biological Invasions* 17: 3491–3502.
- Muskó, I. B., M. Bence & C. Balogh, 2008. Occurrence of a new Ponto-Caspian invasive species, *Cordylophora caspia* (Pallas, 1771) (Hydrozoa: Clavidae) in Lake Balaton (Hungary). *Acta Zoologica Academiae Scientiarum Hungaricae* 54: 169–179.
- Nalbant, T., K. W. Batts, F. Pricope & D. Ureche, 2004. First record of the amur sleeper

- Perccottus glenii* (Pisces: Perciformes: Odontobutidae) in Romania. Travaux du Museum National d'Histoire Naturelle 47: 279–284.
- Novomeská, A. & V. Kováč, 2009. Life-history traits of non-native black bullhead *Ameiurus melas* with comments on its invasive potential. Journal of Applied Ichthyology 25: 79–84.
- Nowak, M., W. Popek & P. Epler, 2008. Range expansion of an invasive alien species, Chinese sleeper, (*Perccottus glenii* Dybowski, 1877) (Teleostei: Odontobutidae) in the Vistula river drainage. Acta Ichthyologica et Piscatoria 38: 37–40.
- Onikura, N., J. Nakajima, R. I. H. Mizutani, M. K. S. Fukuda & T. Mukai, 2011. Evaluating the potential for invasion by alien freshwater fishes in northern Kyushu Island, Japan, using the Fish Invasiveness Scoring Kit. Ichthyological Research 58: 382–387.
- Paulovits, G., Á. Ferincz, Á. Staszny, A. Weiperth, I. Tátrai, J. Korponai, K. Mátyás & N. Kováts, 2014. Long-term changes in the fish assemblage structure of a shallow eutrophic reservoir (Lake Hídvégi, Hungary), with special reference to the exotic *Carassius gibelio*. International Review of Hydrobiology 5: 373–381.
- Pedicillo, G., A. Bicchi, V. Angeli, A. Carosi, P. Viali & M. Lorenzoni, 2008. Growth of black bullhead *Ameiurus melas* (Rafinesque, 1820) in Corbara Reservoir (Umbria – Italy). Knowledge and Management of Aquatic Ecosystems 389: 05.
- Peel, M. C., B. L. Finlayson & T. A. McMahon, 2007. Updated world map of the Köppen-Geiger climate classification. Hydrology and Earth System Sciences 11: 1633–1644.
- Perdikaris, C., N. Koutsikos, L. Vardakas, D. Kommatas, P. Simonović, I. Paschos, V. Detsis, L. Vilizzi & G. H. Copp, G. H. 2015. Risk screening of non-native, translocated and traded aquarium freshwater fish in Greece using FISK. Fisheries Management and Ecology (doi: 10.1111/fme.12149)

- Pheloung, P. C, P. A Williams & S. R. Halloy, 1999. A weed risk assessment model for use as a biosecurity tool evaluating plant introductions. *Journal of Environmental Management* 57: 239–251.
- Piria, M., M. Povž, L. Vilizzi, D. Zanella, P. Simonović, G. H. Copp, 2015. Risk screening of non-native freshwater fishes in Croatia and Slovenia using the Fish Invasiveness Screening Kit. *Fisheries Management and Ecology* (doi: 10.1111/fme.12147)
- Povž, M. & S. Šumer, 2006. A brief review of non-native freshwater fishes in Slovenia. *Journal of Applied Ichthyology* 21: 316–318.
- Puntila, R., L. Vilizzi, M. Lehtiniemi & G. H. Copp, 2013. First Application of FISK, the Freshwater Fish Invasiveness Screening Kit, in Northern Europe: Example of Southern Finland. *Risk Analysis* 33: 1397–1403.
- R Development Core Team, 2015. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. <http://www.R-project.org> (October 2015)
- Reshetnikov, A. N., 2003. The introduced fish, rotan (*Perccottus glenii*), depresses populations of aquatic animals (macroinvertebrates, amphibians, and a fish). *Hydrobiologia* 510: 83–90.
- Reshetnikov, A. N., 2004. The fish *Perccottus glenii*: history of introduction to western regions of Eurasia. *Hydrobiologia* 522: 349–350.
- Reshetnikov, A. N., 2008. Does rotan *Perccottus glenii* (Perciformes: *Odontobutidae*) eat the eggs of fish and amphibians? *Journal of Ichthyology* 48: 336–344.
- Reshetnikov, A. N. & G. F. Ficetola, 2011. Potential range of the invasive fish rotan (*Perccottus glenii*) in the Holarctic. *Biological Invasions* 13: 2967–2980.

- Robin, X., N. Turck, A. Hainard, N. Tiberti, F. Lisacek, J. C. Sanchez & M. Müller, 2011. pROC: an open-source package for R and S+ to analyze and compare ROC curves. *BMC Bioinformatics* 12: 77.
- Roche, K. F., M. Janač & P. Jurajda, 2013. A review of Gobiid expansion along the Danube-Rhine corridor – geopolitical change as a driver for invasion. *Knowledge and Management of Aquatic Ecosystems* 411: 01.
- Rosecchi, E., F. Thomas & A. J. Crivelli, 2001. Can life-history traits predict the fate of introduced species? A case study on two cyprinid fish in southern France. *Freshwater Biology* 46: 845–853.
- Sály, P., P. Takács, I. Kiss, P. Bíró, T. Erős, 2011. The relative influence of spatial context and catchment- and site-scale environmental factors on stream fish assemblages in a human-modified landscape. *Ecology of Freshwater Fish* 20: 251–262.
- Simonović, P., S. Maric & V. Nikolić, 2006. Records Of Amur sleeper *Perccottus glenii* (Odontobutidae) in Serbia and its recent status. *Archives of Biological Sciences Belgrade* 58 (1): 7–8.
- Simonović, P., A. Tošić, M. Vassilev, A. Apostolou, D. Mrdak, M. Ristovska, V. Kostov, V. Nikolić, D. Škraba, L. Vilizzi & G. H. Copp, 2013. Risk assessment of non-native fishes in the Balkans Region using FISK, the invasiveness screening tool for non-native freshwater fishes. *Mediterranean Marine Science* 14: 369–376.
- Specziár, A., 2004. Life history pattern and feeding ecology of the introduced eastern mosquitofish, *Gambusia holbrooki*, in a thermal spa under temperate climate, of Lake Hévíz, Hungary. *Hydrobiologia* 522: 249–260.
- Specziár, A. & B. Turcsányi, 2014. Effect of stocking strategy on distribution and recapture rate of common carp *Cyprinus carpio* L., in a large and shallow temperate lake:

implications for recreational put-and-take fisheries management. Journal of Applied Ichthyology 30: 887–894.

Szalay, M., 1954. Új halfaj Magyarországon – ezüstkárász. [New fish species in Hungary – Gible carp] Halászat 1 (3): 4. (in Hungarian)

Takács, P., T. Erős, A. Specziár, P. Sály, Z. Vitál, Á. Ferincz, T. Molnár, Z. Szabolcsi, P. Bíró & E. Csoma, 2015. Population genetic patterns of threatened European mudminnow (*Umbra krameri* Walbaum, 1792) in a fragmented landscape: implications for conservation management. PLOS One 10 (9): e0138640.

Takács, P., A. Specziár, T. Erős, P. Sály, P. Bíró, 2011. A balatoni vízgyűjtő halállományainak összetétele. [Fish assemblage structures of the Balaton-catchment] Ecology of Lake Balaton 1: 1–21. (in Hungarian with English summary)

Tarkan, A. S., G. F. Ekmekci, L. Vilizzi & G. H. Copp, 2014. Risk screening of non-native freshwater fishes at the frontier between Asia and Europe: first application in Turkey of the fish invasiveness screening kit. Journal of Applied Ichthyology 30: 392–398.

Terlecki, J. & R. Palka, 1999. Occurrence of *Perccottus glenii* Dybowski 1877 (Perciformes, Odontobutidae) in the middle stretch of the Vistula river. Poland. Archives of Polish Fisheries 7: 141–150.

Tóth J., 1975. A brief account on the presence of the silver crucian carp (*Carassius auratus gibelio* Bloch 1873) in the Hungarian section of the Danube, Budapest. Annales Universitatis Scientis Budapestiensis Section Biologica 18–19: 219–220.

Venkatraman, E. S., 2000. A permutation test to compare receiver operating characteristic curves. Biometrics 56: 1134–1138.

Verreycken H., G. Van Thuyne & C. Belpaire, 2009. Nonindigenous freshwater fishes in Flanders: status, trends and risk assessment. PowerPoint presentation, Science Facing . 11 May 2009, Brussels. <http://www.academia.edu/2878630/Non->

indigenous_freshwater_fishes_in_Flanders_status_trends_and_risk_assessment (last
accessed: 11.11.2015)

Vilizzi, L. & G. H. Copp, 2012. Application of FISK, an invasiveness screening tool for non-
native freshwater fishes, in the Murray-Darling Basin (Southeastern Australia). Risk
Analysis 33: 1432–1440.

Vutskits, Gy., 1897. A Balaton halai és gyakoriságuk. [Abundances of fish species in Lake
Balaton] Természettudományi Közlöny 29: 593–595. (in Hungarian)

Wheeler, A.C., N.R. Merrett & D.T.G. Quigley, 2004. Additional records and notes for
Wheeler's (1992) List of the common and scientific names of fishes of the British Isles.
Journal of Fish Biology 65 (Supplement B): 1–40.

Youden, W.J., 1950. Index for rating diagnostic tests. Cancer 3: 32–35.

Zlinszky, A. & G. Tímár, 2013. Historic maps as a data source for socio-hydrology: a case
study of the Lake Balaton wetland system, Hungary. Hydrology And Earth System
Sciences 17: 4589–4606.

Tables

Table 1. Fish species assessed with FISK v2 for the Balaton-catchment. For each species, a priori invasiveness (as per <http://www.issg.org/> and <http://www.fishbase.org>) and protection status, along with corresponding FISK score and certainty factor (CF), are reported. Outcome is based on a calibration threshold of 11.75 between medium and high risk species sensu lato. Criterion: 1 = already occurring in the catchment; 2 = not reported from the catchment yet, but occurring within the territory of Hungary (see text for computations).

Species name	Common name	Origin	Invasiveness/ Protection Status	Criterion	Score					Certainty Factor			
					Mean	Min	Max	SE	Outcome	Mean	Min	Max	SE
<i>Acipenser baeri</i>	Siberian sturgeon	Asia (Siberia)	Non-Invasive/Endangered	1	9.25	5.5	12.0	1.53	M	0.77	0.7	0.8	0.01
<i>Ameiurus melas</i>	black bullhead	North-America	Invasive/Not evaluated	1	29.00	25.0	33.0	2.31	H	0.87	0.8	0.9	0.03
<i>Ameiurus nebulosus</i>	brown bullhead	North America	Invasive/Least concern	1	23.00	16.0	30.0	6.42	MH	0.82	0.8	0.9	0.27
<i>Anguilla anguilla</i>	European eel	Europe	Non-Invasive/ Critically Endangered	1	15.25	14.0	17.0	0.75	MH	0.88	0.9	0.9	0.01
<i>Archrocentrus multispinosus</i>	rainbow cichlid	South America	Non-invasive/Not evaluated	2	7.00	3.0	16.0	3.02	M	0.88	0.8	0.9	0.04
<i>Babka gymnotrachelus</i>	racer goby	Ponto-Caspian	Non-invasive/Least concern	2	17.50	14.0	20.0	1.32	MH	0.88	0.9	0.9	0.03
<i>Carassius gibelio</i>	gibel carp	Far-East	Invasive/ Not evaluated	1	35.75	30.0	40.0	2.17	VH	0.87	0.8	0.9	0.03
<i>Clarias gariepinus</i>	North African catfish	North Africa	Invasive/Least concert	2	12.63	5.0	18.0	2.78	MH	0.81	0.8	0.9	0.04
<i>Ctenopharyngodon idella</i>	grass carp	Far-East	Non-Invasive/Not evaluated	1	17.63	12.0	23.0	2.36	MH	0.83	0.8	0.9	0.03
<i>Gambusia holbrooki</i>	eastern mosquitofish	North-America	Invasive/Not evaluated	1	11.50	7.0	14.5	1.67	H	0.84	0.7	0.9	0.08
<i>Gasterostus aculeatus</i>	threespine stickleback	Europe	Non-invasive/Least concern	2	11.13	4.5	17.0	2.63	M	0.79	0.7	0.8	0.26

<i>Hypophthalmichthys molitrix</i> <i>x H. nobilis</i>	Asian carp hybrid	Far-East	Invasive/Near threatened	1	23.38	6.0	21.0	3.33	MH	0.85	0.6	0.9	0.07
<i>Ictalurus punctatus</i>	channel catfish	North- America	Invasive/Least concern	2	8.67	4.0	15.0	2.33	M	0.78	0.8	0.9	0.26
<i>Ictiobus bubalus</i>	smallmouth buffalo	North- America	Non-invasive/Least concern	2	13.63	11.0	26.0	3.14	MH	0.74	0.7	0.9	0.07
<i>Knipowitshia caucasica</i>	Caucasian dwarf goby	Ponto-Caspian	Non-invasive/Least concern	2	10.25	7.0	20.0	2.43	M	0.81	0.8	1.0	0.03
<i>Lepomis gibbosus</i>	pumpkinseed	North- America	Non-Invasive/Not evaluated	1	19.25	8.0	22.0	3.50	MH	0.81	0.8	0.9	0.05
<i>Micropterus salmoides</i>	largemouth bass	North- America	Invasive/Least concern	2	12.75	10.0	20.0	2.95	MH	0.87	0.7	1.0	0.06
<i>Mylopharyngodon piecus</i>	black carp	Far-East	Invasive/Data deficient	2	15.38	20.5	26.0	2.88	MH	0.83	0.8	1.0	0.03
<i>Neogobius fluviatilis</i>	monkey goby	Ponto-Caspian	Non-Invasive/Not evaluated	1	14.88	8.0	17.0	2.11	MH	0.85	0.6	1.0	0.08
<i>Neogobius melanostomus</i>	round goby	Ponto-Caspian	Invasive/Least concern	2	22.38	5.0	19.5	1.25	MH	0.87	0.8	1.0	0.06
<i>Oncorhynchus mykiss</i>	rainbow trout	North- America	Invasive/Not evaluated	1	12.00	23.0	27.0	1.96	MH	0.79	0.7	1.0	0.09
<i>Oreochromis niloticus</i>	Nile tilapia	North-Africa	Invasive/Not Evaluated	1	12.88	14.5	24.0	3.04	MH	0.88	0.8	1.0	0.06
<i>Percottus glenii</i>	Amur (Chinese) sleeper	Far-East	Non-Invasive/ Vulnerable	1	24.50	5.0	19.0	0.87	MH	0.88	0.8	0.9	0.07
<i>Ponticola kessleri</i>	Kessler's goby	Ponto-Caspian	Non-invasive/Least concern	2	18.25	21.0	30.0	2.15	MH	0.89	0.9	0.9	0.05
<i>Proterorhynchus marmoratus</i>	tubenose goby	Ponto-Caspian	Non-Invasive/ Least concern	1	11.50	7.0	11.0	2.90	MH	0.85	0.8	0.8	0.04
<i>Pseudorasbora parva</i>	topmouth gudgeon	Far-East	Invasive/Not evaluated	1	25.00	6.0	21.0	1.96	H	0.85	0.6	0.9	0.00

Table 2. P values for Venkatraman's permutaton tests comparing the AUCs of the four ROC curves from the four independent assessments.

Assessor	AF	AS	AW	PT
AF	-	0.283	0.875	0.633
AS		-	0.709	0.205
AW			-	0.216
PT				-

Figure legends

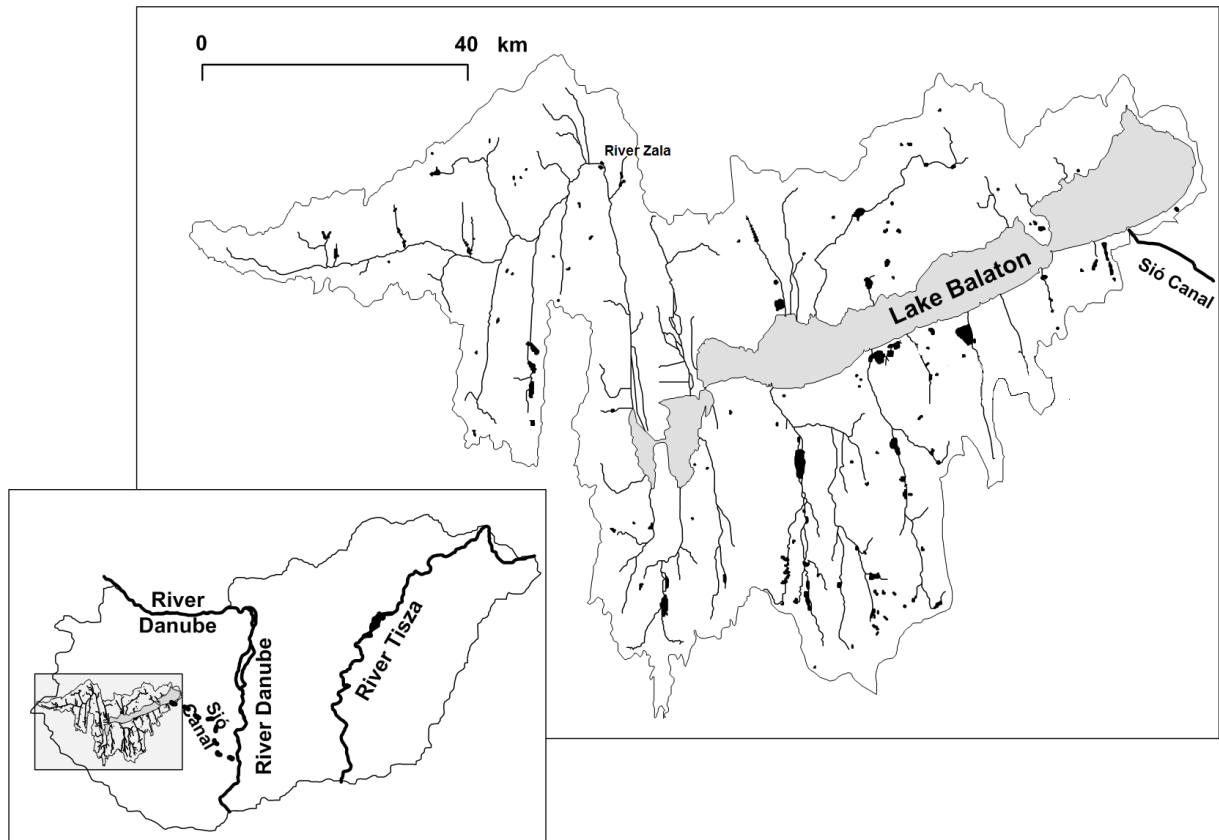


Figure 1. Map of the Balaton catchment (Hungary), with indication of the main inflow (River Zala) and outflow (Sió Canal)

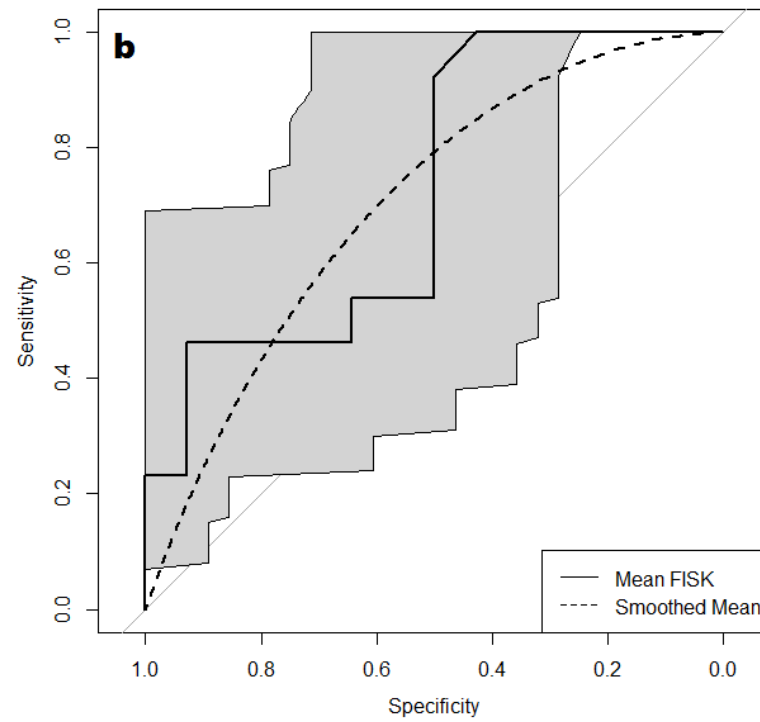
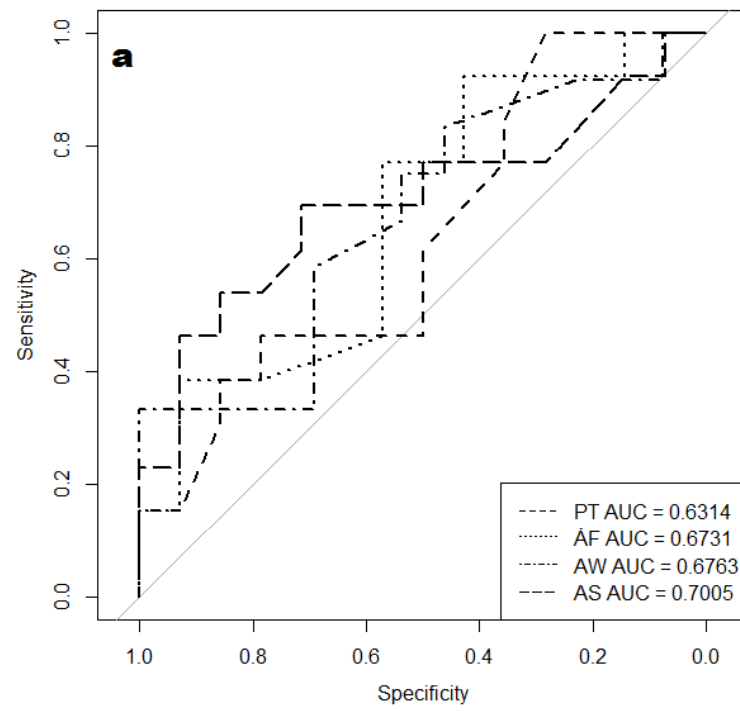


Figure 2. (a) Receiver operating characteristic (ROC) curves for two assessors (AF, AS, AW and PT) on 26 fish species assessed by FISK for the Balaton-catchment. (b) Mean ROC curve based on mean scores from the four assessors, with smoothing line and confidence intervals of specificities (see Table 1).

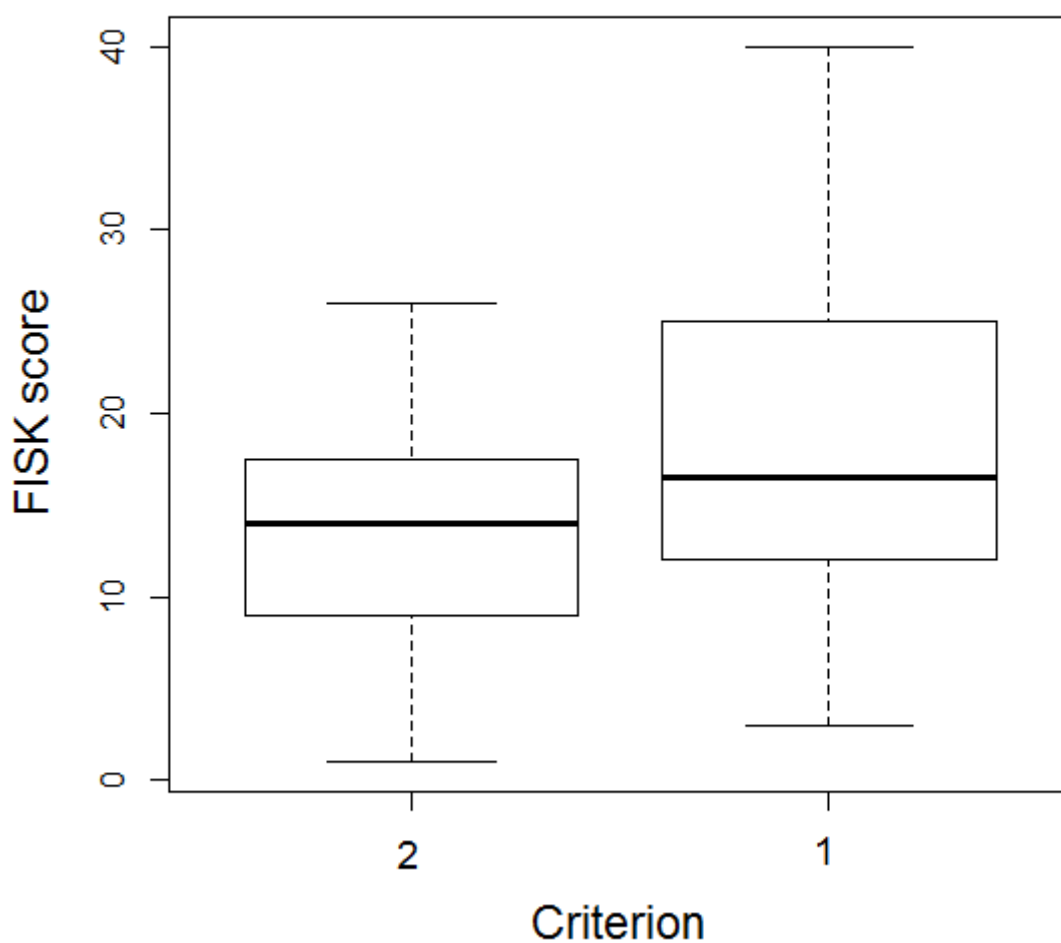


Figure 3. Boxplots of mean FISK scores according to species' selection criteria: 1 = already occurring in the catchment; 2 = not yet reported from the catchment, but occurring within the territory of Hungary.

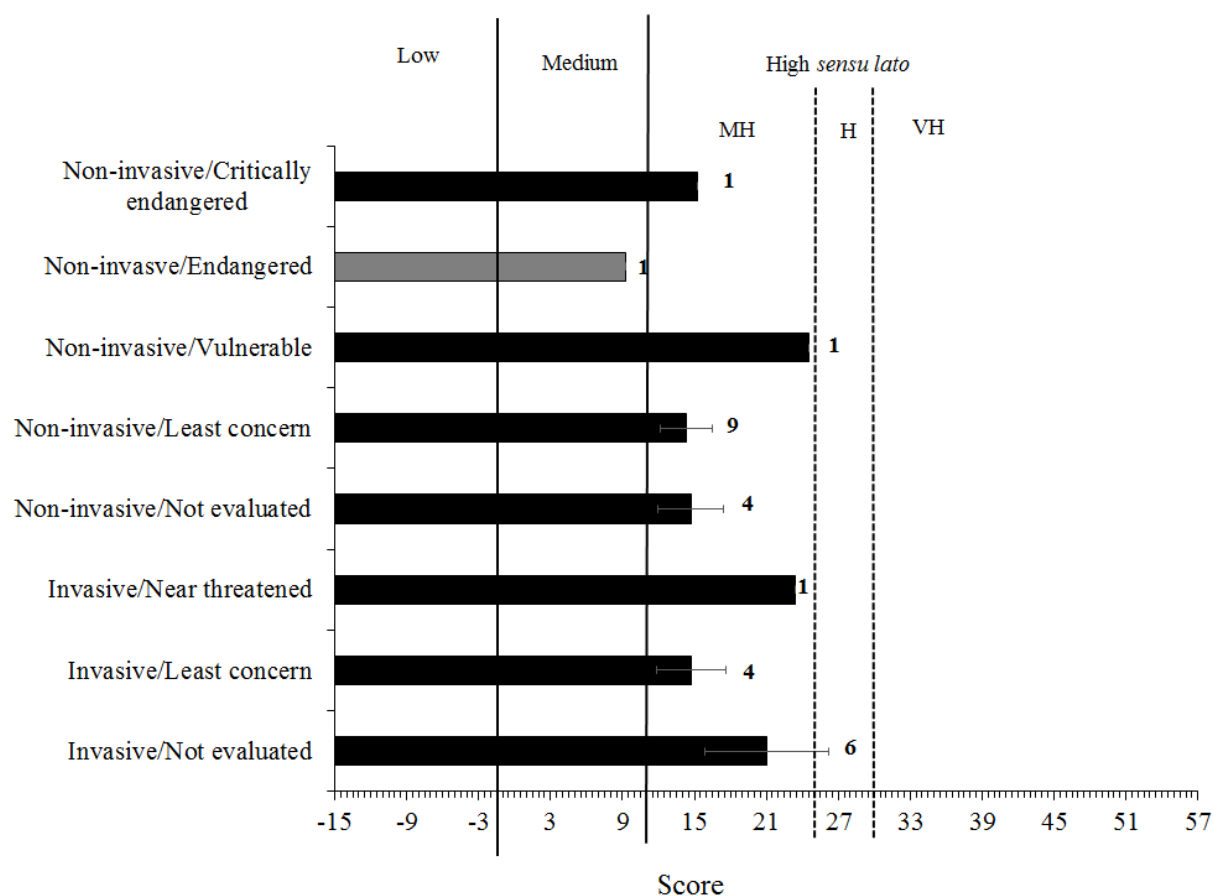


Figure 4. Mean scores (\pm SE and n) for 26 fish species assessed by FISK for the Balaton-catchment and ranked according to their a priori invasiveness and protection status (cf. Table 1). Thresholds are: <1 (low risk) and ≥ 11.375 (high risk *sensu lato*), with medium risk species in between. Risk categories and [lower, upper] scores are: L = low risk $[-15, 1[$; M = medium risk $[1, 11.375[$; MH = moderately high risk $[11.375, 25[$; H = high risk $[25, 30[$; VH = very high risk $[30, 57]$.

