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Stocking of Common Carp (*Cyprinus carpio*) into Some Newly-Established Reservoirs of North-West Anatolia May Enhance the Spread of Non-Native Fish

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Abstract

Stocking of water bodies with non-native fish species for fisheries enhancement is a common practice worldwide. However, overall limited benefits in terms of revenues for local communities have so far been reported in some countries, whilst accidental introductions of several non-native fish species have occurred. To evaluate the benefits vs. costs associated with common carp *Cyprinus carpio* stocking practices, a three-year sampling study (2009–2011) was carried out across twelve adjacent artificial reservoirs of the Kocaeli Peninsula (north-west Anatolia, Turkey). Apart from common carp, 18 fish species in total were recorded, of which 12 native and six non-native, the latter comprising more than half of the total catch and dominated by gibel carp *Carassius gibelio*. Even though the abundance of common carp, natives and non-natives increased over the study period, common carp was always comparatively less abundant relative to most of the other species. Overall, the present findings indicate that stocking of common carp into the studied reservoirs has not fully met with the proposed objectives, likely a result of less-than-optimal age-0 fish release strategies and limited availability of spawning grounds. On the other hand, invasion especially by gibel carp is thought to be under way and this may ultimately impact on the abundance of the native fish fauna.

Keywords: Richness, abundance, invasion, gibel carp, heuristic significance testing.

Kuzey-batı Anadolu'da Bazı Yeni İnşa Edilen Rezervuarlara Yapılan Sazan (*Cyprinus carpio*) Stoklamaları Yabancı Türlerin Yayılımlarını Arttırabilir

Özet

Türkiye'de çoğunlukla 'yerelleşmiş' sazan *Cyprinus carpio* stoklamaları ile bilinen su kütlelerinin yabancı tatlısu balıkları ile stoklanmaları dünyada balıkçılığın geliştirilmesi amacıyla gerçekleştirilen yaygın bir uygulamadır. Ancak, aşılamaların yapıldığı su ortamlarına yakın yerleşim yerlerinde yaşayanlara sınırlı katkısı da olsa bu aşılamalar istilacı türlerin dağılımındaki en önemli kaynaklardan biridir. Türkiye'deki su kütlelerine yapılan sazan aşılamalarının getirdiği kar-zarar durumlarını değerlendirmek için Kocaeli Yarımadası'nda (kuzey-batı Anadolu) birbirlerine yakın 12 suni rezervuarda üç senelik (2009-2011) bir araştırma gerçekleştirildi. Sazan haricinde 12'si doğal altısı yabancı olmak üzere toplam 18 balık türü kaydedildi. Yabancı türler toplam elde edilen birey sayısının yarısından fazlasını oluştururken en fazla yakalanan yabancı tür gümüşi havuz balığı *Carassius gibelio* oldu. Her ne kadar sazan, yerel ve yabancı türler çalışma periyodu boyunca birey sayısı olarak artış gösterse de, sazan diğer türlerin çoğuna nazaran her zaman daha az bollukta elde edilmiştir. Sonuç olarak, sunulan makale rezervuarlara yapılan sazan aşılamalarının uygun olmayan 0 yaş balık aşılama stratejileri ve sınırlı üreme alanları nedeniyle beklenen hedeflere tam olarak ulaşmadığını göstermiştir. Diğer yandan, özellikle gümüşi havuz balığının istilasının devam ettiğini ve bunun sonuçta yerel balık faunasını etkileyeceği düşünülmektedir.

Anahtar Kelimeler: Tür zenginliği, bolluk, istila, gümüşi havuz balığı, sezgisel önem testi.

Introduction

Worldwide, the introduction of non-native freshwater fish has become common practice mainly in response to demands for aquaculture, farming and sport fishing. However, introduced fish can detrimentally affect newly-invaded ecosystems in diverse ways (Simon and Townsend, 2003). These include the transfer of parasites and pathogens (Josefsson and Andersson, 2001, Gozlan *et al*., 2005), predation upon, competition and/or hybridisation with native species (e.g. Arthington, 1991; Crivelli, 1995; Debrot, 2003; Kats and Ferrer, 2003; Mills *et al*., 2004), alteration of community structure and

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ecosystem functioning (e.g. Zambrano *et al*., 2001; Navodaru *et al*., 2002; Beisner *et al*., 2003; Irz *et al*., 2004), as well as accidental introductions of other taxa as contaminants (Adams *et al*., 2003). Endemic fishes in particular are the most vulnerable to these introductions, with several species having disappeared or been subjected to severe reduction in population size or distribution (e.g. Arthington, 1991, Witte *et al*., 1992, Allan and Flecker 1993; Leidy and Moyle , 1996; Saunders *et al*., 2002). At the same time, beside these negative impacts, introduced fish often represent a major source of income, food or livelihood for local communities, thereby supporting profitable economic activities (Gozlan, 2008). For this reason, it is not always easy to strike a balance between the benefits *vs.* risks associated with fish introductions, and even less so whenever attempting to minimise the latter in favour of the former.

Man-made reservoirs are a common pathway for the dispersal of non-native freshwater fish (e.g. Andrews, 1990; Wheeler, 1991, North, 2000; Marchetti *et al*., 2004; Ruesink, 2005; Önsoy *et al*., 2011). These artificial water bodies, which are generally created for water supply storage (i.e. irrigation and drinking water) and/or for the generation of hydroelectric power, have considerably increased in numbers worldwide. However, although fish stocking into reservoirs is generally accomplished with the aim of boosting fish production and sport fishing (e.g. Treer *et al*., 1995; 2003), it can also cause the accidental introduction of non-native fish species. Notable cases are those of goldfish *Carassius auratus*, gibel carp *Carassius gibelio*, eastern mosquitofish *Gambusia holbrooki*, pumpkinseed *Lepomis gibbosus* and topmouth gudgeon *Pseudorasbora parva*, all of which have been associated with the intentional stocking of common carp *Cyprinus carpio* (Özuluğ *et al*., 2005; Balık and Ustaoğlu, 2006; Önsoy *et al*., 2011). The latter is a widely-distributed Eurasian cyprinid, which is highly invasive and noxious in several areas of introduction (review in Vilizzi *et al*., 2015) but also threatened in parts of its native area of distribution (Balon, 1995).

Despite general recognition of the likely detrimental effects of accidental non-native freshwater fish introductions in Turkey (Balık *et al.*, 2004; Gaygusuz *et al.*, 2007; Tarkan *et al.*, 2012b), there is still limited knowledge about the extent of such impacts (Tarkan *et al*., 2012a). The aim of the present study was to assess the consequences on the native fish fauna of accidental introductions of non-native fish species as contaminants of common carp stocking into some newly-established reservoirs of north-west Anatolia. To this end: (i) trends in richness and relative abundance of native and non-native fish and of common carp are compared over a three-year study period, and (ii) the role of pathways of accidental introductions as contaminants of common carp stockings is discussed together with an evaluation of the costs *vs.* benefits involved.

Materials and Methods

Study Area

The Kocaeli Peninsula, separating Marmara Sea from Black Sea, is located in north-west Anatolia, (30°21' E, 40°31' N) (Figure 1). The metropolitan area

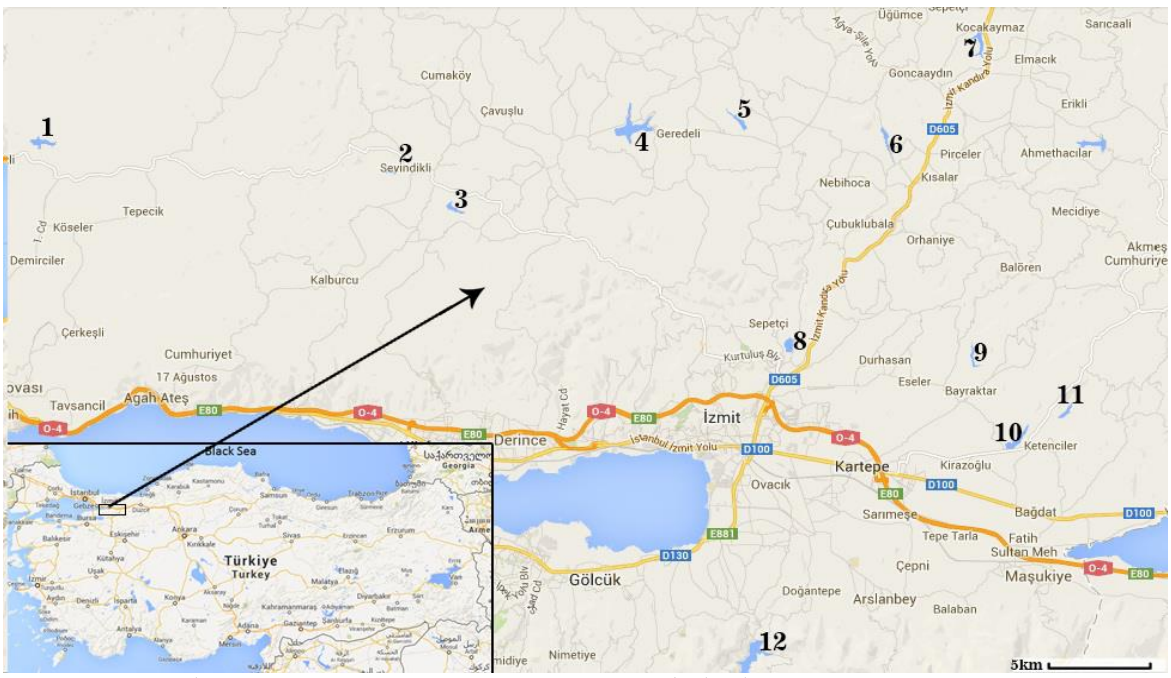

Figure 1. Reservoirs of the Kocaeli Peninsula (north-west Anatolia) sampled for fish from 2009 to 2011. (1) Denizli; (2) Sevindikli; (3) Sipahiler; (4) Tahtalı; (5) Süverler; (6) Davuldere; (7) Ütük; (8) Çayırköy; (9) Bayraktar; (10) Ketenciler; (11) Kirazoğlu, (12) Yuvacık.

of Istanbul extends to the along Kocaeli-Istanbul provincial border and the size and location of the İzmit Bay provides extensive port facilities. Kocaeli is one of the most industrialised and highly populated (250 inhabitant km^{-2}) regions of Turkey with many reservoirs having been established mainly for irrigation purposes, flood control and potable water supply. Most of these reservoirs are close to each other, range in area from 0.2 to 1.6 km^2 and have similar water depths (≈ 10 m on average). The climate of the region is Mediterranean with warm and rainy winters, hot and dry summers, and a relatively higher mean annual precipitation (768–1153 mm). The main environmental issue across the area is related to human-induced pollution, mostly as a result of leisure activities and the high number of restoration venues located around the reservoirs. Also, many agricultural activities with miscellaneous dimensions in the area cause the water budget of both natural and artificial water bodies to become critically low, especially in autumn. Stocking of age-0 common carp in the reservoirs has occurred on an annual basis since 1996, and some 1,252,000 individuals have been released so far (1996–2013 period: the Republic of Turkey, the Ministry of Food, Agriculture and Livestock. Notably, the common carp is native to some eco-regions of Turkey (Vilizzi, 2012), but following translocation in its feral 'naturalised' (*sensu* Copp *et al*. 2005) form has become ubiquitous across the country (and especially Anatolia) and currently represents a valuable resource for local inland fisheries (Turkish Statistical Institute, 2014).

Fish Sampling and Identification

Fish were sampled from 12 adjacent reservoirs (Figure 1) during three consecutive years: 15–30 June 2009, 17–30 May 2010, and 1–5 May 2011 (32 sampling events in total). Sampling was made by backpack electrofishing (SAMUS 725G) at the same locations (i.e. from the feeding streams and around the dams of the reservoirs), which were re-visited at each reservoir over the study period. After sampling, fish were anasthetised with an overdose of 2-phenoxyethanol and transported in ice to the laboratory. Identification of species was done by following the Geldiay and Balık (2007) and Kottelat and Freyhof (2007) methods.

Statistical Analysis

For statistical analysis, species richness was computed as total number of species, and fish relative abundance was expressed as catch-per-unit-effort (CPUE), which was estimated as number of fish captured during 30 min by electrofishing (constant effort across each reservoir and sampling event).

Differences in richness over the three years of sampling were tested between native and non-native species (hence, excluding naturalised common carp) by permutational univariate analysis of variance (PERANOVA), following normalization of the data and using a Euclidean distance. Differences in abundance over the study period amongst common carp, native and non-native species also were tested by PERANOVA, following standardization of CPUE for each fish component (to allow for direct comparisons), normalisation of the data and using a Euclidean distance. In both cases, a two-way factorial design was employed, with years (2009, 2010, 2011) and species (native and non-native, for richness; common carp, native and non-native, for abundance)

Table 1. Fish species caught from 12 reservoirs of the Kocaeli Peninsula (north-west Anatolia) from 2009 to 2011 (Figure 1)

Species	Abbreviation	Common name	Family	Origin	Total (%)	Reservoirs	
						n	%
Alburnus istanbulensis (Battalgil, 1941)	Alb.ist	'Thracian shemaya'	Cyprinidae	Native (endemic)	2.15	3	25.0
Barbus sp.	Bar.spp	–	Cyprinidae	Native	1.01	3	25.0
Carassius auratus (Linnaeus, 1758)	Car.aur	Goldfish	Cyprinidae	Non-native	0.12	2	16.7
Carassius gibelio (Bloch, 1782)	Car.gib	Gibel carp	Cyprinidae	Non-native	32.68	10	83.3
Cobitis vardarensis (Karaman, 1928)	Cob.var	'Velonitsa'	Cobitidae	Native	0.71	4	33.3
Cyprinus carpio (Linnaeus, 1758)	Cyp.car	Common carp	Cyprinidae	Naturalised	2.55	6	50.0
Esox lucius (Linnaeus, 1758)	Eso.luc	Northern pike	Esocidae	Native	0.22	3	25.0
Gambusia holbrooki (Girard, 1859)	Gam.hol	Eastern mosquitofish	Poeciliidae	Non-native	0.95	3	25.0
Gobio gobio (Linnaeus, 1758)	Gob.gob	Gudgeon	Cyprinidae	Native	8.70	8	66.7
Lepomis gibbosus (Linnaeus, 1758)	Lep.gib	Pumpkinseed	Centrarchidae	Non-native	15.34	4	33.3
Leucaspius delineatus (Heckel, 1843)	Leu.del	Belica	Cyprinidae	Native	2.18	2	16.7
Oncorhynchus mykiss (Walbaum, 1792)	Onc.myk	Rainbow trout	Salmonidae	Non-native	0.09	1	8.3
Petroleuciscus borysthenicus (Kessler, 1859)	Pet.bor	Dnieper chub	Cyprinidae	Native	3.38	3	25.0
Phoxinus phoxinus (Linnaeus, 1758)	Pho.pho	Eurasian minnow	Cyprinidae	Native	2.92	3	25.0
Pseudorasbora parva (Temminck & Schlegel, 1846)	Pse.par	Topmouth gudgeon	Cyprinidae	Non-native	5.26	5	41.7
Rhodeus amarus (Bloch, 1782)	Rho.ama	Bitterling	Cyprinidae	Native	4.21	7	58.3
Rutilus rutilus (Linnaeus, 1758)	Rut.rut	Roach	Cyprinidae	Native	2.55	4	33.3
Salmo sp. (Duméril, 1858)	Sal.spp.	–	Salmonidae	Native	0.03	1	8.3
Squalius pursakensis (Hankó, 1925)	Squ.pur	Pursak chub	Cyprinidae	Native (endemic)	14.94	11	91.7

Total relative abundance together with number and corresponding percentage of occurrence across reservoirs are given.

both as fixed factors. Analysis was carried out in PERMANOVA+ v1.0.1 for PRIMER v6.1.11 (Anderson *et al*. 2008) with 9999 permutations of the raw data, and with tests of significance (including *a posteriori* pair-wise comparisons) evaluated at $\alpha = 0.10$ for heuristic purposes (Kline, 2013). Briefly, the advantage of PERANOVA compared to traditional parametric analysis of variance is that the stringent assumptions of normality and homoscedasticity, which prove very often unrealistic when dealing with ecological data sets, are 'relaxed' considerably.

Results

In total, 3253 specimens were caught during the study period from the 12 reservoirs of the Kocaeli Peninsula. Apart from common carp, 18 species in total were recorded, of which 12 native and 6 non-native (Table 1). The native species included *Barbus* sp., *Cobitis vardarensis*, northern pike *Esox lucius*, gudgeon *Gobio gobio*, belica *Leucaspius delineatus*, Dnieper chub *Petroleuciscus borysthenicus*, minnow *Phoxinus phoxinus*, bitterling *Rhodeus amarus*, roach *Rutilus rutilus* and *Salmo* sp., plus endemic Pursak chub *Squalius pursakensis* and *Alburnus istanbulensis*. The non-native species comprised eastern mosquitofish, gibel carp, goldfish, pumpkinseed, rainbow trout *Oncorhyncus mykiss* and topmouth gudgeon.

Overall, native species represented 43.5% of the total catch, non-native species 53.9% and common carp the remaining 2.5% (Table 1). Gibel carp was by far the most abundant species, followed by pumpkinseed and Pursak chub. Gudgeon and topmouth gudgeon both made up > 5% of the fish sampled, whilst eastern mosquitofish, *C. vardarensis*, northern pike, goldfish, rainbow trout and *Salmo* sp. represented <1%, with the latter species found only in one specimen. Common carp occurred in 6 of the 12 reservoirs under study, whereas both native and non-native species were recorded from all of them (Table 1). Pursak chub and gibel carp were the most ubiquitous, occurring in all but one and two reservoirs, respectively, whereas rainbow trout and sea trout each occurred in only one reservoir (Figure 2). Also, in all reservoirs at least one non-native species was recorded during the study period.

Native species richness ranged from ten to one, and non-native from four to one, with two reservoirs having the highest richness (13 and 11 species) and one the lowest (3 species only) (Table 2). Native species richness was significantly higher than that of the non-native species (2.2 *vs.* 1.3; $F^{\#}_{1,62} = 6.53$, $P^{\#} = 0.010$; # = permutational), even though there was no significant change over the study period either overall ($F^{\#}_{2,62} = 0.79$, $P^{\#} = 0.475$) or depending on species (i.e. Species × Year interaction term: $F^{\#}_{2,62} = 0.90$, $P^{\#} = 0.414$).

CPUE abundance for both native and non-native species was generally higher compared to that of common carp (Table 2). Standardised CPUE abundance did not differ significantly amongst species ($F^{\#}_{2,93} = 0.03$, $P^{\#} = 0.967$) nor depending on year of sampling ($F^{\#}_{4,93} = 1.18$, $P^{\#} = 0.326$). However, there were differences over time ($F^{\#}_{2,93} = 2.69$, $P^{\#} = 0.073$), with significantly higher abundance in 2011 relative to 2010 (0.324 *vs.* −0.168; $t^{\#} = 2.01$, $P^{\#} = 0.047$) and 2009 (0.324 *vs.* −0.121; $t^{\#} = 1.77$, $P^{\#} = 0.078$), but no difference between the latter two years ($t^{\#} = 0.22$, $P^{\#} = 0.835$).

Discussion

This study has shown that over a three-year monitoring period the overall abundance of non-native fish species across 12 reservoirs of north-west

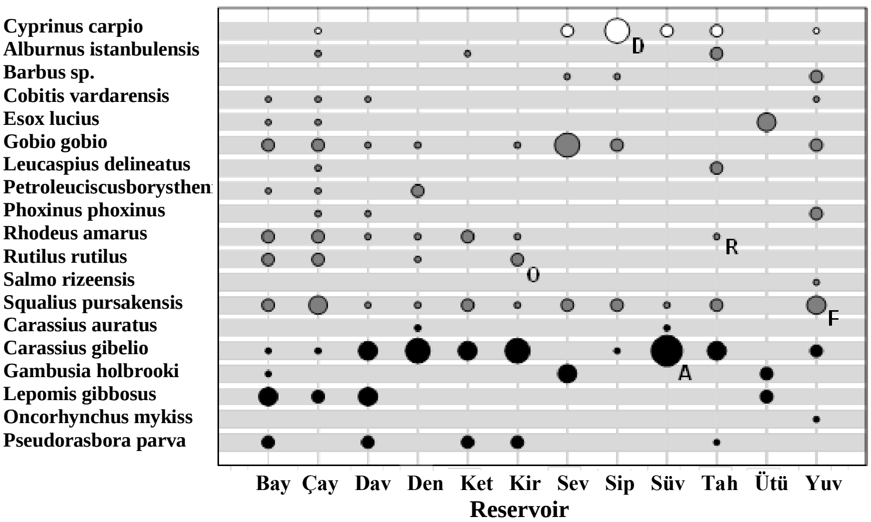

Figure 2. Frequency of occurrence of the fish species sampled from the 12 reservoirs of the Kocaeli Peninsula during the study period. White bubbles: common carp; grey bubbles: native species; black bubbles: non-native species. Bubble size proportional to frequency of occurrence (relative to reservoir): D = Dominant (> 75%); A = Abundant (51–75%); F = Frequent (26–50%); O = Occasional (6–25%); R = Rare (1–5%). Species and reservoir abbreviations as in Table 1 and Table 2, respectively.

Table 2. Presence (P)/Absence (A) of common carp, richness (total number of species) of natives and non-natives and mean catch-per-unit effort (CPUE: number of fish per 30 min electrofishing) of natives, non-natives and common carp sampled from 12 reservoirs of the Kocaeli Peninsula from 2009 to 2011

Reservoir			Richness			CPUE		
Name	Abbreviation	Common carp	Native	Non-native	Total	Common carp	Native	Non-native
Bayraktar	Bay	A	7	4	11	0.0	8.3	14.4
Çayırköy	Çay	P	10	2	13	4.0	10.7	11.6
Davuldere	Dav	A	5	3	8	0.0	1.2	25.1
Denizli	Den	A	5	2	7	0.0	4.2	21.0
Ketenciler	Ket	A	3	2	5	0.0	1.2	2.3
Kirazoğlu	Kir	A	4	2	6	0.0	1.2	9.2
Sevindikli	Sev	P	3	1	5	2.0	2.1	2.0
Sipahiler	Sip	P	3	1	5	4.7	1.6	0.2
Süverler	Süv	P	1	2	4	2.0	0.1	3.8
Tahtalı	Tah	P	4	2	7	5.3	6.3	13.3
Ütük	Ütü	A	1	2	3	0.0	0.1	0.2
Yuvacık	Yuv	P	6	2	9	0.2	6.0	3.5

Anatolia was more than half compared to that of the native species and sharply increased in the last year of sampling (i.e. 2011). However, this increase was paralleled by a corresponding increase in the abundance of the native species as well as of common carp, whose abundance remained comparatively low both across reservoirs and during the study period.

As a reason of concern, non-native species occurred in all of the reservoirs and often in higher abundances compared with the native species (i.e. gibel carp),. This is because the main motivation behind the stocking of common carp into these newly-established reservoirs is often to enhance the species' fisheries in response to demands from local communities. Specifically, the government agencies responsible for common carp stockings aim to compensate the economic losses faced by local communities as a result of private land encroachment from reservoir construction by providing them with an alternative (i.e. fisheries-related) source of revenue. However, the current findings indicate that common carp, where present, was one of the least abundant species in all but one of the reservoirs under study (Figure 2), hence regardless of the routine stocking of age-0 individuals occurring since 1996.

Overall, the present findings indicate that common carp introductions into these newly-established reservoirs may have failed to meet the original economic objectives by enhancing the spread of non-native species. This may represent a problem, since there has been no conclusive report so far on successful introduction schemes for common carp in the study area. A number of factors may have been contributed to this failure. Firstly, it is argued that poor stocking strategies are being implemented in the reservoirs, with local fishermen indicating that the release of age-0 individuals in a reservoir generally occurs from only one location, which is likely to increase the chance of limited survival due to unpredictable and/or unsuitable habitat conditions. Secondly, the intrinsic V-shaped structure of the reservoirs is likely to limit the availability of suitable spawning and nursery areas for common carp (a phytolithophil species: Simon 1999), even though this would be at variance with the colonising success of other cyprinids (both native and non-native) in the same reservoirs (e.g. Noble *et al*., 2007). Finally, despite recent stockings of the fully-scaled relative to the mirror variant to compensate for the low survival rates of the latter (e.g. Balık and Ustaoğlu, 2006; but see Kırankaya, 2007), no noticeable improvements have so far been detected. To this end, recent studies on common carp in Anatolia (Vilizzi *et al*., 2013, 2014) have indicated that the growth of this species is overall slow compared to both its native and invasive areas of distribution worldwide, possibly a result of the large domesticated component of the stocks throughout the region.

Previous studies have reported that the establishment success of introduced species into reservoirs may be high not only compared to natural lakes but also to water courses (Moyle and Light, 1996; Kolar and Lodge, 2002; Han *et al*., 2008; Aydın *et al*., 2011; Tarkan *et al*., 2012b). This has been the case for the gibel carp in Turkey (Aydın *et al*., 2011; Tarkan *et al*., 2012b), and was demonstrated in a large-scale study of water bodies of the Great Lakes Region (USA), which indicated that reservoirs were more prone to invasion compared to neighboring natural lakes (Johnson *et al*., 2008). At the same time, propagule pressure appears to be the most reasonable explanation for the link between reservoirs and non-native species. Thus, beside the deliberate and multiple introductions of common carp by government agencies, which is recognized as the main source for the spreading of non-native species (Aydın *et al*., 2011), local people and fishermen usually admit to the intentional introduction of some non-native species into reservoirs. As the reservoirs of the Kocaeli Peninsula are located in a highly-populated area hosting a large number of recreational activities, this is likely to represent an additional factor contributing to the introduction of non-native species, which would in turn result in an increased likelihood of their successful establishment (Von Holle and Simberloff, 2005).

Despite the many reports worldwide of the severe impacts caused by non-native fish (e.g. Copp *et al*., 2005; Gozlan *et al*., 2010; Olden and Cucheorusset, 2011; Vilizzi 2012), the present study has detected no overall negative effect in terms of a decline or stagnation in either the relative abundance or richness of native/endemic fish species. However, it might be too early to rule out the possibility that an impact has been averted based on the current data. This is because the current status of the fish assemblages in the reservoirs of the Kocaeli Peninsula may not have progressed through all three stages idefined by Ferincz *et al*. (2012), and which have occured in some central European reservoirs (Penczak *et al*., 1998; Riha *et al*., 2009). Accordingly: (i) the first stage (succession) is characterised by the dominance of bog-dwelling or riverine native fishes originating from drainage channels previously existing in the area or from the streams where the reservoir was established; (ii) the second stage (invasion) is characterised by the constant high relative abundance of non-native species such as gibel carp; and (iii) the third stage (stabilisation) by the dominance of native cyprinids such as roach or bleak *Alburnus alburnus* (Ferincz *et al*., 2012). Given the relatively new establishment of the reservoirs of the Kocaeli Peninsula (mid-1990s), a similar invasion pattern by non-native species and especially by gibel carp is to be expected, and this would indicate that a second stage of invasion is under way. Furthermore, although the third stage is characterised in some cases by a notable decrease in non-native species abundance (i.e. Kubecka, 1993; Riha *et al*., 2009; Ferincz *et al*. , 2012), there are examples of gibel carp abundance constantly increasing at the expense of native cyprinids remaining in comparatively lower numbers (e.g. Markovic *et al*., 2007; Tarkan *et al*., 2012b).

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References

Adams, M.J., Pearl, C.A. and Bury, R.B. 2003 Indirect facilitation of an anuran invasion by non-native fishes. Ecology Letters, 6: 343–351. doi: 10.1046/j.1461-0248.2003.00435.x

Allan, J.D. and Flecker, A.S. 1993. Biodiversity conservation in running waters. BioScience, 43: 32–43.

Anderson, M.J., Gorley, R.N. and Clarke, K.R. 2008. PERMANOVA+ for PRIMER: Guide to Software and Statistical Methods. PRIMER-E Ltd., Plymouth, UK, 214 pp.

Andrews, C. 1990. The ornamental fish trade and fish conservation. Journal of Fish Biology, 37: 53–59. doi: 10.1111/j.1095-8649.1990.tb05020.x

Arthington, A.H. 1991. Ecological and genetic impacts of introduced and translocated fresh-water fishes in Australia. Canadian Journal of Fisheries and Aquatic Sciences, 48: 33–43. doi: 10.1139/f91-302

Aydın, H., Gaygusuz, Ö., Tarkan, A.S., Top, N., Emiroğlu, Ö. and Gürsoy Gaygusuz, Ç. 2011. Invasion of freshwater bodies in Marmara Region (NW-Turkey) by non-native gibel carp, *Carassius gibelio* (Bloch, 1782). Turkish Journal of Zoology, 35: 829–836. doi: 10.3906/zoo-1007-31

Balık, İ., Özkök, R., Çubuk, H. and Uysal, R. 2004. Investigation of some biological characteristics of the Silver Crucian Carp. *Carassius gibelio* (Bloch 1782) population in Lake Eğirdir. Turkish Journal of Zoology, 28: 19–28.

Balık, S. and Ustaoğlu, M.R. 2006. Results of fish introduction studies in lakes, ponds and reservoirs of Turkey. 1. Fish Stocking and Reservoir Management Symposium, 07–09 February 2006, Antalya, Turkey.

Balon, E.K. 1995. The common carp, *Cyprinus carpio*: its wild origin, domestication in aquaculture, and selection as colour nishikigoi. Guelph Ichthyology Reviews, 3: 1–55.

Beisner, B.E., Ives, A.R. and Carpenter, S.R. 2003. The effects of an exotic fish invasion on the prey communities of two lakes. Journal of Animal Ecology, 72: 331–342. doi: 10.1046/j.1365-2656.2003.00699.x

Copp, G. H., Bianco, P.G., Bogutskaya, N.G., Erős, T., Falka, I., Ferreira, M.T., Fox, M.G. *et al.* 2005. To be, or not to be, a non-native freshwater fish? Journal of Applied Ichthyology, 21: 242–262. doi: 10.1111/j.1439-0426.2005.00690.x

Crivelli, A.J. 1995. Are fish introductions a threat to endemic fresh-water fishes in the Northern Mediterranean region. Biological Conservation, 72: 311–319. doi: 10.1016/0006-3207(94)00092-5

Debrot, A.O. 2003. A review of the freshwater fishes of Curaçao with comments on those of Aruba and Bonaire. Caribbean Journal of Science, 39: 100–108.

Ferincz, Á., Staszny, Á., Ács, A., Weiperth, A., Tátrai, I. and Paulovits, G. 2012. Long-term development of fish assemblage in Lake Fenéki (Kis-Balaton Water Protection System, Hungary): succession, invasion and stabilization. Acta Zoologica Academiae Scientiarum Hungaricae, 58 (Suppl.): 3–18.

Gaygusuz, Ö.. Tarkan, A.S. and Gaygusuz, Ö.G. 2007. Changes in the fish community of the Ömerli Reservoir (Turkey) following to introduction of non-native gibel carp *Carassius gibelio* (Bloch 1782) and other human impacts. Aquatic Invasions, 2: 117–120. doi: 10.3391/ai.2007.2.2.6

Geldiay, R. and Balık, S. 2007. Freshwater fishes of Turkey. Ege Universitesi, Su Ürünleri Fakültersi Yayınları, İzmir, Turkey. [In Turkish.]

Gozlan, R.E., St-Hilaire, S., Feist, S.W., Martin, P. and Kent, M.L. 2005. Disease threats on European fish. Nature, 435: 1045–1046. doi: 10.1038/4351046a

Gozlan, R.E., Britton, J.R., Cowx, I.G. and Copp, G.H. 2010. Current knowledge on non-native freshwater fish introductions. Journal of Fish Biology, 76: 751–786. doi: 10.1111/j.1095-8649.2010.02566.x

Gozlan, R.E. 2008. Introduction of non-native freshwater fish: is it all bad? Fish and Fisheries, 9: 106–115. doi: 10.1111/j.1467-2979.2007.00267.x

Han, M., Fukushima, M. and Fukushima, T. 2008. A spatial linkage between dams and non-native fish species in Hokkaido, Japan. Ecology of Freshwater Fish, 17: 416–424. doi: 10.1111/j.1600-0633.2008.00294.x

Irz, P., Argillier, C. and Oberdorff, T. 2004. Native and introduced fish species richness in French Lakes: local and regional influences. Global Ecology and Biogeography, 13: 335–344. doi: 10.1111/j.1466-822X.2004.00109.x

Johnson, P.T.J., Olden, J.D. and Vander Zanden, M.J. 2008. Dam invaders: impoundments facilitate biological invasions into freshwaters. Frontiers in Ecology and the Environment, 6: 357–363. doi: 10.1890/070156

Josefsson, M. and Andersson, B. 2001. The environmental consequences of alien species in the Swedish lakes Mälaren, Hjälmaren, Vänern and Vättern. Ambio, 30: 514–521. doi: 10.1579/0044-7447-30.8.514

Kats, L.B. and Ferrer, R.P. 2003. Alien predators and amphibian declines: review of two decades of science and the transition to conservation. Diversity and Distribution, 9: 99–110. doi: 10.1046/j.1472-4642.2003.00013.x

Kline, R.B. 2013. Beyond Significance Testing: Statistics Reform in the Behavioral Sciences. 2nd ed., American Psychological Association, Washington DC, USA, 328 pp.

Kırankaya, Ş.G. 2007. Gelingüllü Baraj Gölü'ndeki (Yozgat) aynalı sazan, pullu sazan (*Cyprinus carpio*, L., 1758) ve gümüşi havuz balığı [*Carassius gibelio* (Bloch, 1782)]'nın büyüme, üreme ve beslenme biyolojisinin karşılastırmalı olarak incelenmesi. PhD Thesis, Hacettepe University, Ankara, Turkey, 199 pp.

Kolar, C.S. and Lodge, D.M. 2002. Ecological predictions and risk assessment for alien fishes in North America. Science, 298: 1233–1236. doi: 10.1126/science.1075753

Kottelat, M. and Freyhof, J. 2007. Handbook of European Freshwater Fishes. Publications Kottelat, Switzerland, 646 pp.

Kubecka, J. 1993. Succession of fish communities in reservoirs of Central and Eastern Europe. In: Straskraba, M., Tundısı, J.G. and Duncan, A. (Eds), Comparative Reservoir Limnology and Water Quality Management. Kluwer Academic Publishers Group, Amsterdam: 153–168.

Leidy, R.A. and Moyle, P.B. 1998. Conservation status of the world's fish fauna: an overview. In: Fiedler, P.L. and Kareiva, P.M. (Eds), Conservation Biology for the Coming Decade, 2nd edn, Chapman & Hall, New York ⁄ London: 187–227.

Marchetti, M.P., Light, T., Moyle, P.B. and Viers, J.H. 2004. Fish invasions in California watersheds: testing hypotheses using landscape patterns. Ecological Applications, 14: 1507–1525. doi: 10.1890/03-5173

Markovic, G., Lenhardt, M. and Gacic, Z. 2007. Successions of the ichtyofauna in an eutrophic Serbian reservoir. Acta Ichtyologica Romanica, 2: 151–160.

Mills, M.D., Rader, R.B. and Belk, M.C. 2004. Complex interactions between native and invasive fish: the simultaneous effects of multiple negative interactions. Oecologia, 141: 713–721. doi: 10.1007/s00442-004-1695-z

Moyle, P.B. and Light, T. 1996. Biological invasions of fresh water: empirical rules and assembly theory. Biological Conservation, 78: 149–161. doi: 10.1016/0006-3207(96)00024-9

Navodaru, I., Buijse, A.D. and Staras, M. 2002. Effects of hydrology and water quality on the fish community in Danube delta lakes. International Review of Hydrobiology, 87: 329–348. doi: 10.1002/1522-2632(200205)87:2/3<329::AID-IROH329>3.0.CO;2-J

Noble, R.A.A., Cowx, I.G., Goffaux, D. and Kestemont, P. 2007. Assessing the health of European rivers using functional ecological guilds of fish communities: standardising species classification and approaches to metric selection. Fisheries Management and Ecology, 14: 381–392. doi: 10.1111/j.1365-2400.2007.00575.x

North, R. 2000. Factors affecting the performance of stillwater coarse fisheries in England and Wales. In: Cowx, I.G. (Ed.), Management and Ecology of Lake and Reservoir Fisheries. Fishing News Books, Blackwell Science Ltd, London: 284–298.

Olden, J.D. and Cucheorusset, J. 2011. Ecological impacts of non-native freshwater fishes. Fisheries, 36: 215–230. doi: 10.1080/03632415.2011.574578

Önsoy, B., Filiz, H., Tarkan, A.S., Bilge, G. and Tarkan, A.N. 2011. Occurrence of non-native fishes in a small man-made lake (Lake Ula, Muğla): past, present, future perspectives. Turkish Journal of Fisheries and Aquatic Sciences, 11: 209–215. doi: 10.4194/trjfas.2011.0205

Özuluğ, M., Acıpınar, H., Gaygusuz. Ö., Gürsoy, Ç. and Tarkan, A.S. 2005. Effects of human factor on the fish fauna in a drinking-water resource (Ömerli Dam Lake-Istanbul, Turkey). Research Journal of Agriculture and Biological Sciences, 1: 50–55.

Penczak, T., Głowacki, Ł., Galicka, W. and Koszaliński, H. 1998. A long-term study (1985–1995) of fish populations in the impounded Warta River, Poland. Hydrobiologia, 368: 157–173. doi: 10.1023/A:1003246115666

Riha, M., Kubecka, J., Vasek, M., Seda, J., Mrkvicka, T., Prchalova, M., Matena, J., Hladik, M., Cech, M., Drastik, V., Frouzova, J., Hohausova, E., Jarolim, O., Juza, T., Kratochvil, M., Peterka, J., Tuser, M. 2009. Long-term development of fish populations in the Rimov Reservoir. Fisheries Management and Ecology, 16: 121–129. doi: 10.1111/j.1365-2400.2008.00650.x

Ruesink, J.L. 2005. Global analysis of factors affecting the outcome of freshwater fish introductions. Conservation Biology, 19: 1883–1893. doi: 10.1111/j.1523-1739.2005.00267.x-i1

Saunders, D.L., Meeuwig, J.J. and Vincent, C.J. 2002. Freshwater protected areas: strategies for conservation. Conservation Biology, 16: 30–41. doi: 10.1046/j.1523-1739.2002.99562.x

Simon, K.S. and Townsend, C.R. 2003. Impacts of freshwater invaders at different levels of ecological organisation. with emphasis on salmonids and ecosystem consequences. Freshwater Biology, 48: 982–994. doi: 10.1046/j.1365-2427.2003.01069.x

Simon, T.P. 1999. Assessment of Balon's reproductive guilds with application to Midwestern North American Freshwater Fishes. In: T.L. Simon (Ed.), Assessing the Sustainability and Biological Integrity of Water Resources Using Fish Communities. CRC Press, Boca Raton, FL, USA: 97–121.

Tarkan, A.S., Copp, G.H., Top, N., Özdemir, N., Önsoy, B., Bilge, G., Filiz, H., Yapıcı, S. *et al.* 2012a. Are introduced gibel carp *Carassius gibelio* in Turkey more invasive in artificial than in natural waters? Fisheries Management and Ecology, 19: 178–187. doi: 10.1111/j.1365-2400.2011.00841.x

Tarkan, A.S., Gaygusuz, Ö., Gürsoy Gaygusuz, Ç. and Copp, G. 2012b. Circumstantial evidence for gibel carp *Carassius gibelio* reproductive competition exerted on native fish species in a mesotrophic reservoir. Fisheries Management and Ecology, 19: 167–177. doi: 10.1111/j.1365-2400.2011.00839.x

Treer, T., Aničić, I. and Safner, R. 1995. The growth and condition of common carps [sic] (*Cyprinus carpio*) introduced into Croatian Vransko Lake. Ribarstvo, 53: 63–73.

Treer, T., Varga, B., Safner, R., Aničić, I., Piria, M. and Odak, T. 2003. Growth of the common carp (*Cyprinus carpio*) introduced into the Mediterranean Vransko Lake. Journal of Applied Ichthyology, 19: 383–386.

Turkish Statistical Institute. 2014. Su Ürünleri İstatistikleri/Fishery Statistics 2013. Ankara: Turkish Statistical Institute, Printing Division, 75 pp.

Vilizzi, L. 2012. The common carp, *Cyprinus carpio*, in the Mediterranean Region: Origin, distribution, economic benefits, impacts and management. Fisheries Management and Ecology, 19: 93–110. doi: 10.1111/j.1365-2400.2011.00823.x

Vilizzi, L., Tarkan, A.S. and Ekmekçi, F.G. 2013. Stock characteristics and management insights for common carp (*Cyprinus carpio*) in Anatolia: A review of weight–length relationships and condition factors. Turkish Journal of Fisheries and Aquatic Sciences, 13: 759–775. doi: 10.4194/1303-2712-v13_4_22

Vilizzi, L., Ekmekçi, F.G., Tarkan, A.S. and Jackson, Z. 2014. Growth of common carp *Cyprinus carpio* in Anatolia (Turkey), with a comparison to native and invasive areas worldwide. Ecology of Freshwater Fish, 24: 165–180. doi: 10.1111/eff.12141

Vilizzi, L., Tarkan, A.S. and Copp, G.H. 2015. Experimental evidence from causal criteria analysis for the effects of common carp *Cyprinus carpio* on freshwater ecosystems: a global perspective. Reviews in Fisheries Science & Aquaculture, 23: 253–290. doi: 10.1080/23308249.2015.1051214

Von Holle, B. and Simberloff, D. 2005. Ecological resistance to biological invasion overwhelmed by propagule pressure. Ecology, 86: 3212–3218. doi: 10.1890/05-0427

Wheeler, A. 1991. The ecological implications of introducing exotic fishes. In: Proceedings of the IFM conference, fisheries to the year 2000. Institute of Fisheries Management, Nottingham. UK: 51–60.

Witte, F., Goldschmidt, T., Goudswaard, P.C., Lightvoet, W., Van Oijen, M.J.P. and Wanink, J.H. 1992. Species extinction and concomitant ecological changes in Lake Victoria. Netherlands Journal of Zoology, 42: 214–232. doi: 10.1163/156854291X00298

Zambrano, L., Scheffer, M. and Martinez-Ramos, M. 2001. Catastrophic response of lakes to benthivorous fish introduction. Oikos, 94: 344–350. doi: 10.1034/j.1600-0706.2001.940215.x