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Occurrence of Non-Native Fishes in a Small Man-Made Lake (Lake Ula, Muğla): Past, Present, Future Perspectives

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Abstract

Changes in fish fauna, fish conditions and some physico-chemical features of water of Lake Ula which was established for irrigation purposes and subjected to introduction of non-native fishes were investigated. Six different fish species were found, five of them belong to Cyprinidae family; common carp *Cyprinus carpio* L., 1758, gibel carp *Carrassius gibelio* (Bloch, 1782), goldfish *Carassius auratus* (L., 1758), chub *Squalius cephalus* (L., 1758) and gizani *Ladigesocypris ghigii* (Gianferrari, 1927). The other species found was eastern mosquitofish *Gambusia holbrooki* Girard, 1859 from Poeciliidae family. Fulton's body condition values varied between 0.99 (chub) and 1.48 (gibel carp). Two *Carassius* species (non-native species) had significantly the higher condition values than those of other species ($P<0.001$). Comparison of condition data of chub and common carp from present study and published work in 1999 revealed no significant differences (*t*-test, $P>0.05$). Some physico-chemical features of water were compared and no big differences were detected between 1998 and 2009.

Keywords: Reservoir, alien fishes, fish introduction, cyprinids.

İnsan Yapımı Ufak Bir Gölette (Ula Göleti, Muğla) Yabancı Türlerin Ortaya Çıkışı: Geçmiş, Günümüz ve Gelecek Bakış Açıları

Özet

Sulama amaçlı yapılmış olan ve yabancı tür aşılamalarına maruz kalan ve Ula Göleti'nin bazı fizko-kimyasal su özellikleri ve balık kondisyonu ile balık kompozisyonundaki değişimler incelenmiştir. Toplam altı farklı tür tespit edilirken Cyprinidae familyasına ait olan 5 tanesi: sazan *Cyprinus carpio* L., 1758, gümüşi havuz balığı *Carrassius gibelio* (Bloch, 1782), kırmızı havuz balığı *Carassius auratus* (L., 1758), tatlısu kefali *Squalius cephalus* (L., 1758) ve gizani *Ladigesocypris ghigii* (Gianferrari, 1927)'dir. Diğer tür ise Poecilidae familyasına ait sivrisinek balığı *Gambusia holbrooki* Girard, 1859 türüdür. Fulton kondisyon faktörü 0,99 (tatlısu kefali) ve 1,48 (gümüşi havuz balığı) değerleri arasında değişiklik göstermiştir. İki *Carassius* türünün (yabancı türler) diğer türlerden önemli derecede yüksek kondisyon değerlerine sahip olduğu tespit edilmiştir ($P<0,001$). Tatlısu kefalinin ve sazanın kondisyon faktörleri 1999 da aynı bölgeden yayımlanan çalışmadaki kondisyon değerleri ile önemli bir fark göstermemiştir (*t*-test, $P>0,05$). Suyun incelenen bazı fiziko-kimyasal özellikleri de 1998 ve 2000 yılları arasında büyük değişimler göstermemiştir.

Anahtar Kelimeler: Rezervuar, yabancı türler, balık aşılamaları, cyprinidler.

Introduction

Man-made lakes have been widely used for hydro-electric power by impounding rivers and streams, supply drinking water and irrigation. Smaller, man-made, water bodies have not received the same degree of attention. Natural water bodies (ponds, pools, small lakes etc.) have become less common in Turkey while artificial water bodies for water supply purposes have increased being 170000 hectares of dams and 700 small dams (Çelikkale *et al*., 2003). Newly formed water bodies have been long subjected to scientific interest (*e.g.* Darwin, 1859) to understand species establishment success, propagule pressure and dispersal mechanisms (Kew, 1893; Talling, 1951).

Man-made lakes are usually influenced by the anthropogenic disturbances such as damming without spillway, water abstraction for irrigation, altered thermal regime by damming and release of non-native species (Semlitsch and Bodie, 1998). Particular scientific concern is about the intentional releases of

non-native species and their impacts to the ecosystems (Andrews, 1990; Wheeler, 1991; North, 2000; Marchetti *et al*., 2004; Ruesink, 2005). Stocking reservoirs with translocated or alien fish species for recreational fishing has long been a pervasive human activity (Allan and Flecker, 1993) and these introductions has also affected to the streams and rivers below the dams, especially where high level of human disturbance exists (Moyle and Light, 1996).

Like many inlands worldwide, inland waters in Turkey has faced with non-native species introductions and subsequent declines of native fish populations for many years. Since 1950s, 25 alien or translocated fish species have been introduced into the Turkish inland waters, and at least 12 of these have established viable populations (İnnal and Erk'akan, 2006). Most abundant introduced species belongs to Cyprinidae and Poeciliidae families, which were introduced to Turkey from Asia and Europe in the beginning of 1900's (Gaygusuz *et al*., 2007; Özuluğ *et al*., 2007). However, our knowledge is on their distribution and impacts to the ecosystems in Turkey are quite poor (Tarkan *et al*., 2006).

We therefore investigated fish fauna of a small water reservoir recently established for irrigation purposes. Our principal aim was to compare changes of fish fauna of the reservoir from its first establishment to up the now. We also discuss management implications of the reservoir in terms of native fish conservation as the reservoir is a model site.

Materials and Methods

Study Site

Lake Ula which is located in Muğla Province, southwest of Turkey (Latitude 37°07′ N, Longitude 28°23′ E) was established in 1987 for irrigation purpose. The catchment's area of the lake is 9.750 km^2 and surroundings are 2.5 km. The deepest zone of the lake is 20 m and the altitude is 645 m (Küçükçe, 1999). The lake fed by a small stream so called Akarca and this stream becomes outflow of the lake when the water level exceeds the lake dam. Mean rainfall in this region is high as the second most in Turkey (Bahar, 2008). The lake has also been used as a water reservoir by helicopters to extinguish the forest fires in the vicinity of Muğla. Approximately 25000 common carp, *Cyprinus carpio* fingerlings were introduced to the lake by Department of Agricultural and Rural Affairs of Turkey in 1988 (Küçükçe, 1999). After then the lake has served as a sport fishery area. There was only one study published in 1999 on the lake about its fish fauna and some environmental features (Küçükçe, 1999) and it was reported that only common carp and chub were present in the lake at that time.

Sampling and Data Analysis

The fish samples were collected on ten occasions between March 2008 and May 2009 by wading electrofishing from the shores with dense vegetation and by boat electrofishing from the open water of the lake while the inflow and outflow stream were sampled only by wading electrofishing (Samus 725 MP). Three stretches (about 1000 m long) was chosen on the streams based on their habitat features (i.e. stone or sandy, high or low velocity, slope situation). After collection, the fish were transported to the laboratory and were either examined fresh or were frozen and examined later after defrosting. In the laboratory, the fish were measured for standard length (SL), fork length (FL) and total length (TL) to the nearest 1.0 mm and wet body weight (W_T) to the nearest 0.1 g. However, for all further analyses TL was used (Önsoy *et al*., in press). Berg (1949a), (1949b), Banarescu (1964), Rauchenberger (1989), Kottelat and Freyhof (2007) were used for identification of the fish samples. The specimens have been deposited in the Museum of Muğla University, Faculty of Fisheries (MUSUM).

To see variation in body condition in fish condition, Fulton's condition (plumpness) factor as per Mills and Eloranta (1985) ($K = WT10^5 * TL^{-3}$) was used. To test differences in condition among the species studied in the present study, one-way ANOVA was performed. When the analysis of variance showed significant differences, a Tukey test was used (Zar, 1999). Differences in fish condition between the same species in the present study and the previous study published in 1999 were tested by student's *t*- test (Zar, 1999).

Relative abundances were calculated on a catch per unit of effort (CPUE) basis (number of fish per 10 min; see Copp *et al*., 2005) from a zodiac boat or by wading at a similar speed of movement in all cases.

Temperature, dissolved oxygen, conductivity, and pH were measured *in situ* using a multi-parameter probe (YSI 556 MPS). Water samples for nutrient analysis (NO_3-N, NO_2-N, o-PO_4, SiO_2, Fe) were kept cool and in the dark before being brought to the laboratory and analyzed according to standard methods (Greenberg *et al*., 1985). Chlorophyll-*a* content was calculated after filtration and extraction into ethanol. Following centrifugation, absorbance was measured before and after acidification in a spectrophotometer (Ryther and Yentsch, 1957).

Results and Discussion

Between March 2008 and May 2009, ten different samplings were accomplished on irregular basis mostly being spring, summer and autumn months from the lake and the streams of the lake. Six different fish species identified in total, five of them belong to Cyprinidae family; common carp, gibel

carp, goldfish, chub and gizani. The other species found was eastern mosquitofish from Poeciliidae family (Table 1).

Condition indices of six fish species belonging to two families in a total of 545 specimens were calculated. Fulton's body condition values varied between 0.99 for chub and 1.48 for gibel carp (Table 1). There were significant condition differences between species (ANOVA, $P<0.001$). Two *Carassius* species had significantly higher condition values than those of other species (Tukey test, $P<0.001$) (Table 1). Comparison past and present condition values of chub, carp and mirror carp revealed no significant differences (*t*-test, $P>0.05$). There were also no big differences in the physical and chemical properties of the water between 1998 and 2009 (Table 2).

Gibel carp and goldfish were the most abundant fish species in the lake while chub was the dominant species in the streams during the study. Vegetated area of the lake and outflow stream was mostly occupied by the abundant fish species; gibel carp, goldfish and common carp. In the inflow stream, however, there were only three fish species, chub being dominant, gizani and eastern mosquitofish (Figure 1). Open water of the lake had the little number of specimens compared to other areas.

Fish introduction of Lake Ula was intentionally started with common carp in 1988 by the Department

Table 1. Species, number of specimens (n), minimum (min.), maximum (max.) lengths, and range of condition of fishes collected in Lake Ula. Mean data points that do not share any latter are statistically different according to Tukey test ($P<0.05$). p.s. = present study

Family	Species	n	min	max	*K*	Range
Cyprinidae	*Cyprinus carpio* – 1998	24	85	175	1.15[a]	0.88-1.45
	Cyprinus carpio – p. s.	54	79	216	1.17[a]	0.87-1.50
	C. carpio (mirror carp)-1998	3	85	160	1.21[a]	1.14-1.30
	C. carpio (mirror carp)-p.s.	8	113	205	1.25[a]	1.03-1.47
	Leuciscus. cephalus-1998	16	85	265	1.01[b]	0.70-1.44
	Leuciscus cephalus-p.s.	184	27	176	0.99[b]	0.42-1.33
	Carassius gibelio	99	66	152	1.48[c]	1.17-2.23
	Carassius auratus	128	94	170	1.47[c]	1.05-2.18
	Ladigesocypris ghiigi	25	22	74	1.17[a]	0.80-1.40
Poeciliidae	*Gambusia holbrooki*	4	22	32	1.06[b]	0.93-1.41

Table 2. Some physico-chemical features of water in Lake Ula in 1998 (based on Küçükçe 1999) and 2009

	Oxygen (mg/L)	pH	Conductivity (µS/cm)	NO_2 (µg/L)	NO_3 (mg/L)	chl-a (µg/L)	o-PO_4 (µg/L)	Fe (mg/L)	SiO_2 (µg/L)
1998	8.31-9.80	8.4-8.6	308 - 360	0-0.025	5 - 10	-	-	-	-
2009 - lake	13.01	10.5	347	0.097	0.515	39.072	0.008	0.043	7000
2009 - stream (inflow)	6.56	9.6	536	0.069	0	0	0.001	0.015	17000
2009 - stream (outflow)	13.62	10.0	588	0.036	0	0	0.025	0.008	9000

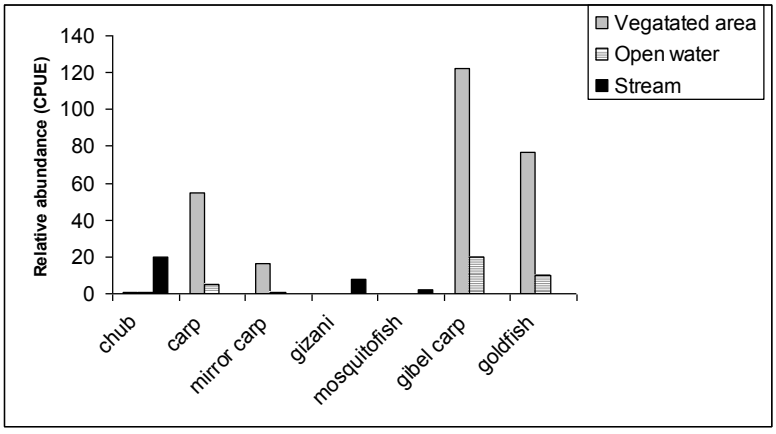

Figure 1. CPUE of the fish species caught in Lake Ula.

of Agricultural and Rural Affairs. Fish stocking man made water bodies have usually been applied by General Directorate of State Hydraulic Works (DSI) in Turkey with the aim of increasing of fish production and sportive fishing. Formerly, introduction of mirror carp was common but recently it was changed by common carp as mirror carp has been found as unsuccessful for the introduction to the new water bodies in which common carp naturally exist (Balık and Ustaoğlu, 2006). However, during these stocking practices, some non-native fish species may have been introduced through unintentional or unauthorized stocking (*e.g.* accidental introduction of gibel carp, goldfish, mosquitofish associated with intentional stocking of common carp) (Özuluğ *et al*., 2005; Balık and Ustaoğlu, 2006; Tarkan *et al*., 2006).

This seems to be likely in the present work as two *Carassius* species (gibel carp and goldfish) were found in Lake Ula. Alternatively, these species can be willingly introduced by the human because this lake has intensively been used as recreation area and received many visitors throughout the year especially in spring and summer months. Our personal communication admitted that local people and anglers might be responsible for these introductions. Previous reports supported that the distributions of non-native fish species have been positively correlated with human population density and the proportion of developed area (Shea and Chesson, 2002; Meador *et al*., 2003). This phenomenon was much clearer in Copp *et al*., (2005) who found negative strong relationship between ornamental varieties of non-native fish species and the distance from the nearest road.

The introduction of *Carassius* species began with goldfish that was taken place in the 20th century and it is now very common in many natural aquatic habitats such as park and garden ponds (Innal and Erk'akan, 2006). Even though introduction history of goldfish is unknown, this probably related to early introductions for aesthetic purposes as is the case with other European countries (*e.g.* Copp *et al*., 2005). The other *Carassius* species, gibel carp was first recognized in the European part of Turkey in the 1980s (Baran and Ongan, 1988), perhaps because of its strong physical resemblance of the other two *Carassius* species introduced to Turkey: crucian carp *Carassius carassius* (L., 1758), and goldfish. As species identification of *Carassius* species have improved, the distribution of gibel carp in Turkey is now thought to include both the Thrace (European) region (Özuluğ *et al*., 2004) and the entire Anatolian (Asia Minor) peninsula (Şaşı and Balık, 2003; Balık *et al*., 2003; İlhan *et al*., 2005; Yılmaz *et al*., 2007). Distinguishing the *Carassius* species has recently begun on genetic basis and recent studies (Hänfling *et al*., 2005; Tóth *et al*., 2005) have demonstrated that additional work is needed into the genetic origins and evolution of *Carassius* species.

Effects of goldfish and gibel carp introductions on native species only recently have been recognized. For example, the decline of native cyprinid fish populations in some parts of Europe and Turkey have been identified as associated with habitat degradation due to the introduction of non-native *Carassius* species (Navodaru *et al*., 2002; Balık *et al*., 2003), which also impact the native cyprinid fishes through reproductive interference (Wheeler, 2000; Tóth *et al*., 2005; Vetemaa *et al*., 2005; Smartt, 2007). In Turkey, some commercially important native and endemic fish species such as Baltic Vimba, *Vimba vimba* (L. 1758), common carp, rudd *Scardinius erythrophthalmus* (L. 1758) and Shemaya *Alburnus chalcoides* (Güldenstädt, 1772) has mostly suffered from these introductions (*e.g.* Balık *et al*., 2004; Gaygusuz *et al*., 2007).

Our comparative analysis showed that there are no considerable variations of condition in chub and carp during last ten years period. However, two introduced *Carassius* species had significantly higher condition values compared to other species, which may suggest their well adaptation to the environment. Both species are reported as a highly resistant species, able to withstand environmental stressors, including fluctuations in water temperature (*e.g.* Spotila *et al*., 1979) and declines in water transparency and oxygen levels (*e.g.* Rowe, 2007). Indeed, they have been reported to benefit from environmental disturbances to the receiving water bodies (Morgan and Beatty, 2004). Most of physico-chemical parameters of water of Lake Ula compared showed no significant differences between 1998 and 2009. Although, this comparison is highly insufficient to draw any conclusions on water quality changes in the lake due to different sampling stations and ontogenetic changes of the lake, it may suggest that the major factor responsible for the invasiveness of *Carassius* species would be the reproduction given that major differences in water quality has not occurred over ten-year period. *Carassius* species are known to undertake multiple spawning events during the same season even after translocation (Gillet *et al*., 1977). Indeed, some gibel carp populations are often composed of almost exclusively triploid gynogenetic females (*e.g.* Peňáz *et al*., 1979; Peňáz and Dulmaa, 1987; Kalous *et al*., 2004) which may provide successful establishment to the new environments. These remain unexplained for Lake Ula populations which require further studies on their reproduction and growth in the lake.

Relative abundance values indicated that goldfish and gibel carp were more abundant than other fish species in Lake Ula but their distribution were limited to the vegetated area in the lake which may isolate these species from the other natural fish species, chub and gizani. Although Küçükçe (1999) mentioned presence of goldfish in Lake Ula, he gave only common name of the species and no information on the abundances of any fish species were available. So, we are not being able to assess changes of

abundance of fish species in the lake. Preference of vegetation of *Carassius* species, especially goldfish may be attributed to the avoidance of avian predators as they are more visible to avian predators (Ödeen and Hästad, 2003). Grey heron (*Ardea cinerea* Linnaeus, 1758) and great cormorant (*Phalacrocorax carbo* Linnaeus, 1758) are observed around the Lake Ula. It is well known that this kind of birds feed upon fishes, especially predate on the most abundant (*e.g.* Adams and Mitchell, 1995) and more noticeable prey. This suggests that more colorful prey items are consumed preferentially and this was supported by the two times higher number of damaged goldfish (i.e. wounded on the body or tail) than other brown color fishes in Lake Ula. Consequently, goldfish would be expected to benefit from greater amount of aquatic cover. This may be considered an advantageous for stream fish populations which could escape from competition pressure of *Carassius* species. However, observations indicated that *Carassius* species and endemic (gizani), and natural (chub) fish species live together in the outflow stream of the lake and possible negative impacts by non-native fishes can be expected in terms of habitat and diet overlap.

We could catch only four specimens of eastern mosquitofish from Akarca stream, but its population would be more abundant as our fishing method was not so suitable to catch this small fish species. It is possibly one of the earliest deliberate introductions of freshwater fish in Turkey with the aim to control of *Malaria* (Öztürk and İkiz, 2004) although there are no exact records of early introductions (İnnal and Erk'akan, 2006). However, it is completely unknown if they are effective to control mosquitoes in Turkish waters.

In conclusion, fish populations, their biology and ecology especially impacts of non-native fishes to the native fauna with the other limnological variables should be continuously monitored on regular basis in Lake Ula as well as in other similar water bodies as these variables are crucial to take necessary measures against unwanted non-native fish introductions. The effective understanding of the attributes in fish communities and their consequent biotic integrity requires data with spatial and temporal amplitude in order to recognize the changes and the relations in the communities respect to disturbance gradients (Rodríguez-Olarte *et al*., 2006). Introductions of fish species are widespread in Turkish reservoirs and occur in all regions, which are suitable (Innal and Erk'akan, 2006). Such introductions are generally voluntary aiming enhance recreational fisheries. However, they were carried out without any prior analysis testing survival chances of introduced species and their potential impact on native communities (İnnal and Erk'akan, 2006). It is most desirable to prevent the introduction of non-native species. If this occurs, their populations can multiply at the expense of native species. In Lake Ula, this would be much more critical for endangered species gizani which is considered vulnerable in International Union for Conservation of Nature (IUCN).

Taking the precautionary approach, native species mainly fish species like gizani should be the subject of conservation measures as part of lake management plans and floodplain rehabilitation strategies for enhancing and maintaining aquatic biodiversity. Currently, there is no regulation or law to control non-native fish species in Turkey and they are freely spread all suitable water resources especially with aid of local people and some government branches through unintentional or unauthorized stocking. As previously reported for natural ponds (*e.g.* Copp *et al*., 2005), native populations especially in man-made water reservoirs at smaller distances from public routes (fairground sites, roads, pathways) are subject to highest chance for non-native fish species exposure. To prevent native fish species from alien species is quite important to maintain genetically pure self-sustaining native populations in newly created water bodies as well as nature ones.

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