www.trjfas.org
ISSN 1303-2712
Turkish Journal of Fisheries and Aquatic Sciences 13: 795-809 (2013) DOI: 10.4194/1303-2712-v13_5_03

Evaluation of the Ecological and Economical Results of the Introduced Alien Fish Species in Lake Eğirdir, Turkey

Sedat Vahdet Yerli[1,*], Ahmet Alp[2], Vedat Yeğen[3], Rahmi Uysal[3], Meral Apaydın Yağcı[3], İsmet Balık[4]

[1] Hacettepe University, Faculty of Science, Department of Biology, SAL, Beytepe, Ankara, Turkey.
[2] Kahramanmaraş Sütçü Imam University, Faculty of Agriculture, Department of Fisheries, Kahramanmaraş, Turkey.
[3] Eğirdir Fisheries Research Station, Eğirdir, Isparta, Turkey.
[4] Ordu University, Fatsa Faculty of Marine Sciences, Fisheries Technology Engineering, Fatsa 52400, Ordu, Turkey

* Corresponding Author: Tel.: +90.312 2978035; Fax: +90.312 2992028;
E-mail: sedatyerli@gmail.com

Received 15 July 2013
Accepted 22 November 2013

Abstract

Lake Eğirdir is the second largest lake in Turkey and its fish fauna in 1950's was consisted of *Barbatula mediterraneus*, *Cobitis turcica*, *Capoeta pestai*, Cyprinus carpio, Hemigrammocapoeta kemali, Pseudophoxinus egridiri, *Pseudophoxinus handlirschi*,*Vimba vimba* and *Aphanius anatoliae*. Sander lucioperca were introduced to the lake and a considerable amount of pikeperch fishery become possible during the 1970s. However, during the 1980's, most of the native fish species in the lake disappeared due to predatory effects of the pikeperch. Cannibalism rate of pikeperch increased (96%) and their size in the catch decreased because of unsufficient prey fish and overfishing. Moreover, with the collapse of crayfish stock because of a fungal infection, the lake fishery became deteriorated. In the followed years, *Gambusia affinis*, *Knipowitschia caucasica*, *Tinca tinca*, *Carassius gibelio*, *Alburnus chalcoides*, *Seminemacheilus ispartensis*, *Atherina boyeri* and *Pseudorasbora parva* were introduced to the lake and cannibalism rate in pikeperch population decreased to 96%. Annual catch in the lake decreased to 38-450 tons in the last five years from 2000 tons in the years of 1970s. At the time of this research 13 fish species was present in the lake and 7 of these were native while 6 were alien species. Consequently, the alien fish species introduced to Lake Eğirdir have caused a change in the lake's native fish fauna, destroyed its endemic species as well as giving damage to both the food-chain structure of the lake's ecosystem and the socioeconomic structure of the region.

Keywords: Invasive, ecology, economy, fisheries, Lake Eğirdir.

Eğirdir Gölüne Aşılanan Yabancı Türlerin Ekolojik ve Ekonomik Etkilerinin Değerlendirilmesi

Özet

Eğirdir Gölü, Türkiye'nin ikinci büyük tatlısu gölüdür. Gölün 1950'li yıllara göre balık faunası *Barbatula mediterraneus*, *Cobitis turcica*, *Capoeta pestai*, *Cyprinus carpio*, *Hemigrammocapoeta kemali*, *Pseudophoxinus egridiri*, *Pseudophoxinus handlirschi*,*Vimba vimba* ve *Aphanius anatoliae* ile temsil edilmiştir. Sander lucioperca'nın (sudak) göle aşılanmasından sonra 1970'li önemli miktarda av vermeye başlamıştır. Bununla birlikte, 1980'li yıllarda göldeki yerli balık faunası sudak balığının predasyon etkisi ile ortamdan kaybolmaya başlamıştır. Sander lucioperca'nın kanibalizm etkisi %96'lara kadar artmış, aşırı av baskısı ile birlikte avlanan sudakların boyları da küçülmüştür. Ayrıca, kerevit stoklarının fungal bir hasatlık nedeni ile çökmesi gölde balıkçılığın daha da kötü bir hal almasına yol açmıştır. Sonraki yıllarda, *Gambusia affinis*, *Knipowitschia caucasica*, *Tinca tinca*, *Carassius gibelio*, *Alburnus chalcoides*, *Seminemacheilus ispartensis*, *Atherina boyeri* ve *Pseudorasbora parva* göle aşılanmış, göldeki ise sudak kannibalizmi azalmıştır. Göldeki yıllık av miktarı son beş yılda, 1970 lerdeki 2000 ton/yıl'dan 38-450 ton/yıl'a kadar azalmıştır. Gölde bu araştırma ile halıhazırda 7 tür yerli, 6 tür yabancı tür olmak üzere 13 balık türünün varlığı belirlenmiştir. Sonuç olarak; Eğirdir Gölü'ne yabancı türlerin aşılanması, gölün yerli balık faunasının değişmesine yol açmış, göl ekosisteminin besin zinciri yapısı bozulmasının yanısıra endemik türler de zarar görmüş, bölgedeki sosyo-ekonomik yapı da etkilenmiştir.

Anahtar Kelimeler: İstilacı, ekoloji, ekonomi, balıkçılık, Eğirdir Gölü.

Introduction

Because of habitat destructions, over-exploitation of stocks and introduction of alien species, freshwater ecosystems are under continuous threats (Moyle and Light, 1996; Cowx and Collares-Pereira, 2002; Leprieur *et al.*, 2006; Santos *et al.*, 2009; Musil *et al.*, 2010). It has been reported that the introductions of alien species has caused to the loss of native aquatic bio-diversity (Vitousek *et al.*, 1997;

Gido and Brown, 1999; Bianco and Ketmaier, 2001; Cowx and Collares-Pereira, 2002; Vitule *et al.*, 2009). Alien fish species is considered to be the greatest of all threats against the preservation of bio-diversity apart from habitat destructions (Cambray, 2003). The after effects of the introduction of alien species into fresh water systems are ecological and economical problem of utmost importance although universally underestimated (Garcia-Berthou and Moreno-Amich, 2000; Garcia-Berthou, 2007). Countless records have been made about the loss of native fish fauna after having encountered with the predatorily alien species in inland waters (Goudswaard and Witte, 1997; Garcia-Berthou and Moreno-Amich, 2000; Leonardos *et al.*, 2008; Strayer, 2010; Marr *et al.*, 2010; Winfield *et al.*, 2010). Even after careful consideration of the increase of food production, its economic contribution and its recreational benefits, the introduction of alien species in the lakes have always been a cause of alteration of the fish fauna in a great number of lakes (Ogutu-Ohwayo, 1990; Porta *et al.*, 2010).

The introduction of alien species to lakes goes back to the 1950's when the first of the alien species, *Gambusia* spp was introduced into many wetlands in order to control malaria in Turkey (İnnal and Erk'akan, 2006). Also around the same years another alien species, *Sander lucioperca* was introduced for the first time to Lake Eğirdir (Numan, 1958). Lake Eğirdir happens to be the first lake in Turkey into which the first and the most of the alien species were introduced and hence its fish fauna and the annual fishery yield display a continuous change. Since the 1920's a lot of studies have been conducted on the fish population of Lake Eğirdir and the attraction of lake have been taken by many researchers in the recent 50 years because of the introduction problems of alien species (Devejian, 1926; Pietschmann, 1933; Kosswig and Geldiay, 1952; Numann, 1958; Ladiges, 1960; Akşiray, 1961; Geldiay and Kocataş, 1970; Saruhan, 1970; Karaman, 1971; Karaman, 1972; Selekoğlu, 1982; ISÜBM, 1984; Rahe and Pelister, 1987; Balık, 1988; Ekmekçi and Erk'akan, 1997; Campbell, 1992; Erk'akan and Bayrak, 1992; Becer and İkiz, 1996; Kesici *et al.*, 1997; Küçük, 1998; Balık *et al.*, 2002; Bolat, 2004; Yeğen *et al.*, 2005; Çubuk *et al.*, 2006; Balık *et al.*, 2006a; 2006b; Yılmaz *et al.*, 2007; Küçük *et al.*, 2009).

Nearly, 90 years of studies on Lake Eğirdir were rewieved and compared with the present situation of the lake in this study. Information from this study may be used to design commercial fisheries management strategies for Lake Eğirdir, conservation of the fish diversity and it may also be a good sample for possible alien fish introductions in another lakes drawing attention to the negative effects of the alien species. Accordingly, the aims of the study were to 1) determine introduced alien fish species and the historical changes in the fish fauna, 2) evaluate the effects of the alien fish species on the fish diversity and annual catch composition, 3) determine the structural changes in the fish populations and 4) assessment of the alteration of annual fishing pressure, annual catch and economic value of the fisheries in Lake Eğirdir.

Materials and Methods

Lake Eğirdir

Lake Eğirdir has an about 468 km^2 surface area and it is Turkey's fourth biggest lake (Figure 1). If considered as a fresh water lake, it is the second biggest lake in Turkey after Lake Beyşehir. Its total volume is 4,000 hm^3 and approximately 1,000 hm^3 is taken away for use with different purposes like irrigation, drinking water etc. The average depth of the lake is 7 m and its maximum deep is about 13 m. Retention time of water takes about 2.5-3 years. There

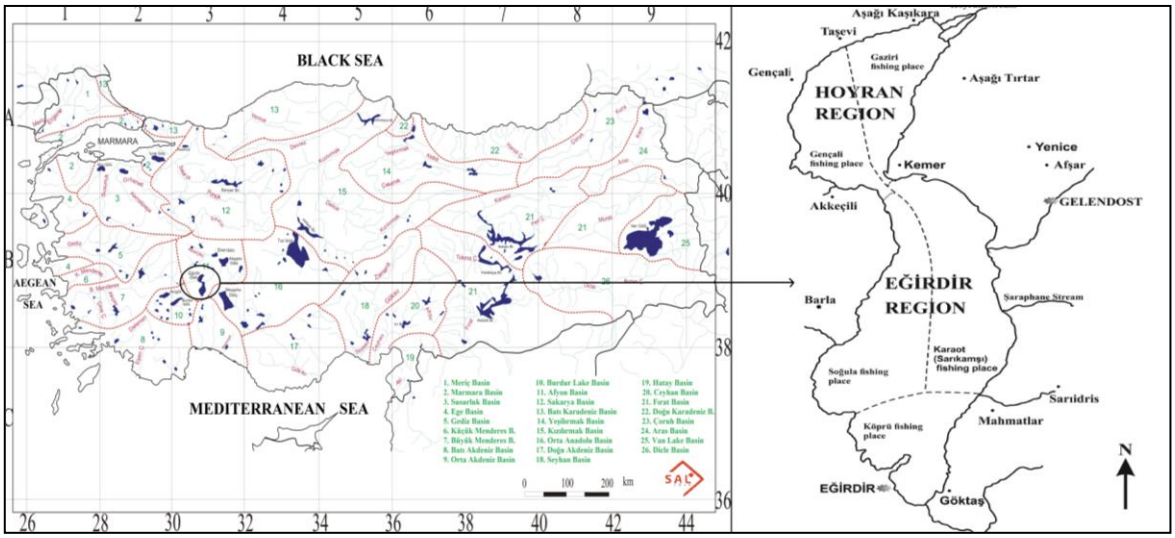

Figure 1. Lake Eğirdir and its location in Turkey.

is no thermal stratification in the lake. Maximum altitude is 919 m and the lake's surface area at this level is 487 km^2. The catchment area of Lake Eğirdir is 3,309 km^2 and the proportion of the surface area of the lake to the catchment area is 1:7 (EFRI, 2010; IPDA, 2010).

Water supply in Lake Eğirdir is provided nearly 40 surface springs some of which become dry during times of drought together with the rainfall in the watershed. Apart from evaporation, loss of water in Lake Eğirdir is because of the water flow into Lake Kovada through the Kovada Channel, as well as water drainage through the approximately 20 ponors found at the bottom of the lake and because of pumping water out for purposes of irrigation. Water drainage as well as intake is possible through the ponors at the bottom of the lake.

A total of 45,000 hectares of agricultural land is irrigated with the water of the 11 irrigation pumps stations in Lake Eğirdir. There has been a decline in water use for power supply and drinking water because of the applying of pressure irrigation systems such as dripping irrigation in the region despite the increase in the need for irrigation water at Lake Eğirdir in the last few years (EFRI, 2010; IPDA, 2010).

As being the second biggest fresh water lake in Turkey, Lake Eğirdir used to be a safe haven for 9 native fish species until the 1950's (Kosswig and Geldiay, 1952; Numan, 1958; Akşiray, 1961). They were generally of cyprinid species and did not present much of an economic worth. Hence, in order to turn these small cyprinids into some economically valuable products; 10,000 pikeperch fry (*Sander lucioperca*) brought from Austria were stocked into the lake in 1955 (Numann, 1958). Starting from the 1960's, the small pikeperch fry population introduced the lake began fishing and until the mid 1980's, displayed a positive development. At the fish processing facilities established at the settlements around the lake, catched pikeperchs were finally filleted and their fillets were exported to the European countries. Nevertheless, only two, *Cyprinus carpio* and *Vimba vimba*, out of the 9 native fish species have survived in the lake while the rest had disappeared because of the predatory effect of the pikeperch by the end of the 1980's (Campbell, 1992; Erk'akan and Bayrak, 1992). Because of this fact, this piscivore fish were unable to find sufficient amount of preys and hence, the cannibalism percentage of pikeperch increased (Campbell, 1992). Unfortunately, because of the lack of sufficient prey fish and their urge for non-stop fishing, the pikeperch population has consumed away. Thus, particularly after the 1990's, many new species of fish were introduced to Lake Eğirdir as prey for the pikeperch population as well as with the purpose of contribution to the development of fisheries for economic progress (Küçük, 1998; Balık *et al.*, 2002; Yeğen *et al.*, 2005; Çubuk *et al.*, 2006; Küçük *et al.*, 2009). Apart from the fish species found in Lake Eğirdir, there is a crayfish species as well (*Astacus leptodactylus*). The lake provided us with quite a good amount of crayfish catch which also meant 75% of Turkey's crayfish production between the years of 1970 and 1985 (Numan, 1958; Geldiay and Kocataş, 1970; Saruhan, 1970; Kesici *et al.*, 1997; Erdemli, 1982; Balık *et al.*, 2005). However, because of the outbreak of an infectuous crayfish plague (*Aphanomyces astacii*) in 1985, the crayfish stocks declined but since they never disappeared completely and they still are existent in the lake (Bolat, 2004; Balık *et al.*, 2005).

Because of the appropriate quality of its water and its natural/environmental beauty, Lake Eğirdir has been used for a variety of different purposes such as for drinking water supply, agricultural irrigation, tourism, fisheries and power supply. It can be said that touristic activities are developing rapidly every day with regard to the existence of many touristic hotels and facilities in the area, especially in central Eğirdir. Furthermore, the lake has also benefited from fishery products economically in times of the fishing season. Even though the people living at surroundings of lake are mostly farmers, some of them has always been laboured in fishery in times of the lake's prolificacy. And yet with the decline of its prolificacy, they have returned to being farmers again.

Data Collection and Analysis

In order to evaluate the fisheries in Lake Eğirdir, data were gathered from the previous studies (Akşiray, 1961; Saruhan, 1970; Ongan, 1981; ISÜBM, 1984; Bayrak *et al.*, 1991; Çubuk *et al.*, 2007), from the records of the Eğirdir Fisheries Research Institute (EFRI, 2010) as well as from the data provided by Isparta's Provincial Directorate of Agriculture (IPDA, 2010). The economic values of the fish were also obtained from the Turkish Statistical Institute.

With regard to the presence of each species in Lake Eğirdir according to years, the tolerance value (TV) of each species is estimated with the equation of $TVi = YOPi / YSPi$. Here, *TVi* is the tolerance value of the species "i"; *YOPi* is the number of the years that the species "i" is observed to be present; and *YSPi* is the number of the years that the species "i" should be present. Tolerance Value (TV) of a species ranges between 0 and 1 and the values of TV close to 0 are considered to indicate low tolerance and weakness of the species, however TV values close to 1 are considered to indicate high tolerance of the species. By making use of the Catch Index (CI) created with regard to the annual catch obtained from fishery, it became possible to evaluate of profitability of the years (Table 1). In order to calculate the economic efficiency of the lake fisheries, some other Economic Index was also created (Table 1).

In order to analyse the correlations between the years and the species with regard to the amount of

yield and also to specify which species were effective in which years, the Principal Component Analysis was applied and the results were given with an ordination graphics SYSTAT.

Results

Natural Fish Species

The studies about the fish species in Lake Eğirdir goes back to the year of 1915. In those years *Acanthorutilus handlirschi*, *Schizothorax prophylax* and *Varicorhinus pestai* were reported form Lake Eğirdir (Devejian, 1926; Pietschmann, 1933). Among them, *S. prophylax* and *V. pestai* are the same species and synonyms of *Capoeta pestai* today. Other species, *Acanthorutilus handlirschi*, is reported as *Pseudophoxinus handlirschi* in later studies in the lake.

The first and the most extensive study about Lake Eğirdir's fish fauna was accomplished by Kosswig and Geldiay (1952). In this study 10 different fish species were reported in the lake. However, with regard to the fact that *S. prophylax* and *V. pestai* are synonyms of each other, there were in fact 9 native fish species in the lake and they were *Barbatula mediterraneus*, *Cobitis turcica*, *Capoeta pestai*, *Cyprinus carpio*, *Hemigrammocapoeta kemali*, *Pseudophoxinus egridiri*, *Pseudophoxinus handlirschi*, *Vimba vimba* and *Aphanius anatoliae* (Table 2). Among them *P. egridiri* and *P. handlirschi* are endemic species. The tolerance value for the native fish species in the lake is low when compared to the tolerance value of the alien species; the tolerance values for two of the native species *C. carpio* and *V. vimba* is 1.00, but for other endemic species it varies between 0.33 and 0.83. And as a result, *H. kemali* and *P.handlirschi* are specified as the weakest species in Lake Eğirdir (Table 2).

The Alien Fish Species and the Changes in the Fish Fauna

Between the years of 1955 and 2010, totally 9

Table 1. Catch Indices (CI) and Economic Indices (EI) in order to to evaluate annual catch and economic values of Lake Eğirdir

Annual catch (tons)	Statement	CI	Annual economic value (USD)	Statement	EI
>500	very low	0	>500000	very low	0
500-1000	low	1	500000-1000000	low	1
1000-1500	moderate	2	1000000-1500000	moderate	2
1500-2000	high	3	1500000-2000000	high	3
>2000	very high	4	>2000000	very high	4

Table 2. Historical changes in native and alien fish species in Lake Eğirdir and their tolerance values (TV)

Species	Years												
	1952	1958	1961	1970	1984	1992	1998	2002	2005	2006	2009	2010	TV
ATHERINIDAE													
Atherina boyeri									Δ	Δ	Δ	Δ	1.00
BALITORIDAE													
Barbatula mediterraneus	●	●	●	●							●		0.42
Seminemacheilus ispartensis								Δ	Δ		Δ	Δ	0.80
COBITIDAE													
Cobitis turcica	●	●	●	●							●	●	0.50
CYPRINIDAE													
Alburnus chalcoides								Δ					0.20
Capoeta pestai	●	●	●	●					●	●	●	●	0.67
Carassius gibelio								Δ	Δ	Δ	Δ	Δ	1.00
Cyprinus carpio	●	●	●	●	●	●	●	●	●	●	●	●	1.00
Hemigrammocapoeta kemali	●	●	●	●									0.33
Pseudophoxinus egridiri	●	●	●	●			●		●		●	●	0.67
Pseudophoxinus handlirschi	●	●	●	●									0.33
Pseudorasbora parva												Δ	1.00
Tinca tinca								Δ	Δ	Δ			0.60
Vimba vimba	●	●	●	●	●	●	●	●	●	●	●	●	1.00
CYPRINODONTIDAE													
Aphanius anatoliae	●	●	●	●			●	●	●		●	●	0.75
GOBIIDAE													
Knipowitschia caucasica							Δ	Δ	Δ		Δ	Δ	0.83
POECILIDAE													
Gambusia affinis						Δ		Δ	Δ		Δ	Δ	0.71
PERCIDAE													
Sander lucioperca		Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	1.00

●: Native species, Δ: Alien species. 1952: Kosswig and Geldiay (1952); 1958: Numan (1958); 1961: Akşiray (1961); 1970: Saruhan (1970); 1984: ISUBM (1984); 1992: Campbell (1992); 1998: Küçük (1998); 2002: Balık *et al.* (2002); 2005: Yeğen *et al.* (2005); 2006: Çubuk *et al.* (2006); 2009: Küçük *et al.* (2009); EFRI, 2010 (Unpublished data)

alien fish species were introduced to Lake Eğirdir and these were: *Sander lucioperca, Gambusia affinis, Knipowitschia caucasica, Tinca tinca, Carassius gibelio, Alburnus chalcoides, Seminemacheilus ispartensis, Atherina boyeri* and *Pseudorasbora parva* (Table 2, Figure 2).

Among the species introduced the lake, *A. chalcoides* and *T. tinca* disappeared again after remaining existent only for a short period. Yet the rest of the species introduced are still present in the lake. Especially when pikeperch was introduced, some species have disappeared for quite a long time. However after the decline of pikeperch stock during the last couple of years, some of those species have reappeared again. Nevertheless, two of the lake's endemic species, *H. kemali* and *P. handlirschi* have totally disappeared after the 1970's (Table 2, Figure 2, Figure 3). Among the alien species, the tolerance value of *S. lucioperca, C. gibelio, A. boyeri* and *P. parva* is notably high (TV=1.00) whereas the tolerance value of *T. tinca* is low (TV=0.60) (Table 2).

Only two alien species were introduced until 1970, eventhough the introduction of alien species in Lake Eğirdir goes back to 55 years ago. No fish introduction was actuated between 1970 and 1990. Although only two alien species were introduced between 1990 and 2000, 5 alien species were

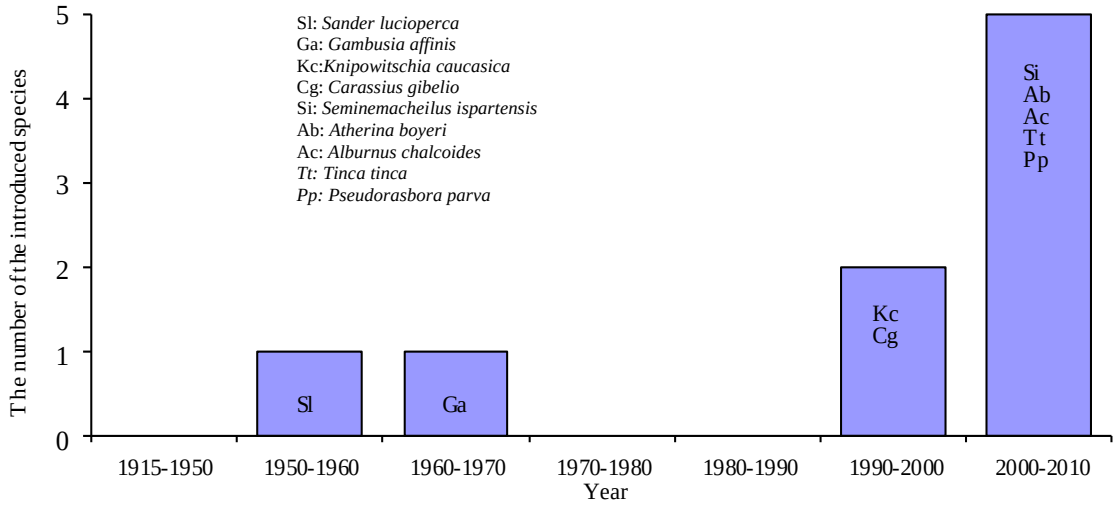

Figure 2. Introduction periods of alien fish species in Lake Eğirdir (See Table 2; Yerli *et al.*, 2010).

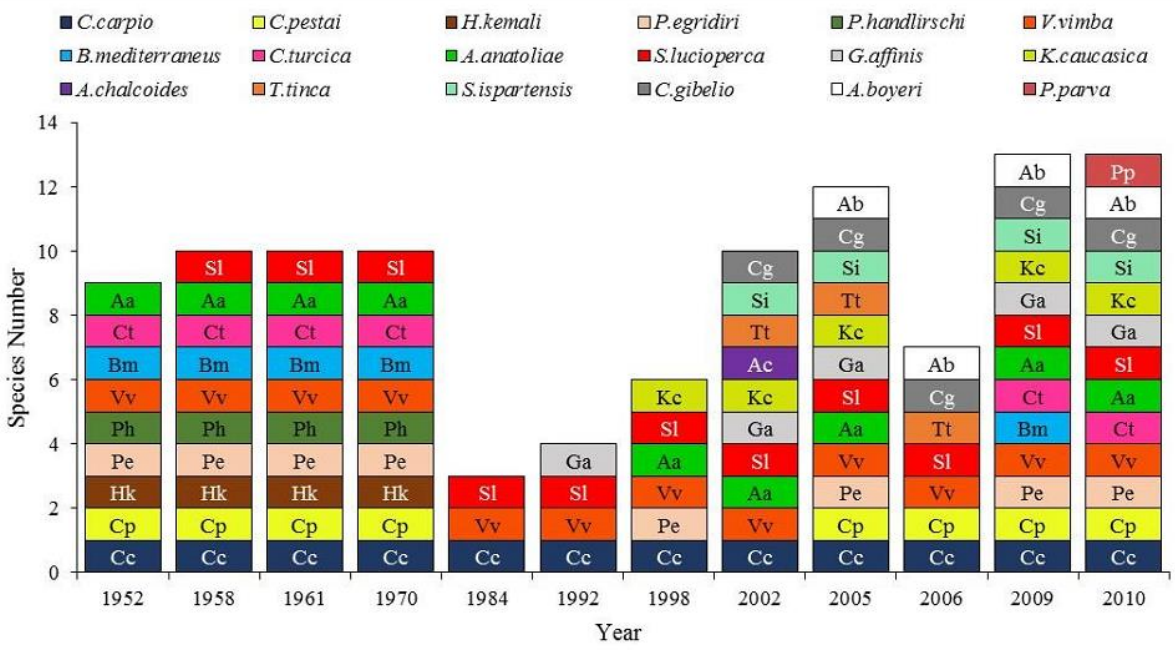

Figure 3. Changes of fish fauna in Lake Eğirdir accordings to the years (See Table 2; Yerli *et al.*, 2010).

introduced to the lake after 2000 (Figure 2).

In the two different studies during the 1960's, the fish diversity in Lake Eğirdir were reported as 5 species (Ladiges, 1960) and 10 species (Akşiray, 1961). Moreover, according to Saruhan (1970) the lake's fish fauna has not changed since the 1960's. However, the research carried out during the 1980's show us the fact that most of the native/endemic species, with the exception of *C. carpio*, *V. vimba* and *C. pestai* (ISÜBM, 1984; Balık, 1988) have disappeared.

After having introduced the pikeperch in 1955, the first signs of change in the fish diversity are observed very clearly through the research caried out after the 1980's. In the researchs at the beginning of the 1990's, only 3 species were present in the lake (Campbel, 1992; Erk'akan and Bayrak, 1992). Moreover, as these studies were about pikeperch feeding and assessment of its stock, it was suggested that since the pikeperch population was suffering highly from shortage of prey fish and the percentage of pikeperch cannibalism was high, some prey fish should be introduced in the lake (Erk'akan and Bayrak, 1992). By the end of the 1990's, fish diversity in the lake is recorded to have risen to 6 species and with the exception of pikeperch and *G. affinis*, the existence of another alien species in the lake, that is *Pomatoschistus marmoratus* was reported (Küçük, 1988). In the following years, this species was modified as *Knipowitschia caucasica* (Table 2, Figure 2). At the beginning of the year 2000, the fish diversity in Lake Eğirdir has risen to 10 species, and fish such as *S. ispartensis*, *A. chalcoides*, *C. gibelio* and *T. tinca* were observed to be present in the lake for the first time (Balık *et al*., 2002). In a study caried out by Yegen *et al*. (2005), it was observed that another alien type, *A. boyeri* was introduced to the lake. Also in the same work it was conducted that one of the native fish species, *C. pestai* which was lost since the 1980's, has reappeared. Küçük *et al*. (2009) reported 13 species and the reexistence of *B. mediterraneus* which was reported to have been lost after 1970.

There have not been many changes in the lake's fish diversity until the 1970's. In this period, only pikeperch as an alien species was released into the lake and 10 different species have survived until the 1970's. As result of the predatory effects of the pikeperch, the fish diversity in the lake had dropped down to 3-4 species (*S. lucioperca*, *C. carpio*, *V. vimba* and *G. affinis*) during the 1980's. After the mid 1990's, the pikeperch stock in the lake declined and cannibalism increased dramatically and hence some alien species *(K. caucasica* and *C. gibelio)* were introduced to the lake. As a consequence, the fish diversity at the end of 1990's rose to 6 species. During the 2000's, as the pikeperch population went into a decline, new alien species (*A. boyeri*, *A. chalcoides* and *T. tinca)* were again introduced to the lake. Some species (*B. mediterraneus*, *C. turcica*, *C. pestai*, *P. egridiri*, and *A. anatoliae)* disappeared after 1970 reappeared in the lake during this period. Today, there are totally 13 species out of which 7 are native (*C. turcica*, *C. pestai*, *C. carpio*, *P. egridiri*, *V. vimba*, *S. ispartensis* and *A. anatoliae*), and the remaining 6 are the alien species introduced to the lake (*S. lucioperca*, *G. affinis*, *K. caucasica*, *C. gibelio*, *A. boyeri* and *P. parva)* (Table 2, Figure 3).

Among its wide range of fish species, crayfish (*Astacus leptodactylus*) happens to be one of the most important population in Lake Eğirdir. According to Numann (1958) crayfish is not among the lake's native species but is introduced. However, its introduction date is unknown. The first and the most extensive study about the crayfish in Lake Eğirdir was caried out by Geldiay and Kocataş (1970) who specified the crayfish as *Astacus leptodactylus salinus*. Especially after the growth of the pikeperch population in Lake Eğirdir, the crayfish became thickly populous between the years of 1970 and 1985. However, although the crayfish stocks collapsed because of the outbreak of a crayfish plague in 1985, they have never been extinct completely in the lake.

Fish Stocks

Structural Changes in the Fish Stocks

In a study conducted on the years of 1991 stock size of the pikeperch population between 1 and 7 years old was assessed as 910,680±99,319 individuals and 254.99 tons (5.5 kg ha^{-1}) in Lake Eğirdir (Erk'akan and Bayrak, 1992). However, it was not evaluated in terms of maximum sustainable yield of the pikeperch stock. In the same study, 39.73% of the pikeperch population was recorded between 1 and 7 years old. According to Ekmekçi and Erk'akan (1997), 94% of the pikeperch population was consisted from 0 and 2 years old individuals. In another study, the pikeperch stock in Lake Eğirdir was assessed by cohort analysis and stock size of the pikeperch over 14 cm in length was 601299 individuals (53.4 tons) and 97.2% of the population consisted form 1 and 2 years old individuals (Balık *et al*., 2002). According to the bio-economic stock analysis, it was suggested that fishing effort should have been decreased 60% in order to obtain maximum sustainable yield (Balık *et al*., 2002). Pikeperch stock consisted of 3.8% of the total fish population (Balık *et al*., 2002).

The individulas of 3 years old and older fish consisted of 52.4% of the population in 1967 and 1969 (Saruhan, 1970), whereas it consisted of 34.9% in 1981 (Selekoğlu, 1982), and 2.8% in 2001 (Balık *et al*., 2002). According to the records of the last years, pikeperch stock is not sufficient for fishery. Because the percentage of the mature individuals (24 cm and over) consisted only 5% of the population.

According to Rahe and Pelister (1987), 69% of

the annual catch was constituted from the fish of 24-25 cm in length, and 69% of the annual catch was between 33 and 40 cm in length. However, the average lengths of the individuals of the annual catch were 25.8 cm in 1990 and 24.7 cm in 1992 (Erk'akan and Bayrak, 1991; Erk'akan and Bayrak, 1992), and 19.3 cm in 2002 (Balık *et al.*, 2002) (Figure 3). The average length of the pikeperch in annual catch in Lake Eğirdir decreased every year (Figure 4).

A cohort analysis was also applied for *C. gibelio* stock in Lake Eğirdir (Balık *et al.*, 2002) and stock size of the fish bigger than 18 cm in length was assessed as 11,737,044 individuals (3462.1 tons). In the present time, annual catch of *C. gibelo* in Lake Eğirdir is 1,205 tons and Balık *et al*. (2002) suggested that fishing pressure on *C. gibelio* should have been increased 10 times in order to obtain maximum sustainable yield (1,734 tons).

If Balık *et al*. (2002)'s stock analysis results are to be taken into consideration, the population of pikeperch, the single predator fish in the lake, is about 1/20th of the *C. gibelio* population and its biomass is about 1/65th of the biomass of *C. gibelio*. If the presence of other fish populations in the lake are to be taken into consideration these will even get higher. Moreover, if the same assessment method is applied to the total number of fish caught in the lake, the biomass of the pikeperch catch is about 1/24th of that of *C. gibelio*'s. Furthermore, while the stock using ratio (E) was reported as 85% (E=0.85) for pikeperch population and 38% (E=0.38) for *C. gibelio* population (Balık *et al.*, 2002). In accordance with these parameters, fishing pressure was incredibly high on pikeperch population whereas that of *C. gibelio*'s was insufficient in the lake.

The Changes in Feeding and Diet Compositions of the Fish Populations

Diet compositions of the pikeperch populations in the years of 1992, 1996 and 2006 were given in Table 3. The pikeperch population was able to find plenty of prey fish in the lake until 1980's, however prey fish consisted of 17.82% of the total diet of

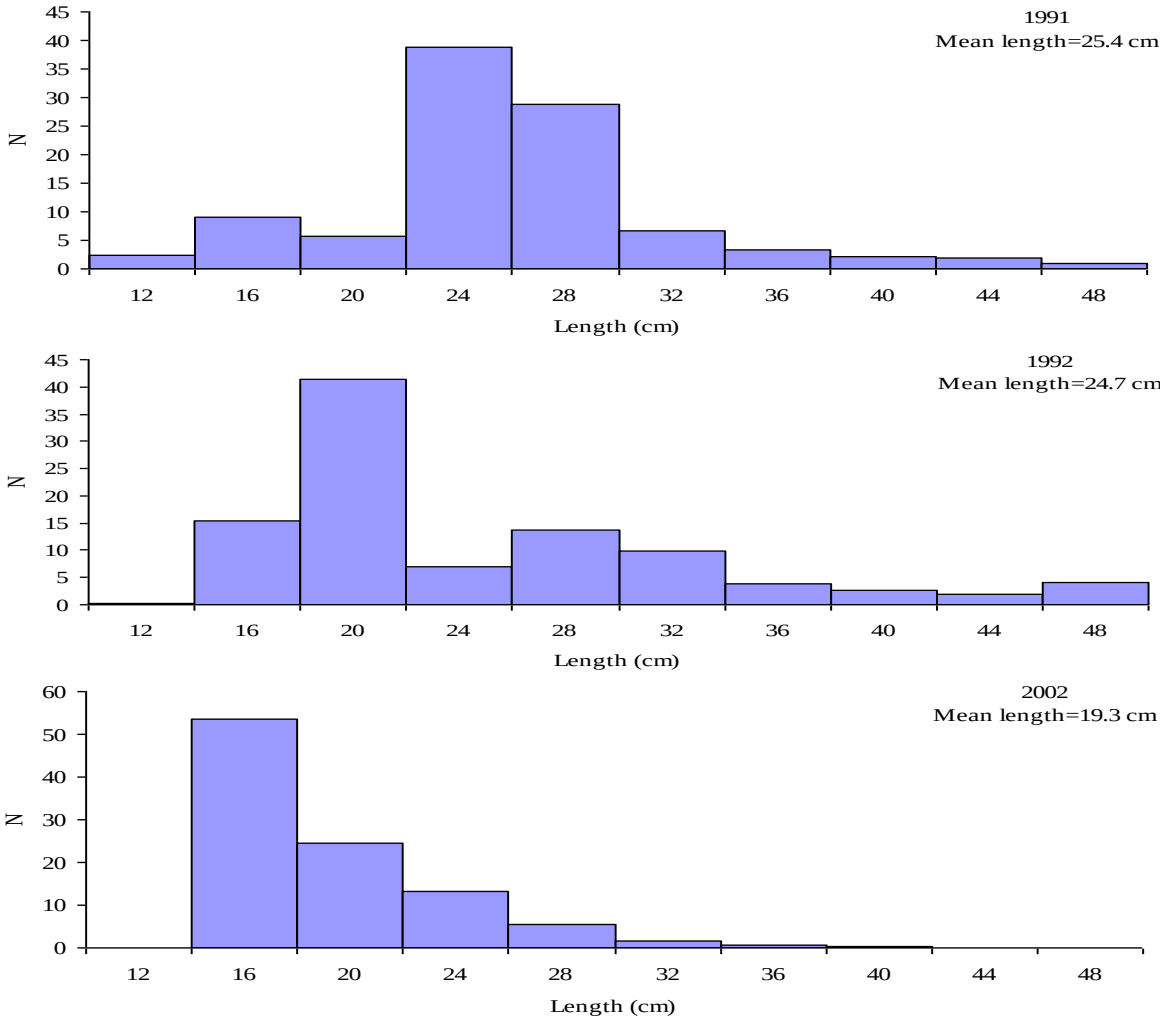

Figure 4. The changes in length compositons of the annual catch in Lake Eğirdir according to the years. [1991: Erk'akan and Bayrak (1991); 1992: Erk'akan and Bayrak (1992); 2002: Balık *et al.* (2002); Yerli *et al*. (2010)]

pikeperch in 1992 (Campbell, 1992). And since the majority of these fish were pikeperch themselves, cannibalism was reported to have reached to 96%. Similar results were obtained about the diet composition of pikeperch in 1996 (Becer and İkiz, 1996). When alien fish species were introduced to the lake, a great change was observed in the diet of pikeperch population (Balık *et al.*, 2006 b). In this study, 52.1% of the prey organisms in the diet were specified as prey fish which were mainly *Knipowithschia* sp and *Aphanius anatolia* while *Carassius gibelio* in the pikeperch diet consisted of only 0.2% of the pikeperch diet. The percentage of cannibalism in pikeperch population was reported as 0.6% (Balık *et al.*, 2006 b) while it was 96% in 1992. Balık *et al.* (2003) stated that majority of diet composition of *C. gibelio* in Lake Eğirdir were *Chrinomus* sp, *Daphnia* sp, *Cyclops* sp and *G. lacustristurca* while some macrophytes belonging to herbal nutrient groups such as Chlorophyta, Bacilloraphyta and Euglenophyta were rarely represented. However, Yılmaz *et al.* (2007) reported 11 different nutritional organism of the diet of *C. gibelio* in Lake Eğirdir and majority of them was herbal organisms. Hence, both of the works indicated that the *C. gibelio* in Lake Eğirdir display a typical omnivorous diet.

Fisheries and Economic Aspects in Lake Eğirdir

Total Yield and its Economic Value

In different periods between the years of 1948 and 2009, totally 8 different fish species and crayfish were caught in Lake Eğirdir (Table 4). As a result of the assessment of the parameters of the last 50 years' of annual catch in Lake Eğirdir, the catch index value of the lake's fishery was 0 and 1 before the introduction of pikeperch whereas it was 4 during the 1975-1985 productive period when the pikeperch and crayfish were caught intensively (Table 4). After 1985, when there was an outbreak of crayfish plague the catch index has decreased to zero once again when the crayfish catch became possible together with the *C. gibelio*, the catch index increased to 2, yet only to drop down to zero in the years that followed (Table 4).

According to Principal Component Analysis, *A. leptodactylus, C. pestai, P. handlirschi* and *T. tinca* are represented in the first component (PC1) while *S. lucioperca, C. carpio, C. gibelio* and *A. boyeri* were represented in the second component (PC 2). There was an opposite correlation between *S. lucioperca* and *C. gibelio* as well as *A. boyeri* (Figure 5). During 2001-2009 when *C. gibelio* and *A. boyeri* were dominant in the yield, pikeperch was almost non-existent in the total catch. Similarly during 1975-1985, *A. leptodactylus* was the dominant in the yield. As for *C. pestai*, *P. handlirschi* and *T. Tinca*, they were never of much importance within the total yield. In the period before pikeperch was introduced and until the 1970's (1958-1970), *C. carpio* was the dominant fish in the yield.

According to the catch parameters of Lake Eğirdir, the native species *C. carpio* and the later introduced *S. lucioperca* are the two most important species for the lake's fisheries. And between 1975 and 1985 crayfish was on top of the list. Moreover, although the native species, *V. vimba, C. pestai* and *P. handlirschi* were present within the total catch parameters until the 1980's, however, they have never been able to establish an economic value. In fact, *C. carpio* has always been a valuable product of fisheries in Lake Eğirdir. Yet the common carp's fight for survival especially after the introduction of alien species into the lake around the 2000's and the excessive amount of its fisheries production have worsened the benefits. Today, the lake's carp yield has reduced by 90% compared to the 1950's. And this

Table 3. The changes in diet composition of pikeperch in Lake Eğirdir according to years

Campbell (1992)		Becer and İkiz (1996)		Balık *et al*., (2006a)	
Preys	%	Preys	%	Preys	%
Mysid	45.8	Mysid	3.4	Mysid	12.7
Amphipoda		Amphipoda		Amphipoda	
Gammarus sp	25.2	*Gammarus* sp	58.8	*Gammarus* sp	8.9
Isopoda	5.7	*Asellus sp*	15.2	Hirudinea	0.1
Diptera		Diptera		Diptera	
Chrinomid	2.3	*Chrinomid*	0.06	*Chrinomid*	5.1
Gastrapoda	0.89	Gastrapoda	0.03	Gastrapoda	0.1
Dreissena polymorpha	1.5	*Dreissena polymorpha*	0.03	Amphibia	2.2
Pisces		Pisces		Pisces	
Sander lucioperca	17.1	*Sander lucioperca*	0.48	*Sander lucioperca*	0.2
Vimba vimba	0.36	*Nemachilus angorae*	0.18	*Nemachilus lendlii*	1.7
Cobitis taenia	0.36	*Astacus leptodactylus*	0.54	*Gambusia affinis*	3.8
		Ephemeroptera	0.15	*Aphanius anatolia*	21.8
		Lumbricus	0.42	*Knipowitschia caucasica*	24.4
		Turbellaria	006	*Carassius gibelio*	0.2
		Odonata	0.06	Odonata	18.8

Table 4. Annual catchs (tons), their economic values (USD) and catch per unit efforts (kg/ha) between 1948 and 2009 in Lake Eğirdir (CI: Cath Index, EI: Economic Index)

Year	*C.carpio*	*S.lucioperca*	*V.vimba*	*C.pestai*	*P.handlirschi*	*C.gibelio*	*T.tinca*	*A.boyeri*	*A.leptodactylus*	Total catch (ton)	Kg ha^{-1}	Value (USD)	References	CI	EI
1948-1956	488									488		384883	Akşiray, 1961	0	0
1958-1961	500		25	150	175					850		453659	Saruhan, 1970	1	0
1961-1964	500	100	25	40						665		470156	Saruhan, 1970	1	0
1964-1967	550	220	6	3						729		598740	Saruhan, 1970	1	1
1968-1969	500	300	6	4						810		634733	Saruhan, 1970	1	1
1970										538	11.26		Ongan, 1981	1	
1972										490	10.41		Ongan, 1981	0	
1975										394	8.68		Ongan, 1981	0	
1976	100	315	12						1712	2136	46.80	2008338	ISUBM, 1984	4	4
1977	90	204	20						2852	3166	68.99	3001920	ISUBM, 1984	4	4
1978	120	380	15						2631	3146	68.56	2965717	ISUBM, 1984	4	4
1979	117	482	23						2403	3025	65.19	2842981	ISUBM, 1984	4	4
1980	120	450	15						2174	2759	59.13	2590072	ISUBM, 1984	4	4
1981	128	310							1573	2021	42.85	1880864	ISUBM, 1984	4	3
1982	160	370							1400	1930	40.69	1791842	Bayrak *et al.*, 1991	3	3
1983	125	260							2075	1460	30.67	2315537	Bayrak *et al.*, 1991	2	4
1984	120	180							2010	2310	48.53	2177565	Bayrak *et al.*, 1991	4	4
1985	80	300							1145	1525	31.99	1426515	Bayrak *et al.*, 1991	3	2
1986	20	278							12	310	6.54	276065	Bayrak *et al.*, 1991	0	0
1987	63	178								241	5.12	205519	Bayrak *et al.*, 1991	0	0
1988	33	90								123	2.62	104739	Bayrak *et al.*, 1991	0	0
1989	30	120								150	3.22	129574	Bayrak *et al.*, 1991	0	0
1990	35	110								145	3.12	124175	Bayrak *et al.*, 1991	0	0
1995	66	130								196	4.28	164487	Çubuk *et al.*, 2007	0	0
2001	60	50	1			1205			603	1919	40.75	1173365	Çubuk *et al.*, 2007	3	2
2002	15	233				24	0.05		214	486.1	10.44	1033775	Çubuk *et al.*, 2007	0	2
2003	4	32				12	1.9		302	351.9	7.50	1044223	Çubuk *et al.*, 2007	0	2
2004	6	4	0.8			7	1.5		189	208.3	4.41	644880	Çubuk *et al.*, 2007	0	1
2005	2.5	4.5	0.8			345	0.1		100	452.9	9.60	778763	Çubuk *et al.*, 2007	0	1
2006		1.2				54.5		25.5	24.7	105.9	2.26	249643	Çubuk *et al.*, 2007	0	0
2007		0.3				85.6		34	5	124.9	2.68	227988	IPDA, 2010	0	0
2008						20		18.4		38.4	0.83	50526	IPDA, 2010	0	0
2009						312				312	6.77	416000	IPDA, 2010	0	0

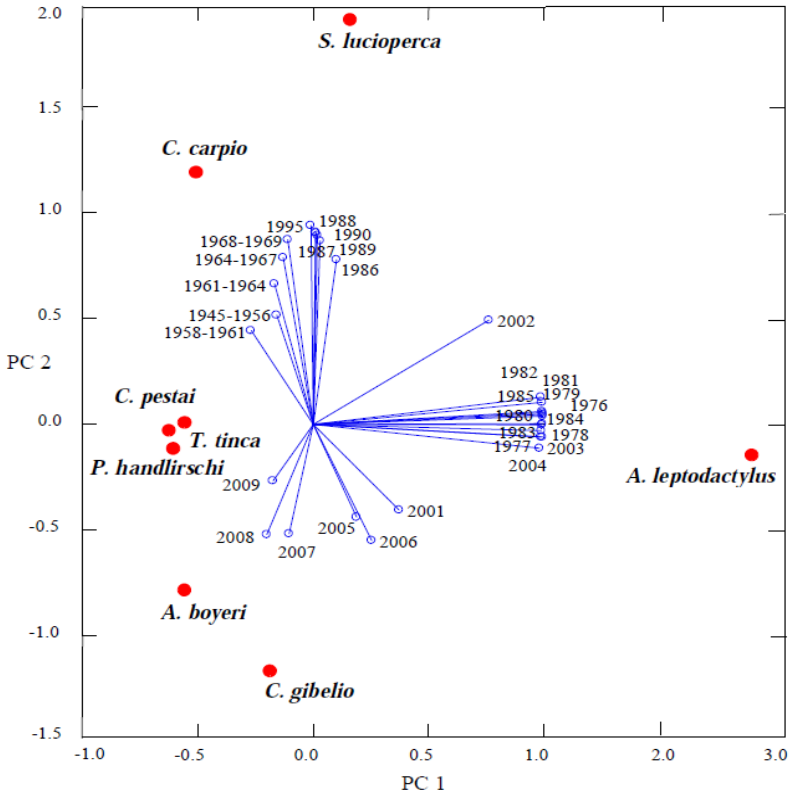

Figure 5. The relationships of annual catch and fish species between the years of 1945 and 2009 in Lake Eğirdir (See Table 4).

is why carp fishery is forbidden for the years 2008-2012.

Starting from the beginning of 1970, pikeperch has been the most valuable fishery product in the lake. And with the increase of pikeperch fishery, some fish processing factories were opened in Eğirdir. The number of the factories established in the area are totally 20.

Until the end of the 1980's, the pikeperch population in Lake Eğirdir has provided us with an excellent yield with each pikeperch weighing over 1 kg. However, it is stated that because of the predatorial force exercised by the pikeperch by the end of the 1980's, most of the natural fish species inherent in the lake had vanished and that the percentage of pikeperch cannibalism had risen to (96%) because of being unable to find the sufficient amount of prey fish (Campbell 1992). Accordingly, the weight of the predator pikeperch had diminished even to 50-100 grams. Between 2006 and 2007, their lengths were about 19 cm. As a result, in the 2000's, pikeperch fisheries have lost importance as far as Lake Eğirdir's fisheries products were concerned, and pikeperch stocks have declined a great deal (Figure 6, and 7)

In order to assessment the pikeperch stock in Lake Eğirdir, quite a number of projects were put in action at the beginning of the 1990's and as a result, prey fish introduction for pikeperch was recommended. The advice also taken, some *C. gibelio* were introduced to the lake in 1996. *Carassius gibelio* which has become the most dominant population in the lake during the last 10 years is today the most important species for the lake's fisheries (Table 4).

One of the most valuable species in Lake Eğirdir is *A. leptodactylus*. Crayfish has become the most valuable product in the lake because of its high potential for exporting. It is stated that in those years, of the 3,000 tons of Turkey's annual crayfish produce, 75% was provided by Lake Eğirdir (Erdemli, 1982; Balık *et al.*, 2005). In Turkey, 40% of the crayfish export at the beginning of the 1980's was the yield of Lake Eğirdir (Kesici *et al.*, 1997). Nevertheless, because of the outbreak of mycosis (*Aphanomyces astacii*) after 1985, the crayfish stocks declined and its catch was completely forbidden between 1986 and 1999. The restriction was abolished by the year 2001 yet the total mass of fisheries production in 2006-2007 has been quite low. As a consequence, the crayfish fishery in the lake was once more forbidden in between the years 2008-2012 but it was abolished earlier since 2010.

In addition to *C. gibelio*, *T. tinca* and *A. boyeri* were also introduced to Lake Eğirdir. While *T. tinca* was not able to survive for a long period, *A. boyeri* has managed to form a very dense population despite its low proportion within the total annual yield of the lake (Table 4). While the fisheries yield for per hectare was 10-12 kg ha^{-1} $year^{-1}$ at the beginning of the 1970's, it became almost 15 kg ha^{-1} $year^{-1}$ after the growth of their population at the beginning of 1980's. Yet starting from the beginning of 1980's until the

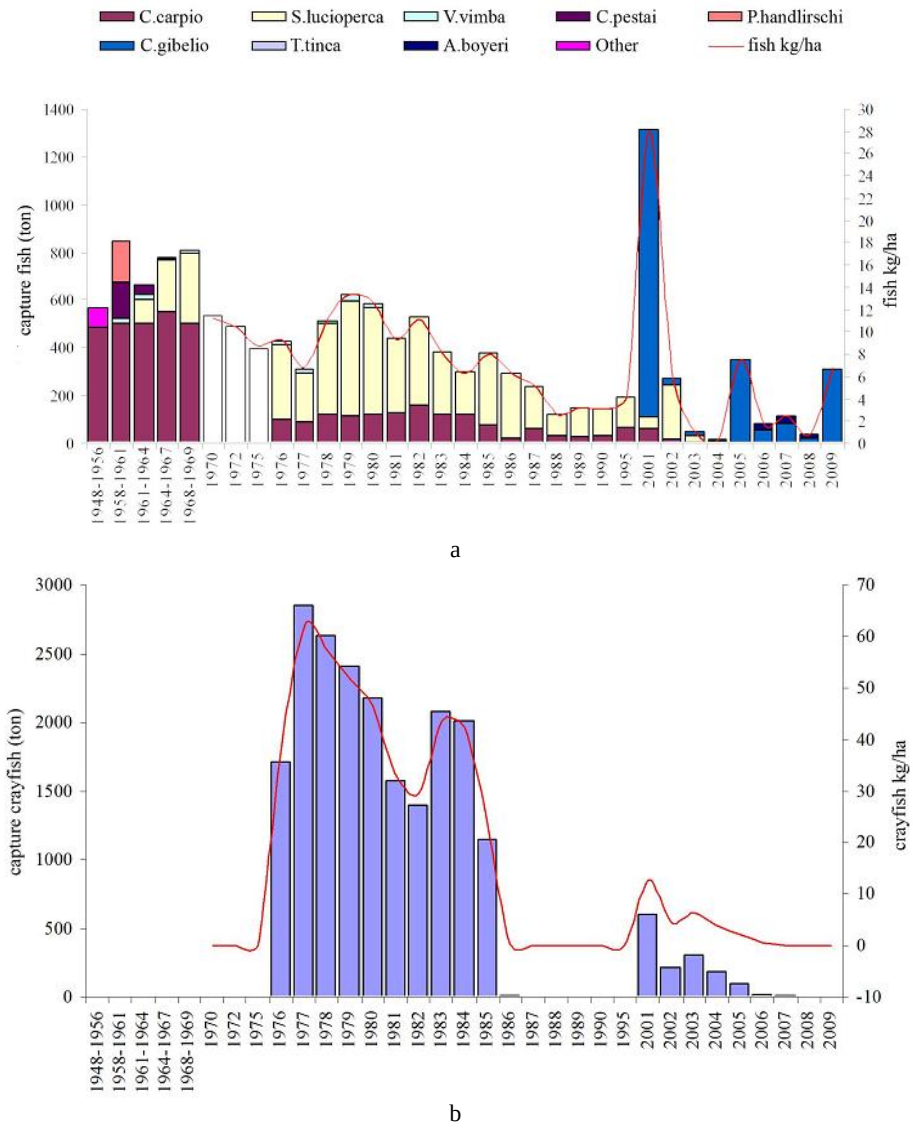

Figure 6. Production of fish and crayfish in Lake Eğirdir a) fish species b) crayfish (Histograms represent catch and lines represent catch per unit of effort in kg/ha) (EFRI, 2010; IPDA, 2010; Yerli *et al*., 2010).

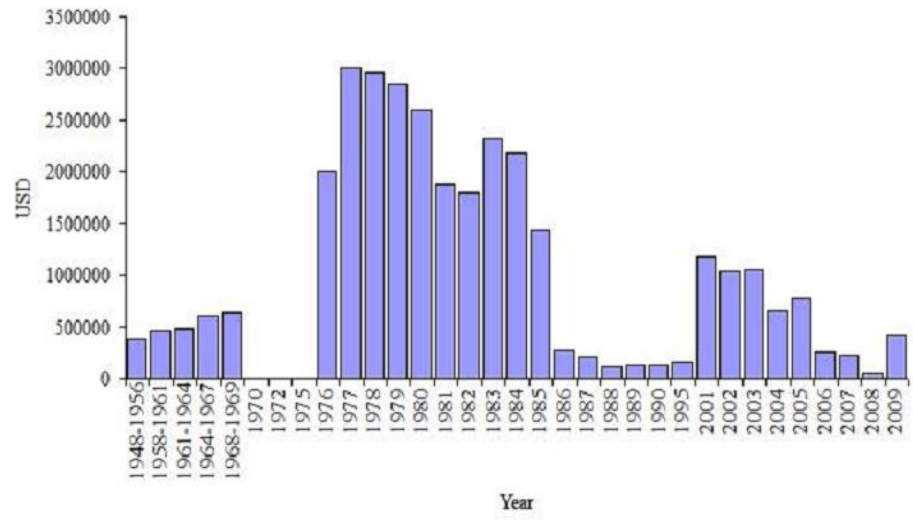

Figure 7. Calculated economical value (USD) of fish and crayfish production in Lake Eğirdir (EFRI, 2010; IPDA, 2010; Yerli *et al*., 2010).

beginning of 2000's, it dropped down to 3-4 kg ha^{-1} year^{-1}. With the start of *C. gibelio* fishing, the amount of annual yield in 2001 has risen to 30 kg ha^{-1} year^{-1} and then decreased to 1-2 kg ha^{-1} year^{-1} in the following years. Starting from 2005, *C. gibelio* fishing has become very productive and nowadays it has reached to the level of 6-7 kg ha^{-1} year^{-1}. Together with the beginnings of crayfish fishing in 1976, the yield in the lake were over 30 kg ha^{-1} year^{-1} and it reached to 30-65 kg ha^{-1} year^{-1} in between 1977 and 1985. The fishing activity was prohibitted in Lake Eğirdir in 2001, however, illegal fishing was applied and aproximately 8-10 kg ha^{-1} year^{-1} was obtained.

The economic value of the annual yields in Lake Eğirdir varied from 50,526 (in 2008) to 3,001,920 (in 1977) USD during the last 60 years (Table 4). The decade between 1975-1985 was the most profitable period and it was value 2-3 million USD (EI=4). Although, the economic value of the total amount of catch declined in the following years, it tended to rise a little in between the years of 2000 and 2003 when *C. gibelio* fishing was applied and crayfish fishing increased, but it went into a decline again in 2008 to its lowest value. The economic index (EI) indicates that the years between 1975 and 1985 were the most profitable periods (EI=4) in Lake Eğirdir whereas before 1970 and after 2005 the economic index value was decreased to zero (Table 4).

Catch per Unit Effort

At the beginning of 1980's, there were 1623 fishing boats in Lake Eğirdir (ISÜBM, 1984). It was reduced to below 100 boats at the beginning of 1990 but starting from the 2000's, more than 200 boats present in the lake. In the years that followed until today, a total of 500 fishing boats present in Lake Eğirdir. Together with the initiation of *C. gibelio* fishing and the abolition of the restriction of crayfish fishing, fisheries began to attract more and more people every day especially after 2001 (Balık *et al.*, 2006 b). The number of the fishing boats was 115 in 1999, 425 in 2001 and 510 in 2002 (Bolat, 2004). Moreover, while 1764 fishermen were reported in 1981, it increased to 2500 in 1987. The number of the fishery families around the lake increased to 1164 in 2009 from 287 in 1991(EFRI, 2010; IPDA, 2010; Yerli *et al*., 2010).

Despite the fall, every year, in the fisheries yields in Lake Eğirdir, the number of fishermen increased continually during 1991-2009 (Figure 8). And with regard to these results, both the pikeperch and the crayfish stocks have been given a continuous and excessive damage. In Lake Eğirdir, catch per unit effort was 1300 kg boat^{-1} year^{-1} in 1981, whereas it increased to 4500 kg boat^{-1} year^{-1} in 2001 with the contirbution of *C. gibelio* fishing. However, it decreased to 500-1,000 kg boat^{-1} year^{-1} between 2007 and 2008. Catch Per Unit Effort was 4,000 kg fisherman^{-1} year^{-1} in 2001 but it decreased to 300 kg fisherman^{-1} year^{-1} in 2009 (EFRI, 2010; IPDA, 2010; Yerli *et al*., 2010).

Conclusion

As a consequence of alien fish introductions, wrong management practices in an effort to turn the small cyprinids to highly valuable species have caused to substantial changes in the lake's ecosystem. After 25-30 years from the introductions of pikeperch to the lake, fishing industry was established in the area and the processed fish fillets have been marketed to European countries. Nevertheless during the 1980's, because of the lack of prey fish in the lake, cannibalism rose among the pikeperch population and so new alien fish species were introduced to the lake in order to supply preys to pikeperch. However, let alone betterment, these practices plus overfishing

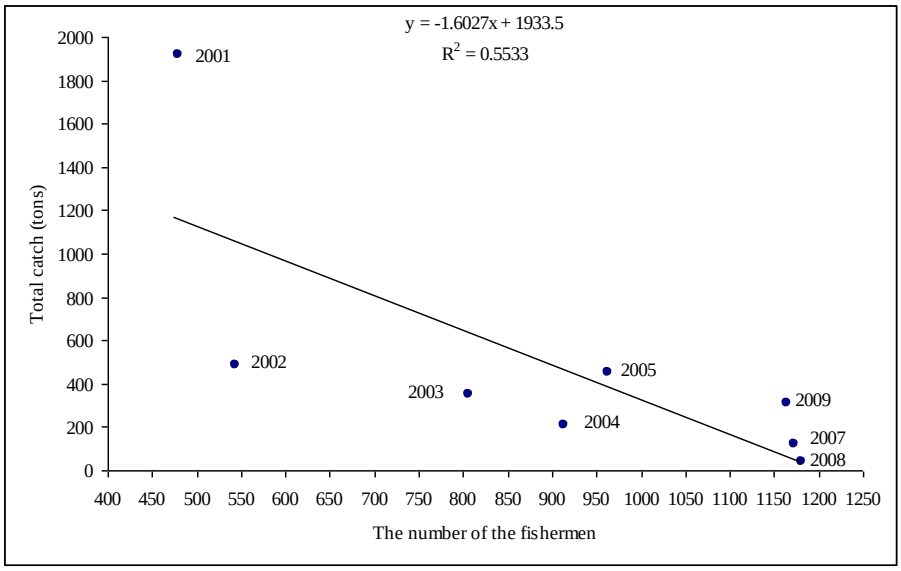

Figure 8. The relationships between annual catch and the number of fishermen according to the years (EFRI, 2010, IPDA, 2010, Yerli *et al*., 2010).

have caused to a decline in pikeperch population. On top of this, as the rise of mycosis among the crayfish caused to a collapse of the crayfish stock in 1985 and so the fisheries collapsed in Lake Eğirdir.

The introduction of alien fish species to the lake and the effects of wrong fisheries management activities can be summarised as follows;

1) Native fish fauna was changed,

2) Aquatic bio-diversity of the lake was adversely affected because some of the endemic fish species disappeared or became extinct.

3) Food chain structure was damaged and altered of the lake's ecosystem

4) The lake's fisheries management was negatively inspired/ affected.

5) Socio-economic lifes of the fishery families were influenced.

6) A negative influence was created around the lake, economically.

7) Annual fishery yields were changed and fluctated year by year.

As a result, because of the introductions of the alien fish species, overfishing and faulty fisheries activities, nonreversible damage has been given in Lake Eğirdir.

Acknowledgements

This study was supported by EU (EuropeAid) and conducted on Eğirdir Fisheries Research Institute. Therefore the authors thank especially the staff of Eğirdir Fisheries Research Institute because of their help and opening their institution for study. A part of this article was presented in FABA 2011.

References

Akşiray, F. 1961. About sudak (*Lucioperca sandra* Cuv. and Val.) introduced into some of the lakes of Turkey. Proceedings of the General Fisheries Council for the Mediterranean, 6: 335–343.

Balık, S. 1988. Systematic and zoogeographic studies on the freshwater fishes of the Mediterranean Region of Turkey [Türkiye'nin Akdeniz Bölgesi iç su balıkları üzerinde sistematik ve zoocoğrafik araştırmalar]. Doga Turk Zoology; 12, 2: 156-179.

Balık, I., Çubuk, H., Özkök, R., Karaşahin, B., Uysal, R. and Yağcı, A. 2002. The changes in fisheries of Lake Egirdir after introduced *Carassius auratus gibelio* Bloch, 1783 and the effects of this species on the lake fisheries. TAGEM, Eğridir Su Ürünleri Araştırma Enstitüsü Proje Sonuç Raporu, Proje no: TAGEM-HAYSÜD-2001-09-02-01 103 pp.

Balık, I., Karaşahin, B., Özkök, R., Çubuk, H. and Uysal, R. 2003. Diet of silver curician carp *Carassius gibelio* in Lake Eğirdir. Turkish Journal of Fisheries and Aquatic Sciences, 3: 87-91.

Balık, I., Çubuk, H., Özkök, R. and Uysal, R. 2005. Some biological characteristics of crayfish (*Astacus leptodactylus* Eschscholtz, 1823) in Lake Eğirdir. Turkish Journal of Zoology, 29: 295-300.

Balık, I., Çubuk, H., Karaşahin, B., Özkök, R., Uysal, R. and Alp, A. 2006a. Food and feding habits of the Pikeperch, *Sander lucioperca* (Linnaeus, 1758), Population from Lake Eğirdir (Turkey). Turkish Journal of Zoology 30, 19-26.

Balık, İ., Çubuk, H., Özkök, R. and Uysal, R. 2006b. Fish fauna and fisheries in Lake Egirdir: Changes from 1950s, when pikeperch (*Sander lucioperca* (Linnaeus, 1758)) was introduced to today. I. Ulusal Balıklandırma ve Rezervuar Yönetimi Sempozyumu, 7-9 Şubat 2006 Antalya 105-118 pp.

Bayrak, M., Karakoyun, S., Menengiç, M. and Vatansever, H. 1991. Investigaiton of the ecology and fisheries of Lake Eğirdir. Project Report, TÜBİTAK DEBÇAĞ 51, Eğirdir Su Ürünleri Araştırma Enstitüsü, Isparta, 44 pp.

Becer, Z.A. and İkiz, R. 1996. Diet composition of the pikeperch in Lake Eğirdir. [Egirdir Gölündeki Sudak (*Stizostedion lucioperca* L,, 1758) Populasyonunun Mide İçerikleri]. XIII. Ulusal Biyoloji Kongresi, Istanbul.

Bianco, P.G. and Ketmaier, V. 2001. Anthropogenic changes in the freshwater fish fauna in Italy with reference to the central region and *Barbus graellsii*, a newly established alien species of Iberian origin. Journal of Fish Biology, 59: 190–208.

Bolat, Y. 2004. Stock assessment of the crayfish (*Astacus leptodactylus*) population in Hoyran Region of Lake Eğirdir with the mark and recapture method. Süleyman Demirel Üniversitesi Fen Bilimleri Enstitüsü Dergisi., 8-1:34-37.

Cambray, J.A. 2003. Impact on indigenous species biodiversity caused by the globalisation of alien recreational freshwater fisheries. Hydrobiologia, 500: 217–230.

Campbell, R.N.B. 1992. Food of an introduced population of pikeperch, *Stizostedion lucioperca* L. in Lake Eğirdir, Turkey. Aquaculture and Fisheries Management, 23: 71-85.

Cowx, I.G. and Collares-Pereira, M. J. 2002. Freshwater fish conservation: options for the future. In: Collares-M.J. Pereira, M. Coelho and I.G Cowx, (Eds). Conservation of Freshwater Fishes: Options for the Future. Blackwell Science, Oxford, 443–452.

Çubuk, H., Çınar, Ş., Uysal, R., Çetinkaya, S., Özkök, R., Tümgelir, L., Yağcı, M., Erol, K.G. and Ceylan, M. 2006. Invesitigation of the economical fish stocks in Lake Beysehir and Eğirdir. Eğirdir Su Ürünleri Araştırma Enstitüsü Müdürlüğü, TAGEM-HAYSÜD/2005/09/02/02.

Çubuk, H., Balık, İ., Çınar, Ş., Özkök, R., Tümgelir, L., Küçükkara, R., Erol, K.G. Uysal, R. and Yağcı, M. 2007. The final situation at fishery of Lake Eğirdir. Eğirdir Gölü balıkçılığında son durum. Türk Sucul Yaşam Dergisi, 3-5, 182-188.

Devejian, K. 1926. Pechc et Pecheries en Turquie, İstanbul, 490 pp.

EFRI (Eğirdir Fisheries Research Institute). 2010, Eğirdir Gölü balıkçılık dokumanları.

Ekmekçi, F.G. and Erk'akan, F. 1997. Assessment of the changes of stock in pikeperch *Stizostedion lucioperca* (Linneaus, 1758) population in Lake Eğirdir. Turkish Journal of Zoology, 21: 421-430.

Erdemli, A. 1982. A comparative study on some biological and morphological charactersitics of crayfish (*Astacus leptodactylus* Esch,, 1823) populations in Lake Beysehir, Eğirdir, Aksehir, Eber and Apa. TÜBİTAK, Veteriner Hayvancılık Araştırma Grubu, Proje no: VHAG-490, 84 pp.

Erk'akan, F. and Bayrak, M. 1991. Stock Assessments in Lake Eğirdir. TÜBİTAK, DEB-ÇAG 97/G p. 147 pp.

Erk'akan, F. and Bayrak, M. 1992. Stock Assessments in Lake Eğirdir. TÜBİTAK, DEBAG 15/G p. 200 pp.

Garcia-Berthou, E. and Moreno-Amich, R. 2000. Introduction of exotic fish into a Mediterranean lake over a 90- year period. Archiv fuer Hydrobiologie1, 49: 271-284.

Garcia-Berthou, E. 2007. The characteristics of invasive fishes: what has been learned so far? Journal of Fish Biology, 71: 33–55.

Geldiay, R. and Kocataş, A. 1970. Determination of diversity and taxonomy of Astacus (Decapoda) populations in Turkey. Ege Üniversitesi Fen Fakültesi İlmi Raporlar Serisi, No: 94, Biologie 63, İzmir, 11 pp.

Gido, K.B. and Brown, J.H. 1999. Invasion of North America drainages by alien fish species. Freshwater Biology, 42: 387–399.

Goudswaard, K.P.C. and Witte, F. 1997, The catfish fauna of Lake Victoria after the Nile perch upsurge. Environmental Biology of Fishes, 49: 21- 43.

IPDA (Isparta Provincial Directorate of Agriculture). 2010. Isparta İli balıkçılık kayıtları.

ISÜBM (Isparta Su Ürünleri Bölge Müdürlüğü). 1984. A study on some of the limnological characteristics of Lake Eğirdir. Tarım Orman ve Köyişleri Bakanlığı, Isparta Su Ürünleri Bölge Müdürlüğü Yayını No:3.

İnnal, D. and Erk'akan, F. 2006. Effects of exotic and translocated fish species in the inland waters of Turkey. Reviews in Fish Biology and Fisheries, 16: 39-50.

Karaman, L.S. 1971. Süsswasserfische der Türkei, 8, Teil, Revision der Barben Europas, Vorderasiens und Nordafrikas, Mitteilungen aus dem Hamburgischen Zoologischen Museum und Institut, 67: 175-254.

Karaman, L.S. 1972. Süsswasserfische der Türkei, 9, Teil Revision Einiger Klein-wüchsiger Cypriniden Gattungen *Phoxinellus*, *Leucaspius*, *Acanthobrama* Usw, Südeuropa, Kleinasien, Vordes- Asien und Nordafrika, Mitteilungen aus dem Hamburgischen Zoologischen Museum und Institut, 69: 115-155.

Kesici, E., Kuşat, M. and Bolat, Y. 1997. Technical characteristics of the fishing boats and fishing geras in Lake Eğirdir. IX. Ulusal Su Ürünleri Sempozyumu, 17-19 Eylül, Eğirdir-Isparta 872-883.

Kosswig, C. and Geldiay, R. 1952. Fishes in Lake Eğirdir. [Eğirdir Gölü Balıkları]. Balık ve Balıkçılık, İstanbul Üniviversitesi Fen Fakülkesi Hidrobiyoloji Araştırma Enstitüsü Yayınları, 3-1: 3-14.

Küçük, F. 1998. Systematic and ecological charactersitics in freshwater fish in the inland waters of Isparta region. Isparta'nın Dünü, Bugünü, Yarını Sempozyumu, Isparta II 2, 75-88.

Küçük, F., Sarı, H.M., Demir, O. and Gülle, İ. 2009. Review of the ichthyofaunal changes in Lake Eğirdir between 1915 and 2007. Turkish Journal of Zoology; 33: 277-286.

Ladiges, W. 1960. Süßwasserfische der Türkei, 1, Teil Cyprinidae, Mitteilungen aus dem Hamburgischen Zoologischen Museum und Institut, 58: 105-150.

Leonardos, I.D., Kagalou, I., Tsomani, M. and Economidis, P.S. 2008. Fish fauna in a protected Greek lake: biodiversity, introduced fish species over a 80-year period and their impacts on the ecosystem. Ecology of Freshwater Fish, 17: 165-173.

Leprieur, F., Hickey, M.A., Arbuckle, C.J., Closs, G.P., Brosse, S. and Townsend, C.R. 2006. Hydrological disturbance benefits a native fish at the expense of an exotic fish. Journal of Applied Ecology, 43: 930-939.

Marr, S.M., Marchetti, M.P., Olden, J.D., Garcia-Berthou, E., Morgan, D.L., Arismendi, I., Day, J.A., Griffiths, C.L. and Skelton, P.H. 2010. Freshwater fish introductions in mediterranean-climate regions: are there commonalities in the conservation problem? Diversity and Distributions, 16: 606-619.

Moyle, P.B. and Light, T. 1996. Biological invasions of fresh water: empirical rules and assembly theory. Biological Conservation, 78: 149-161.

Musill, J., Jurajda, P., Adamek, Z., Horky, P. and Slavik, O. 2010. Non-native fish introductions in the Czech Republic - species inventory, facts and future perspectives. Journal of Applied Ichthyology, 26: 38-45.

Numann, W. 1958. Limnological and fisheries studies on certain Anatolian lakes and the special analysis about carp populations of living in those lakes. [Anadolu göllerinde limnolojik ve balıkçılık ilmi bakımından araştırmalar ve bu göllerde yaşayan sazanlar hakkında özel bir etüd]. İstanbul Üniversitesi Fen Fakültesi Hidrobiyoloji Araştırma Enstitüsü Yayınları Kitaplar Serisi 7, İstanbul, 114 pp.

Ogutu-Ohwayo R. 1990. The reduction in fish species diversity in lakes Victoria and Kyoga (East Africa) following human exploitation and introduction of non-native fishes. Journal of Fish Biology, 37: 207-208.

Ongan, T. 1981. Studies on hydrology and biology of Lake Eğirdir. İstanbul Üniversitesi Fen Fakültesi Hidrobiyoloji Araştırma Enstitüsü, 31 pp.

Pietschmann, V. 1933. Drei neue fisharten aus kleinasien. Mat nat Wien. KI., Tome 70: 21-23.

Porta, G.L., Angeli, V., Bicchil, A., Carosi, A., Pedicillo, G., Viali, P. and Lorenzoni, M. 2010. Variations in the fish community in lake Piediluco (Italy) caused by changes in the lake's trophic status and the introduction of alien species. Journal of Applied Ichthyology, 26: 53-59.

Rahe, E. and Pelister, O. 1987 Comparative limnological and fisheries biological investigations at four central Anatolian lakes. Journal of Aquatic Products of the University of Istanbul, 1: 1-42.

Santos, A.F.G.N., Santos, L.N., Garcia-Berthou, E. and Hayashi, C. 2009. Could native predators help to control invasive fishes? Microcosm experiments with the Neotropical characid, *Brycon orbignyanus*. Ecology of Freshwater Fish, 18: 491-499.

Saruhan, E. 1970. On the biological and economical changes occurred in the Lake Eğirdir after the transplantation of pikeperch (*Lucioperca lucioperca* L.). İstanbul Üniversitesi Fen Fakültesi Hidrobiyoloji Araştırma Enstitüsü Yayınları Kitaplar Serisi 6(3-4): 33-40.

Selekoğlu, S. 1982. Growth and length-weight relationships of pikeperch (*Lucioperca lucioperca* Lin., 1758) in Lake Eğirdir. Yüksek Lisans Tezi. Adana: Çukurova Universitesi,

Strayer, D.L. 2010. Alien species in fresh waters: ecological effects, interactions with other stressors, and prospects for the future. Freshwater Biology, 55: 152-174.

Winfield, I.J., Fletcher, J.M. and James, J.B. 2010. An overview of fish species introductions to the English Lake District, UK an area of outstanding conservation and fisheries importance. Journal of Applied

Ichthyology, 26: 60-65.

Vitousek, P.M., Mooney, H.A., Lubchenko, J. and Melillo, J.K. 1997. Human domination of Earth's ecosystem. Science, 278: 494-499.

Vitule, J.R.S., Freirel, C.A. and Simberloff, D. 2009. Introduction of non-native freshwater fish can certainly be bad. Fish and Fisheries, 10: 98-108.

Yegen, V., Balik, S., Bostan, H., Uysal, R., Ustaoglu, M.R., Sari, H.M., Ilhan, A.. 2005. Fish fauna of the region of Isparta. Eğirdir Su Ürünleri Araştırma Enstitüsü Müdürlüğü, Yayın No: 4, Isparta, 33 pp.

Yerli, S.V., Alp A., Yeğen V., Uysal R., Yağcı Apaydın M. 2010. Action Plan for the rehabilitation of Lake Eğirdir with respect to invasive species, Technical Assistance for Introduction of Stock Assessment to the Fisheries Management System of Turkey (EuropeAid/127296/D/SERlTR, T. Project, TAGEM, Agrotech), 90 pp.

Yılmaz, M., Bostancı, D., Yılmaz, S. and Polat, N. 2007. Feeding regime of the silver crucian carp (*Carassius gibelio* Bloch, 1782) in Lake Eğirdir. Türk Sucul Yaşam Dergisi, 3-5: 230-239.