CHAPTER 3.20

Fisheries ecology of Greece

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Abstract: The Greek inland water fish fauna probably is the most diverse among European countries in terms of endemic species. A total of *c.* 177 species have been recorded. Cyprinidae is the most dominant family with 86 species (48%) which occur in almost every kind of freshwater habitat. Based on the endemic fish fauna distribution, six biogeographical regions are recognized in Greece; however, the existence of the Pindos Mountains separates the country into two main sectors: east of the Pindos Mountains are found mainly cosmopolitan species and subspecies, showing affinities to the Danubian (central and western European) ichthyofauna, while west of the Pindos Mountains there are mainly endemic species. The fishery production during the last six decades has varied as the result of political, social, developmental and environmental influence. During recent years, production has steadily decreased. This could be attributed to the ecosystem degradation; changes in the structure of fish populations through stocking of commercial species; introduction of alien species; pollution from urban wastes, agricultural, small-scale and industrial activities; eutrophication; extinction of several native species; overfishing of commercial species.

Keywords: freshwater fishes, Greece, fish fauna, fishery production

Introduction

Greece (131 957 km^2, population 10.8×10^6) is located in the south-eastern part of the Balkan Peninsula. According to Banarescu (2004), in terms of inland water aquatic fish fauna, Greece is at biological crossroads among Mediterranean, temperate European, Danubian and Black Sea, and Anatolian influences. Due to its highly indented coastline and numerous islands, Greece has the 11th longest coastline in the world with 13 676 km. The country has a diverse topography (OECD, 2000), 40% of land exceeds 500 m in altitude and reaches 2000 m. Eighty per cent of Greece consists of mountains or hills, making the country one of the most mountainous in Europe. Western Greece contains a number of lakes and wetlands and is dominated by the Pindos Mountain range. The Pindos, a continuation of the Dinaric Alps, reaches a maximum elevation of 2637 m at Mount Smolikas (the second highest in Greece) and historically has been a significant barrier to east and west Greece. The Pindos Mountain range strongly affects the climate of the country, as areas to the west of the range are considerably wetter on average (due to greater exposure to south-westerly systems bringing in moisture) than the areas lying to the east of the range (due to a rain shadow effect). This produces an uneven distribution of rainfall (precipitation in western part is three times greater than in eastern parts; Koussouris, 1998).This causes major differences in hydrology and catchment areas, both in time and space (Zacharias *et al.*, 2002), and has created local distinct environments that favoured freshwater fish species isolation and endemism (Economidis, 1995).

The postglacial climate changes in combination with the recent geomorphology (upper Quaternary) gave rise to rather small alkaline river basins and lakes situated mainly in the southern part of the country. According to Skoulikidis *et al.* (1998), the majority of the Greek rivers are moderately polluted, and only a few of them show significant human impact. Up to 80% of the total surface river flow comes from the catchment area of eight large rivers. There are also 39 natural lakes with a total area of *c.* 568 km^2, 21 artificial or dam lakes or reservoirs (total area 334 km^2) (Koussouris, 1998; OECD, 2000) and 378 wetlands (total area 2000 km^2) (Greek Biotope Wetland Centre; www.ekby.gr). Most of the Greek lakes are lowland (altitude <200 m), very shallow (mean depth <3 m) or shallow (mean depth between 3 and 15 m), of medium (1–10 km^2) or large surface (10–100 km^2) area. The majority of the Greek lakes (54%) have a large surface area (surface area between 10 and 100 km^2). Most of them are of calcareous origin (74%) and 22% are of siliceous origin, while the rest (4%) are of organic type; 44% are monomictic, 45% are polymictic, and the rest (only two lakes)

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are dimictic. According to the European Union Water Framework Directive (EU WFD) and its chlorophyll *a* values, 39% of Greek lakes are classified as high, 22% as good, 16% as moderate, 11% as poor and 12% as bad (Kagalou & Leonardos, 2009).

The freshwater fish fauna

Greece, in terms of inland water fish fauna species, is the most diverse in Europe (Economidis & Banarescu, 1991; Economidis, 1995; Zardoya *et al*., 1999; Economou *et al*., 2007; Kottelat & Freyhof, 2007). A total of *c*. 177 species (including some estuarine ones) in 88 genera, 27 families and 15 orders have been recorded. Among the recorded species, 57.0% were Cypriniformes, 11.7% Perciformes and 8.9% Salmoniformes. Cyprinidae is the most dominant family with 86 species (48%) which occur in almost every kind of freshwater habitat, followed by Salmonidae with 16 species and Gobiidae and Cobitidae with 12 species, respectively. Of the members of the family of Cyprinidae, 54.6% belong to the subfamily of Leuciscinae. Most of them are relative small-sized species which are found in small waterbodies.

Biogeographical regions of the Southern Balkan Peninsula

The distribution and origin of freshwater fishes, especially the endemics, have been attributed mainly to geological history (Bobori *et al*., 2001) and the geographical characteristics of the country. Regarding the ichthyogeographical arrangement, Petit (1930) initially proposed the division of the country into two principal faunal regions, which correspond to the main drainage basins separating eastern and western Greece. A similar approach was proposed by Bianco (1990). Economidis and Banarescu (1991) examined the distribution and the origin of the freshwater fishes in the Balkan Peninsula focusing mainly in Greece, summarized the previous approach and named these two areas as the Ponto-Aegean and the South Adriatic–Ionian regions. Recently, Liousia *et al*. (2008*a*) applied cladistics models on the Greek endemic fish species and proposed that the Pindos Mountains divided the freshwater fish fauna of Greece into two ecoregions, which is in clear agreement with the previous observations. According to Tsoumani *et al*. (2013), the existence of a major biogeographical discontinuity separates the Greek native fish fauna into two major biogeographical regions; this coincides with the Pindos Mountains (Economidis & Banarescu, 1991; Durand *et al*., 2003; Banarescu, 2004; Economou *et al*., 2007; Ketmaier *et al*., 2008; Larmuseau *et al*., 2009). The west–east split of the southern Balkans has been well described by many related studies [Gasc *et al*. (1997) and Schmitt (2007) for amphibians and reptiles; Radoman (1985) for aquatic invertebrates; Zogaris *et al*. (2009) for fishes]. East of the Pindos Mountains are found mainly cosmopolitan species and subspecies, showing affinities to the Danubian (central and western European) ichthyofauna (Tsoumani *et al*., 2013), while west of the Pindos Mountains there are mainly endemic species.

Recently, Economou *et al*. (2007) proposed the existence of six biogeographical regions in Greece, which justify the freshwater fish fauna distribution: the northern Aegean (including the Thrace and Macedonia–Thessaly zoogeographical regions), the southern Adriatic (represented in Greece by the Aoos River and Lakes Mikri and Megali Prespa), the Ionian (including the Ionian Islands and the middle and western Peloponnese), the East Peloponnese, the Attiko-Boeotia (in eastern and central Greece) and the Aegean Islands (including Crete).

Zogaris *et al*. (2009) suggested a revision of the previous divisions. They accept the existence of four biogeographic regions in the territory (northern Aegean, south-eastern Adriatic, Ionian and western Aegean) and reported that there is evidence for another two regions within this area: (1) Thrace in the eastern part of the northern Aegean (which previously was included in the northern Aegean region) and (2) one in the southern Balkans (northern Aegean, south-eastern Adriatic, Ionian and western Aegean) and the western Anatolia region which includes Greece's eastern Aegean Islands.

A lot of studies (Bianco, 1990; Economidis & Banarescu, 1991; Ketmaier *et al*., 2008; Tsoumani *et al*., 2013) have proposed possible routes for dispersion of freshwater fish species through the Balkan Peninsula. Economidis and Banarescu (1991) stated that the Danubian and Central Europe ancestors dispersed during the upper Pliocene and the Pleistocene period: (1) by the Black Sea, when it was a fresh- or very slightly brackish-water lake and a very large river which discharged the waters of the Black Sea into the Aegean Sea, and (2) directly from the north from Danube basin to the Axios River basin or ever farther south to the Pinios River.

The Greek freshwater fish fauna in relation to its origins

Greece could be characterized as a hotspot of European freshwater fish fauna, as it includes mainly endemic cosmopolitan and of Asian origin species (Economou *et al*., 2007; Kottelat & Freyhof, 2007). The fish fauna of Greece can be divided into 10 categories (Fig. 3.20.1) according to the origin of the species and the biogeographic regions of the endemic species.

The most abundant category is alien species (ALN); west Greece hosts the highest number of endemic fish species (ENWE) (30) than the others. These are mainly small sized (total length, L_T, ≤50 cm) and they are found in small waterbodies. Seventeen belong to the Cyprinidae, two of them to the subfamily of Barbinae and 15 to the subfamily of Leuciscinae. Among the Leuciscinae, there are species with no commercial value as they are mostly small sized.

The cosmopolitan category (COSM) (33 species) is of global, European or broader regional distribution. This category includes

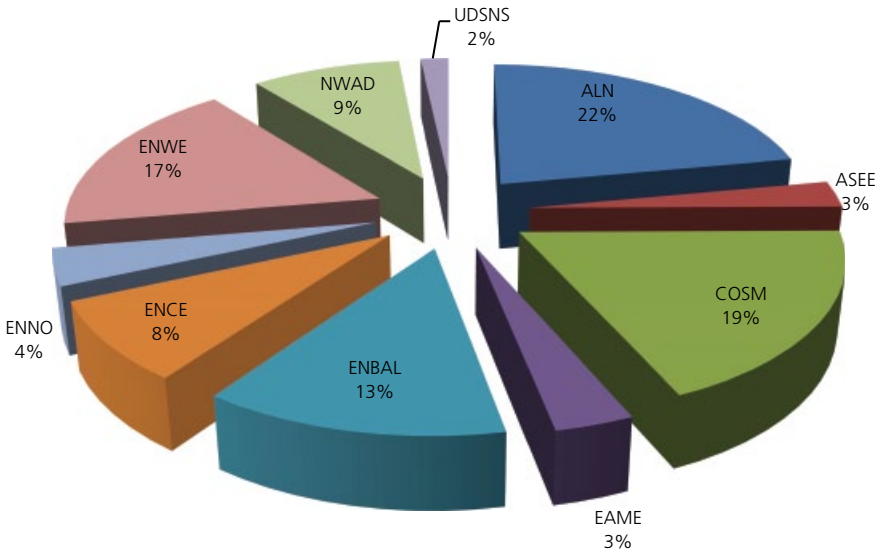

Figure 3.20.1 Endemicity of freshwater fishes of Greece. ALN, alien species (there is no substantiated evidence that the species is native within Greek territory); ASEE, Asian east Europe; COSM, cosmopolitan species; EAME, endemic to the east Aegean Islands and Asian Minor coasts; ENBAL, endemic to the Balkans (*i.e.* south of the Danube River); ENCE, endemic to central-eastern Greece; ENNO, endemic and near endemic to northern Greece; ENWE, endemic to western Greece and the Peloponnese; NWAD, north-western Adriatic; UDSNS, undescribed, possible new species.

species which are found in the lower parts of rivers and in lakes with open connection with rivers, allowing the partial migration into inland waterbodies. Some of this species are larger sized (*i.e.* pike *Esox lucius*, pikeperch *Sander lucioperca* and wels *Silurus glanis*).

Another category contains species endemic to the Balkan Peninsula (ENBAL) (23 species), which are distributed south of the Danube River. The most abundant family of this category is the Cyprinidae with 13 species. Most of them are cosmopolitan and endemic to the southern part of the Danube River with a relative wider distribution.

The species endemic or near endemic to northern Greece (ENNO) (seven species) category belong to genera with a broader distribution but are restricted to transboundary Greek lakes or rivers (*i.e.* Macedonia shad *Alosa macedonica,* Thracian shad *Alosa vistonica,* bleaks *Alburnus macedonicus, Alburnus vistonicus* and *Alburnus volviticus, Phoxinus strymonicus* and Greek brook lamprey *Eudontomyzon hellenicus*).

The category endemic to central Greece (ENCE) has 15 species; most numerous are members of Cyprinidae (12) with eight Leuciscinae, three Barbinae and one of Gobioninae subfamilies. The characteristics and the life traits of these fishes are similar to those of the endemic to west Greece category (*i.e.* small-sized species found in small ponds or rivers). These species during the summer face significant stresses due to the restricted quantity of water, eutrophication and increase of pollutant concentrations. The members of this category are probably the most affected species from anthropogenic activities.

The Asian and east European (ASEE) (five species of the family of Cyprinidae) category includes species of Asian or eastern European origin; they mainly have a broad distribution.

Five species belong to east Aegean Islands and middle Asian coasts (EAME) (three of them are species of Cyprinidae, one of Cobitidae and one of Nemacheilidae and two of the subfamily of Leuciscinae). All of them are small-sized species that are found in small streams of the east Aegean Islands.

Sixteen species belong to north-western Adriatic system (NWAD). These species are found mainly in Lakes Mikri Prespa and Megali Prespa and the Aoos River. The large number of endemic fish species of these aquatic ecosystems highlights the importance of this region.

Until now, 39 alien species (ALN) have been recorded in aquatic ecosystems of Greece. The reasons for the introductions, their origins and the present situation are analysed later.

Finally, there are three species for which there is evidence that they are new undescribed species (UDSNS). These species could be classified into one of the previous categories, as they are found in various regions.

Relationships between species number and aquatic ecosystem characteristics

The number of fish species which inhabits each ecosystem depends on the surface area of the waterbody. For lakes, the maximum number of fish species is found in Trichonis Lake (surface area 95.8 km^2), which is the largest natural lake in Greece sited in the central-west. In this lake, 31 fish species have been counted. The most diverse river is the Axios River with 28 fish species. It is the largest river (length of 388 km) of Greece which rises from FYROM (Former Republic of Macedonia) and empties into the north Aegean Sea.

Problems that face the fish fauna

Due to the steadily increase of human influence upon aquatic ecosystems, especially on inland waters (Perry & Vanderklein, 1996; Maitland & Morgan, 1997; Trudgill *et al*., 1999; Boon *et al*., 2000), the conservation and protection of their biodiversity and habitats have become a major concern (Kirchhofer & Hefti, 1996; Collares-Pereira *et al*., 2002). In Greece, the situation is not different from elsewhere, and a lot of fish species of inland water are under various threats or in danger of extinction (Minns, 2001; Souchon & Keith, 2001; Bobori & Economidis, 2006). The small size of the aquatic ecosystems, the dramatic increase of water demand over the last decades (Angelakis & Diamadopoulos, 1995) in combination with the water pollution, eutrophication (Kagalou & Leonardos, 2009), channelization and flow regulation have contributed to the degradation of surface water resources and the aquatic habitats. Due to the aforementioned reasons, as well as the uncontrolled introduction of exotic species, some fish populations have gradually become locally vulnerable, threatened or extirpated (Economidis, 1991, 1995, 2002; Economou *et al*., 2007).

Alien species

The introduction of exotic fish species into the inland waters of Greece dates back to the 1920s (Livadas & Sfagos, 1940; Stephanidis, 1950), although there are reports which indicate that the common carp *Cyprinus carpio* was introduced in south and Western Europe from the Roman era (Balon, 1995).

The freshwater fishes of Greece contain a large proportion of alien species; of 177 species, 39 (22%) are allochthonous. The number of alien species is among the largest in Europe. This is attributed to various reasons: (1) a lack of central policy to prevent alien species introductions, (2) the large number of transboundary waterbodies through which invasive species enter, (3) the position of the country in south-eastern Europe which could explain the large number of species originating from Asia and (4) the uncontrolled movement of people, materials, plants and animals among neighbouring and also non-neighbouring countries.

Of the alien fish species into Greek inland waters, 22 have been introduced for aquaculture, five for biocontrol (*e.g.* mosquitofish *Gambusia affinis* for mosquito control), four species have escaped or have been released by hobbyists (aquarium keepers), two have been introduced for enhancement of a fishery, two accidentally and four have been introduced for unknown reasons. Some species have introduced for more than one reason. For example, grass carp *Ctenopharyngodon idella* was introduced into some Greek lakes (Pamvotis, Kastoria and Prespa) under the pretext of the control of the aquatic macrophytes, along with the reinforcement of fishery production. In addition for fishery production enhancement, silver carp *Hypophthalmichthys molitrix* was introduced for algal bloom reduction.

Thirteen of the introduced fish species have been introduced by various individuals (*i.e.* private individuals and businessmen), 14 by local authorities, four by government agencies, and four from neighbouring countries through transboundary waterbodies, and for the remaining four species, there are no records.

Of the introduced species, 16 have not become established and disappeared after their introduction. Among them are species which are not able to reproduce in Greek inland waters (*C. idella*, *H. molitrix* and largemouth bass *Micropterus salmoides*). Moreover, there were some species which were not able to complete their life cycle and they disappeared a few months after their introduction (*e.g. Acipenser* sp. in Lake Pamvotis). About 43.6% (17) of the introduced species have become established. Some have formed abundant populations and nowadays dominate where they occur (*e.g.* Prussian carp *Carassius gibelio*). Some species increase in number locally causing significant problems (*e.g.* pumpkinseed *Lepomis gibbosus* in Kastoria and rivers of northern Greece). For six of the introduced fish species, there is no information.

Ten fish species were of Asian origin, eight from North America, three from Eastern Europe, four from the Black and Caspian Seas, and the remaining had their origins in Central America, the Baltic Sea, Atlantic Ocean (for Acipenseridae) and Northern Europe.

Alien fish introductions are controversial. On one side, fishermen and local government officials usually argue that the introductions improve fisheries production and have no negative impact on aquatic ecosystems. On the other side, a lot of studies have been published about the negative impact of the alien fish species in affecting the quality of aquatic ecosystems and the extinction of endemic species (Leonardos *et al*., 2005*a*; Kagalou *et al*., 2008).

Translocations of fish species

Apart from the introduction of alien species in Greece, several cases of translocations of various fish populations have been recorded within the country. The translocations were made by fishermen, members of fishing cooperatives or local authorities. There are two types of translocations: (1) species with significant commercial value which were translocated in order to reinforce fishing activity and (2) accidental translocations.

The first category is the most common including salmonids and cyprinids and some single cases of fish species. Probably, the species with more events of translocations in Greece are the salmonids. Since the late of 1970s until now, salmonids, for example, specimens of *Salmo farioides* and *Salmo dentex,* from various Greek rivers which were caught, were used as genitors and then the fry and fingerlings were repeatedly released in various rivers independently of the origin of the progenitors (Economidis *et al*., 2000; Apostolidis *et al*., 2008). As a result, today, there is confusion about the populations and the distribution of the species. These unnecessary and probably harmful translocations have been detected genetically because the intruders breed with the

wild local *Salmo* spp. populations and gene transfer takes place (Apostolidis *et al*., 1997).

Aristotle's catfish *Silurus aristotelis* is a small-sized endemic catfish of west Greece. This species was introduced into Lake Pamvotis during the middle of the 1950s (Leonardos *et al*., 2008) and into Lake Volvi in 1986 (Economidis, 1991). In Lake Volvi, there was a population of the native *S. glanis*. Since 1996, both species have not appeared in the catches of professional fishermen of the lake (Fishery Agency of Lake Volvi, Unpublished data). The competition between the two congeneric species (*S. glanis* and *S. aristotelis*) (Economidis *et al*., 2000), and probably in combination with other reasons like ecosystem degradation and overfishing, has resulted in the extinction of both populations.

Acheloos roach *Rutilus panosi* is a relative small-sized planktivorous benthopelagic species which is distributed in the lower parts of the Acheloos River and neighbouring lakes (Leonardos *et al*., 2005*b*). During the middle of the 1950s, specimens from Lake Trichonis were translocated into Lake Pamvotis, where it has created an abundant population that colonizes the pelagic ecosystem of the lake. This is because it is an ecologically tolerant species, well adapted as a planktivorous pelagic fish and resistant to eutrophication and pollution (Leonardos *et al*., 2005*b*). The mean percentage mass composition of this species to the total catches during the period 1967 to 1976 was 62%, while during the period 1999 to 2004, it dropped to 52% (Leonardos *et al*., 2008). Despite the fact that this species in its natural habitat is characterized as vulnerable (IUCN, 2012), in a new ecosystem, it forms an abundant population having no competitors or predators. It feeds heavily on zooplankton resulting in phytoplankton blooms.

Some cases of accidental translocation of fishes from one ecosystem to another have been reported by water, fishing gears (as larvae or eggs) or with other fish species (Economidis *et al*., 2000). The European bitterling *Rhodeus amarus* has been accidentally transferred from Thessaly or north-eastern Greece into Lake Ozeros.

Fishery production from fresh waters

Variation in production

The average total annual fishery production of Greece during the decade 2000 to 2011 was *c.* 197 955 t which ranged from 191 708 t (2001) to 211 286 t (2006) (http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=fish_pr_inw09&lang=en). The corresponding value from inland waters during the same period (2000 to 2011) was *c.* 2809 t and ranged from 1818 t (2005) to 7659 t (2000). The small proportion (1.42%) of catches from inland waters in relation to the total fishery production could be attributed to various reasons. First are the feeding preferences of Greeks, who like to consume marine rather than freshwater fishes. Many people think that a lot of inland waters are eutrophic and polluted (Kagalou & Leonardos, 2009). In addition, marine fishes are usually abundant in Greek markets and anyone can easily find a good quality, fresh and cheap marine fish. Finally, it is well known that the sector of marine aquaculture of Greece produces *c.* 120 000 t of marine fishes (sea bass *Dicentrarchus labrax* and gilthead sea bream *Sparus aurata*) which is near to 50% of European production.

Variation of fishery production during the last decades

During the last six decades, the annual fishery production from inland waters in Greece has varied (Fig. 3.20.2). There are a lot of reasons which could be attributed to this variation, like political, social, developmental and environmental influence.

During the period from 1950s to 1960s, the country was in a developmental phase, following World War II (1940–1944) and the civil war (1946–1949). In this period, inland fishery production began to rise until the early of 1960s. This was attributed to the regeneration of the country and the need for development.

From 1960s to 1970s, a decline in fishery production occurred. This was a consequence of urbanization, because a large wave of migration occurred from the provinces to the major cities. Also,

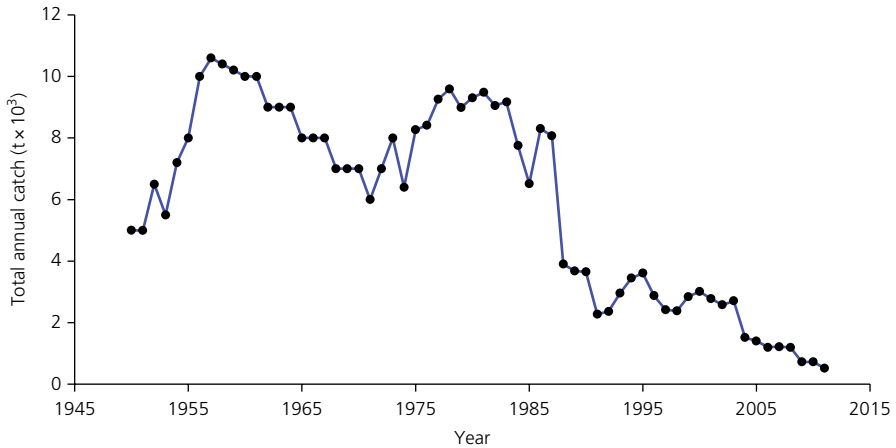

Figure 3.20.2 Total fishery production from inland waters (freshwater and diadromous fishes) of Greece during the period 1950 to 2011. Data from Eurostat; http://ec.europa.eu/eurostat.

during this period, there was a significant migration to countries of Northern Europe, the United States and Australia. As a result of the abandonment of the countryside, primary production along with fishery production from inland waters was reduced. Simultaneously, several major lakes of the country were drained. The main pretences for the drainage of lakes and marshes were the creation of land for agriculture and prevention of the spread of malaria.

Then followed the decade from 1970 to 1980 when there was an increase of fishery production. This was attributed to the return of migrants to their place of origin; several farmers practised fishing in addition to agriculture in order to enhance their family income. Finally, the intensification of fishing effort using various fishing gears and powerful boats resulted in an increase in fishery production. During the next period from 1980 to 2010, some significant changes were observed in many of inland ecosystems of Greece. Most of these were (1) the ecosystem degradation, (2) changes in the structure of fish populations through stocking of commercial species, (3) introduction of alien species, (4) pollution from urban wastes, agricultural, small-scale and industrial activities, (5) eutrophication, (6) extinction of several native species and (7) overfishing of commercial species. These influenced the fish population structures along with inland ecosystem functioning. Anthropogenic interventions led to extinctions of various fish species (endemic and commercial) and the ecological niches left empty which were occupied by alien species.

Exploited freshwater fish species

Among the *c.* 177 species of Greek inland water fishes, there are some which have significant commercial value and are subjected to fisheries exploitation. The main exploited species in Greece are *C. carpio*, *C. gibelio*, freshwater bream *Abramis brama*, *Rutilus* spp., barbels *Barbus* spp. and *Luciobarbus* spp., tench *Tinca tinca*, rudd *Scardinius* spp., *E. lucius*, perch *Perca fluviatilis*, the sand smelt *Atherina boyeri*, the European eel *Anguilla anguilla* and *S. glanis* and *S. aristotelis*.

Cyprinus carpio

According to Balon (1995), *C. carpio* originate from a wild ancestor living in drainages of the Black, Caspian and Aral Seas and dispersed east to Siberia and China and west as far as the Danube River. This species is widely cultivated worldwide, but a lot of cultivated stocks belong to various east Asian species. According to Kottelat and Freyhof (2007), one of them is *Cyprinus carpio haematopterus*, which is cultivated in several eastern European countries, while in Western Europe, some ornamental varieties (koi) possibly derived from *Cyprinus rubrofuscus* are present. There are reports that koi or hybrids are used as brood stock or sperm donors in various hatcheries for propagation of female genitors of *C. carpio* (*i.e.* in Lake Pamvotis; Municipal Hatchery of Lake Pamvotis, Unpublished data). Often, they escape and create hybrids with local populations.

Cyprinus carpio, according to Balon (2004), is an ancient domesticated fish. It was probably introduced into Greece during the Roman era or Middle Ages (Balon, 1995). The first documented report about the introduction of *C. carpio* into Greece, however, comes from Stephanidis (1939) who stated that during the first decades of the 20th century, fingerlings from Italy were introduced into some lakes of western Greece. This species, however, was already known by the population and local lakeshore communities consumed large quantities of it. Repeated introductions and translocations took place during the 1950s and more intensively after the 1980s in many natural lakes, reservoirs and lower parts of rivers with fry and fingerlings of various populations from different countries (Economidis *et al.*, 2000).

The installation of several hatcheries resulted in the enhancement of lakes and reservoirs of Greece with fry and juveniles of the fish. In some cases, an extremely large number of offspring were released into small lakes in order to improve the professional and recreational fisheries. During the period 2001 to 2005, more than 3.3×10^6 fingerlings of *C. carpio* had been introduced into the small shallow Lake Pamvotis (Fisheries Department of Ioannina, Unpublished data). A similar situation was observed in many other lakes.

The fishery production of *C. carpio* from inland waterbodies of Greece appears to have been stable during the last few years (since 1996, the annual catches varied from 169 to 279 t; Fig. 3.20.3). The sustained relative high values of commercial catches are attributed to the continuous enrichment of stocks with fry from hatcheries. It is expected, however, that the annual catches will decline because the water quality of aquatic ecosystems is continuing to be degraded and the operation of hatcheries has virtually stopped.

Carassius gibelio

Carassius gibelio is a widely distributed freshwater species considered as native from Central Europe to Siberia or introduced to European waters from eastern Asia (www.Fishbase.org). Clear and definite data on its original distribution in Europe are not available due to intensive introductions, the confusion with the congeneric species goldfish *Carassius auratus* and crucian carp *Carassius carassius* and especially the complex modes of its reproduction (sperm-dependent parthenogenesis).

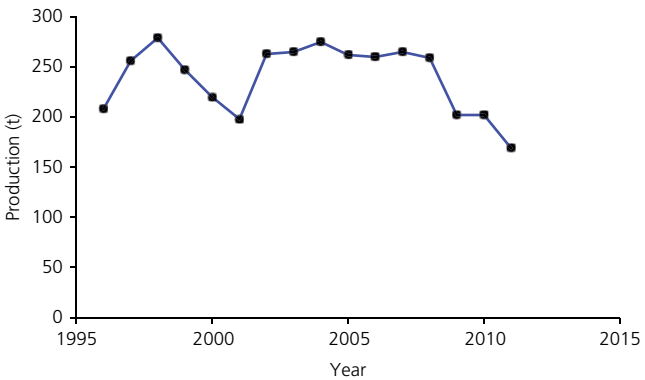

Figure 3.20.3 Fishery production of *Cyprinus carpio* from Greek inland waters. Eurostat; http://www.statistics.gr; Hellenic Statistical Agency; http://www.statistics.gr).

The populations of this species in Greece are almost exclusively triploid, asexually reproduced. The populations are dominated by females. During the last decade, however, males began to appear (Liousia *et al*., 2008*b*). The percentage of males in the populations is very low (<1%), with a slow increasing trend. Males of this species as well as of other cyprinids contribute to asexual reproduction of *C. gibelio* as sperm donors (Liasko *et al*., 2012). Recently, with the exception of triploid females and males (3N *c*. 152), tetraploid females (4N *c*. 212) were found (Liasko *et al*., 2010). In other regions of north-east Europe, triploid females and males along with diploids (2N = 100) occur (diploids are from normal sexual reproduction, while triploids are from asexual reproduction).

At present, *C. gibelio* is widely distributed and commonly stocked together with *C. carpio* which are translocated throughout Europe. This species was initially introduced into Greek inland waters during the middle of 1950s and probably was translocated from Lake Kerkini to Lake Pamvotis or introduced from Italy to the same lake during the 1950s or early 1960s (Leonardos *et al*., 2008; Perdikaris *et al*., 2012). There are some studies, however, indicating that this species was first introduced in Greece during the 1970s or early 1980s from Hungarian hatcheries (Economidis *et al*., 2000). Regardless of the time of first introduction, several populations of this species have been introduced into Greek inland waters during the 1980s along with fry of other cyprinids (*C. carpio* intended for stocking and *C. auratus* for hobbyists). Several introductions in combination with the reproductive mode of this species have resulted in the existence of at least three different clones in Greek inland waters (Moutsaki *et al*., 2006). These clones have probably been introduced from China (through Albania) and probably from Hungary and Israel (Liasko *et al*., 2012).

The high adaptability, the resistance to adverse environmental conditions, along with its reproductive mode, led this species to displace native species and exploit empty ecological niches. This resulted to its dominance in the inland waters. During the last decade, most of the waterbodies ceased to be exploited due to the great abundance of *C. gibelio* and therefore the resulting reduction of commercial fish catches. Fishermen from several lakes reported that they were forced to stop fishing because they caught mainly *C. gibelio* which had no or low commercial value; revenue from the catch was less than expenses (fuel and repair of nets). This is reflected in the data about the catches of this species. The reduction of annual production (Fig. 3.20.4) does not correspond to population decline, but the abandonment of fishing activity.

One of the well-studied populations of *C. gibelio* is of Lake Pamvotis in north-west Greece; its presence coincided with the rapid degradation and alteration of trophic complexes of the system (Perdikaris *et al*., 2005; Leonardos *et al*., 2008). This situation is sadly typical in most lake ecosystems in the country, coinciding with the displacement of native fish species by *C. gibelio*, due to competition for feeding resources, and especially for spawning grounds, because it uses the same places, the same period and especially the sperm of other cyprinids for the triggering of its own eggs (Paschos *et al*., 2004). Accordingly, landings of commercially important fish species have dwindled steadily, affecting significantly the fishing communities and the related local societies (Perdikaris *et al*., 2005). Indicative is the case of Lake Kastoria (north-west Greece), where this species first appeared in the landings at 1985 and within the next 10 years the percentage of its contribution in the catches exceeded 90% [Fig. 3.20.4(b)].

Anguilla anguilla

The population of *A. anguilla* in Greece has been reduced, and the current fishery is considered to be outside the limits of sustainability (Unpublished data). The fishery is limited to the capture of adults during their downstream migration. The majority of fish are caught in lagoons, most of which are found in north-eastern Greece (estuarine systems of Evros, Nestos, Lake Vistonis and Porto Lagos Lagoon) and in western Greece (Mesolongi and Amvrakikos Lagoons).

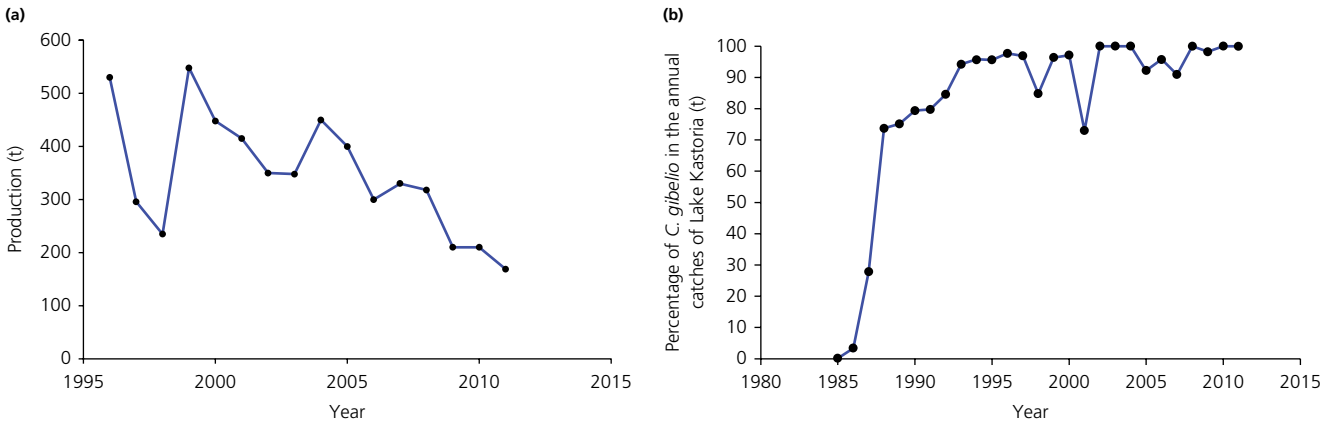

Figure 3.20.4 (a) The downward trend of the catches of *Carassius gibelio*, which does not correspond to population declines, but the abandonment of fishing activity. (b) The percentage of *C. gibelio* in the annual catches of Lake Kastoria. Data from Eurostat; http://ec.europa.eu/eurostat; Hellenic Statistical Agency; http://www.statistics.gr; local fisheries agency, Unpublished data.

The total *A. anguilla* landings in Greece are in continuous downward trend during the last decades (Fig. 3.20.5). According to the Greek Statistical Authority (www.statistics.gr), yields for the period 2002 to 2006 mainly originated from aquaculture (500 t year^{-1}) and from fisheries, both marine and fresh water (21–24 t year^{-1}). Fish catches from lagoons and estuaries, however, are usually reported as coming from aquaculture because these areas are characterized as 'areas of extensive or semi-intensive aquaculture' (even though there is no form of interference in the life cycle of the fish). These catches are estimated to be *c.* 52–85 t year^{-1} for the period 2003 to 2004. The total catch for all the areas for the period 2002 to 2006 ranged from 75 to 110 t year^{-1} (Unpublished data).

Among the main factors contributing to the decline of *A. anguilla* are overfishing, other anthropogenic factors (*e.g.* habitat loss, pollution in inland waters and dams in rivers) and predation from waterbirds (especially from great cormorants *Phalacrocorax carbo*). Probably, one of the major problems is the construction of hydroelectric dams in the rivers. Most of them have no fish passes, which results in the inhibition of fish migration.

Atherina boyeri

Atherina boyeri is an estuarine benthopelagic species which is abundant in the coastal zone of the Mediterranean Sea (www.Fishbase.org/).

In west Greece, an important landlocked population is found in Lake Trichonis. It seems that specimens from the coastal area arrived in the lake through channels and the neighbouring Acheloos River. There, it acclimatized and expanded, occupying the ecological niche of a pelagic planktivorous fish. This landlocked self-reproducing population is now abundant and supports a valuable commercial purse seine fishery (Leonardos, 2001; Doulka *et al.*, 2013). *Atherina boyeri* is the most commercialized species of the Trichonis fish fauna and represents the main source of fishing revenues. Until 1989, local fishermen used boats with oars or small motors equipped with small gillnets having a mesh size of 7–8 mm. Beginning in 1989, because of the abundance and high commercial value of *A. boyeri* in the Greek market, professional trawlers were equipped with larger motors (over 100 HP), and long purse seines were introduced for the fishing of the stock. During the last decade, the mean commercial catches have reached *c.* 500 t year^{-1} (Leonardos, 2001; local professional fishermen, personal communication). One underlying objective in the management of *A. boyeri* in Trichonis Lake was the development of a strategy that satisfied conservation requirements but at the same time resulted in a maximization of fishery benefits. Indications from the exploitation strategy show that the stocks of *A. boyeri* in Trichonis Lake are not declining (Leonardos, 2001). Moreover, the annual catches of *A. boyeri* during the period September 1998 to September 1999 was 530 t (local Fishery Cooperative, Unpublished data). Fishing for *A. boyeri* is frequently inhibited due to its plenitude in the market and the subsequent reduction of its market value. According to Eurostat (http://ec.europa.eu/eurostat), the total European production of *A. boyeri* comes from Greece, that is, the only officially organized exploitation of *A. boyeri* takes place in Greece.

Other species

Perca fluviatilis is reported as endemic to the lakes of northern Greece (Economidis, 1991; Kottelat & Freyhof, 2007). Because of its significant commercial value, populations of this species have been translocated from one lake to another in order to enhance fishery production. The most important lakes in relation to its fishing activity are the Lakes Kastoria and Volvi [Fig. 3.20.6(a)].

Esox lucius is widely distributed and stocked throughout Europe. It is found in most of northern Greek lakes (Economidis, 1991). According to Stephanidis (1950), this species was translocated into Lake Kastoria in the 1930s. Important and exploited populations of this species are found in Lakes Kastoria, Volvi, Vegoritis, Petron, Zazari and Chimaditis (Fig. 3.20.6). Annual catches have declined since the middle of 1980s due to degradation and overexploitation. Its presence seems to have an important influence on the management of ecosystems since it preys on planktivorous *Rutilus* spp. which in turn feeds on zooplankton.

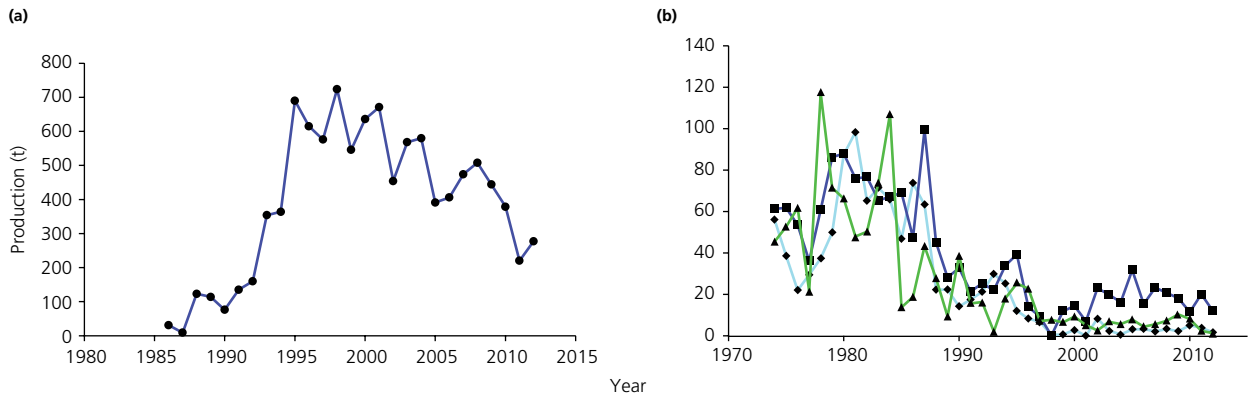

Figure 3.20.5 Total annual catches of *Anguilla anquilla* from (a) Greek inland waters and (b) three Greek lagoons (◆ Logarou; ■ Tsoukalio; ▲ Vistonis) during the period 1970 to 2012. Data from Eurostat; http://www.statistics.gr; Hellenic Statistical Agency; http://ec.europa.eu/eurostat; local fisheries agency, Unpublished data.

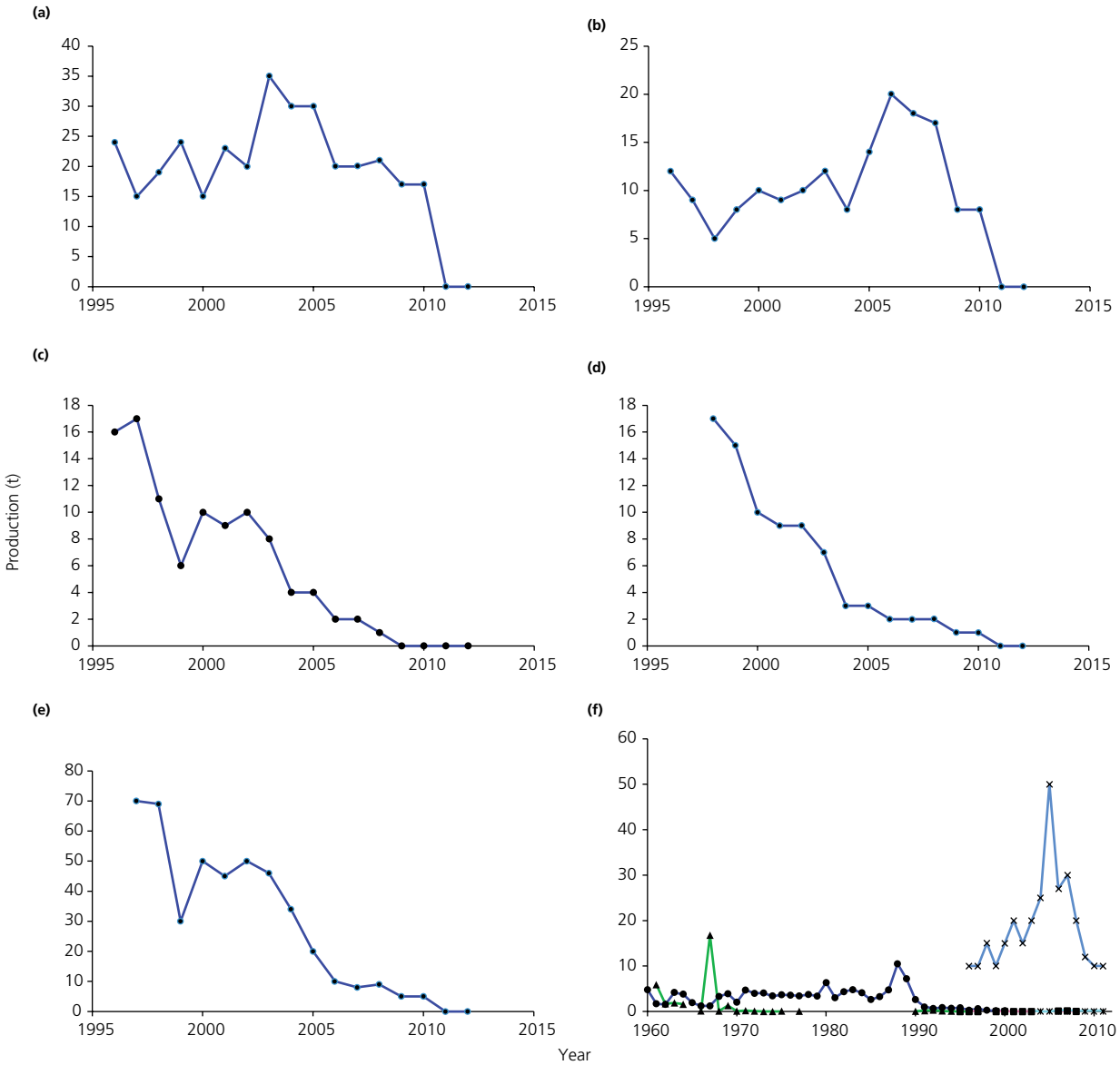

Figure 3.20.6 Total annual catches of (a) *Perca fluviatilis*, (b) *Esox lucius*, (c) *Abramis brama* from Lake Volvi, (d) *Barbus* species, (e) *Scardinius* species and (f) *Silurus glanis* (—●— Kastoria; —■— Vegontis; —▲— Volvi; —×— Polyfytou; —×— Doirani). Data from Eurostat; http://www.statistics.gr; Hellenic Statistical Agency; http://ec.europa.eu/eurostat; local fisheries agency, Unpublished data.

Abramis brama is distributed in aquatic ecosystems of north and north-eastern Greece. It is found in the Rivers Evros, Strymon and Nestos and in Lake Volvi. The only exploited population is that of Lake Volvi (Fisheries Agency of Greek Ministry of Rural Development and Food, Unpublished data). Thus, the annual fishery production of the country coincides with that of the lake. Since 1960, the annual catches of *A. brama* varied from 130.70 t (1967) to 0.81 t (2009). Since 1980, the fish production has steadily decreased [Fig. 3.20.6(c)].

Barbels, 10 species of the genus *Barbus* (*B. balcanicus, B. cyclolepis, B. euboicus, B. macedonicus, B. peloponnesius, B. pergamonensis, B. prespensis, B. rebeli, B. sperchiensis* and *B. strumicae*) and two of the genus *Luciobarbus* (*L. albanicus* and *L. graecus*) have been recorded in Greek inland waters. Most of the species of the aforementioned genera are endemic and face a lot of threats; some have become extinct, while the populations of others have declined significantly. The most commercial important populations are those of Lake Megali Prespa (*B. prespensis*) and of Lake Vistonis (*B. cyclolepis*). The annual catches of these species, however, are steadily declining [Fig. 3.20.6(d)].

Tinca tinca is reported as native in most of Europe, naturally absent only in Ireland, Scandinavia north of 61°30′N, eastern Adriatic basin and western and southern Greece where it is now introduced (www.Fishbase.org/). There has

been commercial interest in capturing it. In recent years, the populations have significantly declined, while in some lakes (Lake Pamvotis), it has become extinct.

Rudd, three species of the genus *Scardinius*, have been reported in Greece (Economidis, 1991; Kottelat & Freyhof, 2007): *Scardinius graecus* which inhabits central Greece (Attiko-Boeotia area, Yliki and Paralimni Lakes), *S. acarnanicus* which inhabits central-western Greece (Ionian basin and especially the lower basin of the Acheloos River and the neighbouring lakes, *i.e.* Lakes Trichonis, Lysimachia, Ozeros and Amvrakia) and the cosmopolitan *S. erythrophthalmus* which inhabits the north Aegean basin with the lower border of its distribution the River Pinios.

The fishery production of *Scardinius* spp. takes place only in lakes of northern Greece where *S. erythrophthalmus* is distributed (Fig. 3.20.6). The lakes with significant fishery production were Lake Kastoria and the neighbouring Lakes Chimaditis, Petron and Zazari. During the 1960s, Lake Kastoria's fishery production ranged from 50 to 234 t. It then declined and since 2000 onwards has not appeared in the catches.

Catfishes, in Greece two species of genus *Silurus* are found. *S. glanis*, which is the second largest freshwater fish in the region (after the beluga sturgeon *Huso huso*; Kottelat & Freyhof, 2007), is distributed in northern Greece. *Silurus aristotelis* is a small-sized endemic in western Greece and especially in the lower reaches of the Acheloos River and the adjacent lakes (Economidis, 1991). An interesting population of *S. glanis* is found in the artificial Lake Polyfytos. This lake was created in 1973 on the River Aliakmonas after the construction of a dam and a large hydroelectric station. Frequently, giant specimens (>200 kg) have been caught. Some have the same age as the construction of the dam (Ntakis *et al.*, 2009). Significant populations are also found in Lakes Doirani, Kastoria, Vegoritis and Volvi (Fig. 3.20.6). The fishery yield of *S. aristotelis*, however, is now almost zero because of reduced demand related to the feeding preferences of the local communities.

Of the roaches, there are at least four species of the genus *Rutilus* (*R. ylikiensis, R. panosi, R. rutilus* and *R. prespensis*), which have been recorded in Greece. There is confusion, however, about two local populations (one in central Greece, *i.e.* Sperchios River, and the other in northern Greece, Volvi Lake) about whether they are new species (Economou *et al.*, 2007; Kottelat & Freyhof, 2007; Tsoumani *et al.*, 2013). *Rutilus rutilus* inhabits northern Greece, *R. prespensis* is distributed in north-western Greece (south Adriatic basin and especially the Lakes Mikri Prespa and Megali Prespa), *R. ylikiensis* inhabits central-western Greece (Ionian basin and especially the lower basin of the Acheloos River and the neighbouring lakes, *i.e.* Lakes Trichonis, Lysimachia, Ozeros and Amvrakia), and *R. panosi* is abundant in Lake Ziros which is in the same drainage of the Louros River.

Fishery activity for *Rutilus* spp. takes place mainly in lakes of northern Greece, where the species *R. prespensis* in Megali Prespa and *R. rutilus* in the lakes of central Macedonia have commercial value. Fishery production has declined since 2000. This is due to degradation of the ecosystems and the reduction of the commercial value of the roaches. The largest quantities of *Rutilus* spp. were caught in Lake Megali Prespa (Fig. 3.20.7) (52.5% in 1996 to 95.9% in 2012). In the past, significant quantities of this fish packaged in cans were sold in Greece and exported to EU countries.

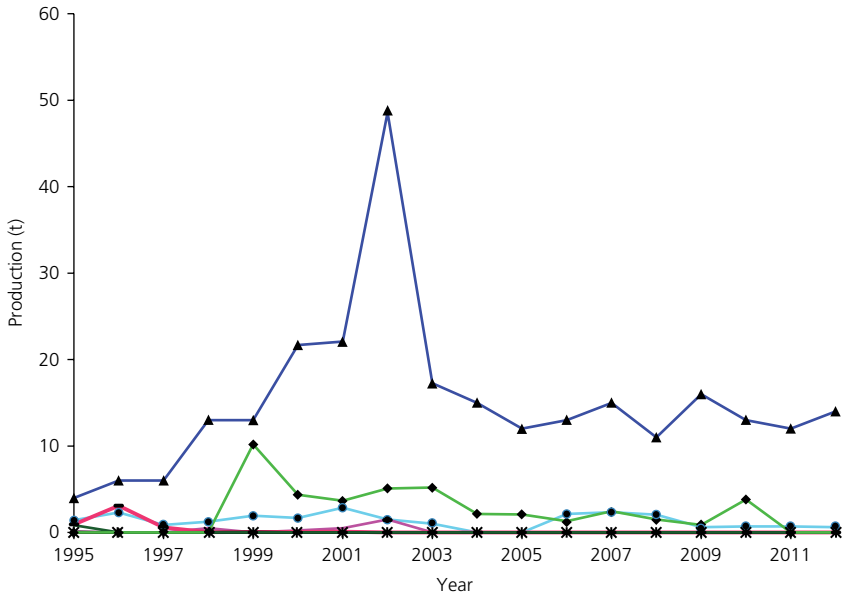

Figure 3.20.7 Total annual catches of species of *Rutilus* genus from Greek lakes [Vegoritis (*Rutilus rutilus*); Mikri Prespa (*Rutilus prespensis*); Magali Prespa (*R. prespensis*); Petron (*R. rutilus*); Chimaditis (*R. rutilus*); Zazari (*R. rutilus*); Kastoria (*R. rutilus*); Volvi (*Rutilus* sp.)]. Eurostat; http://ec.europa.eu/eurostat; Hellenic Statistical Agency; http://www.statistics.gr; local fisheries agencies, Unpublished data.

Reliability of data

In Greece, like many other European countries, a significant problem is observed regarding the compliance of fisheries data along with data reliability. The data about the fishery yields, which are submitted by fishermen or fishing cooperatives to the fisheries agencies or to statistical authorities, have a high degree of inaccuracies. In many cases, the local fisheries agencies declare that the information provided include a high degree of error. In other cases, they mention that it makes no sense to collect data which are completely inaccurate. The inaccuracy of the data is due to the fact that fish production in inland waters is not well organized. There are no fish auctions through which the catches can be monitored. In many provinces, the local authorities are staffed by non-specialists who are unable to supervise and control fisheries production. Moreover, there are no data from non-professional fishermen. In these cases, the fishermen try to present lower catches (for commercial species) in order to avoid taxes.

Information from regional fisheries agencies report that fishermen declare *c.* 25% of their annual catches; the declaration depends on the commercial value of the fishes (usually, they hide or report fewer catches of species with the greatest commercial value). In several cases, they do not report any catch about species that catching is prohibited or is subject to restrictions (*e.g. A. boyeri* fishing in Lake Trichonis).

References

Angelakis, A. & Diamadopoulos, E. (1995). Water resources management in Greece: current status and prospective outlook. *Water, Science and Technology* **32**, 267–272.

Apostolidis, A. P., Triantaphyllidis, C., Kouvatsi, A. & Economidis, P. S. (1997). Mitochondrial DNA sequence variation and phylogeography among *Salmo trutta* L. (Greek brown trout) populations. *Molecular Ecology* **6**, 531–542.

Apostolidis, A. P. M.-J., Madeira, M. H. & Machordom, A. (2008). Genetic structure and demographic history of brown trout (*Salmo trutta*) populations from the southern Balkans. *Freshwater Biology* **53** (8), 155–1566.

Balon, E. K. (1995). Origin and domestication of the wild carp, *Cyprinus carpio*: from Roman gourmets to the swimming flowers. *Aquaculture* **129**, 3–48.

Balon, E. K. (2004). About the oldest domesticates among fishes. *Journal of Fish Biology* **65** (Suppl. A), 1–27.

Banarescu, P. M. (2004). Distribution pattern of the aquatic fauna of the Balkan peninsula. In *Balkan Biodiversity. Pattern and Process in the European Hotspot* (Griffiths, H. I., Krystufek, B. & Reed, J. M., eds), pp. 203–217. Dordrecht: Kluwer Academic Publishers.

Bianco, P. G. (1990). Potential role of the palaeohistory of the Mediterranean and Paratethys basins on the early dispersal of Euro-Mediterranean freshwater fishes. *Ichthyological Exploration of Freshwaters* **1**, 167–184.

Bobori, D. C. & Economidis, P. S. (2006). Freshwater fishes of Greece: their biodiversity, fisheries and habitats. *Aquatic Ecosystem Health & Management* **9**, 407–418.

Bobori, D. C., Economidis, P. S. & Maurakis, E. G. (2001). Freshwater fish habitat science and management in Greece. *Aquatic Ecosystem Health and Management* **4**, 381–391.

Boon, P. J., Davies, B. R. & Petts, G. E. (Eds) (2000). *Global Perspectives on River Conservation. Science, Policy and Practice*. Chichester: John Wiley and Sons Ltd.

Collares-Pereira, M. J., Cowx, I. G. & Coelh, M. M. (Eds) (2002). *Conservation of Freshwater Fishes: Options for the Future*. Oxford: Fishing News Books/Blackwell Science.

Doulka, E., Kehayias, G., Chalkia, E. & Leonardos, I. D. (2013). Feeding strategies of *Atherina boyeri* (Risso 1810) in a freshwater ecosystem. *Journal of Applied Ichthyology* **29**, 200–207.

Durand, J. D., Bianco, P. G., Laroche, J. & Gilles, A. (2003). Insight into the origin of endemic Mediterranean ichthyofauna: phylogeography of *Chondrostoma* genus (Teleostei, Cyprinidae). *Journal of Heredity* **94**, 315–328.

Economidis, P. S. (1991). Checklist of the freshwater fish of Greece (recent status of threat and protection). *Bulletin of the Hellenic Society for the Protection of Nature* (Special Publication). Athens: Hellenic Society for the Protection of Nature.

Economidis, P. S. (1995). Endangered freshwater fish of Greece. *Biological Conservation* **72**, 201–211.

Economidis, P. S. (2002). Biology of rare and endangered non-migratory fish species: problems and constraints. In *Conservation of Freshwater Fishes: Options for the Future* (Collares-Pereira, M. J., Coelho, M. M. & Cowx, I. G., eds), pp. 81–89. Oxford: Blackwell Science. Fishing News Books.

Economidis P. S. & Banarescu, P. M. (1991). The distribution and origins of freshwater fishes in the Balkan peninsula, especially in Greece. *Internationale Revue der gesamten Hydrobiologie und Hydrographie* **76**, 257–283.

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

Economou, A. N., Giakoumi, S., Vardakas, L., Barbieri, R., Stoumboudi, M. & Zogaris, S. (2007). The freshwater ichthyofauna of Greece – an update based on a hydrographic basin survey. *Mediterranean Marine Science* **8**, 91–166.

Gasc, J. P., Cabela, A., Crnobrnja-Isailovic, J., Dolmen, D., Grossenbacher, K., Haffner, P., Lescure, J., Martens, H., Martnnez-Rica, J. P., Maurin, H., Oliveira, M. E., Sofianidou, T. S., Veith, M. & Zuiderwijk, A. (1997). *Atlas of Amphibians and Reptiles in Europe*. Paris: Societas Europaea Herpetologica & Museum Nationall d' Histoire Naturelle & Service du Patrimoine Nature.

Kagalou I. & Leonardos, I. (2009). Typology, classification and management issues of Greek lakes: implication of the Water Framework Directive (2000/60/EC). *Environmental Monitoring and Assessment* **150**, 469–484.

Kagalou, I., Papastergiadou, E. & Leonardos, I. (2008). Long term changes in the eutrophication process in a shallow Mediterranean lake ecosystem of W. Greece: response after the reduction of external load. *Journal of Environmental Management* **87**, 497–506.

Ketmaier, V., Bianco, P. G. & Durand, J. D. (2008). Molecular systematics, phylogeny and biogeography of roaches (*Rutilus*, Teleostei, Cyprinidae). *Molecular Phylogenetics & Evolution* **49**, 362–367.

Kirchhofer, A. & Hefti, D. (1996). *Conservation of Endangered Freshwater Fish in Europe*. Basel: Birkhäuser Verlag.

Kottelat, M. & Freyhof, J. (2007). *Handbook of European Freshwater Fishes*. Berlin: Freyhof and Cornol: Kottelat.

Koussouris, T. S. (1998). *The Water in Nature, in Development, in Environmental Protection*. Athens: National Centre for Marine Research.

Larmuseau, M. H., Freyhof, D. J., Volckaert, F. A. M. & Van Houdt, J. K. J. (2009). Matrilinear phylogeography and demographical patterns of *Rutilus rutilus*: implications for taxonomy and conservation. *Journal of Fish Biology* **75**, 332–353.

Leonardos, I. D. (2001). Ecology and exploitation pattern of a landlocked population of sand smelt, *Atherina boyeri* (Risso, 1810), in Trichonis Lake (western Greece). *Journal of Applied Ichthyology* **17**, 262–266.

Leonardos, I. D., Paschos, I. & Prassa, M. (2005*a*). Threatened fishes of the world: *Phoxinellus epiroticus* (Steindachner 1895) (Cyprinidae). *Environmental Biology of Fishes* **72**, 250.

Leonardos, I. D., Kagalou, I., Triantafyllidis, A. & Sinis, A. (2005*b*). Life history traits of ylikiensis roach (*Rutilus ylikiensis*) in two Greek Lakes of different trophic state. *Journal of Freshwater Ecology* **20**, 715–722.

Leonardos, I. D., Kagalou, I., Tsoumani, M. & 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* **7**, 239–250.

Liasko, R., Liousia, V., Vrazeli, P., Papiggioti, O., Chortatou, R., Abatzopoulos, T. J. & Leonardos, I. D. (2010). Biological traits of rare males in the population of *Carassius gibelio* (Actinopterygii: Cyprinidae) from Lake Pamvotis (north-west Greece). *Journal of Fish Biology* **77**, 570–84.

Liasko, R., Koulish, A., Pogrebniak, A., Papiggioti, O., Taranenko, L. & Leonardos, I. (2012). Influence of environmental parameters on growth pattern and population structure of *Carassius auratus gibelio* in Eastern Ukraine. *Hydrobiologia* **658**, 317–328.

Liousia V., Georgiadou P. & Leonardos I.D. (2008*a*). Fish fauna of Greece: a phylogenetic approach through cladistics. In *Proceedings of 30th Congress of Hellenic Society of Biological Sciences. Thessaloniki, Greece* (Beis, I., ed.), pp. 280–281. *Thessaloniki*: Hellenic Association for Biological Sciences.

Liousia, V., Liasko R., Koutrakis, E. & Leonardos, I.D. (2008*b*) Variation in clones of the sperm-dependent parthenogenetic *C. gibelio* (Bloch) in Lake Pamvotis (north-west Greece). *Journal of Fish Biology* **72**, 310–314.

Livadas, G. A. & Sfagos, I. K. (1940). *The Malaria in Greece (1930–1940). Researches and Fighting. Biological Methods*. Athens: Pyrsos (in Greek).

Maitland, P. S. & Morgan, N. C., (Eds) (1997). *Conservation Management of Freshwater Habitats. Lakes, Rivers and Wetlands*. Dordrecht: Kluwer Academic Publishers.

Minns, C. K. (2001). Science for freshwater fish habitat management in Canada: current status and future prospects. *Aquatic Ecosystem Health Management* **4**, 423–436.

Moutsaki, P., Triantafyllidis, A., Liasko, R., Kagalou, I., Abatzopoulos, T. J. & Leonardos, J. (2006). Genetic structure of *Carassius gibelio* (Bloch) population in lake Pamvotis (Greece). *Journal of Fish Biology* **69** (Suppl. C), 262–263.

Ntakis, A., Karageorgiou, G., Papistas, A., Tsikliras, Ath., Economidis, P. & Leonardos, I. D. (2009). The age of the giant Wels catfishes of the Polyfytos damlake (Macedonia, Greece). In *Proceedings of the 31st Scientific Conference of Hellenic Association for Biological Sciences. Patra, Greece* (Beis, I., ed.), pp. 253–254. Athens: Hellenic Association for Biological Sciences.

OECD (Organization for Economic Cooperation and Development) (2000). *Environmental Performance Reviews – Greece. Athens*: Greek Ministry of the Environment, Physical Planning and Public Works.

Paschos, I., Nathanailides, C., Tsoumani, M., Perdikaris, C., Gouva, E. & Leonardos, I. (2004). Intra and inter-specific mating options for gynogenetic reproduction of *C. gibelio* (Bloch, 1783) in Lake Pamvotis (NW Greece). *Belgian Journal of Zoology* **134**, 55–60.

Perdikaris, C., Nathanailides, K., Gouva, E., Karipoglou, C. & Paschos, I. (2005). Collapse of epirus minnow (*P. epiroticus*) population in Lake Pamvotis, Greece (Teleostei: Cyprinidae). *Ichthyological Exploration of Freshwater* **16**, 371–373.

Perdikaris, C., Ergolavou, A., Gouva, E., Nathanailides, C., Chantzaropoulos, A. & Paschos, I. (2012). *Carassius gibelio* in Greece: the dominant naturalized invader of freshwaters. *Reviews in Fish Biology and Fisheries* **22**, 17–27.

Perry, J. A. & Vanderklein, E. (1996). *Water Quality Management; Water Rights; Government Policy; Social Aspects*. Cambridge, MA: Blackwell Science.

Petit, G. (1930). Remarques sur la distribution g´eographique des poissons d' eau douce des Balkans. *Compte Rendu des séances de la Societe de Biogeographie. Biogeographie* **59**, 77–82.

Radoman, P. (1985). *Hydrobioidea, a Superfamily Prosobranchia (Gastropoda), II. Origin, Zoogeography, Evolution in the Balkans and Asia Minor*. Beograd: Institute of Zoology.

Schmitt, T. (2007). Molecular biogeography of Europe: pleistocene cycles and postglacial trends. *Frontiers in Zoology* **4** 11, 1–13.

Skoulikidis, N. T., Bertahas, I. & Koussouris, T. (1998). The environmental state of freshwater resources in Greece (rivers and lakes). *Environmental Geology* **36**, 1–17.

Souchon, Y. & Keith, P. (2001). Freshwater fish habitat: science management and conservation in France. *Aquatic Ecosystem Health and Management* **4**, 401–412.

Stephanidis, A. (1939). Freshwater fishes of West Greece and Corfu Island. Doctoral Dissertation, Special Publication of University of Athens, Athens, Greece (in Greek).

Stephanidis A. (1950). Contribution to the study of freshwater fish of Greece. *Proceedings of Academy of Athens* **18**, 200–210 (in Greek).

Trudgill, T., Walling, D. E. & Webb, B. W. (Eds) (1999). *Water Quality. Processes and Policy*. Chichester: John Wiley and Sons, Ltd.

Tsoumani, M., Apostolidis, A. P. & Leonardos, I. D. (2013). Biogeography of *Rutilus* species of the southern Balkan Peninsula as inferred by multivariate analysis of morphological data. *Journal of Zoology* **289**, 204–212.

Zacharias, I., Bertachas, I., Skoulikidis, N. & Koussouris, T. (2002). Greek Lakes: limnological overview. *Lakes & Reservoirs: Research and Management* **7**, 55–62.

Zardoya, R., Economidis, P. S. & Doadrio, I. (1999). Phylogenetic relationships of Greek Cyprinidae: molecular evidence for at least two independent origins of the Greek cyprinid fauna. *Molecular Phylogenetics and Evolution* **13**, 122–131.

Zogaris, St., Economou, A. N. & Dimopoulos, P. (2009). Ecoregions in the southern Balkans: should their boundaries be revised? *Environmental Management* **43**, 682–697.

Electronic Reference

IUCN (2012). *IUCN Red List of Threatened Species*. Version 2012.1. Available at http://www.iucnredlist.org/ (last accessed 31 December 2014).