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The common carp, *Cyprinus carpio*, in the Mediterranean region: origin, distribution, economic benefits, impacts and management

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Abstract Literature data are reviewed on the origin, distribution, economic benefits and impacts of common carp *Cyprinus carpio* L. in the Mediterranean region. Despite the ubiquity of domesticated and feral forms, wild populations of the genetically pure ancestor are still found in confined areas of Thrace and Northern Anatolia, and possibly in eastern parts of Greece. Introductions and translocations throughout the region from at least Roman times have been driven by a combination of historical, economic and cultural motives, which have contributed to the spread of the species into many freshwater systems. Although impacts have been either documented or suspected in most areas of distribution, and intervention by biomanipulation successfully implemented in some water bodies, there is a compelling need for more focused research in more vulnerable areas characterised by drier/warmer and overall more unpredictable climate conditions, which appear to favour successful common carp population dynamics. In contrast to large-scale (i.e. country-wide) control measures, likely to prove unfeasible because of the intrinsically high costs associated and/or loss of revenue from sport fishing and fisheries activities, localised (integrated) management actions, followed by post-intervention monitoring, are likely to benefit targeted water bodies for increased amenity and restoration value.

KEYWORDS: biomanipulation, domesticated, ecoregion, feral, Köppen-Geiger, wild.

Introduction

Odi et amo [I hate and I love] Catullus

The opening dactyl from Catullus's elegiac couplet encapsulates the schism that has long pervaded peoples' attitude towards the common carp, *Cyprinus carpio* L. (hereafter carp). Thus, whilst many scientific papers, reports, magazine articles and educational brochures have been written on the detrimental effects of carp on freshwater biota since Cole's (1905) and Cahn's (1929) early considerations, carp remains the number one fish in aquaculture (http://en.wikipedia.org/wiki/Common_carp), and some of its ornamental varieties make it one of the most expensive and sought-after fish in the aquarium industry (Axelrod *et al.* 1996). Similarly, whilst densities of feral forms can reach a biomass of up to 1000 kg ha^{-1} in some invaded areas (Koehn 2004; Bajer & Sorensen 2009), there is concern over the progressive disappearance of the wild carp and its consequent genetic loss in several native areas of distribution (e.g. Balon 1995; Mabuchi *et al.* 2006; Li *et al.* 2007; Yousefian 2011; Yousefian & Laloei 2011). Further, whilst carpathons and catch-a-carp events regularly take place in certain countries (Gilligan *et al.* 2005) to increase public awareness about carp-related impacts, in several European countries carp is highly prized for sport fishing (e.g. Arlinghaus & Mehner 2003; Hickley & Chare 2004; Rapp *et al.* 2008) and/or still represents a valuable and productive fishery (e.g. Shumka *et al.* 2008; Mrdak 2009; Harlioğlu 2011), as well as a traditional ethnic dish (Balon 1974).

The Mediterranean Region comprises the lands around and surrounded by the Mediterranean Sea (Fig. 1a) and conventionally, it represents the Old World (http://en.wikipedia.org/wiki/Mediterranean_Basin), covering portions of Europe, Asia and Africa, and hosting an array of different cultures, historical backgrounds and economies. Contrasting attitudes towards the carp similar to those found world-wide are therefore to be expected in this area.

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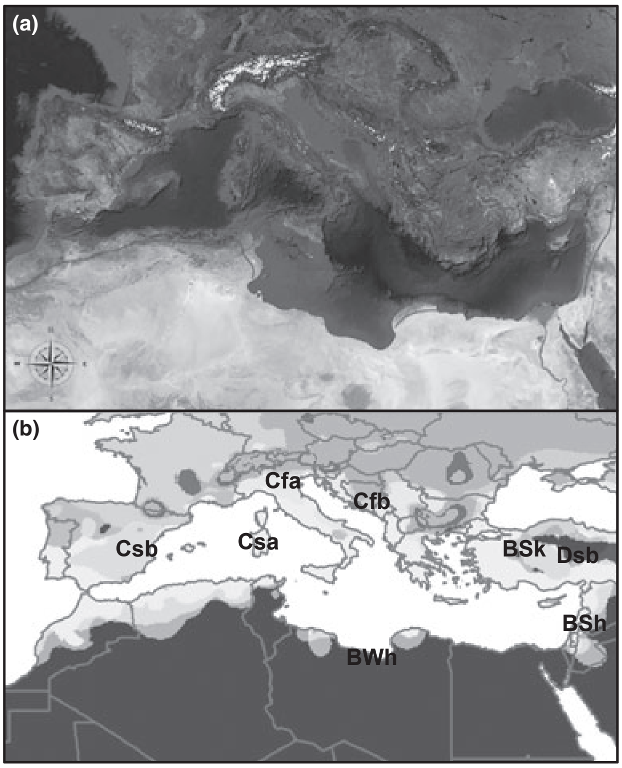

Figure 1. (a) Map of the Mediterranean Region with delimitation of areas where olive trees grow (source http://en.wikipedia.org/wiki/Mediterranean_Basin). (b) Map of climate types in the Mediterranean region according to the Köppen-Geiger classification system (after Kottek *et al.* 2006). BSh/BSk: arid steppe hot/cold; BWh: arid desert hot; Cfa/Cfb: temperate without dry season and hot/warm summer; Csa/Csb: temperate with dry and hot/warm summer; Dsb: cold with dry and warm summer.

Weber and Brown (2009) reviewed the effects on aquatic biota that carp, acting as ecosystem engineers (*sensu* Jones *et al.* 1994), thereby confirming the importance of assessing rather than detecting an impact (e.g. Roberts & Tilzey 1997; Koehn & MacKenzie 2004). Carp are also known to cause much higher impacts in some areas of introduction relative to others (i.e. North America and Australia vs Europe), as originally noted by Crivelli (1981) and more recently elaborated upon by Bajer and Sorensen (2009). However, localised and country-wide impacts have been reported from elsewhere, including Mexico (Zambrano & Hinojosa 1999; Tapia & Zambrano 2003), India (Kumar 2000; Singh *et al.* 2010; Singh & Lakra 2011), the UK (Moss *et al.* 2002), the Azores (Bio *et al.* 2008) and Kenya (Hickley *et al.* 2008). At the same time, there is an ongoing debate over the need to assess both the positive and negative aspects of fish introductions in general (e.g. Gozlan 2008; Vitule *et al.* 2009; Gozlan *et al.* 2010), ultimately reconciling ecology with economics.

The aim of the present study was to review the ecological and economic aspects of carp in the Mediterranean region. Specific objectives were to: (1) distinguish wild, domesticated, feral and escapee forms of carp; (2) report on the distribution and, whenever possible, time(s) of introduction/translocation of domesticated strains into Mediterranean countries; (3) document the economic benefits brought about by the presence/exploitation of carp stocks; and (4) discuss the ecological effects of carp as measured by impacts on freshwater biota and the management actions and interventions that have been undertaken and/or suggested for mitigation. A critical assessment is then provided on how future research and management may be able to reconcile economic demands with habitat conservation needs.

Data collection and study area

For the economic aspects, Mediterranean countries were defined as those riparian to the Mediterranean Sea (Cardia & Lovatelli 2007), excluding Monaco and other minor territories (Table 1). For each country, data on status and establishment of carp were obtained from the FAO Database on Introductions of Aquatic Species (DIAS: http://www.fao.org/fishery/dias/en, see also Welcomme 1988), data on the species' relevance for aquaculture and production from the FAO Fishery Statistical Collections – Global Production (http://www.fao.org/fishery/statistics/global-production/en), and information on socioeconomic and/or ecological benefits from the FAO database on Fishery and Aquaculture Country Profiles (http://www.fao.org/fishery/countryprofiles/search/en). Notably, as full historical evidence on carp introductions into countries and areas of the Mediterranean region was available only for a limited number of areas (cf. Balon 1995; Hoffmann 1995; Waelkens *et al.* 2004), information drawn from available literature on more recent introductions for farming and sport fishing was used as a surrogate.

For the ecological component, freshwater ecoregions were identified within each political entity based on Abell *et al.*'s (2008) biogeographic units for freshwater biodiversity and conservation (Table 1). Following Kottek *et al.*'s (2006) updated world map of the Köppen-Geiger climate classification, three climate classes are encountered in the Mediterranean Region: B (arid), C (temperate), D (cold) (Fig. 1b). Class C predominates along most coastal areas (types Csa and Csb) and more inland (Cfa and Cfb); B in parts of

Table 1. List of Mediterranean countries and corresponding ecoregions (after Abell *et al.* 2008) with information on the status of common carp, its relevance for aquaculture and its ecological and socioeconomic benefits. Data from FAO Database on Introductions of Aquatic Species (DIAS: http://www.fao.org/fishery/dias/en)

				Benefits	
Country	Ecoregion(s)	Status	Aquaculture	Ecological	Socioeconomic
Spain	Southern Iberia; Eastern Iberia	Established	Negligible	Unknown	Unknown
France	Cantabric Coast – Languedoc	Established	Widespread	Probably none	Unknown
Malta	Italian Peninsula & Islands	Established	None	Unknown	Unknown
Italy	Italian Peninsula & Islands; Gulf of Venice Drainages	Established	Moderate	Unknown	Some/Beneficial
Slovenia	Dalmatia	Probably established	Widespread	Unknown	Unknown
Croatia	Dalmatia	Probably established	Widespread	Unknown	Unknown
Bosnia and Herzegovina	Dalmatia	Probably established	Moderate	Unknown	Unknown
Montenegro	Dalmatia	Probably established	None	Unknown	Unknown
Albania	Southeast Adriatic Drainages	Established	Widespread	Unknown	Unknown
Greece	Ioinian Drainages; Aegean Drainages; Vardar; Thrace	Established	Limited	Unknown	Unknown
Turkey	Thrace; Western Anatolia; Southern Anatolia; Central Anatolia; Northern Anatolia; Western Transcaucasia; Upper Tigris & Euphrates	Probably established	Moderate	Unknown	Unknown
Cyprus	Southern Anatolia	Established	None	Unknown	Unknown
Syria	Orontes; Coastal Levant	Established	Moderate	Unknown	Unknown
Lebanon	Coastal Levant	Established	None	Unknown	Unknown
Israel	Coastal Levant	Established	Widespread	Unknown	Some/Beneficial
Egypt	Sinai; Nile Delta	Established	High	Unknown	Some/Beneficial
Libya	Sahara	–	None	–	–
Tunisia	Mediterranean Northwest Africa	Probably established	Limited	Some/Undecided	Some/Undecided
Algeria	Mediterranean Northwest Africa	Established	Negligible	Some/Beneficial	Some/Beneficial
Morocco	Atlantic Northwest Africa	Established	Moderate	Unknown	Unknown

Mediterranean Africa up to the coast (BWh), in the coastal Levant (BSh), and in areas of Central and Northern Anatolia (BSk); D in parts of Northern Anatolia and the Upper Tigris & Euphrates (Dsb).

Origin

As the oldest domesticated fish (Balon 2004, 2006), carp has been subjected to many genetic interventions (cf. Chistiakov & Voronova 2009), along with geographical isolation, adaptation, accumulation of mutations and natural as well as human selection pressures (Mondol *et al.* 2006). This has resulted in a variety of races, landraces, breeds, strains, stocks and hybrids with significant loss of genetic variability relative to the wild form (e.g. Murakaeva *et al.* 2003; Ludanny *et al.* 2006; Memiş & Kohlmann 2006; Chistiakov & Voronova 2009; Khalili & Armikolaie 2010).

In contrast to the wild carp, which has an elongated and torpedo-shaped body with full scale cover, domesticated forms nearly always have a much deeper body, a wider mouth gape and longer intestine (Balon 1995). Four types of scalation (hence phenotypes controlled by a pair of alleles corresponding to six viable out of the nine possible genotypes) are found in domesticated forms: (1) fully scaled, resembling the wild ancestor; (2) mirror, with a small number of large scattered scales; (3) line, with large scales along the lateral line; and (4) leather (or naked/nude), with no scales (Balon 1995; Kirpitchnikov 1999). According to Kirpitchnikov (1999), fully scaled and mirror carp have similar viability, although the latter are less resistant and achieve lower growth rates when reared under unfavourable conditions, whereas leather and especially line carp are less viable even under favourable conditions. Further, coloured Japanese varieties known as *nishikigoi* (or, somewhat tautologically, koi carp), artificially selected from some domesticated or feral forms (Balon 1995), are also encountered as escapees in the wild (Tempero *et al.* 2006; Osborne *et al.* 2009).

Once released into the natural habitat (the wild: *sensu* Copp *et al.* 2005), domesticated forms of the fully scaled carp may revert over time to feral forms resembling their wild ancestor, although they still differ in a range of behavioural, morphological, physiological and reproductive traits (Balon 1995, 2006; Matsuzaki *et al.* 2009, 2010), and possibly also organoleptic properties (Balon 1974). Overall, domesticated and feral forms are more resistant and able to cope with an unpredictable environment than their wild ancestor, which is typically highly specialised and dependent on predictable floods (Balon 1995).

The postulated existence of two sub-species of wild carp loosely distinguishable by morphological and ecophysiological traits (Balon 1995; Kirpitchnikov 1999) and originating from the ancestral form of the Caspian/Aral/Black Sea basins (namely the western dispersant *C. c. carpio* and the far eastern dispersant *C. c. haematopterus*) has been recently confirmed genetically (cf. Chistiakov & Voronova 2009, and references therein). The taxonomic validity of a third south-east Asian sub-species *C. c. viridiviolaceus*, as originally postulated by Kirpichnikov (1967) but later questioned by Balon (1995) and Kirpitchnikov (1999) himself and re-proposed by Baruš *et al.* (2002), still remains unresolved (Chistiakov & Voronova 2009) (Fig. 2a). Also, recent studies have indicated that human-mediated translocation of carp across Chinese drainage basins has likely resulted in high levels of gene flow preventing clear identification of the three postulated sub-species *C. c. carpio*, *C. c. haematopterus* and *C. c. rubrofuscus* (an endemic cultured sub-species from that area (Wang *et al.* 2010). Finally, reference to domesticated varieties as *C. c. domestica* as well as e.g. *C. c. communis* (fully scaled), *C. c. specularis* (mirror), *C. c. regularis* (line) and *C. c. nudus* or *C. c. coriaceus* (leather) based on scalation (e.g. Ramakrishna & Alikhuni 1962; Rhouma 1975; Toor & Brar 1975; Baruš *et al.* 1997; Wakida-Kusunoki & Amador-del-Ángel 2011) is taxonomically invalid (http://www.fishbase.org/Nomenclature/SynonymsList.php?ID=1450&SynCode=49418&GenusName=Cyprinus&SpeciesName=carpio+carpio).

Based on the above taxonomy, introduced feral/domesticated forms of the European wild carp *C. c. carpio* would make up most of the populations inhabiting fresh waters of the Mediterranean region. In this respect, Balon (1995) indicated the Piedmont zone flood plain of the Danube River as the westernmost point of distribution of the European wild carp, where it is now listed as endangered if not locally extinct (Holčík 2003; Koščo *et al.* 2010). According to Kirpichnikov (1999; Fig. 2a), the distributional range of the European wild carp would encompass several areas of Turkey and the easternmost part of Greece (ecoregions of Thrace, Northern Anatolia, Western Transcaucasia and Upper Tigris & Euphrates: Abell *et al.* 2008). Whilst this distribution has been endorsed by Chistiakov and Voronova (2009), amongst others, other sources would seemingly point to the absence of the wild carp from all the Mediterranean countries, limiting its distributional range to the northern coastlines of the Black Sea and to the Caucasus (Fig. 2b).

Recent identification by molecular genetics of wild carp in three Turkish lakes (İznik and Sapanca in Thrace, and Bafra Cernek in Northern Anatolia) supports the hypothesis of a single origin of present-day European domesticated and wild/feral forms from a common ancestor with Central Asian carp (Memiş & Kohlmann 2006), hence in line with Kirpitchnikov's (1999) map (Fig. 2a). Further, archaeozoological evidence indicates that wild carp was the most common freshwater fish species consumed at Salagassos (south-west Turkey) during the Augustan–Early Byzantine Period (1st–7th Century ACE) and was likely present in lakes Akşehir, Beyşehir, Eğirdir and Eber in Central Anatolia (Waelkens *et al.* 2004).

Conversely, the claim that wild carp would be native to central and northern parts of Greece (ecoregions of Thessaly, Macedonia and Thrace: Economidis *et al.* 2000) would be only partly supported by the maps in Hoffmann (1995), which do not include Thessaly. However, because of the very high level of gene flow resulting from massive hybridisation of the (putative) wild form with historical stockings of domesticated forms (Economidis *et al.* 2000), it is likely that true wild populations no longer exist in the area. This has been supported genetically by Imsiridou *et al.* (2009), who were able to identify a common haplotype in three out of four populations from Macedonia and Thrace, thereby pointing to their ancestral, though not necessarily wild, status.

Distribution

Historically, carp was the first freshwater fish species to be introduced around Europe, even though the exact times and pathways of introduction remain uncertain (Balon 1995; Hoffmann 1995; Copp *et al.* 2005). Carp being found in all Mediterranean countries (cf. Table 1) is therefore not surprising given the very high spreading potential and environmental tolerances of the species (Koehn 2004; Zambrano *et al.* 2006).

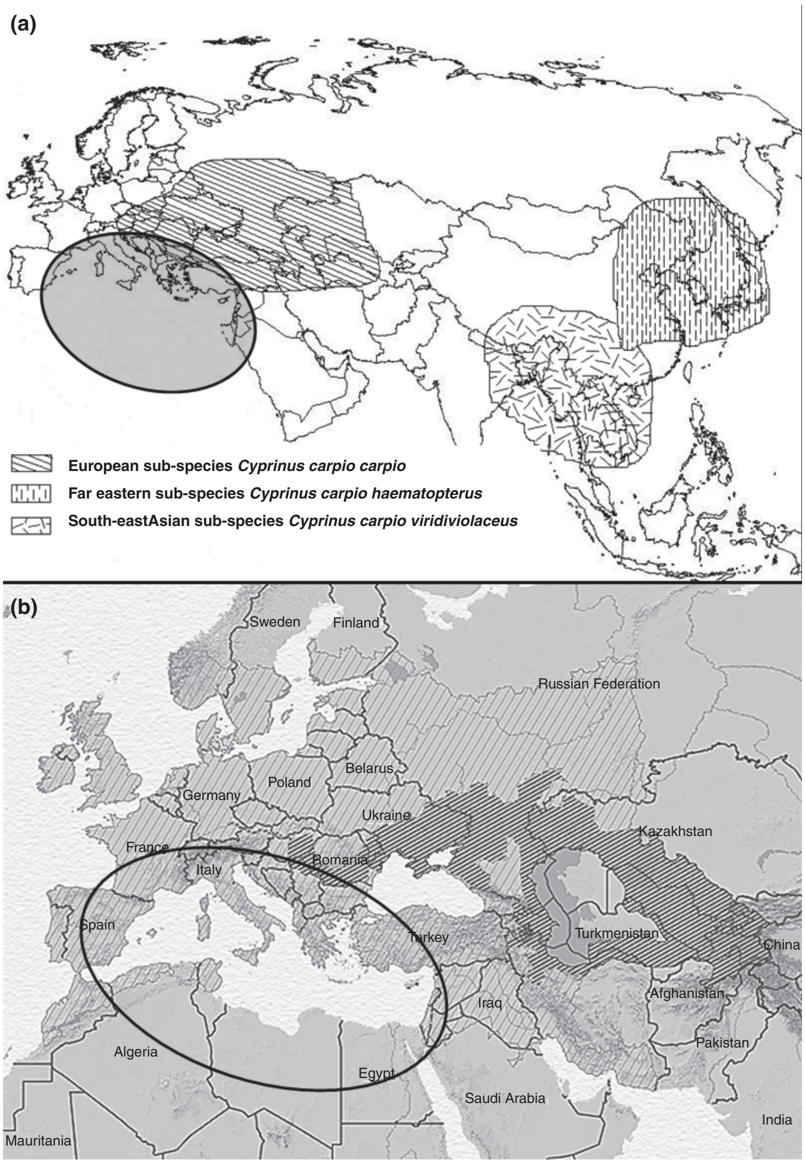

Figure 2. (a) Eurasian distribution of the three currently recognised subspecies of wild common carp *Cyprinus carpio* (after Kirpitchnikov 1999), with Mediterranean Region highlighted. (b) Proposed distribution of wild (finely hatched) and feral/domesticated (loosely hatched) common carp, with Mediterranean Region highlighted (source http://www.ittiofauna.org/webmuseum/pesciossei/cypriniformes/cyprinidae/cyprinus/cyprinus_carpius/index.htm). In both cases, the oval highlights the Mediterranean Region relative to the two different maps of distribution.

Spain

According to Elvira and Almodóvar (2001), carp was introduced in the 17th Century for ornamental purposes, and is currently widespread (see also Elvira 1998). Carp was found to be dominant in the lower Guadiana Basin in southern Iberia (Godinho & Ferreira 1998), in the Terri River Basin in Catalonia (Vila-Gispert *et al.* 2002), in Lake Albufera (Blanco *et al.* 2003; Blanco & Romo 2006) and in 14 reservoirs sampled by Carol *et al.* (2006). The ubiquity of carp as an invasive species has also been confirmed by Clavero and García-Berthou (2006) and Prenda *et al.* (2006).

France

Crivelli (1981) reported historical evidence for the presence of carp in the Etang de Mauguio (South France) in 1659 and indicated that date as the first record in the area. Hoffmann (1995) documented verbal records for an earlier presence of carp in the same area dating back to 1350–1600, and even as early as 1100–1350 further north. Rosecchi *et al.* (1997) identified feral (*sauvage*: fully scaled), domesticated (*pisciculture*: mirror) and hybrid forms from samples collected in the Camargue from 1982 to 1995, which could be differentiated morphometrically. They also noted a sharp decrease of the feral form relative to the hybrid throughout the sampling period.

Italy

Detailed accounts of the introduction and domestication of carp in the Italian peninsula are provided by Balon (1995) and Hoffmann (1995), who proposed the possibility of Roman and monastic domestication (see also Copp *et al.* 2005). However, the possibility of a non-Roman and non-monastic route westward of the Danube through Franco-Burgundian secular pond culture in the 12th–13th Centuries should not be discounted (Hoffmann 1995, 2002, 2008), as such pathways of introduction currently are still under debate (cf. Gherardi *et al.* 2008). Finally, Orrù *et al.* (2010) documented historical releases into water bodies and small river catchments on the island of Sardinia in the 1920s, with a subsequent fast diffusion and prompt adaptation of the species because of favourable environmental conditions.

Slovenia

Introductions were the result of fish farming practices, which are well developed in the country with over 100 years of aquaculture history (Jenčič 2005). Povz (1995) listed carp as part of the freshwater fish fauna of the Adriatic basin in Slovenia but did not provide any information about the species' status. Also, Veenvliet (2000) documented the presence in Cerknica polje (a karstic formation) of adult individuals only, previously released for sport fishing but apparently not reproducing in those waters.

Croatia

The first introductions for aquaculture occurred at the turn of the 19th to 20th Century, with stocks originating from Germany, Czech Republic and Hungary (Treer *et al.* 2000). Between 1948 and 1950, domesticated forms along with a small percentage of wild carp from the River Drava (north Croatia, part of the Danube Basin) were stocked into Lake Vransko to boost fisheries production as a remedy to post-war food shortages (Treer *et al.* 1995, 2003). Following introduction, a reversion from the domesticated to the feral form was observed in the following two-three decades that involved a change in the proportion of the fully scaled form relative to the mirror one (Treer *et al.* 1995). Carp introductions were reported in the majority of other Croatian Adriatic freshwater systems, including the rivers Krka and Cetina, and Lake Vrana (Mrakovic *et al.* 1995). Finally, young-of-year carp have also been identified as part of the diverse fish community inhabiting the littoral shallows of the Neretva and Mala Neretva estuaries, which support important commercial fisheries (Dulčić *et al.* 2007).

Bosnia and Herzegovina

The time of introduction, although not stated explicitly, can be inferred by the development of the first aquaculture facilities in the late 1900s (Omeragić 2009). Carp is present in some tributaries of the River Neretva basin (Šanda *et al.* 2008) and is also part of the ichthyofauna of the wetland ecosystem of the Bardača area, where it has experienced a decline in abundance, possibly because of a combination of overfishing and hydrological interventions (Vuković *et al.* 2008).

Montenegro

Stein *et al.* (1975) reported selective predation of carp on benthic molluscs in Lake Skadar, with indirect evidence pointing to its presence since the mid-1900s (Mrdak 2009). Carp is also present in the River Morača (Šanda *et al.* 2005), a functional part of the Lake Skadar system (Mrdak 2009).

Albania

Shumka *et al.* (2008) indicated 1968 and 1988 as the two years of introduction into lakes Shkodra (= Skadar), Ohrid and Prespa, which are regularly stocked on an annual basis for aquaculture and fishing purposes. Carp fisheries are also of particular value in the Prespa lakes system, a small section of which stretches into Albania (Crivelli *et al.* 1997).

Greece

Although native to Macedonia and Thrace (Imsiridou *et al.* 2009), several introductions initially occurred from Italy to central and western Greece in the late 1930s, followed by translocations since the 1950s as well as later introductions of mostly domesticated forms from Israel and Hungary in the 1980s (Economidis *et al.* 2000; Leonardos *et al.* 2008; Perdikaris *et al.* 2010). Carp was dominant in catches from Lake Tavropos (Bobori *et al.* 2006), and a survey of 18 protected lakes and reservoirs in Greece indicated its presence in all ecosystems (Drakou *et al.* 2009). Carp is currently regarded as the second most widespread, intentionally introduced/translocated species in Greece (Zenetos *et al.* 2009).

Turkey

As indicated by Hoffmann (1995) and Kirpitchnikov (1999), and more recently by Memiş and Kohlmann (2006), carp is native to several parts of Turkey (cf. *Origin*). However, this species has been subjected to intensive translocations since the 1960s, and currently successful populations from escapees and releases remain in many inland waters, resulting in a highly productive fishery (Çetinkaya 2006; Innal & Erk'anan 2006).

Cyprus

As the first experiments on fish farming in Cyprus were conducted on carp in 1947 (Demetropoulos 1985), this can be regarded as at least the first date of introduction in modern times. However, Waelkens *et al.* (2004) provided striking evidence for carp trade at the site of Apikli dating back to the Early Bronze Age (3500–2000 BCE). No further information is available on the species' distribution on the island, except for its marginal use in cage aquaculture (Cardia & Lovatelli 2007).

Israel

Introductions of carp into the freshwater systems of Israel and Palestine occurred between the late 1920s and the early 1930s (Ben-Tuvia 1981; Golani & Mires 2000), and according to Tamir (2010), these were driven by a combination of social, economic and cultural motives. Since then, carp has gradually dispersed throughout the country to become the most abundant fish species in the aquaculture industry (Goren & Galil 2005), but it is also established and common in the majority of freshwater habitats (Roll *et al.* 2007), including Lake Agmon (Gophen *et al.* 1998) and, in more recent years, Lake Kinneret (Goren & Galil 2005). Notably, Golani and Mires (2000) observed that feral populations are dominated by scaled forms.

Syria

Stunkard (1959) referred to a study carried out in the mid-1930s in Syria reporting on worms found in carp, so that date could be regarded as an indication of at least the first presence of the species in the country.

Egypt

First introduction occurred in 1934 from Indonesia, followed by two other consignments between 1940 and 1941 (El Bolock & Labib 1967). Mirror carp was introduced later in 1949 from France, where it had established self-sustaining populations (Bishai *et al.* 1974). Release of juveniles into the River Nile in 1941 and 1942 did not lead to establishment, possibly because of increased fishing effort and predation by Nile perch *Lates niloticus* (L.) (El Gamal 1992; Moreau & Costa-Pierce 1997).

Libya

Carp was introduced into ponds from a dam near Tripoli in 1977 (Wood & Ghannudi 1985), and more recently, Jawad and Busneina (2000) recorded carp from Lake BuDezera.

Tunisia

Carp was introduced from Germany and France between 1965 and 1966, and farming quickly expanded thereafter throughout the country (Rhouma 1975). In the mid-1970s, carp was recorded from Lake Kelbia (Morgan 1982).

Algeria

Carp has been sampled in the Marais de la Macta since the mid-1970s (Morgan 1982), and Meddour *et al.* (2005) documented several introductions into the country from 1985 to 1991 for aquaculture, which is particularly well developed in the Guenitra reservoir (Tandjir & Djebar 2009). Carp is also abundant and widespread in the River Soummam (Bacha & Amara 2007) as well as in the coastal wetlands of Numidia (north-east Algeria), where it represents one of the main prey items of the purple heron, *Ardea purpurea* (Nedjah *et al.* 2010).

Morocco

Azeroual *et al.* (2000) indicated 1924–1935 as the period of first introduction of carp into the country,

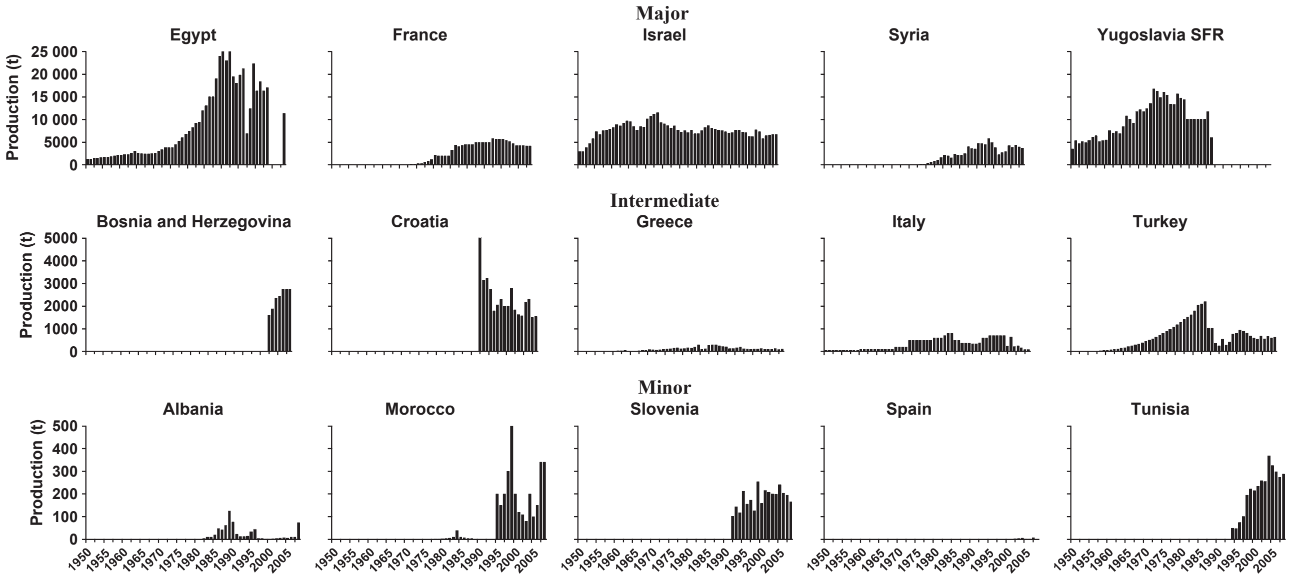

Figure 3. Classification of Mediterranean countries into major, intermediate and minor aquaculture producers (tonnes yr^{-1}) of common carp (source FAO Fishery Statistical Collections – Global Production http://www.fao.org/fishery/statistics/global-production/en).

which was also confirmed by El Wartiti *et al.* (2008) for carp in the northwestern Tabular Middle Atlas.

Economic benefits

In classifying Mediterranean countries according to their annual carp production (Fig. 3), arbitrary limits were used to group countries into major, intermediate and minor producers (i.e. > 6000, 600–6000, and < 600 t yr^{-1}, respectively).

Major producers include Egypt, France, Israel, Syria and the former Yugoslavia (cf. Bosnia and Herzegovina, Croatia and Slovenia, below). In Egypt, modern aquaculture began in the mid-1930s and from then until the early 1960s carp was kept mostly for research purposes until the first modern semi-intensive commercial farm was built in 1961. Carp is reared in a variety of growout systems, including conventional pond culture, duck cum fish, cage culture, aquaculture in irrigated areas, fish culture in rice fields, village fish farms and large-scale commercial farms (Moreau & Costa-Pierce 1997). In France, where aquaculture is a long established activity, carp has been farmed since the Middle Ages in the south-west and central/eastern regions. In Israel, aquaculture began with the importation of carp during 1927–1928, and an experimental farm was established in 1934 on the coast south of Acre; farming began in 1937–1938 and by 1939 commercial activities had expanded throughout the Bet Shean valley. In Syria, where carp is the main freshwater fish produced commercially along with tilapia species, modern aquaculture began in the late 1950s and soon provided outstanding results.

Intermediate producers include Bosnia and Herzegovina, Croatia, Greece, Italy and Turkey. In Bosnia and Herzegovina, carp represents an important component in the production of food fish by aquaculture (Omeragić 2009). In Croatia, the first carp farm was established in 1897 and the largest farms later in the early 1920s, followed by repeated stockings into Lake Vransko in the late 1940s (Treer *et al.* 1995). However, since the 1980s, carp production has progressively decreased (Turk 1997; Knjaz 2007), mostly because of internecine wars. In Greece, carp was originally introduced into the western part of the country in the 1920s for the purpose of improving fisheries and ultimately aquaculture, although the latter is not considered a developed sector of the country's economy (Bobori & Economidis 2006). Currently, commercial catches of this species have replaced those of all other native species in many freshwater systems of the country and are thought to have contributed to the overall enhancement of fish production in those lakes and water bodies characterised by an impoverished fish fauna (Crivelli *et al.* 1997; Economidis *et al.* 2000; Zenetos *et al.* 2009). In Italy, where the aquaculture tradition was conceived in inland areas, lagoons and ponds, the main production is still represented by freshwater species amongst which carp plays a relevant role (Bianco & Ketmaier 2001); sport fishing adds to the economic value of the species (E. Tricarico, personal communication). In Turkey, carp was one of the first species translocated for fisheries and aquaculture, with translocations starting in the 1960s (Innal & Erk'anan 2006) and farming in the 1970s. Carp is currently caught throughout the country, where it represents the most important species for inland fisheries along with the tarek (or 'inci kefali') *Alburnus tarichii* (Harlioğlu 2011).

Minor producers include Albania, Morocco, Slovenia, Spain and Tunisia. In Albania, carp aquaculture has represented a relatively cheap and easy way of achieving increased food production since the early 1960s, and starting from the 1990s, repeated stockings into lakes Skadar, Ohrid and Prespa have occurred (Shumka *et al.* 2008). In Morocco, carp represents a fair component of the aquaculture production with several hatcheries distributed throughout the country, the most important being located at Azrou (Atlas Mountains area) (Moreau & Costa-Pierce 1997). In Slovenia, where the first fish farm for artificial carp breeding was established in 1870, carp currently represents the second most important breeding species, accounting for 19% of the total freshwater fish production and 89% of the total warm-water fish production. In Spain, although carp attains some levels of production, these are secondary to the farming of rainbow trout *Oncorhyncus mykiss* (Walbuam). In Tunisia, inland aquaculture consists of farming and enhancing local fisheries by stocking fish species, including carp.

Impacts

Several Mediterranean countries have expressed concerns about the potential impacts of carp on freshwater ecosystems, often regardless of the species' local status as either native and translocated or naturalised (*sensu* Copp *et al.* 2005). In Croatia, Treer *et al.* (1995) questioned the advantages of the repeated stockings of carp into Lake Vransko aimed at improving the local fisheries, and similar concerns were raised by Shumka *et al.* (2008) in Albania. However, in both cases, criticisms were based on an overall awareness of the risks associated with the introduction of non-native fish species in general as widely reported in the literature, rather than on more focused impact studies carried out in the specific areas of interest. Studies addressing ecosystem impacts of carp are reported below for some of the other Mediterranean countries.

Spain

Despite overall consensus about the harmful effects of introduced species on native Iberian fish assemblages (Elvira 1998; Godinho & Ferreira 1998; Vila-Gispert *et al.* 2002), no direct evidence has been provided for negative impacts caused by carp, except for records of its presence in degraded areas (e.g. Vila-Gispert *et al.* 2002). However, a field-based (mesocosm) experiment by Angeler *et al.* (2002) indicated an increase in turbidity, chlorophyll *a*, phosphorous and total nitrogen in the presence of carp, which was also found to lower zooplankton biomass indirectly by re-suspension of sediments (see also Angeler *et al.* 2003).

France

In the Camargue area (southern France), Crivelli (1983) replicated North American field-based enclosure experiments to test the effects of carp on aquatic vegetation. Although indirect destruction of plant beds caused by feeding activities was noted, no significant threats posed by carp in the study area were identified, and this was attributed to limited growth and recruitment as a result of annual drying of the wetlands, water quality and avian predation (Crivelli 1981, 1983).

Greece

In a study of the fish fauna of Lake Pamvotis, Leonardos *et al.* (2008) attributed the serious decline in macro-invertebrate communities experienced during the last decades to intensive carp stocking. However, no direct experimental evidence was provided in support but only a general discussion of the detrimental effects of carp on freshwater biota as widely reported elsewhere.

Italy

Despite national law, controls on legal and illegal introductions and translocations have been generally ineffective or absent in this country (Orrù *et al.* 2010), where the number of unintentional non-native introductions is the highest in Europe, threatening local fauna and contributing to the extirpation of approximately 70% of the native fish species (Copp *et al.* 2005). However, Orrù *et al.* (2010) documented the spread and proliferation of carp on the island of Sardinia.

Turkey

Wildekamp *et al.* (1999) pointed to serious degradation of the habitat for *Aphanius anatoliae splendens* (Kosswig & Sözer), a threatened endemic cyprinodontid of Lake Salda, where carp and rainbow trout have been introduced. In Lake Eymir, high levels of turbidity and chlorophyll *a* along with low densities of large-bodied zooplankton measured before biomanipulation were attributed to carp and tench, *Tinca tinca* (L.), causing sediment resuspension by their feeding behaviour (Beklioğlu *et al*. 2000). Similarly, carp biomass and plant coverage displayed a strong inverse correlation in lakes Marmara and Uluabat (Beklioglu *et al*. 2006). Innal and Erk'anan (2006) indicated that, whilst the introduction of carp into Lake Kara in the early 1990s threatened the endemic frog *Rana holtzi*, competition between tench and carp in Kayaboğazi Reservoir and in Çamkoru Pond prevented carp from maintaining viable populations, whereas competition for food and space between carp and crucian carp *Carassius carassius* (L.) was recorded in Mumcular Reservoir. Finally, Zengin and Buhan (2007) discussed the negative effects that stocking of carp in the Almus-Atatürk reservoirs may have had on the native fish fauna.

Israel

Goren and Galil (2005) reported on the negative effects often caused by carp feeding behaviour on freshwater ecosystems. In the rivers Yarqon and Qishon, where water velocities are very slow for most of the year because of water abstraction and diversion, sediments and pollutants sink to the bottom forming particles that adhere to the riverbed and are then resuspended by carp, thereby increasing turbidity levels that in turn prevent growth of submerged vegetation. For this reason, Goren and Galil (2005) concluded that introduced carp and mosquitofish *Gambusia affinis* (Baird & Girard) are the two worst offenders responsible for the deterioration of inland waters of Israel.

Algeria

Repeated introductions of non-native fish including carp are reported to have greatly impoverished zooplankton at Lake Oubeïra leading also to the disappearance of some autochthonous fish species (García *et al*. 2010). The impact of the widespread dissemination of carp across most dams and reservoirs of Algeria, albeit not yet assessed, is expected to be detrimental.

Management

A study on the Camargue area of France (Rosecchi *et al*. 1997) recognised the need for a better understanding of the interactions between introduced species and native fish assemblages, even though more emphasis was placed on non-native species other than carp given its status as naturalised in that country. In an assessment of the potential threats posed by non-native freshwater fishes in Albania, the lack of an action plan aimed at preserving the country's biodiversity and pointing to several deficiencies in the management system was emphasised (Shumka *et al*. 2008). In Greece, with reference to Lake Pamvotis in particular but to the rest of the country in general, Leonardos *et al*. (2008) criticised the use of fish introductions by local people and official authorities as a management tool, which is in contrast with both national and international regulations, and recommended that, given the impossibility of eradicating introduced species, efforts should be aimed at preventing further introductions and spread of currently invasive species. In Israel, Goren and Galil (2005) also pointed to the need for better research and risk assessment before allowing further introductions. In Spain, Vilá and García-Berthou (2010) suggested implementation of a suite of strategies consisting of: (1) prevention and early detection; (2) direct management (although regarded as expensive and often unsuccessful); and (3) active/passive restoration following removal. Finally, in Turkey, Çetinkaya (2006) emphasised the need for more detailed impact assessments to achieve better understanding of the current status and effects of introduced species. In all of the above cases, carp was either directly or indirectly included in the list of offending non-natives, although this was in the absence of a specific management plan tailored to this species.

The main applied carp management study carried out in the Mediterranean region aimed at addressing responses in carp-affected ecosystems to intervention by biomanipulation is that by Beklioglu *et al*. (2003) in Lake Eymir. Between 1998 and 1999, following 57% reduction of a fish stock dominated by planktivorous tench and benthivorous carp (for which 83% biomass reduction was eventually achieved), a substantial decrease in turbidity was observed. This was mainly the result of a decrease in suspended solids and, to some extent, chlorophyll *a*. An increase in size of *Daphnia pulex* also was recorded and macrophyte recovery, which was initially limited to 6% of the total lake surface likely because of the synergistic effects of an insufficiently viable seedbank, oxygen deficiency in the sediments and avian predation, later increased to 50% within a 5-year period (Beklioglu & Tan 2008). In addition, a modelling study by Tan and Beklioglu (2006) on five shallow Anatolian lakes (i.e. Beyşehir, Işıklı, Marmara, Mogan and Uluabat) showed that an ecosystem would resist bioturbation effects of an increased carp biomass ratio up to 20% of the total fish biomass and would then be followed by a steep decrease in the probability of submerged plant occurrence to 0 at a carp biomass reaching 40% of the total fish biomass.

Recently, restoration of a water fowl community by eradication of invasive carp was successfully achieved in the Laguna de Zóñar (Andalusia, southern Spain) with the application of rotenone (Fernández-Delgado 2009). The methodology was very efficient, with 100% eradication of carp following the first treatment. Habitat conditions considerably improved one year after treatment, with the previous low-quality bird community, dominated by piscivorous species, rapidly changing to another dominated by diving species. Restoration efforts were therefore able to return the lake to its normal natural values prior to carp invasion.

Discussion

The identification of wild carp in some confined water bodies of Turkey (Memiş & Kohlmann 2006) indicated the need to preserve endangered populations by preventing contamination with genes from feral/domesticated stocks through either accidental or intentional transfers. Translocations of wild carp stocks to carp-free water bodies could also be considered an option, whereas it is unknown to what extent intervention measures aimed at the rehabilitation of shallow lakes by, for example, biomanipulation (see below) may achieve low enough biomasses of feral/domesticated carp to prevent hybridisation with wild forms (cf. Matsuzaki *et al.* 2010).

The major concerns over carp impacts on freshwater biota (either directly assessed or presumed/implied) have been expressed by those Mediterranean countries/regions (cf. Spain, Sardinia, Greece, Turkey, Israel, Algeria) characterised by warmer and, possibly, more extreme climates (i.e. types Csa/Csb and BSh/BSk: Fig. 1b) as well as by networks of natural lakes, water courses and/or man-made reservoirs; whereas other Mediterranean countries/regions (cf. Croatia, Bosnia and Herzegovina, Montenegro) with predominantly milder climates (types Cfa/Cfb: Fig. 1b) have hitherto not expressed major concerns about the presence of carp.

As shown for Lake Eymir (Beklioglu *et al.* 2003), biomanipulation by reduction of carp biomass successfully returned a eutrophic and turbid, shallow Mediterranean lake to its native clear water state, with overall long-term positive effects, despite subsequent drought conditions (Beklioglu & Tan 2008). As Lake Eymir falls within the Csa climate type, it is to be expected that similar intervention measures in carp-impacted shallow lakes of the Mediterranean Region under comparable (i.e. Csa/Csb) or drier climatic conditions (i.e. BSh/BSk/BWh) may lead to equally satisfactory results, as well as provide for further corroboration of the findings and contribute to test the model-based predictions of Tan and Beklioglu (2006). Also, given expectations of extreme climate events in the Mediterranean area (Sánchez *et al.* 2004), the frequency of droughts and floods leading to unstable habitat conditions favourable to the spread and establishment of carp is likely to increase. This is especially relevant in view of Bajer and Sorensen's (2009) hypothesis that superabundance of invasive carp in certain areas may be linked to recruitment bottlenecks. These seem to be overcome by carp where environmental conditions create unstable peripheral areas that are later exploited by the species for successful spawning and nursery habitat in the absence or scarcity of predators (Bajer & Sorensen 2009).

Elevated carp densities of up to 5000–6000 kg ha^{-1} were reported by Angeler *et al.* (2002) in Las Tablas de Daimiel National Park (TNDP) in central Spain, mostly linked to spawning aggregations. Angeler *et al.* (2002) also observed that the TNDP natural inundation pattern fluctuates considerably intra- and inter-annually, resulting in dramatic fluctuations in the density of the biota's populations. Climate type similarities with areas of invasion such as those found in south-eastern Australia, as encountered in the Iberian Peninsula, the island of Sardinia, Anatolia, the coastal Levant and some coastal areas of Mediterranean Africa (Fig. 1b), would point to the existence of mechanisms similar to those postulated by Bajer and Sorensen (2009) contributing to either the success or potential of carp to act as an invasive species.

Given the above, management-oriented research along with intervention measures should concentrate in those areas of the Mediterranean region more vulnerable to the presence and/or future establishment and spread of carp. In this respect, biomanipulation (Angeler *et al.* 2003) together with other localised methods of control, both tested, such as water drawdowns (Shields 1958; Verrill & Berry 1995; Yamamoto *et al.* 2006), blocking nets (Parkos *et al.* 2006) and selective jump traps (Stuart *et al.* 2006), and proposed, such as exclusion screens (French *et al.* 1999; Hillyard *et al.* 2010) and selective push traps (Thwaites *et al.* 2010), are likely to prove an effective means of control as part of integrated carp management actions in impacted areas (Brown & Walker 2004). However, as emphasised by Vilá and García-Berthou (2010) prevention and early detection still represent the real fail-safe and cost-effective management strategy that environmental scientists and managers alike should be pursuing Vilá and García-Berthou (2010)..

Considering the importance of historical, economic and cultural motives (Tamir 2010) behind the introduction and/or translocation of carp into most countries of the Mediterranean region, there is a need to reconcile ecological requirements for habitat conservation with economic demands (e.g. Gozlan 2008; Gozlan *et al.* 2010). As carp is likely to continue to represent an important economic asset for both developed and emerging economies of the Mediterranean region, efforts for prevention and early detection, but also for control and, whenever feasible, removal, should rely on informed decisions based on uncontroversial identification of potential risk areas backed up by implementation of rigorous risk assessments (cf. Copp *et al.* 2009). Failure to do so because of biased attitudes towards carp is likely to lead to unfruitful efforts.

Britton *et al.* (2011) recommended a series of management action strategies based on a matrix combination of categorised distribution and risk levels, whereby widespread and high-risk species would be classified as medium priority based on cost-benefit considerations. A pre-screening (FISK) assessment (cf. Copp *et al.* 2009) on the invasive potential of carp in the UK resulted in a very high-risk score for this species (Britton *et al.* 2011), which is even more relevant considering the colder climate of that area relative to the Mediterranean region, where similar or even higher risk scores are therefore predicted. Thus, in countries such as Spain and Turkey, where carp is widespread (Clavero & García-Berthou 2006; Innal & Erk'anan 2006), the feasibility of management actions on a country-wide scale will have to be carefully assessed given the very high costs involved and potential for loss of revenue. This is the case of Turkey, where carp is highly valued for fisheries and sport fishing (Harlioğlu 2011), but also of the Adriatic countries of Italy, Slovenia, Croatia and Albania, where carp represents an important component of the fish market (AdriaMed 2003), as well as of several Mediterranean African countries, where suitable conditions exist for prospective commercial fish farming (Aguilar-Manjarrez & Nath 1998). Unfortunately, chemical (Sorensen & Stacey 2004), biological (McColl *et al.* 2007) and genetic (Thresher 2008) carp control technologies, which are likely to prove cost-effective on large scales, are still under development and many years from deployment. However, there remains potential for localised intervention measures (cf. above) in targeted water bodies, as dictated by the need for amenity and conservation value, although careful post-intervention monitoring and assessment will be crucial for ultimate success (cf. Moss *et al.* 2002).

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References

Abell R., Thieme M.L., Revenga C., Bryer M., Kottelat M., Bogutskaya N. *et al.* (2008) Freshwater ecoregions of the world: a new map of biogeographic units for freshwater biodiversity conservation. *BioScience* **58,** 403–414.

AdriaMed (2003) *Aspects of Fish Markets in the Adriatic Sea. Report of the AdriaMed Meeting on Aspects of Fish Markets in the Adriatic Sea.* FAO-MiPAF Scientific Cooperation to Support Responsible Fisheries in the Adriatic Sea. GCP/RER/010/ITA/TD-10. AdriaMed Technical Documents **10,** 152 pp.

Aguilar-Manjarrez J. & Nath S.S. (1998) *A Strategic Reassessment of Fish Farming Potential in Africa.* CIFA Technical Paper. No. 32. Rome: FAO, 170 pp.

Angeler D.G., Álvarez-Cobelas M., Sánchez-Carrillo S. & Rodrigo M.A. (2002) Assessment of exotic fish impacts on water quality and zooplankton in a degraded semi-arid floodplain wetland. *Aquatic Sciences* **64,** 76–86.

Angeler D.G., Chow-Fraser P. & Hanson M. (2003) Biomanipulation: a useful tool for freshwater wetland mitigation? *Freshwater Biology* **48,** 2203–2213.

Arlinghaus R. & Mehner T. (2003) Socio-economic characterisation of specialised common carp (*Cyprinus carpio* L.) anglers in Germany, and implications for inland fisheries management and eutrophication control. *Fisheries Research* **61,** 19–33.

Axelrod H.R., Balon E.K., Hoffmann R.C., Rothbard S. & Wohlfarth G.W. (1996) *The Completely Illustrated Guide to Koi for Your Pond. T.F.H.* Neptune City: Publications, 312 pp.

Azeroual A., Crivelli A.J., Yahyaoui A. & Dakki M. (2000) L'ichthyofaune des eaux continentales du Maroc. *Cybium* **24,** 17–22.

Bacha M. & Amara R. (2007) Les poissons des eaux continentales d'Algérie. Étude de l'ichtyofaune de la Soummam. *Cybium* **31,** 351–358.

Bajer P.G. & Sorensen P.W. (2009) Recruitment and abundance of an invasive fish, the common carp, is driven by its propensity to invade and reproduce in basins that experience winter-time hypoxia in interconnected lakes. *Biological Invasions* **12,** 1101–1112.

Balon E.K. (1974) *Domestication of the Carp Cyprinus carpio L*. Toronto: Royal Ontario Museum Life Sciences Miscellanous Publication, 37 pp.

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

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

Balon E.K. (2006) The oldest domesticated fishes, and the consequences of an epigenetic dichotomy in fish culture. *Aqua, Journal of Ichthology and Aquatic Biology* **11,** 47–86.

Baruš V., Prokeš M. & Peňáz M. (1997) Dispersion and density assessment of the common carp (*Cyprinus carpio* m. *domestica*) in the Mohelno Reservoir, Czech Republic. *Folia Zoologica* **46,** 315–324.

Baruš V., Peňáz M. & Kohlmann K. (2002) *Cyprinus carpio* (Linnaeus, 1758). In: P.M. Bănărescu & H.-J. Paepke (eds) *The Freshwater Fishes of Europe*. Vol. 5/III, Cyprinidae 2, Part III: Carassius to Cyprinus, Gasterosteidae. Wiebelsheim: AULA-Verlag GmbH, pp., 85–179.

Beklioglu M. & Tan C.O. (2008) Restoration of a shallow Mediterranean lake by biomanipulation complicated by drought. *Fundamental and Applied Limnology* **171,** 105–118.

Beklioglu M., İnce Ö. & Tüzün I. (2003) Restoration of eutrophic Lake Eymir, Turkey by external nutrient loading control and biomanipulation. I. First case study on a warm temperate lake. *Hydrobiologia* **489,** 93–105.

Beklioglu M., Altınayar G. & Tan C.O. (2006) Water level control over submerged macrophyte development in five shallow lakes of Mediterranean Turkey. *Archiv für Hydrobiologie* **166,** 535–556.

Beklioğlu M., Burnak L. & İnce Ö. (2000) Benthi-planktivorous fish-induced low water quality of Lake Eymir before biomanipulation. *Turkish Journal of Zoology* **24,** 315–326.

Ben-Tuvia A. (1981) Man-induced changes in the freshwater fish fauna of Israel. *Fisheries Management* **12,** 139–148.

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

Bio A., Couto A., Costa R., Prestes A., Vieira N., Valente A. *et al*. (2008) Effects of fish removal in the Furnas Lake, Azores. *Arquipélago Life and Marine Sciences* **25,** 77–87.

Bishai H.M., Ishak M.M. & Labib W. (1974) Fecundity of the mirror carp *Cyprinus carpio* L. at the Serow Fish Farm, Egypt. *Aquaculture* **4,** 257–265.

Blanco S. & Romo S. (2006) Ictiofauna del Lago de la Albufera de Valencia: Evolución histórica y situación actual. *Boletín de la Real Sociedad Española de Historia Natural (Sección Biología)* **101,** 45–56.

Blanco S., Romo S., Villena M.-J. & Martínez S. (2003) Fish communities and food web interactions in some shallow Mediterranean lakes. *Hydrobiologia* **506–509,** 473–480.

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

Bobori D.C., Tsikliras A.C. & Economidis N.I. (2006) Some morphological and biological characteristics of fishes from Tavropos reservoir (western Greece). *Folia Zoologica* **55,** 199–210.

Britton J.B., Copp G.H., Brazier M. & Davies G.D. (2011) A modular assessment tool for managing introduced fishes according to risks of species and their populations, and impacts of management actions. *Biological Invasions* **13,** 2847–2860.

Brown P. & Walker P. (2004) CARPSIM: stochastic simulation modelling of wild carp (*Cyprinus carpio* L.) population dynamics, with applications to pest control. *Ecological Modelling* **176,** 83–97.

Cahn A.R. (1929) The effect of carp on a small lake: the carp as a dominant. *Ecology* **10,** 271–274.

Cardia F. & Lovatelli A. (2007) A review of cage aquaculture: Mediterranean Sea. In: M. Halwater, D. Soto & J.R. Arthur (eds) *Cage Aquaculture – Regional Reviews and Global Overview*. FAO Fisheries Technical Paper No. 498. Rome: FAO, pp. 156–187.

Carol J., Benejam L., Alcaraz C., Vila-Gispert A., Zamora L., Navarro E. *et al*. (2006) The effects of limnological features on fish assemblages of 14 Spanish reservoirs. *Ecology of Freshwater Fish* **15,** 66–77.

Çetinkaya O. (2006) *Türkiye Sularina Aşilanan Veya Stoklanan Egzotik ve Yerli Balık türleri, Bunların Yetiştiricilik Balıkçılık, Doğal Populasyonlar ve Sucul Ecosistemler Üzerindeki Etkileri: Veri Tabanğ İçin Bir Ön Çalişma* [Exotic and native fish species introduced or stocked into Turkish waters, their impacts on aquaculture, fisheries, wild populations and aquatic ecosystems: a preliminary study on constructing a database]. Balıklandırma and Yönetimi Reservoir Symposium, 7–9 February 2006, Antalya, pp. 206–236. (In Turkish.)

Chistiakov D.A. & Voronova N.V. (2009) Genetic evolution and diversity of common carp *Cyprinus carpio* L. *Central European Journal of Biology* **4,** 304–312.

Clavero M. & García-Berthou E. (2006) Homogenization dynamics and introduction routes of invasive freshwater fish in the Iberian Peninsula. *Ecological Applications* **16,** 2313–2324.

Cole J.L. (1905) *The German Carp in the United States*. Washington, D.C: Department of Commerce and Labour, Bureau of Fisheries, pp. 523–641.

Copp G.H., Bianco P.G., Bogutskaya N.G., Erős T., Falka I., Ferreira M.T. *et al*. (2005) To be, or not to be, a non-native freshwater fish? *Journal of Applied Ichthyology* **21,** 242–262.

Copp G.H., Vilizzi L., Mumford J., Godard M.J., Fenwick G. & Gozlan R.E. (2009) Calibration of FISK, an invasiveness screening tool for non-native freshwater fishes. *Risk Analysis* **29,** 457–467.

Crivelli A.J. (1981) The biology of the common carp, *Cyprinus carpio* L. in the Camargue, southern France. *Journal of Fish Biology* **18,** 271–290.

Crivelli A.J. (1983) The destruction of aquatic vegetation by carp. *Hydrobiologia* **106,** 37–41.

Crivelli A.J., Catsadorakis G., Malakou M. & Rosecchi E. (1997) Fish and fisheries of the Prespa lakes. *Hydrobiologia* **351,** 107–125.

Demetropoulos A. (1985) Cyprus Fisheries. *Marine Policy* **9,** 69–72.

Drakou E.G., Bobori D.C., Kallimanis A.S., Mazaris A.D., Sgardelis S.P. & Pantis J.D. (2009) Freshwater fish community structured more by dispersal limitation than by environmental heterogeneity. *Ecology of Freshwater Fish* **18,** 369–379.

Dulčić J., Tutman P., Matić-Skoko S., Kraljević M., Jug-Dujaković J., Glavić N. *et al*. (2007) A list of Y-O-Y fish species found in the littoral shallows of the Neretva and Mala Neretva estuaries (Eastern Adriatic, Croatian coast). *Acta Adriatica* **48,** 89–94.

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.

El Bolock A.R. & Labib W. (1967) Carp culture in the U.A.R. *FAO Fisheries Report* **44,** 165–174.

El Gamal A.A. (1992) Predation by Nile perch *Lates niloticus* (L.) on *Oreochromis niloticus* (L.), *Cyprinus carpio* (L.), *Mugil* sp. and its role in controlling tilapia recruitment in Egypt. *Journal of Fish Biology* **40,** 351–358.

El Wartiti M., Malaki A., Zahraoui M., El Ghannouchi A. & Di Gregorio F. (2008) Geosites inventory of the northwestern Tabular Middle Atlas of Morocco. *Environmental Geology* **55,** 415–422.

Elvira B. (1998) Impact of introduced fish on the native freshwater fish fauna of Spain. In: I.G. Cowx (ed.) *Stocking and Introduction of Fish*. Oxford: Fishing News Books, pp. 186–190.

Elvira B. & Almodóvar A. (2001) Freshwater fish introductions in Spain: facts and figures at the beginning of the 21st century. *Journal of Fish Biology* **59**(Suppl. A), 323–331.

Fernández-Delgado C. (2009) Restoration of a water fowl community by eradication of the invasive fish species Cyprinus carpio, with rotenone. Available at: http://www.veso.no/default.asp?FILE = items/719/229/CARPA-CORREGIDO.pdf (accessed 3 September 2011).

French J.R.P., Wilcox D.A. & Nicols S.J. (1999) Passing of northern pike and common carp through experimental barriers designed for use in wetland restoration. *Wetlands* **19,** 883–888.

García N., Abdul Malak D., Kraïem M., Samraoui B., Azeroual A., Cuttelod A. *et al*. (2010) The status and distribution of freshwater fish. In: N. García, A. Cuttelod & D. Abdul Malak (eds) *The Status and Distribution of Freshwater Biodiversity in Northern Africa*. Gland, Switzerland: IUCN, xiii + 141 pp.

Gherardi F., Bertolino S., Bodon M., Casellato S., Cianfanelli S., Ferraguti M. *et al*. (2008) Animal xenodiversity in Italian inland waters: distribution, modes of arrival, and pathways. *Biological Invasions* **10,** 435–454.

Gilligan D., Gehrke P. & Schiller C. (2005) *Testing Methods and Ecological Consequences of Large-Scale Removal of Common Carp*. Narrandera, NSW, Australia: NSW Department of Primary Industries Narrandera Fisheries Centre, 48 pp.

Godinho F.N. & Ferreira M.T. (1998) The relative influences of exotic species and environmental factors on an Iberian native fish community. *Environmental Biology of Fishes* **51,** 41–51.

Golani D. & Mires D. (2000) Introduction of fishes to the freshwater system of Israel. *The Israeli Journal of Aquaculture – Bamidgeh* **52,** 47–60.

Gophen M., Yehuda Y., Malinkov A. & Degani G. (1998) Food composition of the fish community in Lake Agmon. *Hydrobiologia* **380,** 49–57.

Goren M. & Galil B.S. (2005) A review of changes in the fish assemblages of Levantine inland and marine ecosystems following the introduction of non-native fishes. *Journal of Applied Ichthyology* **21,** 364–370.

Gozlan R.E. (2008) Introduction of non-native freshwater fish: is it all bad? *Fish and Fisheries* **9,** 106–115.

Gozlan R.E., Britton J.R., Cowx I.G. & Copp G.H. (2010) Current knowledge on non-native freshwater fish introductions. *Journal of Fish Biology* **76,** 751–786.

Harlioğlu A.G. (2011) Present status of fisheries in Turkey. *Reviews in Fish Biology and Fisheries* **21,** 667–680.

Hickley P. & Chare S. (2004) Fisheries for non-native species in England and Wales: angling or the environment? *Fisheries Management and Ecology* **11,** 203–212.

Hickley P., Muchiri M., Britton R. & Boar R. (2008) Economic gain *versus* ecological damage from the introduction of non-native freshwater fish: case studies from Kenya. *The Open Fish Science Journal* **1,** 36–46.

Hillyard K.A., Smith B.B., Conallin A.J. & Gillanders B.M. (2010) Optimising exclusion screens to control exotic carp in an Australian lowland river. *Marine and Freshwater Research* **61,** 418–429.

Hoffmann R.C. (1995) Environmental change and the culture of common carp in medieval Europe. *Guelph Ichthyology Reviews* **3,** 57–85.

Hoffmann R.C. (2002) Carp, cods, connections: new fisheries in the medieval European economy and environment. In: M.J. Henninger-Voss (ed.) *Animal in Human Histories: The Mirrors of Nature and Culture*. Rochester, New York: University of Rochester Press, pp. 3–55.

Hoffmann R.C. (2008) Medieval Europeans and their aquatic ecosystems. In: B. Herrmann (ed.) *Beiträge zum Göttiger Umwelthistorischen Kolloquium 2007–2008*. Göttingen: Graduiertenkolleg Interdisziplinäre Umweltgeschichte Universitätsverlag Göttingen, pp. 45–64.

Holčík J. (2003) Changes in the fish fauna and fisheries in the Slovak section of the Danube River: a review. *Annales de Limnologie: International Journal of Limnology* **39,** 177–195.

Imsiridou A., Triantafyllidis A., Baxevanis A.D. & Triantafyllidis C. (2009) Genetic characterization of common carp (*Cyprinus carpio*) populations from Greece using mitochondrial DNA sequences. *Biologia* **64,** 781–785.

Innal D. & Erk'anan F. (2006) Effects of exotic and translocated fish species in the inland waters of Turkey. *Reviews in Fish Biology and Fisheries* **16,** 39–50.

Jawad L.A. & Busneina A.M. (2000) Fecundity of mosquitofish, *Gambusia affinis* (Baird & Girard) as a function of female size in fish from two lakes in Libya. *Miscellània Zoològica* **23,** 31–40.

Jenčič J. (2005) Fish health management in Slovenia. *Veterinary Research Communications* **29**(Suppl 2)**,** 135–138.

Jones C.G., Lawton J.H. & Shachak M. (1994) Organisms as ecosystem engineers. *Oikos* **69,** 373–386.

Kagalou I., Economidis G., Leonardos I. & Papaloukas C. (2006) Assessment of a Mediterranean shallow lentic ecosystem (Lake Pamvotis, Greece) using benthic community diversity: response to environmental parameters. *Limnologica* **36,** 269–278.

Khalili K.J. & Armikolaie A.K. (2010) Comparison of common carp (*Cyprinus carpio* L.) morphological and electrophoretic characteristics in the southern coast of the Caspian Sea. *Journal of Fisheries and Aquatic Science* **5,** 200–207.

Kirpitchnikov V.S. (1967) Homologous hereditary variation and evolution of wild common carp Cyprinus carpio L. *Genetika* **8,** 65–72.

Kirpitchnikov V.S. (1999) *Genetics and Breeding of Common Carp*. Paris: INRA, 97 pp.

Knjaz V. (2007) Slatkovodno ribarstvo rh [Croatian freshwater fishery]. *Ribartsvo* **65,** 111–121. (In Croatian.)

Koehn J.D. (2004) Carp (*Cyprinus carpio*) as a powerful invader in Australian waterways. *Freshwater Biology* **49,** 882–894.

Koehn J.D. & MacKenzie R.F. (2004) Priority management actions for alien freshwater fish species in Australia. *New Zealand Journal of Marine and Freshwater Research* **38,** 457–472.

Koščo J., Košuthová L., Košuth P. & Pekárik L. (2010) Non-native fish species in Slovak waters: origins and present status. *Biologia* **65,** 1057–1063.

Kottek M., Grieser J., Beck C., Rudolf B. & Rubel F. (2006) World map of the Köppen-Geiger climate classification updated. *Meteorologische Zeitschrift* **15,** 259–263.

Kumar A.B. (2000) Exotic fish and freshwater fish diversity. *Zoos' Print Journal* **15,** 363–367.

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* **17,** 165–173.

Li D., Kang D., Yin Q., Sun X. & Liang L. (2007) Microsatellite DNA marker analysis of genetic diversity in wild common carp (*Cyprinus carpio* L.) populations. *Journal of Genetics and Genomics* **34,** 984–993.

Ludanny R.I., Chrisanfova G.G., Vasilyev V.A., Prizenko V.K., Bogeruk A.K., Ryskov A.P. *et al.* (2006) Genetic diversity and differentiation of Russian common carp (*Cyprinus carpio* L.) breeds inferred from RAPD markers. *Russian Journal of Genetics* **42,** 928–935.

Mabuchi K., Miya M., Senou H., Suzuki T. & Nishida M. (2006) Complete mitochondrial DNA sequence of the Lake Biwa wild strain of common carp (*Cyprinus carpio* L.): further evidence for an ancient origin. *Aquaculture* **257,** 68–77.

Matsuzaki S.S., Mabuchi K., Takamura N., Nishida M. & Washitani I. (2009) Behavioural and morphological differences between feral and domesticated strains of common carp. *Journal of Fish Biology* **75,** 1206–1220.

Matsuzaki S.S., Mabuchi K., Takamura N., Hicks B.J., Nishida M. & Washitani I. (2010) Stable isotope and molecular analyses indicate that hybridization with non-native domesticated common carp influence habitat use of native carp. *Oikos* **119,** 964–971.

McColl K.A., Sunarto A., Williams L.M. & Crane M.S.J. (2007) Koi herpes virus: dreaded pathogen or white knight? *Aquaculture Health International* **9,** 4–6.

Meddour A., Rouabah A., Meddour-Bouderda K., Loucif N., Remili A. & Khatal Y. (2005) Experimentations sure la reproduction artificielle de *Sander lucioperca*, *Hypophthalmichthys molitrix* et *Aristschthys* [sic] *nobilis* en Algerie. *Sciences and Technologie C* **23,** 63–71.

Memiş D. & Kohlmann K. (2006) Genetic characterization of wild common carp (*Cyprinus carpio* L.) from Turkey. *Aquaculture* **258,** 257–262.

Mondol R.K., Islam S. & Alam S. (2006) Characterization of different strains of common carp (*Cyprinus carpio* L.) (Cyprinidae, Cypriniformes) in Bangladesh using microsatellite DNA markers. *Genetics and Molecular Biology* **29,** 626–633.

Moreau J. & Costa-Pierce B. (1997) Introduction and present status of exotic carp in Africa. *Aquaculture Research* **28,** 717–732.

Morgan N.C. (1982) An ecological survey of standing waters in North West Africa: II. Site descriptions for Tunisia and Algeria. *Biological Conservation* **24,** 83–113.

Moss B., Carvalho L. & Plewes J. (2002) The lake at Llandrindod Wells – a restoration comedy? *Aquatic Conservation: Marine and Freshwater Ecosystems* **12,** 229–245.

Mrakovic M., Misetic S. & Povz M. (1995) Status of freshwater fish in Croatian Adriatic river systems. *Biological Conservation* **72,** 179–185.

Mrdak D. (2009) *Environmental Risk Assessment of the Morača Dams: Fish Fauna of Morača River Canyon and Skadar Lake*. Report committed by WWF MedPO and Green Home under the framework of Sharing Water Project – Skadar Lake component. Podgorica, September 2009, 76 pp.

Murakaeva A., Kohlmann K., Kersten P., Kamilov B. & Khabibullin D. (2003) Genetic characterization of wild and domesticated common carp (*Cyprinus carpio* L.) populations from Uzbekistan. *Aquaculture* **218,** 153–166.

Nedjah R., Boucheker A., Samraoui F., Menai R., Alfarhan A., Al- Rasheid K.A.S. *et al*. (2010) Breeding ecology of the purple heron *Ardea purpurea* in Numidia, north-eastern Algeria. *Ostrich* **81,** 189–196.

Omeragić J. (2009) Aquaculture development in Bosnia and Herzegovina. In: M.G. Bondad-Reantaso, J.R. Arthur & R.P. Subasinghe (eds) *Strengthening Aquaculture Health Management in Bosnia and Herzegovina*. FAO Fisheries and Aquaculture Technical Paper. No. 524. Rome: FAO, pp. 27–33.

Orrù F., Deiana A.M. & Cau A. (2010) Introduction and distribution of alien freshwater fishes on the island of Sardinia (Italy): an assessment on the basis of existing data sources. *Journal of Applied Ichthyology* **26**(Suppl. 2)**,** 46–52.

Osborne M.W., Ling N., Hicks B.J. & Tempero G.W. (2009) Movement, social cohesion and site fidelity in adult koi carp, *Cyprinus carpio*. *Fisheries Management and Ecology* **16,** 169–176.

Parkos J.J., Santucci V.J. & Wahl D.H. (2006) Effectiveness of a plastic mesh substrate cover for reducing the effects of common carp on aquatic ecosystems. *North American Journal of Fisheries Management* **26,** 861–866.

Perdikaris C., Gouva E. & Paschos I. (2010) Alien fish and crayfish species in Hellenic freshwaters and aquaculture. *Reviews in Aquaculture* **2,** 111–120.

Povz M. (1995) Status of freshwater fishes in the Adriatic catchment of Slovenia. *Biological Conservation* **72,** 171–177.

Prenda J., Clavero M., Blanco-Garrido F., Menor A. & Hermoso V. (2006) Threats to the conservation of biotic integrity in Iberian fluvial ecosystems. *Limnetica* **25,** 377–388.

Ramakrishna K.V. & Alikhuni K.H. (1962) Growth and propagation of common carp (*Cyprinus carpio* L.) in India—V. Observations on the size of eggs, hatchlings and fry of parents of various size. *Journal of the Bombay Natural History Society* **64,** 238–250.

Rapp T., Cooke S.J. & Arlinghaus R. (2008) Exploitation of specialised fisheries resources: the importance of hook size in recreational angling for large common carp (*Cyprinus carpio* L.). *Fisheries Research* **94,** 79–83.

Rhouma A. (1975) L'élevage de la carpe en Tunisie. Quelques aspects de sa biologie. *Bulletin de l'Institut Nacional Scientifique et Technique d'Océanographie et de Pêche, Salammbô* **4,** 97–113.

Roberts J. & Tilzey R. (eds) (1997) *Controlling Carp: Exploring the Options for Australia*. Proceedings of a workshop 22–24 October 1996, Albury. Canberra: CSIRO and Murray-Darling Basin Commission, 141 pp.

Roll U., Dayan T., Simberloff D. & Goren M. (2007) Characteristics of the introduced fish fauna of Israel. *Biological Invasions* **9,** 813–824.

Rosecchi E., Poizat C. & Crivelli A.J. (1997) Introductions de poissons d'eau douce et d'écrevisses en Camargue: historique, origines et modifications de peuplements. *Bulletin française de la Pêche et de la Piscicolture* **344/345,** 221–232.

Sánchez E., Gallardo C., Gaertner M.A., Arribas A. & Castro M. (2004) Future climate extreme events in the Mediterranean simulated by a regional climate model: a first approach. *Global and Planetary Change* **44,** 163–180.

Šanda R., Lusková V. & Vukić J. (2005) Notes on the distribution and taxonomic status of *Gobio gobio* from the Morača River basin (Montenegro). *Folia Zoologica* **54**(Suppl. 1), 73–80.

Šanda R., Bogut I., Doadrio I., Kohout J., Perdices A., Perea S. *et al*. (2008) Distribution and taxonomic relationships of spined loaches (Cobitidae, *Cobitis*) in the River Neretva basin, Bosnia and Herzegovina. *Folia Zoologica* **57,** 20–25.

Shields J.T. (1958) Experimental control of carp reproduction through water drawndowns in Fort Randall Reservoir, South Dakota. *Transactions of the American Fisheries Society* **87,** 23–32.

Shumka S., Paparisto A. & Grazhdani S. (2008) Identification of non-native freshwater fishes in Albania and assessment of their potential threats to the national biological freshwater [sic] diversity. *Proceedings Balwois Conference* **040,** 1–6.

Singh A.K. & Lakra W.S. (2011) Risk and benefit assessment of alien fish species of the aquaculture and aquarium trade into India. *Reviews in Aquaculture* **3,** 3–18.

Singh A.K., Pathak A.K. & Lakra W.S. (2010) Invasion of an exotic fish–common carp, *Cyprinus carpio* L. (Actinopterygii: Cypriniformes: Cyprinidae) in the Ganga River, India and its impacts. *Acta Ichthyologica et Piscatoria* **40,** 11–19.

Sorensen P.W. & Stacey N.E. (2004) Brief review of fish pheromones and discussion of their possible uses in the control of non-indigenous teleost fishes. *New Zealand Journal of Marine and Freshwater Research* **38,** 399–417.

Stein R.A., Kitchell J.F. & Kneievit B. (1975) Selective predation by carp (*Cyprinus ccrrpio* L.) on benthic molluscs in Skadar Lake. Yugoslavia. *Journal of Fish Biology* **7,** 391–399.

Stuart I., Williams A., Mckenzie J. & Holt T. (2006) Managing a migratory pest species: a selective trap for common carp. *North American Journal of Fisheries Management* **26,** 888–893.

Stunkard H.W. (1959) The morphology and life-history of the digenetic trematode, *Asymphylodora amnicolae* n. sp.; the possible significance of progenesis for the phylogeny of the Digenea. *Biological Bulletin* **117,** 562–581.

Tamir D. (2010) Motives for introducing species: Palestine's carp as a case study. *Environment and History* **16,** 73–95.

Tan C.O. & Beklioglu M. (2006) Modelling complex nonlinear responses of shallow lakes to fish and hydrology using artificial neural networks. *Ecological Modelling* **196,** 183–194.

Tandjir L. & Djebar A.B. (2009) Carpiculture au barrage de Guenitra (Skikda, Algerie). *Sciences and Technologie C* **29,** 30–34.

Tapia M. & Zambrano L. (2003) From aquaculture goals to real social and ecological impacts: carp introduction in rural central Mexico. *Ambio* **32,** 252–257.

Tempero G.W., Ling N., Hicks B.J. & Osborne M.W. (2006) Age composition, growth, and reproduction of koi carp (*Cyprinus carpio*) in the lower Waikato region, New Zealand. *New Zealand Journal of Marine and Freshwater Research* **40,** 571–583.

Thresher R.E. (2008) Autocidal technology for the control of invasive fish. *Fisheries* **33,** 114–121.

Thwaites L.A., Smith B.B., Decelis M., Fleer D. & Conallin A. (2010) A novel push trap element to manage carp (*Cyprinus carpio* L.): a laboratory trial. *Marine and Freshwater Research* **61,** 42–48.

Toor H.S. & Brar J.S. (1975) Studies on the biology of the exotic fish, *Cyprinus carpio specularis* Linnaeus, from the Punjab waters. 2. Food and feeding habits. *Journal of Research Punjab Agricultural University* **12,** 394–397.

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

Treer T., Safner R., Aničić I., Kolak A. & Dražić M. (2000) Morphological variation among four strains of common carp *Cyprinus carpio* in Croatia. *Folia Zoologica* **49,** 69–74.

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

Turk M. (1997) Hrvatsko slatkovodno ribartsvo u godini 1996 [Croatian freshwater fisheries in 1996]. *Ribartsvo* **55,** 121–133.

Veenvliet P. (2000) The ichthyofauna of Cerknika Polje. *Biota* **1/2,** 35–42.

Verrill D.D. & Berry C.R. (1995) Effectiveness of an electrical barrier and lake drawdown for reducing common carp and bigmouth buffalo abundances. *North American Journal of Fisheries Management* **15,** 137–141.

Vilá M. & García-Berthou E. (2010) Monitoring biological invasions in freshwater habitats. In: C. Hurford, M. Schneider & I. Cowx (eds) *Conservation Monitoring in Freshwater Habitats*. Dordrecht: Springer, pp. 1–9.

Vila-Gispert A., García-Berthou E. & Moreno-Amich R. (2002) Fish zonation in a Mediterranean stream: effects of human disturbances. *Aquatic Sciences* **64,** 163–170.

Vitule J.R.S., Freire C.A. & Simberloff D. (2009) Introduction of non-native freshwater fish can certainly be bad. *Fish and Fisheries* **10,** 98–108.

Vuković D., Tursi A., Carlucci R. & Dekić R. (2008) Ichthyofauna of the wetland ecosystem in the Bardača area (Bosnia and Herzegovina). *Ribarstvo* **66,** 89–103.

Waelkens M., Poblome J., Mumford G., Friedman R., Lernau O. & Van Neer W. (2004) Fish remains from archaeological sites as indicators of former trade connections in the Eastern Mediterranean. *Paléorient* **30,** 101–148.

Wakida-Kusunoki A.T. & Amador-del-Ángel L.E. (2011) First record of the common carp *Cyprinus carpio* var. *communis* (Linnaeus, 1758) and the mirror carp *Cyprinus carpio* var *specularis* (Lacepède, 1803) in Tabasco, Southern Gulf of Mexico. *Aquatic Invasions* **6**(Suppl. 1)**,** S57–S60.

Wang C., Liu H., Lou Z., Wang J., Zou J. & Li X. (2010) Mitochondrial genetic diversity and gene flow of common carp from main river drainages in China. *Freshwater Biology* **55,** 1905–1915.

Weber M.J. & Brown M.L. (2009) Effects of common carp on aquatic ecosystems 80 years after 'Carp as a dominant': ecological insights for fisheries management. *Reviews in Fisheries Science* **17,** 524–537.

Welcomme R.L. (1988) *International Introductions of Inland Aquatic Species*. FAO Fisheries Technical Paper **294,** Rome: FAO, 318 pp.

Wildekamp R.H., Küçük F., Ünlüsayin M. & Neer W.V. (1999) Species and subspecies of the genus *Aphanius* Nardo

1897 (Pisces: Cyprinodontiformes) in Turkey. *Turkish Journal of Zoology* **23,** 23–44.

Wood C.S. & Ghannudi S.A. (1985) Study of a shallow carp (*Cyprinus carpio* L.) pond and its relevance to inland fish farming in Libyan Jamahiriya. *Aquaculture* **44,** 125–131.

Yamamoto T., Kohmatsu Y. & Yuma M. (2006) Effects of summer drawdown on cyprinid fish larvae in Lake Biwa, Japan. *Limnology* **7,** 75–82.

Yousefian M. (2011) Genetic variations of common carp (*Cyprinus carpio* L.) in south-eastern part of Caspian Sea using five microsatellite loci. *World Journal of Zoology* **6,** 56–60.

Yousefian M. & Laloei F. (2011) Genetic variations and structure of common carp, (*Cyprinus carpio*) populations by use of biochemical, mitochondrial and microsatellite markers. *Middle-East Journal of Scientific Research* **7,** 339–345.

Zambrano L. & Hinojosa D. (1999) Direct and indirect effects of carp (*Cyprinus carpio* L.) on macrophyte and benthic communities in experimental shallow ponds in central México. *Hydrobiologia* **409,** 131–138.

Zambrano L., Martínez-Meyer E., Menezes N. & Peterson A.T. (2006) Invasive potential of common carp (*Cyprinus carpio*) and Nile tilapia (*Oreochromis niloticus*) in American freshwater systems. *Canadian Journal of Fisheries and Aquatic Sciences* **63,** 1903–1910.

Zenetos A., Pancucci-Papadopoulou M.A., Zogaris S., Papastergiadou E., Vardakas L., Aligizaki K. *et al.* (2009) Aquatic alien species in Greece (2009): tracking sources, patterns and effects on the ecosystem. *Journal of Biological Research-Thessaloniki* **12,** 135–172.

Zengin M. & Buhan E. (2007) *Almus-Ataköy Baraj Göller-i'nde (Yeşilırmak Havzası, Tokat) Balıklandırma Sonrası Balık Faunasında Görülen Değişimin Değerlendirilmesi* [Evaluation of the change in native fish fauna in Almus-Atatürk Dam Lakes (Yeşilirmak Basin, Tokat) after a fish stocking programme]. Antalya: Ulusal Su Günleri, 16–18 May 2007, pp. 267–277. (In Turkish)