Chapter 37
The Common Carp, Cyprinus carpio: Effect on the Environment and the Indigenous Fish Species in Iraq

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Abstract The common carp (*Cyprinus carpio*) is an extremely invasive species and an ecological destructive. It has been frequently shown to upturn nutrient concentrations and phytoplankton biomass while destroying submerged macrophytes. The effects of the common carp on both the environment and the biota of the freshwater system have discussed briefly in the following pages. The review of the status of C. carpio in the inland Iraqi waters is given in this chapter with emphasis on the population size, reproduction and growth. The results of studies performed on this species about these aspects have shown that the populations of the common carp have flourished in the marsh areas better than the lakes and the main rivers. Such differences in the increase in the population of the common carp could be due to the differences in the environmental and the biological factors between regions.

37.1 Introduction

Due to its impact on the aquatic environment, the common carp (Cyprinus carpio) is considered one of the world's damaging invasive species, which is widely distributed around the world (Florian et al. 2016). This cyprinid species has tough direct consequences on the communities of aquatic invertebrates, fish and waterbirds through predation or competition (Weber and Brown 2009). Additionally, this species of carp is considered ecosystem engineers causing bioturbation and high turbidity through their feeding behaviour (Bajer et al. 2009; Kloskowski 2011). With resulting high turbidity, the cover of submerged vegetation will be reduced and a shift from a clear to turbid state in shallow lakes, which results in a reduction in biodiversity (Bajer et al. 2009). To recover any freshwater body inhabited by this

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species needs removal of this invasive species, which result in a recovery of macrophytes together with a drop in turbidity, nutrient concentrations and phytoplankton biomass (Bajer and Sorensen 2015).

The common carp is omnivorous, feeding largely on macrophytes and invertebrates, and up to 25% of the biomass ingested consists of zooplankton (Meijer et al. 1990a, b; Khan 2003; Britton et al. 2007). Therefore, the effect on zooplankton community is eminent by several ways such as: by direct predation (Miller and Crowl 2006), by consuming macroinvertebrates that themselves are zooplankton predators (Khan 2003), through loss of macrophytes that provide shelter, and by increasing phytoplankton biomass and promoting cyanobacterial blooms (Parkos et al. 2003). In addition, the bottom feeding habit of the common carp can cause resuspension of sediment particles, which in turn interfere with the filtering apparatus of cladocerans (Kirk and Gilbert 1990), and bioturbation may also affect the inactive stages in sediments, which has negative effects on emergence patterns (Angeler et al. 2002).

In the warm areas such as the Middle East and the Mediterranean region, the impacts of carp appear to be tougher than in temperate latitudes because relatively high temperatures all year round increase the levels of fish activity. In spite of such information, evidence on how the common carp can affect the zooplankton is not available. Several studies have shown that common carp has a significant effect on zooplankton in part of the semi-arid and temperate lakes (Angeler et al. 2002; Williams and Moss 2003), but a need for integrated studies to be performed on the

whole ecosystem scale.
The aim of this chapter is to investigate the changes that may happen in the zooplankton communities due to the presence of the common carp in the freshwater body system. Also, the effects of this species on the diversity and species richness, and how these changes were related to macrophyte cover, phytoplankton abundance. At the end of the chapter, a recommendation about how to deal with such a problem in the Iraqi freshwater system are given in order to contend such a problem.

37.2 The Effects of the Common Carp on the Environmental Factors in the Aquatic Ecosystem

The process of bringing nutrients from the bottom of the aquatic ecosystem to the top is known as 'Bottom-up processes' (McQueen et al. 1986). Fishes in general play a vital role in this process through multiple pathways (Vanni 1996). For the common carp, it links benthic and pelagic food webs through benthic foraging activities and subsequent excretion (Lamarra 1975). It has been found that common carp can increase water column nutrients (Weber and Brown 2009) and may also increase water column phosphorus, nitrogen and ammonia as a result of benthic foraging activities (Parkos et al. 2003), excretion (Lamarra 1975; Qin and Threlkeld 1990) or

destruction and subsequent decomposition of aquatic macrophytes (Carpenter and Lodge 1986). Common carp may also interact in collaboration with external nutrient loading to further improve the eutrophication process (Drenner et al. 1998).With the increase in number of individuals of the common carp biomass, this may lead to a proportionately greater effect in water column nutrients and facilitate eutrophication processes (Chumchal et al. 2005).
The bottom feeder fish species may increase water column nutrients and phytoplankton through their excretion (Chumchal and Drenner 2004) and nutrient flux (Carpenter et al. 1992). In the low-productivity freshwater ecosystem, nutrient mobilization may be beneficial as this process will increase the primary productivity. Common carp are among the factors that cause increasing eutrophication of shallow lakes (Chumchal et al. 2005). At least 50% of the phosphorus excreted by common carp may be readily available for phytoplankton production (Lamarra 1975), indicating a potential direct pathway. Food and feeding habits of the common carp can vary due to several causes, and such variations will have a direct effect on the water column nutrients, but the small common carp (<100 cm) that consume primarily zooplankton instead of benthic invertebrates may not have an effect on nutrients (Meijer et al. 1990a, b). On the other hand, the activity of the common carp in mobilizing the nutrients depends on the type of the substrate. The hard substrate can hamper the benthic foraging behaviours of the common carp (Roberts et al. 1995), and this is also true for the sediments composed of large, dense particles (i.e. sand, gravel, cobble), which are not resuspended by common carp foraging behaviours. Because common carp do not increase water column nutrients in systems with hard substrates, bioturbation, not excretion, is likely the major driver behind elevated water column nutrients.
The turbidity in small or shallow ecosystem can be due to the abundance of bottom feeder fish species. (Barton et al. 2000). It has been known that increased turbidity has numerous harmful effects on aquatic ecosystems, including reduced light penetration, primary productivity, aquatic macrophyte growth (Sidorkewicj et al. 1996), zooplankton filtering efficiency (Kirk 1991) and foraging abilities of visual planktivorous (Miner and Stein 1996) and piscivorous fishes (De Robertis et al. 2003). The common carp is one of the main factors in increasing turbidity in the aquatic system and causing resuspended solids (Lammens 1991) and increase turbidity (Chumchal et al. 2005) by search for food and expel non-food items. It has been noted that the large individuals of the common carp have the ability to penetrate up to 12 cm into the substrate while searching for food (Panek 1987). In doing so, such individuals can disturb more than the sediment surface layer and resuspending fine particles.
The effect of mobilization of nutrients in the ecosystem by the common carp can influence the production of the phytoplankton. With the increase in turbidity due to disturbances of the substrate, a shift in the phytoplankton species composition

happened. A change from one dominated by chlorophyta (green algae), an important energy source for higher trophic levels, to noxious and often toxic cyanobacteria (blue-green algae) (Williams and Moss 2003) that more commonly compete with macrophytes for nutrients and light can occur.

37.3 The Effects of the Common Carp on the Invertebrate Communities in the Aquatic Ecosystem

The planktivorous fishes have a vital role in structuring the aquatic ecosystems from top to bottom of the freshwater ecosystem. Such ability will be performed by reducing invertebrate communities through predation, which in turn releases algal communities from predatory control by zooplankton (Carpenter et al. 1985). Common carp activity is linked with increases and decreases in zooplankton diversity, size structure and abundance.

Reductions (Lougheed et al. 1998) and increases in zooplankton biomass (Parkos et al. 2003) are associated with the growth of common carp populations. Moreover, size structure of zooplankton communities generally changes from large-bodied to small-bodied taxa in the presence of common carp.

With the variation in the growth of common carp population, variable effects of common carp on zooplankton communities may occur. Indirectly, adult common carp populations may show an effect on zooplankton abundance and size structure through nutrient mobilization or a reduction in zooplankton grazing capabilities through increased turbidity (Parkos et al. 2003). There are two possibilities for increasing the zooplankton biomass. It is either due to the increase phytoplankton biomass (i.e. prey resources) (Khan et al. 2003) or by a reduction in the abundance of benthic invertebrates (Miller and Crowl 2006) that may prey on zooplankton (Johnson and Crowly 1980).

Adults common carp can cause an increase in inorganic turbidity, and they can inhibit ingestion of phytoplankton by large-bodied zooplankton (Kirk 1991), thereby reducing the abundance of these large-bodied grazers. With such changes in the zooplankton size structure from large- to small-bodied species, an effect could happen on phytoplankton density (McQueen et al. 1986). In the balanced freshwater ecosystem, large-bodied zooplankton can regulate phytoplankton biomass (Meijer et al. 1990a, b), whereas small-bodied zooplankton taxa are ineffective grazers. This shift in zooplankton size structure is one of the factors that cause a switch in shallow lakes from a clear to turbid water state (Scheffer et al. 1993). In a direct way and in the early stages of the life of common carp, zooplankton can receive a significant effect as the young of this species of carp (<100 mm) feed on zooplankton (Britton et al. 2007).

The bottom feeding behaviour of the common carp, which include foraging on detritus, annelids, chironomids, amphipods and odonates around 100 mm TL (Britton et al. 2007) may reduce benthic invertebrate abundance, diversity, evenness and richness (Stewart and Downing 2008). Change in the population structure of the benthic invertebrate may happen towards large-bodied species due to selective predation by common carp on small-bodied prey (Covich and Knezevic 1978). Annelids, chironomids and odonates face large reductions even at low common carp densities (Zambrano et al. 1999). With the effect on the macrophytes and the periphytic community and their reduction, common carp may affect indirectly the abundance of Decapoda (Hinojosa-Garro and Zambrano 2004). In regard to the

native fish species, common carp may be more efficient at consuming benthic invertebrates (Parkos et al. 2003) and therefore enter in completion with those species. At a certain period of time, the water of a freshwater ecosystem will become turbid. This is because the benthic invertebrate populations decline due to the predation of the common carp predation and in turn, common carp increase foraging time and expel additional sediment into the water column (Werner and Anholt 1993) causing the turbid water state.

Aquatic macrophytes are important to the clear water-stable state due to their capability to stabilize sediment, compete with phytoplankton for light and nutrients, provide invertebrates a food resource and refugia, and habitat for fishes (Scheffer et al. 1993; Hanson and Butler 1994). With the increase in turbidity, aquatic macrophytes generally disappear (Lougheed et al. 1998) as a result of increasing wind-driven sediment resuspension (Scheffer 1998). The increase in the biomass of common carp will lead to the reduction of aquatic macrophyte diversity and abundance (Matsuzaki et al. 2009). The common carp also destroy aquatic macrophytes on hard substrates through collisions and increased algal growth that competes with aquatic macrophytes for light and nutrients (Miller and Provenza 2007). On contrary and on soft substrates, common carp directly dislodge aquatic macrophyte roots from the sediment (Parkos et al. 2003) and increase sediment turbidity, nutrient release and algal biomass, attenuating light needed for aquatic macrophyte growth (Skubinna et al. 1995; Sidorkewicj et al. 1999).

In the shallow water system where light penetrates down to the substrate, macrophytes can survive in the presence of the common carp (Lougheed et al. 1998). Furthermore, aquatic macrophyte taxa vary in their susceptibility to common carp uneasiness (Evelsizer and Turner 2006). Aspects such as root system, soil type preference, shade tolerance, tissue strength, and timing of seed dispersal may have a possible influence on macrophyte vulnerability. Physical damage to macrophytes by common carp can be seen in the uprooted of a weak aquatic macrophytes from loose and fine substrate (Parkos et al. 2003), and damaging the soft tissues of aquatic macrophytes in collisions (Zambrano and Hinojosa 1999). The physical damaging has more effects on submerging species than emergent species because they generally have weaker root systems and are more influenced by turbidity (Roberts et al. 1995). The aquatic macrophytes with deeper or stronger root systems can also be eliminated and removed due to an increased turbidity from foraging-induced sediment resuspension.

37.4 The Effects of the Common Carp on the Native Fish Species in the Aquatic Ecosystem

There are several ways that the common carp can affect the life of the native fish species inhabiting the same environment. With the highly eutrophic ecosystems and experience population increases with increasing lake productivity, for example,

common carp are more adapted than the native fish and the populations of the later may decline under similar conditions (Egertson and Downing 2004). Common carp may damage spawning habitat or upset spawning behaviour (Panek 1987) and have been shown to eat eggs of some fishes (Miller and Beckman 1996). Fish growth rates are sometimes decreased in the presence of common carp. Examples on such results have seen in the case of several fish species (Wolfe et al. 2006; Egertson and Downing 2004). Fish species that can acclimatize to conditions linked with the presence of common carp may not be affected, whereas those with specific niches for biotic and abiotic conditions may experience reductions in growth or survival, particularly during susceptible early life stages.

37.5 The Status of the Common Carp in the Freshwater System in Iraq

The common carp, Cyprinus carpio, was introduced into the Iraqi inland waters during the period 1960–1972 (Jawad 2003, 2006, 2013). When the number of this species has increased dramatically, it started to be a real danger on the native fish species. By the mid-1980s, the common carp has established very well in the freshwater systems of Iraq and succeeded in eliminating several native fish species such as the Mesopotamichthyes sharpeyi, *Luciobarbus xanthopterus* and *Arabibarbus grypus* (Jawad 2003, 2006, 2013). Several biological features that the common carp has and numerous other environmental factors have assist in the successful of the common carp in the Iraqi freshwater system.

In spite of such a great attainment of this species in Iraqi waters, the studies that dealt with its impact on both the biota and the environment of the freshwater system were very scarce (Jawad 2003). In addition, the studies that are related to the biology of this species, which include detecting the growth and distribution of common carp, were sporadic and did not follow any time interval or any geographical coverage. The studies were mainly performed in the middle and southern of Iraq and have covered certain topics that are related to the stock assessment of the common carp such as reproduction, food, feeding habits and food interaction with the native species, age and growth and population studies. On the other hand, the literature archive of the research on common carp is full of studies that deal mainly on the effects of different pollutants on the common carp, parasitology and basic biology, which contribute less to the issue of controlling the common carp in Iraq.

To know the status of the common carp in the inland waters of Iraq, a short review to the available literature should be given. As mentioned above, the studies published on the common carp that one can come up with an idea about the population status in Iraq are focused on specific subjects, which the following review will deal with it in this section.

37.5.1 Common Carp Composition and Distribution in the Inland Waters of Iraq

In any of the population studies that have been performed on the Iraqi inland waters, *C. carpio* was represented. The available literature for this short review covers the period 2003–2006 and, geographically, covers the north, middle and south of Iraq. There was only one study from North of Iraq and that related to the Dukan Dam Lake, while there are few for the middle and southern reaches of Euphrates and Tigris Rivers. As to the lake, there were five studies that concerned with population study of the Habbaniyah Lake, al-Tharthar Lake (Shakir et al. 2015), Hamrin Dam Lake (Lazem and Attee 2016) and Al-Rathwania Lake (Al-Rudaini et al. 1998; Al-Rudaini 2010). Since the data on the distribution and composition of the common carp in the fish community in the freshwater of Iraq derive from different freshwater ecosystems, i.e. lake, river and marsh, the following review will be constructed on each ecosystem separately.

37.5.2 Lakes

The lakes that studies have been performed in are located in the north of Iraq (Dukan dam Lake on one of the tributaries of Tigris River), Middle part of Iraq and on the Euphrates River, Habbaniyah Lake and Tharthar Lake), on the Tigris River, Al-Rathwania Lake.

37.5.2.1 Al-Rathwania Lake

The earliest study of Al-Rudaini et al. (1998) has shown that the total catch of fish samples was 3884 individuals with a total weight of 1179.79 Kg for a period of 10 months. Out of this number, individuals of *C. carpio* collected were 105 (2.7%) and with total weight of 6.27 Kg (3.5%) of the total catch. During the period of 2000–2001, Al-Rudaini (2010) has shown that the number of individuals that collected from the same lake within the same period of time (10 months) has increased nearly 17 times. The total number of the individuals of *C. carpio* collected was 1758 (36.43%) with total weight of 140.68 Kg (11.42%) out of the total number of fish individuals of 4826 and total weight of 1230.74 Kg. On the other hand, the total number of individuals of the family Cyprinidae other than common carp was 3796 (78.65%) with total weight 1180.58 (95.92%). The individuals of *C. carpio* represent 46.31% with total weight of 11.9% of the same data obtained for the members of the family Cyprinidae.

Habbaniyah Lake

Al-Rudaini et al. (1999) have shown that the number of common carp individuals collected for the period of 12 months in 1997 is 436 (9.46%) with a total weight of 175.24 Kg (43.26%) of the total catch of 4609 and total weight of 410.73 Kg. During this study, the catch of *C. carpio* and *Carassius auratus* was the highest for the catch being made in the period of the study. Also, *C. carpio* was present in all months of the study.

Epler et al. (2001) have collected 134 individuals of common carp (124 and 10 individuals by gill net and trawling respectively) (0.9%) of the total catch. It is clear that there is a significant reduction in the population of the common carp in comparison with the results of Al-Rudaini et al. (1999). Such great decrease in the population within 2–3 years could be explained on the basis that Epler et al. (2001) study was only for 6 months in comparison with that of Al-Rudaini et al. (1999), which last for 12 months.

Comparing the number of individuals and the biomass in Al-Habbaniyah Lake with those in Al-Rathwania Lake for the 1999 period of time, it appears that population of the common carp in the former lake has flourished better than in the latter lake.

Tharthar Lake

In 2001, Epler et al. (2001) have performed an ichthyological investigation for 6 months, but no specimens of common carp were collected. Shakir et al. (2015) have accomplished a study on the ichthyofauna of Al-Tharthar Lake and collected 116 individuals of *C. carpio* (23.6%) with total weight of 80.21 Kg (39.38%) of the total catch. Among the 15 fish species collected in their study, Shakir et al. (2015) have shown that the common carp was present in the catch of every month for the 12-month period of study. Also, the number of individuals of this species was higher than of the 15 species collected. This result is also true for the total weight obtained for the common carp.

Razzazah Lake

Except for the work of Epler et al. (2001), no population study has been performed on the fish fauna of Razzazah Lake. In this study, a total of 9828 fish individuals of 16 species were collected during the period of 6 months. The total number of individuals of common carp was 77 (0.8%) of the total catch.

Hamrin Dam Lake

The only ichthyological survey performed in Hamrin Dam Lake is that of Lazem and Attee (2016). In this study, 12-month collection was accomplished in which the relative abundance of the common carp range 9.54% in summer to 16.67% in winter of the period of the study. With the 19 species studied, C. carpio was in the third place abundance wise after the *Arabibarus grypus* and the goldfish *Carassius auratus*.

Dukan Dam Lake

So far, the only report on the population study of the common carp from north of Iraq is Sediq and Abbas (2013). This study was performed in the period 2007–2008 for 12 months. There were 27 fish species encountered in this study, with total individuals collected of 3006 and total weight of 678.5 Kg. The common carp was not well represented in this lake, where only 237 individuals (7.9%) collected with biomass of 104.7 Kg (15.4%) of the total catch.

37.5.2.2 Euphrates River

The available data on the populations of *C. carpio* of the Euphrates Rivers are only those from the middle and southern reaches of the river. In order to show the fluctuations in the number of individuals and the biomass of the common carp collected from the Euphrates River, the following information is based on the region of the river.

Middle Region

The data on the number of individuals and the biomass of the common carp were obtained from 4 localities in the middle reaches of the Euphrates River, and these are Al-Mussiab area (AI-Rudainy et al. 2006), Al-Hindia area (Al-Amari et al., personal communication; Al-Salman et al. 2014) and Hilla City locality (Al-Amari et al., personal communication).

For the period of 11 years, there was a study increase in the number of individuals of the populations of the common carp collected from the 3 localities at the middle reaches of the Euphrates River. The result of AI-Rudainy et al. (2006) in Al-Mussiab area has shown that the presence of C. carpio formed 11.3% of the total number of individuals collected with total weight of 421.74 (27.2%). During the period of 2010 and 2014, Al-Amari et al., personal communication and Al-Salman et al. (2014) have shown an increase in the number of the individuals collected from Al-Hindia area compared with the result of AI-Rudainy et al. (2006). The catch of individuals

from 13.4% and 16% by Al-Amari et al., personal communication and Salman et al. (2014) respectively. The percentage has decreased dramatically to 0.77% at Hilla area in 2010 (Al-Amari et al., personal communication). Such significant drop can be explained on the basis of the short time of survey and probably to the differences in the environmental and the biological factors in Al-Hilla area.

Southern Region

The number of studies performed on the southern reaches of the Euphrates River is very scarce. Hussein et al. (2015) reported very low presence of the common carp with 0.15% of the total catch. On the other hand, Mohamed et al. (2017) showed the relative abundance of *C. carpio* is 1.68% of the total catch of the river for 12 months of study from Al-Diwania River. Mohamed et al. (2017) in their study on the lower reaches of Euphrates River at Qarmat Ali area near Basrah City reported a very low relative abundance of the common carp (0.04).

37.5.2.3 Tigris River

Mohamed et al. (2006) studied the population of the common carp in the Tigris River. They investigated the fish assemblage at the lower reaches of the Tigris River at City of Qurna. They have shown that the relative abundance of the common carp is 2.36% of the total catch of the river for 12 months of study. With one study available, it is not possible to deduce the status of the population of *C. carpio* in the Tigris River.

At the middle region of the Tigris River, Al-Shawi and Wahab (2007) have investigated the fish population in Tuz Jae a tributary of Al-Audhaim River and both are tributary of the Tigris River. They collected 211 individuals of common carp (10.18%), with 60.120 KG total weight (16.32%) of the total catch. In the same region, Wahab and Hassan (2011) have studied this species showed that the individuals of *C. carpio* 65 (1.55%) and 38.8 Kg (7.29%) of the total catch.

37.5.2.4 Shatt al-Arab River

With the start of the flourishing distribution of the common carp in the inland waters of Iraq in the late 1990s, the number of individuals of this species was low as 87 (0.6%) (Hussain et al. 1997) and 26 (0.31%). After nearly two decades, the relative abundance of C. carpio in the Shatt al-Arab River has increased to reach 3.0 and 3.1 reported by Mohamed et al. (2012) and Mohamed et al. (2013), respectively.

37.5.2.5 The Marshes

The studies that took into consideration the populations of C. carpio in the southern marshes of Iraq are scarce. Hussain et al. (2009) reported a relative abundance of 2.9 of this species from Al-Hammar marsh, northwest of Basrah City, while Al-Shamary et al. (2011) have collected 162 individuals for 12 months of study in the same marsh with 3.17% of the total catch. Further to the east at Al-Huwaiza Marsh, Mohamed et al. (2008) gave very low value for the relative abundance of the common carp of 0.72.

37.5.2.6 Shatt al-Basrah Canal

Shatt al-Basrah Canal was dredged in early 1970, but start operating in 1983, to connect the lower reaches of Euphrates River near the Al-Hammar Marsh with Khor al-Zubair, North West of the Arabian Gulf. This canal is under a tidal effect with saltwater intruded during the tide (Al-Daham and Yousif 1990).

An ichthyological survey has been performed in the Shatt al-Basrah Canal, and specimens of C. carpio were collected by Al-Daham and Yousif (1990). The total number of individuals obtained was 26 (0.31%), with total weight of 7539.7 Kg (3.33%) of the total catch. The specimens of C. carpio were only found in the collecting station close to the Euphrates River. No individuals were seen in the middle and southern collecting stations where salinity is high.

37.5.3 Reproduction

So far, there are only three studies on the reproduction of the common carp, two of these were performed in the Middle region of Iraq, while the third study was accomplished at Al-Hammar Marsh, south of Iraq. Hamady (2009) determined the sex ratio of *C. carpio* from AL-Gharraf Canal at Wasit province, Iraq, as 1:0.09 in favourite of males. Male and female fish mature at 213 and 215 mm total length, respectively. Hamady (2010) has calculated the relative fecundity as 177 egg/g. From the southern part of Iraq and at Al-Hammar marsh, Abdul Retha et al. (2009) have calculated the GIS of the common carp as 0.96–2.20.

37.5.4 Condition Factor

As with the studies on other biological parameters, the condition factor of the common carp has not been investigated very well in Iraq. The only available studies are those for fish samples collected from the Tigris River tributaries in the north and

middle of Iraq. At Darbandikhan Dam Lake, the value of condition factor ‘K’ was reported by Rasheed (2012) to be 0.71, while the value has increased dramatically and reached 1.46 in 2012 (Wahab and al-Ani 2012) and range 1.120–1.880 in the eastern Drainage in Balad City (Wahab and Al-Ani 2013).

37.5.5 General Conclusion

In general, the population of the common carp has increased significantly since this species has been introduced to Iraq in the period 1960–1972. Based on the above short review, it is clear that the lakes in Iraq have smaller populations of C. *carpio* than the main rivers and marshes. Similarly, The Euphrates River inhabited by populations of this species smaller than those of the Tigris and Shatt al-Arab Rivers. The population of the common carp seems to be flourished in the marsh areas better than any inland water bodies in Iraq. Having saying this, it is important to mention that such a conclusion is based on what available of data on the populations of the common carp in Iraq which are very scarce and not suitable for any management program to be performed. Because the number of individuals given in the population studies is far less than that given in the reproduction or growth studied, where relatively higher number of individuals were collected from the same localities and at the same period of time.

Reproductive speaking, the common carp has shown better adaptation to the Iraqi new environment and showed good fecundity value. As to the condition factor, those studies on the populations from the Tigris River have shown that individuals of this species have a good well-being. More researches are needed in order to put future plans for the management of controlling the common carp in Iraq.

It is not possible to combine the results of population studies of the common carp performed in the 6 Iraqi lakes due to the differences in their topography, geographical locations, climate, substrate, environmental and biological factors. But on the other hand, it is possible to highlight some points that indicate clearly the increase in the abundance of the common carp in the 6 lakes mentioned above. Future studies on the population of the common carp in all the lakes mentioned above are needed to follow up the increase in the abundance of C. carpio in relation to the native species.

In spite of the experiment of Saleh and Abdul Karim (2013) on the hybridization of the common carp with Mesopotamichthys sharpeyi a native fish species, the future results of such hybridization in the nature will have more ecological impacts than the presence of the alien species *C. carpio* itself.

Conservation and biodiversity can be in great threat in case of the interbreeding that could happen between related species. Endemic species can interbreed with a more common, introduced species occurs frequently (Rhymer and Simberloff 1996). Such dangerous hybridization, if I may call it, cross-species can lead to the development of invasive lineages that are effectively new species (Nolte et al. 2005) and can even replace parental forms (Ellstrand and Schierenbeck 2000). The weak hybridization may produce hybrid generation with low fitness, but can still introduce

individual advantageous alleles into populations of non-endemic species and facilitate them becoming invasive in their new environment (Hänfling 2007).

Several factors may affect the inbreeding with the common carp, among these are (1) the potential for hybridization can be difficult to predict; (2) levels of crossspecies hybridization can vary greatly between different locations and over time (Kijewska et al. 2009); (3) hybridization can be strongly biased, where the bulk of F1 hybrids happen through the males of one species mating with the females of another (Roberts et al. 2009), or can be bidirectional (Yaakub et al. 2006); (4) hybridization can also be lacking between ecologically similar sympatric sister species (Anderson et al. 2009); (5) the rate and direction of cross-species hybridization can be intensely affected by the spawning times of the species involved (Roberts et al. 2009).

37.6 Recommendation for Common Carp Management

Weber and Brown (2009) have suggested a set of counteractive steps to follow in order to control the presence of the common carp in the freshwater ecosystem. These measures can be summarized as follows:

1. Among the ways to manage the freshwater ecosystem and control the presence of common carp is by removal of individuals of this fish (Schrage and Downing 2004). It is one remedial recovery policy essential to decline internal nutrient cycling, increase water transparency, re-establish aquatic macrophytes and

return the ecosystem to the clear water state. Nevertheless, elimination of common carp is problematic, costly and time overwhelming (Schrage and Downing 2004). It has been known that more than 70% of common carp biomass may have to be removed to achieve enhancements in biotic and abiotic variables (Schrage and Downing 2004).
Besides the plan of removing common carp from an ecosystem, individual common carp size and ecosystem size, substrate and trophic state influence common carp effects on ecosystems should be considered too (Chumchal and Drenner 2004).

2. Moderately regulating plan against the presence of the common carp populations by freshwater body morphometry as the population of the common carp declines with increasing water depth (Egertson and Downing 2004). Consequently, the water body should be selected and decisions must be made to determine where restoration efforts are best directed (Weber and Brown 2009).

3. For example, low abundance of common carp populations may be easy to further reduce, but such efforts might have little ecological effect on aquatic ecosystems.

4. With water bodies that have hard substrate, the effects of the common carp can be reduced by decreasing the sedimentation, nutrient loading and lake eutrophication. For example, common carp have had little effect on suspended solids or

turbidity in lakes with sand, gravel or cobble substrate, even at high densities (Sidorkewicj et al. 1999).

5. Several control methods have been endeavoured to manage common carp populations, including chemical and physical elimination, demolition of common carp spawning habitat, water level manipulation, fish barriers and predator introduction (Parkos et al. 2006).

6. It has been known that individuals of common carp assemble in large quantities deep area of the freshwater body during cold seasons (Penne and Pierce 2008). Therefore, aiming such aggregations may make removal efforts more successful.

7. In spite of the chemical removal of common carp is an accepted removal technique (Bonneau 1999), non-target species are also susceptible (Marking 1992). Chemical spot treatments in areas of common carp aggregations may be an option to minimize undesirable effects on the surrounding lake community and increase removal success on large water bodies (Bonneau 1999).

8. The effectiveness of the physical removal techniques is coupled with habitat types. Such techniques include seining, electrofishing, gill netting and a variety of trap types, and (Pinto et al. 2005).

9. Poison lures have also been recommended to target common carp populations and diminish effects on other species (Rach et al. 1994), but field experiments have been unsuccessful (Bonneau 1999). Even when removal efforts are successful, only short-term benefits may accrue because common carp recolonize quickly (Barton et al. 2000).

10. Precautionary measures (i.e. electrical barriers, fish weirs, traps, etc.) established prior to removal efforts are suggested to lessen the probability of common carp recolonization (Lougheed and Chow-Fraser 2001).

11. Common carp population dynamics may be used in the management plans. It is possible to control the fast-growing, short-lived populations by reducing recruitment (Brown and Walker 2004). The technology that can deal with the sex ratio and biased males over females for multiple generations will ultimately causing population collapse (Grewe 1996) and could also be used to control short-lived populations (Brown and Walker 2004). On the other hand, long-lived, slowgrowing populations could be controlled in removing adult population (Brown and Walker 2004) in addition to consideration recruitment.

12. The usual habit of the common carp spawn over aquatic macrophytes in waters generally less than 0.5 m (Edwards and Twomey 1982) can be used in the control efforts. Drawdowns during spawning may reduce spawning habitat and recruitment (Shields 1958). Such a plan has been successfully implemented in

Australia (Koehn et al. 2000). Barriers stopping adult common carp contact with the spawning areas may also decrease recruitment (Stuart et al. 2001). Furthermore, physical agitation of water in shallow spawning bays may damage eggs. Nevertheless, consequences of all these techniques on native fishes should be well thought-out when formulating a set of management strategies.

Koehn et al. (2000) have given a strategic management plan, which have been summarized in this chapter and given below. Koehn et al. (2000) have identified the four components of the strategic approach to carp management as defining the problem, developing a management plan, implementing the plan and monitoring and evaluating results. As an editor of this book, I preferred to keep the original recommendations without changes except in certain parts where they are not related to the subject of this chapter. And here I quote,

1. To define the problem. This means determining the nature and scope of the management concern (for example, loss of water quality or aquatic vegetation). A number of factors in addition to the presence of carp can contribute to observed problems, including human interference, habitat type, local influences on water flow and quality and other fish species present. The problems caused by carp may affect many natural resources. Therefore the management of carp as a pest species is a natural resource management issue which extends well beyond the realm of traditional fisheries management.

2. To develop a management plan. This must include clear objectives set in terms of the economic and/or conservation outcomes being sought. These management objectives should include interim and long-term goals. Developing the plan will involve an assessment of the most appropriate control technique(s) and strategy and setting the priorities for management. Best results in pest management are often achieved with a combination of techniques rather than relying on a single technique. Options for carp management include: prevention of further spread, local, small-scale poisoning or removal, exclusion, habitat rehabilitation to enhance native fish species, commercial or recreational removal, and wide-scale control options which may include new technologies. In developing a management plan, one or more of these options need to be selected that will best meet the management objectives. Measurable performance indicators then need to be defined which can be used to measure progress against the management objectives.

3. Implementation, is dependent on an integrated approach for success. Although much of the responsibility will rest with a range of government agencies, cooperation and ownership must also be undertaken with other stakeholders and community groups. Ownership of carp management must ultimately reside with many agencies and groups, not just those with fisheries interests.

4. Monitoring and evaluation. This should occur at different levels throughout implementation and on completion of actions. The efficiency of the operation needs to be monitored to ensure that the management plan is executed in the most cost effective manner. Monitoring will help identify inefficiencies so the management strategy can be continually refined. In addition, the effectiveness of the program in achieving the objectives needs to be monitored so that either the program objectives or the management strategy can be modified if necessary, in the light of further knowledge and experience. This may mean modifying the objectives, if they are unrealistic, or adding new objectives. Effectiveness is determined by evaluating achievements and outcomes against the performance

indicators included in the management plan. Different techniques may have different success rates under different circumstances. Economic frameworks are needed to assist in the assessment of the relative cost and value of alternative strategies. Such frameworks require: the definition of the economic problem, data on the relative costs of different carp control strategies, and an understanding of why the actions of individual management agencies may not lead to optimal levels of carp control and how management may be improved.

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