Chapter thirteen

Growth and reproduction of the goldfish Carassius auratus: a case study from Italy

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INTRODUCTION

The goldfish *Carassius auratus* (Linnaeus) is a scaly, high-bodied, laterally compressed fish; its mouth is small and terminal, without barbels. The dorsal fin is long with a slightly serrated third spine. This species is very similar to the crucian carp *Carassius carassius* (Linneaus), but is more elongated and has a slightly concave dorsal fin and slightly larger scales (Lelek 1987).

There has been considerable confusion concerning the taxonomic status of *C. auratus*. Many authors have recognized two subspecies in its native range: *C. a. auratus* (goldfish, Chinese goldfish, or Asian goldfish) from Asia, and *Carassius auratus gibelio* Bloch (Prussian carp, gibele carp, or European goldfish) from Eastern Europe (Hanfling *et al.* 2005). Howells (1992, in Nico and Schofield 2006) reported that goldfish typically observed in the US waters are crucian carp × goldfish hybrids. Goldfish commonly hybridises with the carp *Cyprinus carpio* Linnaeus, giving rise to individuals that are intermediate in morphology between the two parent species. Recent studies have indicated

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that European goldfish populations represent probably an assemblage of lineages of different origins (various clonal lineages as well as hybrids between goldfish and crucian carp) which might have contributed to the taxonomic confusion in the genus *Carassius* Jarocki (Hanfling *et al.* 2005).

Goldfish may grow to 45 cm total length (TL) and 3 kg; however, they generally reach only 20 cm TL and weigh 100–300 g (Muus and Dahlström 1967). Their lifespan is typically 6–7 years, but it has been reported to be as long as 30 years (Menassè 1974). There is no parental care of the eggs or larvae.

Typical habitat includes weedy ponds, shallow lakes, and slow-flowing rivers, especially those with submerged aquatic vegetation (Lelek 1987, Maitland 2004). Many different varieties of goldfish have been produced by man through selective breeding to produce a wide range of colours and fin shapes. When released from captivity, these fishes usually revert to their natural olive-bronze colour and normal fin shapes.

DISTRIBUTION

There is still considerable uncertainty regarding the distribution of goldfish. This species is indigenous to Eastern Asia (Lelek 1987), including China and neighbouring countries, and, if *C. a. gibelio* is a valid subspecies and not just a feral introduction (Raicu *et al.* 1981), also to some parts of central-eastern Europe. However, the distribution of goldfish in Europe today extends from the Iberian Peninsula to the Black Sea area, with the exception of northern regions (Ireland, Scotland, and part of the Scandinavian Peninsula) (Lelek 1987, Maitland 2004). Wild populations have often been established by released pet goldfish, but many have been introduced unintentionally through restocking with young carp, from which goldfish are difficult to distinguish (Halacka *et al.* 2003); goldfish have been also introduced as bait fish (Nico and Schofield 2006). The species can also spread spontaneously using the connections of hydrological networks. The range of this species in Europe is currently expanding (Lelek 1987).

The goldfish was probably the first foreign fish species to be introduced into North America, arriving in the late 1600s (Jenkins and Burkhead 1994). Today this species is established or reported in all the American states except Alaska (Nico and Schofield 2006). The species can also be found in South America, where it was introduced at the beginning of the 1900s by European immigrants (Gomez *et al.* 1997). The goldfish was first taken to New Zealand in the late 1860s and is now widespread and well established in the country. A large number of *C. auratus* have been reported in many lakes, dams, and rivers in Australia since the late 1870s (Department of Fisheries of Western Australia 2005).

ECOLOGICAL AND BIOLOGICAL CHARACTERISTICS

The goldfish has the potential to be invasive on account of some of its ecological and biological characteristics: high tolerance of water pollution, high fecundity, and wide-ranging diet. Its omnivorous diet includes planktonic crustaceans, phytoplankton, insect larvae, fish eggs and fry, benthic vegetation, and detritus (Muus and Dahlström 1967, Scott and Crossman 1973, Maitland 2004, Nico and Schofield 2006). Its populations grow rapidly, as the species can reproduce through gynogenesis (Abramenko *et al.* 1997, Xie *et al.* 2001, Kuznetsov 2004).

Goldfish are extremely tolerant of environmental stress (Abramenko *et al.* 1997), including high levels of turbidity and fluctuations in pH and temperature (Spotila *et al.* 1979). Laboratory tests have revealed pH tolerance levels between 4.5 and 10.5, and a preference for pH levels between 5.5 and 7.0 (Szczerbowski 2001). Goldfish have been captured in waters with salinity levels as high as 17 ppt, and adults can survive water temperatures between 0°C and 41°C (Nico and Schofield 2006). Moreover, the species is highly tolerant of water pollution (Abramenko *et al.* 1997) and can cope with low levels of dissolved oxygen and even prolonged periods (several months at 2°C) of total anoxia (Walker and Johansen 1977, Van den Thillart *et al.* 1983). This ability requires metabolic adaptation: below critical oxygen content in the water, the fish are able to exploit an anaerobic, or mixed aerobic-anaerobic, metabolism (Holopainen and Hyvarinen 1985, Nilsson 2001). This ability allows them to colonize a wide variety of habitats, including small ponds. In shallow pond conditions in Finland, the crucian carp *C. carassius* abounds and dominates the ecosystem (Holopainen and Pitkanen 1985, Holopainen *et al.* 1991).

Goldfish are considered to be vulnerable to competition (Piironen and Holopainen 1988, Paszowski *et al.* 1990) and to predation (Tonn *et al.* 1991); however, the rapidity of their growth limits their vulnerability as prey for ichthyophagous fish (Nico and Schofield 2006).

Concerns have been raised about the impact that goldfish have on the aquatic community, including increasing turbidity (Cowx 1997) and competition with indigenous fish (Scheffer *et al.* 1993). Indeed, declines in invertebrate numbers have been attributed to the establishment of this species (Richardson and Whoriskey 1992) and local eradication of aquatic macrophytes through direct consumption and uprooting has also been documented (Richardson *et al.* 1995). The bottom-sucking feeding methods of goldfish can also contribute to algal blooms by re-suspending nutrients, which makes them available to phytoplankton (Richardson *et al.* 1995). Furthermore, recent studies have demonstrated that growth of cyanobacteria is stimulated by the passage through goldfish intestines (Kolmakov and Gladyshev 2003). The primary threat to indigenous fish species is probably competition for food and other resources (Moyle 1976). Goldfish have also been known to prey upon eggs, larvae, and adults of indigenous fishes (Scott and Crossman 1973). Other threats may include the introduction and persistence of parasites (such as *Lernea* sp.) that commonly live on goldfish. In the US, the introduction of goldfish was believed to be a major cause of the decline of populations of *Empetrichthys latos* Miller during the early 1960s (Deacon *et al.* 1964); it seems that also the Sacramento sucker *Catostomus occidentalis* Ayres suffers in the presence of goldfish (Moyle 1976). In Europe it has been reported that in some habitats the goldfish introduced affect resident fish, such as crucian carp and tench *Tinca tinca* (Linnaeus) (Halacka *et al.* 2003); in addition, declines in pike abundance (*Esox lucius* Linnaeus) can occur as a result of increased water turbidity (Cowx 1997).

CASE STUDY

Lake Trasimeno is a lake of tectonic origin situated in central Italy (43°9′11″ N and 12°15′ E) between the Tiber and Arno River basins. It is the fourth largest lake in Italy ($124.3\,\mathrm{km}^2$) and the most extensive of the Italian peninsula. Its shallowness (average depth: 4.72 m; maximum depth: 6.3 m) makes Lake Trasimeno the largest laminar lake in Italy. The catchment basin is made up of lands with low permeability and covers an area of $357.98\,\mathrm{km}^2$, about three times greater than the lake surface (Mearelli *et al.* 1990). The water is supplied by short intermittent streams which have little or no water in the summer. Owing to the morphologic characteristics of Lake Trasimeno, the water temperature is almost the same as the air temperature, exceeding 30°C in the summer; thermal stratification being usually absent (Lorenzoni *et al.* 1993). Lake Trasimeno is classified as mesotrophic (Mearelli *et al.* 1990).

The fish community, composed of 19 species (Mearelli *et al.* 1990), is dominated by cyprinids. Fishing is still one of the main commercial activities of the local population and, although it has declined in recent years, the number of professional fishermen is the highest in Italy with regard to inland lakes (Lorenzoni *et al.* 2002). Goldfish have been found in Lake Trasimeno since the end of the 1990s (Mearelli *et al.* 1990) and, owing to the absence of predators, man included, their numbers are currently high. This probably exerts a negative impact on fish communities owing to interspecific competition.

Little information is available on the biological characteristics of goldfish populations in Italy and in Western Europe in general. A study was conducted to collect information on the growth and reproductive biology of goldfish, in order to investigate the causes of their rapid expansion in Lake Trasimeno and to gather data on which to design a plan for the control of these unwanted populations. Sampling was conducted monthly, from February 2003 to January 2004; individuals were caught by means of electrofishing and multi-mesh gill-nets at 6 sampling stations along the perimeter of the lake. Two types of net were used: fyke nets and gill-nets. The gill-nets were assembled using panels with differently sized mesh (22, 25, 28, 35, 40, 50, and 70 mm), to allow more efficient and representative sampling (Craig *et al.* 1986, Degerman *et al.* 1988). The panels, each of which was 1 m high and 50 m long, were positioned for one night near the bottom, perpendicular to and about 1,000 m from the shore. The fyke nets were positioned for one night in the vicinity of the gill-nets.

Electrofishing was conducted monthly, except in April, when it was conducted weekly. Sampling was carried out from boats by means of 4.5 kW electric stunning devices; these devices supplied continuous pulsating current. Electrofishing has been used to study fish populations in lotic wadable waters for some considerable time, but is seldom used in lentic systems, where it is effectively restricted to the littoral area (Eloranta 1990, Reynolds 1996). In Lake Trasimeno, however, this technique is more efficient, in that the water is shallow in most of the lake, as pointed out by a previous research (Mearelli *et al.* 2004). During each sampling at each of the six stations, a variable number of transects of varying lengths were examined. These transects were chosen on the basis of their different environmental conditions (in terms of substrate, vegetation, depth, and transparency) in order to determine in which conditions catches would be optimised.

The fish caught (expressed as biomass) were standardized with regard to the ‘‘fishing effort’’ (CPUE = catch per unit effort) (Degerman *et al.* 1988, Wilderbuer and Kappenman 1998). For fyke nets, fishing effort was defined as the time of sampling, and CPUEs are expressed as $g\ h^{-1}$; for gill-nets, fishing effort was the area of nets (CPUEs = $g\ 10^{-2}\ m^{-2}$); for electrofishing, fishing effort was the time of sampling (CPUEs = $g\ min^{-1}$). The lengths of the sampling areas were measured by a GPS meter.

Laboratory analysis and data elaboration

All specimens were measured in terms of total length (TL) and standard length (SL) with an accuracy of 1 mm, and weighed (W) with an accuracy of 1 g (Anderson and Neumann 1996). Sex was determined by macroscopic examination of the gonads (Bagenal 1978) and gonads were weighed (W_g) with an accuracy of 0.1 g. Age was evaluated in the laboratory by a microscopic scalimetric method (Bagenal 1978, Britton *et al.* 2004): the scales were removed from the left side of the fish, above the lateral line, near the dorsal fin (De Vries and Frie 1996) and stored in ethanol (33%). The TL-SL relationship ($TL = a + b\ SL$) and TL-weight relationship ($W = a\ TL^b$) were calculated separately for the two sexes, using a least-squares method (Ricker 1975). The relationships between the sexes were compared by analysis of covariance (ANCOVA).

The theoretical growth in length was described by the Von Bertalanffy growth equation (1938): $L_t = L_\infty(1\text{-}\exp^{(-K(t-t_0))})$, where L_t is the theoretical total length (in cm) at age t, L_∞ the asymptotic length, K the coefficient of growth, t_0 the theoretical age (in years) at length = 0 (Bagenal 1978). The analysis was conducted using the values of total length and age of the single individuals. Because no difference emerged in the TL-SL and TL-weight relationships, the theoretical growth in length was analysed without distinction between sexes.

The Gonado-Somatic Index was evaluated by the following formula (Ricker 1975): GSI = (100 W_g)/W, where W_g is gonad weight (in g) and W is total weight (in g). The ovaries of 92 females were excised, weighed, and fixed immediately in 10% buffered formalin. Some cross sections of ovaries from each fish were weighed and microscopically examined, and the oocytes were counted. Ten oocytes were selected for each female and the diameter was measured by means of a computerized system of image analysis (IAS2000) connected to the microscope. The relationship between TL and number of eggs ($N = a\ TL^b$) was calculated using a least-squares method (Ricker 1975).

Age structure and sex ratio

The sample was composed of 3,111 specimens. The TL, weight, and age of the specimens analysed ranged between 4.30 and 40.60 cm, 1 and 1137 g, 0.2 and 7.9 years, respectively. Eight age-classes were found, with most specimens in the 2+ age-class; the number of captured individuals decreased progressively as the age increased. The 0+ age group is not well represented in the sample, probably because of the selectivity of the capture nets. Females were grouped into 7 age-classes, while in the male subsample, 8 age-classes were found. Results showed that the population was composed mostly of females (males = 102, females = 1953, sex ratio: 1:19). The sex ratio also seems to be unbalanced in May, when sampling was carried out among the groups during reproduction (males = 20, females = 575, sex ratio: 1:29).

In many European populations of *C. auratus* a similar imbalance in the sex ratio has been observed, which is probably due to the reproductive system of the population (Abramenko *et al.* 1997, Xie *et al.* 2001, Kuznetsov 2004). Indeed, in Europe many populations are made up exclusively of females that reproduce by gynogenesis through mitotic divisions of eggs due to heterologous species of sperm (Muus and Dahlstrom 1967, Sani *et al.* 1999). By contrast, in Asia the sex ratio is around 1:1 (Muus and Dahlstrom 1967, Abramenko *et al.* 1997, Kuznetsov 2004).

Growth

The TL-SL relationship estimated for the whole sample was $TL = 0.0822 + 1.2155\ SL$ ($R^2 = 0.992$; $P = 0.000$). On covariance analysis, the difference between the two sexes was not statistically significant ($F = 3.700$, $P = 0.054$). The weight-length relationship estimated for the whole sample was: $W = 0.0147\ TL^{3.062}$ ($R^2 = 0.990$, $P = 0.000$), without any significant difference between sexes ($F = 3.124$, $P = 0.077$). The results show that in Lake Trasimeno the species displays allometric growth ($b > 3$ in both sexes). The

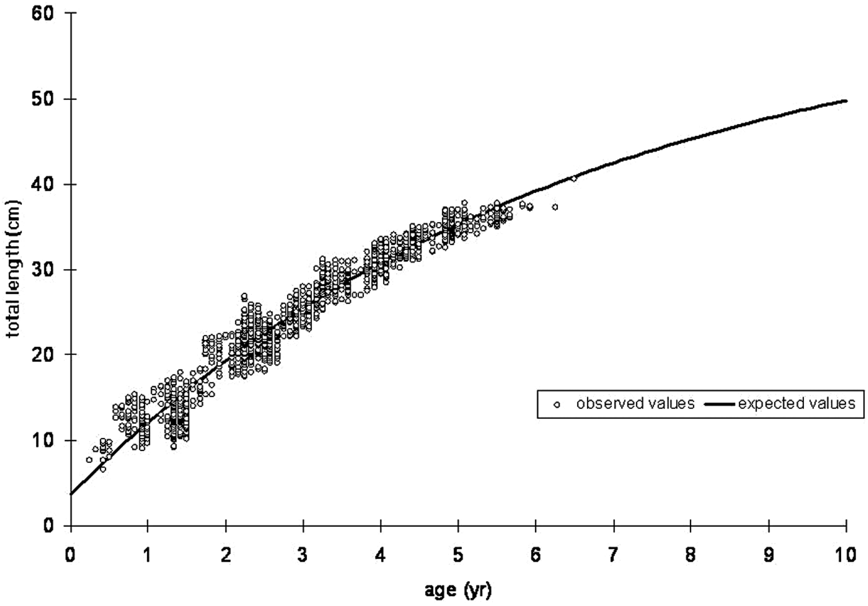

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Fig. 1 Goldfish: curve of theoretical growth in length.

regression coefficient values for the population of Lake Trasimeno are generally higher than those of other populations investigated (Froese and Pauly 1998).

The curve of the theoretical growth in length was $TL = 46.967 \{1\text{-}e^{(-0.154(t+1.048))}\}$ ($R^2 = 0.982$) for the total sample (Fig. 1). Froese and Pauly (1998) and Kuznetsov (2004) report data on numerous other European and Asian populations of goldfish.

Reproductive biology

The gonad-somatic index (GSI) was calculated in both sexes. The average GSI value was 6.25 in females, varying between a minimum of 0.18 and a maximum of 46.51, while in males it was 1.69, varying between 0.19 and 11.19. The differences between the two sexes were highly significant on *t*-test ($t = 7.36$; $P = 0.000$). The monthly trend in GSI for the female sample (Fig. 2) showed that maturation of ovarian eggs reached a maximum in April, while in August reproduction ended and gonads were in a resting condition. The GSI value began to rise in autumn; during the winter, when fish metabolism is slowed and food supply is scarce, the GSI value tended to decrease slightly and then increased rapidly from February onwards. In Lake Trasimeno, the female reproductive investment was high, reaching almost 50% of the entire body mass at its maximum peak. Analyses of the GSI showed that the reproductive period of the population extends over an ample time period, from the end of March

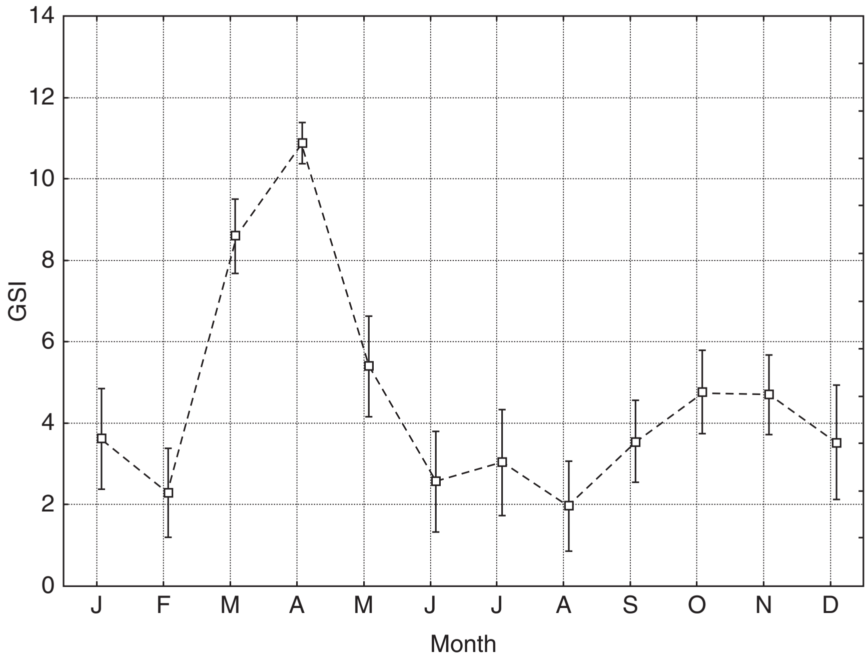

Fig. 2 Goldfish: monthly average values (with confidence limits) of GSI.

until June. The water temperature recorded at the beginning of reproduction was about 13°C.

Most of the females (85% of the population sampled) attained sexual maturity in the second year, while in the third and subsequent years this percentage rose to 100%; however, some (7.55%) 1-year-old females were able to spawn. The smallest sexually mature female was 12.20 cm TL. The relationship between TL and the number of eggs was $N = 0.0198\ TL^{4.339}$ ($R^2 = 0.743$, $P = 0.000$). Fecundity varied from 286 to 219 104 eggs, averaging (± SE) 46,253 ± 3,921 eggs. The diameter of mature eggs in the spawning season ranged from 0.74 to 1.71 mm, with a 1.27 ± 0.01 mm average. Average relative fecundity was 103 ± 5 eggs g^{-1}. The relative fecundity and the diameter of mature eggs of the population sampled were positively correlated with TL (cm) (fecundity: $r = 0.315$, $P = 0.002$; egg diameter: $r = 0.561$, $P = 0.000$) and body weight (fecundity: $r = 0.216$, $P = 0.012$; egg diameter: $r = 0.511$, $P = 0.000$).

Catch per unit effort

In Lake Trasimeno the statistical records kept by commercial fishermen do not include catches of goldfish, as this species is not marketed. In the 1980s, the total commercial yield of the lake was $0.048\,t\ ha^{-1}\ y^{-1}$, while recently

(2002–2004) it has fallen to 0.023 ha^{-1} y^{-1} (unpublished data). At the end of the 1980s, tench (31.05% of total yield), European perch *Perca fluviatilis* (Linnaeus) (21.28%), sandsmelt *Atherina boyeri* (Risso) (20.59%), and eel *Anguilla anguilla* (Linnaeus) (13.46%) were the species most caught in the lake. By 2002–2004, the situation had changed markedly: sandsmelt (29.76%) was the most caught species, followed in decreasing order by tench (21.95%), largemouth bass *Micropterus salmoides* (Lacépède) (10.39%), eel (10.28%), carp (10.16%), and black bullhead *Ictalurus melas* (Rafinesque) (8.53%); catches of European perch, the most lucrative fish in the lake, had plummeted to 5.07% of the total yield.

Our research confirmed concerns over the abundance of goldfish in Lake Trasimeno: in the last few years the population has noticeably increased. In our samples, it was by far the most abundant species, representing 58.08% of the individuals and 73.23% of the whole biomass caught with nets, and 48.24% of individuals and 62.63% of the biomass captured by means of electrofishing. The average value of the CPUEs of goldfish caught by gill-nets was 10,175.48 $\text{g}10^{-2}$ m^{-2}, while with fyke nets the average value was 246.97 $\text{g}\,\text{h}^{-1}$ (Table 1). With regard to electrofishing, the number of transects was 97, while the average fishing effort applied was 10.72 min, for a length of 387.93 m. Goldfish were also the species most captured by electrofishing: the average value of the CPUEs was 606.50 g min^{-1}. A similar monitoring campaign conducted in 1993 by means of electrofishing turned up on *C. auratus*; comparison with the present data points up the changes that have occurred in the fish populations (Table 1).

Figure 3 shows monthly average values and pertinent confidence limits in the CPUEs of goldfish. The efficiency of electrofishing was not equal in all periods of the year: no fish were caught in winter; catches increased in spring, reaching a maximum in May; from June to August they declined and then increased again in autumn. The Kruskall-Wallis non-parametric test showed that the differences in CPUEs among monthly median values were highly significant ($\chi^2 = 26.05$, $P = 0.006$). The variability in catches was partly due to the different environmental characteristics of the sampling sites; however, statistically significant differences among the CPUEs emerged only with regard to vegetation. Indeed, goldfish were far more abundant near submerged vegetation (mean CPUEs ± S.E. = 758.46 ± 123.51 g min^{-1}) than in areas lacking vegetation (212.51 ± 74.32 g min^{-1}); these differences were significant (Kruskall-Wallis non-parametric test: ($\chi^2 = 5.90$, $P = 0.015$). When the sample was subdivided on the basis of the sampling season the average yields were higher in all seasons in the areas with submerged vegetation, but the CPUE was particularly elevated in spring, when the population was reproducing (areas with vegetation: 1,268.52 ± 291.60 g min^{-1}; areas without vegetation: 469.52 ± 181.90 g min^{-1}).

Gill-nets yielded abundant catches of goldfish at all times, without marked differences from one month to another (Fig. 3); the average CPUEs reached their

Table 1 Descriptive statistics of the CPUEs yielded by nets and by electrofishing.

	Gill-nets (g 10^{-2} m^{-2})			Fyke nets (g h^{-1})		
	Sample size	Mean	Standard deviation	Sample size	Mean	Standard deviation
Goldfish	84	10,175.48	9,733.86	12	246.97	202.88
European perch	84	275.25	1,485.69	12	1.99	4.90
Pumpkinseed	84	214.39	1,523.93	12	5.87	9.05
Rudd	84	2,018.21	4,319.34	12	1.39	4.81
Tench	84	1,388.68	2,899.12	12	13.54	20.50
Largemouth bass	84	520.32	1,304.61	12	133.33	456.66
Black bullhead	84	363.76	1,205.45	12	16.04	15.83
Pike	84	80.05	648.55	12	0.00	0.00
Eel	84	0.00	0.00	12	3.47	6.61

	2003–2004			1993		
Electrofishing (g min^{-1})	Sample size	Mean	Standard deviation	Sample size	Mean	Standard deviation
Effort (min)	97	10.72	6.17	14	56.07	33.75
Length (m)	97	387.93	233.31			
Goldfish	97	606.50	931.89	14	0.00	0.00
Tench	97	45.62	89.35	14	199.40	95.35
Rudd	97	17.13	51.20	14	17.65	32.91
Topmouth gudgeon	97	0.51	1.90	14	0.00	0.00
Black bullhead	97	3.10	15.32	14	13.05	12.42
Largemouth bass	97	39.84	82.74	14	20.65	24.09
Pumpkinseed	97	0.98	4.51	14	9.29	7.10
European perch	97	0.65	2.17	14	1.94	1.69
Pike	97	3.98	17.24	14	47.06	35.59
Sandsmelt	97	1.26	4.41	14	0.00	0.00
Carp	97	253.63	709.63	14	0.00	0.00
Eel	97	6.64	25.94	14	2.22	3.08
Bleak	97	0.10	0.63	14	0.00	0.00

highest values in the period preceding reproduction and during the reproduction period. However, the nets also showed good sampling efficiency in winter, when goldfish reduce their activity and move offshore. The Kruskall-Wallis nonparametric test showed that the differences in CPUEs among monthly median values were not significant ($\chi^2 = 10.70$, $P = 0.469$).

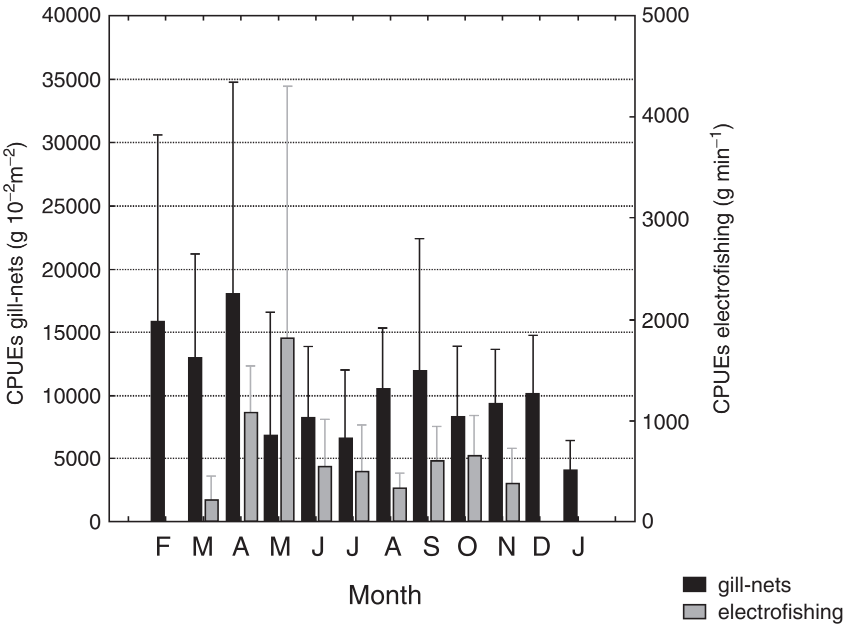

Fig. 3 Goldfish: monthly average values (with upper confidence limits) of the CPUEs yielded by electrofishing and by gill-nets.

CONCLUSION

The main characteristic that determines the high invasive potential of the goldfish is its great adaptability and its ability to tolerate extreme environmental conditions. Another important factor in its success is its growth capability, which enables this species to rapidly reach a size that makes it safe from predators in Lake Trasimeno. Predation on *C. auratus*, as on *C. carassius*, is size-dependent (Piironen and Holopainen 1988, Bronmark *et al.* 1995), predators preferring individuals of small size (Holopainen *et al.* 1991, Tonn *et al.* 1991). Its reproductive biology – precocious maturity, ability to reproduce by gynogenesis, high fecundity, and reproduction several times per year – is also a prerequisite to the invasive potential of this species.

In dealing with invasive species, eradication is obviously the favoured strategy and several studies have demonstrated its success (Chapter 34). However, success has been limited to small, isolated biotopes, on a local scale and in the first stages of invasion (Zavaleta *et al.* 2001). Efforts fail when eradication is not complete and if re-invasion is likely; in such cases, an *r*-strategist like the goldfish can rapidly increase. For this species, therefore, it seems preferable to adopt a control programme aimed at reducing the density of the unwanted populations and at maintaining it below an impact threshold (Mueller 2005).

The adoption of a particular strategy depends both on the assessment of its costs/benefits and on its potential to be successful (Myers *et al.* 2000). Generalization is difficult, as the choices vary according to several aspects, which also regard the economic and social context. In lakes, netting probably remains the most common and effective method of keeping down an invasive fish population, although a substantial effort was required: various mesh size were necessary to target the full range of size classes present. In the Rotopiko Lake (New Zealand) the eradication of rudd made with nets alone was unlikely and additional control techniques were required (Barnes *et al.* 2003). Where commercial fishermen operate, a good strategy of control may be to encourage the harvesting of invasive populations, for example by offering financial incentives or encouraging the trade in fish or fish parts (e.g. eggs).

Electrofishing is a specific sampling technique for shallow water, and habitat preference among species or life stages affects their vulnerability to it (Reynolds 1996). In favourable situations, this sampling technique can be effectively combined with the use of nets in the containment of some invasive fish populations. These results have application for managing goldfish because they should be easier to remove when they are aggregated: in a goldfish removal project conducted at Medical Lake (Washington, USA) in 1983, 17,837 goldfish were harvested by electrofishing over a period of seven days. The efficiency of the procedure was quantified by comparing goldfish county and gill-net CPUEs: an estimated 95–99% of the goldfish were removed (Scholz 1984). Electrofishing has some advantages over gill-nets: it causes little injury to the fish captured and it exerts modest selectivity regarding the size of the specimens. In spring, when goldfish and other cyprinids congregate in shallow, vegetated areas to reproduce, it can be effectively used without greatly affecting other species.

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