

Parasites of introduced goldfish (*Carassius auratus* L.) in the Massaciuccoli water district (Tuscany, Central Italy)

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Abstract

This study was carried out from 2010 to 2012 in the district of Massaciuccoli, Italy (lake, marsh and reclaimed areas with drainage channels). In this area the goldfish (*Carassius auratus* L.) is an introduced species. Morphometric characteristics were determined and parasites were isolated and identified in 103 fish, 32 of which were infected, including 11 by more than one parasite species.

Introduction

The water district of Massaciuccoli is an eutrophic coastal basin, located in Tuscany (central Italy) in the provinces of Lucca and Pisa and includes the lake, marsh and reclaimed areas with their drainage channels (Chelucci, 2005). The average depth of the lake is 2.5 meters, with a variation of 90 cm between the dry summer season and the rainy winter. The average pH of the water is 8.2, and the average temperature ranges from 7°C in winter to 22°C in summer (Spandre et al., 1997). In the last century the fish fauna reflected a progressive increase in introduced species, which tend to be very resistant (Gozlan et al., 2010), to the disadvantage of the species that evolutionarily originated in the basin (Alessio et al., 1992).

The goldfish (*Carassius auratus* Linneus 1758)

is an introduced species in the basin. This fish is common in deep, slow, cloudy waters of rivers, channels, lakes and ponds and can live also in brackish waters near the mouth of watercourses. It is highly resistant to a lack of oxygen and temperature variations. Its diet is omnivorous and includes invertebrates (insects, crustaceans, rotifers, molluscs, worms), eggs of other fishes, plants and organic debris at the bottom. Reproduction requires temperatures of around 20°C. Eggs are laid on vegetation. In this species gynaogenesis is possible, i.e. eggs can be activated by male gametes of other related species such as crucian carp (*Carassius carassius*) and carp (*Cyprinus carpio*). Without a true fecundation, eggs develop embryos that receive maternal genes and therefore produce a progeny of only females.

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This species was brought to Europe from East Asia for ornamental purposes. The release of the goldfish into the natural environment has given rise to feral populations. Now the goldfish is widespread throughout almost all Europe. It was introduced in Italy in the seventeenth century and today it is present in almost all regions (Chelucci, 2005).

From a previous more extensive study (Mascioni et al., 2015), it appears that in the Massaciucoli district, the fish are generally highly infected by parasites, especially ectoparasites. Parasites can have a considerable impact on the growth and behaviour of fish (Scholz, 1999) and cause mortality in cases of a high parasitic burden.

The purpose of this study was to identify the parasites of the goldfish in the Massaciucoli district, and to estimate their prevalence.

Materials and methods

From July 2010 to June 2012, 103 goldfish were caught in the water district of Massaciucoli. The sampling sites were chosen according to the different degrees of water pollution and presence of fish. Commercial fishing gear (fixed networks, mobile networks and "bertovelli" (movable trap nets) and sport devices (fishing rods) were used. The fish were transported in a portable refrigerator and analyzed at the Department of Veterinary Science, University of Pisa.

The following morphometric parameters of the fish were determined: total length from the apex of the mouth to the apex of the caudal fin and weight (accuracy: ± 1 mm and ± 1 g, respectively). The condition factor K of each subject was evalu-

ated according to Beckmann's formula (1948). If P is the weight in grams and L is the length in centimeters, it follows that:

$$K = (P / L^3) * 100, P = \beta * L^\alpha$$

The exponent α in the preceding equation varies generally from 2 to 4, and is equal to 3 in the case of isometric growth and higher than 3 for stocky subjects.

Skin, eyes, gills, digestive system, liver, bladder and kidneys of each fish were examined for the presence of ecto- and endoparasites. Diagnostic procedures were based on external observations of the skin and subsequent examination of various specimens of the fish under a stereomicroscope (magnification 8-35X) and an optical microscope (10X, 40X). The parasites found were identified according to different keys (Moravec, 1994; Yamaguti, 1963).

For the statistical analysis, the prevalence of parasites and its 95% confidence interval (CI) were calculated. Linear univariate regression was carried out in order to calculate the alpha and beta parameters in the above equation (after using logarithms). In addition, multivariate logistic regression was carried out, taking the positivity of the fish to parasites as the dependent variable, and length, weight and gender as covariates. Significance of the tests was reached for P values less than 0.05.

Results

In the sample of 103 goldfish, 15 were males, of which two were infected by parasites, and 88 were females, of which 30 were parasitized.

Fish morphometric parameters were as follows:

average length 28.7 cm (CI 27.9-29.5 cm), average weight 479.6 g (CI 437.6-521.1 g) and condition factor K 1.92 (CI 1.81-2.03). There was no significant difference for these parameters in relation to gender. The coefficients α and β in Beckmann's equation, as estimated by linear regression techniques, were 3.00 (CI 2.65-3.34) and -3.98 (CI(-5.14)-(-2.82)), respectively.

Table 1 shows isolated parasite species from the goldfish. The total prevalence of infected fish was 31.1% (CI 22.2-40.0%); 29 specimens had only ectoparasites, 2 had only endoparasites *Diplostomum spathaceum* (Digenea: Diplostomatidae) in one lens and *Botriocephalus* spp (Eucestoda: Bothriocephalidae) in the intestine and 1 had mixed infection *Gyrodactylus elegans* (Monogenea: Gyrodactylidae) on the gills and nematodes of the Capillaridae family in the intestine.

The prevalence of parasitic infections was not significantly different in respect to gender.

Logistic regression analysis supports that positivity to parasitic infection depends on the length of the fish (P value=0.014): the prevalence was lowest in large fish, i.e. adults, compared to smaller fish.

Discussion

No gross pathology was observed in 103 goldfish examined. From the mean K factor, it appears that these fish were well nourished. In addition, the prevalence of parasitic infection in this species was lower (31.1%, CI 22.2-40.0%) compared to other species in the district, in particular carp (66.0%, CI 58.3-73.6%) (Macchioni et al., 2015). This indicates the high adaptability of the goldfish even in habitats with poor ecological conditions such as the Massaciucoli district,

which can result in an increased susceptibility of other host species to parasites (Chubb, 1997; Galli, 2000). From recent data of ARPAT (2010-2013) the Massaciucoli waters are dark, cloudy and eutrophic, with high concentrations of nitrogen and phosphorus from intensive farming around the lake and a high organic load. Similar adaptability of the goldfish has been observed in the water reservoir of Corbara (Umbria, Italy) (Pedicello et al., 2010).

The fact that females prevailed in the sample (N=88) might be related to the type of reproduction, as reported in Pedicello et al. (2010).

The parasitological investigation revealed high infection levels of ectoparasites (in 31 goldfish), probably affected by specific water conditions, like slow circulation, higher water temperature and high concentration of organic matter (Galli, 2000; Ghittino et al., 2004). Also, a general increase of the average temperature of water by 1-2 degrees in the last fifty years could support parasite proliferation (Chelucci, 2005).

Larger fish appear to be less frequently parasitized than smaller ones potentially due to the death of young smaller fish or their lesser immunocompetence (Poulin, 2000). *Trichodina* spp. and *Trichodinella* spp. (Ciliophora: Trichodinidae) had the highest prevalence in this study, 9.7% and 13.6%, respectively. Their widespread occurrence and comparatively high prevalence might be explained by their capability to temporarily survive on several other non-fish hosts (Lom, 1995) and high organic load in Massaciucoli district's waters.

Other frequently found ectoparasites were *Dactylogyrus vastator* (Monogenea: Dactylogy-

Table 1. Parasites of the 103 goldfish captured, location on the fish, their prevalence % with a 95% confidence interval (CI) and multiple infections of the 32 parasitized goldfish.

| Parasite species (localization) | Infection order | | | | N. fish | % | CI |
|---|-----------------|--------|--------|--------|---------|-------|------------|
| | Quadruple | Triple | Double | Single | | | |
| Protozoa | | | | | | | |
| <i>Trichodina</i> spp. (skin, gills) | x | x | x | x | 10 | 9.71 | 3.99-15.43 |
| <i>Trichodinella</i> spp. (skin, gills) | x | x | x | x | 14 | 13.59 | 6.97-20.21 |
| <i>Apiosoma cylindriciformis</i> (gills) | x | x | | | 2 | 1.94 | 0-4.60 |
| Platyhelminthes | | | | | | | |
| <i>Dactylogirus vastator</i> (gills) | | | x | x | 6 | 5.82 | 1.30-10.34 |
| <i>Gyrodactylus elegans</i> (skin, gills) | x | x | x | | 9 | 8.74 | 3.28-14.19 |
| <i>Diplostomum spathaceum</i> (eye) | | | | x | 1 | 0.97 | 0-2.86 |
| <i>Botriocephalus</i> spp. (intestine) | | | | x | 1 | 0.97 | 0-2.86 |
| Nemathelminthes | | | | | | | |
| Capillaridae (intestine) | | | x | | 1 | 0.97 | 0-2.86 |
| Crustacea | | | | | | | |
| <i>Lernaea cyprinacea</i> (skin) | x | | x | x | 3 | 2.91 | 0-6.16 |
| <i>Argulus foliaceus</i> (skin) | | | | x | 1 | 0.97 | 0-2.86 |
| infection order n. fish | 1 | 1 | 1 | 1 | 7 | 5 | 5 |
| | | 3 | 1 | 1 | 1 | 1 | 1 |

ridae) (prevalence 5.8%) and *Gyrodactylus elegans* (prevalence 8.6%), monogeneans parasitizing gills and skin. The high prevalence of these parasites could be explained by their high reproduction rate and by direct life cycle.

Argulus foliaceus (Crustacea: Branchiura) was isolated from one individual, as in Noaman et al. (2010).

Interestingly, five identified parasitic species in this study were also found in goldfish exported to other countries for ornamental purposes from Sri Lanka (Thilakarathne et al., 2003). The goldfish of Massaciuccoli are often used for aquaculture sport fishing, and therefore their parasites may have been introduced into other water districts. Despite being prohibited, sometimes these fish are eaten so that their parasitological fauna should be investigated in respect to potential presence of zoonotic parasites.

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