Goldfish (Carassius auratus)

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Goldfish (*Carassius auratus*)

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Culum Brown, David Wolfenden, and Lynne Sneddon

23.1 History and Context

23.1.1 Natural History

Goldfish (*Carassius auratus*) are members of the cyprinid family (carp and their relatives). They originated in Southeast Asia, although the cyprinid family covers a far wider global range. Because of accidental and deliberate introduction into the wild (Angeler et al. 2002), goldfish are now found worldwide, with a few exceptions such as Greenland and Antarctica. *C. auratus* are classified as least concern (IUCN 2015).

Goldfish are usually considered a temperate water fish; however, they may survive in temperatures below 10 °C and up to 30 °C. Collectively, their broad environmental tolerances mean that they can be found inhabiting a very wide range of habitats. Their natural diet is very varied, with wild goldfish eating anything from terrestrial insects to vegetation to detritus (Richardson et al. 1995; Pinto et al. 2005). Goldfish show a variety of social behaviours and are often found in the company of other goldfish (Pitcher and Magurran 1983). Breeding typically occurs in spring, and males chase and court gravid females. Mate attraction and species recognition involves pheromones (Sisler and Sorensen 2008). Females lay eggs in aquatic vegetation, and the eggs are

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adhesive and hatch in 2 to 3 days. Under optimal conditions, fry grow rapidly and can be sexually mature within a year. In captivity, goldfish typically live for 5–10 years, but in large ponds they can live for up to 30 years. The oldest goldfish on record died aged 43.

As shallow water fish, goldfish vision is most sensitive to red, green, blue, and ultraviolet wavelengths (Neumeyer 1992). Their vision often corresponds best to vertical orientated stimuli, e.g. aquatic vegetation (Mednick and Springer 1988; Warburton 1990). Goldfish can differentiate certain shapes, colours, and sounds (e.g. Wyzisk and Neumeyer 2007; Shinozuka et al. 2013) and can remember associations for as long as a year (Brown et al. 2006), which can help foraging in anti-predator behaviour (Brown et al. 2011). They can also sense vibration, and their hearing capabilities are sensitive across a broad range of frequencies (Fay and Popper 1974). Goldfish can also detect different odours in the water, which they can use to find food, avoid predators, or preferentially associate with one another (Sisler and Sorensen 2008). Their skin cells can release an alarm substance when the skin is damaged that prompts other goldfish to display anti-predator responses such as shoaling or reduced feeding (Zhao and Chivers 2005; Brown and Laland 2011).

23.1.2 Domestic History

Goldfish were originally kept in China at least 2000 years ago, where they were primarily raised as food fish. By around 800 CE, rearing the orange (gold) morph in ponds became commonplace and goldfish had an important role in Chinese culture. Goldfish were exported to Japan and then to Portugal and the rest of Europe (Brewster and Fletcher 2004). Goldfish are also used in laboratory research (e.g. to study memory, Rodríguez et al. 2006). Once goldfish were being reared indoors, a number of morphs were produced through selective breeding (Zhen 1988). Today, more than 120 varieties exist which vary in their shape, colours, fin structure, and the morphology of their eyes (Komiyama et al. 2009), including the 'comet' variety, which closely resembles the wild type. Various extreme morphologies have been developed, such as 'bubble eye' goldfish, selected for large sacs under each eye (UFAW 2013). Many, if not all, of these lines can revert to wild type in just a few generations after being released to the wild.

23.2 Principles of Fish Welfare

23.2.1 Diet

Goldfish are generalist omnivores and eat a range of food varieties, from insects to plants. A balanced diet can be provided with some standard commercial flake and pellet foods, with other food types added. As a rule of thumb, goldfish should be fed only as much as they can eat in a few minutes, so that the breakdown of additional food does not cause nitrates, nitrites, and ammonia to build up in the water, which can cause irreversible gill and other damage.

Goldfish are motivated to forage amongst substrates and aquatic vegetation. They appear to forage more in sandy substrates than gravel, pebbles, or cobbles, suggesting

that these latter substrates are less suitable (Smith and Gray 2011). The addition of live food such as mosquito larvae or bloodworms can be a source of additional enrichment for the fish. Goldfish can rapidly learn the time and place of feeding (Gee et al. 1994) and may show signs of anticipation when it is meal time, for example looking at their owner and waiting in a designated feeding area. They therefore respond well to routine, so long as it is maintained. This learning can also allow owners to train goldfish to feed themselves, for example using 'demand feeders' that deliver food when a submerged lever is nudged by the fish.

23.2.2 Environment

All goldfish need adequate space for shoaling, keeping adequate distances between individuals, maintaining adequate water quality, and allowing all goldfish to reach their full size potential. This requires ponds and aquaria to be many times the expected adult sizes, depending on the number of fish kept together. Common goldfish can reach as much as 60 cm in length in suitable conditions (Orme 1991). Tanks and ponds should be secure and situated so as to ensure that the fish cannot escape into nearby waterbodies during floods.

Although goldfish may tolerate some variation in water parameters, poor water quality can be fatal, and some fancy varieties are at particular risk. It is better to perform small, frequent water changes than change all the water together to avoid causing chemical or thermal shock. The volume and frequency of water changes depend on the water quality, and owners should measure water parameters regularly and carefully using standard aquarium test kits (Table 23.1), particularly in small aquaria where the water quality can quickly deteriorate. Any new water should be dechlorinated before being added to the tank because excessive chlorine can be toxic. Goldfish are relatively resilient to changes in salinity, but acute exposure to high salt concentrations can result in high mortality.

Goldfish may be kept indoors or outdoors, although optimal temperature ranges depend on the strain. As examples, outdoor ponds may be suitable for comet variety goldfish even in cool climates, whereas some 'fancy' fish are less hardy. Similarly, although goldfish may survive in low dissolved oxygen levels, this is unsuitable. Goldfish may obtain additional oxygen by gulping air at the water surface. Full spectrum lighting designed for shallow, tropical species normally suit goldfish, although too much light, particularly direct sunlight, can encourage algal growth. Prolonged exposure to noise can result in hearing loss and high levels of stress (Smith et al. 2004). Indoor goldfish

Table 23.1 Ideal aquarium water quality conditions for goldfish.

Ammonia	<0.1 ppm
Nitrite	<0.1 ppm
Nitrate	<75 ppm
pH	6.5–7.5
KH	70–140 ppm
GH	150 ppm
Temp	18–24 °C

tanks should therefore be kept in places that are relatively free from loud noises, particularly repeated tapping on the glass by people or disturbance by pets.

Tank substrates should be provided to meet behavioural needs for manipulation and foraging, such as appropriate freshwater sand. The manipulation of sifting the sand with their mouths may be a behavioural need, which cannot be fulfilled with larger pebbles or cobbles (Smith and Gray 2011). Substrates and sediments should be kept clean, particularly to remove debris from gravel and to prevent anaerobic fauna development in sand. Sand is a compact substrate but is prone to becoming anaerobic, which can cause problems in aquarium hygiene if not kept clean. Sufficient live aquatic vegetation may be provided, but plant cover should not exceed 50% of the area of the aquarium. Goldfish often dig plants up while they are searching for food, so plants should be given time to become established before any fish are introduced. Care should be taken not to uproot plants during cleaning.

In consideration of the relatively complex cognitive abilities goldfish display, their environment should allow for expression of natural behaviour. However, some degree of familiarity may allow fish to adapt to their environment (Pitcher and Magurran 1983) and avoid fear of novelty.

When transporting goldfish, care should be taken to minimise thermal and physical disturbances. Goldfish are often sold and transported in small plastic bags (Figure 23.1). These risk being shaken, cooling, and being located next to sources of fear such as other pets such as dogs or cats. In addition, leaving goldfish too long in the transportation container can lead to changes in water quality such as deoxygenation and a build up of ammonia. Following transportation, goldfish need to be acclimatised to the water into which they will be put, to avoid any sudden thermal or other shocks.

Figure 23.1 A fish in a small transportation bag (this fish was then swallowed whole, leading to a successful animal welfare prosecution) (*Source:* Courtesy RSPCA.)

23.2.3 Animal Company

Goldfish are motivated to shoal and may form schools in large ponds. The strength of this motivation is shown by the fact that, in one study, goldfish would pay a cost (receiving electric shocks) to access the social company of another goldfish (Dunlop et al. 2006). Moreover, isolation stress can interfere with memory formation (Laudien et al. 1986). Apart from being a natural defence against predators, shoaling has other benefits. Larger shoals are more likely to discover the location of new foraging patches because they are able to copy the behaviour of their shoal mates (Pitcher et al. 1982). The behaviour of one fish on finding food attracts others to the location.

However, although goldfish tend not to be aggressive to one another, owners should ensure that fish are compatible and avoid environmental challenges such as overcrowding that may lead to aggression. Maintaining stable groups of familiar tank mates may also reduce the potential for stress during introductions. Given their sensitivity to alarm substances, the presence of injured goldfish may induce stress and unusual behaviour in others, such as food avoidance, tight schooling, or hiding. Anecdotal evidence suggests that some fish may show signs of aggression to injured fish, and fish may need short-term isolation during treatment.

Goldfish may be kept with certain other species of fish, provided such fish do not out-compete or attack the goldfish. Goldfish may perceive other pets as predators, such as cats, dogs, and terrapins. In particular, outdoor ponds should be protected to prevent predation by birds.

23.2.4 Human Interactions

Direct handling and disturbances should be minimised to avoid injury. Anecdotal evidence from owners suggests that goldfish can distinguish between different members of the human family based on vision alone. However, it seems unlikely that goldfish form particular affiliative relationships with humans or enjoy the interactions with humans in general, beyond any response to feeding. Their learning ability also allows goldfish to be trained to perform particular actions (Mackintosh et al. 1971; Breuning et al. 1981). Any such training should be carried out in ways that minimise disturbances to the goldfish, use rewards rather than punishment, and that aim at providing enrichment for the animals' benefit, rather than teaching tricks for humans'. At the same time, their learning ability may also be expected to increase fear responses following previous unpleasant interactions, such as handling or environmental disturbance.

23.2.5 Health

Goldfish can be affected by a variety of health problems (Table 23.2), including bacterial infections (e.g. fin-rot and ulcers; Figure 23.2), fungus outbreaks (e.g. fungal growths on the skin), and parasitic infestations (e.g. whitespot disease [*Ichthyophthirius multifiliis*]). They may also suffer from noninfectious diseases such as skin tumours (e.g. benign fibromas; Figure 23.3). Many common health problems are linked to poor water conditions, such as skin or gill damage arising from high levels of ammonia in the water, which generally indicate a lack of water changes or inadequate filtration. New fish should be quarantined to reduce the risk of introducing infectious diseases. The feeding of wild-harvested live foods (e.g. pond collected water fleas and aquatic worms)

Table 23.2 Selected health problems in goldfish.

Condition			Welfare effects
Infectious or parasitic	Bacteria	*Aeromonas* species	Skin ulcers; osmoregulatory stress; secondary infections.
		Flavobacterium columnare	Fin rot
	Fungi (water moulds)	*Saprolegnia* spp.	Mild to severe skin damage.
	Internal Parasites	Gut nematodes and gut cestodes	Mild to moderate debilitation; emaciation; lethargy
		Ichthyophthirius (whitespot disease)	Skin, fin and gill damage; respiratory stress; secondary infections
	External Parasites	Various ecto-parasitic protozoa (e.g. *Chilodonella; Ichthyobodo; Trichodina*)	Skin and fin damage; gill damage and respiratory stress (caused by certain species of parasitic protozoa); secondary infections
		Argulus (fish-louse)	Skin damage; anaemia; secondary infections
Water quality problems		Low dissolved oxygen (e.g. as a result of overcrowding; inadequate aeration; water pollution)	Respiratory stress
		Chlorine poisoning (caused by failure to dechlorinate tapwater)	Gill damage; respiratory stress.
		Ammonia poisoning	Gill damage; respiratory stress
		Nitrite poisoning	Respiratory stress.
Tumours		Skin fibroma	Generally benign
Buoyancy problems		Positive buoyancy (fish floats at surface); negative (fish sinks)	Distress; difficulty in obtaining food; drying of air-exposed skin in cases of positive buoyancy
Traumatic		Physical handling by owner	Distress; skin damage; skin infection
		Aerial emersion	Distress; skin and gill damage; respiratory stress

Figure 23.2 Goldfish with skin ulceration (probably as a result of *Aeromonas* bacteria) (*Source:* courtesy Peter Burgess).

Figure 23.3 Goldfish with skin fibroma (*Source:* courtesy Peter Burgess and Stan McMahon).

is inadvisable because these wild prey organisms can transmit certain diseases (e.g. parasitic worms) to goldfish. Owners should also regularly check their goldfish closely for signs of diseases, such as the 1-mm small white spots on body and fins that suggest *Ichthyophthirius*.

Treatments depend on the disease. Some conditions require a water change or a salt bath (e.g. fungal diseases may respond to salt concentrations of about 2–3 g/L). Others may require commercial disease remedies added to the water, following the manufacturer's instructions. More serious diseases, such as internal bacterial infections, require antibiotics. Many treatments have a low safety margin and can be highly stressful to

fish if the recommended dosage is exceeded (e.g. formalin and malachite green). Many treatments can also kill the beneficial waste-removing bacteria in the filter and gravel, with potentially catastrophic effects on water quality (e.g. some antibiotics and methylene blue). For some diseases it may be necessary to medicate the whole aquarium or pond, particularly for diseases caused by organisms that have free-living stages in the water (e.g. whitespot parasites). In other cases, the affected fish may be treated in isolation.

Some of the more extreme phenotypes, such as bubble eye or fancy fins, have implications for welfare and health (Table 23.3). The bubbles under the eye are prone to rupture if sharp objects are in the aquarium, with likely subsequent pain and risks of infection. Varieties with very fancy fins (e.g. butterfly tail) can have issues with sustained swimming. Certain fancy strains of goldfish are particularly prone to buoyancy problems due to swim bladder disorders and may float at the surface or sink to the bottom. Although the average life span is around 10–15 years, some fancy strains tend to live for shorter periods. Owners should obtain goldfish with less extreme body shapes which have been bred to be healthy pets.

23.2.6 Euthanasia

Acceptable methods of the euthanasia of goldfish are listed in Table 23.4. The most efficient method should involve two stages, the first to cause unconsciousness and the second to ensure death. Sedation may also be valuable for some methods. The first stage should involve either head trauma or an anaesthetic overdose by immersion or in larger goldfish, injection. Immersion can be slower and goldfish should be left in the anaesthetic for at least 10 minutes after cessation of opercular movement (Neiffer and Stamper 2009). Some immersion anaesthetics (e.g. MS-222) are highly acidic and will need to be buffered to a neutral pH. In any case, once all gill movements have ceased for a prolonged period, the second stage of euthanasia is to destroy the brain by pithing or exsanguination (blood loss). The owner needs to be competent and legally permitted

Table 23.3 Welfare issues associated with the breeding of some fancy goldfish strains.

Strain	Trait selected for	Impact on the fish
Bubble eye	Fluid-filled sacs under the eyes	Impaired vision and behaviour; injury; infection; pain
Celestial eye	Abnormal eye position where eyes point upwards to the 'stars'	Retinal degeneration and blindness; impaired behaviour
	Absence of dorsal fin	Movement affected; lack of stability and agility
Eggfish	Absence of dorsal fin	Movement impaired; lack of stability and agility
Pompom		
Lionhead	Excessive facial tissue	Restricted vision and breathing; infection; pain
Ranchu		
Lionchu	Absence of dorsal fin	Movement affected; lack of stability and agility

Source: UFAW (2013) www.ufaw.org.uk/fish.php.

Table 23.4 Methods of euthanasia for goldfish kept as companion animals (followed by a method to ensure death such as brain destruction or blood loss).

Method	Restraint required	Welfare risks
Anaesthetic overdose, immersion	Containment in limited water volume	Irritation of product (varies with type of anaesthetic drug used)
Anaesthetic overdose, injection into a vein	Handling for immobility Sedation advised	Must be done by a veterinarian to ensure efficiency of injection. Involves handling and emersion which will cause stress
Concussion	Handling for immobility in air Sedation advised	Emersion Possibility of recovery of consciousness if concussion not done properly or pithing or exsanguination does not take place immediately after concussion

to use the appropriate method. Flushing goldfish down the toilet may lead to a slow death or spread diseases into the natural waterways and is unacceptable.

23.3 Signs of Welfare Problems

23.3.1 Pathophysiological signs

Decreased survival or growth can generally indicate some sort of welfare issue, such as poor water conditions or insufficient space. Fast initial growth is normal but once fish reach maturity, growth should slow considerably. Signs of disease include an increased respiratory rate (i.e. faster gill beats per minute) and changes to the fins, skin, eyes, and overall body shape. A change in colour can be indicative of stress or disease; however, goldfish naturally alter in colour over time and may become very pale, even silver, as they reach old age. 'Dropsy', in which the body becomes distended with fluid and the scales stick out to give a pine-cone appearance to the body contour is normally a sign of poor osmotic balance which is commonly caused by bacterial infections.

23.3.2 Behavioural Signs

Reduced levels of activity, listlessness, a reduction of feeding behavior, or unusual levels of hiding are all signs that can indicate a problem such as poor water quality. A loss of buoyancy is indicative of swim bladder or diet-related issues or a variety of causes (Wildgoose 2007). Fish gulping at the surface may be normal feeding behaviour or a sign of poor water quality. Goldfish show anomalous rubbing behaviour when experimentally injected with acetic acid that is reduced by the analgesic drug morphine (Newby et al. 2009). This suggests that goldfish are capable of feeling discomfort and pain, which is alleviated through the administration of analgesics. Rubbing is also seen in the case of external pathogens which may be an attempt to remove them or may be

a sign of itchiness of the infection. Another carp species, koi, exhibit reduced feeding, decreased activity and spend more time lower in the water column post-surgery (Harms et al. 2005; Baker et al. 2013).

23.4 Action Plan for Improving Goldfish Welfare Worldwide

It is important to raise public awareness that goldfish have feelings, perceive pain, and so on. – such that they should be treated with the same care and respect as any other pet. Owners should be made aware that goldfish are not unintelligent or inactive, so that they provide adequate environments to meet their genuine needs. This is a cycle: keeping goldfish in more suitable and enriched environments may mean owners see a wider range of their potential behaviour. Goldfish should not be seen as disposable ornaments but as individual pets. Goldfish should only be kept by owners who have the commitment and knowledge to look after them for their entire lifetime, which is potentially for several decades. This means goldfish should not be given as prizes (e.g. at fairs) or as mascots as in the Chinese tradition of giving goldfish to wish good fortune.

Governments should set out minimum care standards specifically for pet goldfish, particularly with reference to minimal size of tank and isolating goldfish. In the absence of such legislation, responsible pet shops should ensure they only sell aquaria that can properly accommodate the fish as adults and sell goldfish in pairs or possibly as established groups dependent upon the owner's tank size. Greater research is also needed into the requirements of pet goldfish, for example, in terms of precise space requirements, environmental enrichment, and social housing. Research is also needed to evaluate the welfare issues associated with fancy forms that have impairments such as eye deformities and distorted backbones. When particular strains are shown to have health problems, they should not be bred or sold. Education of purchasers and breeders about the welfare impact of these genetic conditions is important and there may even be a case for regulation, although dog breed-specific legislation has proven problematic. More generally, veterinary surgeons need to have a greater involvement in the care of goldfish. Owners may be reluctant to obtain veterinary advice because of the difficulty of moving goldfish, their low financial value, high veterinary care costs, and the ease of obtaining nonprescription medicines. Veterinary surgeons need appropriate training so that they can provide sound advice.

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