

Trouble Outside the Tank:

Negative Impacts and Control of Invasive
Goldfish in British Columbia, Canada.

Prepared by Dr. Brian Heise of Thompson Rivers University for the
Invasive Species Council of BC

Executive Summary

The goldfish, *Carassius auratus*, is one of the most popular aquarium fishes in the world, but it is also one of the world's worst invasive species, capable of causing harm to local British Columbia (B.C.) lakes, ponds and rivers if released into the wild. This report reviews the factors that contribute to the invasive success of goldfish, the damage that they can cause to B.C. lakes and rivers, and possible management actions to suppress current goldfish populations and to prevent new introductions from taking place.

Goldfish possess a number of biological traits that make them extremely well-adapted to be a superior invasive species. Goldfish are omnivorous, feeding on plants, benthic invertebrates, zooplankton, and the eggs and larvae of amphibians, and possibly fish. They spawn multiple times in a season, and each female can produce up to 219,000 eggs. Goldfish are also reported to use gynogenesis, a form of reproduction in which females use the sperm of another species of minnow to stimulate egg division, which produces clones of the female and means that a single gravid female could conceivably start a new population. Goldfish can tolerate a wide range of environmental variables, including temperature, oxygen, pH, salinity and turbidity. Temperature modelling using Climatch indicated that goldfish could survive in lakes throughout most of B.C., although they require water temperatures of at least 15 °C for reproduction. Amazingly, goldfish can survive total anoxia (lack of oxygen) for several days or perhaps much longer, giving them an advantage over local fishes.

Goldfish have the ability to cause various types of biological harm to B.C. water bodies. Goldfish use a “suck, spit and pick” strategy of feeding on the soft bottom of lakes and rivers, which creates turbidity, which causes feeding and breathing problems for fish, and reduces light penetration for plants. Goldfish also harm plants by directly eating and uprooting them during benthic feeding. Goldfish in ponds can alter the food chains present, shifting the dominant plants present from macrophytes to algae. Goldfish also feed on amphibian eggs and larvae, and they potentially compete with native fishes for invertebrate food. Goldfish also carry 23 species of parasite, including some that can spread to sockeye salmon (*Oncorhynchus nerka*) and koi (an ornamental type of carp – *Cyprinus rubrofuscus*).

Eradication of goldfish populations requires the prolonged draining of a lake, or the use of the piscicide rotenone, neither of which is practical for medium or large lakes. For these larger water bodies, population suppression is the only practical action to be taken, and boat electrofishing done in the shallows during the spring spawning season is the best option. However, this treatment can get prohibitively expensive. The best overall strategy that should be taken by provincial and federal governments is to reduce the release of pet goldfish by the public. This should go beyond the excellent “Don't Let it Loose” behaviour change program and other public campaigns to include commitments from the pet industry to educate the public at the point of sale, and to ensure retailers adopt a policy of accepting the return of unwanted fish.



Table of Contents

1. Introduction.....	4
2. Identification & Classification of Goldfish	4
3. Distribution of Goldfish.....	6
4. Biology of Goldfish.....	9
5. Negative Effects of Introduced Goldfish	13
6. Methods of Introduction & Spread	16
7. Methods of Control for Goldfish.....	18
8. Management Recommendations	21
9. Acknowledgements	21
10. Literature Cited	211

1. Introduction

The goldfish, *Carassius auratus*, is one of the most popular aquarium fishes in the world. However, it is also one of the world's worst invasive species, capable of causing harm to local B.C. lakes, ponds and rivers if released into the wild. The main source of these populations is thought to be the release of unwanted pets into local lakes. The biology of goldfish allows them to prosper in a large variety of freshwater habitats; goldfish are tolerant to a wide range of oxygen, temperature, pH, and salinity levels. Goldfish are prolific spawners, and are also generalist feeders, competing with local fishes.

Goldfish can unfortunately cause problems in B.C. lakes. Their feeding causes harmful changes in turbidity, and reduces aquatic plant abundance. Goldfish also feed on salamander eggs and larvae, thus contributing to their decline.

This paper reviews the biology of goldfish, including their identification and classification, current and predicted distribution, feeding, reproduction, environmental requirements, and parasites and diseases. It goes on to discuss the negative impacts of introduced goldfish and outlines possible control strategies. The paper concludes with management recommendations to control current populations and to prevent new introductions in B.C.

2. Identification & Classification of Goldfish

The goldfish, *Carassius auratus* (Linnaeus, 1758), is a member of the family Cyprinidae (carps and minnows). In B.C., we have 17 species of minnow (McPhail, 2007), as well as the introduced fish carp (*Cyprinus carpio*) and tench (*Tinca tinca*), all from this family.

The morphology of goldfish has been described by Scott and Crossman (1973), Kottelat and Freyhof (2007); McPhail (2007) and Nico et al. (2025a)



Figure 1. Goldfish collected from Dragon Lake, B.C., June 29, 2017. Photo by Kwynn Bodman.

The goldfish is a deep-bodied minnow with a thick caudal peduncle and elongated dorsal fin. The head is broadly triangular, and the mouth lacks barbels. There is a single spine with a serrated posterior edge at the origin of the dorsal and anal fins. Large, cycloid scales numbering 25 – 31 (Nico et al., 2025a), 26 – 31 (Kottelat & Freyhof, 2007), or 27 – 30 (Scott & Crossman, 1973) are found along a complete lateral line. The red/gold colour of goldfish in the aquarium trade is not natural; feral goldfish populations vary in colour, from olive-green, golden brown to bronze, and may have black patches. An example of this colour variation can be seen in the goldfish from Dragon Lake, B.C., sampled by Kwynn Bodman and Brian Heise in June 2017 (Figure 1).

The sexes are difficult to separate, except during the spawning season, when males develop nuptial tubercles on their opercula, and often on their backs and pectoral fins.

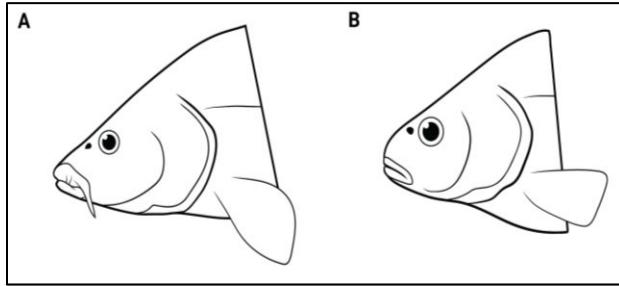


Figure 2. Head of a carp (A) and goldfish (B) showing the presence of barbels on the mouth of the carp, but not the goldfish. Source: McPhail (2007).

While it might seem obvious what a goldfish is, there has been considerable confusion regarding the species status of goldfish, with other species within the genus *Carassius*, and how to identify the species (Japoshvili et al., 2013; Nico et al., 2025a). Note that goldfish can be identified as different from carp (*Cyprinus carpio*) as goldfish lack the barbels on the mouth found in carp (McPhail, 2007; Figure 2). Species within the genus *Carassius* (including goldfish) can be identified as separate from native cyprinids by their long dorsal fin base, which has more than 11 rays (Scott & Crossman, 1973).

Over the last few years, other species of *Carassius* have been reported in B.C. In 2018, Halas, Lovejoy, and Mandrak (2018) reported the presence of the Japanese ginbuna (*Carassius langsdorfii*) (Temminck and Schlegel, 1846) from a pond on the University of British Columbia Vancouver campus (in addition to goldfish). Halas et al. did not examine goldfish populations from elsewhere in the province. Goldfish from Dragon Lake, B.C., were identified as *C. auratus* (B. Heise & J. Van Hamme, Thompson Rivers University, unpublished data). Although it has not been found in B.C., the Prussian carp, *Carassius gibelio* (Block, 1782) is widely distributed in Alberta (Elgin et al., 2014).

The species identifications listed above were all made using genetic analyses, not from morphological features. It is currently not possible to separate all of the species of *Carassius* using external morphological features, making identification of new populations of these species very difficult. The keys in Kottelat and Freyhof (2007) separate goldfish from Prussian carp based on the colour of the fish (golden-brown, bronze vs. silvery-brown), which is difficult given the large amount of intraspecific variation in colour seen in goldfish. The Royal BC Museum online key to exotic carps and minnows of B.C. (Hanke, 2017) will separate goldfish from crucian carp (*C. carassius*), but not from Prussian carp or the Japanese ginbuna. The three species of *Carassius* found in B.C. and Alberta are sufficiently similar morphologically that identification of these species is not possible using morphological features alone (Kalous et al., 2013).

Reports of “goldfish” in B.C. are usually based on morphological features. So it is also possible that some of these fish are misidentified, and not pure goldfish, but rather hybrids with other cyprinid species. Goldfish are known to hybridize with carp (Taylor & Mahon, 1977), as well as with crucian carp and Prussian carp, with both F1 and backcrosses being present with these *Carassius* species (Hänfling et al., 2005; Smartt, 2007).

There are problems with the traditional use of mitochondrial cytochrome c oxidase subunit I (COI) DNA analyses to positively identify which invasive species are present (Comia & Morris, 2024). Alternative analyses include the use of haplotype networks (Comia & Morris, 2024) and the use of cytochrome B based qPCR assays to analyze eDNA samples (Hambrook et al., 2025).

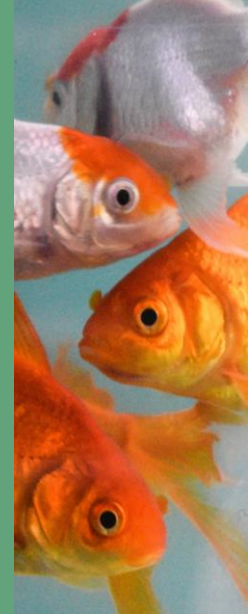
Uses of Goldfish

The goldfish is a popular pet fish around the world, with the development of 70 genetic “strains” with a range of phenotypes, as well as over 180 variants (Omori & Kon, 2019). Small goldfish are sold as “feeder” fish (Stone et al., 2003), which are used to feed larger carnivorous fishes, as well as snakes.

Wild goldfish are caught for food in China (Balon, 2004). In 2015, Chinese aquaculture produced 2.9 million tons of *C. auratus*, although the fish were described as crucian carp (Ministry of Agriculture-Bureau of Fisheries 2016), as cited in (Li et al., 2019).

Goldfish have been used in research as a model to study Parkinson’s and retinal degenerative diseases (Omori & Kon, 2019), and have been proposed as being more efficient than guppies (*Poecilia reticulata*) for control of mosquito larvae (Gupta & Banerjee, 2009).

Goldfish can be used as live bait in sportfishing in places where it is legal.



3. Distribution of Goldfish

Native to China, the Amur River Basin, and Korea (Balon, 2004), goldfish have been introduced around the world (Takada et al., 2010; Rylková et al., 2013; CABI, 2019; Nico et al., 2025a), as shown in Figure 3.

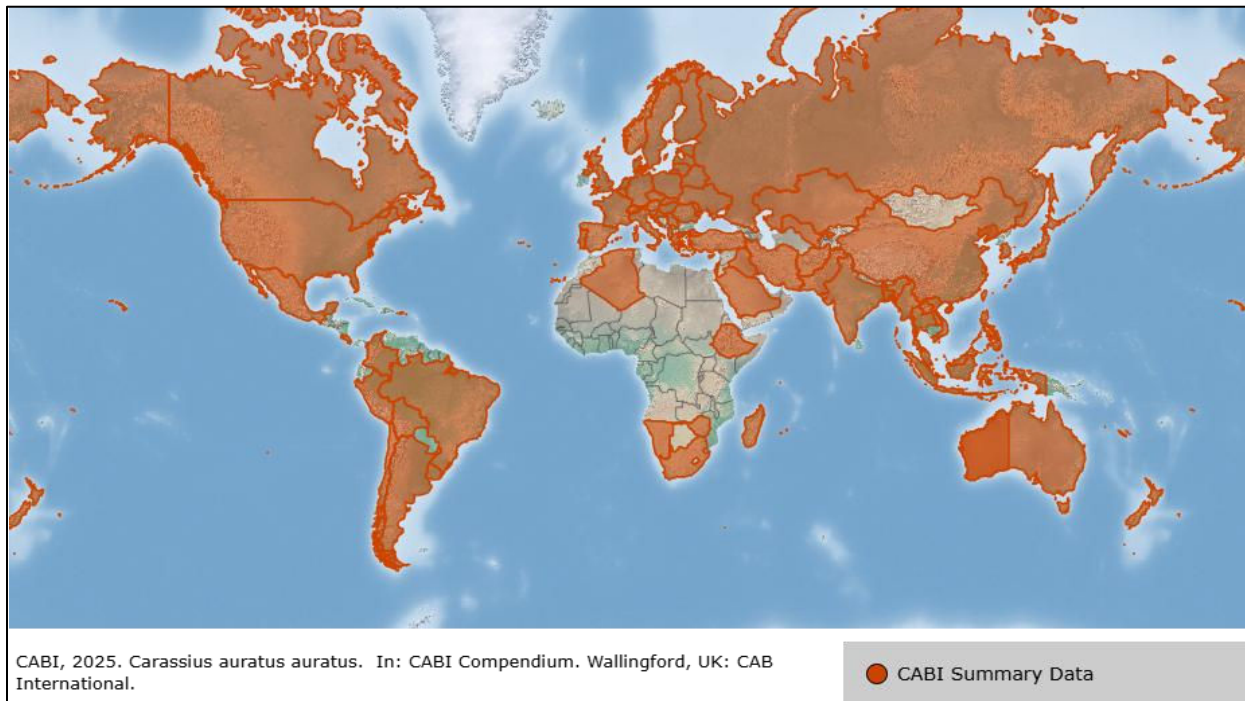


Figure 3. World distribution of introduced goldfish. Source: CABI Compendium. <https://www.cabidigitallibrary.org/doi/10.1079/cabicompendium.90563> (Downloaded June 24, 2025).



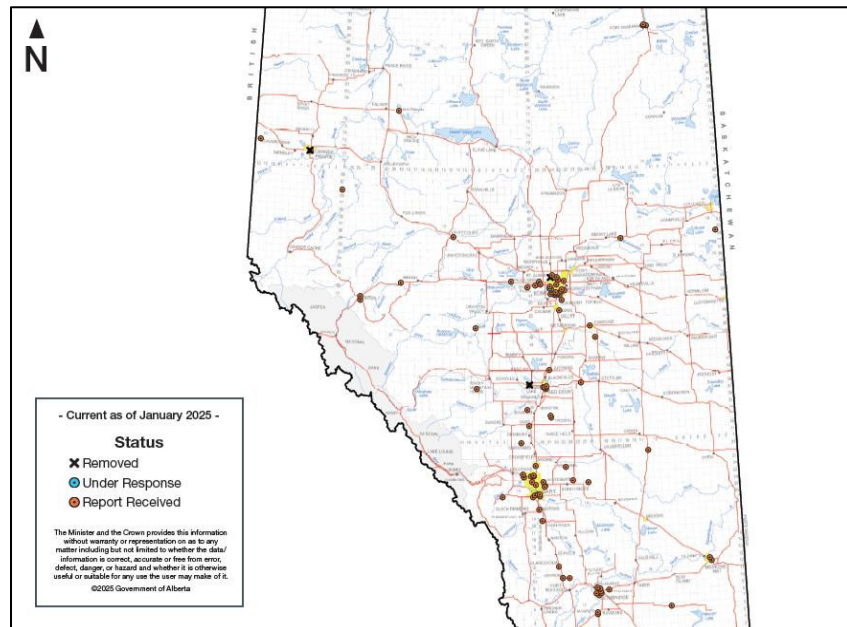
Figure 4. Distribution of introduced goldfish to lakes in British Columbia (red dots) as of May 2024. Map produced by the BC Ministry of Water, Land and Resource Stewardship based on: 1. BC Data Catalogue layers, 2. Data collected via the provincial Inspect app (confirmed reports only), and 3. iNaturalist (research grade reports only)

Goldfish are reported to occur throughout B.C. (Figure 4), with a concentration in Lower Mainland, but extending into the northwest corner of the province. Goldfish have also become established in watersheds to the south of B.C. in the United States, and to the east, in Alberta. Goldfish are widely distributed in Alberta (Figure 5). Goldfish can co-occur with Prussian carp in Alberta, and eDNA work has been used to determine the distribution of Prussian carp in the province (Hambrook et al., 2025). As of 2021, Prussian carp eDNA has been discovered in the Bow, Oldman, Red Deer and South Saskatchewan watersheds (Association, 2021).

Canada

Goldfish have been reported from various locations across Canada (Scott & Crossman, 1973), including British Columbia, Alberta, Ontario, Nova Scotia and New Brunswick (Canadian Rivers, 2019).

Figure 5. Distribution of goldfish in Alberta, Canada as of January 2025. Downloaded from <https://open.alberta.ca/publications/goldfish-distribution-map#summary> (Downloaded June 25, 2025).



United States

Goldfish are reported to occur in all of the United States, including the neighbouring states of Washington, Idaho, and Montana (Nico et al., 2025a) (Figure 6).

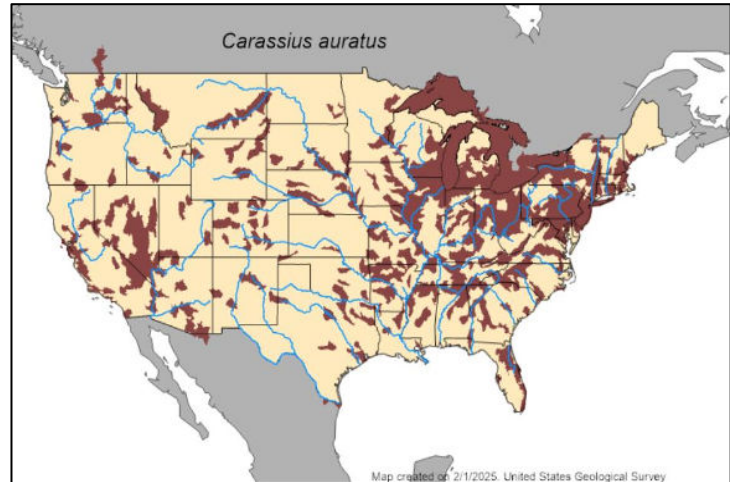


Figure 6. Distribution of goldfish in the United States of America as of February 2025; goldfish are not native to any of these watersheds. Source: Nico et al., 2025a. Downloaded from <https://nas.er.usgs.gov/queries/factsheet.aspx?SpeciesID=508> (Downloaded Feb. 2, 2025).

Potential future spread in B.C.

The potential spread of goldfish throughout B.C. based on temperature was modelled using the Climatch program of the Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES) (<https://climatch.cp1.agriculture.gov.au/climatch.jsp?>). Ten lakes where goldfish are currently established in B.C. (Table 1) were used to predict the spread of goldfish using a Euclidean algorithm (which uses the average of the climate variables), the complete set of temperature variables, and no rainfall variables. The climate dataset used was WorldClim v2 Sample 2019.

Table 1. Distribution of some recent (post-2008) introduced goldfish lakes in British Columbia, as of July 2019, which were also used to model climate effects on goldfish distributions in B.C. List compiled from discussions with BC Water, Land and Resource Stewardship fish biologists.

#	Name	Nearest Centre	Latitude	Longitude
1	White Lake	Blind Bay	50.88383	-119.26176
2	Little White Lake	Blind Bay	50.8766	-119.31368
3	Hidden/Lost Lake	Celista	50.96077	-119.42979
4	Yellow Lake	Okanagan Falls	49.33546	-119.76064
5	UBC Pond	Vancouver	~49.25384	~-123.24991
6	Pinecrest Lake	Whistler	50.00054	-123.1414
7	Alta Lake	Whistler	50.11678	-122.98152
8	Millar's Pond	Whistler	50.08734	-123.00884
9	Dragon Lake	Quesnel	52.94964	-122.42685
10	Lost Lake	Terrace	54.60601	-128.65296

The Climatch model predicted that only 4 out of 158 climate station locations in the province had a score of 0 or 1 (Figure 7), indicating that most of the province is suitable for goldfish. Not surprisingly, the better locations were in the southern half of the province, where temperatures are higher.

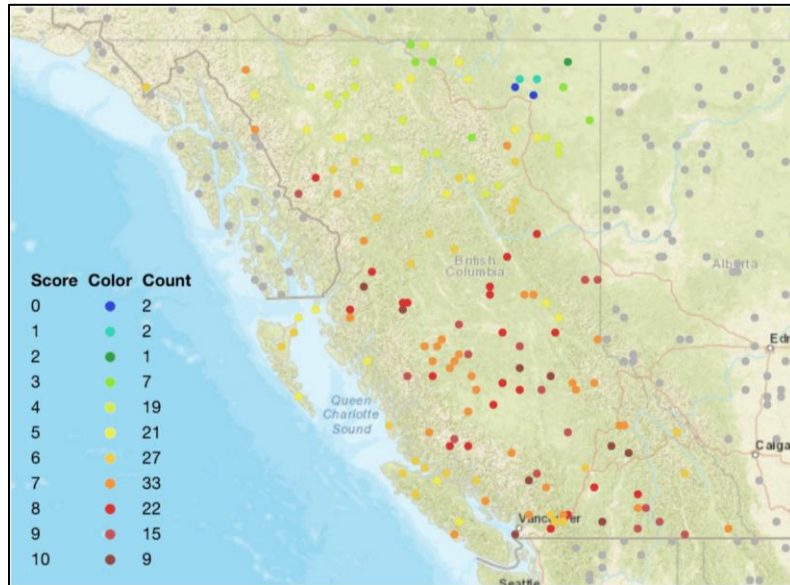


Figure 7. Map of Climatch (<https://climatch.cp1.agriculture.gov.au/climatch.jsp>) climate matches for goldfish (*Carassius auratus*) in British Columbia based on 10 goldfish lakes listed in Table 1. Scores of 0 = Lowest match, 10 = Highest match. Points on map represent available weather stations from the Climatch world database. Table on left of map shows the number of weather stations with each score.

The spread of goldfish in the northern part of the province will most likely be limited by their need for spring/early summer water temperatures of at least 15 °C for the initiation

of spawning (McPhail, 2007). This requirement, combined with the need for warm temperatures for juvenile rearing, suggests that summer temperatures in northern B.C. may be a limiting factor for goldfish. However, models of future climate change indicate that even parts of the Arctic will be suitable for goldfish by 2050 (Massey et al., 2025).

4. Biology of Goldfish

Goldfish have a number of biological characteristics, including their generalist diet, tolerance of adverse environmental conditions, including extremely low oxygen levels, and reproductive habitats that together make them a “superinvader.” Their unique biology is discussed below.

Feeding Ecology

Having a broad diet is an advantage to an invasive fish, and this holds true for the goldfish. Goldfish are omnivores, consuming benthic aquatic invertebrates (insects, molluscs, worms), zooplankton in the water column, and aquatic vegetation, including both rooted macrophytes and phytoplankton (Scott & Crossman, 1973; Archibald, 2011; Wydoski & Whitney, 2003; McPhail, 2007; Richardson, Whoriskey, & Roy, 1995; Gupta & Banerjee, 2009). Larger goldfish will also consume the eggs and larvae of salamanders (Monello & Wright, 2001). The diet of goldfish in two B.C. lakes has been examined by students in the author’s lab at Thompson Rivers University. The diet of Dragon Lake goldfish sampled in June 2017 comprised mainly cladocerans (65%), phytoplankton (18%) and chironomid larvae (14%) (K. Bodman, Thompson Rivers University, unpublished data). In White Lake, B.C., the diet of goldfish sampled in November 2015 was dominated by ostracods, chironomid larvae, and plant seeds (J. Glover,

Thompson Rivers University, unpublished data).

Goldfish consume both the eggs and larvae of eastern long-toed salamanders (*Ambystoma macrodactylum columbianum*) in Idaho (Monello & Wright, 2001). Goldfish are not known to feed on adult fishes but may feed on fish eggs and fry (see Nico et al., {2025a}).

The broad diet just described means that goldfish can feed at most levels of freshwater food chains, with the potential to cause disturbance within these food chains at high goldfish densities. Goldfish have also shown boldness (i.e., how they behave in a risky situation) in feeding experiments, a trait associated with enhancing dispersion (Dickey et al., 2022).

Life Cycle, Spawning and Growth

Although there are no published accounts of goldfish life histories in B.C. (McPhail, 2007), goldfish fry collected in Dragon Lake (B. Heise, unpublished data, Figure 8) indicate that goldfish are successfully reproducing in B.C. lakes. The details on goldfish life cycles below are based on other introduced goldfish populations from around the world.

Figure 8. Goldfish collected from Dragon Lake, B.C., June 29, 2017. Photo by Brian Heise.



Spawning

Goldfish will repeatedly spawn over their lifetime (i.e., they are iteroparous), typically spawning each year. There are no published accounts of goldfish reproduction in B.C. (McPhail, 2007), but there are for other introduced populations of goldfish from elsewhere in Canada, and around the world. Just over half of male goldfish reach sexual maturity in their first year, while most females mature by their second year (Lorenzoni et al., 2010). Goldfish spawning takes place in the weedy shallows of lakes and ponds in the spring when water temperatures reach 15° C (Kottelat & Freyhof, 2007), and can continue throughout the summer. Goldfish in Ontario's Hamilton Harbour undertook pre-spawning ("staging") movements into shallow spawning areas at mean daily temperatures of ~10 °C (Boston et al., 2024). This corresponded with a Cumulative Growing Degree Days (CGDD) of >250 (above 5 °C).

Goldfish are "portional" or "fractional" spawners, spawning multiple times in a season. Females will release 2–3 batches of eggs at intervals of 8–10 days (Balon, 2004). Two goldfish populations in Cambridge and Hamilton, Ontario, had bimodal spawning timing, with the majority of fish spawning in the spring (May to June), and a smaller group spawning later in August (Munkittrick & Leatherland, 1984; Boston et al., 2024).

During the spawning season, males develop tubercles on their gill covers and pectoral fins (Wydoski & Whitney, 2003). Single females spawn with several males, although one Italian population had an extreme sex ratio of 1 male: 19 females (Lorenzoni et al., 2010). The eggs are 1.25–1.46 mm in diameter, are adhesive, attaching to plants, and are laid singly or in groups of two or three (Battle, 1940), after which they are fertilized by the males. The eggs hatch in 3 days at 25 °C, and in 3–4 days over the range of 18.5–28.9 °C. Fecundity (number of eggs produced per female) is positively correlated with the size of the female. Reports of goldfish

fecundity in the literature vary greatly, from “probably” 500–2,000 for goldfish in the United States (Wydoski & Whitney, 2003), to “about” 3,000–20,000 (McPhail, 2007), to a recorded range of 1,491–52,033 in British ponds (Lorenzoni et al., 2010). Fecundity of goldfish in Dragon Lake, B.C., were reported to range from 12,930 (L. Sandy, TRU, unpublished data) to an average of 50,000 (Mike Phelps, BC Ministry of Forests, personal communication).

An alternative form of reproduction seen in some *Carassius* species is that of gynogenesis. In this process the female fish uses sperm from another species of cyprinid to stimulate egg division, but the sperm does not fertilize the egg. The larvae produced are therefore all clones of the mother. This form of reproduction allows an invasive species to rapidly colonize watersheds, as has taken place with Prussian carp in southern Alberta (Docherty et al., 2017; Elgin et al., 2014; Ruppert et al., 2017).

Gynogenesis is reported to be present (McPhail, 2007), rare (Balon, 2004) or absent (Tarkan et al., 2010) in goldfish, but seems possible, and has been induced in the lab. Paschos et al. (2001) used eggs from three different variations of *C. auratus* (e.g., “round fat body” and “telescopic eyes”), which are modified forms of goldfish. However, there is confusion in the literature regarding which species are being used in some experiments. For example, Qin et al. (2018) induced gynogenesis in *C. auratus* red var. females, but discussed work on “red crucian carp”, implying that the species used was *C. carassius* (Crucian carp), and not *C. auratus*, the goldfish. As well, according to Tarkan et al. (2010), the terms “golden carp” and “crucian carp” have also been used inappropriately to describe *C. auratus*.

Growth

Juvenile goldfish require warm temperatures for growth (Kottelat & Freyhof, 2007). Battle (1940) examined the growth of larval goldfish in Ontario kept at 25 °C. The length of larvae at days post-hatch were: 4.5 mm at hatch, 5.8 mm at 1.5–2.5 days, 6.8 mm at 7–8 (with yolk sac absorbed between 5.8 and 6.8 mm), 7.9 mm at 15–18 days, 9.4 mm at 22–23 days, 11.6 mm at 37 days, and 15.7 mm at 9 weeks. Growth rates of adult fish are highly variable; Tarkan et al. (2010) showed back-calculated standard lengths of goldfish at age 6 varied from approximately 150 mm to 360 mm for several populations from England and Australia. The highest growth rate observed is that of goldfish in the lower Vasse River, in south-western Australia. Here, goldfish grew to 180 mm in total length at 1 year old, with a maximum size of 411 mm and a weight of 2,200 g at age 8 (Morgan & Beatty, 2007). Goldfish in Dragon Lake, B.C., reach sizes of 296 mm and 646 g (L. Sandy & B. Heise, Thompson Rivers University, unpublished data). Goldfish growth is related to temperature and food supply, and so populations kept at high density and restricted food are typically stunted and prone to disease (Stone et al., 2003). The maximum age of feral populations appears to be 10 years, but goldfish in captivity can live 20 or 30 years (Kottelat & Freyhof, 2007; McPhail, 2007).

Movement and Migration

Introduced goldfish in B.C. are likely to travel considerable distances. Goldfish in Australia were determined to move an average of 0.3 km per day, with one fish moving 5.4 km in one day, and a total of 231 km over a year (Beatty et al., 2017). Goldfish in a South Korean reservoir travelled an average of 1.3 km/day, with one of 6 individuals tracked moving 192 km over 48 days (Kim et al., 2014)

Goldfish are known to occupy different habitats at different times of day and season. Goldfish follow a shift in depth, preferring deeper water during the day and moving into shallow water at

night (Laroque et al., 2020). Fish activity, as indicated by acoustic telemetry detections, is greatest at night compared to the day (Kim et al., 2014)

Goldfish also show a seasonal pattern in depth preferences. In Hamilton Harbour, Ontario, Boston et al. (2024) found that goldfish were in the shallow weedy areas (mean depth of 0.85 m) for spawning in April and May, but occupied progressively deeper water from September into the winter, where they occupied the deepest depth (~6.0 m) in December. Fish moved into progressively shallower depths starting in January.

Tolerance of Poor Environmental Conditions (Including Anoxia)

Goldfish are extremely hardy fish that are able to withstand extreme water conditions with respect to high and low temperatures, low oxygen, high turbidity and various types of water pollution. Goldfish originated in tropical to temperate watersheds in China (Balon, 2004), but they have established populations under very different conditions around the world. Limiting habitat conditions are discussed below and listed briefly in Table 2.

Temperature: Goldfish can tolerate near-freezing temperatures under ice, and have overwintered in B.C. lakes (e.g., Dragon Lake). Goldfish require temperatures of 15–25 °C for spawning (McPhail, 2007), and can tolerate upper temperatures of 41–43 °C (Fry et al., 1942; Ford & Beiting, 2005).

Oxygen: One huge advantage that goldfish have over local fishes is their ability to live under anoxic conditions. In laboratory experiments at 4 °C, 100% of goldfish survived 6 days without oxygen, 40% were alive after 9 days, and then the experiment was terminated, suggesting that the remaining goldfish could have survived for much longer (Walker & Johansen, 1977). In a separate experiment, goldfish survived for shorter times, with median lethal times of ~2 days at 5 °C and 22 hours at 20 °C (Van den Thillart et al., 1983). The closely related crucian carp can tolerate anoxia for at least 2 months (Blazka, 1958), and possibly up to 5 months in outdoor ponds (although the exact level of oxygen was unknown). Crucian carp in experiments at 3 °C survived over 4.5 months (Piironen & Holopainen, 1986). Both *Carassius* species are able to survive without oxygen because they have evolved an alcohol dehydrogenase anaerobic metabolic pathway, that produces alcohol, which exits the fish via the gills (Fagernes et al., 2017).

pH: Goldfish have a preferred pH range of 5.5–7.0, but demonstrate a tolerance range of 4.5–10.5 (Szczerbowski, 2001, as cited in Nico et al., 2025a).

Salinity: In laboratory experiments, goldfish survival is excellent at salinities up to 10 ppt, but they experience high mortalities at salinities of 15 and 20 ppt (Schofield et al., 2006). In the Vasse River watershed in Australia, goldfish had a gradual salt tolerance of ~21 ppt (unpublished data cited in Beatty et al., 2017). Juvenile goldfish are found in water up to ~17 ppt (Tweedley et al., 2012). It is possible that goldfish in B.C. could use river estuaries as a “saltwater bridge” (Beatty et al., 2017; Brown et al., 2001) to disperse to adjoining watersheds. Salinity may also limit the heat stress tolerance of goldfish, although acclimation to high temperatures buffers these effects (Claus et al., 2025).

Table 2. Summary of habitat requirements/limiting factors for establishment of goldfish in B.C. (see text for details and sources).

Water Temperature	Dissolved Oxygen	Ph Range	Turbidity	Salinity	Habitat Needs
<ul style="list-style-type: none"> » 0–43°C » >15°C for spawning » Can overwinter in frozen lakes 	Withstand total anoxia for >6 days	4.5–10.5	Very tolerant; increases turbidity via feeding	0–~21 ppt	Need rooted plants in shallows for spawning

Parasites and Disease

Goldfish are host to 113 species of parasites in their natural range, with 23 parasite species reported from North American goldfish (Trujillo-González et al., 2018). The parasites of highest risk to spread to local fishes are *Schyzocotyle acheilognathi* (Cestoda: Bothriocephalidae), *Ichthyophthirius multifiliis* (Ciliophora: Ichthyophthiriidae), *Argulus japonicus* (Crustacea: Argulidae), *Lernaea cyprinacea* (Crustacea: Ergasilidae), *Dactylogyrus anchoratus*, *D. vastator* and *D. f ormosus* (Monogenea: Dactylogyridae). One of these, *Ichthyophthirius multifiliis*, contributed to high mortalities of adult sockeye salmon in the Skeena watershed, B.C. (Traxler et al., 1998).

Goldfish (*C. auratus* and *C. auratus gibelio*) are susceptible to and carry cyprinid herpesvirus 2 (CyHV-2), also known as herpesviral haematopoietic necrosis virus (HHNV) (Zhu et al., 2019). The herpesvirus 2 virus is lethal to goldfish, has been found around the world, and is widely distributed in the United States, where it is a cause of goldfish mortality (Goodwin et al., 2006). This virus is a threat to B.C. lakes because it can cross-infect other species of fish (Zhu et al., 2019).

Goldfish can also get the koi herpesvirus (CyHV-3) from infected koi (Sadler et al., 2008).

Genetic Information

Numerous genetic studies have been done on goldfish. Given the difficulty in separating species of *Carassius* using morphological features, several studies have used genetic analysis to identify the distribution and diversity of goldfish and closely related species (Takada et al., 2010; Rylková et al., 2013; Elgin et al., 2014; Halas et al., 2018). Other genetic studies have looked at goldfish hybridization with other *Carassius* species and carp (Taylor & Mahon, 1977; Pullan & Smith, 1987; Hänfling et al., 2005; Smartt, 2007; Kalous et al., 2012, 2013) and development of gynogenesis (Paschos et al., 2001; Qin et al., 2018).

5. Negative Effects of Introduced Goldfish

The introduction of goldfish to lakes and rivers can have both direct and indirect environmental impacts.

In the United States, goldfish are suspected of causing a decline of an endangered poolfish (*Empetrichthys latos*) (Deacon et al., 1964) and of the Sacramento sucker (*Catostomus occidentalis*) (Moyle, 1976). In both cases, the exact nature of the interaction (e.g., competition,

predation) was not determined.

The impacts described in this section apply to goldfish, but if some of the “goldfish” populations in B.C. are actually Prussian carp (*C. gibelio*), then the effects would be more profound. Prussian carp are known to expand rapidly (largely using gynogenesis), and to negatively affect local fishes, invertebrates and plants (Lusk et al., 2010; Tarkan et al., 2012; Docherty et al., 2017; Ruppert et al., 2017).

Direct Impacts

1. Competition for food with native fishes and altered food chains

While goldfish are generally known to be omnivores consuming plant material, aquatic invertebrates and zooplankton (see Feeding Ecology section, above), there are no published accounts of feeding overlap between goldfish and native trout populations in B.C. However, unpublished studies by students of Brian Heise at Thompson Rivers University have been done comparing the diets of goldfish and rainbow trout (*Oncorhynchus mykiss*) in Dragon Lake, B.C., by Kwynn Bodman (June 2017) and White Lake, B.C., by Jennifer Glover (Nov. 2015).

Dragon Lake: Goldfish in Dragon Lake consumed primarily cladocerans (water fleas), followed by phytoplankton and chironomid larvae. This diet overlapped with that of rainbow trout, which also consumed cladocerans (26% of food items, the most important item), as well as chironomid pupae. It thus appears that goldfish in Dragon Lake feed both in the water column as well as in the benthic substrate. Despite an overlap in diet, trout do not seem to be affected negatively by the goldfish (Russ Bobrowski, BC Ministry of Forests, personal communication). Rainbow trout in Dragon Lake are the Blackwater and, more recently, Horsefly piscivorous strains of rainbow trout. These trout have been eating juvenile goldfish, which could account for the good trout growth rates in this lake.

White Lake: The diet of goldfish and rainbow trout overlapped, as goldfish diets were dominated by ostracods (seed shrimp) and chironomid larvae, while trout preferred amphipods and ostracods.

Goldfish in White Lake appeared to be concentrating on benthic feeding, as opposed to the mixed feeding of goldfish in Dragon Lake. However, the time of year was not the same for the sampling of the two lakes, and this may have influenced these results. Rainbow trout in this lake are the invertebrate-feeding Pennask strain, which could compete with goldfish. However, the lower trout size reported in this lake could be due to high stocking rates, and not goldfish.

It is clear that research is needed on the effects of goldfish on rainbow trout, as well as other salmonids, in B.C. lakes and rivers.

Research on permanent ponds in France where goldfish replaced predatory newts showed the collapse of food webs in both horizontal and vertical dimensions, and reduced taxonomic diversity (Lejeune et al., 2024). The goldfish pond food chain changed from one dominated by macrophytes with benthic periphyton to one dominated by phytoplankton and detritus, with few macrophytes.

2. Turbidity and reduced macrophytes

Goldfish living in soft-bottomed water bodies produce high levels of turbidity. Goldfish use a “suck, spit and pick” strategy for their benthic feeding that suspends sediment in the water column (Richardson & Whoriskey, 1992; Crone et al., 2023). Almost all of the turbidity is produced by larger goldfish (those greater than ~9 cm). High turbidity impedes fish respiration, can smother the eggs of fish and amphibians, and makes it difficult for visual predators such as trout to feed (Pekcan-Hekim & Lappalainen, 2006; Quesenberry et al., 2007). It also makes it more difficult for avian predators to feed on goldfish (Richardson, Whoriskey, & Roy, 1995).

3. Negative impacts on amphibians

Amphibian populations are in decline worldwide (Stuart et al., 2004; Wake & Vredenburg, 2008), and this decline is aided by the introduction of fishes into fishless ponds (Hayes & Jennings, 1986). Monello and Wright (1999) concluded that goldfish eliminated a number of amphibian species from ponds in northern Idaho, and recommended a reduction in the number of ponds containing goldfish. In a separate study, Monello and Wright (2001) found that goldfish in Idaho consumed both the eggs and larvae of eastern long-toed salamanders (*Ambystoma macrodactylum columbianum*). As well, these authors found that non-egg-eating goldfish placed with goldfish that did eat eggs then began consuming eggs, suggesting that goldfish learn to eat novel foods from conspecifics.

Sublethal effects of goldfish on amphibians include effects on recruitment. The presence of goldfish inhibited reproduction of alpine newts (*Ichthyosaura alpestris*), even though goldfish do not consume adult newts (Winandy & Denoël, 2013). Goldfish also caused alpine newts to alter their habitat selection, shifting their distribution in networks of habitat patches, preferring fishless over fish-bearing patches (Winandy et al., 2017).

Goldfish introduced into small ponds or wetland areas within B.C. may negatively affect Species at Risk recoveries, as indicated for Great Basin spadefoot (*Spea intermontana*) (Ashpole et al., 2018) and western tiger salamander (*Ambystoma mavortium*) (COSEWIC, 2012). Note that the COSEWIC report mentioned goldfish but gave the scientific name *Crassius crassius*.

4. Transmission of parasites and disease to native fishes

There are 23 species of parasites reported from North American goldfish (Trujillo-González et al., 2018). Just one of these, *Ichthyophthirius multifiliis*, contributed to high mortalities of adult sockeye salmon in the Skeena watershed of B.C. (Traxler et al., 1998, although the source of the parasite in that case was not identified as a goldfish).

Goldfish carry cyprinid herpesvirus 2 (CyHV-2), which is a threat to B.C. lakes because it can cross-infect other species of fish (Zhu et al., 2019). Goldfish can also contract the koi herpesvirus (CyHV-3) from infected koi (Sadler et al., 2008), and could therefore spread the virus to uninfected koi in B.C.

Indirect Impacts

1. Creation of harmful blooms of cyanobacteria (Blue-green algae)

Cyanobacteria are enhanced, showing increased growth, after passing through the digestive tract of the goldfish (Kolmakov & Gladyshev, 2003). Passing through the gut may provide nutrient enrichment for the cyanobacteria, as well as mechanically re-agglutinate cyanobacterial cells. The enhancement could lead to blue-green algal blooms in B.C. lakes, which would

negatively affect fish and aquatic food chains, and the use of the lake for recreation and as a water source for people living on the lake.

2. Hybridization with carp

While hybridization of goldfish with carp/koi may not cause any direct problems, the offspring produced do have intermediate morphologies (e.g., number of lateral line scales, the shape of the pharyngeal teeth and presence of reduced barbels; (Pullan & Smith, 1987), making identification challenging.

Economic Impacts

The economic impacts of goldfish introductions relate to their effects on important native fish and their fisheries. Reduced numbers of native trout and salmon caused by goldfish could result in reduced angling opportunities, which, through angler days, generate a lot of license revenue to the province of B.C.

The transmission of parasites or diseases (e.g., koi herpesvirus [CyHV-3]) to ornamental koi could lead to financial loss, as koi are very expensive to buy, and are cherished as pets by their owners.

Economic losses are also possible in the commercial harvesting of sockeye salmon if they become infested with parasites (e.g., *Ichthyophthirius multifiliis*) from goldfish, and experience higher mortality rates.

Social Impacts

A reduction in population levels of trout and salmon could result in reduced angling opportunities, which would reduce recreational opportunities in the province.

There could also be a reduction in the food and ceremonial use of salmon by Indigenous communities in the province if sockeye salmon are infected with parasites and experience high mortalities.

6. Methods of Introduction & Spread

Human release of unwanted goldfish from the pet aquarium and garden pond trades is thought to be the major source of goldfish populations in the province. The pet trade is poorly regulated (Raghavan et al., 2013) and is responsible for a third of all aquatic invasive alien species. This is consistent with a British study (Copp et al., 2010) in which human population density was a good predictor of introduced fish propagule pressure. People releasing fish to the wild may be influenced by convenience, misconceptions of the effect of the introduction, or lack any obvious rationale (Drake et al., 2014). Closer to B.C., 96.7% of pet stores in the Pacific Northwest sell goldfish (Strecker et al., 2011), with, on average, aquarists owning ~9 fish, and 6.4% of owners admitting that they had released live fish in the past.

With 328 businesses that sell pet food and supplies in B.C. (Statistics Canada, 2018), and with presumably not all of them selling fish, this is still a strong indicator of the large number of potential pet fish that could serve as propagules for new invasive goldfish populations in the province.

An additional source of aquarium fishes and other aquatic pets is online auction markets such

as AquaBid, which often operate outside of regulations (Olden et al., 2021).

In addition to the pet aquarium and garden pond trades, goldfish could be released as part of religious or cultural traditions. The Buddhist tradition of Fang Sheng is an ancient ritual in which Buddhists free captive animals to generate positive karma through an act of kindness. The use of a “pond of mercy” dates back to the Sung Dynasty in China (Balon, 2004). Persians celebrate their New Year (at the spring equinox) of Nowruz. As part of that tradition, a goldfish is often kept in a bowl on the Haft Seen table (Lovgreen, 2021), and it is released into local rivers or

lakes on the last day of Nowruz (BBC, 2016).

The use of live bait in sportfishing is not allowed in B.C., but in some provinces and states it is (Figure 9), which suggests a possible route for goldfish introduction through bait buckets and live wells of boats.

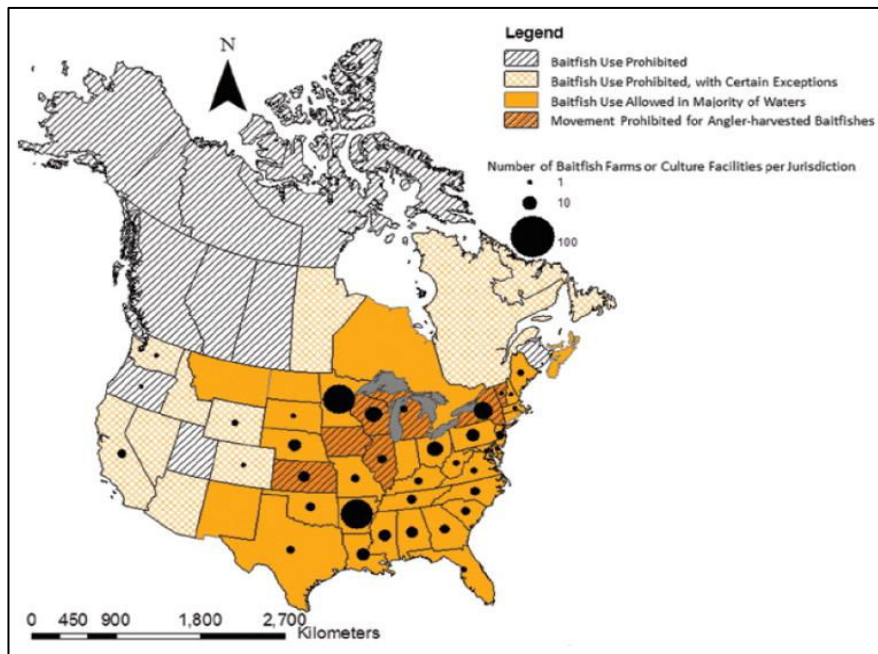


Figure 9. Baitfish regulation status of Canadian provinces and American states (Drake & Mandrak, 2014), based on (Dunford, 2012).

Unintentional human-assisted dispersal is possible from ornamental ponds located close to natural water bodies, and that are temporarily connected to those natural water bodies during spring floods. Climate change is likely to increase the frequency of atmospheric rivers and catastrophic flooding, such as occurred in the Sumas Prairie area of B.C. in November 2021. This level of flooding potentially facilitates the movement of invasive fishes from one water body to another, as observed for bighead carp (*Hypophthalmichthys nobilis*) and silver carp (*Hypophthalmichthys molitrix*) in the United States and Asia (Kolar et al., 2005; Nico et al., 2025b).

Municipalities are increasingly making use of stormwater ponds to reduce flooding in urban areas; unfortunately, the public appears to be releasing unwanted pet goldfish into these ponds, where they occur at high densities and grow very large (Loss, 2022).

Natural dispersal of goldfish is possible by swimming from locations where they presently exist. Goldfish can swim long distances, as seen in the 231 km migration of goldfish in Australia (Beatty et al., 2017). Most locations in B.C. are in lakes, and goldfish could migrate via inlet and outlet streams from those lakes. If goldfish were released into the Fraser River, they could likely spread using slow water habitats at the edges of the river and flooded side channels in the spring.

Any source of natural introduction would involve transboundary water bodies such as the Pend

d'Oreille or Columbia Rivers, or shared lakes such as Osoyoos Lake. Once introduced into a neighbouring river system, juvenile and adult goldfish could easily drift with the current to downstream locations. Drift of eggs downstream is unlikely due to the adhesive nature of the eggs, which are attached to plants or other submerged objects.

7. Methods of Control for Goldfish

As is the case for most invasive fishes, once goldfish have established themselves in a water body, it is extremely difficult to completely eradicate them, and so control efforts are usually restricted to population suppression.

Complete eradication is extremely difficult, as the only two available methods kill all fish in a lake, including desirable non-target species such as rainbow trout. As a result, most control strategies for goldfish are population suppression programs, aimed at keeping goldfish populations at levels below which they will have adverse effects on the ecology of the lake or stream. This discussion of potential techniques is split into a. eradication techniques and b. suppression techniques. Cost estimates are provided for the top recommended technique for each approach.

Goldfish eradication techniques

1. Killing all fish in the water body using rotenone

This is the preferred eradication technique for water bodies that are small enough to make rotenone treatment practically and economically feasible, and that contain no aquatic species at risk. Rotenone is a naturally occurring piscicide that is found in the roots of some South American plants in the family Fabaceae (peas and beans). The chemical kills all gill-breathing organisms, including fish and aquatic invertebrates. Fish killed by rotenone are safe for consumption by predators and scavengers, as the chemical is broken down in the guts of birds and mammals. Rotenone applied to a lake is usually broken down by sunlight within two weeks, depending on water temperature, pH, water hardness and sunlight levels. Rotenone (CFT Legumine) was recently (July 2019) used to eliminate goldfish from Cuddy Pond in Anchorage, Alaska. The treatment was successful, killing both adult and young-of-the-year fish (J. Baumer, Area Management Biologist, Alaska Department of Fish and Game, personal communication). Another critical part of the planning of any rotenone treatment is extensive consultation with local residents, anglers and environmental groups. Reviews of the use of rotenone for killing unwanted fishes can be found in Ling (2003) and Finlayson et al. (2018). A review of all methods of eliminating invasive fishes can be found in Rytwinski et al. (2019).

The high costs of rotenone treatment in a lake are a major consideration in an early detection and rapid response (EDRR) plan. Based on the resistance of crucian carp (*C. carassius*) to rotenone (Meadows, 1973), the concentration of rotenone should be higher than those levels used for trout. The rotenone treatment of Cuddy Pond was successful at a targeted rotenone concentration of 50 ppb (0.05 ppm), but in bioassays, goldfish died at concentrations as low as 5.5 ppb (0.005 ppm) (K. Dunker, Invasive Species Research Biologist, Alaska Department of Fish and Game, personal communication). As an example, very approximate costs for a rotenone treatment of Dragon Lake (Quesnel) at 2.0 ppm CFT Legumine, based on the costs of treating Gardom Lake (between Enderby and Salmon Arm, B.C.) would be as follows (cost estimates provided by A. Klassen, Senior Fish Biologist, Water, Land and Resource Stewardship, Kamloops, personal communication).

- » **Volume to be treated:** area (225 ha) x mean depth (5.8 m) = 13,050,000 m³
- » **Desired concentration of rotenone:** 2.0 ppm CFT Legumine (liquid product, easy to apply)
- » **Rotenone (product only, 2017 prices):** US \$672,100 ~ = CAD \$889,453 (+ inflation + freight & brokerage fees)

This estimate does not include the labour costs for the application. An additional, large expense is the provision of drinking water for residents on the lake; in 2009, this came to \$150,000 for Gardom Lake.

Alternatively, the cost of a rotenone treatment of a smaller lake without any residents can be as low as \$30,000.

Restocking of a lake with the desired species can be done approximately one month following treatment. Water samples should be tested and test fish placed in cages in the lake to check for any residual rotenone. Restocking is probably best done the year following treatment to allow recolonization of the lake by aquatic invertebrates.

2. Drainage of the water body

Completely draining small water bodies such as ponds will ensure that all of the goldfish are dead; however, this option is only practical for very small water bodies. In addition, care must be taken to ensure that goldfish do not escape in the drainage water to colonize another water body.

Goldfish Suppression Techniques

Suppression activities should focus on reducing the number of larger goldfish, as these are the ones producing the most turbidity, producing the most offspring, and consuming the most macroinvertebrates that are also eaten by trout. In addition, most of the suppression techniques outlined below are more effective, in terms of catch rate and benefit-cost ratio, for larger goldfish.

1. Capture fish using boat electrofishing

Boat electrofishing is the most efficient suppression technique when the use of a piscicide is not an option, as it is possible to selectively remove goldfish while releasing non-target fish. White Lake and Dragon Lake both produce a large number of angler days, and Dragon Lake provides the Freshwater Fisheries Society of BC (FFSBC) with broodstock of Blackwater strain rainbow trout (thus reducing the appeal of the poisoning option), so boat electrofishing is the most appropriate suppression technique for these lakes. A boat electrofishing trial that took place on Dragon Lake in 2019–2022 was successful at capturing adult goldfish (Tisdale, 2019; R. Bobrowski, personal communication), but it costs approximately \$20,000 per year. Goldfish spawning takes place primarily in the spring in shallow water, so boat electrofishing at that time of the year would be the most efficient and cost-effective. It is worth investigating if the equipment used could also be used to capture juvenile fish. Goldfish will spawn multiple times over the summer, but effective electrofishing in the early spring should catch most spawners. Electrofishing should be limited to shallow water, as fish easily escape downwards in deeper water (J. Baumer, personal communication). Boat electrofishing requires skill on the part of the boat operator, as an unstealthily approach results in the scattering of the goldfish (G. Tisdale, personal communication).

In shallow water bodies, such as wetlands and creeks, backpack electrofishing may be used to collect goldfish, although it is unlikely to prove effective in eradication, as has been shown for Prussian carp in Alberta streams (Card et al., 2020).

2. Capture fish in gill and fyke nets

Gill nets have been used successfully to catch goldfish (Morgan & Beatty, 2007; Rowe & Smith, 2008; Lorenzoni et al., 2010; Almeida et al., 2013), but they have the disadvantage that they also catch (and kill) the native non-target species.

Fyke nets work well for catching goldfish in shallow water (Morgan & Beatty, 2007), and have the advantage that the gear does not result in fish mortality, which may be required if the killing of non-target species is a concern. When gill netting and fyke netting were done in Dragon Lake, the gill nets caught adult goldfish in deeper water, while the fyke net caught only small juveniles, in shallow water (K. Bodman & B. Heise, Thompson Rivers University, unpublished data).

Netting of goldfish does not catch all of the fish, and they are adept at avoiding being netted and trapped. This may be because goldfish and other cyprinids have high cognitive abilities, including spatial awareness (Rodriguez et al., 1994; Braithwaite & De Perera, 2006). Goldfish are able to judge distances (Sibeaux et al., 2022) and have been trained to “drive” an aquarium towards a target in order to earn a food reward, demonstrating their ability to navigate even in a terrestrial environment (Givon et al., 2022). In an Australian study, goldfish appeared able to avoid traps (Conallin et al., 2012), and in White Lake, B.C., goldfish escaped under the lead line of nets by burrowing into the mud substrate (B. Heise & J. Sorensen, Thompson Rivers University, unpublished data). The efficiency of netting may be increased by locating where goldfish congregate in deeper water, as they do during the winter (Boston et al., 2024). The “Judas fish” technique of tagging fish and using telemetry to locate the congregation has been done successfully with carp (e.g., Bajer et al., 2011).

3. Partial drawdown of a lake

Drawdown of a lake in the spring to remove the vegetated zone needed for egg deposition would not remove adults, but would reduce the reproductive effort of the population. While this would reduce the early spring spawning production, goldfish typically spawn over a period of a few months, reducing the effectiveness of this technique.

4. Biological control

It may be possible to develop a cyprinid herpesvirus to reduce goldfish numbers (as has been proposed in Australia to control carp). However, the herpesvirus is unlikely to be completely effective, may negatively affect non-target species (Boutier et al., 2019), and viruses are known to mutate. This option should not be considered.

5. Education and outreach to promote behaviour change

The best strategy for reducing the spread of goldfish populations in B.C. is to stop the public from releasing their unwanted pet goldfish into lakes. Although public campaigns such as “Don’t Let it Loose” educate the public, the pet store and outdoor garden centres need to be educated and be more proactive in letting their customers know that they can return their unwanted goldfish to the store where they were bought (in most cases). It may be possible for the province of B.C. to exert pressure on the pet trade to adopt best practices of customer education in this regard.

6. Maintained ban on use of live baitfish

The province of B.C. should also maintain its ban on the use of live bait in sport fishing and ensure that inspections of boats entering the province have live wells inspected for live baitfish.

8. Management Recommendations

The provincial and federal governments should work with the pet and aquarium trade to 1. educate the public concerning the problems associated with releasing unwanted goldfish into B.C. waters, and 2. ensure that pet stores have policies that allow them to take back unwanted pets. Non-governmental organizations, such as the Invasive Species Council of BC and Invasives Canada, should continue to educate the public and industry with “Don’t Let it Loose” behaviour change campaigns.

Eradication of goldfish from small lakes and ponds is possible using the piscicide rotenone. In lakes where there are aquatic species at risk, including amphibians, the government should use boat electrofishing in the spring to reduce goldfish populations. Further research is needed to determine if electrofishing is justified on lakes where goldfish may be competing with rainbow trout.

9. Acknowledgements

This document was funded by the Invasive Species Council of BC. Content was generously provided by the following: unpublished data from Kwynn Bodman, Jennifer Glover, Lynden Sandy, Jon van Hamme and Brian Heise of Thompson Rivers University, Kamloops, B.C.; goldfish specimens and Dragon Lake management history by Russ Bobrowski, Fish Biologist, BC Ministry of Water, Land and Resource Stewardship, Williams Lake, B.C.; goldfish distribution information and rotenone treatment costs from Andrew Klassen, Senior Fish Biologist, BC Ministry of Water, Land and Resource Stewardship, Kamloops, B.C.; boat electrofishing information from Gene Tisdale of Tisdale Environmental Consulting Inc.; Rotenone treatment information of Cuddy Pond from Jay Baumer, Area Management Biologist, Alaska Department of Fish and Game, Anchorage, Alaska; ; rotenone treatment information for goldfish from Kristine Dunker, Invasive Species Research Biologist, Alaska Department of Fish and Game, Anchorage, Alaska; and helpful comments on an earlier version of the manuscript from Nick Wong.

10. Literature Cited

- Almeida, D., Ribeiro, F., Leunda, P. M., Vilizzi, L., & Copp, G. H. (2013). Effectiveness of FISK, an invasiveness screening tool for non-native freshwater fishes, to perform risk identification assessments in the Iberian Peninsula. *Risk Analysis*, 33(8), 1404–1413. <https://doi.org/10.1111/risa.12050>
- Archibald, C. P. (2011). Experimental Observations on the Effects of Predation by Goldfish (*Carassius auratus*) on the Zooplankton of a Small Saline Lake. *Journal of the Fisheries Research Board of Canada*, 32(9), 1589–1594. <https://doi.org/10.1139/f75-184>
- Association, A. C. (2021). *Using eDNA to document the distribution of Prussian carp in Alberta: 2020/21 project summary report.*

- Bajer, P. G., Chizinski, C. J., & Sorensen, P. W. (2011). Using the Judas technique to locate and remove wintertime aggregations of invasive common carp. *Fisheries Management and Ecology*, 18(6), 497–505. <https://doi.org/10.1111/j.1365-2400.2011.00805.x>
- Balon, E. K. (2004). About the oldest domesticates among fishes. *Journal of Fish Biology*, 65(SUPPL. A), 1–27. <https://doi.org/10.1111/j.1095-8649.2004.00563.x>
- Battle, H. (1940). The Embryology and Larval Development of the Goldfish (*Carassius auratus* L.) from Lake Erie. *Ohio Journal of Science*, 40(2), 82–93.
- BBC. (2016). *Iran president shuns Nowruz goldfish tradition*. BBC News from Elsewhere. <https://www.bbc.com/news/blogs-news-from-elsewhere-35861954>
- Beatty, S. J., Allen, M. G., Whitty, J. M., Lymbery, A. J., Keleher, J. J., Tweedley, J. R., Ebner, B. C., & Morgan, D. L. (2017). First evidence of spawning migration by goldfish (*Carassius auratus*); implications for control of a globally invasive species. *Ecology of Freshwater Fish*, 26(3), 444–455. <https://doi.org/10.1111/eff.12288>
- Blazka, P. (1958). The anaerobic metabolism of fish. *Physiological Zoology*, 31(2), 117–128.
- Boston, C. M., Larocque, S. M., Tang, R. W. K., Brooks, J. L., Bowman, J. E., Cooke, S. J., & Midwood, J. D. (2024). Life outside the fishbowl: Tracking an introduced population of goldfish (*Carassius auratus*) in an embayment on the Laurentian Great Lakes. *Journal of Great Lakes Research*, 50. <https://doi.org/10.1016/j.jglr.2023.102253>
- Boutier, M., Donohoe, O., Kopf, R. K., Humphries, P., Becker, J. A., Marshall, J., & Vanderplasschen, A. (2019). Biocontrol of carp: The Australian plan does not stand up to a rational analysis of safety and efficacy. *Frontiers in Microbiology*, 10(APR), 1–4. <https://doi.org/10.3389/fmicb.2019.00882>
- Braithwaite, V. A., & De Perera, T. B. (2006). Short-range orientation in fish: How fish map space. *Marine and Freshwater Behaviour and Physiology*, 39(1), 37–47. <https://doi.org/10.1080/10236240600562844>
- Brown, J. A., Moore, W. M., & Quabius, E. S. (2001). Physiological effects of saline waters on zander. *Journal of Fish Biology*, 59(6), 1544–1555. <https://doi.org/10.1006/jfbi.2001.1800>
- CABI. (2019). *Carassius auratus auratus (goldfish)*. Original Text by Sunil Siriwardena, Updated by Vicki Bonham In Invasive Species Compendium. Wallingford, UK: CAB International. www.cabi.org/isc
- Canadian Rivers, I. (2019). *Goldfish, Carassius auratus*. Inland Fish Species of New Brunswick, University of New Brunswick. <https://www.unb.ca/research/institutes/cri/links/inlandfishesnb/Species/goldfish.html>
- Card, J. T., Hasler, C. T., Ruppert, J. L. W., Donadt, C., & Poesch, M. S. (2020). A Three-pass electrofishing removal strategy is not effective for eradication of Prussian Carp in a North American stream network. *Journal of Fish and Wildlife Management*, 11(2), 485–493. <https://doi.org/10.3996/JFWM-20-031>
- Conallin, A. J., Smith, B. B., Thwaites, L. A., Walker, K. F., & Gillanders, B. M. (2012). Environmental Water Allocations in regulated lowland rivers may encourage offstream movements and spawning by common carp, *Cyprinus carpio*: Implications for wetland rehabilitation. *Marine and Freshwater Research*, 63(10), 865–877. <https://doi.org/10.1071/MF12044>
- Copp, G. H., Vilizzi, L., & Gozlan, R. E. (2010). The demography of introduction pathways, propagule pressure and occurrences of non-native freshwater fish in England. *Aquatic Conservation: Marine and Freshwater Ecosystems*, 20(5), 595–601. <https://doi.org/10.1002/aqc.1129>
- Deacon, J. E., Hubbs, C., & Zahuranec, B. J. (1964). Some Effects of Introduced Fishes on the Native Fish Fauna of Southern Nevada. *Copeia*, 1964(2), 384–388.

- Dickey, J. W. E., Arnott, G., McGlade, C. L. O., Moore, A., Riddell, G. E., & Dick, J. T. A. (2022). Threats at home? Assessing the potential ecological impacts and risks of commonly traded pet fishes. *NeoBiota*, 73, 109–136. <https://doi.org/10.3897/NEOBIOTA.73.80542>
- Docherty, C., Ruppert, J., Rudolfsen, T., Hamann, A., & Poesch, M. S. (2017). Assessing the spread and potential impact of Prussian Carp *Carassius gibelio* (Bloch , 1782) to freshwater fishes in western North America. *BioInvasions Records*, 6(3), 291–296. <https://doi.org/10.3391/bir.2017.6.3.15>
- Drake, D. A. R., & Mandrak, N. E. (2014). Ecological Risk of Live Bait Fisheries: A New Angle on Selective Fishing. *Fisheries*, 39(5), 201–211. <https://doi.org/10.1080/03632415.2014.903835>
- Drake, D. A. R., Mercader, R., Dobson, T., & Mandrak, N. E. (2014). Can we predict risky human behaviour involving invasive species? A case study of the release of fishes to the wild. *Biological Invasions*, 17(1), 309–326. <https://doi.org/10.1007/s10530-014-0729-7>
- Dunford, L. A. (2012). *Survey of North American recreational baitfish regulations*.
- Elgin, E. L., Tunna, H. R., & Jackson, L. J. (2014). First confirmed records of Prussian carp, *Carassius gibelio* (Bloch, 1782) in open waters of North America. *BioInvasions Records*, 3(4), 275–282.
- Fagernes, C. E., Stensløkken, K.-O., Røhr, Å. K., Berenbrink, M., Ellefsen, S., & Nilsson, G. E. (2017). Extreme anoxia tolerance in crucian carp and goldfish through neofunctionalization of duplicated genes creating a new ethanol-producing pyruvate decarboxylase pathway. *Scientific Reports*. <https://doi.org/10.1038/s41598-017-07385-4>
- Finlayson, B., Skaar, D., Anderson, J., Carter, J., Duffield, D., Flammang, M., Jackson, C., Overlock, J., Steinkjer, J., & Wilson, R. (2018). *Planning and Standard Operating Procedures for the Use of Rotenone in Fish Management: Rotenone SOP Manual* (2nd ed.). American Fisheries Society.
- Ford, T., & Beitinger, T. L. (2005). Temperature tolerance in the goldfish, *Carassius auratus*. *Journal of Thermal Biology*. <https://doi.org/10.1016/j.jtherbio.2004.09.004>
- Fry, F. E. J., Brett, J. R., & Clawson, G. H. (1942). Lethal limits of temperature for young goldfish. *Revue Canadienne de Biologie*, 1, 50–56.
- Givon, S., Samina, M., Ben-Shahar, O., & Segev, R. (2022). From fish out of water to new insights on navigation mechanisms in animals. *Behavioural Brain Research*, 419, 113711. <https://doi.org/10.1016/j.bbr.2021.113711>
- Goodwin, A. E., Khoo, L., LaPatra, S. E., Bonar, C., Key, D. W., Garner, M., Lee, M. V., & Hanson, L. (2006). Goldfish hematopoietic necrosis herpesvirus (cyprinid herpesvirus 2) in the USA: Molecular confirmation of isolates from diseased fish. *Journal of Aquatic Animal Health*, 18(1), 11–18. <https://doi.org/10.1577/H05-007.1>
- Gupta, S., & Banerjee, S. (2009). Food preference of goldfish (*Carassius auratus* (Linnaeus, 1758)) and its potential in mosquito control. *Electronic Journal of Ichthyology*, 2, 47–58.
- Halas, D., Lovejoy, N., & Mandrak, N. E. (2018). Undetected diversity of goldfish (*Carassius* spp.) in North America. *Aquatic Invasions*, 13(2), 211–219. <https://doi.org/10.3391/ai.2018.13.2.03>
- Hänfling, B., Bolton, P., Harley, M., & Carvalho, G. R. (2005). A molecular approach to detect hybridisation between crucian carp (*Carassius carassius*) and non-indigenous carp species (*Carassius* spp. and *Cyprinus carpio*). *Freshwater Biology*, 50(3), 403–417. <https://doi.org/10.1111/j.1365-2427.2004.01330.x>
- Hanke, G. (2017). *Exotic carps and minnows of BC*. Royal BC Museum. http://taxonomy.royalbcmuseum.bc.ca/Taxonomy/viewer/Exotic_Carps_and_Minnows_of_BC.aspx

- Hayes, M. P., & Jennings, M. R. (1986). Decline of Ranid Frog Species in Western North America: Are Bullfrogs (*Rana catesbeiana*) Responsible? *Journal of Herpetology*, 20(4), 490–509.
- Japoshvili, B., Mumladze, L., & Küçük, F. (2013). Invasive *Carassius* carp in Georgia: Current state of knowledge and future perspectives. *Current Zoology*, 59(6), 732–739. <https://doi.org/10.1093/czoolo/59.6.732>
- Kalous, L., Bohlen, J., Rylková, K., & Petrtyl, M. (2012). Hidden diversity within the Prussian carp and designation of a neotype for *Carassius gibelio* (Teleostei: Cyprinidae). *Ichthyological Exploration of Freshwaters*, 23(1), 11–18.
- Kalous, L., Rylkova, K., Bohlen, J., Sanda, R., & Petrtyl, M. (2013). New mtDNA data reveal a wide distribution of the Japanese ginbuna *Carassius langsdorfii* in Europe. *Journal of Fish Biology*, 82(2), 703–707. <https://doi.org/10.1111/j.1095-8649.2012.03492.x>
- Kim, J. H., Yoon, J. D., Heo, W. M., Kim, D. S., Kim, C., & Jang, M. H. (2014). Movement patterns of three freshwater fish species after upstream transportation by fishway in the Jangheung Dam. *Paddy and Water Environment*, 12(SUPPL1), 141–148. <https://doi.org/10.1007/s10333-014-0429-z>
- Kolmakov, V. I., & Gladyshev, M. I. (2003). Growth and potential photosynthesis of cyanobacteria are stimulated by viable gut passage in crucian carp. *Aquatic Ecology*, 37(3), 237–242. <https://doi.org/10.1023/A:1025801326088>
- Kottelat, M., & Freyhof, J. (2007). *Handbook of European freshwater fishes*. Kottelat, Cornol, Switzerland and Freyhof.
- Li, T., Qi, M., Gatesoupe, F.-J., Tian, D., Jin, W., Li, J., Lin, Q., Wu, S., & Li, H. (2019). Adaptation to Fasting in Crucian Carp (*Carassius auratus*): Gut Microbiota and Its Correlative Relationship with Immune Function. *Microbial Ecology*, 78, 6–19. <https://doi.org/10.1007/s00248-018-1275-0>
- Ling, N. (2003). Rotenone—a review of its toxicity and use for fisheries management. In *Science for Conservation* (Vol. 211).
- Lorenzoni, M., Ghetti, L., Pedicillo, G., & Carosi, A. (2010a). Analysis of the biological features of the goldfish *Carassius auratus auratus* in Lake Trasimeno (Umbria, Italy) with a view to drawing up plans for population control. *Folia Zoologica*, 59(2), 142–156.
- Lorenzoni, M., Ghetti, L., Pedicillo, G., & Carosi, A. (2010b). Analysis of the biological features of the goldfish *Carassius auratus auratus* in Lake Trasimeno (Umbria, Italy) with a view to drawing up plans for population control. *Folia Zoologica*, 59(2), 142–156.
- Loss, H. (2022). *Supersized Goldfish Could Become Superinvaders*. Scientific American. <https://www.scientificamerican.com/article/supersized-goldfish-could-become-superinvaders/>
- Lovgreen, T. (2021). *Celebrating renewal at Nowruz*. CBC News Interactives. <https://newsinteractives.cbc.ca/longform/nowruz-rebirth-and-regrowth>
- Lusk, S., Luskova, V., & Hanel, L. (2010). Alien fish species in the Czech Republic and their impact on the native fish fauna. *Folia Zoologica*, 59(1), 57–72.
- McPhail, J. D. (2007). *The freshwater fishes of British Columbia*. The University of Alberta Press.
- Meadows, B. S. (1973). Toxicity of rotenone to some species of coarse fish and invertebrates. *Journal of Fish Biology*, 5(2), 155–163. <https://doi.org/10.1111/j.1095-8649.1973.tb04444.x>
- Ministry of Agriculture-Bureau of Fisheries. (2016). *China Fishery Statistical Yearbook 2016 (in Chinese)*. China Agriculture Press.
- Monello, R. J., & Wright, R. G. (1999). Amphibian habitat preferences among artificial ponds in the Palouse region of northern Idaho. *Journal of Herpetology*, 33(2), 298–303.

- Monello, R. J., & Wright, R. G. (2001). Predation by Goldfish (*Carassius auratus*) on Eggs and Larvae of the Eastern Long-Toed Salamander (*Ambystoma macrodactylum columbianum*). *Journal of Herpetology*, 35(2), 350–353.
- Morgan, D. L., & Beatty, S. J. (2007). Feral Goldfish (*Carassius auratus*) in Western Australia: A case study from the Vasse River. *Journal of the Royal Society of Western Australia*, 90(3), 151–156.
- Moyle, P. B. (1976). *Inland fishes of California*.
- Munkittrick, K. R., & Leatherland, J. F. (1984). Seasonal changes in the pituitary- gonad axis of feral goldfish, *Carassius auratus* L., from Ontario, Canada. *Journal of Fish Biology*, 24(1), 75–90. <https://doi.org/10.1111/j.1095-8649.1984.tb04778.x>
- Nico, L. G., Schofield, P. J., Larson, J., Makled, T. H., & Fusaro, A. (2019). *Carassius auratus* (*Linnaeus, 1758*): U.S. Geological Survey, *Nonindigenous Aquatic Species Database*. <https://nas.er.usgs.gov/queries/factsheet.aspx?SpeciesID=508>
- Nico, L. G., Schofield, P., Larson, J., Makled, T., Fusaro, A., & Morningstar, C. (2024). *Carassius auratus* (*Linnaeus, 1758*): U.S. Geological Survey, *Nonindigenous Aquatic Species Database, Gainesville, FL*. <https://nas.er.usgs.gov/queries/factsheet.aspx?SpeciesID=508>
- Olden, J. D., Whattam, E., & Wood, S. A. (2021). Online auction marketplaces as a global pathway for aquatic invasive species. *Hydrobiologia*, 848(9), 1967–1979. <https://doi.org/10.1007/s10750-020-04407-7>
- Omori, Y., & Kon, T. (2019). Goldfish: An old and new model system to study vertebrate development, evolution and human disease. *Journal of Biochemistry*, 165(3), 209–218. <https://doi.org/10.1093/jb/mvy076>
- Paschos, I., Natsis, L., Nathanailides, C., Kagalou, I., & Kolettas, E. (2001). Induction of gynogenesis and androgenesis in goldfish *Carassius auratus* (var. oranda). *Reproduction in Domestic Animals*, 36(3–4), 195–198. <https://doi.org/10.1046/j.1439-0531.2001.d01-36.x>
- Pekcan-Hekim, Z., & Lappalainen, J. (2006). Effects of clay turbidity and density of pikeperch (*Sander lucioperca*) larvae on predation by perch (*Perca fluviatilis*). *Naturwissenschaften*, 93(7), 356–359. <https://doi.org/10.1007/s00114-006-0114-1>
- Piironen, J., & Holopainen, I. J. (1986). A note on seasonality in anoxia tolerance of crucian carp (*Carassius carassius* (L.)) in the laboratory. *Annales Zoologici Fennici*, 23(3), 335–338.
- Pullan, S., & Smith, P. J. (1987). Identification of hybrids between koi (*Cyprinus carpio*) and goldfish (*Carassius auratus*). *New Zealand Journal of Marine and Freshwater Research*, 21(1), 41–46. <https://doi.org/10.1080/00288330.1987.9516198>
- Qin, Q. B., Huo, Y. Y., Liu, Q. W., Wang, C. Q., Zhou, Y. W., & Liu, S. J. (2018). Induced gynogenesis in autotetraploids derived from *Carassius auratus* red var. (♀) × *Megalobrama amblycephala* (♂). *Aquaculture*, 495(February), 710–714. <https://doi.org/10.1016/j.aquaculture.2018.06.028>
- Quesenberry, N. J., Allen, P. J., & Cech, J. J. (2007). The influence of turbidity on three-spined stickleback foraging. *Journal of Fish Biology*, 70(3), 965–972. <https://doi.org/10.1111/j.1095-8649.2007.01350.x>
- Raghavan, R., Dahanukar, N., Tlustý, M. F., Rhyne, A. L., Krishna Kumar, K., Molur, S., & Rosser, A. M. (2013). Uncovering an obscure trade: Threatened freshwater fishes and the aquarium pet markets. *Biological Conservation*, 164, 158–169. <https://doi.org/10.1016/j.biocon.2013.04.019>
- Richardson, M. J., & Whoriskey, F. G. (1992). Factors influencing the production of turbidity by goldfish (*Carassius auratus*). *Canadian Journal of Zoology*, 70(8), 1585–1589. <https://doi.org/10.1139/z92-218>

- Richardson, M. J., Whoriskey, F. G., & Roy, L. H. (1995). Turbidity generation and biological impacts of an exotic fish *Carassius auratus*, introduced into shallow seasonally anoxic ponds. *Journal of Fish Biology*, 47(4), 576–585. <https://doi.org/10.1111/j.1095-8649.1995.tb01924.x>
- Rodriguez, F., Duran, E., Vargas, J. P., Torres, B., & Salas, C. (1994). Performance of goldfish trained in allocentric and egocentric maze procedures suggests the presence of a cognitive mapping system in fishes. *Animal Learning & Behavior*, 22(4), 409–420. <https://doi.org/10.3758/BF03209160>
- Rowe, D. K., & Smith, J. P. (2008). The role of exotic fish in the loss of macrophytes and increased turbidity of lake Wainamu, Auckland. In *Auckland Regional Council Technical Report Number 2008/003* (Vol. 0504, Issue 003).
- Ruppert, J. L. W., Docherty, C., Neufeld, K., Hamilton, K., MacPherson, L., & Poesch, M. S. (2017). Native freshwater species get out of the way: Prussian carp (*Carassius gibelio*) impacts both fish and benthic invertebrate communities in North America. *Royal Society Open Science*, 4(10). <https://doi.org/10.1098/rsos.170400>
- Rylková, K., Kalous, L., Bohlen, J., Lamatsch, D. K., & Petrtyl, M. (2013). Phylogeny and biogeographic history of the cyprinid fish genus *Carassius* (Teleostei: Cyprinidae) with focus on natural and anthropogenic arrivals in Europe. *Aquaculture*, 380–383, 13–20. <https://doi.org/10.1016/j.aquaculture.2012.11.027>
- Rytwinski, T., Taylor, J. J., Donaldson, L. A., Britton, J. R., Browne, D. R., Gresswell, R. E., Lintermans, M., Prior, K. A., Pellatt, M. G., Vis, C., & Cooke, S. J. (2019). The effectiveness of non-native fish removal techniques in freshwater ecosystems: A systematic review. *Environmental Reviews*, 27(1), 71–94. <https://doi.org/10.1139/er-2018-0049>
- Sadler, J., Marecaux, E., & Goodwin, A. E. (2008). Detection of koi herpes virus (CyHV-3) in goldfish, *Carassius auratus* (L.), exposed to infected koi. *Journal of Fish Diseases*, 31, 71–72. <https://doi.org/10.1111/j.1365-2761.2007.00830.x>
- Schofield, P. J., Brown, M. E., & Fuller, P. L. (2006). Salinity tolerance of goldfish *Carassius auratus* L., a non-native fish in the United States. *Florida Scientist*, 69(4), 258–268.
- Scott, W. B., & Crossman, E. J. (1973). *Freshwater Fishes of Canada*. Fisheries Research Board of Canada. Bulletin 184.
- Sibeaux, A., Karlsson, C., Newport, C., & de Perera, T. B. (2022). Distance estimation in the goldfish (*Carassius auratus*). *Proceedings of the Royal Society B: Biological Sciences*, 289(1984). <https://doi.org/10.1098/rspb.2022.1220>
- Smartt, J. (2007). A possible genetic basis for species replacement: preliminary results of interspecific hybridisation between native crucian carp *Carassius carassius* (L.) and introduced goldfish *Carassius auratus* (L.). *Aquatic Invasions*, 2(1), 59–62.
- Statistics Canada. (2018). *Table 33-10-0105-01 Canadian business counts, with employees. December 2018* (Issue December). <https://doi.org/https://doi.org/10.25318/3310010501-eng>
- Stone, N., McNulty, E., & Park, E. (2003). The Effect of Stocking and Feeding Rates on Growth and Production of Feeder Goldfish in Pools. *North American Journal of Aquaculture*, 65(2), 82–90. [https://doi.org/10.1577/1548-8454\(2003\)65<82:teosaf>2.0.co;2](https://doi.org/10.1577/1548-8454(2003)65<82:teosaf>2.0.co;2)
- Strecker, A. L., Campbell, P. M., & Olden, J. D. (2011). The Aquarium Trade as an Invasion Pathway in the Pacific Northwest. *Fisheries*, 36(2), 74–85. <https://doi.org/10.1577/03632415.2011.10389070>
- Stuart, S. N., Chanson, J. S., Cox, N. A., Young, B. E., Rodrigues, A. S. L., Fischman, D. L., & Waller, R. W. (2004). Status and trends of amphibian declines and extinctions worldwide. *Science*, 306(December), 1783–1786.

- Szczerbowski, J. A. (2001). *Carassius auratus* (Linnaeus, 1758). In P. M. Bănărescu & H.-J. Paepke (Eds.), *The Freshwater Fishes of Europe, Vol. 5/III; Cyprinidae 2/III and Gasterosteidae* (pp. 5–41). AULA-Verlag GmbH.
- Takada, M., Tachihara, K., Kon, T., Yamamoto, G., Iguchi, K., Miya, M., & Nishida, M. (2010). Biogeography and evolution of the *Carassius auratus*-complex in East Asia. *BMC Evolutionary Biology*, *10*(7), <https://doi.org/10.1186/1471-2148-10-7>.
- Tarkan, A. S., Cucherousset, J., Zieba, G., Godard, M. J., & Copp, G. H. (2010). Growth and reproduction of introduced goldfish *Carassius auratus* in small ponds of southeast England with and without native crucian carp *Carassius carassius*. *Journal of Applied Ichthyology*, *26*(SUPPL. 2), 102–108. <https://doi.org/10.1111/j.1439-0426.2010.01506.x>
- Tarkan, A. S., Gaygusuz, O., Gürsoy Gaygusuz, C., Saç, G., & Copp, G. H. (2012). Circumstantial evidence of gibel carp, *Carassius gibelio*, reproductive competition exerted on native fish species in a mesotrophic reservoir. *Fisheries Management and Ecology*, *19*(2), 167–177. <https://doi.org/10.1111/j.1365-2400.2011.00839.x>
- Taylor, J., & Mahon, R. (1977). Hybridization of *Cyprinus carpio* and *Carassius auratus*, the first two exotic species in the lower Laurentian Great Lakes. *Environmental Biology of Fishes*, *1*(2), 205–208.
- Tisdale, A. E. (Gene). (2019). *Dragon Lake Goldfish Boat Electrofishing. July 8, 2019*.
- Traxler, G. S., Richard, J., & McDonald, T. E. (1998). *Ichthyophthirius multifiliis* (Ich) Epizootics in Spawning Sockeye Salmon in British Columbia, Canada. *Journal of Aquatic Animal Health*, *10*(2), 143–151. [https://doi.org/10.1577/1548-8667\(1998\)0102.0.CO;2](https://doi.org/10.1577/1548-8667(1998)0102.0.CO;2)
- Trujillo-González, A., Becker, J. A., & Hutson, K. S. (2018). Parasite Dispersal From the Ornamental Goldfish Trade. *Advances in Parasitology*, *100*, 239–281. <https://doi.org/10.1016/bs.apar.2018.03.001>
- Tweedley, J. R., Hallett, C. S., & Chambers, J. M. (2012). *A baseline survey of the fish fauna of the highly eutrophic Vasse and Wonnerup estuaries* (Issue July).
- Van den Thillart, G., Van Berge-Henegouwen, M., & Kesbeke, F. (1983). Anaerobic metabolism of goldfish, *Carassius auratus* (L.): Ethanol and CO₂ excretion rates and anoxia tolerance at 20, 10 and 5°C. *Comparative Biochemistry and Physiology -- Part A: Physiology*, *76*(2), 295–300. [https://doi.org/10.1016/0300-9629\(83\)90330-4](https://doi.org/10.1016/0300-9629(83)90330-4)
- Wake, D. B., & Vredenburg, V. T. (2008). Are we in the midst of the sixth mass extinction? A view from the world of amphibians. *Proceedings of the National Academy of Sciences*, *105*(Supplement 1), 11466–11473. <https://doi.org/10.1073/pnas.0801921105>
- Walker, R. M., & Johansen, P. H. (1977). Anaerobic metabolism in goldfish (*Carassius auratus*). *Canadian Journal of Zoology*, *55*(8), 1304–1311. <https://doi.org/10.1139/z77-170>
- Winandy, L., & Denoël, M. (2013). Introduced goldfish affect amphibians through inhibition of sexual behaviour in risky habitats: An experimental approach. *PLoS ONE*, *8*(11). <https://doi.org/10.1371/journal.pone.0082736>
- Winandy, L., Legrand, P., & Denoël, M. (2017). Habitat selection and reproduction of newts in networks of fish and fishless aquatic patches. *Animal Behaviour*, *123*, 107–115. <https://doi.org/10.1016/j.anbehav.2016.10.027>
- Wydoski, R. S., & Whitney, R. R. (2003). *Inland fishes of Washington* (2nd ed.). University of Washington Press.
- Zhu, M., Li, K., Xuan, Y., Sun, Z., Liu, B., Kumar, D., Jiang, M., Pan, Y., Zhang, Y., Gong, Y., Lu, X., Yu, D., Hu, X., Cao, G., Xue, R., & Gong, C. (2019). Host Range and Vertical Transmission of Cyprinid herpesvirus 2. *Turkish Journal of Fisheries and Aquatic Sciences*, *19*, 645–652. https://doi.org/10.4194/1303-2712-v19_8_02