Review and assessment of the Inland Fisheries Service Carp Management Program eradication efforts in Lake Sorell

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Executive Summary

Only one female carp was caught from Lake Sorell this year (2022-23), bringing the total number of carp caught to 41,504 since the Inland Fisheries Service (IFS) Carp Management Program (CMP) began in 1995. The last viable male carp was caught over four years ago, in December 2018. There appears to be no fertile males left in the lake. Nearly 40,000, 100 m net hours (one 100 m net hour = 100 m net set for one hour) of focused fishing effort was undertaken from October 2022 to January 2023. The environmental conditions this summer were perfect to promote carp spawning activity and increase fishing efficiency, with the highest lake levels recorded in Lake Sorell since the 1970's and extended periods of warm, sunny weather. However, despite these favourable conditions and extensive focused fishing effort, only one female carp was caught. The ideal environmental conditions for spawning activity over the past two spring-summer seasons and continued low catch rates are a strong indication that carp can now be considered as functionally eradicated from Lake Sorell. Additionally, extensive monthly juvenile carp surveys conducted during and after the spawning season have not detected any sign of recruitment. Given there has not been a significant successful spawning event since 2009, and the last three male carp caught had the jelly gonad condition (JGC), it is increasingly likely that any remaining carp are unable to breed. All water released from Lake Sorell is still being screened as a precautionary measure, and no carp were found in Lake Crescent or downstream in the River Clyde. Lake Sorell will remain open for public recreational use. As carp can be considered functionally eradicated from the lake, the IFS will commence decommissioning the CMP and all associated infrastructure. This is likely to occur in the new financial year and will involve removing all preventative containment measures. This will include the removal of barrier net, the removal of mesh/grating from the outflow screen structures, and the demolition of the Kermodes cut levy bank. However, ongoing juvenile and recruitment monitoring will continue as a precautionary screening measure.

Background

Invasive fish species can cause significant damage to native ecosystems by competing with or preying upon native fish, altering habitat, and introducing disease. Eradication of invasive fish is challenging and typically involves a combination of management strategies, including regulations on fishing and boat traffic, physical removal, chemical treatments, and biological control (Sorensen 2021). Physical removal is most commonly used and involves directly removing the invasive fish from the ecosystem, through electrofishing, netting, or trapping, and the use of physical barriers. Chemical treatments involve using pesticides or other chemicals to eliminate the invasive fish, but this approach can also harm non-target species and can have long-term effects on the ecosystem. Biological control involves introducing a natural predator or disease to control the invasive fish population. This approach can be effective but requires careful consideration of potential unintended consequences (Sorensen 2021). Overall, the success of invasive fish eradication depends on many factors, including the specific species, the size and complexity of the ecosystem, and the resources available for eradication efforts.

Invasive fish species in freshwater lakes can have significant implications for the ecosystem, including the displacement of native species, alteration of food webs, and changes in water quality. It can also impact human activities, such as recreational fishing and water use (Yick et al 2021). Effective monitoring and management of invasive fish populations are essential to minimize their impact on the ecosystem. Monitoring involves identifying the presence and abundance of invasive species through various techniques, such as electrofishing, gillnetting, genetic analyses (e.g., eDNA) and acoustic/visual surveys. Once identified, targeted management strategies can be implemented to control or eradicate invasive species. Although the eradication of invasive fish populations has usually only been accomplished with biocides (such as rotenone; see e.g. Britton et al. 2011). However, using biocides is strongly restricted and are normally only used in relatively small and enclosed

water bodies. Therefore, physical removal by commercial harvesting and gillnetting are more commonly used to positively minimize and control invasive fish populations (Haubrock et al 2018), although the specific methods need to be chosen carefully (Nuñez et al. 2012). The success of different strategies will vary depending on the specific invasive species, the size and complexity of the ecosystem, and the resources available for management. Eradication of invasive fish populations is incredibly difficult to achieve, and management efforts often instead focus on containment and minimizing their spread.

Prevention is also a critical aspect of managing invasive fish in freshwater lakes. In addition to management efforts, preventing the introduction of invasive species through measures such as education and regulations on the use of live bait and the release of non-native fish into lakes is crucial. Measures such as education and outreach, early detection and rapid response, and regulations on the movement of fish and boats can help to prevent the introduction and spread of invasive species.

Effective management of invasive fish species requires an adaptive, coordinated, and multi-disciplinary approach, involving collaboration amongst scientists, managers, policymakers, and the public. It involves ongoing research to improve our understanding of the impacts of invasive species and the effectiveness of management strategies. A combination of prevention, monitoring, and management efforts is essential to minimize the impact of invasive fish species on freshwater ecosystems.

The common carp, *Cyprinus carpio*, is one of the most cultivated freshwater species worldwide, and is also considered an invasive species. *C. carpio* has been introduced to more than 100 countries worldwide, causing significant ecological and economic damage in many parts of the world, including North America, Europe, and Australia. Carp cause many negative impacts on recipient ecosystems, such as an increase in sedimentation, erosion, dissolved nutrients, phytoplankton growth, and decreased abundance of macrophytes, macrozooplankton, benthic invertebrates, and native fish

(Haubrock et al 2018). Carp now comprise more than 90% of the fish biomass in some waterways in south-eastern Australia, destroying aquatic vegetation, increasing turbidity, competing with native fish for resources, and altering invertebrate community composition (Koehn, 2004, 2016). Carp are known for their ability to reproduce rapidly, and tolerate a wide range of environmental conditions. Several management strategies have been used to control carp populations around the world. Physical removal methods for carp include netting, trapping, and electrofishing. Chemical treatments have also been used, with rotenone being a commonly used pesticide for carp eradication. However, these methods are costly and may have unintended consequences on non-target species and the environment. Biological control (biocontrol) methods for carp include the use of predators or diseases that specifically target carp (e.g., McColl et al 2014). However, these methods can also have unintended consequences. The control and eradication of invasive carp populations is challenging and often requires a combination of methods tailored to the specific ecosystem and species involved.

Complete eradication of invasive carp from an ecosystem is often difficult to achieve, particularly in large and complex ecosystems. Lake Arreo (136 ha, maximum depth of 24 m), in Spain, supports dense populations of invasive fish species, including common carp (*Cyprinus carpio*) (Haubrock et al 2018). Invasive species were caught and removed from Lake Arreo in 2014-15 with the objective of eradicating carp. A large number (> 27,000) of individuals of invasive species were removed (> one tonne), yet eradication was not achieved for any species (Haubrock et al 2018). In the Great Lakes of North America, fishery managers are trying to limit the spread and damaging effects of Asian or Chinese Carp invasive species (Silver Carp - *Hypophthalmichthys molitrix*, Bighead Carp - *H. nobilis*, Black Carp - *Mylopharyngodon piceus*, and Grass Carp *Ctenopharyngodon idella*) and prevent additional invasions from occurring (Harris et al. 2021). Management efforts in this region are focused on eradicating Asian Carp to prevent spread, establishment, and negative consequences to aquatic and terrestrial communities (Harris et al. 2021).

Targeted removal is used to reduce carp abundance, with an ultimate aim of eradication to prevent spread and establishment in the other Great Lakes. However, eradication in this region has been unsuccessful to date (Harris et al. 2021).

There have been some successful carp control efforts on small scales in specific areas. In South Africa, Dalu et al (2020) investigated the ecological impacts of using rotenone to eradicate common carp from a small reservoir (0.86 ha, mean depth 0.74 m). Rotenone treatment effectively removed common carp and led to significant positive changes in water quality, plankton, and macroinvertebrate communities (Dalu et al 2020). However, this study also found that native fish populations did not fully recover after two years post-treatment (Dalu et a 2020). This research provided valuable insights into the impact of invasive fish species on freshwater ecosystems and the potential consequences of their removal method.

Tiberti et al (2021) developed an analytical approach to estimate residual population size and derive eradication probability in open populations while accounting for multiple removal methods, population dynamics, and imperfect detection. The approach was applied to twenty eradication projects in the U.S.A. and Europe. The study provided insights into the dynamics of fish populations subject to eradication in high mountain lakes of different countries and represents an informative tool to optimize eradication efforts and efficacy of conservation actions. However, despite a few cases of small-scale success, there are very few examples of complete eradications of invasive carp populations, and they remain a significant problem in many areas. Ongoing efforts are needed to prevent their spread and minimize their impact on native ecosystems.

IFS Carp Management Program

The Carp Management Program (CMP) was established within the Inland Fisheries Service (IFS) in 1995, in response to *Cyprinus carpio* (common carp) found in Lake Crescent, at Interlaken, in central Tasmania. To prevent a serious threat to a range of environmental, economic, and recreational values across Tasmania, the CMP team successfully contained carp to Lake Crescent and the interconnected, upstream Lake Sorell. Integrated pest management strategies resulted in the successful eradication of carp from Lake Crescent in 2007, and have been ongoing in Lake Sorell (Yick et al 2021). This report serves as a review and assessment of the recent CMP eradication efforts in Lake Sorell.

Eradication of carp in Lake Sorell (5300 ha) has been more complicated than in Lake Crescent (2300 ha) due to its larger size and diverse habitats (e.g., rocky shores, deep reefs, extensive wetlands). The CMP team have used intensive and integrated pest management strategies (physical carp removal using an integrated fishing down approach) in Lake Sorell since a large recruitment event in 2009. To prevent spawning and catch as many carp as possible each year, the CMP team have used a combination of techniques including electrofishing (backpack and boat), net fishing (gill and seine nets), traps (steel and fyke nets), physical barriers, and transmitter-tagged carp (fish surgically implanted with radio transmitters) (Diggle et al 2012; Yick et al 2021).

Over the 2022/23 sampling season, only one female carp was caught, bringing the total number of carp removed from Lake Sorell to 41,504, since their discovery in 1995. There now appears to be no fertile males left in the lake, and more than half of the male carp caught since 2017 have been affected by advanced stages of a never-before documented jelly gonad condition (JGC), where watery blisters form on the gonads, and eventually make the fish completely sterile (Mahmud et al 2020). This degenerative condition appears to be progressive, and the lack of any evidence of fertile, healthy males since

late 2018 indicates that the risk of any further spawning and recruitment events is extremely low. While the catch of four females in 2021/22 initially appears high, relative to the reduced number of netting hours and last season's catch, this was to be expected due to the favourable environmental conditions (high lake level coinciding with long periods of warm, sunny weather) over spring. This increased carp activity therefore resulted in effective targeted gillnet fishing. The ideal carp spawning environmental conditions over the past two spring and summer seasons (2021-22 and 2022-23) and extremely low catch rates (only one female in 2022-23) indicates a critically low remaining carp population, of most likely only females, and no healthy males. Therefore, carp can now be considered as functionally eradicated from Lake Sorell.

Consistent and high levels of targeted gillnet effort have significantly reduced the risk of spawning, and made it increasingly difficult to locate and catch carp, and despite increasing the targeted fishing pressure over the last few seasons, the total carp catch and catch per unit effort (CPUE) has continued to decline significantly. In addition, extensive juvenile carp surveys have not found any evidence of recuitment, and all released water from Lake Sorell is still screened as a precautionary measure. Therefore, the CMP estimates that there are few, if any, carp remaining. Additionally, the remaining Lake Sorell carp also have a stunted average size, poor general condition, and most males caught in recent years have been sterile from the JGC, which all adds to the evidence that strongly suggests that carp are functionally eradicated from Lake Sorell. Therefore, the IFS reopened Lake Sorell for public recreational use in February 2020, and the lake and has remained open since.

The IFS CMP appears to have satisfied the three Bomford Model criteria (Bomford and O'Brien 1995), considered as essential for achieving eradication or control for vertebrate pests, which are:

(i) rate of removal exceeds rate of increase at all population densities,
(ii) immigration is zero, and
(iii) all reproductive animals must be at risk (Bomford and O'Brien 1995).

In addition, the following evidence suggests that carp are now effectively eradicated from Lake Sorell:

- Despite perfect carp spawning environmental conditions, the highest lake levels recorded since the 1970's, and high-level, targeted fishing effort, only one female carp was caught this season (2022-23).
- Despite intensive targeted fishing effort, only one female carp was caught this season (2022-23), and only four female carp were caught last season (2021-22), and it is likely that only one of those females had the potential to be reproductively capable.
- There were no signs of carp recruitment detected in 2015-16, 2021-22, and 2022-23 despite ideal spawning conditions. La Niña conditions this season (2022-23) resulted in the highest lake levels recorded since the 1970s.
- The last population tagged carp was caught on the 30th of November 2017 (Donkers et al 2012, IFS 2012).
- The last ex-transmitter carp was caught on the 11th of December 2018, and there were very few wild/untagged carp caught in 2018 during the transmitter carp targeting events (Diggle et al 2012; Yick et al 2021).
- The dominant carp cohort (2009 recruits) in Lake Sorell are approaching 14 years old; therefore, most of the remaining population are likely close to natural mortality given their overall poor general condition (Vilizzi 1997; Brown et al 2005).
- The sex ratio of the population is strongly biased towards females, and if any male carp are remaining, there is the high probability they will have the Jelly

Gonad Condition (JGC) and be sterile.

- The non-targeted gillnet catch per unit effort (CPUE) has continued to decline each year.
- The Allee Effect is likely to have a strong effect on the remaining population (Liebhold and Bascompte 2003), and evidence of this is carp being caught in poor condition, and with tumour growths recorded internally on three out of four females caught in 2021-22.
- The last significant spawning event was in 2009, with a very small recruitment event (11 carp caught) detected in the 2013-14 season. No spawning or small carp were found in Lake Sorell over the 2022-23 season or the preceding eight seasons.

Therefore, carp can now be declared as functionally eradicated from Lake Sorell, and the IFS plan is to move into a monitoring phase and for Lake Sorell to remain open for public recreational use. Long-term barrier nets that have blocked access to carp spawning areas will be removed, as well as the mesh/grating installed in the water control outlet structures to prevent downstream movement of carp into Lake Crescent. The Levee bank at Kermodes cut will also be demolished and reinstated to allow water to flow into Lake Crescent once full supply level is reached. In March 2024, recruitment and juvenile surveys (electrofishing and fyke net effort) will be undertaken, to ensure that there is still no carp spawning and recuritment occuring. This is especially important as the single carp caught over the 2022-23 season was a healthy mature female. However, as carp can now be considered as functionally eradicated from Lakes Sorell and Crescent, it is time to completely scale-back the CMP and remove all preventative measures and barriers. In addition to ongoing juvenile/recruitment monitoring, it is possible that eDNA methods could be investigated as an ongoing precautionary screening measure (see Furlan et al 2019). Future decision-making will need to be adaptable and dynamic, and based on ongoing recruitment monitoring over the 2023-24 spring/summer season. It will also involve assessing the relative costs of the different strategies and cost

effectiveness of each approach, to inform and optimise future strategies and direction.

The state-wide functional eradication of carp from Tasmania is an outstanding, rare achievement on a global scale, and a remarkable result for the conservation of Lakes Sorell and Crescent, which are Ramsar listed wetlands of national and international significance. To the best of our knowledge, this is the largest-scale successful eradication of carp from a lake worldwide and is an extraordinary achievement for the IFS CMP and Tasmania's freshwater ecosystems.

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