Prior Park Landscape Garden
Signal Crayfish Project

Report on Phase 1, 2019 - 2023

Contents

1 Introduction

This report describes the actions carried out to control American signal crayfish *Pacifastacus leniusculus* within three ornamental lakes at the Prior Park Landscape Garden, Bath BA2 5AH between 2019 and 2023.

Signal crayfish were introduced to the UK for aquaculture in the mid 1970's and have spread throughout the UK. Signal crayfish can have major adverse effects on ecosystems through predation of fish and invertebrates, consumption of detritus and vegetation and siltation/ecosystem engineering though their burrowing and bioturbation actions. They have been responsible for an 80-90% decline in native white-clawed crayfish *Austropotamobius pallipes* since 1976 through out-competition and crayfish plague *Aphanomyces astaci,* a fungal pathogen carried by signal crayfish which is fatal to the native white-clawed crayfish (Holdich et al 2014).

The site, owned by the National Trust, consists of an 18th century landscape garden. The three lakes, separated by dams, are of historical significance, featuring one of only four Palladian bridges in the world which is Grade 1 listed and a scheduled monument (cover photograph). Signal crayfish have been recorded in the lakes since 2009 and their burrowing activities caused damage to the dams, banks and surrounding paths, leading to a major restoration project between 2019 and 2022 (National Trust 2023).

1.1 Background

The three lakes are set in a steep valley, spring fed and up to 1.5m deep with steep sided banks (Figure 1). Lake size increases with descent, the uppermost 'top lake' being the smallest at approximately 660m^2. The middle lake (2000m^2) was drained in approximately 2015 due to concerns about the condition of the dam, and remained empty until spring 2022. The lower (bottom) lake is by far the largest at 6000m^2 and had been used for angling prior to the National Trust acquiring the site in 1993. Fish species present in this lake prior to the restoration works were Common carp *Cyprinus carpio,* perch *Perca fluviatilis,* tench *Tinca tinca,* roach *Rutilus rutilus* and bream *Abramis brama.* Signal crayfish had been reported at the site since 2009 and it is likely they were introduced as a result of this angling activity, either through fish introductions or their use as bait. This lake was drained between 2020 and 2022.

Figure 1. *Aerial photograph of lakes at Prior Park, Bath*

The restoration works consisted of the rebuilding of the dams in the middle and lower lakes in order to prevent further damage by signal crayfish. Prior to commencement of works the author was consulted on ways to control or eradicate the crayfish as part of the project. Site staff and volunteers received training from the author in 2019 with a view to gathering baseline crayfish data and initiating control efforts prior to the commencement of construction works. These control works continued from 2019 to December 2023 and are outlined in the following sections. Works will continue over the long term, subject to a management plan for the period January 2024 – December 2028 inclusive.

2 Methods

2.1 Rationale for management approach

The eradication of signal crayfish is considered impossible in the absence of biocides (Stebbing et al. 2014) though it has been shown that reductions in numbers through population control can have positive effects on ecosystems (Moorhouse et al. 2014). One key principle of invasive species control is that all life stages of populations must be targeted. Most of the control methods commonly implemented have limitations therefore a multi-method, adaptive approach is necessary. One such approach, shown to be successful in the USA, is the combination of removing large breeding adults with the use of fish, which target small and medium sized crayfish, as predators (Hein et al. 2007). As the lakes supported fish, and volunteers were available to undertake removals, it was considered the best overall approach. At the commencement of the project in 2019, the sterilisation of adult male crayfish was also incorporated (Green et al. 2020) but discontinued in March 2022. It was also hoped that crayfish removals would take place during the dewatering of the lower lake but this was not possible for health & safety reasons.

2.2 Removals

In order to target as wide a size range and equal proportions of males and females, removals used two types of baited trap and artificial refuge traps.

2.2.1 Baited traps

Baited traps are the most commonly used trapping method where the crayfish are attracted into an enclosed trap using bait such as fish or cat food. They are relatively labour-intensive as they need checking every 24 hours for animal welfare reasons. Baited traps are effective in still, deep waters but are biased towards larger animals, particularly males. The project used a combination of plastic Trappy type traps and net type traps such as the 'Fladen' (Fig. 2). The smaller mesh diameter of the Fladen trap aimed to capture a wider range of size classes.

Figure 2. *Fladen net trap (left) and Trappy trap (right)*

2.2.2 Artificial Refuge Traps (ART)

This trap (Fig. 3) consists of a number of plastic tubes attached to a metal base and acts as a habitat mimic. It does not require bait therefore can be left for long periods between checks. The ART is not sex biased and captures juvenile and small adult crayfish which are less likely to be captured by baited traps (Green et al. 2018). It is also effective at capturing crayfish at low densities. A 'standard' sized ART was predominantly used, with the introduction of higher capacity versions in 2022.

Figure 3. *Standard artificial refuge trap*

2.2.3 Timing and effort

Crayfish trapping aimed to take place twice weekly, year-round though varied in accordance to a number of issues, not least the Covid 19 lockdown in 2020. There were other stoppages due to health and safety issues and volunteer availability, and trapping was restricted to the top lake whilst the dam restoration works were underway. Trap numbers also varied, and slowly increased as more traps were acquired. Trapping with baited traps in the top lake was discontinued in July 2021 due to low catch rates and insufficient volunteer resources. Biosecurity best practice was adhered to throughout.

2.3 Sterile male release technique

At the commencement of the project Dr Nicky Green was undertaking PhD research into the manual sterilisation of male crayfish (Green et al. 2020, 2022; Green 2022) and it was considered a useful technique to trial at Prior Park, with the aim of reducing crayfish reproduction. Sterilisation was applied to all males ≥ 35 mm carapace length (CL) by cutting off the gonopods (appendages used in the transfer of sperm during mating) with a pair of scissors. This technique has been shown to not affect the health or the natural behaviour of the crayfish (Green et al. 2020) and volunteers were fully trained in its application. Due to the imminent dewatering of the lower lake, all sterilised males captured there were released into the top lake.

2.4 Manipulation of fish populations

Some species of fish, including perch, are effective predators of crayfish, especially juveniles which comprise 80% of crayfish populations and are hard to capture using other methods. Non predatory species such as roach can also have an effect on crayfish activity and survival rates just by 'being there', competing for food with and instigating avoidance behaviours by the crayfish (Nystrom 2005). Most fish are limited by gape size to eating small to medium sized crayfish therefore the removal of larger crayfish by other means is necessary to prevent ongoing reproduction and replenishment of the crayfish population (Hein et al. 2007).

The planned dam restoration works required the dewatering of the lower lake, therefore fish rescues were required. In January 2020 320 roach, 235 perch, 24 tench and 2 bream were captured in the lower lake and released into the top lake. The carp were captured and moved off site for rehoming.

Once dam restoration works were complete, the middle and lower lakes were refilled in March 2022 and trapping recommenced. It was clear that crayfish were still present in all three lakes, so it was imperative that the fish were redistributed to avoid a population explosion. In March 2023, 400 roach and 180 perch were captured in the top lake and redistributed between the three lakes at a rate of 240 each middle and lower, and 100 top.

Table 1. *Schedule of management events 2019 - 2023*

Date	Item	Lake
c. 2015	Dewatered	Middle
March 2019	Commencement of crayfish trapping	Top, lower
September 2019	Commenced male sterilisation	Top, lower
January 2020	Fish moved from lower to top lake, trapping discontinued lower lake	Top, lower
Mar – Nov 2020	Trapping discontinued due to Covid	Top
2020	Dewatered (date unsure due to lockdown)	Lower
Nov 2020 – Dec 2023	Removal of crayfish via trapping	Top
July 2021	Use of baited traps discontinued	Top
March 2022	Sterilisation discontinued	Top
March 2022	Refilling of lakes	Middle, lower
Sept 2022 – Dec 2023	Removal of crayfish via trapping	Middle, lower
March 2023	Redistribution of fish from top lake	Top, middle, lower
Dec 2023	Management plan prepared	All lakes

2.5 Crayfish processing and data analysis

Up until July 2022 the size (measured as carapace length in mm using callipers) and sex of each crayfish was recorded together with incidental data such as moult and damage. From July 2022 the method was simplified to record small (≤ 25 mm CL), medium (26 – 44 mm CL) and large (≥ 45 mm CL) on a measuring board to save time.

The data was initially collated in Excel spreadsheets and interrogated using Excel and SPSS. Since September 2022 an online database (Airtable) has been used which simplifies recording and enables ongoing plotting of results.

3 Results

3.1 Top lake

A total of 1522 crayfish were captured and removed from the top lake over the four-year period, with 95 males being sterilised and returned and a further 158 sterilised males introduced from the lower lake between September 2019 and March 2022. Catches decreased dramatically after the fish introduction in 2020, and have remained low since that point despite most of the fish being removed in March 2023 (Fig. 4).

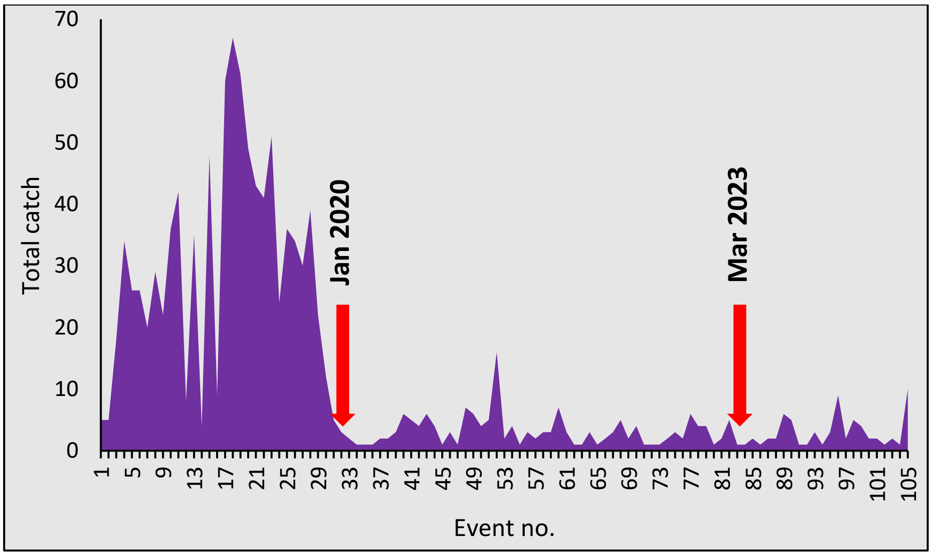

Figure 4. *Total catch, top lake 2019 - 2023*

3.2 Middle and lower lakes

Between March 2019 and January 2020, a total of 1247 female and small male crayfish were captured and removed from the lower lake, whilst 158 mature male crayfish were sterilised and moved to the top lake between September 2019 and January 2020. This catch was unexpectedly high, given the size of the existing fish populations, though catches of small crayfish were low and catches of large slightly higher than expected (Sec. 3.3), suggesting some impacts of predation (Fig 5). This was attributed to a combination of dense underwater vegetation, which provides shelter for crayfish, and potentially high numbers of carp (Section 4).

In 2023 catch rates on the lower lake were considerably lower, but indicated the ability of crayfish to survive in damp conditions. Catches of small crayfish (155 in 2019–20 vs. 9 in 2022–23) were particularly low, suggesting that the redistribution of fish in spring 2023 had the desired effect of reducing juvenile survival rates (Fig 5). However only one bank of the lake was trapped due to health and safety reasons and possible damage to post-works landscaping so the data may not show the true status of the population.

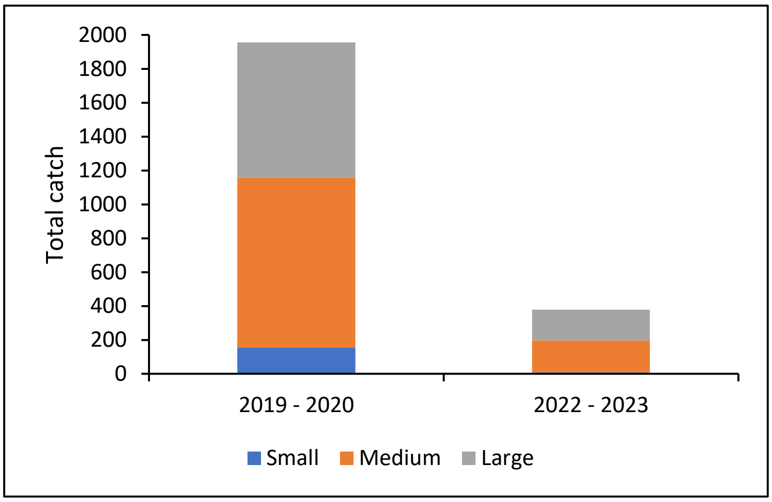

Figure 5. *Comparison of size structure, lower lake 2019-20 vs. 2022-23*

During the dewatering process it was not possible to capture crayfish or to fence the lake to prevent crayfish movement, so it is likely that many crayfish migrated to the middle and top lakes during dewatering. This migration is evident in the catch data for the middle lake subsequent to refilling (Fig. 6). and the top lake subsequent to dewatering (events Fig. 4). Over 700 crayfish were captured from the middle lake in the six months after trapping recommenced. Although this lake had been dewatered several years ago, various rivulets crossed the waterbody and it too was heavily vegetated, providing damp conditions in which the crayfish survived. The large catches of medium sized crayfish also indicated potential reproduction in the rivulets or migration of juveniles, potentially from the top lake to escape fish predation (Fig. 6).

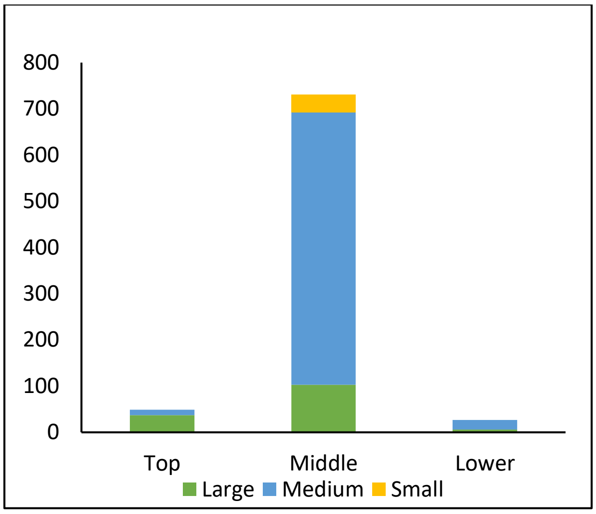

Figure 6. *Total catch by size and location, Sep 2022 - May 2023*

3.3 Sterilisation

The population structure in the top lake has changed considerably between 2019 and 2023. In 2019 (Year 1, Fig. 7), the catch structure is typical of mixed trapping with 15% small, 55% medium and 30% large. By 2023 the ratio of small animals has fallen to 3% whilst the percentage of large has increased to 68%. Whether this change could be initially attributed to sterilisation is unclear, due to the introduction of fish in early 2020 (Year 2). Due to the length of the crayfish incubation period (6 months) and the difficulties of capturing juvenile (less than one year old) crayfish, there is an 18-month time lag before the effects of the treatment become evident in catches, so reductions in catches of small crayfish would be expected by Year 3 (2021). However, reductions in the proportions of small and medium crayfish did not occur till years 4 and 5 (2022 and 2023; Fig. 7).

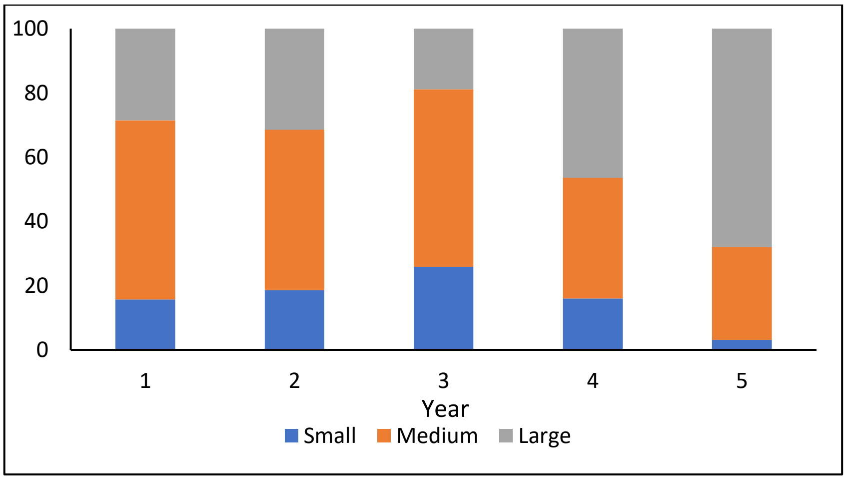

Figure 5. *Size structure of catches (as percentage of total), 2019 - 2023*

Sterilisation was discontinued in March 2022 because the majority of animals being captured were large, sterilised males, who, being dominant in the population, deterred smaller animals from entering traps. The reintroduction of fish would also have achieved the objective of controlling reproduction and it was considered that removal of the breeding males was a more effective management strategy, given the unknown efficacy of the technique and the tendency for sterilised males to dominate catches, particularly in baited traps.

4 Conclusions

The experiences with the top lake have confirmed the potential for the crayfish population on site to be suppressed by a combination of trapping and fish predation. It is hoped that over the next five years, fish populations will grow, and in combination with the removal of breeding adult crayfish will achieve the long-term objective of maintaining low numbers of crayfish with minimal trapping intervention. The high crayfish catches in the lower lake prior to dewatering raises questions about the role of carp in signal crayfish control. There have been few studies of carp/crayfish interactions though they are widely seen as a predator of crayfish. However, waterbodies where carp are the only fish present often support large crayfish populations (BUG 2023), and sites with mixed fish populations including large numbers of carp can also have large crayfish populations (C. Jackson, pers. comm). Carp are prolific breeders, females producing up to one million eggs a year, and it is postulated that carp eggs and juveniles provide a more attractive food source than crayfish to predators such as perch, as well as an excellent food source for crayfish. Future trapping and study of the interaction between crayfish and fish on site in the absence of carp will provide valuable knowledge in the field of crayfish control. High vegetation levels may have also affected catch rates by providing cover for crayfish, and regular vegetation management has been initiated as a result.

Due to health and safety concerns it was not possible to capture crayfish during the dewatering process or to fence off the other lakes, and it is clear that a large number of crayfish moved overland into the damp conditions of the middle lake where they survived and reproduced for two years. It is also likely that crayfish moved from the top to the middle lake subsequent to the fish introduction in 2020, so fencing of that lake to contain those animals could have prevented this migration. These experiences at Prior Park demonstrate the ability of crayfish to survive in damp conditions and stress the importance of containing the overland movements of crayfish during management works.

The limited application of male sterilisation produced inconclusive results in concurrence with other field trials (Green 2021). Significant changes to the size structure of the crayfish population in the top lake could not be attributed to sterilisation, but are more likely due to the introduction of predatory fish, or a combination of both techniques.

The drawbacks of using baited traps were apparent: - during the sterilisation trial these traps were dominated by previously sterilised large males, whose presence reduced the numbers of smaller animals entering the traps and the ongoing removal/sterilisation of smaller animals. In addition, the presence of bait is likely to attract predatory fish which will also dissuade smaller crayfish from entering the traps. Ongoing management works will include a comparison of baited traps and ARTs in the presence of predatory fish to determine the most effective trap type. Brash bundles will also be trialled; these have shown to be highly effective attractants of juvenile crayfish (Green 2023) and will provide cover for juvenile fish, thus boosting survival rates.

Overall, despite some constraints the first five years of this project have demonstrated the value of adaptive management of crayfish by making use of existing site conditions and with limited resources. Considerable success has been achieved in reducing crayfish numbers and these successes, including lessons learnt, provide a sound basis for the next five years of management and experiences that can be disseminated to other management projects.

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