PESTSMART

Effectiveness of carp removal techniques: options for local governments and community groups

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Invasive Animals CRC
Queensland Government
An Australian Government Initiative
CRC Australia
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Executive summary

Carp (*Cyprinus carpio*) are one of 34 freshwater fish introduced into Australia which have established self sustaining populations (Lintermans 2004). Now widespread throughout the inland waterways of south-eastern Australia, carp are widely believed to have detrimental effects on native aquatic plants, animals and general river health, particularly through their destructive feeding habits (Koehn et al 2000, Smith 2005, Miller and Crowl 2006).

Public concern that the high numbers and widespread distribution of carp pose a major threat to aquatic ecosystems has resulted in increasing interest from catchment management groups to actively manage carp. Whilst research is progressing to develop large scale methods of carp control, there is a pressing need to firmly establish the benefits of existing methods that can be applied by local communities and landholders. There are a number of commonly used fisheries techniques that can help manage localised carp populations when used in an integrated manner. These tools vary greatly in their effectiveness, species specificity, cost and the technical skill required. This report compares these attributes for some of the techniques most commonly used to manage carp at a smaller scale.

Catch per unit effort (CPUE) was calculated as the carp catch resulting from each man-hour of effort each time a technique was implemented. Standardising in this manner enabled direct comparison between techniques. No fiscal value was placed on each man-hour due to differences in operator skill level requirements between techniques. Techniques were initially examined individually to calculate catch efficiencies and effectiveness across a range of carp densities and habitats. Direct comparisons were also made between six techniques applied concurrently at eight sites. Annual surveys were conducted to examine how long removal activities had an impact on carp populations at a number of treatment and control sites.

Electrofishing was the most efficient technique and captured the widest size range of carp. Electrofishing CPUE varied between 0.89–83.56 carp/man-hour with a mean of 5.32 carp/man-hour for the backpack unit, 10.82 for the small boat unit and 9.73 for the large boat unit. Electrofishing could be used successfully in most habitats, except for areas with water depths greater than 3–4 m or where salinity is high. Electrofishing also had the least impact on non-target species.

The second most efficient technique was the hopper trap which was developed as part of the project. This portable carp trap utilises an automated feed dispenser to lure carp through the entrance into a holding pen. Following a pilot study testing different attractants, the trap was trialled at 14 sites. CPUE varied with habitat and season, with a mean catch rate of 8.91 carp/man-hour. The carp trap targeted sub-adult and adult fish and was used successfully in lagoons, lakes, dams and rivers. A number of large-bodied native species, including turtles, were caught as bycatch — but all could be readily released unharmed. An added benefit of the trap design is that the wings can be detached and used as a seine net.

Seine netting was another highly effective technique, but only suitable in a limited number of areas. Seine nets caught large numbers of carp when used in lagoons, dams and lakes free of snags. CPUE ranged from 0.0–86.9 carp/man-hour, with a mean of 27.5 carp/man-hour in lagoons. Woody debris and other structures were generally too prevalent for the technique to be useful in creeks and rivers. Seine netting captured a wide range of species, but bycatch could be released unharmed by ensuring the pocket of the net was not removed from the water at the end of a haul.

Previous studies have found gill-nets to be an effective carp removal technique. However, the abundance of large-bodied non-target species, particularly turtles, limited the technique's suitability in the regions where our research was conducted. Bycatch impacts can be large and gill-netting is only recommended for use in a restricted number of scenarios.

Bait traps and fyke nets were also found to be inefficient carp removal techniques. Bait traps only caught carp at two out of eight sites where they were tested, with a mean CPUE of 1.16 carp/man-hour. Fyke nets caught carp at three out of eight sites with a mean CPUE of 1.48 carp/man-hour. Both techniques only caught smaller fish and only where carp were present in high densities in the shallows.

Angling was found to be an ineffective technique for removing carp. Three carp angling competitions were assessed using tag-recapture to estimate population sizes and then calculating catch efficiencies and proportional reductions. The CPUE for the competitions was very low with a mean of only 0.042 carp/man-hour. The removal efforts occurred over large areas, resulting in low angling pressure and removal rates. Carp population reductions were observed in the range of 0.5–1.8% across the competition areas. Outside of competitions, angling CPUE did increase by an order of magnitude for a mean CPUE of 0.34 carp/man-hour.

Concurrent application of six techniques at eight sites confirmed the results from individual technique assessments. When electrofishing, the hopper trap and seine nets were used in combination, they caught the most carp and returned the highest CPUE. The daily CPUE of electrofishing tended to decrease over the week-long period it was employed at each site. Conversely, the daily catch rates of the hopper trap increased over the same period. The latter is most likely an artefact of the time taken for the food scent to disperse and lure the carp in. Seine nets were only effective in lagoons.

An integrated approach combining electrofishing, the hopper trap and seine netting would result in the greatest catch per unit effort whilst still targeting all sizes of carp in an area. Baited carp traps will capture medium to large carp and can be set to operate whilst other active techniques are employed. Electrofishing will target all sizes of carp, including smaller fish which the traps may miss. Electrofishing can also be used to herd carp towards a trap, increasing capture rates of both techniques. In large, shallow areas, seine netting can be combined with the other techniques to quickly remove carp from large areas. Gill nets could also be considered if a low number of non-target species are present and the water depth is more than 3m.

Most techniques were more effective during warmer months when carp are more active. When water temperatures were cool the passive techniques caught substantially fewer carp. Several techniques can be used to increase the effectiveness of removal techniques. Berley and pre-feeding can be used to concentrate or lure carp to an area where removal can be more easily undertaken. Manipulation of water levels can also be used to help congregate carp. Water draw-down can decrease the size of the area that needs to be managed and help concentrate carp numbers. Complete water draw-down has the potential to eradicate carp from a site if the area is left dry for several months. Care needs to be taken with this approach because impacts on non-target species can be drastic. Management activities need to make the most of environmental opportunities. During periods of low water carp may be concentrated into smaller pools where migration is not possible. Similarly, rainfall may stimulate mass movement of carp through bottlenecks which can be exploited for removal.

The value of carp removal activities needs to be considered with regards to the speed with which carp populations can recover through immigration and recruitment. Complete eradication is often desirable, but rarely practical or possible. Once-off removal efforts rarely have a long-term impact unless substantial carp population reductions occur and immigration is prevented. Once-off activities were found to reduce carp populations by a level which was significantly lower than paired control sites for several months. These impacts did not persist more than 12 months. Periodic control is more likely to have longer lasting benefits and can result in an on-going carp population decline in areas where migration is low. In wetlands, the installation of exclusion screens may prevent reinvasion by adult fish whilst still allowing the passage of smaller native fish.

This project demonstrated that a range of currently available, generally low cost techniques can be used to capture carp. The effectiveness of these techniques varies with habitat type, carp density, carp size and the presence of non-target species. No single technique is appropriate in every scenario and thus a combination of techniques in an integrated approach is required. Organisations wishing to employ these techniques will need to seek permits and training from the appropriate regulatory bodies for their area.

Recommendations:

- An integrated approach will be most effective for carp removal by local governments and community groups trying to manage carp in local waterways.
- Carp removal efforts should integrate the use of electrofishing, hopper traps and seine nets where possible to maximise catch per unit effort, whilst still targeting all sizes of carp. If non-target species are rare then potential exists to also incorporate gill-nets, especially if used via splash-netting, or another technique that will herd carp into the gill-nets.
- Where possible, management activities should utilise water level fluctuations and draw-downs to maximise control efforts when carp are concentrated by low water levels.
- Control efforts should be on-going, rather than once-off to achieve appreciable benefits.
- The best value for management actions will be achieved in high value wetlands or drought refugia where carp re-invasion can be managed through the use of exclusion screens or ephemeral connections.

1. Introduction

Common carp (*Cyprinus carpio*) originated in central Asia and spread throughout Asia and Europe as an ornamental and aquaculture species. During the 1970’s, floods assisted the rapid spread of carp in Australia and they are now widely distributed throughout the Murray–Darling Basin, with smaller populations in the coastal rivers of eastern Australia as well as Tasmania and Western Australia (Koehn et al 2000). Carp are now the most abundant large freshwater fish in the Murray–Darling Basin and are the dominant species in many fish communities in south-eastern Australia (Gehrke et al 1995). In some areas they contribute up to 90% or more of the total fish biomass (Reid and Harris 1997, Brown et al 2003).

Carp are widely believed to have detrimental effects on native aquatic plants, animals and general river health, particularly through their destructive feeding habits (reviewed in Koehn et al 2000, Smith 2005, Miller and Crowl 2006). Carp are often found in degraded areas, although it is not clear whether they cause the degradation or are simply able to survive in areas where native fish have been eliminated. While in some cases carp have probably been blamed for degradation that is actually the result of human activities, it is clear that they can have major impacts.

The decline in aquatic ecosystem health in many areas has generated strong concern, particularly in rural and regional areas. Widespread public concern that the high levels of carp infestation pose a major threat to aquatic ecosystems has resulted in increasing interest from catchment management groups to actively manage carp. Carp management plans are now more frequently being developed and incorporated into holistic catchment and regional management planning processes.

It is currently not feasible to attempt comprehensive eradication of carp at a large scale. Carp are widespread, well established and abundant and there is a lack of effective control techniques. Carp are also very resilient to control work in various locations, even where control efforts are repeated and extensive. Carp are an incredibly resilient species to both environmental conditions and management efforts. They possess the ability to tolerate high levels of salinity (Geddes 1979; Gehrke 1991, 1992; Whiterod 2001), extremely low levels of dissolved oxygen (Otte et al 1980), blue-green algae (Carbis et al 1997) and a wide temperature range (Koehn et al 2000). Carp are also able to disperse widely, consume a range of food types and are extremely fecund (Brown et al 2003, Smith 2005). These factors combine to make them difficult to eradicate from an area once they become established, as well as difficult to prevent reinvading.

Whilst research is progressing to develop large scale methods of carp control, there is a pressing need to firmly establish the benefits of existing methods that can be applied by local communities and landholders. There are a number of commonly used fisheries techniques that can help manage localised carp populations when used in an integrated manner. These tools vary greatly in their effectiveness, species specificity, cost and the technical skill required. This report compares these attributes for some of the techniques most commonly employed to manage carp at a smaller scale. Preventative measures which help limit carp recruitment or reinvasion are not evaluated. The techniques described are those which could be employed by a community group or local government to help manage carp in waterways and habitats considered to be of high conservation value or significantly threatened by carp. There is some anecdotal evidence that the removal of carp may help to keep carp numbers under control, especially when repeated over time. Often the main argument for removing carp is to provide some respite to aquatic habitats and native species. When integrated with habitat rehabilitation efforts, a reduction in carp numbers can give native species the opportunity to re-establish and give habitat time to recover.

2. Objectives

The aims of the research reported in this report were to:

1. Determine the catch efficiency of a range of carp fishing methods
2. Determine how efficiency changes with habitat type and carp density
3. Assess the effectiveness of fishing methods at reducing carp populations
4. Compare non-target bycatch between the techniques
5. Develop recommendations of how fishing techniques can best be integrated for local carp management

3. Effectiveness of individual techniques

3.1 Methodology

An assessment of the effectiveness, or efficiency, of individual carp removal techniques was undertaken at locations with known carp densities or population numbers. Efficiency is commonly expressed in terms of the number of fish captured by a fishing technique in a given unit of time, usually an hour. A more rigorous definition calculates the percentage removal of carp from a population by a fishing technique. In this report, efficiency is described as catch per unit effort (CPUE) and the percentage removal is described as effectiveness.

Catch per unit effort (CPUE) was calculated as the carp catch per man-hour effort each time a technique was implemented. The effort was calculated as the time taken to deploy, maintain and clear passive gear, or the time spent implementing active forms of control such as electrofishing. Effort did not take into account gear soak time because that does not have an active labour element and thus is unlikely have a large impact on cost. For example, if 21 carp were caught over a 3 hour period by a two person team in the small electrofishing boat, the total effort would be 2 persons x 3 hours = 6 man-hours of effort. The CPUE would be 21/6 = 3.5 carp/man-hour. Standardising in this manner enabled direct comparison between techniques. No fiscal value was placed on each man-hour as the difference in operator skill level varies between techniques. Details of carp density and habitat type were also recorded to facilitate discussion of the impact these variables have on technique effectiveness.

Where possible, population estimates were derived from mark recapture data. Prior to testing a technique, an initial trip was made to sites to collect carp for marking with coloured 100mm PDS dart tags (Hallprint). Tags were placed through their dorsal musculature with the barb locked behind about the fourth or fifth dorsal fin pterygiophores. Only fish larger than 150mm FL were tagged and thus the population estimates are for adult and sub-adult fish only. Population estimates were derived from fish caught on subsequent visits using an un-biased Lincoln Peterson method (in Williams et al 2002) and the standard error was calculated to provide information on the precision of the estimate.

$$N = \frac{(n1+1)(n2+1)}{(m+1)} - 1,$$

where,

N = Estimate of total population size
n1 = Total number of animals tagged on the pre-competition sampling
n2 = Total number of animals captured on the post-competition sampling
m = Number of tagged animals re-captured

Standard error (SE) = $\text{sqrt}\ \{\ [(n1+1)(n2+1)(n1-m)(n2-m)]\ /\ (m+1)^2(m+2)\ \}$

Where mark-recapture methods could not be used, site population estimates were based on carp densities reported during annual surveys. Standardised electrofishing surveys do not necessarily detect or capture all fish in an area but rather provide an overview of species composition and relative abundance. A scaling factor based on catchability helped to provide an estimate of the magnitude by which annual survey carp densities differed from those derived from mark-recapture population estimates.

Population estimates from survey densities were first compared to mark-recapture estimates at sites where both datasets were available (Table 1). The ratio of the survey estimate to mark-recapture estimate was calculated and averaged to determine a scaling factor. Population size at a given site was calculated by multiplying the survey density by the scaling factor and the size of the area.

Table 1: Sites where electrofishing surveys (ES) and mark-recapture (MR) were both used to calculate carp adult and sub-adult population estimates. Scaling factor was the ratio of MR/ES that needed to be applied to survey data to obtain more realistic population estimates.

Site	Survey density (carp/ha)	Area (ha)	Survey estimate	MR estimate	Scaling factor
TF2	142[1]	50	7,100	9,746	1.37
Tabragalba	139[1]	2.7	375	700	1.87
South McLean	27	3.0	81	164	2.02
Rainbow Reserve	200	7.2	1,440	1,548	1.08
Booberoi	227	1.6	363	681	1.87
Yellowbank Reserve	20	1.5	30	119	3.9
Mean					**2.02**

Averaged from 2007 and 2009 survey densities

3.2 Longlining

Longlining is technique commonly employed by commercial fishers in the marine environment to capture large numbers of demersal and pelagic fish. The technique involves setting out a long length of main line to which short lengths of line, called snoods, containing baited hooks are attached at intervals. The lines can be set vertically or horizontally in the water column. Horizontal lines may be set on the surface or near the bottom. The size and type of fish caught is determined by location, hook size and the bait used.

Longlining can be used in a variety of habitats but can be limited by the amount of woody debris present. Longlining has the potential to be used to catch carp in deep waters which cannot effectively be targeted with other techniques. Lines need to be checked regularly to ensure that any air-breathing animals caught can be released before they drown or die from exhaustion. The use of appropriate hooks and baits could reduce impacts on non-target bycatch.

3.2.1 Methods

Long lines were trialled at four locations. The trials were designed to test CPUE and the relative effectiveness of three hook sizes and two bait types. Each long-line consisted of a 50m main line which was held horizontally near the bottom by a weighted vertical float line at each end. The main line had knotted loops tied at 0.5m intervals to which individual droppers or snoods could be attached. Droppers were constructed from 30lb breaking strain monofilament line with the hook tied at one end and a shark clip tied to the other to facilitate quick attachment. Three different line lengths (1.5m, 3m, and 7m) were utilised to enable any air-breathing bycatch to reach the surface if hooked. The spacing of the droppers along the main line was dependent upon the water depth in which the lines were set. The droppers were spaced so that no two hooks could touch and thus become entangled. In shallow waters shorter droppers were used and up to 18 hooks could be set on a mainline. In deep water where the longest droppers were used, only six could be set on each main line.

Circle hooks were used to minimise damage to bycatch from gut-hooking and to provide high hook retention. Circle hooks have a recurved point which faces back in towards the shank of the hook. If swallowed, the hook will pull back out of the stomach easily and only catch when it is drawn across the edge of the jaw. This results in the majority of fish being hooked in the corner of their jaw, leading to minimal damage and good fish retention. Three hook sizes were evaluated to determine the optimal size for carp; Mustad Demon Circle size 1, size 1/0 and size 3/0. This brand was chosen because the hooks were constructed of fine but strong wire. Two different baits were also compared for carp and target specificity. Corn kernels are commonly used by anglers targeting carp because few native fish species take them as bait. We compared the capture rates of tinned corn kernels and artificial Berkley Gulp corn baits which have been specifically developed for the lucrative European carp fishing scene. This artificial bait stays on the hook longer, has inbuilt chemical attractants and would hopefully be less appealing to native species.

Baits were set in blocks of six droppers consisting of one of each bait and hook combination. The order of each hook was randomly allocated within the block. The number of blocks per main-line was dependent upon the water depth and ranged between 1 and 3. A total of 120 hooks (in 20 blocks) were spread around each site. Initially the lines were set for a 3 hour soak period and periodically inspected for bycatch. A low catch was recorded and the soak time was increased to 24 hrs to ensure active bite periods were sampled. Lines were again checked periodically for bycatch. At the end of the soak time the lines were hauled in by hand and any hooked fish netted with a landing net. Data on the hook size and bait type was recorded for each fish as well as for any hooks that were busted off or straightened.

The catch data was analysed using Chi-squared tests to compare between the effectiveness of hook size and bait type.

3.2.2 Results

Longlines were trialled at 4 locations with soak times of 3–24 hours. A total of 30 carp between 281–610mm FL were captured for a mean CPUE of 0.73 carp/man-hour. Approximately 15 hooks were bitten or broken off and several snoods which had caught fish required replacing due to line twist. There were no significant differences in the number of carp caught carp between the two baits ($x^2_{df=1}$=0.13) or three hook sizes ($x^2_{df=2}$=0.2). The size of carp captured also did not vary significantly with any of these variables.

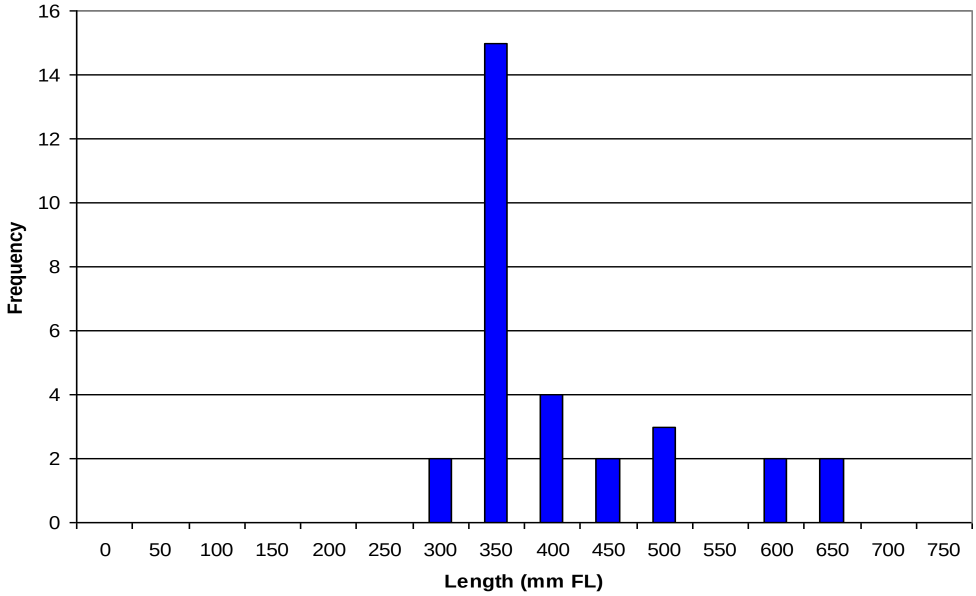

Figure 1: Length-frequency of carp captured by longlines (n=30).

Bycatch including bream, fork-tailed catfish and turtles and were all released unharmed and in good health except for two turtles. There were no significant differences in bycatch between bait type ($x^2_{df=2}$=0.47) or hook sizes ($x^2_{df=1}$=0.06). Unfortunately two turtles drowned between observations periods in a somewhat unusual way. Both turtles were cleanly hooked through the jaw and the webbing of one of their front legs. It appears that once they had taken the bait the turtles attempted to dislodge the hook from their jaw using their front leg and subsequently hooked their foot to their jaw. Although they should have been readily able to swim with their other legs and easily reach the surface, both were found dead.

Table 2: CPUE and estimated carp population reductions by longlining

Site	Habitat	Survey density (carp/ha)	Estimated population	CPUE (carp/hr)	Reduction
ALC	Lagoon	156	7,878	0.34	0.04%
TF2	Lagoon	244	9,746	1.63	0.18%
Tabragalba	Lagoon	27	700	0.37	0.43%
Wolfdene	River	7	85	0.58	7.06%
Mean				0.73	1.93%
Overall			18,331	0.78	0.16%

3.2.3 Discussion

Longlining for carp only had limited success. The longlines caught carp, but with a low CPUE and several bycatch issues. Longlines provide a more intense level of fishing pressure to the carp population than angling, and thus should result in a higher CPUE. The mean longlining CPUE of 0.73 carp/man-hour confirms this, being an order of magnitude higher than the mean CPUE for angling (see Section 3.10.2). However, the CPUE is still too low for the technique to be a very effective management tool.

One of the key reasons longlines were considered in this study is their potential to catch carp from areas where other techniques are not effective, especially deeper waters. Unfortunately, low CPUE and the potential for bycatch mortality limit the usefulness of the technique. The bycatch issue is particularly important for two reasons. First, turtle mortality occurred despite periodic checking of the lines and droppers long enough for any hooked animals to reach the surface to breathe. If implemented on a wider scale this technique could impact upon turtle populations. Turtles readily feed on most of the baits used in angling and thus will most likely form part of the bycatch in any areas where they are present. The use of circle hooks resulted in no gut hooked turtles. However, several turtles became hooked through both their jaw and front foot, presumably after trying to dislodge the hook.

Bycatch also limits the effectiveness of longlines by reducing the number of baits available to carp. The species caught were highly site dependent, but it is anticipated that spangled perch (*Leiopotheron unicolor*) would be a bycatch issue in many inland waterways. Setting lines in deeper water may help avoid this species to some degree. A more carp specific bait is required if further work on the technique is to be conducted.

Only one other study on using longlines for carp could be found in the literature. Longlines were trialled as part of a carp removal experiment at several small waterbodies in Sydney (Graham et al 2005). The gear used consisted of a small number of large hooks (3/0–5/0), and lines set near the surface. The bait consisted of corn, meat and fish and no carp were reportedly caught. There may be several reasons why no carp where caught via the longline. Meat and fish do not form a large part of the diet in carp (Smith 2005). Their use also increases the likelihood of bait being taken by turtles. Setting lines near the surface does enable air-breathing animals to reach the surface, but is not the preferred feeding zone for carp. Post-larval carp are predominantly benthic feeders, sifting food from sediment with their gill rakers (Hume et al 1983, Lammens and Hoogenboozem 1991).

3.3 Gill netting and splash netting

Gill nets are a mesh net panel held vertically in the water to entangle fish. The panel of netting has a rope along the top to which floats are attached and another along the bottom with lead weights. The use of gill-netting has been the principal method of harvesting native fish in inland waterways (Graham et al 2005).

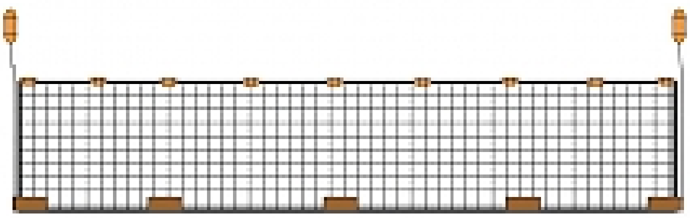

Figure 2: Diagram of a basic gill net

Through their design, gill nets are indiscriminate apparatus which entangle a wide range of animals. They can be effective for carp, but can damage native species bycatch and drown air-breathing animals if not cleared frequently. Regulations in most states stipulate minimum mesh sizes (typically >120mm) to help minimise bycatch. The use of gill-nets in the traditional manner is rarely recommended unless minimal bycatch is expected. Gill nets can be set either sunken or floating depending upon the area and species being targeted. They can be used in wide range of habitats and water depths, and with care can be used in regions with moderate levels of woody debris.

Graham et al (2005) describes how commercial carp fishermen from northern NSW have adapted their technique of splash-netting for mullet to successfully catch carp whilst minimising non-target bycatch. Splash-netting involves setting long gill-nets in shallow water around areas where carp are feeding. The nets are usually quietly set from a net boat rowed parallel to the shore before the fish are frightened into the net by splashing the oars on the water. The startled carp hit the net hard as they try to escape and entangle their serrated ventral and dorsal spines. The nets are retrieved immediately to minimise bycatch and any native fish or air-breathers such as turtles, are quickly released. Relatively heavy netting is used to allow easy release, minimise injury to bycatch and reduce damage to nets should they get tangled on underwater obstructions. This technique is best suited to shallow habitats with clean substrates.

3.3.1 Methods

A range of gillnets were trialled in an irrigation dam near Jimboomba on the Logan River. The location was chosen because it was known to have carp but only few native species that would catch in the nets. In the 2006 benchmark survey, the density of carp catch from electrofishing was 31 fish/ha. At the time of netting, the dam covered approximately 1.85ha and had a maximum water depth of 3m. The dam had quite steep banks creating a contoured bottom. The eastern margins of the dam were lined with immersed grass.

A range of different gillnets were trialled:

50 mm mesh x 2.5 m drop x 50 m length monofilament
50 mm mesh x 2.0 m drop x 30 m length monofilament sinking net
75 mm mesh x 3.0 m drop x 45 m length monofilament
100 mm mesh x 3.0 m drop x 38 m length monofilament
100 mm mesh x 3.0 m drop x 50 m length multifilament
125 mm mesh x 3.0 m drop x 50 m length monofilament
150 mm mesh x 3.0 m drop x 60 m length monofilament
Multifilament panel net (50, 75 and 113 mm mesh) x 50 m length

These nets were set around the dam, generally perpendicular to the shore. The ends of some nets overlapped with those from the opposite shoreline, presenting a continuous barrier. Nets were checked every hour to release bycatch and the total soak time was five hours.

Whilst the nets were soaking, carp could be seen jumping over and moving around them. It was decided that splash-netting would be worth trialling. Splash-netting involved setting gill nets and scaring fish with the boat to run them into the nets as they flee. The small boat electrofisher was used to scare the carp by running current through the water and revving the engine.

The high incidence of turtles caught in the net precluded any further trials of this technique in other locations.

3.3.2 Results

Gill-nets were soaked for five hours for a total catch of six carp, along with numerous turtles, all of which were released unharmed. Four carp were caught in the 100 mm multifilament net, one from the multifilament panel net, and one from the 75 mm monofilament net. Whilst the nets were soaking, carp could be seen jumping over and moving freely around them. The labour efforts was 4hrs comprising 1hr to set the nets, 1.5hrs to periodically check nets and release turtles, and 1.5hrs to clear the nets.

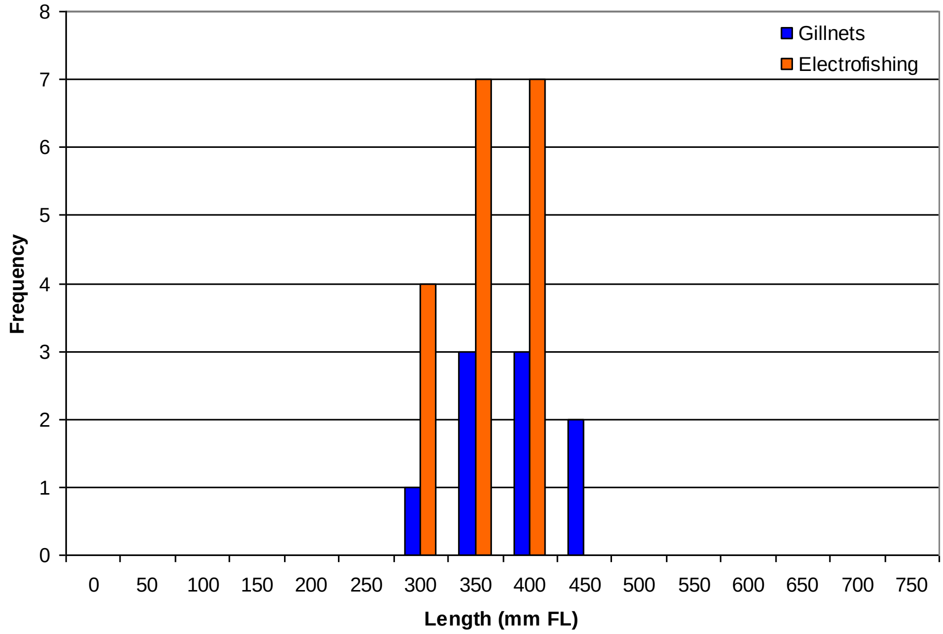

Figure 3: Length-frequency of carp captured by gillnets and splash-netting with the small boat electrofisher (n=27).

In the subsequent 90 minutes of splash-netting, a further three carp were caught in the nets. Many carp were again seen avoiding the nets by either jumping over or swimming parallel to and the around their ends. The carp could clearly detect the presence of the nets and most appeared to easily avoid them. The water of the dam was quite turbid so the nets should not have been highly visible. Most of the carp caught had entwined their serrated dorsal or anal spines. Only a few fish properly gilled themselves. The electrofisher boat caught 18 carp during the same time with a power on time of 2102 seconds. The total number of carp removed was 27 with a combined mass of 29.4 kg. The bycatch consisted of 66 turtles.

Table 3: CPUE and population reductions by gill-netting and splash-netting in an irrigation dam

Technique	Survey density (carp/ha)	Population estimate	CPUE (carp/hr)	Reduction
Gill-netting	31.01	115	1.50	5.2%
Splash-netting	31.01	115	1.00	2.6%

3.3.3 Discussion

The use of gill nets was very limited in this project. In the Logan and Albert Catchment there are many large bodied native species that make the use of the apparatus difficult. Turtles in particular, limited the soak time and made the use of gill nets impractical in many waterbodies. This was highlighted by the high turtle bycatch from the irrigation dam at Jimboomba. The nets were checked every hour, however even during this short soak period several of the turtles caught appeared exhausted when untangled from the net. All were released on the bank and recovered in time.

Carp seemed to easily detect and evade the gill nets even though they were set in quite turbid water. The secchi depth at the site was only 10cm. The carp could be seen swimming along, around and jumping over nets, or pushing through any holes where the net had a small tear. There appeared to be little difference in the ease with which they detected monofilament or multifilament mesh, although lighter weight multifilament tended to entangle the serrated anal and dorsal fins better.

There was no discernable difference in the catch number between different mesh sizes, however the total catch size was small. In other studies 4–6” mesh sizes have proven to be most effective for catching adult carp (Pinto et al 2005, Diggle et al 2004). This size mesh will be effective on medium to large carp but will not catch smaller fish. Small natives should pass through the mesh relatively unimpeded. Bony bream are a species which gill easily and if present may get caught in nets in high numbers, despite the large mesh size.

In some scenarios gill nets can be effective, and they are commonly employed by commercial carp fishers in southern Australia (Koehn et al 2000, Graham et al 2005). The gear is relatively cheap and can catch large numbers of fish in the right conditions. One commercial team operating in NSW employ splash-netting to harvest large quantities of carp whilst minimising bycatch. Most of their fishing occurs in large artificial water storages where long 6” mesh nets are run out parallel to the shore in shallow water (<4m) where carp are known to occur (Graham et al 2005). The boat is then used to scare the fish away from the shore into the net. The total time per set is about one hour which together with prudent site selection minimises bycatch. Their bycatch averages less than four fish per set and typically consists of small numbers of turtles, eel-tail catfish, silver perch, golden perch and bony bream.

A long-term project to manage carp in Botany Wetlands used 4.5”, 5” and 6” gillnets in conjunction with electrofishing (Pinto et al 2005). The initial carp density was 100 carp/ha and over 8 years the mean yearly CPUE varied between 14–122 carp/day. This was often greater than electrofishing in the same area. A total net length of 750m was used and the carp catch was found to be greater at night. The gill nets caught no carp smaller than 200mm and were cleared every two hours. The bycatch was very low with only 21 eels, 274 catfish, 84 bass and 210 turtles caught over the eight year sampling period. The low bycatch may be partially attributed to the low density of non-target species in the area.

Gill-nets have been one of the main removal apparatus used by Tasmania’s Inland Fisheries Service in their attempt to eradicate from Lakes Crescent and Sorrell. The lakes hold very few large native species, so impacts on non-target species is minimal (IFS 2004). Large hauls of carp have been taken, with 5” and 6” mesh nets proving to be the most effective (Wisniewski 2009). Gill-nets were often laid in shallow areas along the margins to vegetation. To increase catch rates, the back-pack electrofisher was used to scare fish into the nets in a manner similar to splash-netting.

Gill-nets are an indiscriminate apparatus and their use in the traditional manner is not recommended unless minimal bycatch is expected. Bycatch issues will preclude their use in most natural rivers and waterways and they are therefore best suited to artificial impoundments where bycatch species are known to be minimal and splash-netting can be used. Some impoundments have lots of turtles and large bodied native fish and the technique is not appropriate in these locations.

3.4 Seine netting

Seine netting, or hauling as it is sometimes known, can be a very effective method for quickly catching large numbers of fish. A seine is a large fishing net that hangs vertically in the water with weights along the bottom edge and floats along the top. Seines are usually long flat nets like a fence and may contain a pocket to help concentrate the catch for ease of removal. Seine nets are typically used to encircle a school of fish or area likely to have fish. Both ends of the net are drawn towards the bank trapping the fish in the net. Seine nets with an appropriate mesh size tend to catch a high proportion of all fish in the area netted. Leaving the last bit of the net in the water enables protected bycatch species (native fish and air-breathing animals) taken during seining operations to be sorted from the carp catch and released unharmed.

Figure 4: Hauling a small seine through the shallow end of a lagoon

The method is best suited to locations such as shallow lakes or dams where the bottom is relatively smooth, firm, and clear of snags. However, large parts of most natural waterways are probably unsuited to seining as lake and river beds are normally littered with woody debris and other snags. Artificial lakes and irrigation impoundments or canals may provide suitable opportunities for seining. During times of low water levels (e.g. during droughts), potential netting sites around the shores of lakes can be identified and mapped. Carp catch rates may be increased by first attracting carp with berley into the netting area before shooting the seine.

3.4.1 Methods

Several nets were used due to the variety of habitats examined. The first net was 90m x 3.6m drop with a square, 8 ply 12mm mesh and had no cod end. The 3.6m drop caused the net to bag sufficiently in shallow water to sufficiently trap fish and prevent them jumping out. The 90m seine net was typically hauled by one person at each end; however at one site the size of the catch necessitated the use of two excavators to complete the shots. The second net was a tiered drop 12 ply, 25mm mesh, 30m long seine with a pocket. The drop was 1.2m on the outer parts of the net and 1.8m in the middle. This net was very useful in small areas and was easily moved through the water. The third net consisted of 12 ply 25mm mesh with a length of 50m and a tiered drop going from 1.8m at the edges to 2.4m around the pocket. In conjunction with these nets, a pair of 110m long, 1.2m drop fence nets was used to help partition large areas off into manageable units.

The seine nets were deployed using two techniques. In large open areas, the seines were deployed in a curved line across the far end of where the shot is to be run. The two ends were then walked towards the shore creating a pocket in which fish would be trapped. Upon reaching the shore, the nets were hauled by hand until only the pocket remained in the water. This ensured damage to bycatch was minimised. Fish were scooped from the wet net individually and bycatch released. This technique was also used when running lanes between the fence nets. The fence nets were 100m long nets consisting of 19mm stretch mesh with a 1.5m drop. The fence nets are used as a barrier to divide large areas into smaller more manageable sections and acts as a barrier to prevent carp escaping in that direction. The technique used from the bank in smaller waterbodies involved walking one end of the net out from the bank, encircling the body of water to be sampled. Both ends were then hauled in simultaneously by hand and the fish processed in the manner describe above.

The large seine net was employed at the lagoon on the southern end of Riemore Downs Estate. This large lagoon is typically full of water, only having gone dry three times in recorded history. The lagoon has generally been highly infested with carp and thought to be a major breeding ground when full. The drought reduced the size of the lagoon to about one twentieth of its normal size. The bottom of the lagoon was relatively free of debris and the water a maximum of 3m deep. The net was spread along the bank at the southern end and hauled through four times. Mechanical assistance in the form of two dozers was required to haul the net due to the large catch. Carp and turtles were sorted after each haul and the carp euthanized.

Seine nets were also trialled on five other occasions. In three lagoons/impoundments the nets were set from the water and hauled shoreward for sorting. At one lagoon blocker nets were set to create a corridor parallel to the shore. This reduced the chance of carp fleeing the seine net. In river and creek sites the seine nets could only be used in a limited number of places. Typically the nets were run in rings around sandbars and shallow sections clear of debris and hauled to shore.

3.4.2 Results

Riemore Downs Estate

A total of four passes were made over three days in November 2007 with progressively reduced carp catches. The numbers of carp for the four hauls were approximately 2000, 2000, 250 and 250 fish. Inclement weather halted netting procedures. The depth of the water in the middle of the shot was approximately 3m deep and during each haul, the top of the heavily laden net was dragged under at that point allowing a few carp to escape. Approximately one tonne of turtles (both short and long-neck) were also captured by the net each haul. These were released unharmed into an adjacent swamp, but many proceeded to return to the lagoon between shots.

Set up time for each shot was around 20 min and involved two people. Hauling the net required three people and took about 20 min with the aid of two excavators. Clearing and sorting time for the catch varied with catch number and involved four people for between 1.5 and 3 hours. A further 1hr was taken to clean the gear, mend any damage and repack the net ready for the next shot.

Average fish size was ~2kg giving a total removal weight of approximately nine tonne. Nearly all of the fish caught were sizeable adults, with many readily emitting milt or eggs when gently squeezed. Heavy flooding in early 2008 resulted in the lagoon reconnecting with the river and filling within a mere three hours. The connection was approximately 400mm deep and carp were seen re-entering the lagoon during this time. Further removal efforts in the lagoon revealed that the carp density remains extremely low despite the reconnection.

Other sites

Seine netting was also undertaken at five other sites in the Logan and Albert Catchment with a total catch of 265 carp. The technique captured a wide size range of carp (35–406 mm FL) although larger carp were more prone to jump the net as it was hauled in to the bank. The technique was most effective in irrigation dams and lagoons where large areas of debris free, shallow water made sampling possible (mean CPUE = 27.4 carp/man-hour). Few sites were suitable for seine netting in open river systems and those where the activity was possible yielded only low numbers of carp (mean CPUE = 0.41 carp/man-hour). All bycatch was successfully released unharmed.

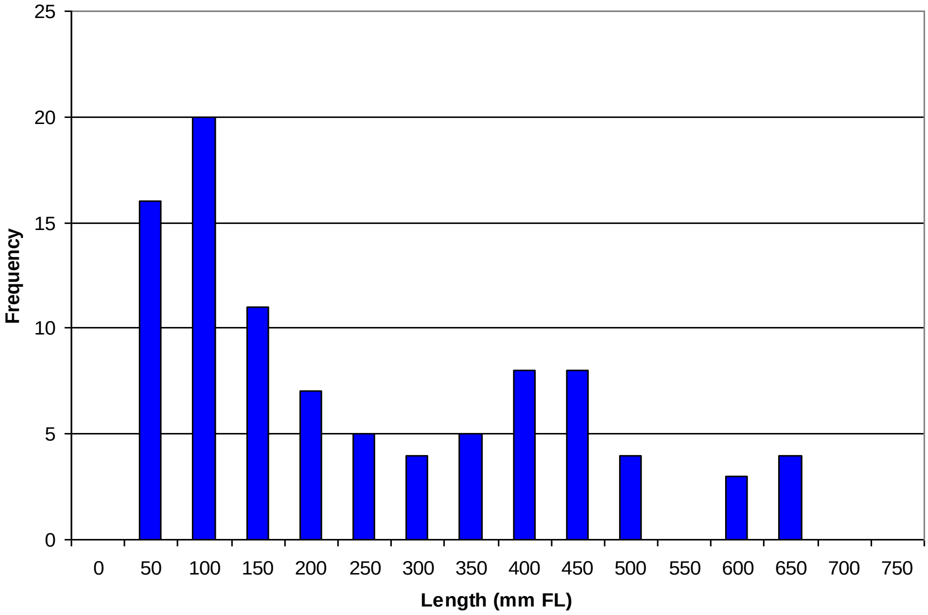

Figure 5: Length-frequency of carp captured by seine netting (n=95)

Table 4: CPUE and estimated carp population reductions by seine netting

Site	Habitat	Survey density (carp/ha)	Population estimate	CPUE (carp/hr)	Reduction
Riemore	Lagoon	4,247.6	5,522	86.87	81.50%
TF2	Lagoon	244.4	9,746	14.91	2.52%
Tabragalba	Lagoon	26.7	700	7.50	2.14%
Riemore (2nd time)	Lagoon	11.7	1,022	0.27	0.01%
Sandy Creek	Creek	230.0	46	0.82	6.50%
Sth McLean	River	27.0	164	0.00	0.00%
Mean		798	2,867	18.40	15.5%
Overall			17,200		27.7%

3.4.3 Discussion

Seine netting is a potentially very effective method of removing carp. This technique recorded the highest CPUE of all methods examined in this study. Large numbers of carp can be caught and bycatch quickly sorted and released unharmed. Prudent selection of netting sites can help reduce bycatch impacts. The technique is best suited to shallow lakes, lagoons and dams where the substrate is relatively firm and clear of obstructions. Most natural waterways are not suitable to seine netting because the bottoms are littered with woody debris and other snags. This limits the number of locations where the technique can be used.

Seine netting is a relatively low cost technique. Nets can be purchased for under a thousand dollars and with proper treatment and repairs should last many years. Hauling seine nets does not require specialized skills and with basic training can be implemented by most people. The technique forms the mainstay of the carp fishery in Victoria (K.Bell, KandC Fisheries pers. comm.) and is commonly used in the USA (Cooper 1987).

Berley or pre-feeding can be used to successfully increase carp catches. Pre-feeding can be used to help concentrate carp numbers, or lure them into areas where netting can be more easily undertaken. One technique that was found to be very effective was to lure carp into a clean inlet or outlet channel with burley and set the net across the channel to block off any avenue for escape. The net was then hauled through the channel to clear the carp. Berley can consist of any food item found in the diet of carp, but the most commonly used are corn products, grains, bread and livestock feed pellets. In the present study the most effective berley mix consisted of chicken layer pellets mixed with creamed corn and corn kernels.

Carp are highly skilled at avoiding seine nets. When the nets are drawn towards the shore carp will frequently jump or burrow down in an attempt to escape. These behaviours make it important to use a net with a billowy bunt or pocket. When fish see the net wall and attempt to jump they hit the top of the pocket and remain in the enclosed section. A pocket also makes handling the net easier as the catch is concentrated into a bag rather than distributed along the net.

Blocker nets can be used to more effectively seine large open waterbodies. Dividing the waterbody into smaller, more manageable work units reduces the likelihood of carp fleeing and allows shorter, more easily hauled nets to be used. Once the blocker net is in place a boat can be used to scare fish into the corridor created before running the seine net through the area.

Seine netting is a great tool to use for opportunistic carp removal, especially with water levels fluctuations. In this study the great reduction in size of the lagoon at Riemore enabled seine netting to be conducted very efficiently. When full, carp removal at this site is very difficult due to the large area of the lagoon. The reduced water level concentrated the carp into a much more manageable area resulting in highly efficient removal and high CPUE. A similar approach was taken at Macleod's Morass, in Gippsland, Victoria, where a commercial operator was able to remove several tonnes of carp from the remaining waterhole when the wetland dried in 1997 (Koehn et al 2000).

In areas where water levels are regulated, carp frequently congregate below weirs or wetland entrances as water levels change. If the substrate is suitable, seine netting can be used to remove these fish. For example, when the regulator at the entrance to the Moira wetland was opened to lower the water level after the waterbird breeding season, 76 tonnes of carp were removed using a modified seine net from the pool immediately upstream of the regulator (Stuart and Jones 2002). Alternatively, when lagoons connect to the river or regulators are opened to fill lagoons, congregations of carp can be netted.

Recent research in Minnesota highlights how effective seine netting can be, if aggregations of carp are detected in areas suitable for netting. Winter carp aggregations under ice were detected in Lakes Susan and Riley in early 2009 with the aid of radio-tracked fish (Sorensen et al 2009). Seine nets were then deployed in each lake resulting in catches of 3,278 carp and 4,440 carp in the lakes respectively. These removal efforts represent a capture of 78% of the carp population in Lake Susan and 37.3% in Lake Riley, each accomplished within a day.

3.5 Electrofishing

Electrofishing is a non-lethal active fish capture technique, most effective in clear, shallow waters (Kolz et al 1998). When performed correctly, electrofishing results in no permanent harm to fish, which quickly return to their natural state after the power is switched off.

Electrofishing can be one of the most versatile and species specific methods for pest fish control. The efficiency of the operation is dependent upon operator skill level, equipment choice, water characteristics, fish behaviour, and habitat type. Three main types of electrofishing equipment are commonly used by fisheries agencies: backpack units, small boats and large boats. Bank-side units are also used by some agencies, but rarely for carp management. The effective stunning range of the equipment typically increases with the unit's size and power. Carp are generally less sensitive to stunning than native species and it is therefore best to use the most powerful unit practical for a given waterbody.

Electrofishing has been effective for carp harvest or removal in areas of high density, but it has a high capital cost and is labour intensive. Electrofishing equipment requires substantial maintenance and must be operated by qualified people. The technique is suitable for a wide range of habitats, including areas with high levels of woody debris, but is restricted to shallow waters (<4m). Capture rates are also best in water with low turbidity and low conductivity (Kolz et al 1998, Bayley and Austen 2002).

Habitat features, water quality parameters and access issues make it necessary for a range of electrofishing apparatus to be used for carp removal. During this study three different electrofishing apparatus were used. They have been treated separately due to the substantial differences in sites where they are suitable, their capture efficiencies and cost of operation.

3.5.1 Backpack electrofishing

3.5.1.1 Methods

Backpack electrofishing is usually carried in smaller creeks and rivers where it is difficult for fish to evade the electric field and shallow enough for operators to wade. Removals efforts can be a one-off event, consist of multiple passes, or be sustained and on-going. The effectiveness and impacts of each of these approaches was tested with a Smith Root LR-24 backpack unit at four sites within the Logan and Albert Catchment.

Logan River at Tamrookum – single pass

The Logan River at Tamrookum is quite shallow and narrow and suitable for backpack electrofishing. The initial benchmark survey in 2006 revealed there to be a high density of carp. In February 2007, 1km of the river was intensely electrofished for carp with a Smith-Root LR-24 backpack unit. The upper and lower margins of the reach were marked by very shallow riffle sections. A pass was made from the downstream margin to the upstream limit and back again. Carp were euthanized with an anaesthetic overdose and measured.

Canungra Creek – multiple passes

Canungra Creek is one of the main tributaries flowing into the Albert River. The creek is fed by water from nearby ranges and only rarely ceases to flow. The mid reaches of the creek consist of natural riffle-run-pool formations. The substrate in the runs and riffles consist of river pebbles, whilst finer sediment gets deposited and forms the bottom layers in the deeper and slower moving pools. In March 2009, a 1.8km stretch of the creek was identified as suitable for repeated passes with a backpack electrofisher. The selected reach was bounded at the top and bottom by very shallow riffles. Three passes by the two man electrofishing team were made in an upstream direction over three consecutive days targeting carp. All carp were euthanized and measured.

Sandy Creek – multiple passes

In the initial benchmark survey, Sandy Creek was found to have one of the highest carp densities in the catchment. This small tributary of the Logan River flows intermittently with only a slow trickle between flow events. A series of pools in this stream were a good place to trial multiple pass removal via backpack electrofishing. The creek was subjected to periodic control in 2007 (see below) and a period of more than a year was left to allow carp numbers to recover before the multiple pass control was examined. During this period several major flow events had occurred and it was expected that the carp had recolonised the reach of creek being considered. In January 2009 three passes of the 400 m stretch of creek were made over three days. The team worked upstream from the riffle delineating the site boundary, paying particular attention to the deeper pools and aquatic vegetation.

Sandy Creek – periodic control

Monthly electrofishing removal of carp along 400m of the creek was undertaken between February and November 2007. A control site was located several kilometres downstream and was of similar size to the treated pools. During each visit, secchi depth and macrophyte cover were recoded in three pools and the control site prior to commencing electrofishing. Starting at the downstream end, a pass was made along the creek with the backpack electrofisher, thoroughly stunning the water. Special attention was paid to areas likely to hold carp or where carp had been caught previously. All carp caught were euthanized with an anaesthetic overdose. Fork length and weight were measured and the gonads (where developed) removed to determine the gonadosomatic index. The entire pass usually took 1.5 hours and involved around 2600 seconds of power-on time.

3.5.1.2 Results

Logan River at Tamrookum – single pass

The two person team spent 1.5 hrs at the site with a power on time of 3015 seconds for the electrofishing unit. A total of 21 carp, with a combined weight of 5.52kg were removed from the 1km stretch of river. The carp ranged in size from 75–430mm FL and weight from 7.9–1441.4g. The carp were mostly taken from several deeper pools, particularly where large woody debris was present. No bycatch was taken although sea mullet (*Mugil cephalus*) and numerous small native fish species were temporarily stunned. All swam away unharmed once the power was off.

Canungra Creek – multiple passes

Over a week long period in March 2009, a 1.8km stretch of Canungra Creek was electrofished with the backpack unit for carp. The two person team put in a total of 7.5 man-hours of effort and captured nine carp covering a size range of 138–441mm FL. The majority of carp were captured around the woody margins of the generally fast flowing creek or within several of the deeper pools. CPUE was highest on the first pass and decreased by fourfold on subsequent passes (Figure 6). No bycatch was taken.

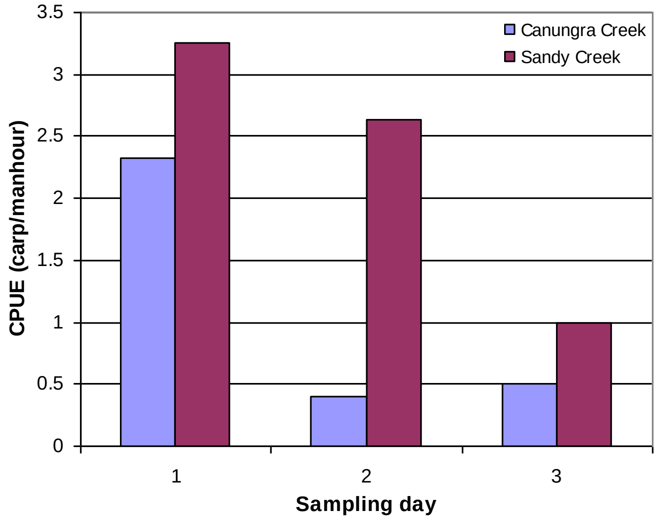

Figure 6: Carp CPUE at two sites repeatedly sampled with backpack electrofishing over three consecutive days.

Sandy Creek - multiple passes

Over a week long period in January 2009, multiple passes of a 400m stretch of Canungra Creek were made with a backpack electrofisher. The two person team put in a total of 10.5 man-hours of effort and captured 28 carp covering a size range of 136–324mm FL. The CPUE was highest on the first pass (3.26 carp/man-hour) and decreased substantially on subsequent passes (Figure 6). The majority of carp were captured around macrophytic cover and inundated grass. No bycatch was caught.

Sandy Creek - periodic control

Monthly electrofishing removal of carp along 400m of the stream was undertaken between February and November 2007. A control site was located several kilometres downstream and was of similar size to the treated pools. The entire pass usually took 1.5 hours and involved around 2600 seconds of power-on time.

The number of fish caught each month steadily declined from 26 in February to only three in September (Figure 7). During this period there were several small and brief flow events that connected the pools, but no major flows. At the control site, the number of carp remained relatively constant (Figure 8). A moderate flow event in late September resulted in re-colonisation of the top pool and an increase of turbidity (Figures 8). A second major flow in early October restructured the top pool by removing most of the lower wall. This resulted in the size of the pool decreasing significantly in size and shallowing in depth. Figure 8 shows both the secchi depth and number of carp caught in each of the four main pools. In all pools the secchi readings increased as the carp numbers dropped. A halving of the carp biomass corresponded to a threefold increase in water clarity. In the control reach where carp numbers were relatively stable, turbidity and also remained constant. The decrease in secchi depth at all sites in November was due to the large flow early in that month.

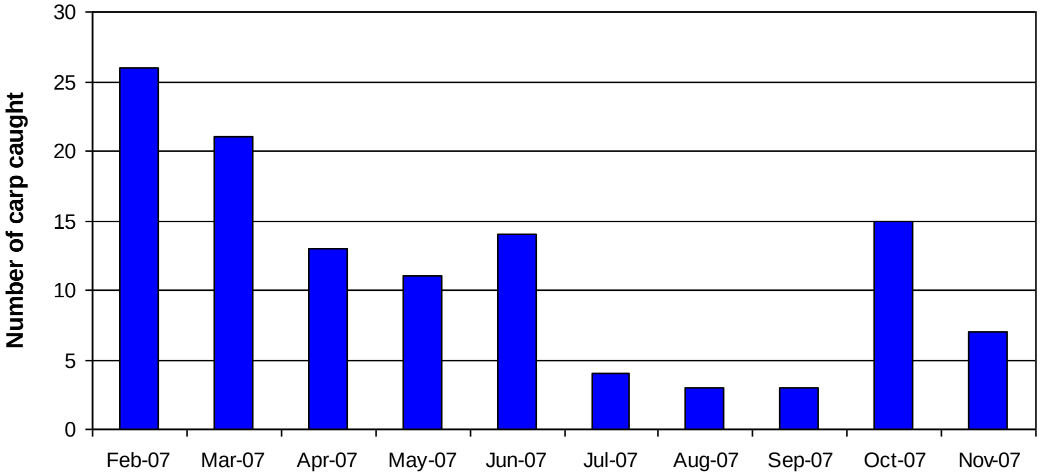

Figure 7: Numbers of carp removed by monthly backpack electrofishing at Sandy Creek.

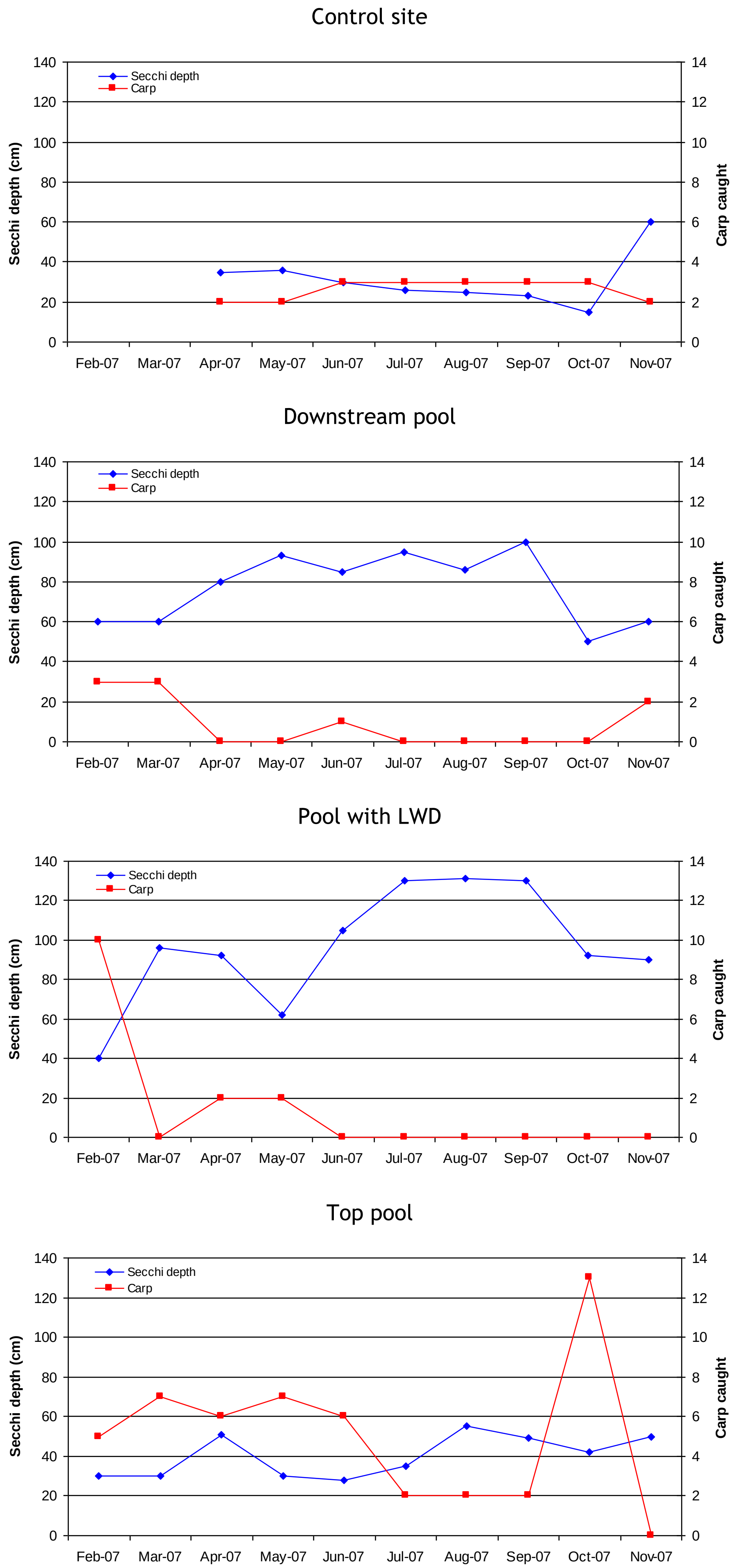

Figure 8: Secchi depth and carp catch at the four monitored pools in Sandy Creek

Figure 9: The turbidity levels at Sandy Creek on the Logan River in February, July and September 2008 after monthly carp removal via backpack electrofishing. Note the marked increase in water clarity.

Macrophytic cover in the creek increased substantially throughout the monitoring period. In two of the pools monitored, macrophytic coverage increased 2--3 times during the course of the research (Figure 10). This increase corresponded with the decrease in carp and turbidity in both cases.

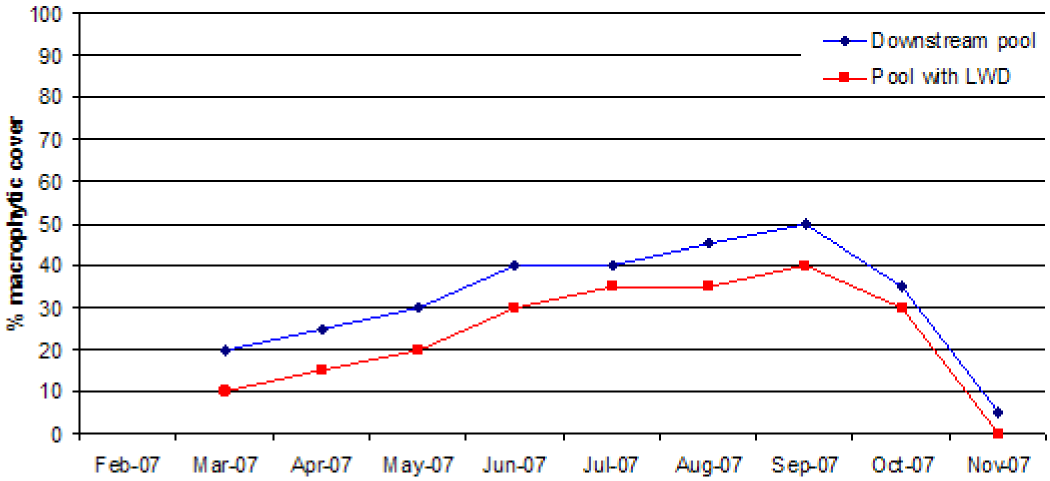

Figure 10: Macrophytic cover in two of the monitored pools in Sandy Creek during ten months of carp removal. The other two pools had no aquatic macrophytes. Flow events in October and November led to the decreases in Macrophytic cover.

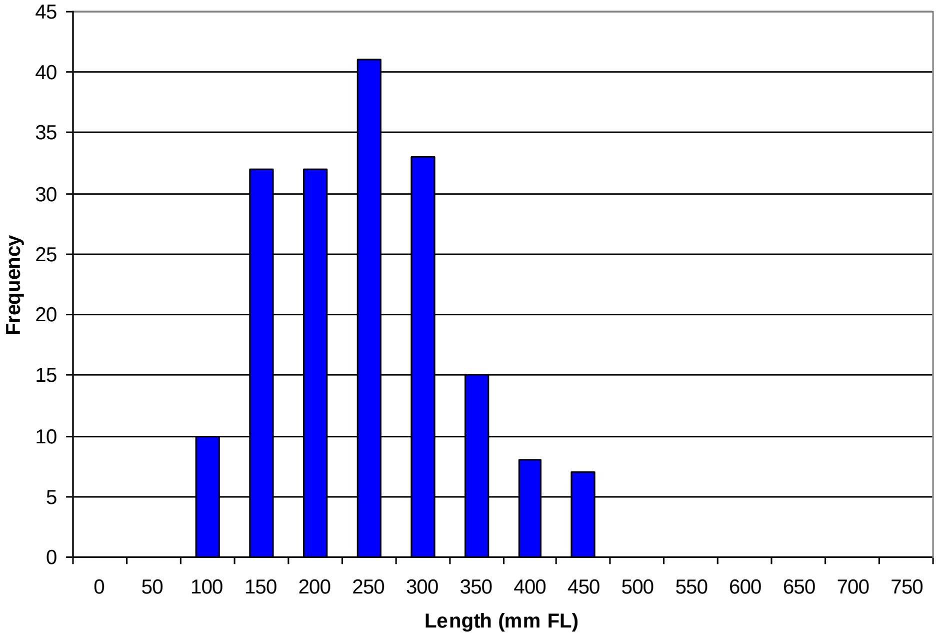

Figure 11: Length-frequency for carp captured with the backpack electrofisher.

Table 5: CPUE and estimated carp population reductions by backpack electrofishing.

Site	Habitat	Survey density (carp/ha)	Population estimate	CPUE (carp/hr)	Reduction
Sandy Creek (1st visit)	Creek	230	46	10.40	56.5%
Tamrookum	Creek	150	30	7.00	70.0%
Canungra Creek	Creek	5	12	1.20	75.0%
Sandy Creek -revisited	Creek	10	36	2.67	77.8%
Mean		98	31	5.32	69.8%
Overall			124		67.7%

3.5.2 Small boat electrofishing

3.5.2.1 Methods

The small electrofishing boat consists of a 3.6m aluminium punt with a 5.0kVa Smith-Root electrofishing unit attached. A single netter operates up the front around the two anode booms, which had an effective radial range of 1 to 2 metres. The efficiency of removal using this set-up was assessed at seven locations. The first four locations tested the efficacy of making a single pass with the electrofisher. The latter three looked at the impact of multiple passes over consecutive days.

Albert River at Chardon's Bridge

Chardon Bridge is located in the lower freshwater reaches of the Albert River. In the 2006 Benchmark survey when the water level was much higher, carp density was 107 fish/ha at this location. Below the bridge crossing is a series of pools and runs and upstream a shallow riffle. The water level varies between 0.2m to 1.5m. A large tree trunk lays across the river 300 m downstream which blocks boat access and restricts most water movement to a shallow riffle. In July 2007, a two person team in the small electrofishing boat made several passes in a two hour period over this stretch hunting carp.

Albert River at Darlington

The upper reaches of the Albert River at Darlington forms a series of riffle-pool-riffle reaches above a series of rock pools. The area was found to contain a substantial number of carp in 2006. The rocky barrier at the downstream end of the site, together with shallow riffles above, mean that migration of carp into this area is limited and water level dependent. Small flow events enable carp to move downstream over the cascading rocky riffles, but major flow events would be required to permit the passage of carp upstream. The contained nature of this system suggests that control could be beneficial and potentially persist between major flow events. In August 2007, the small electrofishing boat was used to clear the waters of carp for 400m upstream of the road bridge at Darlington Park, and the backpack unit a further 100m downstream.

McIntyre River at Yellowbank Reserve, Goondiwindi

The McIntyre River at Yellowbank Reserve consists of a relatively shallow stretch of river which was accessible by boat for about 1km upstream from the access point. The river here is a combination of runs and shallow pools with a substrate predominantly consisting of river pebbles and gravel. In the deeper parts the substrate also contains finer sediment. Due to the general substrate type the water was quite clear for a western drainage in Queensland. The northern shoreline was generally deeper and held low to moderate amounts of woody debris. This particular stretch of river was chosen as a monitoring site for angler impact in the 2007 Goondiwindi Carp Cull. Prior to the event, the two person electrofishing team made a single pass upstream from the launch site over a period of three hours. Carp were targeted in all accessible areas, but particular attention was paid to large woody debris and undercut section of bank.

Booberoi Lagoon

The top lagoon at Booberoi was also monitored as part of the 2007 Goondiwindi Carp Cull. In June 2007 when carp were targeted at the lagoon the water levels were quite low. The lagoon stretched approximately 400m long and averaged 40m in width. Several large fallen trees were located on the northern bank where the water reached a maximum depth of 1.5m. Elsewhere, the lagoon was shallow with a gradual slope in the shoreline. The substrate was principally made up of very fine sediment and clay particles which resulted in very turbid water. Several sandbars contained small gravel and sand grit. The electrofishing team made several circuits around the lagoon in a three hour period chasing carp. Extra attention was paid to submerged pieces of timber and fallen trees.

Albert River at Wolfdene – multiple pass
Wolfdene marks the tidal limit of the Albert River and experiences minor tidal movement. At this location the river was generally wide and open, except for several narrow runs formed by rock bars or islands. The river was relatively shallow with a sandy substrate. Electrofishing was conducted three times along approximately 1km of river over three consecutive days in February 2009.

Albert River at Luscombe weirpool – multiple pass
Luscombe weir is the largest weir on the Albert River and is located just above the tidal reaches. The weir wall is approximately 4m high and causes water to back up in a weirpool for approximately 1km. The water closest to the wall is around 2–3m deep but shallows further upstream. Within the weirpool there is a moderate amount of fallen or submerged timber and the substrate appears to consist of soft mud with the occasional sandbar and gravel patch. Substantial riparian vegetation occurs for much of the section sampled. The small electrofisher boat made three upstream passes over three consecutive days during April 2009. Due to the size of the system each part was only electrofished twice within this period. Electrofishing was predominantly focussed near the shoreline and woody structures. Limited effort was made electrofishing the middle of the weirpool.

Logan River at South MacLean – multiple pass
The South McLean weir has been recently rebuilt. It is the most downstream weir on the Logan River and contains a vertical slot fishway. Similar to Luscombe weir, the wall has created a pool that backs water up for approximately 0.8km upstream. Above this the river enters a series of shallow sections weaving amongst numerous sandbars. Very little riparian vegetation remains in this stretch of the river and cattle are grazed right to the waters edge. The substrate almost exclusively consists of river sand. The water depths near the weir wall reached down to 2m but shallowed once around the first upstream bend. Several sandbars occurred in the middle of the river and sandbars also protrude from the inside of bends. Three passes upstream with the electrofishing boat were made over four days. The passes covered each bank for 1km upstream form the weir wall. Close attention was given to large woody debris and drainage entrances.

3.5.2.2 Results

Albert River at Chardon's Bridge
In the 2006 Benchmark survey when the water level was much higher, 40 carp were caught at this location. In July 2007, over a two hour period, the small electrofishing boat made several passes over this stretch hunting carp. The total power on time was 3000 seconds and 23 carp were caught. No other species were landed or harmed during the electrofishing. The open nature of this site means that migration is unconstrained and likely to quickly refill niches vacated by removed fish. Twenty seven carp were caught during the annual monitoring survey in November 2007, supporting this notion. Large stretches of river delineated by barriers to fish movement need to be cleared for control efforts to have any lasting impact.

Albert River at Darlington
Over a period of two hours, 23 carp (37.5kg) were removed by the small electrofishing boat. No carp were found in the shallower reaches with the backpack unit. Overall power-on time was 2806 seconds. No young-of-year carp were captured, with the majority of fish lengths

evenly distributed between 300mm and 550mm. Nine carp were detected in the monitoring survey in November 2007. No flows occurred in this period suggesting these carp may have been missed in the July removal efforts.

McIntyre River at Yellowbank Reserve, Goondiwindi

The small boat electrofisher captured 32 carp from this open river site in two hours of operation during 2007. The carp ranged in size from 153–581mm FL and were mostly caught around submerged woody debris. The narrow waterway allowed carp to be herded into areas where they became trapped and easier to capture. A range of native fish species were also stunned by the electrofisher, but swan away unharmed.

Booberoi Lagoon

The small enclosed lagoon at Booberoi was very shallow when electrofished in 2007. The shallow waters restricted access to the entire lagoon and reduced the strength of the electric field via earthing from the hull. A total of 178 carp between 139–654mm FL were captured over a three hour period. Carp were predominantly found around fallen trees and smaller debris along a drop-off on the steeper northern bank.

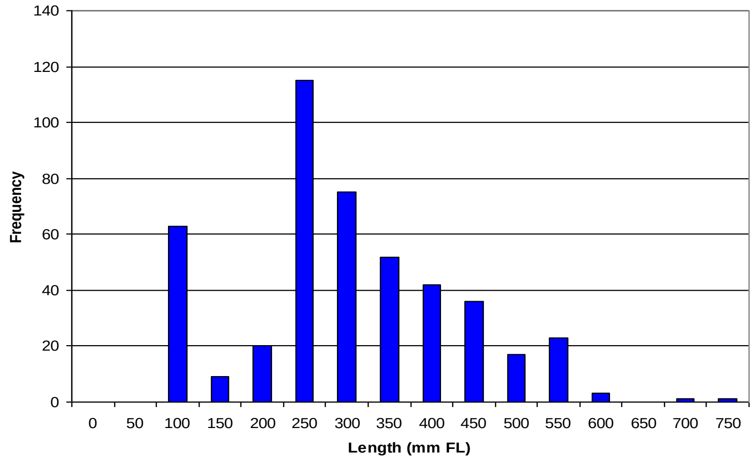

Figure 12: Length-frequency for carp captured with the small boat electrofisher (n=457).

Table 6: CPUE and estimated carp population reductions by small boat electrofishing.

Site	Habitat	Survey density (carp/ha)	Population estimate	CPUE (carp/hr)	Reduction
Chardon's Bridge	River	38	34	5.75	70.6%
Darlington	Creek	57	43	6.00	53.5%
Booberoi 2007	Lagoon	426	681	6.00	26.1%
Rainbow Res	Lagoon	154.8	1,548	20.50	10.6%
Yellowbank Res	River	79	118	29.67	31.0%
Luscombe	River	7	100	11.32	60.0%
Wolfdene	River	12	145	3.88	42.8%
Sth Mclean	River	27	164	4.08	22.0%
Mean				10.82	39.56%
Overall total			2,424	9.96	23.89%

3.5.3 Large boat electrofishing

3.5.3.1 Methods

The large electrofishing unit consists of a 6 metre plate alloy hull with a 7.5kVa Smith-Root electrofishing unit attached. Two netters operate up the front around the two anode booms, which had and a radial effective range of 3 to 4 metres.

Figure 13: Large electrofishing boat with the Wisconsin array set-up for the anodes. Carp catches were increased in most water bodies by adding a single long wire to the centre of each array.

There are several environmental restrictions for using electrofishing in larger water bodies. With a standard Wisconsin array set-up (Figure 13), the depth penetration of the effective stunning field is only 3 to 4m. In deeper waters fish may not be stunned, or if stunned not float to be visible to the netters. A range of anode array modifications to increase the effectiveness of deep water sampling were trialled.

The efficiency of the large electrofishing boat was assessed at 29 sites over two years. Three sites were located in the Logan and Albert Catchment and three in the Condamine Catchment. The remaining 23 sites were in the Murray-Darling Basin on the McIntyre and Balonne Rivers and associated with carp angling competitions at Goondiwindi and Thallon. Detailed site descriptions can be found in the report *The role of fishing competitions in pest fish management* (Norris et al 2013). Population estimates were generated via mark-recapture enabling removal efficiencies to be accurately calculated.

The three sites located in the Logan and Albert Catchment were all contained waterbodies. They represented an irrigation dam, a semi-modified oxbow lagoon, and a large, shallow natural lagoon. The latter was filled by surface run-off and only connected to the river in 1 in 20 year floods. The irrigation dam and oxbow were both filled via pumping from nearby rivers and used primarily for irrigation.

Large boat electrofishing efficiencies were also evaluated from carp removal activities conducted for the Condamine Alliance catchment management group at the end of 2009. Carp removal was conducted at three sites within the Condamine River Catchment: Oakey Creek at Bowenville Reserve, Myall Creek in Dalby, and the Condamine River at Loudan Weir. At these sites mark-recapture was used to determine local carp population size prior to removal activities. Multiple passes of the electrofisher were made over a five day period during both day and night.

The sites associated with the carp angling competitions covered a wide range of habitats. Three were located in natural lagoons, whilst the rest represented a cross-section of riverine habitats typical to the region. Mark-recapture was again used to determine local carp population size prior to removal activities. Each site was electrofished for three hours by a three person electrofishing team. Generally only one pass was made of each site, with the exception of several smaller sites where between two and three passes over the area were made.

3.5.3.2 Results

The majority of sites were located in open riverine habitat, but seven were located in lagoons. The results are summarised in Table 7. A total of 3,272 carp of 21–671mm FL were caught with the large electrofishing boat. Estimated population reductions ranged from as low as 2.3% up to 58.2% and were higher in smaller, shallower waterways. The mean CPUE from all sites was 9.73 carp per man-hour and the mean population reduction 15.4%. Carp catches were increased in water depths greater than 1m by the addition of a single long dropper to the middle of each anode array. The dropper appeared to stun fish that were deeper or further away from the vessel and could be quickly detached for shallow waters where it was found to be of little or no benefit.

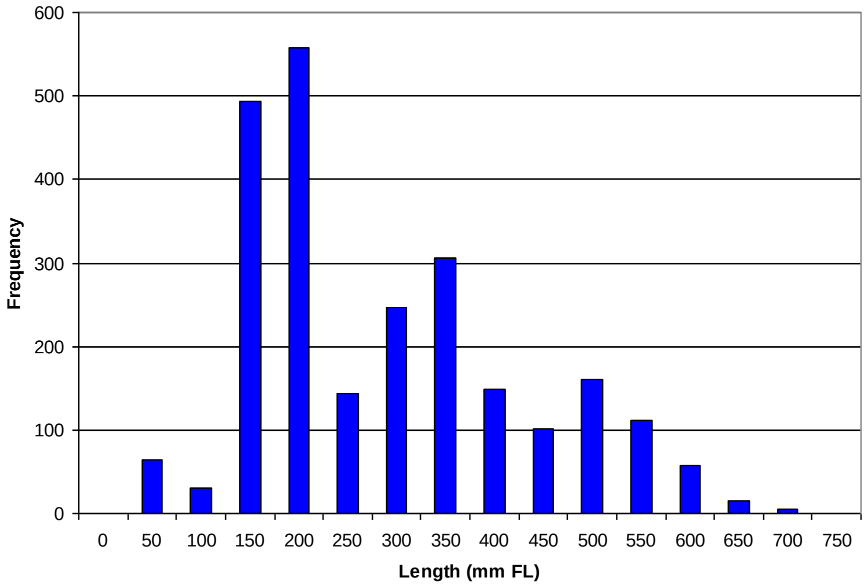

Figure 14: Length-frequency of carp captured with the large boat electrofisher (n=2439).

Table 7: CPUE and estimated carp population reductions by large boat electrofishing.

Site	Habitat	Density (carp/ha)	Population estimate	CPUE (carp/man.hr)	Reduction
Goondiwindi 07		**295**	**1,476**	**2.37**	**4.3%**
Site 2	River	89	178	1.89	9.6%
Site 4	River	364	727	2.44	3.0%
Control - river	River	571	571	2.78	4.4%
Thallon 08		**245**	**5,936**	**9.66**	**18.4%**
Site 1	Lagoon	3144	2,201	83.56	34.2%
Site 2	River	35	98	0.89	8.2%
Site 3	River	93	186	1.44	7.0%
Site 4	River	50	160	1.22	6.9%
Site 5	River	44	133	3.56	24.1%
Site 6	River	347	521	4.00	6.9%
Site 7	River	495	743	6.11	7.4%
Site 8	River	234	281	4.89	15.7%
Site 9	River	747	224	3.00	6.7%
Site 10	River	133	199	1.78	8.0%
Site 11	River	162	389	1.00	2.3%
Site 12	River	151	559	5.00	8.1%
Control	River	605	242	6.22	23.1%
Goondiwindi 08		**159**	**7,302**	**6.41**	**9.5%**
Main reach	River	48	1344	1.78	7.1%
Site 8	River	351	526	2.89	4.9%
Site 9	River	49	74	1.78	21.6%
Site 10	River	399	718	5.00	6.3%
Site 11 - lagoon	Lagoon	416	3,540	45.00	11.4%
Control - river	River	283	849	5.44	5.8%
Control - lagoon	Lagoon	157	251	6.11	21.9%
Condamine		**73**	**650**	**6.72**	**47.5%**
Oakey Creek	River	48	167	4.93	41.3%
Myall Creek	River	47	134	4.88	58.2%
Condamine River	River	145	349	10.13	46.4%
Logan and Albert Catchment		**11,468**	**82**	**22.62**	**9.7%**
TF2	Lagoon	142	9,746	43.95	8.3%
Tabragalba	Lagoon	139	700	19.24	39.9%
Riemore Lagoon	Lagoon	12	1022	10.13	2.3%
Mean				**9.73**	**15.5%**
Overall total			**26,832**	**9.53**	**12.2%**

The CPUE and population reductions for the large electrofishing boat were far greater in the lagoons than the river sections (Table 8). Mean carp density was approximately five times greater in lagoons; however the CPUE was nearly ten times higher. The proportional population reductions were also marginally higher in the lagoons.

Table 8: Large electrofishing boat CPUE and population reductions of carp by habitat

Habitat	Density (carp/ha)	Mean CPUE (carp/man.hr)	Population Reduction
Lagoon	674	27.94	13.5%
River	222	3.49	14.1%

This result may partially be due to the density dependent nature of electrofishing efficiency (Figure 15) and the ability of the electrofisher to more effectively fish the shallower lagoon regions. Gear saturation occurred at higher densities. At densities around 3,000 carp per hectare the ability of the netters to capture all stunned carp was limited by how much their nets could hold. High numbers of small fish could easily be netted before emptying, whilst only a few large fish could be netted at the one time. When a school of large fish was encountered the number of fish missed was higher. The CPUE should plateau at higher density.

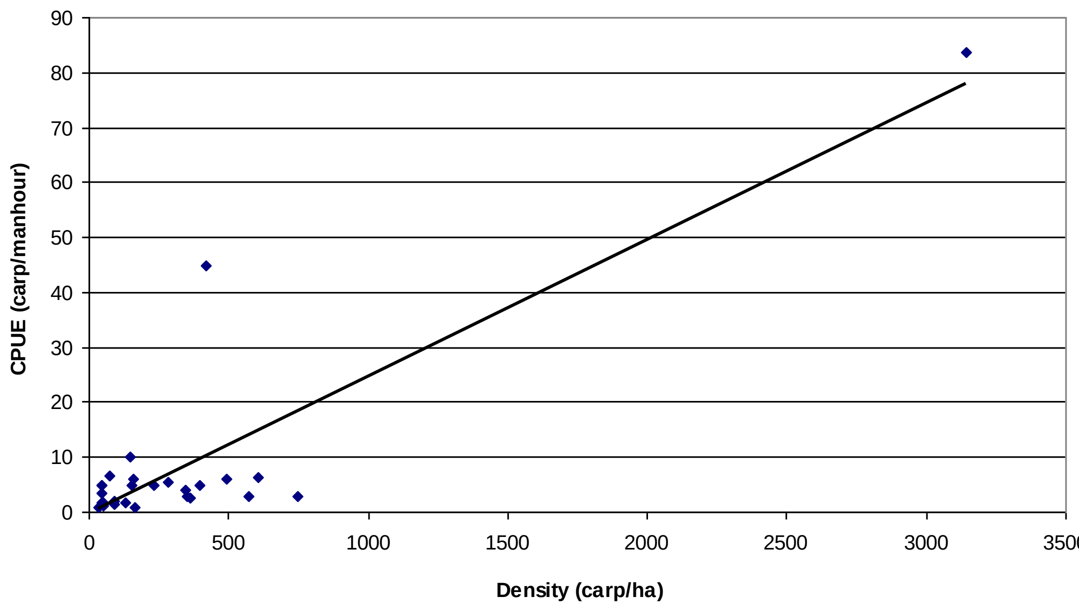

Figure 15: Relationship between carp density and CPUE for the large electrofishing boat (n = 26). CPUE = 0.0248 x density - 0.2251 (R^2 = 0.7428).

3.5.4 Discussion

Electrofishing was a highly effective carp removal method and could be employed in a wide range of habitats if several gear types are available. The technique has a very low bycatch and stunned fish typically recovered in just a few seconds. Compared to many native species carp were often less effected by the electric field and more likely to evade netters. Carp would frequently leap when the field was turned on and land with enough momentum to push them beyond the holding boundaries of the field. At other times carp would be moving rapidly and although stunned their momentum would carry them through the effective field or down deep beyond the view and reach of the netters.

Several techniques were successful in increasing carp catch rates. When operating in water greater than 1m deep we employed an extra dropper in the centre of each Wisconsin anode array. This dropper was 2.5m long, a length which prevented the dropper reaching the hull or a person netting if flicked up by a net, thus preventing the risk of electrocution. A longer, partially shielded dropper was also trialled but found to be ineffective. The dropper was most effective in deeper water where it appeared to disturb carp and push them up into the stronger field created by the standard Wisconsin array. The central dropper also seemed to create a field which held carp better. Electric field strength and shape is determined by the shape and size of the anodes relative to the hull. Greater anode surface area creates a wider but less intense field (Kolz et al 1998). The dropper may have caused lower gradient of the stunning field in a downwards direction and in doing so increased the effective field in that direction.

The size of the effective stunning field increases with the size of the electrofishing unit. The outputs from the large electrofishing units can also cope with a wider range of conductivities. The largest possible unit should be used at each site. This is regulated to a large degree by access, fallen timber and water depth. In the Logan and Albert Catchment the banks were typically very steep and made boat access to the river extremely difficult for large sections. A combination of equipment may be required to effectively fish large sections. The backpack unit worked well in creeks with predominantly shallow riffles and runs, but was not so effective in deeper pools where many of the carp are found. These areas could only be sampled around their edges by carefully walking the shoreline and reaching in with the anode. Carp in the middle of the pool may have been missed. Electrofishing these areas by boat would be far more effective if possible.

Electrofishing tended to work best where there was some form of structure in the water where startled fish could seek refuge. In areas with a clean, relatively debris free substrate carp could be seen fleeing from the weaker margins of the field. Stuart and Jones (2002) also noted decreases in electrofishing efficiency in shallow floodplain lakes. Where there was no cover, carp appeared to move away from the boat. Where large woody debris, aquatic macrophytes and emergent grasses were present carp often fled to these structures. Carp seeking these refuges were more likely to remain there long enough to immobilise them for capture. Although netting can be more difficult around structure our catch rates were consistently higher than in open areas.

When chasing carp in smaller lagoons, one technique that increased catch rates was to make an initial pass around the shoreline, followed by a pass through the middle and a second pass around the shore. Carp catches were typically lower during the initial and centre pass, but increased greatly on the second lap. We believe that during the initial pass a number of carp are avoiding the boat and moving to deeper waters in the centre of the lagoon. The majority of carp caught were associated with some form of structure. When the boat makes the pass through the centre it causes fish there to move to the margins and seek some form of refuge. These fish are then caught during the second pass along the shoreline.

Pre-feeding an area with burley prior to electrofishing also increased catch rates and helped concentrate carp in areas suitable for netting. Burleying was most effective in large or structure-less waterways. Best results were achieved when the burley was placed near a structure (e.g. fallen tree) around which carp could congregate. The burley we used consisted of a combination of chicken layer pellets, creamed corn and corn kernels.

In deeper sections of river with steep banks, electrofishing was also more efficient at night. It appears that the carp were moving out of the deep water in towards the bank to feed after dark. This diurnal movement is supported by data from radio-tracking in the pilot study on trap attractants and personal observations of carp foraging right up to the shore at night. In shallow lagoons and areas where extensive structure or shallow flats exist, night time electrofishing was not found to be any more effective.

The efficiency of electrofishing was heavily influenced by water quality parameters. At extremely high or low conductivities the size of the effective stunning field was reduced and fewer fish stopped. Catch rates were also highest in clear waters where netters could easily see stunned fish well below the surface. In some locations stunned carp were prone to sinking and unless netted immediately disappeared from view or reach. In turbid water blind netting was required and more stunned carp are likely to have gone undetected.

Portable barrier nets can be used to increase the effectiveness of electrofishing, particularly in smaller waterbodies. Setting blocker nets at the up and down-stream limits of the work area prevent carp from escaping. Multiple passes of an area can then be made to ensure all carp are caught. In smaller creeks natural delineations, such as shallow riffles, can be used instead of nets to define working zones.

The value of ongoing, periodic removals efforts was well illustrated in Sandy Creek. For a small creek it was quite surprising the number of carp that continued to be caught. After each trip it was felt that the majority of carp were removed from the site. There were many shallow areas with tall, dense reeds which were difficult to electrofish effectively. We believe that this may be where some of the smaller carp resided. Few large fish were caught after the first few trips, and those that did generally came after a flow event.

In many small creeks electrofishing may be an effective method for removing carp. The fish are typically concentrated in deeper pools. Shallow water and a lack of connectivity between these pools enables them to be treated as individual management units in the between flow events. Sequentially removing the carp from such areas is possible and may result in more sustained benefits. Carp will reinvade during flow events, but it would be likely that the incursions would occur at the lower section of creek where removal occurred. Thus, for most flow events effort may only need to be focussed in this area rather than the entire cleared section. As an example, Sandy Creek regularly has water for approximately 10km of its length. The next level of control would be to undergo removal along as much of this area as possible. This would take more than a week. As mentioned above, the area would need to then be revisited several times to ensure the majority of fish were captured. In the lower reaches of Sandy Creek there are several natural barriers that would prevent reinvasion, except during significant flow events. Control efforts could be targeted after the end of the wet-season rains to ensure the impact is the greatest and the system has the longest time to recover.

Electrofishing has been widely applied in the past to manage carp populations, however data on the effectiveness of the technique has rarely been published. As part of a river restoration project in Gippsland, Victoria, carp were removed from a section of the Little Moe River using electrofishing. A small in stream barrier was constructed to restrict carp movement upstream and carp were removed by an intense one-off, back-pack electrofishing effort (Koehn et al 2000). One hundred and twenty seven carp were removed and as the carp were in relatively low numbers it was assumed that all carp were caught. Based on the results from Sandy Creek, it is likely that all carp were not captured and further efforts would be required to achieve eradication.

As part of a project investigating environmental response to carp removal, SMEC (Snowy Mountains Engineering Corporation) instigated carp removal from two lagoons in southern Queensland. A number of techniques were utilised, however the most effective and consistent technique was electrofishing which accounted for 42% of their catch per labour hour in one lagoon, and 59% in the other (Gehrke 2009). The effectiveness of the technique increased to 94% and 77% when analysed as catch per hour of activity rather than labour effort. This more accurately reflects the techniques effectiveness compared to its cost of implementation.

Other projects have reported quite high electrofishing CPUE from areas with relatively low carp densities. An electrofishing program in Eagle Springs Lake, Wisconsin, caught 269 carp in six hours for a CPUE of 44.8 carp per hour operation (Eagle Spring Lake Management District 2009). The lake’s carp density is estimated to be only 4.26 carp/ha with the electrofishing removing 6.3% of the carp population. A carp control project was also conducted in Dewey Lake, Kentucky, where the carp population was estimated to be 4,462 fish with a density of 10.02 carp/ha (Wanner et al 2009). During 18.5 hours of boat electrofishing a total of 744 carp were caught for a CPUE of 40.2 carp per hour operation. This represents a population reduction of 16.7%.

The comparatively high CPUE from low carp density areas in these projects is much higher than found in the current study. This may in part be potentially explained by the size of the waterbodies worked on. Both occurred in large, deep lakes (Eagle Springs – 1008 ha, Dewey – 445 ha). Carp often prefer shallower areas and thus would be found near the shores of the lake where electrofishing effort is concentrated. The deeper waters cannot be effectively sample by electrofishing due to insufficient depth penetration of the stunning field. Thus, the density of carp where the electrofishing occurred was most likely locally higher than the lakes’ averages. Alternatively other environmental parameters such as conductivity, turbidity, schooling or operator skill levels may have been more favourable.

Converted back to carp per hour of operation, the mean CPUE from the current project was:

- Backpack electrofisher – 10.6 carp per hour
- Small boat electrofisher – 21.6 carp per hour
- Large boat electrofisher – 29.2 carp per hour.

In rivers and lagoons the CPUE of the large boat rises to 89.2 carp per hour, but occurs at a very high mean density of 674 carp/ha. These values are similar to the results from the USA.

Electrofishing was a very effective, but expensive technique for carp control. Operators require specialised skills and equipment, which has a high maintenance cost. The technique is suitable for use in all habitats, but is most effective where there is some structure present. Impacts on non-target species are minimal.

3.6 Water level manipulation

Manipulating the water level to help control carp numbers and spawning activities is a technique that is simple and can be implemented wherever control of water level is possible. Manipulating water levels can be used to eradicate carp by complete drawdown or assist removal by concentrating carp into smaller, more easily managed areas. Drawing down water levels can also be employed to reduce carp recruitment by preventing access to aquatic vegetation during spawning periods or to desiccate eggs once they are laid. Recent research suggests that filling lagoons can also be used to concentrate carp at lagoon entrances where a variety of removal techniques can be utilized (Smith and Thwaites 2009).

Water level manipulation targets all size classes of carp but can have drastic impacts on non-target species. If threatened or endangered species are present and their safe removal cannot be guaranteed, then alternative techniques should be implemented.

The results of natural water level fluctuations can be used in the same manner as artificial water level manipulation. During extended periods of low water, carp will become concentrated in smaller, more manageable waterbodies and may not have access to suitable spawning sites. Alternatively, carp may congregate at wetland and canal entrances during flow events providing opportunities for cost efficient removal.

3.6.1 Methods

During 2007 a large turf farm took advantage of low water levels resulting from the drought to drain most of the water from their main irrigation dam to undertake extension and deepening activities. The dam was divided into three sections and the earthworks undertaken as each section was drained sequentially. The first section was drained into the river, whilst water from other sections was shifted to the sections not being worked upon. The mean size and weight of a subset of carp was calculated and used to determine the carp biomass removed.

3.6.2 Results

When the water was drained/lowered in the first section, closest to the river and wall approximately, 10 tonnes of carp were removed with an excavator. Another five tonnes were removed from the other two sections. Heavy machinery was used to scoop the carp from the mud after water levels were dropped. Approximately 12 hours were spent on the activity all up, excluding the labour involved in building the levees and lowering the water levels which are unknown. A follow-up electrofishing survey revealed that although adult numbers were low, the remaining individuals had spawned when the dam was refilled and juvenile carp were highly prevalent.

Table 9: CPUE and population reductions by water level manipulation.

Site	Habitat	Population estimate	Survey density	CPUE (carp/hr)	Reduction (%)
Bidadabba	Lagoon	12,676	251	708.3*	67.1%

* Does not include time spent altering water levels as this was unknown.

3.6.3 Discussion

In private waterbodies and wetlands fitted with regulators to control water levels, it may be possible to eradicate carp by draining the water and allowing the waterway to dry completely. Carp have been shown to be less adept at returning to connecting rivers from off-stream waters than many native species (Koehn and Nicol 1998). When a wetland is drained, native fish tend to leave before it is dry, whereas carp swim against the current of the out-flowing water, moving deeper into the drying wetland until they are stranded (Smith and Thwaites 2009). This dichotomy in behaviour can significantly reduce the non-target by-catch impacts of draining.

In the example presented in the current study, the water could not be completely removed so the waterbody was divided into three by temporary levees. Only one third of the water was drained, with the remainder pumped between the different sections. This ensured the irrigator did not have to wait for a significant flow in the river to refill the dam. Unfortunately, using this method some carp survived in the remaining water or mud. These carp spawned successfully when the dam was refilled, and although the biomass has been dramatically reduced, carp density remains high from the recruitment. The primary function of the water level manipulation was to restructure the dam to increase its capacity. Carp management was a bonus artefact of the activity. If possible, the various sections of the dam should have each been dried for a period of time to kill the surviving fish before refilling.

Carp have been successfully eradicated from Pilby Creek in South Australia through water level manipulation. The 17ha wetland was drained in 1993 with commercial operators removing 1,200 carp (Koehn et al 2000). A control drain was constructed at one end of the wetland to enable draining to occur and to prevent reinvasion; the mouth of the regulator was fitted with a fish screen to prevent the passage of adult carp into the wetland. The funding received for this project over ten years, including monitoring was $103,500 and has been assisted by in-kind support from agencies, volunteers and commercial fishers. The majority of the funds were used to construct the drain and regulator. Pilby Creek remained carp free for at least five years following these activities.

A similar approach was taken at Reedy Lake in Victoria. A water regulator and fish screen were installed, the water level dropped and the lake dried in 1997. More than 10,000 carp were killed and the lake refilled (Koehn et al 2000). The project cost $16,500 with the proceeds raised by a community group.

Richardson's Lagoon on the Murray River near Echuca was used to evaluate the effectiveness of water drawdown to kill the resident carp population (Stuart and Jones 2002). Prior to manipulating water levels, surveys were conducted to ensure there were no significant fish fauna were in the lagoon. Natural drawdown of the lagoon by evaporation was supplemented by pumping of the deeper pools over a two day period. It was estimated that 1.5 tonnes of carp and 50 goldfish were stranded and no native fish were sighted. The lagoon was left dry for 12 months to allow the benthos to crack and bind nutrients within the soil. To prevent carp reinvading the lagoon two fine mesh screens were installed in the wetland regulator. The carp-free persistence of this intervention is unknown.

Another approach to manage carp populations is manipulating water levels during spawning periods to prevent carp accessing suitable spawning habitat. This technique has been used successfully in Lakes Crescent and Sorrell in Tasmania in conjunction with barrier nets to inhibit spawning success (Diggle et al 2004, Wisniewski 2009). Spawning in these lakes is limited by only a short period of suitably warm water temperature and habitat access. Together, these activities have prevented successful spawning events since 2000 in Lake Crescent and 2005 in Lake Sorrell.

Deliberate increases in water levels can also be used to lure carp to areas where they can easily be removed by conventional techniques. Recent research suggests that filling lagoons attracts carp to lagoon entrances where a variety of removal techniques can be utilized (Smith et al 2009). A number of traps have been specially developed to catch carp as they move into or out of lagoons through regulated channels (Stuart and Jones 2002, Thwaites et al 2010). The traps use innate behaviours of carp when they reach a barrier to migration to sort the carp from native species (see Section 3.9.3 for a more detailed discussion).

The results of natural water level fluctuations can be used in the same manner as artificial water level manipulation. During extended periods of low water, carp will become concentrated in smaller, more manageable waterbodies and may not have access to suitable spawning sites. Alternatively, carp may congregate at wetland and canal entrances during flow events providing opportunities for cost efficient removal.

Water level manipulation targets all size classes of carp but can have drastic impacts on non-target species. If threatened or endangered species are present and their safe removal cannot be guaranteed, then alternative techniques should be implemented. Prior to drying, efforts should be made to capture and relocate native fish species into more permanent waterbodies.

In summary, the manipulation of water levels is a technique which can be used as an outright control method through drying a wetland, or as a tool to increase the success of other techniques by concentrating carp densities or reducing the size of area managed. The technique is limited to wetlands where inflows and outflows are regulated, but advantage can also be made of natural wetting and drying cycles in unregulated sites.

3.7 Bait traps

Bait traps can be effective means of trapping small fish, including carp. They are cheap and easy to deploy and may provide a method for targeting young-of-year at carp recruitment hotspots.

3.7.1 Methods

The ability of small collapsible yabby traps to catch carp was assessed at six sites in the Logan and Albert Catchment. The traps were 610mm long, 300mm wide, 300mm tall with a cone entrance diameter of 35mm. Traps were baited with a mixture of layer pellets, creamed corn and corn kernels and placed around the margins of waterways. Where possible the bait traps were placed near areas likely to be inhabited by juvenile carp, including places with macrophytic cover, woody debris or inundated grass. Traps were baited and checked daily over a 3 to 4 day period.

Figure 16: Bait traps used to catch small carp.

3.7.2 Results

Bait traps proved to be an ineffective technique, capturing only 97 carp from just two of the six sites where they were trialled. Captured carp were small (28-267mm FL) with a mean size of 51 ± 25mm FL (Figure 17). The technique caught most fish at a site where recent spawning had occurred and numerous fingerlings inhabited submerged grass around the dam shore. The bait traps frequently captured high numbers of small native species, particularly gudgeons, which were all released unharmed. Two small turtles managed to squeeze in through the small trap entrance ring, but both were released unharmed. At some locations high numbers of gambusia were also caught.

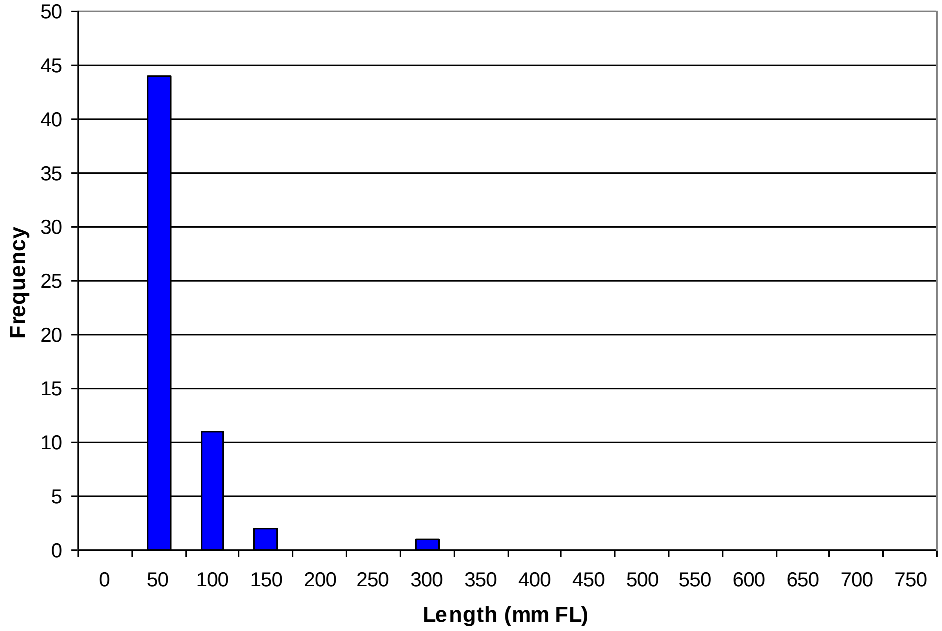

Figure 17: Length-frequency of carp captured in bait traps

Table 10: CPUE and estimated carp population reductions using bait traps

Site	Habitat	Survey density	Population estimate	CPUE (carp/hr)	Reduction
Canungra Creek	Creek	5	12	0.00	0.0%
TF2	Lagoon	142	9,746	9.14	1.0%
Riemore Lagoon	Lagoon	12	1,022	0.00	0.0%
Wolfdene	River	7	85	0.00	0.0%
Tabragalba Lagoon	Lagoon	139	700	0.00	0.0%
Luscombe weirpool	River	7	100	0.00	0.0%
Sth McLean weirpool	River	27	164	0.16	0.6%
Sandy Creek	Creek	10	36	0.00	0.0%
Mean		42	1,483	1.16	0.2%
Overall			11,865	2.24	0.8%

3.7.3 Discussion

Fine mesh collapsible bait traps have been successfully used for the capture of juvenile estuarine and small native freshwater fish (Graham et al 2005). In this study the bait traps only caught carp at two locations. The majority of fish (99%) were caught from an irrigation dam which had just experienced a successful carp spawning and recruitment, resulting in very high numbers of juvenile carp. Bait or a suitable attractant was required to entice carp into the traps. Preliminary trials without bait resulted in no carp being caught despite an abundance of juveniles being present.

Bait traps only target small fish. The small entries into the traps may inhibit the entry of larger carp into the traps. The largest carp caught was 267mm FL and the fish just fitted through the trap opening. The majority of carp were less than 100mm FL and young-of year. Interestingly, many larger carp were caught by electrofishing in the vicinity of the traps, suggesting these fish were attracted by the bait, but unable to gain entry. For smaller fish, the rigid trap entrance enabled fish to easily swim in and out. This was highly evident by the far greater number of carp caught in trap which had bait remaining, compared to those where the bait had dispersed or been consumed.

Bait traps are cheap and easy to deploy but are not an effective method for managing carp. The traps could be incorporated into an integrated management effort targeting young-of year carp in wetlands after successful recruitment, however other techniques are more effective. The traps are unlikely to capture sufficient carp to have a lasting impact on the carp population and target a life stage where natural mortality is high.

3.8 Fyke nets

Fyke nets are a type of collapsible trap net. They are relatively small and lightweight compared to other types of fishing gear. The traps consist of a tunnel made from a series of overlapping conical hoops. The nets are typically between 5 and 11 metres long with 1 to 3 long netting wings out in front to help guide fish into the trap. The entrance is D-shaped in smaller nets and rectangular in larger ones. Internal funnels are used to direct the fish inside. The final funnel exit is collapsed so that the fish are trapped and retained in the final compartment of the net. Traps must allow access to the surface for air-breathing animals. In deeper water, traps can be floated to maintain a space above the water or, if fully submerged, be fitted with an escape ‘sock’ to the surface. Care must be taken to prevent twisting or blockages in a netting sock or cod-end by securing it to a stake or other fixed point above the surface.

The nets are staked out in areas where carp are known to move through. The shape of the nets means that they are usually set in relatively shallow water to be most effective. With care they can be set in areas with a moderate amount of woody debris. Fyke nets must be checked every 48 hours to release bycatch and remove any air-breathing animals caught. These nets can trap a lot of bycatch but their design usually results in minimum harm and a safe release. Setting a portion of the net above water ensures that air-breathing wildlife can be released with minimal harm. Due to their size and the shallow locations where they are set, fyke nets typically are more effective for smaller carp.

Figure 18: A fyke net set up to show the tunnel with cones (A) and two fyke nets set back-to back in a river (B).

3.8.1 Methods

Fyke nets were trialled at eight sites in the Logan and Albert Catchment. The nets were constructed from 19mm 9 ply mesh with two 5m wings of 60cm drop. The net entrances were made from a 60cm D ring. The cod ends contained two cones and six hoops and were finished with a drawstring for easy access and clearing.

Between two and six fyke nets were set at each site for a period of a week. The nets were located with their entrance in water less than 0.6m deep and oriented to face either up or down stream. The nets were held in place by three stakes, one at the end of each wing and another attached to the cod-end. The cod-end contained a 150mm ball float to ensure an air pocket for any trapped air breathing animals. The fyke nets were situated in areas where carp were likely to move through and which had suitable habitat. Most nets were set adjacent to the shore, however where water depth was consistently shallow or sandbars were present, some nets were set away from waterway margins. The cod-end of each net was baited daily with a mixture of chicken layer pellets, creamed corn and corn kernels. The nets were cleared daily to release bycatch.

3.8.2 Results

The small fyke nets were not very successful in catching carp. Only 49 carp were caught from three of the eight sites where they were used. The mean size of these fish was 99.6 ± 116mm FL although carp from 34 to 424mm FL were captured (Figure 19). On occasions carp were observed to congregate in the vicinity of the fyke nets but did not enter. The fyke nets captured a wide range of bycatch including high numbers of small native fish species, mullet, long-finned eels, and spangled perch. These non-target fish were easily released unharmed. Turtles were also frequently caught in the nets but were all released unharmed. A float in the cod-end enabled access to air for the turtles and other air breathers. The use of fyke nets was limited to locations where the water depth was sufficiently shallow for the wings to cover the majority of the water depth. In several locations the traps were set around woody debris and stones.

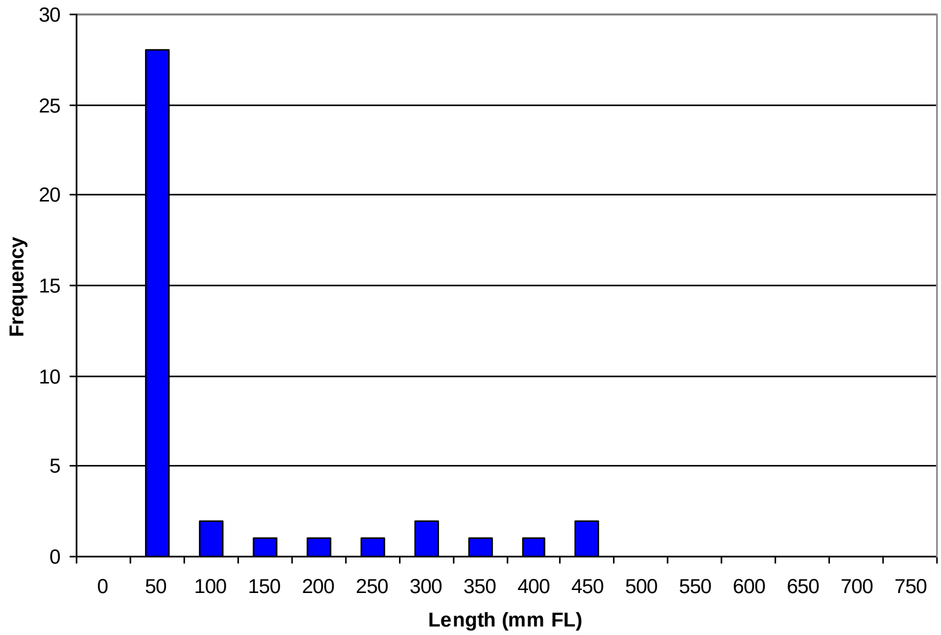

Figure 19: Length-frequency of carp captured in fyke nets.

Table 11: CPUE and estimated carp population reductions by fyke nets.

Site	Habitat	Survey density	Population estimate	CPUE (carp/hr)	Reduction
Canungra Creek	Creek	5	12	0.00	0.0%
TF2	Lagoon	142	9,746	11.08	0.5%
Riemore Lagoon	Lagoon	12	1,022	0.00	0.0%
Wolfdene	River	7	85	0.00	0.0%
Tabragalba Lagoon	Lagoon	139	700	0.00	0.0%
Luscombe weirpool	River	7	100	0.27	2.0%
Sth McLean weirpool	River	27	164	0.00	0.0%
Sandy Creek	Creek	10	36	0.46	2.8%
Mean			1,483	1.48	0.7%
Overall			11,865	1.25	0.4%

3.8.3 Discussion

It was anticipated fyke nets would be much more successful than they were. A good CPUE was only recorded in one lagoon where the carp density was very high and many young-of-year fish inhabited shallow waters near the shore. Past survey work in the Queensland portion of the MDB using fyke nets has found carp to be a frequent bycatch, although rarely in high numbers.

The size of the nets used should not have posed any physical constraints to entry by most carp. This is supported by the wide size range of fish caught: 34-424mm FL. Fish larger than 600mm may have some difficulty entering the fyke nets, but these fish only comprise a very small proportion of the carp population in most places. The carp trap used with attractants in Section 3.9 follow the same basic design as the smaller fyke nets and carp appear to have little hesitation entering that trap. This suggests that carp may find the entrance to the smaller fyke nets too small and inhibitive to entry. A larger fyke net with tunnel dimensions of 0.75-1.0m diameter may result in less trap shyness and greater catch rates.

The fyke nets could be set in a range of habitats, including areas with some woody debris. However, the nets were limited to locations where the water was less than 60cm in depth. This typically restricted their use to shallow lagoons and adjacent to the bank. In areas where the banks dropped steeply into deeper water the nets could not be deployed. Fyke nets work most effectively when the entrance to the tunnel reaches from the substrate to the surface. Fish which follow the wings in are less likely to go over or under the entrance. Using fyke nets with a larger diameter tunnel (as discussed above) would enable the nets to be set in a greater number of locations and reduce the necessity of carp to travel into very shallow water to enter the fyke nets. Another option to decrease depth limitation would be to use longer wings with a greater drop to guide fish towards the entrance from deeper waters. Tapered wings could help minimise excess bag near the entrance which can trap turtles as they try to surface for air.

Fyke nets have generally been unsuccessful in past carp removal exercises. Graham et al (2005) caught no carp in fyke nets set in Botany Pond and Lane Cove River, NSW, despite good catches with electrofishing in the same area. In Tasmania's carp eradication project in Lakes Crescent and Sorrell, fyke nets are used mostly as a survey tool to assess recruitment. Fyke nets have also been used to monitor the movement of adult carp into marsh areas for spawning, but catches have typically been low (Diggle et al 2004, Wisniewski 2009). Initial efforts to use them as a control technique proved unsuccessful with a CPUE of 0.002 carp per trap-hour. Some degree of success was had in a carp project by SMEC to remove carp from two lagoons in southern Queensland using slightly larger nets. At one lagoon fyke nets contributed 55% of the carp catch per hour labour effort and 16% in the other (Gehrke 2009). At the first site strong carp recruitment had occurred the previous summer and young-of-year fish were numerous. The fyke nets set near woody debris in the shallows caught the most fish.

3.9 Trapping with attractants

Removal methods rely on many variables to be effective, but one of the most important factors is the presence of fish in the area being operated in. Fish can be actively herded into areas or encouraged to congregate. A pilot study was conducted on the effectiveness of a range of possible attractants deployed in conjunction with a large trap. The goal was to construct a trap that was portable, fast to set-up and able to be employed by community groups. The most successful attractant was field tested with the trap at a number of locations.

3.9.1 Methods

3.9.1.1 Pilot study – comparison of attractants

The trap design was based on an over-sized fyke net. The net wings and tunnel were constructed of 9 ply 15mm square set mesh. The two net wings were each 45m long with a drop of 3.6 metres. This size ensured the net conformed to the contours of the bottom profile and could be deployed in water with moderate depths. The entrance of the trap consisted of a 1.5m diameter circular hoop linked to three one way cones with an apex ring of 300mm diameter. The rings at either end of the cone were constructed from stainless steel multi-strand wire to ensure the entrances remained open. Attached to the tunnel was a large circular cod-end. A large cod-end was used to ensure that any carp in the trap were not stressed and thus would not emit distress signals causing other fish to shy away. The 5m diameter cod-end was constructed from 15 ply 25mm square set mesh and had side walls with a 2m drop. The cod end was held in shape by two rings of 25mm diameter heavy duty PVC electrical conduit. Each ring required four lengths of conduit and was attached to the net by elastic toggles. The net was put together on the bank and then floated out to where it was set. The bottom ring of the cod-end was sunk by flooding with water whilst the top ring provided enough buoyancy to ensure the net remained on the surface. Several 30cm foam floats were added to the cod-end to ensure any air-breathing bycatch could breathe. An access flap at the rear of the cod-end enabled trapped fish to be easily cleared.

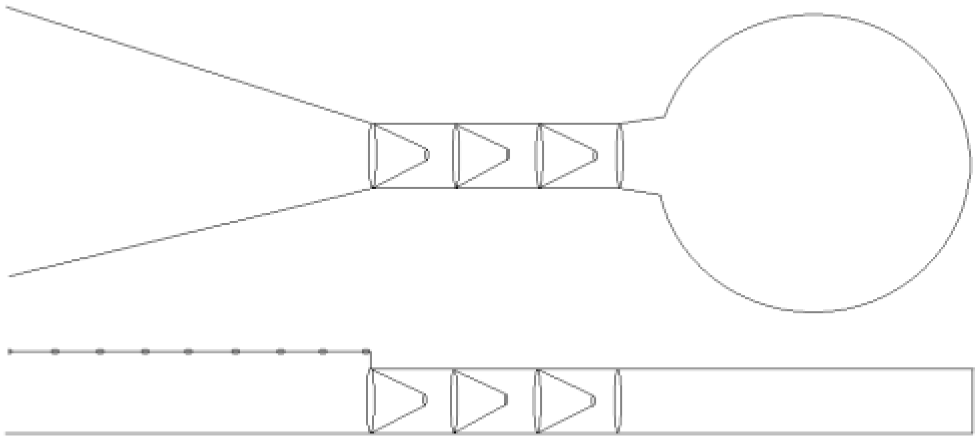

Figure 20: Plan and lateral views of the carp trap design

The pilot study was conducted in a large turf farm dam with a known high density of carp. Mark-recapture was utilised to obtain a carp population estimate for the dam to help evaluate removal efficiency. Additionally, six radio-tagged carp were released to monitor movement patterns in relation to each attractant. The position of each carp was recorded every three hours over the four days of each trial. The radio-tracking enabled observations of the length of time it took carp to respond to each attractant and their willingness to enter the trap. Radio-tracking would identify if the carp were attracted to the vicinity of the trap but were unwilling to enter, indicating the necessity for changes in trap design.

Three attractants were tested, along with an empty control net. The trap was set in one arm of the dam in water approximately 1.5m deep (Figure 21). Each attractant was put in place for four days (92-96 hours soak time) and the number of carp and bycatch were recorded. The traps were emptied daily to minimise stress to bycatch, particularly turtles. The attractants were trialled in a random order so as not to bias the results from learned behaviours. The experiments were also spaced several weeks apart to allow fish to settle after capture.

Figure 21: The trap set up in a large irrigation dam at Biddadabba.

Control

Control trials were conducted during February 2008 (summer) and November 2009 (spring). The net was deployed without an attractant for a period of four days (92 hours soak time) to provide baseline data against which the effectiveness of the attractants could be compared. All fish caught were measured for fork-length, checked for tags and released so as not to change the population size between treatments.

Automated feeder

The first attractant to be trialled was food based. Initial testing occurred in February 2008 (summer) and was repeated in June 2008 (winter). A floating automated fish feeder (here-on termed 'hopper') was developed to dispense prescribed amounts of food at set times of the day. The hopper consists of a feed holding container located over two floats from a dam paddle-wheel aerator. The feed rate was controlled by a programmable custom built dispenser housed below the hopper. The unit was raised about 50cm about the water's surface to ensure that turtles and other animals could not get their heads or other appendages into the dispenser. The hopper was programmed to deliver 775g of Ridley 6mm native fish pellets (70% floating, 30% sinking) over a 10 min period every two hours. This feed rate delivered 9.3kg of food into the area over a 24 hour period and required the prototype hopper to be filled every two days. The feed was chosen because it provided both sinking and floating pellets to help with dispersal. The area behind the net was also laced with pellets at the start of the trial to increase the scent in the water and encourage fish to enter. The position of radio-tagged fish was recorded every three hours for the duration of the experiment.

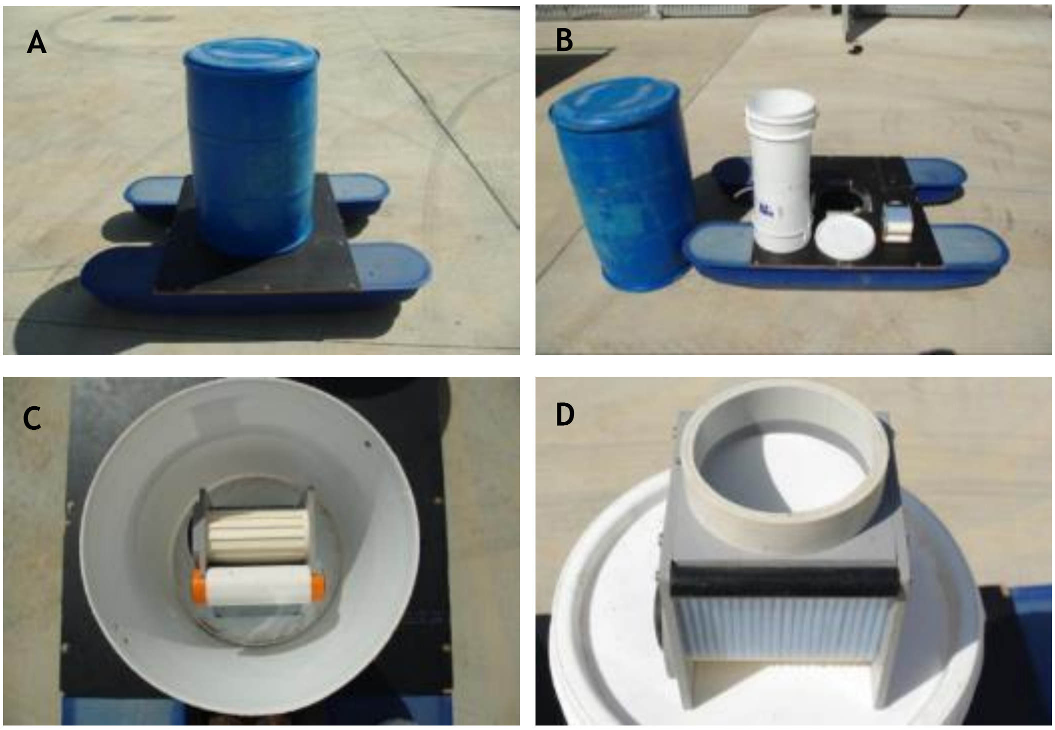

Figure 22: The automated feed dispenser ('hopper') used to attract carp into the trap A – Assembled hopper; B – Hopper components; C – Automated feeder attached below feed bin (view from below); D- Programmable auto-feeder.

Automated feeder with flow

It was anticipated that providing water flow past the trap would help disperse the scent of the food being released by the automated feeder. This in turn would attract carp to the trap from a greater distance, and ultimately increase carp catches. The hopper and trap were set up as described above. To provide the flow a Davey 'Firefighter 5 series' pump was used to pump 500 $l.min^{-1}$ of water through the trap from the rear (Figure 23). The pump was run continually for 92 hours, except when refuelling. The water pickup was located 70m away along the shore, past the trap wings so as to reduce possible disturbance from pump noise and vibrations. The water was pumped through 50mm flat hose, exiting from a brace 30cm above the water surface. It was anticipated the sound of water spilling from the hose outlet would also attract carp. The water flowed through the cod-end towards the mouth of the trap carrying small particles of feed with it. The feed rate on the hopper remained set at 9.3kg of Ridley 6mm native fish pellets per day. The trial was conducted over four days during November 2008 (spring) with a trap soak time of 92 hours. The position of radio-tagged fish was recorded every three hours for the duration of the experiment.

Figure 23: The automated feed dispenser ('hopper') and pump outlet used to create flow to attract carp into the trap.

Judas carp

During the breeding season hormone induced carp (Judas carp) were used as attractors to capture other carp. Induced fish exhibit their mating displays and provided both behavioural and chemical cues to attract other carp. Mature adult carp for use as the Judas fish were collected via electrofishing prior to the trial. The adult carp were anaesthetised and their sex determined by inserting a 2mm nylon canula into the urinogenital papilla. The canula inserts easy into female carp but not in males. Carp were held at the Southern Fisheries Centre in a freshwater recirculation system. Ripe male and female carp were injected with a single dose of 40µg/kg body weight LHRHa (luteinizing hormone-releasing hormone) directly into muscle tissue. Two hormonally induced male fish were released into a 0.3m^3 cage located within the trap cod-end. A second cage containing two induced females was also placed within the cod-end of the trap. The cages were located far enough apart so that the fish would not attempt to spawn with each other. Fish induced via injection are thought to produce a suitable display for 48 hrs after induction and thus Judas fish were replaced after two days. The trial was conducted during November 2008 (spring) and involved a trap soak time of 92 hours over four days. The position of radio-tagged fish was recorded every three hours for the duration of the experiment.

3.9.1.2 Field use of the carp trap

The results of the pilot study suggested that Judas fish were the most effective attractant (see Section 3.9.2.1). However, Judas fish can only be utilised at certain times of the year and are logistically difficult to manage. The feed attractant lured in reasonable numbers of carp and was a lot easier to implement. It was therefore decided to test the effectiveness of the hopper traps on a broader scale. Ridley 6mm native fish pellet is expensive when used on a large scale and a cheaper alternative was sought. Chicken layer pellets contain a number of ingredients that may be attractive to carp, are relatively inexpensive and widely. For subsequent trials chicken pellets were used in the hopper. The Golden Yoke brand layer pellets were found to have several desirable properties (high proportion of corn, sinking, readily available) compared to some other brands and were thus used.

During the pilot study it was also found that the trap design could be improved in several ways. The wings of the trap were far longer and deeper than necessary. The optimal depth for easy clearing of the trap cod-end is less than 1.5m. The trap was designed primarily for use in ephemeral wetlands and slow moving waterways where the bottom typically slopes gradually. Therefore the extra drop on the wings is not required and may result in increased impacts on non-target species which could become entangled in the folds of the net. The mesh of the wings was also found to not be ideal. Nine ply mesh tangles readily and is quite weak. The 15 mm square mesh was also found to be too small resulting in the gilling of small native fish such as bony bream and heavy accumulation of algae.

The second version of the carp trap had 25m long wings constructed from 21 ply 38mm square mesh with a 1.8m drop. The tunnel and cod end are constructed from 24 ply 45mm square trawl mesh and the cod-end size has been reduced to 3m diameter and 1.5m drop. The tunnel attaches to the wings with a zipper. The rings supporting the tunnel are 1.2m diameter, made from 20mm conduit in order to keep the weight down and drilled in multiple places to ensure they fill with water and sink.

The improved trap, using the hopper with chicken layer pellets as the attractant, was trialled at seven sites in the Logan and Albert Catchment, three in the Condamine Catchment and one in the McIntyre Catchment. The feed rate was maintained at 9.3kg per day and the traps were set for between 3 and 4 days (69-94 hour soak time). Traps were emptied daily and the hopper refilled after 48 hours. These sites cover a wide range of habitats, including ephemeral lagoons, weir-pools, small creeks, and open rivers.

3.9.2 Results

3.9.2.1 Pilot study results

Control

The control trap was trialled twice, once in spring and once in summer. The trap was deployed for period of five days (91 hours soak time) without an attractant as the control against which the effectiveness of the various attractants were judged. In spring 16 carp were caught, whilst in summer 30 carp were trapped. The sizes were from 110mm to 230mm fork length. The bycatch consisted of a total of 18 turtles and two eels.

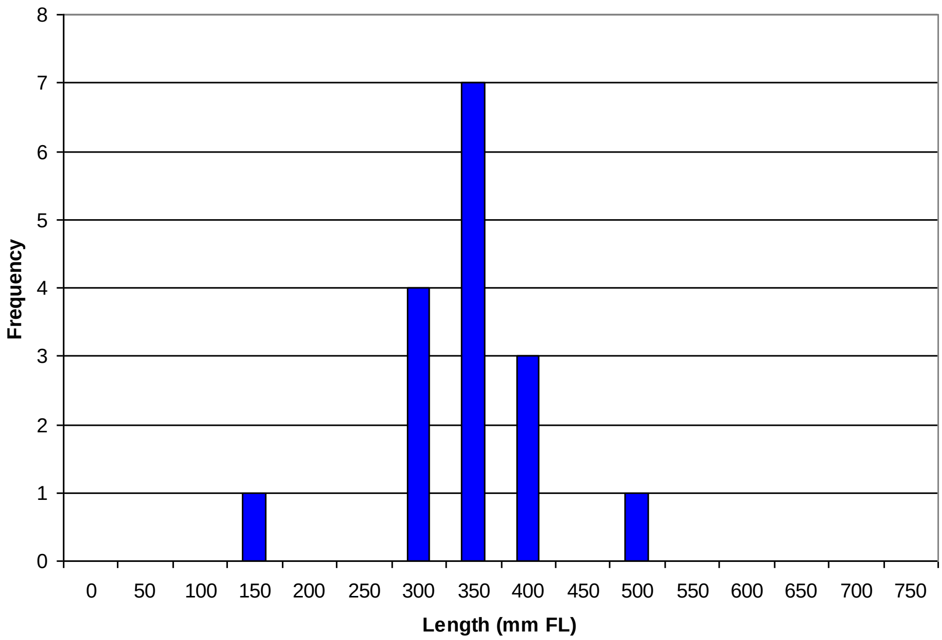

Figure 24: Length-frequency of carp captured in carp trap with no attractant (n=46).

Automated feed dispenser

During the summer trial, a total of 207 carp were caught over five days (92 hours soak time). The carp varied in size from 187mm to 478mm fork length. The bycatch consisted of 34 turtles and three eels all of which were released unharmed. Total effort in setting up the trap, topping up the hopper and clearing the trap was 8.2 man-hours.

At the commencement of the trial, the radio-tracked fish were found in two distinct areas of the dam (Figure 25). Distinct diurnal patterns of movement were evident with fish generally moving into the shallow margins from dusk to dawn and into deeper waters during the day. The carp also exhibited considerable vertical movements in the deeper sections. The signal strength would vary from weak to strong as fish rose from the depths towards the surface and then fade as they swam back down. This was visually validated for several fish. These actions were most prominent around dawn and dusk, and to a lesser degree through the night. By the third day, the tracked carp had clearly moved more towards the corner of the dam where the trap and attractant was. Figure 25 shows their location after 3.5 days with one tagged fish having entered the trap. This pattern persisted until the end of the trial.

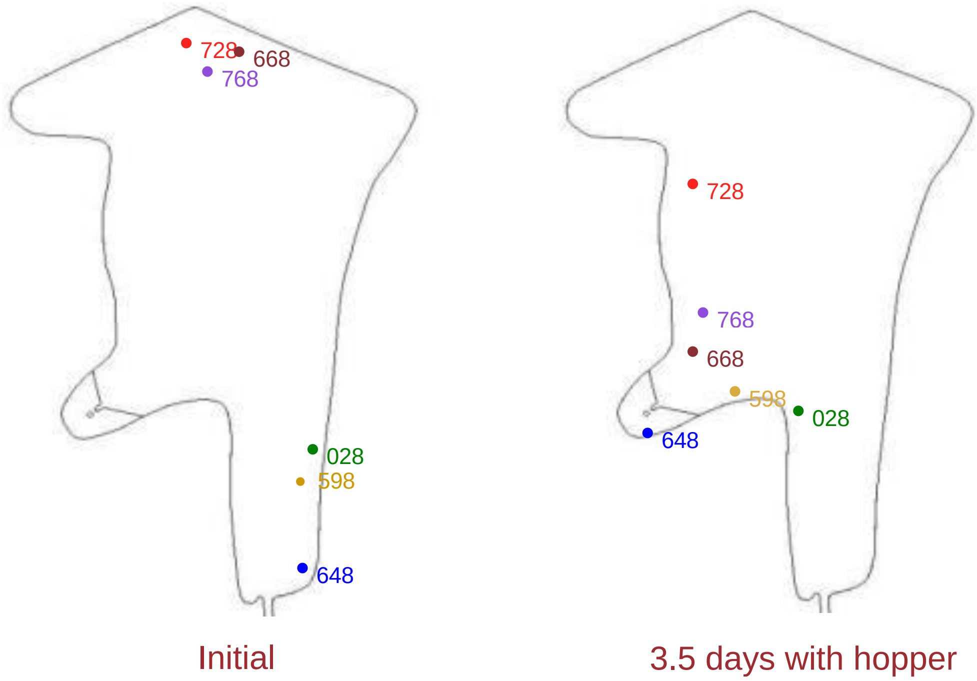

Figure 25: Location of radio-tracked carp prior to the addition of an attractant and 3.5 days after a food attractant had been continually added via an automated feeder.

Trials were repeated for the automated feed dispenser to determine if there were any seasonal differences in catch rates. The second trial in winter resulted in the capture of only 24 carp over five days (92 hours soak time). The carp varied in size from 196mm to 540mm fork length. Bycatch consisted of 15 turtles and one eel which were released unharmed. The total labour effort for this trial was 7.2 man-hours.

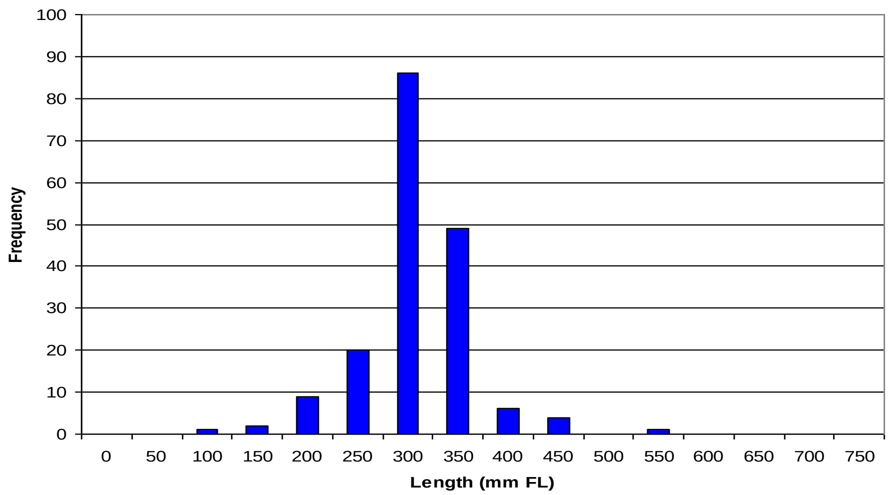

Figure 26: Length-frequency of carp captured in the carp trap with an automated feed dispenser as the attractant (n=178).

Automated feed dispenser plus flow

A total of 17 carp were caught over five days (92 hours soak time). The carp varied in size from 249mm to 478mm fork length. The radio-tracked fish displayed no tendency to congregate around the trap area and were actually more dispersed at the end of the trial (Figure 28). No tracked fish moved into the trap or near the entrance at any time.

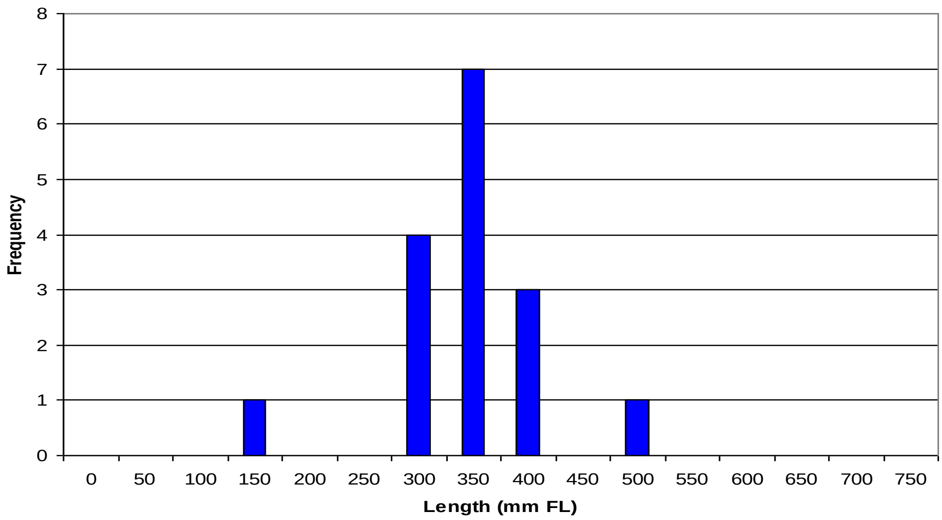

Figure 27: Length-frequency for carp captured in the carp trap with an automated feed dispenser and flow as the attractant (n=232).

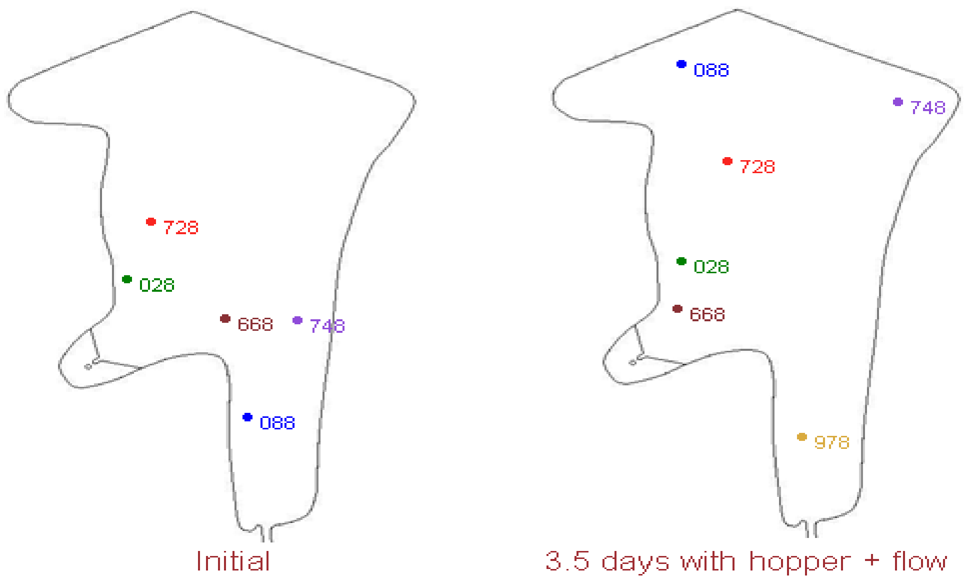

Figure 28: Location of radio-tracked carp prior to the addition of an attractant and 3.5 days after a food attractant and flow had been continually added via an automated feeder and irrigation pump.

Judas carp

Using Judas carp to lure con-specifics into the trap worked exceptionally well. A total of 288 carp moved into the trap during the 92 hour period the trap was operating. The carp ranged in size from 200-477mm which suggests a proportion of immature carp were captured (Figure 29). The sex ratio of captured carp was biased towards males approximately three females caught for every four male fish (1 female : 1.35 male). Bycatch consisted of 47 turtles and seven eels which were released unharmed.

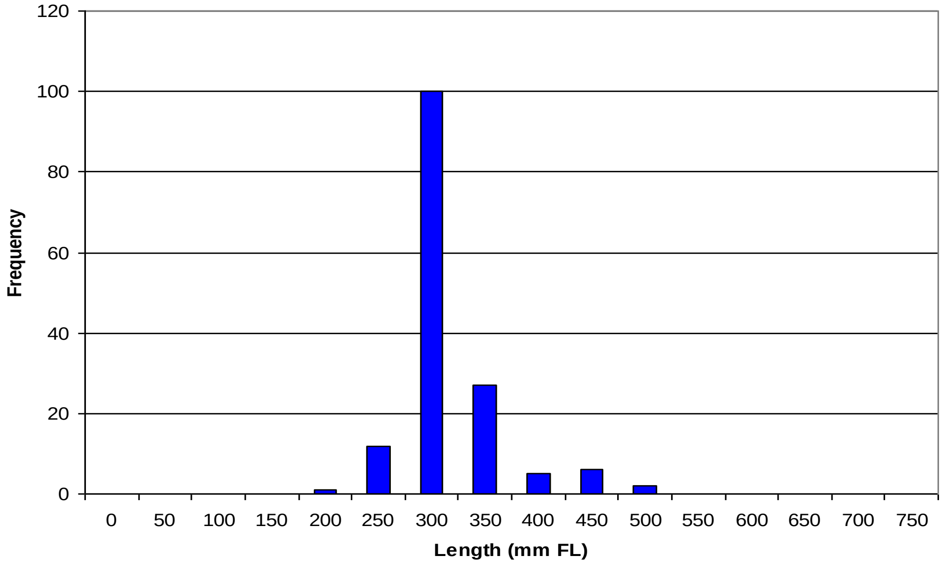

Figure 29: Length-frequency for carp captured in the carp trap with Judas carp as the attractant (n=153).

During the trial the dam experienced heavy rainfall which appeared to stimulate movement and spawning in the carp. The radio-tracked fish started congregating around the arm of the dam where the trap was located from the second day onwards. After 3.5 days their distribution was very similar to that observed during the hopper trial and one radio-tracked fish entered and remained in the trap (Figure 30).

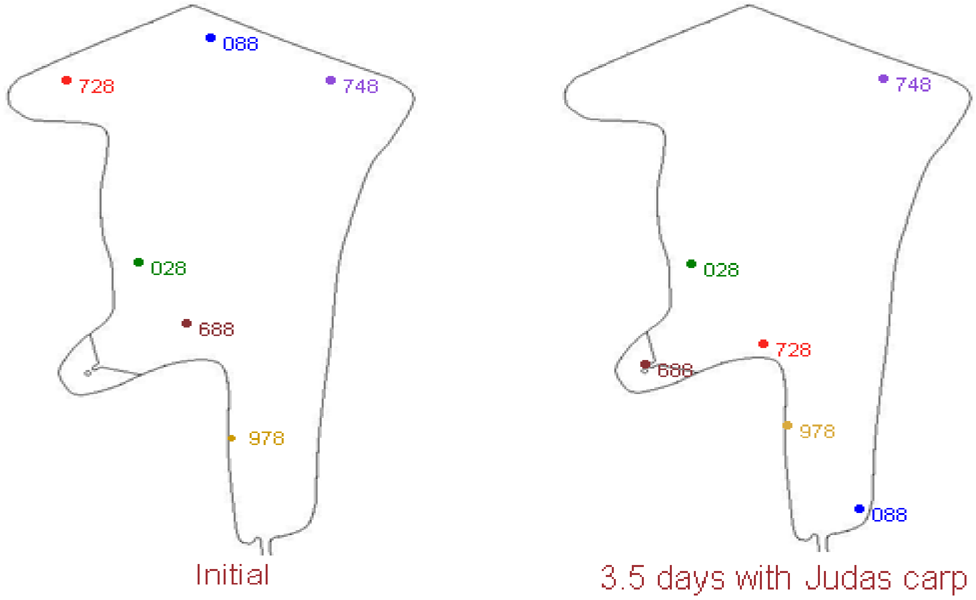

Figure 30: Location of radio-tracked carp prior to the addition of an attractant and 3.5 days after the addition of induced male and female Judas fish.

Pilot study summary

The data from the pilot study indicated that using Judas fish was the most effective form of trap attractant (Figure 31). Using the automated feed dispenser also produced good results during summer. Due to the difficult logistics of providing and using Judas fish, it was decided that the trap using the automated feed dispenser would be used for further field trials.

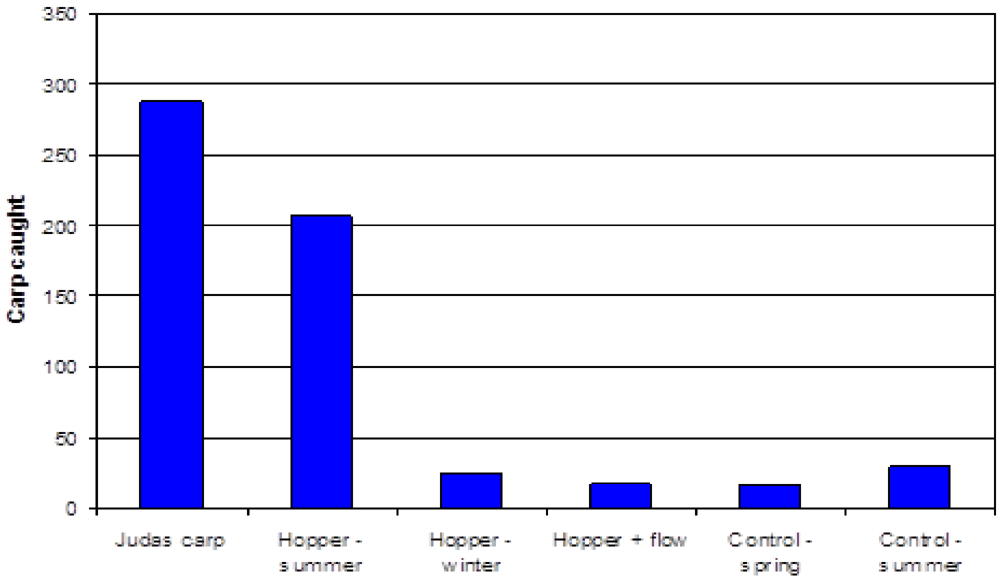

Figure 31: Numbers of carp lured into a trap over a 5 day period by different types of attractants.

3.9.2.2 Field use of the carp trap

The carp trap using the automated feed dispenser as an attractant was trialled at a further 12 locations with mixed results (Table 12). The traps caught a total of 689 carp of 70-620mm FL and were most effective during summer and spring in lagoons, impoundments and weirpools. The trap did not catch many carp in cool waters or smaller streams and creeks. In the 1,763 hours of soak time the traps were set, the bycatch caught included 1,100 turtles, 68 bony bream, 37 eel-tail catfish, 36 sea mullet, 15 eels, 13 golden perch, 11 freshwater mullet, three fork-tail catfish and two spangled perch. All of these were released unharmed except for 15 bony bream which gilled themselves in the net wings.

Table 12: CPUE & estimated carp population reductions by carp trap & different attractants.

Site	Attractant	Habitat	Survey density (carp/ha)	CPUE (carp/hr)	Applied CPUE[a]	Reduction
			Pilot study			
TF2	Control	Lagoon	244	1.52	2.00	0.2%
TF2	Control	Lagoon	244	3.62	4.75	0.3%
TF2	Hopper	Lagoon	244	2.72	3.49	0.3%
TF2	Hopper	Lagoon	244	18.00	25.35	3.0%
TF2	Hopper + flow	Lagoon	244	1.39	1.76	0.2%
TF2	Judas	Lagoon	244	25.04	33.88	2.1%
			Field trials			
Canungra Cr	Hopper	Creek	5	0.10	0.14	8.3%
TF2	Hopper	Lagoon	149	30.00	38.23	2.6%
Riemore	Hopper	Lagoon	12	0.37	0.49	0.3%
Wolfdene	Hopper	River	7	1.54	2.79	23.5%
Tabragalba	Hopper	Lagoon	27	4.0	5.03	3.7%
Luscombe	Hopper	River	7	0.81	1.23	15.0%
South McLean	Hopper	River	4	8.45	16.03	79.9%
Condamine R	Hopper	River	145	6.27	8.32	14.9%
Condamine R	Hopper	River	145	10.12	13.44	24.1%
Oakey Cr	Hopper	River	48	0.35	0.42	2.4%
Myall Cr	Hopper	River	47	11.39	13.79	44.8%
Botanic Gdn	Hopper	Lagoon	-	2.71	3.45	-
Mean-control				**2.57**	**3.38**	**0.3%**
Mean-hopper				**6.92**	**8.91**	**17.1%**

[a] Applied CPUE is calculated from the actual amount of time it would take to implement the trap in a non-research scenario. This includes time for set-up, keeping the hopper filled and clearing the trap at the end. The project's ethics permit specified that the nets would need to be emptied daily. In practice the trap is designed to be left in place for up to five days with only daily checks made for stressed animals.

The relationship between CPUE and carp density could quite strongly (R^2=0.74) be described as lineal (Figure 32). At very low carp densities catch per unit effort was very poor. Once carp densities reached approximately 50 carp/ha catch rates plateau slightly around the 10 carp/man-hour. At densities higher than 150 carp/ha catch rates increased more quickly with density. Gear saturation was not observed at any stage. The trap could hold more than large 1000 fish without overcrowding occurring.

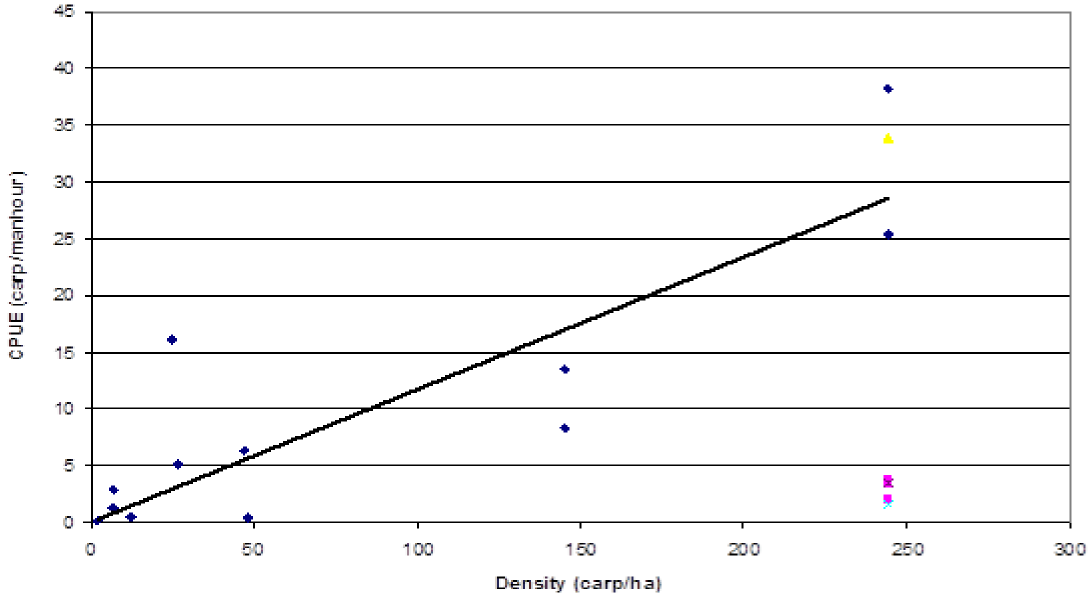

Figure 32: Relationship between carp density and CPUE for the hopper and trap (n = 11). CPUE = 0.1168 x (R^2 = 0.7383). The yellow triangle (▲) represents the Judas result, the blue cross (x) hopper + flow and the pink squares (■) the control trials.

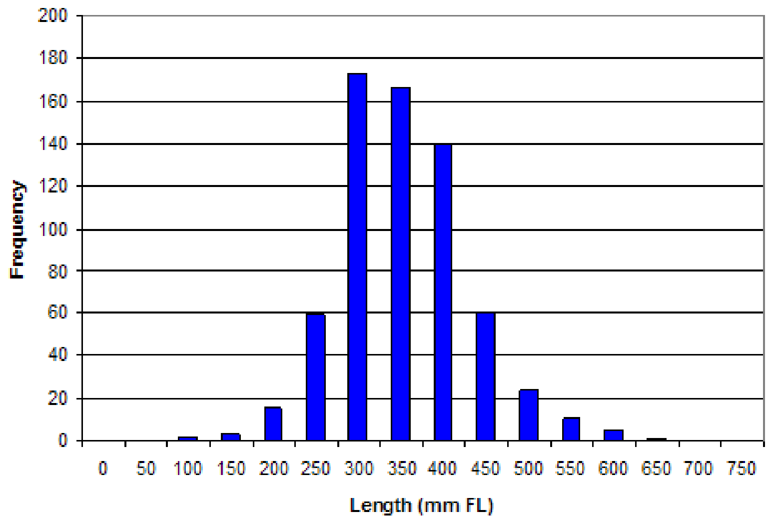

Figure 33: Length-frequency of carp captured by the carp trap with automated feed dispenser as the attractant (n=660).

3.9.3 Discussion

The pilot study demonstrated the addition of attractants to the carp trap could significantly increase carp capture rates. Unfortunately, time constraints restricted the number of replicates of each attractant that were compared in the pilot study. It was observed that a seasonal trend in catch rates may occur. In the pilot study the catch rates of the control trap and the hopper trap were both higher in warmer months than in winter. The results were supported by the field trials where catch rates dropped off during late autumn and winter. A similar trend was observed in North Carolina where no carp were captured in traps until the summer months (Schwartz 1986). Carp are most active in warmer months, particularly during the spawning season (Smith 2005). Water flow is also a key determinant in carp movement (Stuart and Jones 2002, Smith 2005) and most rainfall occurs in the warmer months in Queensland.

The preliminary results demonstrated that Judas fish may prove to be a very successful way to lure carp into traps during spawning periods. Judas fish were chosen as an attractant because carp often congregate during spawning. A pilot study on the use of Judas carp has previously been undertaken in Tasmania as part of their carp eradication program in Lakes Crescent and Sorrell (IFS 2004). Adult carp were injected with concentrated pituitary gland extract from freshly killed carp. The adult carp were used as pheromone generators to attract other carp into traps. In eight trials where induced male and females were placed in traps, radio-tracked fish were observed to move towards the induced fish in all cases. A small number of carp were caught overnight in several of the traps.

In the current project, carp were induced with LHRHa, a commonly available hormone which is used to induce brood stock. This negated the need to process carp pituitary extract and still produce successful results. The timeframe which carp were thought to release pheromones and undergo display behaviours was thought to be short. Brood stock induced with LHRHa typically spawn within 36-48 hours of injection, thus it was decided to replace induced fish every two days. Further research is required on the longevity the induced attraction.

Two components most likely comprise the attraction of Judas fish to conspecifics; chemical signals and behavioural displays. Sorensen et al. (2000) have found carp to be strongly attracted to both male and female-derived pheromone attractants. Research is underway to develop a method for utilising these and other pheromones to chemically attract carp. Behavioural displays can also form an important component of spawning signals in many fish species. Displays convey information to conspecifics in addition to that transmitted by pheromones. The use of induced Judas fish utilises both of these transmission pathways and potentially has a greater attraction to carp than the use of chemical cues alone. Unfortunately, handling logistics for live fish are difficult and the effectiveness of induced fish is potentially short lived. Use of slow release pheromone attractants may be logistically much simpler and more broadly applicable if developed.

The focus of the current study was to compare the effectiveness of techniques that can be used by local governments and community groups to control carp in local high value areas. The use of Judas fish is technical and time consuming and may not be suitable for these groups. The technique is probably most useful when trying to catch a low number of remaining fish when targeting eradication, following intense removal efforts. As the CPUE of other techniques decrease with carp density, the logistical issues of Judas fish lessen in comparison. The technique is only useful during periods of active spawning and thus limited to warmer months. Further research is required on this potentially very useful technique.

The use of food to lure carp into areas for management is common practice (Koehn et al 2000, Graham et al 2005). A variety of baits can be used to attract carp, including cottonseed soaked in molasses, soured grains, bread, corn kernels and chicken pellets (Schwartz 1986, Graham et al 2005, Koehn et al 2000). Specialised carp anglers in Europe also use corn syrup, chickpeas, cheese, meats, sausage, worms, dog and cat biscuits, seeds and nuts. In the pilot study an aquaculture pellet feed designed for native fish was used a bait to lure the carp in. Although effective, this feed was expensive and not suitable for broad scale application. Switching to the chicken layer pellets as the attractant actually resulted in a higher carp catch rate at the same location. This may be due to the higher corn content of the layer pellets or how they persisted longer before disintegrating. The use of berley or ground bait does not always work and has been unsuccessful in the Tasmanian Carp Eradication Program where carp were found not to congregate in baited areas at higher densities (IFS 2004).

The trap design used in the current study was effective in rivers and lagoons. In some cases the CPUE was higher than that for electrofishing. Anecdotal evidence suggests that a continual supply of food may be better than using a bait bag. The feed hopper can be built to accommodate enough food to last for a week, negating the necessity of swapping bait bags after several days. The hopper has been designed to dispense a range of pellet sizes between crumble and 16 mm, and can accommodate a variety of bait types. Dispensing pellets into the trap allows some to drift away in the current, spreading the scent and creating a trail for carp to follow. As the pellets disperse they gradually disintegrate further increasing the scent in the water. The pellets also provide a food source for carp in the area and those caught in the trap. The sound of carp feeding is thought to attract other carp and bait in a berley bag does not allow this to happen. An advantage of the automated feeder is that it can be programmed to dispense food at different rates for different conditions. When set in flowing waterways a greater feed output can be used to ensure all pellets are not quickly washed away.

Several options exist to increase the attractiveness of the food delivered by the hopper and potentially increase catch rates. An automated spray jet can be added to the feed dispenser to spray the pellets with an oil or syrup attractant as they are dropped. Alternatively a separate container containing creamed corn could be used which would dispense small amounts in conjunction with the pellets. These options would add to the price per unit and research into the increase in catch rates needs to be undertaken before they are to be considered.

It was interesting to note that the addition of an artificial flow behind the feed hopper, to aid in the dispersal of the attractant, actually decreased the number of carp caught. Although only one replicate was completed, the number of carp caught was similar to the attractant-free control traps. Similar results have been observed by one of the commercial carp fishermen in Victoria (K.Bell, K&C Fisheries pers.com. 2008). Pumped water was trialled as an attractant but found to have the opposite effect. Mr Bell believed the noise and vibrations of the pump were travelling through the water and scaring fish away. Carp are often attracted to areas with flowing water (Smith 2005) and during annual surveys of the Logan and Albert Catchment carp were commonly observed to aggregate at the entry points for creeks and drains from surface run-off (pers. obs.). In the current study, the outlet hose was raised above the surface level of the dam and the water cascaded down in order to disperse any noise from the pump. The pump was also kept distant to the outlet to minimise noise, but these efforts appeared unsuccessful.

The passive nature of the trap requires carp to first detect the attractant and then actively work their way towards the source. It was therefore predicted that the trap and hopper would be most effective in flowing waterways where the current could disperse the scent. However, CPUE was far greater in lagoons than rivers and creeks. This could be an artefact of the higher carp densities in lagoons or the current in flowing waters moving the feed away too quickly for the carp to pin-point the source. The latter is unlikely because considerable amounts of deposited food were trapped within the mesh on the bottom of the trap when it was emptied at the end of a week.

Carp appeared to take some time to respond to the feed dispersed by the hopper, as evidenced by the location of the radio-tracked fish. The radio-tracked carp in the pilot study took approximately 3.5 days to congregate around the trap from the time the hopper was activated. Radio-tracked fish would move around the dam and into the shallows much more at night, before generally moving back to deeper waters during the day. At night their locations were much more clustered around the trap indicating that greater catch rates were likely during this period. At night carp were also found to mover right up into the shallows, sometimes foraging with their back partially out of the water. At first light these fish would disappear back into deeper water.

The trap was designed to be bycatch friendly. The only bycatch mortalities recorded were several bony bream which gilled themselves in the trap wings, despite the use of heavy ply trawl mesh. Inclusion of several floats in the holding area ensured air-breathing animals, such as turtles or platypus, could access the surface at all time. Turtles were found to be the greatest bycatch issue. In the Logan and Albert turtles occurred in very high densities and frequently outnumbered the carp catch. These turtles were all released unharmed, however they increased the time it took to clear the trap.

Turtles are a common bycatch in many submerged static fishing apparatus. Turtles readily enter traps, particularly if baited, and turtles feeding within traps attract others (Spencer 2001), thereby increasing their capture rate. A number of approaches have been developed to reduce the likelihood of turtles entering or dying in traps. In eel traps, the soft cod-end is either staked above the water surface or a float is introduced to allow turtles to the surface to breathe (Lowry et al 2004). This method is only suitable in static waters because during high flows the cod-end can twist or collapse, preventing access to the air-space. In the USA, attaching an escape chimney to hoop nets reduced turtle bycatch in catfish traps by 84% (Fratto et al 2008). The top of the escape chimney was floated just above the surface so turtles could escape. This design did not significantly decrease the average number of size of catfish caught.

Other designs rely on excluding turtles from a trap by modifying the entrance funnel. Mesh bars or excluder rings can be effective in preventing larger turtles entering the trap, but allow smaller turtles in and prevent access to larger target species (Barko et al 2004, Lowry et al 2004, Fratto et al 2008). Such bycatch reduction devices for air-breathing animals have been successfully used in eel fyke nets in Victoria, Australia (Beumer et al 1981) and Europe (Koed and Dieperink 1999) since the 1980s.

In the present study, a turtle escape aperture (following Graham et al 2005) was included in the holding area of one trap to reduce the number of turtles captured in the trials at the Goondiwindi Botanical Gardens. The surface of the holding section of the trap floats on the surface and contains an extra pocket created by a ball float. The aperture with the ramp below sits level with the water surface enabling turtles to easily climb out. Excluders were not utilised at the entrance funnel because to be of adequate size they would block access by larger carp. Turtles were still caught in all traps and it was unclear whether the number was reduced by the escape aperture. It is also unknown what proportion of carp can escape through the aperture so the effectiveness of turtle escape apertures remains unclear, but warrants further investigation. A reduction in turtle bycatch will help minimise trap clearing times and the ease with which it is conducted.

The trap was designed to be highly portable and compact enough that several could be carried on the tray of a utility vehicle or in a boat. Apart from the netting, the components of the trap were constructed from readily available materials that could be replaced by parts from any hardware store if a breakage was to occur. The trap can be set up in under an hour and be modified if necessary to suit many local waterways. The trap is not suitable for use in areas with high flow, where a box trap may be more suitable (See below).

A number of different trap designs have been used to catch carp. Many traps are designed to catch carp in certain habitats or adapted from existing commercial techniques. Commercial carp fishermen in NSW and Victoria initially targeted carp using standard drum traps which were used to catch native species (Reid et al 1997, Koehn et al 2000, Graham et al 2005). Drum traps are very similar to double wing fyke nets and rely on wings guiding fish into a tunnel with a series of cones. The cones make it difficult for the fish to swim out so they get trapped in the cod-end until the trap in emptied. These traps can be used unbaited, however better catch rates are achieved through the use of a berley bag hung inside (Wilson and Hyde 1999).

Larger baited box traps can also be effective for carp. Rectangular box traps can be made from a collapsible steel frame which is covered with mesh. One end is shaped into a soft funnel entrance. These traps can be set in shallow water to allow air-breathing bycatch access to the surface to breathe, or can be supported by floats in deeper water.

A modified cylindrical box trap, called the Enviro-trap, has been designed to be set submerged but still allow air-breathing bycatch to escape. The design uses a bait bag to attract carp and incorporates an aperture on the top of the trap to facilitate the escape of turtles. A shallow platform is located directly beneath the aperture to minimise the escape of carp. The design assumes trapped turtles will swim towards the surface and upon impacting the roof, swim along the top searching for a means to escape. Conversely platypus search the lower portion of the trap for escape and removing one square of netting in the corner is enough to facilitate their escape (Graham et al 2005). Although the majority of turtles escaped through the aperture in the Enviro-trap, some remained trapped. Evidence suggests that turtles are unlikely to survive submerged for more than 12-18 hrs in ideal conditions (Jackson 2000, Caligiuri et al1981, Lowry et al 2005). Therefore the remaining trapped turtles are likely to be killed if the traps are submerged for longer than this. Clearing carp traps this frequently may not be viable and the disturbance is likely to reduce catch rates. During an 8 day trial, 3 Enviro-traps caught 149 carp from Eagle creek, for a mean CPUE of 6.2 carp/trap/day (Graham et al 2005). Carp density in the creek was unknown. The trap was emptied twice daily and highest carp catches coincided with pumping which led to the onset of creek flow.

Carp were found to escape both the box trap and Enviro-trap, particularly in rough weather (Graham et al 2005). In the Enviro-trap carp escaped both through the entrance funnel and the escape aperture. The shape and size of both these traps types can also restrict their use to locations with easy access to the water (Wilson and Hyde 1999). When baited these traps are most effective in flowing waterways and catches are enhanced if the traps are fitted with netting wings to one or both banks to guide carp into the trap.

In recent years several traps have been developed to specifically target carp in fishways and the culverted entrances to wetlands. These new traps target specific innate behavioural traits of carp to minimise bycatch.

The carp separation cage (also known as William's separation cage) was designed to catch carp moving through fish-ways (Stuart et al. 2006, Gilligan and Rayner 2007). Trapped carp display a pronounced escape behavior of jumping out of the water; this behavior is not exhibited by most Australian native fishes. This important behavioural difference provides an important opportunity to exploit the unique jumping behavior of carp for selective removal. The Williams cage is a simple device that automatically separates jumping common carp from non-jumping fish. The trap consists of two compartments separated by an adjustable height baffle (Stuart et al 2006). Fish pass through a cone entrance into the first compartment where they become trapped. Carp attempt to escape by jumping over the baffle and land in the second holding cage Figure 34). Native fish remain in the initial chamber until cleared. An automated version of the trap periodically raises a false floor and native fish exit gate allowing non-jumping fish to be released (Stuart et al 2006).

Apart from attempting to jump over obstacles, carp also try to push through them whilst native fish have not been reported to do so (Thwaites et al 2010). The carp push trap has been developed to exploit this behaviour. The trap is designed for use in the entrances to wetlands into which carp in the southern parts of Australia move during their annual migration. The trap has an entrance constructed from a number of vertically hanging fingers which can only swing in one direction. The fingers have been weighted so that carp only require approximately 5% of their pushing power to lift them high enough to swim through (Thwaites et al 2010). When carp approach the trap they attempt to push past the fingers and move through into a holding cage. Once the fish have moved through the entrance, the fingers drop back down preventing escape. Native species do not attempt to push through and remain excluded from the trap. The trap is designed to capture carp greater than 250mm total length.

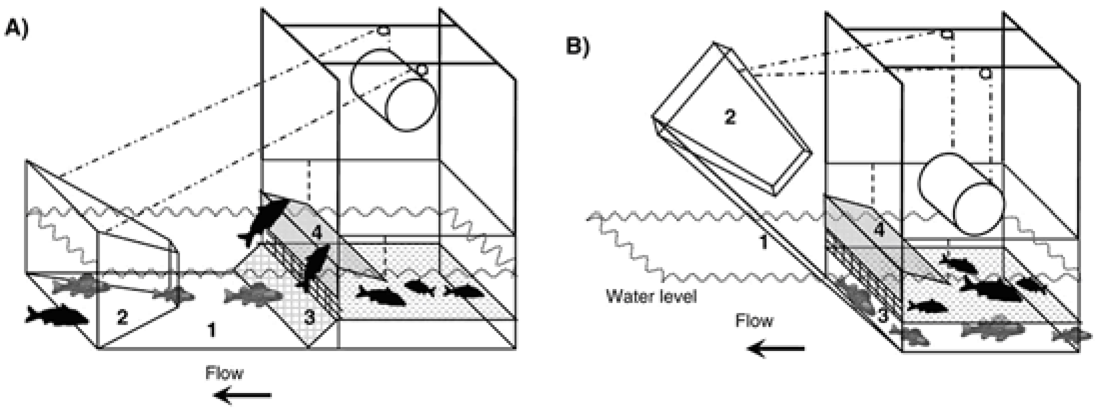

Figure 34: Illustration of the Williams cage, showing (A) the operating position used to catch and separate jumping carp (black fish symbols) and non-jumping native fishes (gray fish symbols), and (B) the raised position to released trapped natives (from Stuart e et al 2006).

Both the separation cages and push traps require carp to be motivated enough to attempt to pass the cages. In the cooler waters found in southern Australia, annual migrations for spawning provide carp with the drive to attempt to pass the barriers. Such migration has not been reported from warmer waters further north, however carp movement has been observed to be stimulated by flow events and they are often seen below weirs trying to push upstream when flow levels increase.

These traps are both very effective in capturing large numbers of carp for minimal effort, but also require structured entrances to wetlands or fishways in order to work. In the northern parts of the Murray-Darling Basin these structures are rare and the wetlands are of a more ephemeral nature. In coastal catchments invaded by carp the presence of mullet and other jumping species may preclude their use.

Trapping provides a viable alternative, or additional, means of harvesting carp. The carp trap developed by this project can be implemented by local groups with appropriate training. The traps require minimal maintenance and labour to operate and could be set and checked once a week. Field trials demonstrated that the trap could capture a broad size range of carp and not adversely impact non-target populations. The carp trap is suitable for use in carp control operations in areas where conventional fishing methods, such as mesh-netting or seining, are not possible. The deployment of the traps, with their relatively low capital cost, may be sufficient to control carp at a local level, but would best be combined with other techniques in an integrated approach.

3.10 Angling

It is well known that fishing pressure can run down fish stocks in a river (Templeton 1995). Large numbers of carp are caught on line by recreational anglers, either intentionally or more often as bycatch while targeting native species. The National Recreational and Indigenous Fishing Survey (Henry and Lyle 2003) found that carp was the most common species caught by inland anglers. It was estimated that in 2000-01 anglers across Australia caught 2.1 million carp, weighing 1500 tonnes. Recreational fishers/anglers can therefore play a role in the removal of pest fish species.

To combat the impacts and spread of carp some community groups have organised 'fish-out' events. These events are becoming more popular as people see them to be a fun way to help deal with the carp problem. Many of the competitions are organised by local fishing groups who see the events as a real opportunity to have an impact on local pest fish populations and/or raise money for the restocking of native species or other community based projects. The number of people participating in these events can range from a few to more than two and a half thousand. The impacts of these competitions on local carp populations have not been well researched.

Angling can be used in a wide variety of habitats and typically has little impact on non-target species. Anglers frequently use corn kernels, worms and bread as bait, which are more attractive to carp than most native species. Bycatch can also be easily unhooked and released relatively unharmed. Targeting carp with hook and line is biased towards taking larger specimens. Smaller fish are unlikely to be caught due to gear size and dietary preferences.

3.10.1 Methods

The catch rates of anglers at three carp fishing competitions were evaluated. The events were located at Goondiwindi on the McIntyre River in 2007 and 2008, and Thallon on the Moonie River in 2008. Prior to each event, competition areas were divided up into sections that could easily be covered in three hours of electrofishing and surveyed with the large electrofishing boat. All carp caught during the survey were measured, dart tagged and released. During the competitions the angling pressure in each section was surveyed twice daily. Post competition, the sections were surveyed again with the large electrofishing boat. All carp caught were euthanized in an anaesthetic overdose. Population estimates were calculated from the tag returns from the combined efforts of the anglers and the electrofishing boat. Population estimates were generated using an unbiased Lincoln-Peterson method (see Williams et al 2002). The population reduction in each section and for the entire competition area, were calculated from the competition catch data.

Catch per unit effort for anglers was also estimated for each competition. Calculations of angler effort were based on the assumption that the average participant fishes for eight hours during daylight and a further two hours after dark for each full day a competition is held. These assumptions were formed from discussions with anglers participating in the competitions. The Goondiwindi Carp Cull in 2007 was held from 10am Saturday to 12pm on Sunday. It was assumed that anglers fished for seven hours on the first day, two hours during the evening and a further five hours on the second day, for a total effort of 14 hours per angler. The Thallon Carp Competition in 2008 was run from 6pm Friday until 12pm Saturday. The average angler was calculated to spend 18 hours fishing during this period. The Goondiwindi Carp Cull in 2008 ran from 8pm Friday to 12pm Sunday and anglers were estimated to again fish for 18 hours each over the competition.

Angling catch rates were also assessed from visits to seven sites within the Logan and Albert Catchment. At these locations, between one and three anglers targeted carp using rod and reel, and a variety of baits (e.g. corn, worms etc). Burley was used to attract carp to the area and promote feeding. Lines were monitored at all times. The number of carp and other bycatch were recorded, along with carp fork length.

3.10.2 Results

A total of 466 carp of 140-706mm FL were caught via angling during the project (Figure 35). The catch per unit effort was very low ranging from 0.00 to 1.20 carp per man-hour. In competitions where anglers with a wide range of skill and experience were participating the CPUE was extremely small (0.03-0.06 carp/man-hour). For comparison the CPUE of electrofishing at these sites was approximately 100 times greater. Angling bycatch included turtles, golden perch, eel-tail catfish, spangled perch, Murray cod, bream and fork-tailed catfish. All bycatch was released. Angling proved to be most effective in lagoons with shallow muddy substrates. Schools of carp appeared to periodically move through these areas, potentially searching for food. Angling also caught fish in deeper waters (>4.0m) where other techniques were found to be relatively ineffective. The use of berley significantly increased angler catch rates. At competitions all of the anglers who caught a high number of carp heavily utilised berley with most developing their own special concoctions.

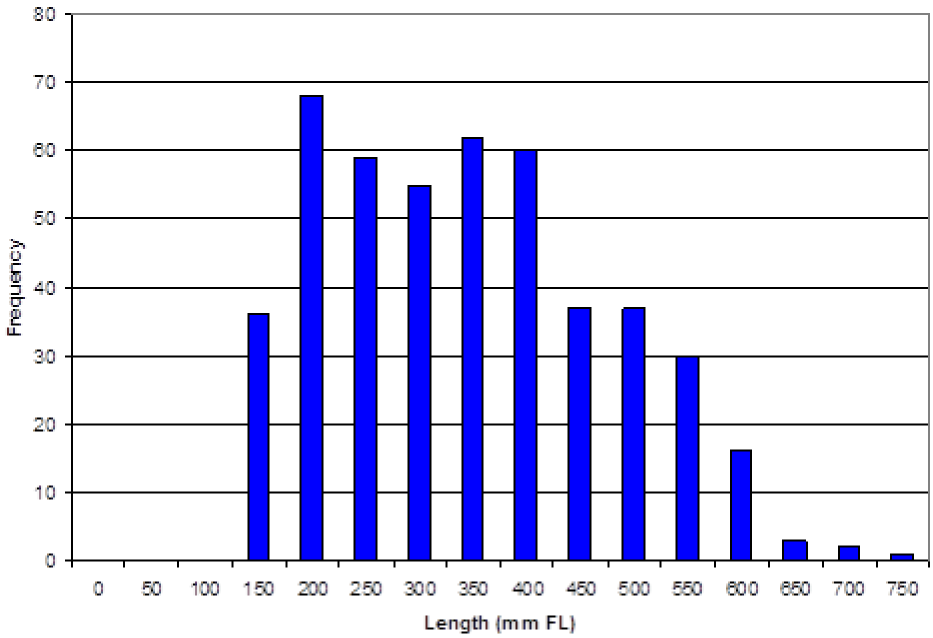

Figure 35: Length-frequency of carp captured by angling (n=466).

Table 13: CPUE and estimated carp population reductions by angling.

Site	Habitat	Survey density (carp/ha)	Population estimate	CPUE (carp/hr)	Reduction
Competitions					
Goondiwindi 2007	Mostly River	24	7,646	0.06	1.8%
Thallon 2008	Mostly River	79	5,936	0.03	2.9%
Goondiwindi 2008	Mostly River	67	8,021	0.04	1.9%
Standard angling					
Canungra Creek	Creek	5	12	0.00	0.0%
TF2	Lagoon	142	9,746	1.20	0.1%
Riemore	Lagoon	12	1,022	0.00	0.0%
Wolfdene	River	7	85	0.25	1.2%
Tabragalba	Lagoon	139	700	0.80	0.1%
Luscombe	River	7	100	0.13	1.0%
South McLean	River	27	164	0.00	0.0%
Mean		51	3,343	0.25	0.9%
Overall			33,432	0.04	1.4%

3.10.3 Discussion

The carp catch per man-hour was very low for angling. Angling pressure is unlikely to have an impact on broad-scale carp populations. Except for rare events, which target carp in a specific small waterway, most angling effort is dispersed across large areas. Even at carp angling competitions the dilution of angling effort makes it unlikely for these events to have any significant ecological impact on carp populations. The estimated population reductions for angling from the three competitions reflect this.

The results demonstrate that carp angling competitions are not a very effective form of direct carp management. The removal efforts often occur over large areas, resulting in low angling pressure and very low population reductions. In the format these events are currently run, they will not have any significant impact on local carp population numbers.

Many of the participants in the carp competitions were juniors or only occasional anglers who typically only achieve modest catches. The more serious fishermen consistently caught good numbers of fish at each event and were observed to refine their techniques along the way. This combination of skill levels will be common in many carp competitions and result in lower mean catches per angler. A small event with only highly skilled anglers may result in greater numbers or percentages of carp being removed.

It is well known that fishing pressure can decrease stock levels in a river, so are competitions likely to result in a prolonged reduction in carp numbers and more importantly their impact? The short answer is no and there are several reasons for this. Firstly, competitions do not remove an adequate proportion of the carp population. The mean numerical reduction to local carp populations from the angling competitions was only 1.3%.

Recreational fishing species often undergo sustained, intense angling pressure. If a fish escapes an angler one day, it may potentially be caught the next. This repeated exposure to potential capture is one of the key aspects of successful pest fish management. Gradually the numbers of the targeted species are lowered over time. For long-term declines in carp populations to occur, the rate of removal needs to exceed the rate of replacement (reproduction or immigration) and all carp must be at risk of removal. If competitions are held only once a year they need to be removing greater than 90% of the carp population biomass at one time (Thresher 1997). The chance of that proportion of carp actively feeding and being line caught during a fishing competition is extremely low even if the population is small. Repeated competitions would have a greater impact, but because the reductions at each event are so small, any long-term benefit is again unlikely.

Most competition areas involve open waterways where immigration can easily occur. Even if competitions achieved meaningful population reductions, immigration of carp from nearby waterways could dilute the results. Like other pest management techniques, competitions are most likely to have an impact in closed systems.

Angling also does not target all size classes of fish. Gear, bait and angling locations all restrict the size of carp that can be caught. Very few fish under 120mm are caught by anglers. This enables a portion of the population to escape removal and become a recruitment source in future years. Carp in the McIntyre, Balonne and Moonie Rivers were observed to be sexually mature at fork lengths as low as 230mm. Fish escaping an angling event one year can grow from <120mm to greater than 230mm FL in good conditions (Smith 2005). Thus small carp may have the opportunity to reproduce between annual competitions.

Carp fishing competitions do however have a range of more non-tangible management benefits. The events help educate the wider community on the detrimental impacts pest fish have, raise awareness and ownership of the pest fish issue and provide a social focal point for smaller regional communities. The competitions can generate revenue which can be directed into native fish restocking or fund carp removal activities in high value areas.

3.11 Comparison of techniques

The effectiveness of the different techniques varied substantially with habitat type and carp density. Comparison between the mean $\log_{10}$ transformed CPUE using unbalanced analysis of variance found habitat ($P=0.037$), carp density ($P=0.006$) and technique ($P<0.001$) all to be significant variables. Electrofishing caught significantly more carp per man-hour effort than any other technique (Figure 36). This was followed by the hopper trap. The catch rates from the remaining techniques were insignificant in comparison.

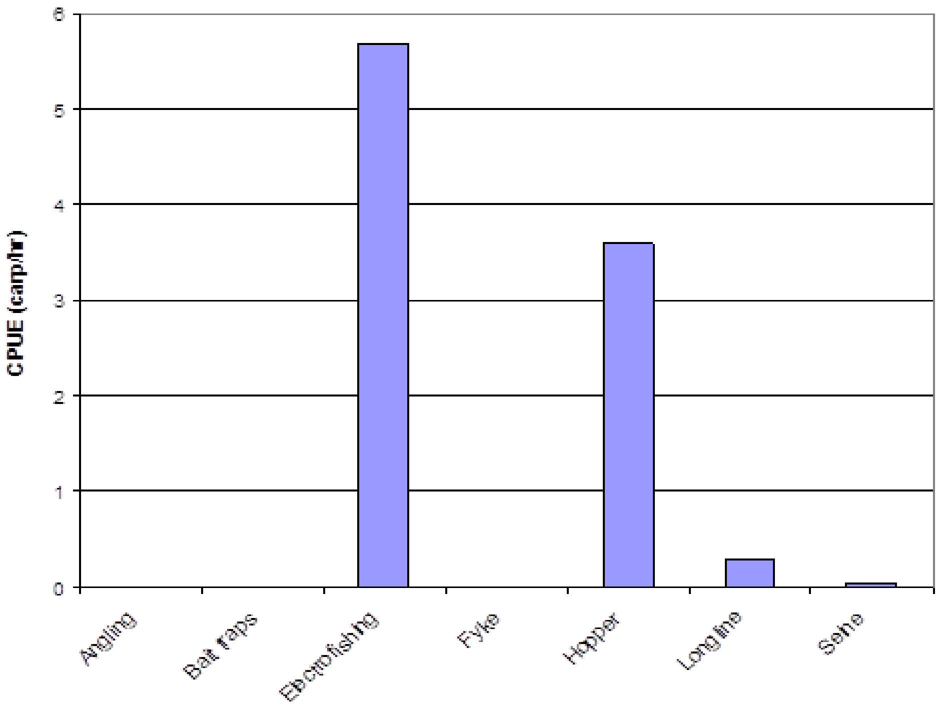

Figure 36: CPUE for carp control techniques standardized for habitat type and density.

Lagoons typically had a higher carp density than creeks or rivers, resulting in the highest CPUE for all techniques occurring in this habitat (Table 14). Electrofishing (32 carp/man-hour) and seining (27 carp/man-hour) in lagoons recorded the highest CPUE, followed by the carp traps (13 carp/man-hour).

Table 14: Mean technique CPUE (carp/man-hour) in three habitats.

	Habitat		
Technique	**Creek**	**River**	**Lagoon**
Gill nets	-	-	4.25
Bait traps	0.00	0.05	3.05
Fyke nets	0.23	0.09	3.69
Seine netting	0.82	0.00	27.34
Angling	0.00	0.09	0.67
Longline	-	0.58	0.78
Carp traps	0.14	7.04	12.67
Electrofishing	4.16	4.06	32.27

The proportion of the carp population susceptible to a technique is partly due to the size range of fish that can be caught with the apparatus used. The mean length of carp caught was greatest on longlines (389mm FL) and smallest in bait traps (51mm FL). Electrofishing caught the widest size range of carp (Table 15). Angling and longlines both caught no small carp (<113mm FL) whilst bait traps only caught one carp larger than 110mm FL.

Table 15: Size range of carp caught by each technique.

Technique	Mean length (mm FL)	Minimum size (mm FL)	Maximum size (mm FL)
Gill nets	361	284	423
Bait traps	51	28	267
Fyke nets	100	34	424
Seine netting	223	32	621
Longlines	389	271	610
Angling	324	113	466
Carp traps	330	70	620
Electrofishing	264	21	701

The amount and variety of bycatch varied greatly between techniques. Conducted properly, electrofishing was the most target specific technique and should result in little to no lasting impacts on non-target species. The trapping techniques all caught a wide variety of bycatch which were mostly released unharmed. The potential of air-breathing animals in the bycatch limits the locations where traps can be set, however a number of mitigation techniques are available to prevent mortality. Angling and long-longlines both caught a variety of species other than carp, but most were released with minimal damage. Anglers did cause damage to some of the larger native species when attempting to remove the hook. Set lines (recreational or longline) have potential to cause stress to turtles and are not recommended.

4. Concurrent comparison of techniques

An effective way to directly compare the effectiveness of techniques is through concurrent application. Data obtained in this fashion is not influenced by variables such as weather conditions, water conditions, carp density and flow regimes. The results of this comparison highlight differences between the techniques when used across a range of habitats.

4.1 Methods

The carp catching efficiency of six different techniques was compared directly via concurrent application at eight sites within the Logan and Albert Catchment between January and May 2009. At each site, electrofishing, the carp trap (hopper), bait traps, fyke nets, angling and seine netting were applied over a week to catch as many carp as possible. The sites were chosen to enable comparison between the effectiveness of the techniques in a range of habitat types and carp densities.

The sites included three lower river reaches, three lagoons or dams, and two upper river/creek sites. It was intended that a third upper river site was to be sampled, however flooding and inclement weather prevented access to the last site. At each location the time spent implementing the control activity, the size and number of carp caught and bycatch were recorded for each technique.

Catch per unit effort was compared between techniques via analysis of variance using Genstat (2008). The validity of the analytical assumptions was checked via residual plots. CPUE proved to be positively skewed with heterogeneous variance, so the log10-transformation was used to stabilise this variable for analysis.

4.2 Results

CPUE varied significantly with habitat type ($P<0.001$), capture technique ($P<0.001$) and day of sampling ($P=0.004$). Overall, electrofishing was the most efficient form of carp removal, followed by the hopper trap and seine netting (Figure 37). Small fyke nets, bait traps and angling all had low CPUE.

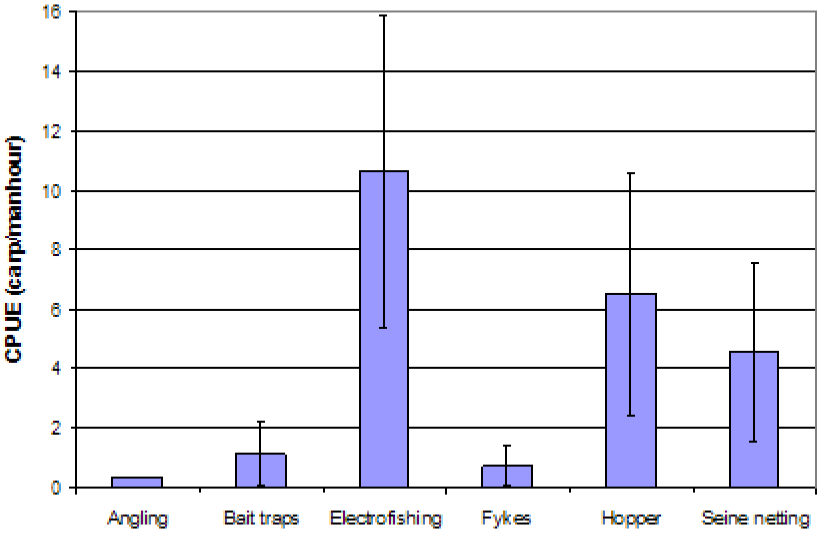

Figure 37: Mean CPUE (± SE carp/man-hour) for carp caught using a range of techniques concurrently at a site over a week-long period. The trials were repeated at eight different locations.

Electrofishing was the most effective technique in all habitat types (Figure 38). In creeks, the low number of carp caught resulted in only minimal differences between the CPUE of the other five techniques. Seine netting was somewhat effective in only one creek whilst bait traps and small fyke nets only captured a few small carp. In the larger water bodies of the main rivers and lagoons, the hopper trap was the second most effective method for capturing carp. In one location more carp were caught with this technique than by electrofishing. Seine netting was a successful technique in lagoons and dams where it could be widely implemented. In creeks and rivers the high load of debris mostly precluded its effective use. Angling, bait traps and fyke nets were the least efficient methods for capturing carp.

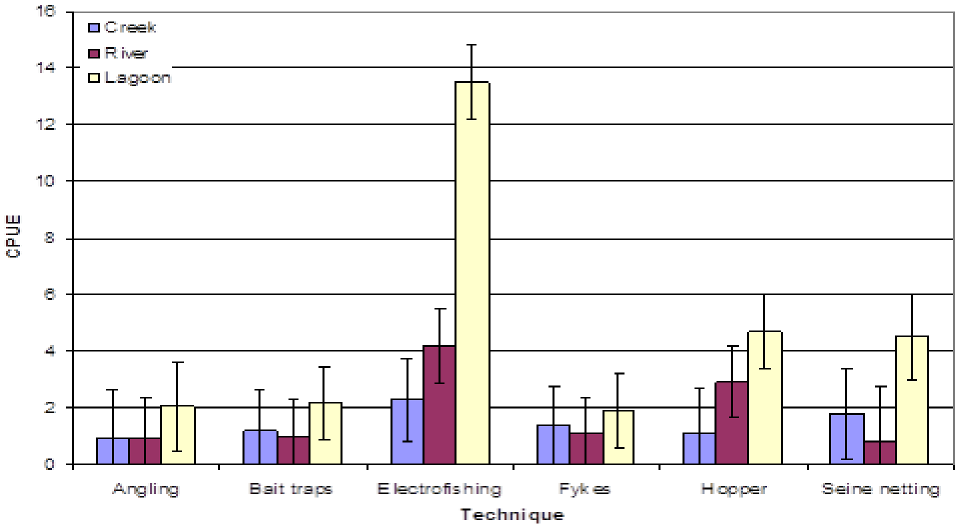

Figure 38: Mean CPUE (± SE carp/man-hour) for six carp removal techniques in three habitat types.

Catch rates for each of the habitat types and techniques changed throughout the 4-5 day period in which removal was implemented (Figures 39 and 40). In lagoons and dams CPUE of combined methods increased thought the sampling week due to the hopper attracting more fish with time. Conversely in the creeks there was a general decline in catch rates. At river sites no change in CPUE with sampling day was observed. CPUE for electrofishing decreased by more than half during the five day sampling period (Figure 40). In contrast, a four-fold increase in the CPUE of the hopper trap occurred in the same timeframe. There were no clear temporal trends for the CPUE of angling, bait traps, seine netting and the fyke nets.

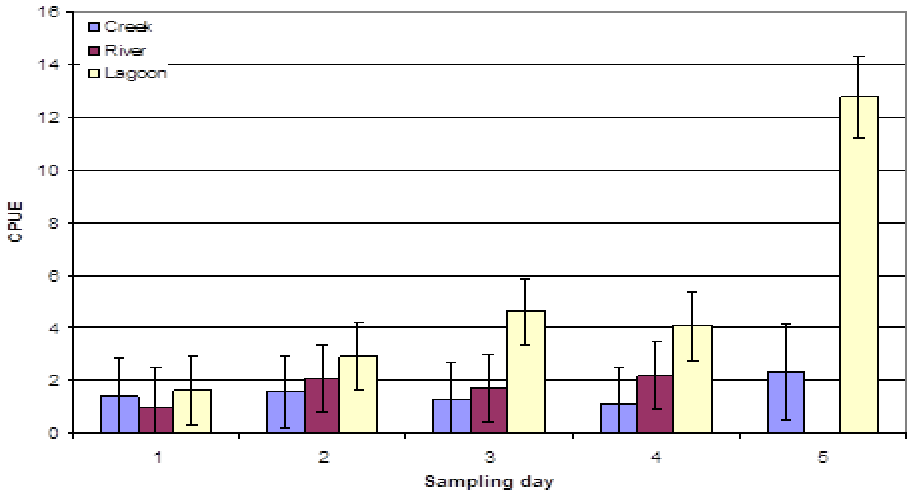

Figure 39: Mean daily carp CPUE for creek, river and lagoon/dam sites where removal efforts were implemented over a 4-5 day period.

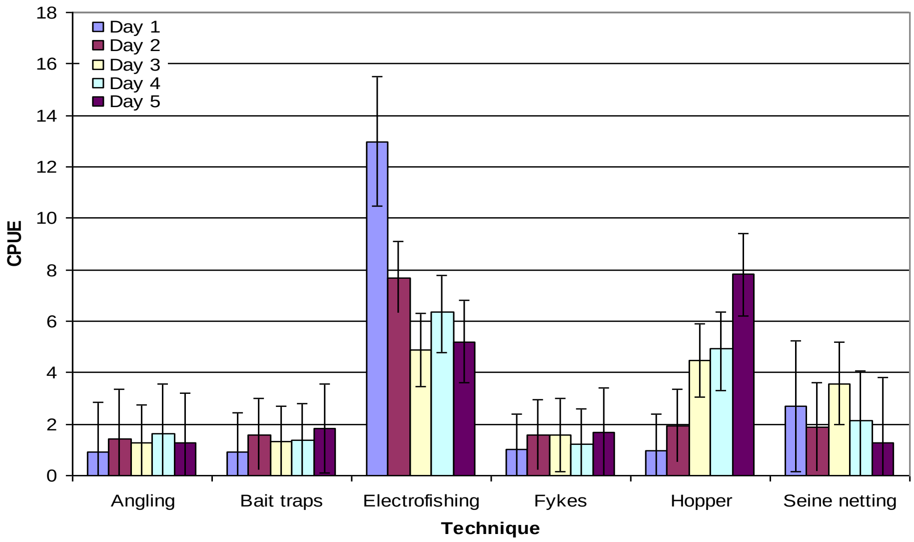

Figure 40: Mean daily carp CPUE for six types of carp removal techniques implemented over a 4-5 day period.

4.3 Discussion

The results from direct comparisons confirm the findings from the individual assessments (Section 3). Comparison of CPUE demonstrated electrofishing, followed by the hopper trap to be the most effective technique at catching carp. Electrofishing was highly effective in all three habitat types and had no significant bycatch. Decreasing CPUE with sampling time for electrofishing suggests the component of the carp populations susceptible to electrofishing may have been sequentially depleted or learned to avoid the boat. The fish removed were not being replaced at the rate with which fish were being caught. This suggests a good efficiency for electrofishing for the proportion of the carp population readily catchable by the technique.

The hopper trap worked well in lagoons and rivers but performed poorly in creeks. The hopper trap was most likely less efficient in the creek for a number of reasons. The trap was only set in one creek due to limitations on where it could be set and the poor weather conditions limiting access. The application in the creek location occurred in the middle of autumn and at this time the water temperature had dropped to 18˚C. The initial trials of the hopper trap in the irrigation lagoon also found the carp catch to drop dramatically as the water cooled (Section 3.9.2.1, Figure 31). Further trials during summer or spring comparing electrofishing efficiency with the hopper traps are required to clarify differences in efficiency. In small creeks the pools are typically small and this is where the hopper trap needs to be set. The number of carp that can reach the trap and the spread of the scent are limited in a creek unless the waters downstream of the pool are connected by suitable runs. Only carp in the pool with the trap could be caught in a creek, whereas in rivers and lagoons fish can be drawn in from greater distances and captured fish replaced by others moving through the area.

Carp appeared to take some time to respond to the feed dispersed by the hopper, as evidenced by the increase in CPUE throughout the sampling period. The passive nature of the trap requires carp to first detect the attractant and then actively work their way into the holding section. The increase in CPUE is likely a result of accumulation of scent from the feed being continually released and the time taken for carp to detect and locate the source. This notion is supported by the movements of the radio-tracked carp in the trapping pilot study (Section 3.9.2.1) which took approximately 3.5 days to congregate around the trap from the time the hopper was activated.

Overall, seine netting produced a mid level CPUE. Habitat strongly influenced the catch rate. In lagoons, seine netting was equally as effective as the hopper trap. However, in rivers seine nets could only be used on a limited number of shallow sandbanks, resulting in poor catch rates. The technique was only used in one creek where it was dragged through a couple of deeper pools for a low catch rate.

Angling, fyke nets and bait traps were all ineffective in comparison to the other techniques. These techniques caught few carp for the effort involved. Fyke nets and bait traps caught mostly small, young-of-year carp whilst angling targeted larger fish. These results confirm the inefficient nature of these techniques and the low probability they would be useful in a larger integrated carp management activity.

Successful techniques can be integrated to increase CPUE. Electrofishing and the hopper trap are two techniques that could work well in an integrated approach. The hopper trap is a passive form of targeting carp whilst electrofishing actively pursues the fish. The hopper trap could be set at the start of a sampling period and then electrofishing conducted. The electrofisher can directly catch carp but also be used to drive carp towards the trap. The electrofisher can also catch smaller carp that would not be held by the trap. Used in this manner carp that are difficult to catch with either technique are more likely to be captured. The trap can also draw carp out of deeper waters where the electrofisher is less effective. During the present study carp were electrofished from the vicinity of the trap entrance on numerous occasions.

5. Impacts on local carp populations

An important component of carp management is to understand the impacts an activity has on the carp population. In lagoons and dams natural recruitment will eventually replace carp that have been removed. If a population is reduced sufficiently it may take many years before the carp numbers return to pre-intervention levels. Such a reduction might provide moderate to long-term ecological benefits. In connected waterways, such as river and creeks, the impacts of immigration may quickly obscure any changes to the local carp population structure from carp removal, preventing longer-term benefits. In this section the persistence of impacts on local carp populations for several removal activities was evaluated with respect to untouched control sites. It should be noted that the removal activities were conducted as part of the assessment of technique effectiveness and thus were typically one-off. To consistently achieve lasting benefits a strategic and on-going control program is required.

5.1 Methods

Annual surveys were conducted in the Logan and Albert Catchment to investigate the resultant impact and persistence of carp removal activities. Between the annual 2006 and 2007 surveys, carp removal was conducted at six of the survey sites. The changes in survey densities and biomass of the carp at these sites were compared to paired control sites using repeated measures analysis of variance on Genstat (2008).

At four sites carp removal activity was only undertaken once prior to the 2007 survey. A further four survey sites had no intervention activities undertaken at any stage. The survey densities and biomass from 2009 were compared to investigate the persistence of the carp removal activities. Pairwise comparisons between the treatment (removal) and control sites (no removal) were made using repeated measures analysis of variance on Genstat (2008).

Six of the concurrent applications of carp removal techniques in Section 4 were conducted in survey sites. The results at these sites from the 2007 and 2009 surveys were again compared to paired control (no removal) sites using repeated measures analysis of variance on Genstat (2008).

5.2 Results

The carp removal efforts at six sites between 2006 and 2007 were found to have significantly reduced carp survey densities ($P=0.016$) and biomass ($P=0.021$) when compared to control sites (no carp removal). At the control sites, mean survey density rose from 1.22 carp.ha^{-1} to 1.80 carp.ha^{-1} (47.5% increase) and mean survey biomass from 22.8 kg.ha^{-1} to 32.4 kg.ha^{-1} (42.1% increase). In comparison, at the treatment sites mean survey density fell from 2.01 carp.ha^{-1} to 1.71 carp.ha^{-1} (14.9% decrease) and mean survey biomass from 86.4 kg.ha^{-1} to 28.8 kg.ha^{-1} (66.6% decrease).

The effects of the carp removals did not appear to persist. There was no statistically significant difference between treatment and control sites for carp survey density ($P=0.242$) and biomass ($P=0.361$) in 2009 (Table 16).

Table 16: Changes in carp catch density and biomass between 2006 and 2009 at removal and untreated control sites. Removal was undertaken only once in late 2006 and then not again until after the 2009 survey.

Site	Intervention	Change in Density (%)	Change in Biomass (%)
Albert at Darlington	Electrofishing	62%	-28%
Rathdowney	Control	-63%	-18%
Chardon's Bridge	Electrofishing	45%	-76%
Jimboomba	Control	-64%	117%
ALC	Water level manipulation	-38%	-62%
Bromelton	Control	-92%	-94%
JTF	Gill netting	-83%	-96%
Riemore lagoon	Control	-33%	50%

Carp removal activities between the 2007 and 2009 surveys were conducted at six of the survey sites. These were matched to untreated control sites to examine the impact of the carp removal. Comparison with repeated-measures analysis of variance found no significant difference in the change of survey carp density ($P=0.234$) and biomass ($P=1.88$) between the two site types. However, the magnitude of change was similar to that observed in 2006/2007 at the treatment sites. For control sites, mean survey density changed little, from 1.191 carp.ha^{-1} to 1.187 carp.ha^{-1} (0.3% decrease) and mean survey biomass from 20.9 kg.ha^{-1} to 18.3 kg.ha^{-1} (12.4% decrease). In comparison, the treatment sites mean survey density declined from 2.01 carp.ha^{-1} to 1.71 carp.ha^{-1} (14.9% decrease) and mean survey biomass from 24.0 kg.ha^{-1} to 7.0 kg.ha^{-1} (70.8% decrease). The values for the control sites were highly variable which likely masked any statistically significant effects of the treatments in 2009.

Table 17: Changes in carp catch density and biomass at carp removal and untreated control sites between 2007 and 2009.

Pair	Site	Intervention	Change in Density (%)	Change in Biomass (%)
A	Sandy Creek	Carp removal	-83%	-90%
	Albert at Darlington	Control	+86%	-19%
B	Canungra Creek 2	Carp removal	-100%	-100%
	Canungra Creek 1	Control	-89%	-96%
C	Luscombe weirpool	Carp removal	-70%	-80%
	Albert at Chardon's Bridge	Control	-30%	-70%
D	Sth McLean weirpool	Carp removal	-84%	-72%
	Logan at Jimboomba	Control	-64%	+117%
E	Turf Force 2 lagoon	Carp removal	+511%	-34%
	ALC lagoon	Control	+8%	+1306%
F	Tabragalba lagoon	Carp removal	-89%	-41%
	Riemore Estate lagoon	Control	-68%	-97%

5.3 Discussion

Carp removal activities undertaken at six sites between 2006 and 2007 led to significantly lower carp density and biomass compared to matching control sites. The carp catches at the control sites rose, whilst at the intervention sites the catches fell. Control was also undertaken at six survey sites between 2007 and 2009, however no significant differences in density or biomass between intervention and control sites were detected. During this period the mean biomass and density at both the control and interventions sites decreased, but to different extents. At control sites carp density barely changed (-0.3%) whilst the biomass decreased a small amount (12.4%). In comparison, at the intervention sites the mean density decreased by 12.4% and the biomass by 70.8%. The differences in the mean values are quite substantial. A high degree of variability within the catch values from the control sites masked the statistical differences between the two treatments.

An interesting aspect of this is that half of the treatment sites are in open river locations. It was expected that migration would partially or wholly obscure the removal impacts on the local carp population. Radio-tracking research on carp movements in the system have shown that fish are generally quite residential, only undertaking large movements during flow events. The lack of flow events between the 2006 and 2007 surveys meant that few carp were on the move, thus reducing the probability of removed carp being quickly replaced.

In general the effects of interventions made between 2006 and 2007 did not persist through to 2009 when no further interventions were undertaken. Typically the amount of carp removed was not high enough to tip the local populations into natural decline or immigration could have easily occurred in that timeframe, to replace the removed fish. In one large irrigation dam, the carp population was drastically reduced when the water was almost fully drained to allow excavation and bank stabilisation to be undertaken. Approximately 15 tonnes of carp, presumably a large proportion of the local population, were removed during this operation. The dam does not connect to the river except during very major flow events and thus no immigration can occur. Upon refilling the dam, the remaining carp spawned and recruitment appeared to be high. This was reflected in the 2007 survey which recorded a density decrease of only 43.7%, but a biomass decrease of 97%. The density in 2009 was similar to that detected in 2007, but the biomass had increased twelve-fold to be 37% of the original population. This suggests that survival of that 2007 spawning event was high and the carp continue to grow well. This confirms that removal of carp must be ongoing to sustain benefits.

6. General Discussion

At the present time it is not feasible to eradicate carp from large areas. However a range of currently available techniques can be used to manage carp numbers and their impacts at a smaller scale at sites considered to be important or of local significance. The results of this study quantified the effectiveness of different techniques and how catch rates varied with habitat and carp density. Some techniques were highly effective at catching large numbers of fish, but with little species specificity. Other techniques caught fewer fish but with much greater species specificity.

An important component of controlling carp using physical removal is the ability to effectively target carp populations using species specific equipment. This is essential to maximise catch per unit effort as well as reduce impacts on non-target species. Releasing bycatch can be time consuming and in some cases restrict the use of a technique. All techniques in the present study were found to impact native species to some degree. Electrofishing resulted in almost no bycatch being landed but still impacted a range of non-target species present. The electrofishing equipment stuns all fish species in an area and the netters then select which fish to remove. The non-target impacts of this technique are minimal, especially if appropriate voltages and current are used. Angling has the potential to be relatively species specific if appropriate bait and gear are used. Whilst the majority of bycatch was quickly released unharmed, some injuries related to hook penetration and extraction occurred.

Techniques based on trapping were generally less target specific. The carp trap was the most target specific, enabling smaller native species to escape through the relatively coarse sized mesh. A low number of larger natives were caught in the trap. The fyke nets and bait traps were not species specific and typically caught a representative sample of all species occurring in the area. Trapping bycatch was usually in good condition but handling was necessary to remove them for release. When large numbers of turtles and fish were caught, care had to be taken to ensure the larger turtles did not squash the fish. Access to the surface for breathing ensured no trapped turtles drowned.

The least species specific apparatus were seine nets and gillnets. Seine netting was limited to areas with a clean bottom and relatively little aquatic vegetation. This limited the amount of bycatch because many small native species do not prefer this environment. Impacts to bycatch were also minimised by ensuring the bag in the net remained in the water until all fish were cleared. Squashing and handling injuries were the main threats to non-target species but were mostly mitigated through careful conduct. Gillnets are generally very non-specific apparatus. The use of large mesh sizes can avoid the capture of small fish, however all larger native species are susceptible to entanglement. Gilled fish can be released, but often suffer scale loss and damage. A high number of turtles were caught in gillnets, which necessitated frequent clearing of the nets.

Many non-target impacts can be mitigated through careful handling, site selection and choice of the most appropriate technique. In areas with few non-target species, a wider range of techniques can be safely used. In such areas high catch, species non-specific techniques such as gillnets and seine nets may be considered. If rare or threatened species, high numbers of native fish of similar size to carp, or air-breathing animals are expected greater consideration is necessary. Where possible carp should be lured into areas where bycatch is likely to be less prevalent. This can be achieved through the application of burley, manipulating flows or other means. If rare or threatened species are present sampling should avoid their preferred habitat. Trapping and electrofishing can be useful due to their low impact on bycatch.

All members of the carp population were not equally vulnerable to all control methods. Most techniques targeted a specific size range of carp. These are summarized in Table 15. Electrofishing caught the widest size range of carp and is suitable for all carp sizes. Smaller electrofishing units may not be suitable for very large carp which tend to detect and flee electric fields, or move fast enough that their momentum carries them through the stunning field without stopping. Seine nets also captured a wide size range or carp and can be used to target specific size ranges by using appropriate mesh sizes. Bait traps and fyke nets caught small carp, whilst the carp trap, and angling target larger fish. The size of carp caught in gill nets was dependent upon the mesh size, although the spines of large fish can still tangle in finer mesh. Multi-panel nets can be used to target a range of carp sizes. By combining both size selection and species specificity, resources can be targeted more accurately to achieve successful outcomes.

Not all control techniques were equally effective in all types of habitat. Although potentially highly effective, seine netting is probably the most restricted by habitat. This technique can only be successfully conducted in areas free from debris and with a relatively firm substrate. This typically limits its use to lagoons, dams and lakes, or small sections of river. Fyke nets can be used in amongst vegetation and debris, but site selection is limited to shallow water depths. Angling can be conducted in a wide range of habitats, but can be limited by heavy woody debris and bank access. The carp trap worked best in shallow to moderate depths, but required a debris free area for the cod-end. This technique is also not suitable to high flow velocities and thus performs better in flood-runners, backwaters and lagoons. Gillnetting can be used over the greatest range of water depths and with care around moderate levels of woody debris. The nets can be floating or sunk and used in areas with moderate flow. Sinking nets can help avoid a build up of floating debris. Electrofishing is probably the most versatile technique and can be used in nearly all habitats. The main habitat parameters which limit electrofishing are water depth and water quality. Electrofishing is only effective in waters less than 3 m deep, although carp can sometimes be pulled from deeper pieces of woody debris by remaining stationary over structure with the power on. Carp sometimes float up after a short delay. This approach must be used with care so as not to harm Murray cod which also frequently inhabit these pieces of timber.

Habitat constraints also influence the effectiveness of a technique to target different carp life stages. As discussed above, certain apparatus cannot be used in particular habitats, limiting their ability to catch carp sizes which prefer those areas. Multiple techniques are necessary to target all carp in an area.

Habitat constraints and gear selectivity mean that relying on a single technique to manage carp is unlikely to target all fish. An integrated approach is the only feasible way of managing carp in waterways. Integrated pest management relies on a combination of approaches to manage a pest species. For carp, utilising a range of complementary techniques enables all sizes to be targeted in all habitats. Integration of complementary techniques can have a synergistic effect. For example, splash-netting with an electrofisher will catch more carp than using the gill nets and the electrofisher separately. Fish that flee the electrofisher are likely to entangle in the gill nets resulting in a greater overall catch.

The results indicate that a combination of techniques can be used to increase carp catch rates. Integrating the use of electrofishing, carp traps and seine nets (where applicable) should result in the greatest catch per unit effort whilst still targeting all sizes of carp in an area. The carp traps will capture medium to large carp and being a passive form of capture can be set to operate whilst other active techniques are employed. Electrofishing will target all sizes of carp, including smaller fish which the traps may miss. Electrofishing can be used to herd carp towards the trap, increasing capture rates using both techniques. There is a small risk that electrofishing may put carp off feeding and if this were the case electrofishing near the net should only be implemented on the last day. In large, shallow areas, seine netting can be combined with the other techniques to quickly remove carp from large areas. If a low number of non-target species are present and the water is greater than 3m deep, gill nets could also be considered.

A number of techniques can be used to enhance carp catch rates using the above techniques. Berley should be used to lure carp into areas where they can most efficiently be removed. Pre-feeding for several days can lure carp from debris laden areas into sites that are suitable for seine netting. Berley can also be used to concentrate carp in an area for electrofishing. If seine netting is not suitable, carp can be lured towards areas with structure and woody debris, which will reduce the likelihood of them fleeing when electrofishing. Laying berley around the vicinity of the carp trap can help carp locate the entrance and again potentially concentrate numbers for electrofishing.

Regulating water flows can also be used to aid carp capture. Lowering the water level in wetlands, dams or lakes will concentrate carp into a smaller water body, increasing CPUE. An additional benefit may be that native species migrate out of the water body with the falling water level, whilst carp move to the deeper remaining sections (Smith and Thwaites 2009). In a river system, sequentially lowering the water level between weirs could be used to similar effect. Inflows generated whilst refilling a water body may attract remaining carp, enabling cost effective removal to continue.

The objective of the current project was to assess the effectiveness of currently available techniques that could be employed by local governments and community groups to manage carp in areas deemed to be a high value. The techniques assessed are relatively simple and typically of low cost to implement, except for electrofishing. A number of other techniques have been developed to catch carp at a larger scale and may be suitable for integrating into management actions. Many of these techniques are specialized, suitable for only particular scenarios or highly technical and often associated with high costs.

Poisons are commonly used in pest control, however the widespread use of poisons is not currently possible in freshwater habitats due to the lack of species specificity and the high risk to native species is often unacceptable. Poisons are instead used for control or eradication of new and localised pest species incursions or for the restoration of small to medium sized water bodies.

Currently rotenone is the only available poison control option available in Australia, although Antimycin has also been identified as having potential. Rotenone has been used to successfully eliminate carp from Tasmania in the 1970s and 1980 (Sanger and Koehn 1997), numerous farm dams in the Adelaide Hills (Hall 1988) and used in New Zealand to remove Koi carp from farm dams (Chadderton et al 2003). However poisoning is not always effective on a wider scale. A major campaign to eliminate carp from Victorian waterways using rotenone was undertaken in the 1960s. More than 1300 dams were treated with the poison, however some carp escaped into the La Trobe River and became establish (Clements 1988). Of the 200 dams surveyed following poisoning, none were found to still contain carp.

Fishways can provide a key point at which to control carp. Traps located in fishways can provide a means for removing large numbers of carp as they migrate. Several designs were discussed in Section 3.9.3. These traps exploit innate behaviours to sort carp from native fish, providing one of the most species specific forms of carp management. Fishways traps can be very effective in capturing large numbers of carp for minimal effort, but also require structured entrances to wetlands or fishways in order to work. In the northern parts of the Murray-Darling Basin these structures are less common and the wetlands are of a more ephemeral nature. In coastal catchments invaded by carp, the presence of mullet and other jumping species may preclude their use.

Both carp separation cages and push traps require fish to be motivated enough to attempt to pass the cages. In the cooler waters found in southern Australia, annual migrations for spawning provide carp with the drive to attempt to pass the barriers. Similar migration may occur in warmer waters further north, but has not been recorded yet. However, carp movement has been observed to be stimulated by flow events and they are often seen below weirs trying to push upstream when flow levels increase.

Biocontrol has successfully been used to manage many terrestrial pest species. Two potential viral control agents for carp have been identified. Spring viraemia of carp virus (*Rhabdovirus carpio*) is an infectious disease commonly found in carp overseas, but currently exotic to Australia. The virus has the potential to reduce carp populations; however some properties of the virus and the disease it causes suggest that it would not be suitable for use in Australia (McColl et al 2007).

Koi Herpes virus (subsequently renamed Cyprinid herpesvirus-3, CyHV-3) is a significant pathogen of carp industries overseas and is being researched as a possible biological agent for carp populations in Australia (McColl et al 2007). The disease caused mass carp mortalities in several countries during 1997-1998 and since spread to many other countries around the world, devastating the carp and koi industries.

CyHV-3 is a highly contagious viral disease causing significant morbidity and mortality in common carp, but other related cyprinid species such as goldfish and grass carp are unaffected by the virus (McColl et al 2007). The virus affects both common and koi carp varieties specifically (Haenen et al 2004). Other fish species present during these outbreaks have been unaffected. CyHV-3 has not established in Australia to date and the Invasive Animals CRC and CSIRO's Australian Animal Health Laboratory are undertaking research on aspects of the disease's potential and suitability as a biocontrol agent for carp in Australia.

In recent years CSIRO has been exploring genetic options for carp control. The Daughterless gene technology is a highly novel approach to controlling carp. Release of genetically modified carp in wild populations is predicted to skew the sex ratio of the population, resulting in reduced productivity and eventually extinction (Bax and Thresher 2005, Grewe et al 2005). The concept, using gene silencing technology, is based on the notion that a diminution in the number of female fish in a population will ultimately result in a reduction in population size. When fish develop, all embryos start life as males. Aromatase is the enzyme responsible for stimulating female development in carp at the embryonic stage. By silencing the production of aromatase, scientists can bias sex ratios towards male development through to adult. The daughterless carriers have normal reproductive capacity and the gene is heritable, so daughterless males can pass on the daughterless gene to wild type carp. Research is still underway on this potential long-term solution.

Commercial fishing can provide a means for removing large volumes of carp. Commercial operators employ a variety of techniques, including electrofishing, gill nets, seine nets and traps across drainage canals and wetland inlets (Koehn et al 2000, Kelly 2003, Graham et al 2005). Subsidised commercial harvest has the potential to rapidly reduce pest fish populations (Gilligan and Rayner 2007). Whilst commercial fishing can remove relatively large numbers from some areas, it may not reduce carp numbers sufficiently enough to have lasting impacts on carp populations. Catch efficiency decreases with decreasing carp density, until it reaches a point where commercial harvest is no longer economically viable. At this point commercial operators need to move to locations where carp densities are higher to avoid making a loss. The population density for economic viability is often greater than the ecological density required for lasting impacts on carp populations, and thus carp numbers and their level of impact return quickly. Analyses by Hassall and Associates (1998) and Thresher (1997) strongly suggest that commercial harvesting is likely to reduce carp numbers in localised areas only and have little effect on the control of carp populations on a wide scale.

Incentive schemes, such as the one implemented by the New South Wales Government in 1998, can generate large-scale harvests by offering commercial fishing licences to parties who demonstrate their ability to catch and sell the target species (e.g. carp utilised in fertilisers, bait and smoked products; Koehn et al. 2000, Gilligan et al 2005, Gilligan and Rayner 2007). In some states, such as Queensland, the commercial use of carp is still prohibited by legislation.

An alternate role for commercial carp fishers is to apply their expertise towards dedicated removal operations. Several commercial fishers have been contracted by local NRM groups to remove carp from specific, highly valued waterways. The costs for the commercial operator are either fully covered in the contract, or subsidised by proceeds from the sale of the catch. This type of collaborative activity enables community groups to utilise the knowledge, skills and equipment of commercial operators to reduce carp impacts to a level which would otherwise be unachievable, and at lower population densities than would be economically feasible for the commercial partners.

Disposing of large quantities of carp is an issue that needs to be considered before removal efforts commence. Carp need to be disposed of in a humane and safe manner. Inappropriate disposal can lead to health risks, attraction of vermin and pollution. A project funded by the

Murray-Darling Basin Association is currently investigating carp disposal options. One potential solution is to place carp into 'BiobiNs®' which facilitate rapid breakdown enabling them to be recycled into useable products. BiobiNs® are a mobile in-vessel organic waste management solution that initiates the composting process and effectively manages odour from putrescible waste. Each bin has a capacity for up to 10 cubic metres and can be left on site until filled. Full bins are returned to the depot where the contents are used for soil conditioner or other products. The bins require access a power supply to run the internal fan which may limit their use in remote areas unless they are used in conjunction with a generator.

Carp may be a fisheries resource that is currently under-utilized. In locations where carp numbers are high, sale or use of captured fish may help off-set the costs associated with their removal. Depending upon the removal technique and quality of fish, commercial operators can use carp for fertiliser, protein enrichment of feed, crayfish bait, pet food or human consumption.

Timing of carp removal activities can have a bearing on the CPUE. Catch rates for the majority of techniques were greater when water temperatures were warmer and carp moving about actively. In the Logan and Albert Catchment this period extended from early spring to mid-autumn. The impact of water temperature was most noticeable with the passive gear, such as the carp traps, which rely on fish movement. Electrofishing catches also decreased slightly in cooler months although this is thought to be due to carp utilizing deeper water where the electrofisher was less efficient.

Early spring is a prime time to conduct carp control activities. In Queensland carp can spawn from early spring through to mid-autumn. As the water temperatures warm carp become more active and responsive to environmental cues. Rainfall and river flows during this time can see carp aggregating in preparation to spawning. Significant rises in river levels connect ephemeral wetlands, which encourages carp to move into these shallow habitats. This is a great time to implement removal activities because the fish are concentrated and actively moving. Targeting carp before they spawn also prevents recruitment from those fish.

Carp management in Bowman-Haley Reservoir, South Dakota, highlights how appropriate timing of carp removal can lead to high catch rates and large population reductions. A combination of seine netting and application of rotenone were used to remove carp when they moved up a tributary to spawn (Bonneau et al 1995). During peak carp spawning activity, long seine nets were positioned completely across the mouths of the three tributaries to prevent carp from escaping back into the reservoir. The tributaries were then treated with rotenone. More than 350 tonnes of adult carp were killed, nearly half the estimated 1.5 million pounds of adult carp in the reservoir.

Advantage should be taken of natural fluctuations in water levels. During drought periods carp will be confined to smaller bodies of water and thus be in higher densities. Recruitment may be low during this period and greater levels of population reduction are possible. During floods, rivers may connect to ephemeral wetlands and flood runners. Carp will move into these areas as they fill, providing a great opportunity to set traps to catch the migrating fish. Alternatively, blocker nets and traps can be set to contain carp in these backwaters when water levels recede.

Whilst physical removal of carp is a direct control method, environmental rehabilitation and restoration of ecosystem processes can impose natural pressure on carp populations. Undisturbed ecosystems with established native fish populations are more resilient to invasive species such as carp (Harris 1997). Rehabilitating habitats in conjunction with carp removal activities places greater natural pressure on remnant carp and reduces the likelihood of carp re-establishing (Driver et al 1997, Koehn et al 2000).

Stocking predatory species has been shown to reduce recruitment in cyprinids overseas (Prejs et al 1994, Berg et al 1997). In areas with high carp density and recruitment it is unlikely that predatory species will have a large impact on carp populations. However if carp numbers are reduced sufficiently, predation may help suppress population growth. Data on the impacts of predators on carp is lacking. A study is underway on prey preferences of Australian bass and Murray cod, with respect to prey preference of carp compared to native species. Results from initial tank trials suggest that both species prefer carp and shrimp over gudgeons and rainbowfish (Katie Doyle, pers.com. 2009). Furthermore, Australian bass prefer smaller carp in the consumable size range whilst Murray cod prefer the largest they can consume. Stocking predatory species of fish for carp management needs to be approached with caution. Overstocking will lead to destabilisation of the ecosystem and excess pressure on small native species.

The ultimate goal of carp management is to reduce the impacts of carp. Reductions in carp numbers are one way to achieve this, however because only a proportion of the carp population is removed, carp numbers can quickly return to their original levels. Often the main reason for removing carp is to provide some respite to aquatic habitats and native species. When integrated with habitat rehabilitation, a reduction in carp numbers can give native species the opportunity to re-establish. The benefits derived from carp removal will depend upon the level to which the carp population was reduced and the timeframe with which it recovers. The longer the carp population is suppressed the greater the time for re-establishment and the longer ecological benefits can accrue. Preventing carp from re-establishing is therefore very important in order to gain the greatest benefit from removal efforts.

In closed waterways, removal efforts are likely to have a greater impact and produce a larger benefit. Since the population of carp is finite, numbers can only be replaced by emigration or reproduction. In lagoons, wetlands and lakes emigration can normally only occur through a small number of pathways. Installing barriers across these pathways will prevent access by carp and increase the length of time carp populations remain low and benefits are achieved. Many wetlands only link to river systems through a single regulated canal and large carp can be excluded through the installation of a fish screen. These fish screens have proven effective in keeping carp out (Koehn et al 2000, Stuart and Jones 2002, Wisniewski 2009, Thwaites et al 2010). However in the northern Basin, most wetlands link via natural channels or overbank flows where fish screens cannot be installed. In open, connected river systems, nearby carp will quickly fill the niche vacated by removed fish. Carp will migrate from areas adjacent to removal activities into the management area. If there are no barriers to fish movement (natural or artificial), it is unlikely any substantial long-term benefit will be accrued, unless control is on-going. Benefits from removal will be diluted unless the entire carp population is reduced.

Carp are a highly fecund species (Smith 2005) and recruitment can quickly replace carp that have been removed. Removal activities conducted just prior to or post spawning potentially have the longest benefits. Removing carp prior to spawning prevents recruitment from their offspring. However since carp recruitment is density dependent (Thresher 1997) the recruitment and survival of the offspring from remaining fish may increase. Implementing carp removal post spawning, results in a greater number of fish to remove, but reduces the chance of fish being replaced until the next spawning event. This means the benefits of the carp reduction may persist longer. Preventing carp access to spawning habitat or desiccating eggs through water level manipulation can work very successfully to limit recruitment and extend the benefits of removal activities (IFS 2004).

A number of different strategies can be used to manage carp at the local level. One-off management involves a single management action to achieve a large reduction in population size. This form of management is very reactive and unlikely to result in long-term benefits. In smaller waterways local eradication is possible but the potential for reintroduction remains a problem. This approach is often used for small farm dams or ephemeral waterways which can be dried or poisoned. In the majority of cases sustained or targeted management is required to manage carp in high value areas. Sustained management involves the ongoing or periodic carp removal. The goal is to achieve an initial population reduction with intense activity, followed by regular removal activities to ensure the carp population remains at low levels or reduce it further. This approach is suitable for larger waterways because it does not rely on removing a large proportion of the population in one hit. Regular use of the carp trap would fall into this category. Targeted management, sometimes called opportunistic control, involves application of control efforts at times when the carp population is most vulnerable. This may occur during floods, droughts, spawning time or during annual migration. The approach relies on exploiting innate congregation behaviours to increase catch rates and is a very useful tool when used in conjunction with sustained management. It is a key component of an integrated pest management approach.

The goal of this study was to investigate and compare the effectiveness of different carp control techniques that are suitable for local governments and community groups to use in their local area. In order to effectively manage carp, activities need to be strategically planned and implemented at appropriate sites. This falls beyond the scope of the current project. However, a comprehensive discussion of strategic carp management can be found in Koehn et al (2000). Braysher and Barrett (2000) have also produced a detailed document on how to rank sites for carp management activities. Together with this report, the information should provide the basis for carp management groups to choose who, where, when and how carp management can be effectively undertaken in order to achieve their management objectives.

7. Conclusions

This project has demonstrated that a range of currently available, generally low cost techniques can be used to capture carp. The effectiveness of these techniques varied with habitat type, carp density, carp size and the presence of non-target species. No single technique was applicable in every scenario and thus a combination of several techniques used in an integrated approach is required. Organisations wishing to employ these techniques will need to seek permits and training from the appropriate regulatory bodies for their area.

Electrofishing was the most efficient technique and captured the widest size range of carp. Electrofishing could be used successfully in most habitats, except for areas with water depths greater than 3-4m or where conductivities were high. Electrofishing also had the least impact on non-target species. The second most efficient technique was the hopper trap which was developed as part of the project. The trap targeted sub-adult and adult fish and was best in lagoons, lakes, dams and rivers. A number of large body native species, including turtles, were caught as bycatch, but all could be readily released unharmed. An added benefit of the trap design is that the wings can be detached and used as a seine net. Seine netting was the other highly effective technique, but only suitable in a limited number of areas. Seine nets caught large numbers of carp when used in lagoons, dams and lakes where large debris-free areas could be found. In creeks and rivers woody debris and other structure were generally too prevalent for the technique to be useful. Seine netting captured a wide range of species, but bycatch could be released unharmed by ensuring the pocket of the net was not removed from the water at the end of a haul. Previous studies have found gill-nets to be an effective carp removal technique. However, in the regions where our research was conducted the abundance of large-bodied non-target species, particularly turtles, limited the techniques suitability. Bycatch impacts can be large and the technique is only recommended for use in a restricted number of scenarios. Low catch rates and non-target impacts demonstrated angling, bait traps, longlining and small fyke nets to all be ineffective techniques for catching carp.

An integrated approach combining electrofishing, the hopper trap and seine netting would result in the greatest catch per unit effort whilst still targeting all sizes of carp in an area. The carp traps will capture medium to large carp and being a passive form of capture can be set to operate whilst other active techniques are employed. Electrofishing will target all sizes of carp, including smaller fish which the traps may miss. Electrofishing can be used to herd carp towards the trap, increasing capture rates using both techniques. In large, shallow areas, seine netting can be combined with the other techniques to quickly remove carp from large areas. If a low number of non-target species are present and the water is greater than 3m deep, gill nets could also be considered.

Most techniques were more effective during warmer months when carp are more active. When water temperatures were cool the passive techniques caught substantially fewer carp. Several techniques can be used to increase the effectiveness of removal techniques. Berley and pre-feeding can be used to concentrate carp in an area or lure carp into areas where removal can be more easily undertaken. Manipulation of water levels can also be used to help congregate carp. Water drawdown can decrease the size of the area that needs to be managed and help concentrate carp numbers. Complete water drawdown has the potential to eradicate carp from a site if the area is left to dry for several months. Care needs to be taken with this approach because impacts on non-target species can be drastic. Management activities need to make the most of environmental opportunities. During periods of low water carp may be concentrated into smaller pools where migration is not possible. Similarly, rainfall may stimulate mass movement of carp through bottlenecks which can be exploited for removal.

The value of carp removal activities needs to be considered with regards to the speed with which populations recover through immigration and recruitment. Complete eradication is often desirable, but rarely practical or possible. The impact on carp populations of one-off removal efforts rarely persists for long unless substantial population reductions occur and immigration is prevented. One-off activities were found to reduce carp populations by a level which was significantly lower than paired control sites for several months. These impacts did not persist more than 12 months. Periodic control is far more likely to have longer lasting benefits and can result in an on-going population decline in carp where migration is low. In wetlands the installation of exclusion screens may prevent reinvasion by adult fish whilst still allowing passage of smaller natives.

7.1 Recommendations

- An integrated approach be used by local governments and community groups to manage carp in local waterways
- This approach should integrate the use of electrofishing, the hopper trap and seine nets where possible to maximise catch per unit effort, whilst still targeting all sizes of carp. If non-target species are rare then potential exists to also incorporate gill-nets, especially if used via splash-netting.
- Where possible, management activities should utilise water level fluctuations and draw down to maximise control efforts
- Control should be on-going, rather than one-off to achieve appreciable benefits
- The best value for management actions will be achieved in high value wetlands or drought refugia where carp re-invasion can be managed through the use of exclusion screens or ephemeral connections.

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