PESTSMART

The role of fishing competitions in pest fish management

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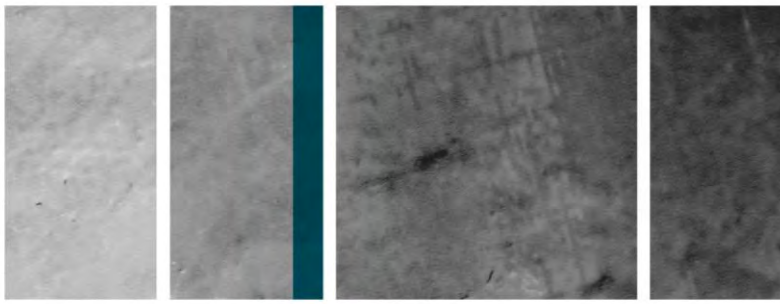
Invasive Animals CRC

An Australian Government Initiative

CRC AUSTRALIA



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Queensland Department of Agriculture, Fisheries and Forestry

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An Invasive Animals CRC Project

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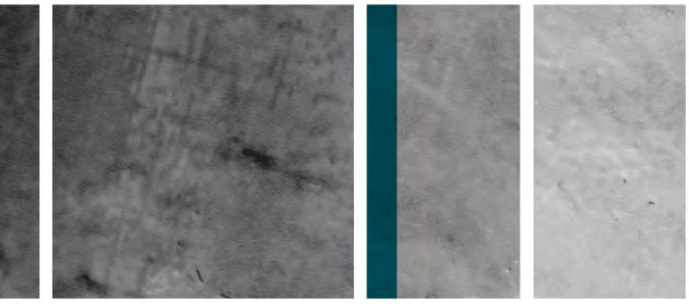

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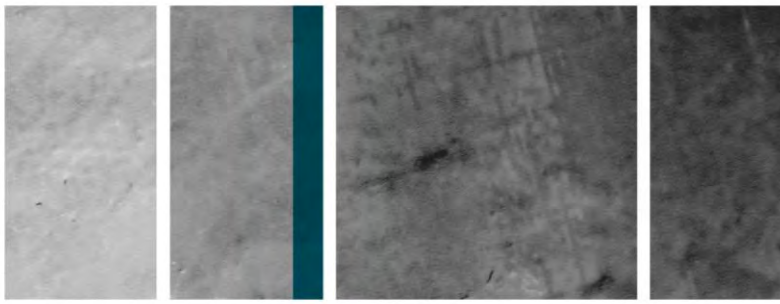

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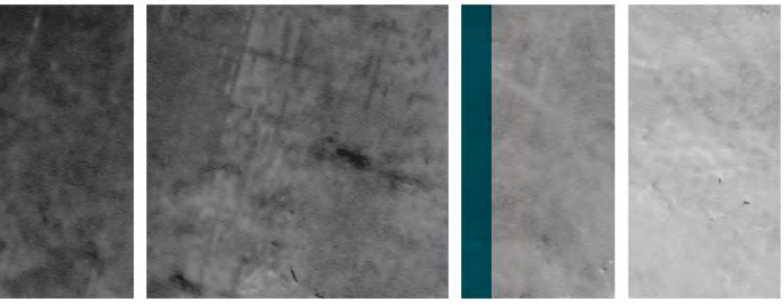

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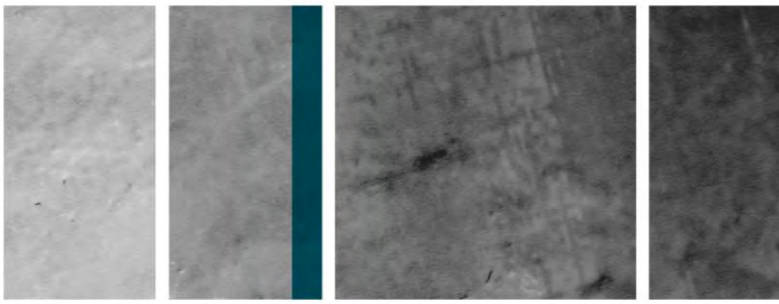


Summary

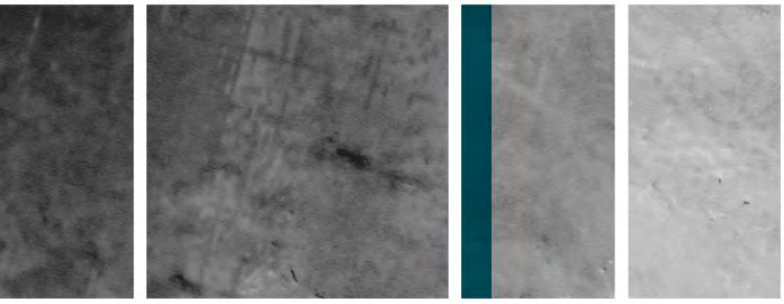
Carp (*Cyprinus carpio*) are one of at least 34 freshwater fish species introduced into Australia that have established self-sustaining populations (Lintermans 2004). Carp are now the most abundant large freshwater fish in the Murray–Darling Basin, comprising up to 90% of fish biomass in some locations, and are the dominant species in many fish communities in south-eastern Australia (Reid and Harris 1997, Brown et al 2003).

Many community groups are concerned about the detrimental impacts carp are having in their local waterways, and some groups have organised 'fish-out' events to actively address the issue. It is well known that fishing pressure can run down fish stocks in a river (Templeton 1995), but it remains unclear as to whether community-based fish-out events have a significant impact on their target species. This project quantified the percentage of carp population removed in three 'fish-out' competitions in the Queensland portion of the Murray-Darling Basin.

At each competition, a series of monitoring sites were established. Before the events began, carp were captured at these sites via electrofishing, marked with dart tags and released. The competition catch and post-event electrofishing enabled the carp population size at each site to be estimated from tag return rates using the Lincoln–Peterson method. Population reductions from both the competition angling and the subsequent electrofishing were calculated. A total of 1006 carp were tagged with an overall tag return of 12% for the whole project.

The results demonstrated that carp angling competitions are not very effective as a direct form of carp management. The removal efforts occurred over large areas, resulting in low angling pressure and removal rates. Population reductions were observed in the range of 0.5%–1.8% across the competition areas. In comparison, removal via boat electrofishing resulted in a carp population reduction of 8.3%–16.1%. When compared to electrofishing, the catch per unit of effort (CPUE) of competition angling was found to be nearly 100 times less in terms of carp caught per man hour. We conclude that the way these events are currently run, they are unlikely to have any significant impact on local carp population numbers.

Carp fishing competitions do, however, have a range of less tangible management benefits. The events help educate the wider community on the detrimental impacts of pest fish, raise awareness and ownership of the pest fish issue and provide a social focal point for smaller regional communities. The competitions can also generate money, which can be directed into native fish restocking, river restoration or funding contractors to remove carp in high-value areas.



1. Introduction

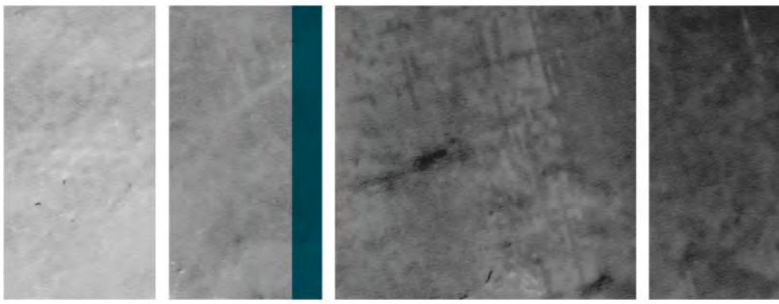
Carp (*Cyprinus carpio*) are one of at least 34 freshwater fish species introduced into Australia that have established self-sustaining populations (Lintermans 2004). They were released into the wild on numerous occasions in the 1800s and 1900s but did not become widespread until a release of 'Boolara' strain from a fish farm into the Murray River near Mildura in the 1960s (Koehn et al 2000). The spread of carp throughout the Murray–Darling Basin coincided with widespread flooding in the mid-1970s. Carp are now the most abundant large freshwater fish in the Murray–Darling Basin, comprising up to 90% of fish biomass in some locations, and are the dominant species in many fish communities in south-eastern Australia (Reid and Harris 1997, Brown et al 2003). Carp have also found their way into both Tasmania and Western Australia and have been introduced to new localities through escapes from garden ponds, their use as bait, or deliberate release by recreational anglers (Koehn et al 2000).

Carp can have detrimental impacts on native aquatic plants, animals and general river health, particularly through their destructive feeding habits. Although often found in degraded areas, it is still not entirely clear whether carp are a cause or a symptom. In some cases carp have probably been blamed for degradation that is actually the result of human activities.

Many community groups are concerned about the impacts carp are having on their local waterways and want to actively address the issue. To combat the impacts and spread of this pest fish, some groups have organised 'fish-out' events. These events are becoming more popular as people see them as a fun way to help deal with the pest fish problem. Many of the competitions are organised by local fishing groups who see the events as an opportunity to have a real impact on local pest fish populations and/or raise money for the restocking of native species or other community-based projects.

It is well known that fishing pressure can run down fish stocks in a river (Templeton 1995), but it remains unclear whether community based fish-out events have a significant impact on their target species. Is such investment in pest fish management worthwhile or can the money be otherwise better spent? This research quantifies the effectiveness of pest 'fish-out' competitions in reducing pest fish densities and discusses their role as a management tool.

The Queensland portion of the Murray–Darling Basin provided the ideal scenario in which to examine the impacts of angling competitions. Fishing clubs in many of the area's small regional towns had already established or were interested in setting up carp fishing competitions. The regional catchment management group, the Queensland Murray–Darling Committee (QMDC), was also interested in investing in these activities. In 2007 QMDC helped fund several carp fishing competitions, but decided to increase their investment in 2008 by helping establish and run a carp fishing series. The 2008 Regional Carp Busters Series was held in southern Queensland and comprised six carp fishing competitions held throughout the year. Participants could win prizes at each of the individual events and their results were also combined across all six competitions to determine a series winner. The series was cosponsored by Queensland Department of Employment, Economic Development and Innovation (DEEDI) and the Invasive Animals Cooperative Research Centre (IA CRC) as part of their carp research program. The aim of the series was to encourage people to attend more than just their local carp fishing competition, thus increasing the potential impact of each event on local carp populations as well as helping stimulate local economies.



2. Methods

2.1. Competitions

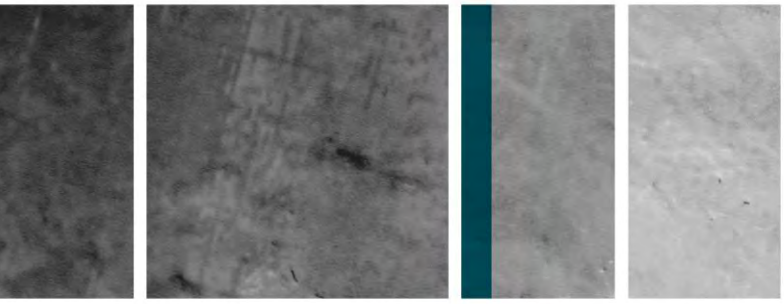
Three carp fishing competitions were examined as part of this study, one in 2007 and two in 2008. The first event in 2007 was the inaugural Goondiwindi Carp Cull, established by Goondiwindi District Promotions in conjunction with local fishing clubs and DEEDI. Principal funding for the event was provided by QMDC and IA CRC along with smaller contributions from local retailers. The competition was held on 19–20 May and primarily focussed on the capture of carp, with a small section for the catch and release of native species. The competition was based in Goondiwindi along the McIntyre River and its backwaters in the Waggamba Shire (about 40 km of river plus numerous lagoons). Organisers were predicting over 400 entrants but heavy rain in the days leading up to the event and the threat of rain for the competition weekend appeared to deter many participants. Registrations were taken from 169 competitors, coming from throughout the Darling Downs, Western Downs, north-west New South Wales and Brisbane.

The Thallon Carp Comp 2008 was the second event to be investigated. The competition was the second event of the 2008 Regional Carp Busters series and was held along a 6-km stretch of the Moonie River adjacent to the Thallon township. The competition area was essentially a closed system with a causeway delineating the upstream boundary and a dry stretch below the town weir forming the downstream margin. During the competition period no flow occurred through this region. Camping was allowed along much of the river enabling entrants to more comfortably fish through the night. The competition was well attended with 305 anglers registering. Again, competitors came from a wide area, with onstream camping encouraging many to make the effort to attend.

The third event examined was the 2008 Goondiwindi Carp Cull, again held on the McIntyre River. In 2008, event organisers reduced the size of the competition area after discussions with DEEDI and switched to a carp only competition. The competition area extended along the McIntyre River from the Town Commons (below the Goondiwindi town weir) to the base of the Boggabilla Weir, a distance of approximately 12 km. The area also included the off-river lagoon at Rainbow Reserve, where participants could camp and fishing efficiency could be evaluated in a closed environment.

2.2. Assessment

Monitoring sites were selected with the help of competition organisers. At each competition venue, both fished and unfished sites were selected. Each site was based on an area taking three hours of active hunting for carp with electrofishing boats. One to two weeks before the competition, each section was heavily electrofished for three hours and all carp caught were measured to fork length (FL), dart tagged and released. The tagging served two purposes. Firstly, it enabled population estimates to be derived using mark–recapture techniques. These estimates facilitated calculations of angler and electrofishing removal efficiencies. Secondly, prizes were offered for the capture of tagged fish to encourage participants to fish in these areas, increasing angling pressure and facilitating more accurate estimates of angler effort.



Each of the sites were electrofished for three hours with a large electrofishing boat. The electrofishing unit consisted of a 6-m plate alloy hull with a 7.5 kV Smith-Root electrofishing unit attached. Two netters operated at the front around the two anode booms, which had an effective range of 3–4 m. During electrofishing, stunned carp were dip-netted from the water and transferred into onboard live-wells. At the end of each shot, carp were anaesthetised, measured for fork length, dart tagged and released. Only carp with a fork length greater than 150 mm were tagged. Recreationally important fish species were also measured at some sites.

The number of anglers at each location was monitored during the competition to determine the amount of angling pressure being placed on the carp population. Boat- and car-based inspections were used twice daily to count the number of anglers fishing at each survey section. Anglers in the vicinity of the water, but without any visible line in the water were not counted.

Populations were estimated using an unbiased Lincoln–Peterson method (in Williams et al 2002). This method assumes that the study population is 'closed'. In other words, the two visits to the study area are close enough in time so that no individuals die, are born, move into the study area (immigrate) or move out of the study area (emigrate) between visits. The model also assumes that no marks fall off animals between visits to the field site by the researcher, and that the researcher correctly records all marks.

This modified formula reduces bias in the population estimate:

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

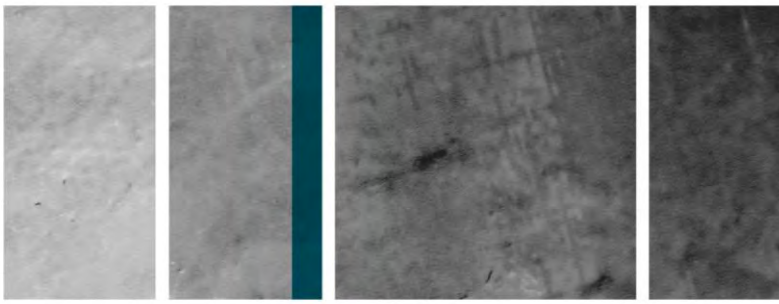
Where: N = estimate of total population size
n1 = total number of animals tagged on the pre-competition sampling
n2 = total number of animals captured on the post-competition sampling
m = number of tagged animals recaptured.

As in all estimates, it is also useful to have some information about the uncertainty of the estimate (as measured by the standard error). The standard error of the estimate of N is given by the following formula:

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

The unbiased Lincoln–Peterson method for population estimation from only two visits generates rough estimates of total population sizes. This method relies on the assumptions that:

- there is no migration
- there is no mortality
- there is no reproduction
- there is no tag loss
- all tagged fish recaptured are identified
- there is no difference in the catchability of tagged and untagged fish.



However, in river sites, the assumption of no migration will not hold, and without knowledge of immigration and emigration rates these estimates will be very rough and slight overestimates. Lagoon sites or sites in river pools will have more accurate population estimates. To minimise the migration effect, the data from all river sites in the McIntyre River between the weir and the boat ramp have been pooled for the 2008 Goondiwindi Carp Cull event. No tagged carp were recaptured outside of the site in which they were tagged in any competition, suggesting short-term migration was minimal. The assumption of no mortality is difficult to hold true as estimates of mortality rates are not known for the region. It is likely that the number of mortalities will be minimal given the short time between the pre- and post-competition surveys, thus mortalities are likely to have minimal impact on the population estimates. Tank- based observations have found extremely low short-term tag loss in the species (Norris, unpublished data).

2.3. Sites

Goondiwindi 2007

Five treatment (fished) sites and two corresponding control sites (not fished) were selected in the region. The first treatment site was Rainbow Reserve, a lagoon off the McIntyre River (Figure 1; location 3). The lagoon fills intermittently from the main river channel during large flow events, but has been filled via pumping during the recent drought. The other treatment sites were located on the McIntyre River. The second site was located at Ley's stock reserve (Figure 1; location 5). The river here consisted of two deep pools divided by an emergent rock bar. The third site was located at Yellowbank stock reserve (Figure 1; location 4). Upstream of the access track is a 1-km long shallow-to-moderately deep pool with a large amount of woody debris. The fourth treatment site was in the Boggabilla weir pool near the boat ramp (Figure 1; location 2). The water was deep in the middle rising to shallow, muddy banks. A large amount of mostly vertical timber was present in parts of the area sampled. The last treatment site was along the Town Commons, below the Goondiwindi town weir (Figure 1; location 1). This area of shire-owned land has numerous access points and the river follows a riffle-pool-riffle formation. Typically, the current is faster through this site compared to the other treatment areas.

The first control site was located on Booberoi farm, 30 km west of Goondiwindi. The lagoon at this site was chosen because (1) it has held a large carp population in the past, (2) the land manager is highly amenable to assisting fisheries research and (3) being on private land, it was not accessible to fishing by competition participants. At the time of sampling, the water level in the lagoon was very low, with a maximum depth of around 1 m.

The other control site was located in the McIntyre River several kilometres upstream from the Boggabilla weir pool. This area is accessible only by boat and requires the navigation of several shallow runs to reach it. Two pool areas either side of a very shallow run were surveyed.

More detailed descriptions of each competition site can be found in Appendix A.

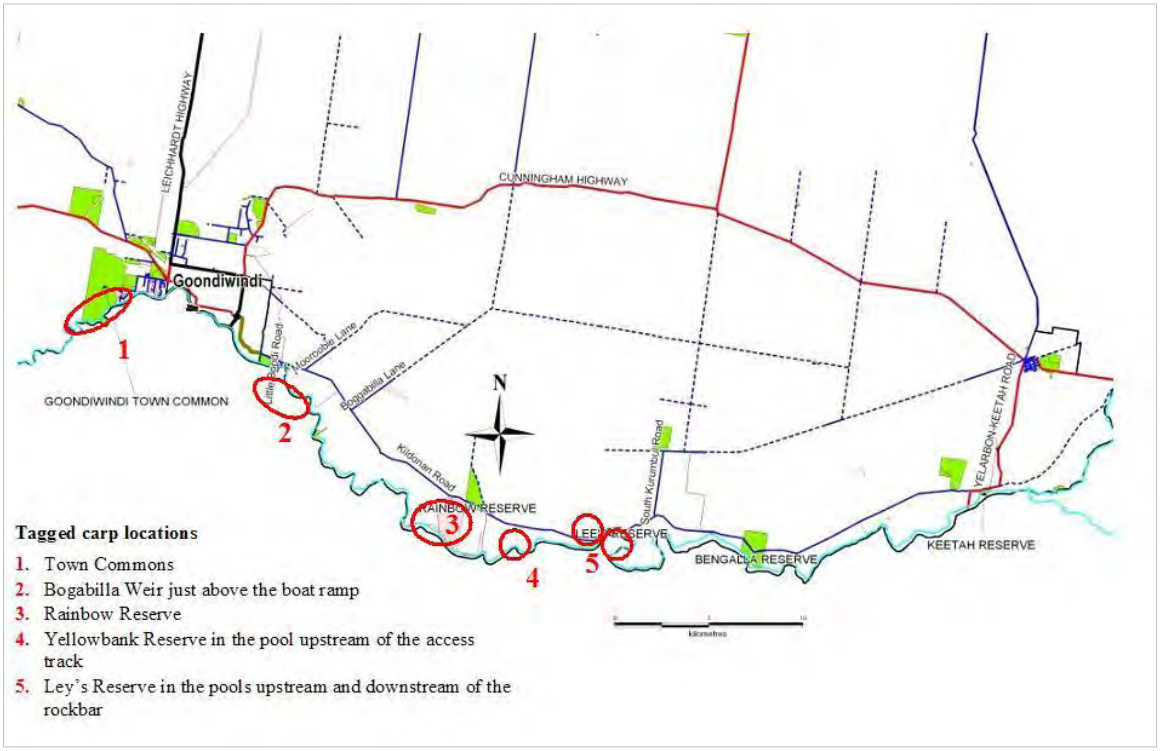


Figure 1. Map of the 2007 Goondiwindi Carp Cull competition area. Red rings indicate where electrofishing surveys were conducted and tagged fish were released.

Thallon 2008

The relatively small size of the Thallon competition area enabled the entire stretch of river to be monitored. The river was divided into 12 reaches with an additional unfished control site located 8 km further upstream on private land (Figure 2). Each section was surveyed for an equal amount of time, except for Section 9, which was located between two closely spaced confining structures (old weir and low bridge). More detailed site descriptions can be found in Appendix B.

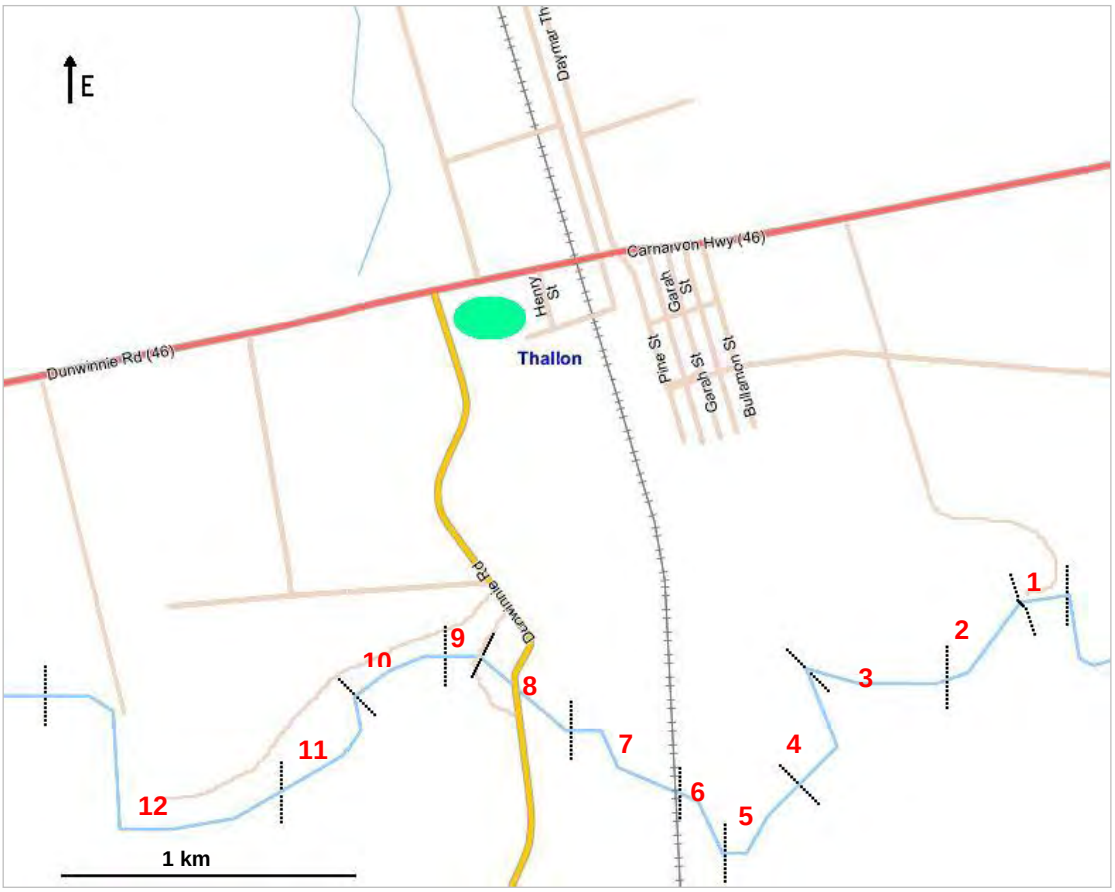
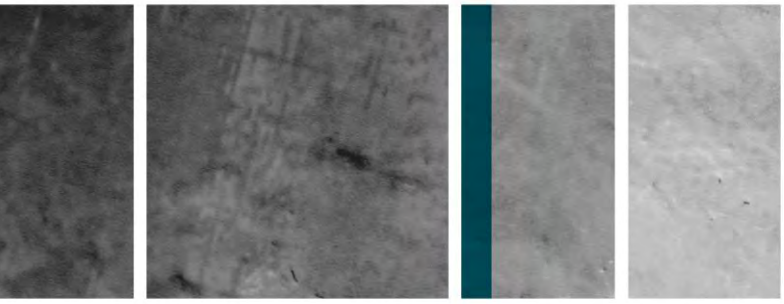


Figure 2. Map of the 2008 Thallon carp competition area on the Moonie River. The monitoring sections are labelled 1–12 with the control site approximately 8 km north (off the map).

Goondiwindi 2008

The lagoon treatment and control sites were at Rainbow Reserve and Booberoi farm Lagoon (same as in 2007). More river treatment sites were assessed in 2008 compared to 2007, and in 2008 the river treatment sites began at the base of Boggabilla Weir where a moderately deep pool (~2 m) had formed immediately below the weir wall. An extremely shallow riffle contained this pool before the site then formed into a typical river reach with very high levels of bankside woody debris. The next two sites were located above and below the Bondi Bridge, a popular fishing and camping area. The upper Bondi site extended upstream from the bridge, encompassing an area of shallow sand and/or clay substrate followed by moderately deep water with extensive woody structure. The lower Bondi site (Site 8) extended downstream from the weir and included a large expanse of shallower river (<1 m) followed by a wider stretch with tall grass and treed banks. The stretch of river between the town weir and the boat ramp formed the majority of the other treatment sites. This reach was divided into six sections, most of which were relatively uniform. The area was chosen because many boat and shorebased anglers commonly fish there. The river banks were steep with areas of submerged grass, tree roots and large woody debris. The bank margins were lined by aquatic plants



(*Azolla sp*. and *Myriophyllum sp*.). The last river site was along the Town Commons, below the Goondiwindi town weir. This area of shire-owned land has numerous access points and the river follows a riffle-pool-riffle formation.

The river control site was located in the Boggabilla weir pool near the boat ramp. This area was used as a treatment site in 2007. The water level was deep in the middle but shallow, muddy banks were present at the margins. A large amount of timber was present in parts of the area sampled.

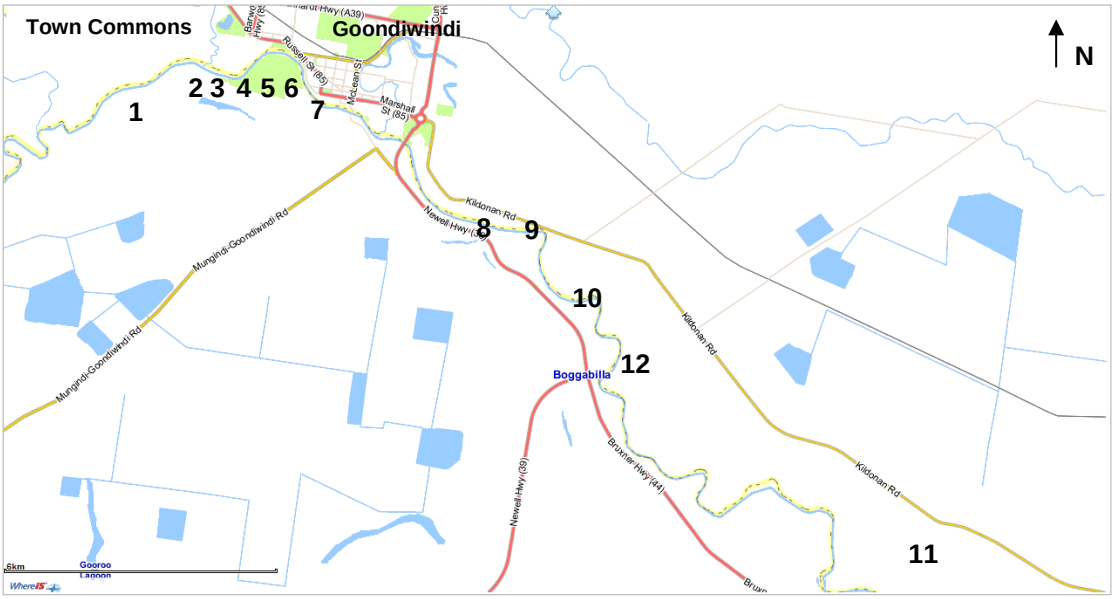
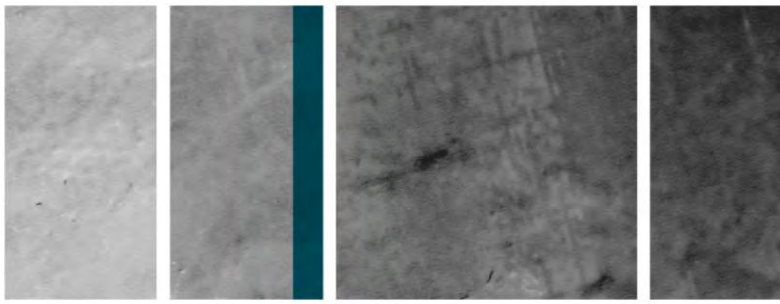


Figure 3. Map of the 2008 Goondiwindi Carp Cull competition area on the McIntyre River. The monitoring sections are labelled 1–11 and the river control site 12. The lagoon control site was located approximately 30 km west of the Goondiwindi township (off the map).



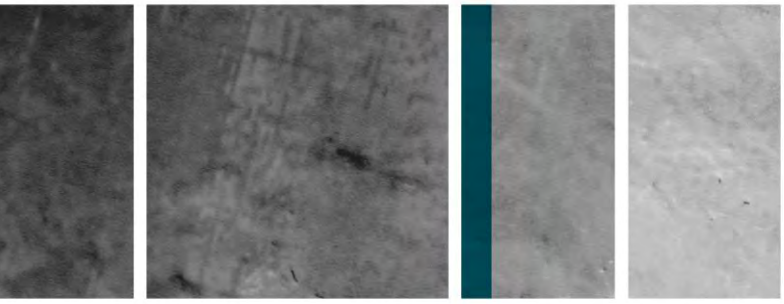
3. Results

3.1. Pre-competition sampling

A total of 1034 carp were caught just before the competitions, with 1006 of these of suitable tagging size (>150 mm FL). Table 1 shows the breakdown of the sites where these fish were caught, tagged and released. A range of native and introduced species were also caught. These species included golden perch (*Macquaria ambigua*), Murray cod (*Maccullochella peeli*), spangled perch (*Leiopotherapon unicolour*), silver perch (*Bidyanus bidyanus*), eel-tail catfish (*Tandanus tandanus*), goldfish (*Carassius auratus*) and a number of smaller fish such as olive perchlet (*Ambassis agassizi*), carp gudgeon (*Hypseleotris sp.*), Murray River rainbowfish (*Melanotaenia fluviatilis*), Australian smelt (*Retropinna semoni*) fly-specked hardyhead (*Craterocephalus stercusmuscarum*) and mosquitofish (*Gambusia holbrooki*). All native fish were released unharmed, but the introduced goldfish and mosquitofish were euthanised.

Table 1. The number of carp tagged during pre-competition surveys at the three carp competition events.

Event	Site	Tagged carp
2007 Goondiwindi Carp Cull	1	45
	2	20
	3	17
	4	25
	5	45
	Control - lagoon	60
	Control - river	21
	TOTAL	233
2008 Thallon Carp Comp	1	143
	2	10
	3	10
	4	6
	5	12
	6	28
	7	23
	8	11
	9	8
	10	19
	11	29
	12	27
	Control	17
	TOTAL	343



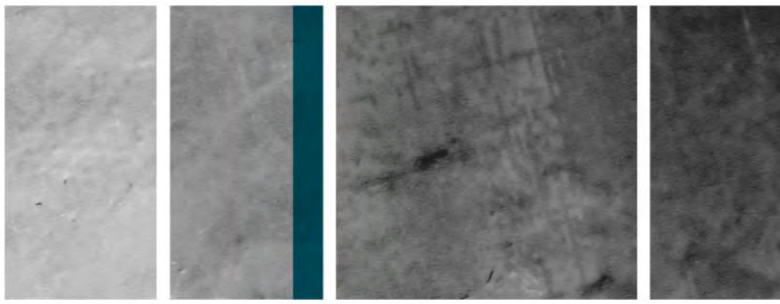
Event	Site	Tagged carp
2008 Goondiwindi Carp Cull	1	70
	Main reach (2-7)	118
	8	38
	9	14
	10	48
	11	96
	Control - lagoon	33
	Control - river	13
	TOTAL	430

3.2. Length-frequency

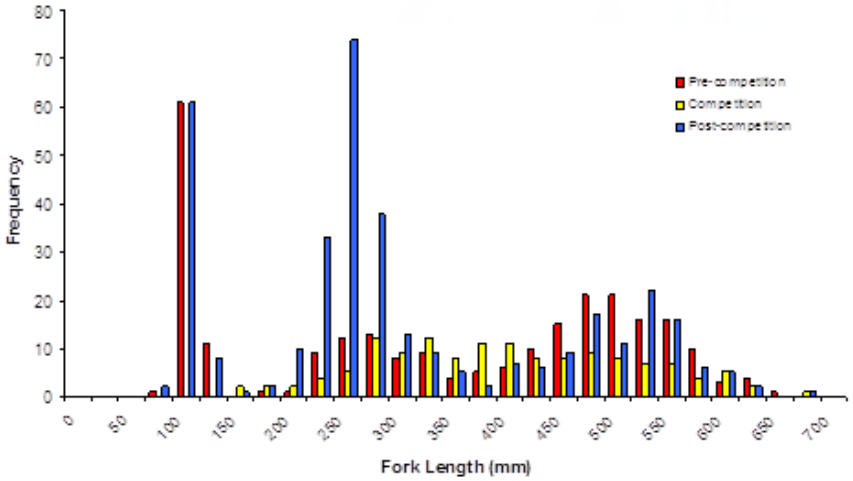
Captured carp ranged in size from 76–735 mm FL. Length–frequency histograms for each competition are shown in Figure 4. The graphs display the significant length–frequency peaks representing different age cohorts. The data from carp caught in each of the surveys and those caught by anglers follow a similar trend. The only exception is carp under 100 mm FL from Goondiwindi in 2007. This anomaly reflects the differences in gear selectivity between angling and electrofishing: the latter captures a far greater range of sizes, and is more effective on small fish than angling.

The length--frequency histograms from the 2008 Goondiwindi Carp Cull show how the cohorts have progressed in one year. It appears that between the 2007 and 2008 events, no major spawning events occurred in the sites monitored. The length–frequency peak observed in 2007 for carp of fork lengths between 250–300 mm is somewhat diminished.

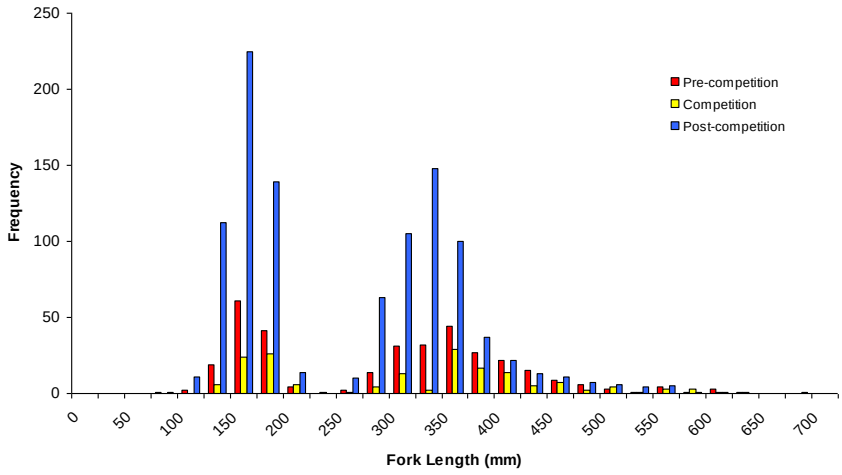
Very distinct length–frequency peaks were also observed in waters of the Moonie River at Thallon. The peaks occurred for carp around 150 mm FL and 325 mm FL. Only a few larger fish were captured and there was no length–frequency peak for large fish similar to that which occurred at Goondiwindi.



Goondiwindi 07



Thallon 08



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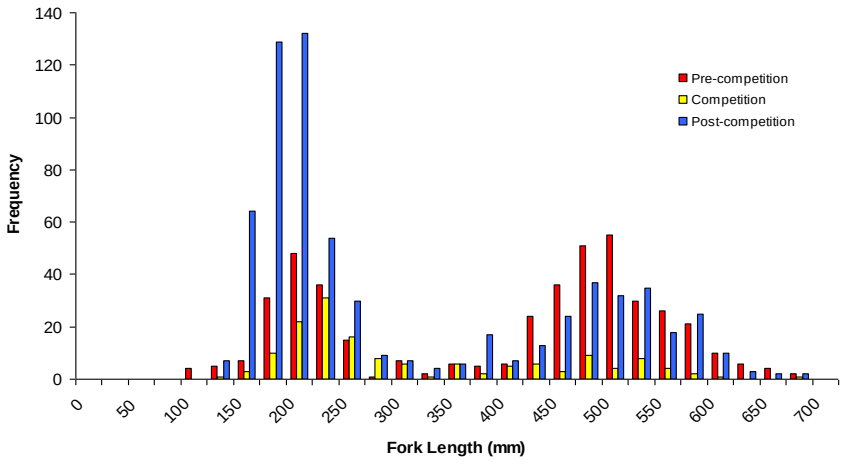
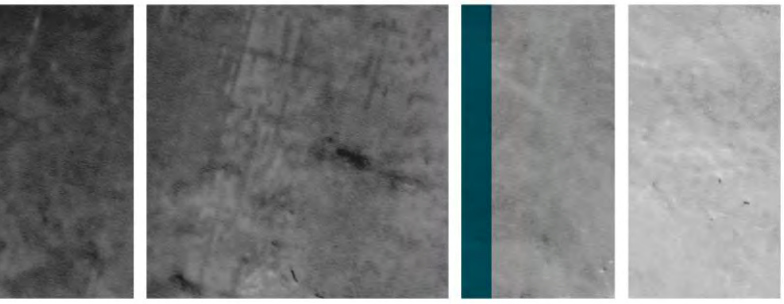


Figure 4. Length–frequency histograms for carp caught from pre-competition surveys (tagged), during the competition by anglers and post-competition electrofishing.



3.3. Competition catches

A combined total of 740 registrations were received for the three competitions. The 2007 Goondiwindi Carp Cull had 169 people from throughout the Darling Downs, Western Downs and North West New South Wales registering for the weekend. This consisted of 139 individual (junior and senior) and six team nominations. Competitors caught 138 carp ranging in size from 140 mm up to 706 mm FL. Of these only 44 were captured from surveyed sites. The amount of fishing pressure was assessed with twice-daily counts of anglers at monitored sites. The results of these counts indicate that approximately 26% of anglers fished monitored sites. The mean catch per angler varied significantly between sites and competitions. Sites adjacent to barriers across rivers, enclosed lagoons and dams, or those adjacent to irrigation inlets provided the highest catch per angler. The number of anglers was surveyed three times during the event at the six monitored sites. Around 27% of registered anglers were observed to be fishing monitored sites during these surveys. The mean number of anglers fishing at each site during the survey is summarised in Table 2.

Table 2. Angler fishing pressure and catch at monitored sites during the 2007 Goondiwindi Carp Cull.

Site	Mean number of anglers	Carp caught	Carp per angler
1	15	39	2.6
2	4.1	0	0
3	6.5	0	0
4	4	5	1.3
5	15.2	0	0
Control — lagoon	0	0	0
Control — river	0	0	0

The 2008 Thallon carp competition had a good turn out with 305 anglers registering for the event. This comprised 177 senior, 96 junior and eight team nominations. A total of 170 carp with a combined weight of 108 kg was caught during the two days. The smallest carp was only 113 mm FL while the largest was 619 mm FL and weighed 3.6 kg. Twice-daily angler observations indicate that 53% of anglers were observed fishing in the monitored sites when surveys were undertaken. The highest angling pressure was at Site 1.

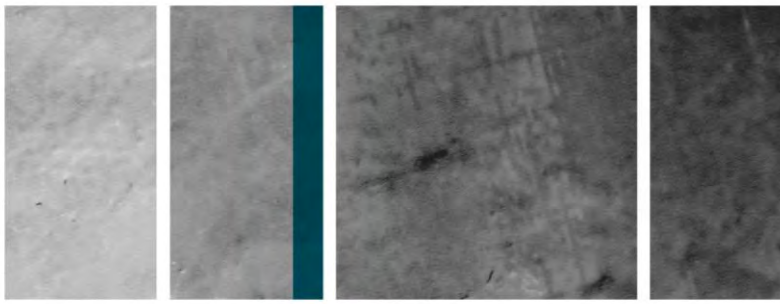


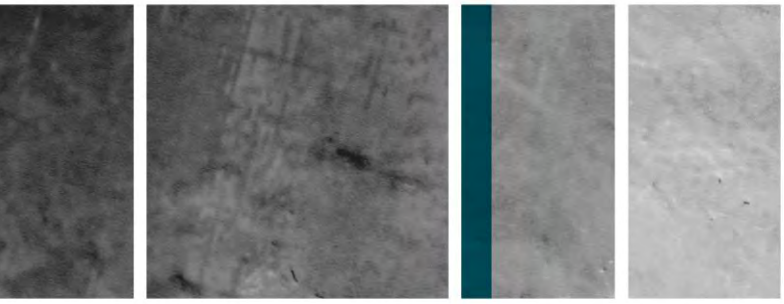
Table 3. Angler fishing pressure and catch at monitored sites during the 2008 Thallon Carp Competition.

Site	Mean number of anglers	Carp caught	Carp per angler
1	40.3	88	2.2
2	4.0	0	0.0
3	4.0	3	0.8
4	1.7	11	6.6
5	0	0	0.0
6	1.3	0	0.0
7	14.3	7	0.5
8	20.7	3	0.1
9	16.7	9	0.5
10	18.3	4	0.2
11	22.0	3	0.1
12	17.7	15	0.8
Control	0	0	0

The 2008 Goondiwindi Carp Cull attracted 266 people from throughout the Darling Downs, Western Downs and northwest New South Wales for the weekend of fishing. Over the two and a half days, 242 individuals (86 junior and 156 senior) and six teams participated in the fishing competition. Competitors caught 149 carp ranging in size from 120–670 mm FL. Carp were caught across the entire competition area, with a total of 127 fish caught at surveyed sites. The greatest catches came from the Town Commons (60), Rainbow Reserve (40), and the main river reach (weir to boat ramp, 25). Twice-daily angler counts suggested that 35% of entrants were fishing at monitored sites at those times.

Table 4. Angler fishing pressure and catch at monitored sites during the 2008 Goondiwindi Carp Cull event.

Site	Mean number of anglers	Carp caught	Carp per angler
1	53	60	1.1
Main reach (2-7)	47	25	0.5
8	2	0	0
9	8	1	0.1
10	0	0	0
11	35	40	1.1
Control — lagoon	0	0	0
Control — river	0	0	0



3.4. Post-competition electrofishing

A total of 2283 carp were caught in post-competition electrofishing, along with 297 goldfish. These fish were euthanised with an overdose of anaesthetic and disposed of in animal pits at local rubbish tips. A suite of native fish species identical to those caught in the pre-competition surveys was also observed and released unharmed.

Post-competition electrofishing at the 2007 Goondiwindi Carp Cull captured 437 carp (Cyprinus carpio) and 112 goldfish (Carassius auratus). The carp ranged in size from 56–654 mm FL with a combined weight of approximately 250 kg.

The post-competition electrofishing at Thallon 2008 was conducted two weeks after the event. A total of 1179 carp and 73 goldfish were caught and removed from the competition area. The carp ranged in size from 74–658 mm FL and equated to a combined mass of approximately 500 kg.

A total of 667 carp (Cyprinus carpio) and 112 goldfish (Carassius auratus) were caught during the post-competition electrofishing at Goondiwindi in 2008. Carp size ranged from 111–656 mm FL and equated to a combined mass of approximately 500 kg. Unfortunately Site 1 could not be resampled due to extremely low water levels.

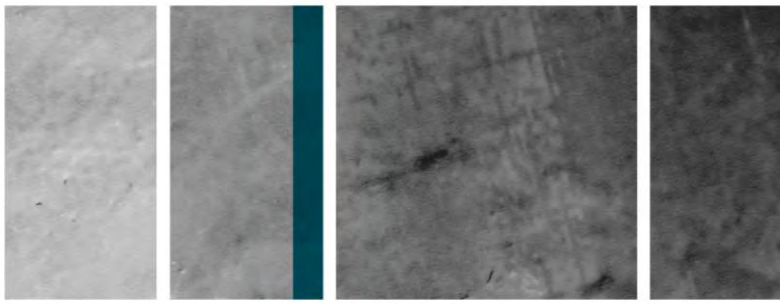
3.5. Tag returns

The Tag returns were far greater for electrofishing than they were for angling at all three competitions. At every site the electrofishing tag return was equal to or greater than that from anglers during the competition period, reflecting the difference in relative catch rates.

At Goondiwindi in 2007, only two tagged fish were caught by anglers during the competition period, both from Site 1. One further tagged fish was hooked, but was lost entering the landing net. The tag returns from angling were between 0% and 4.4%. The tag recapture for anglers across the entire competition area was only 0.9%. Tag returns overall were far higher for the electrofishing surveys. During post-competition electrofishing, 23 tagged carp were recaptured with tagged fish coming from four of the six sites surveyed. Tag returns ranged from 0% to 25% with an average tag return of 12.2% (excluding the tagged fish from Site 5, which was not resampled) for the competition area.

Table 5. Tag returns from angling and electrofishing at the 2007 Goondiwindi Carp Cull event.

Site	Angling (%)	Electrofishing (%)	Total (%)
1	4.4	6.6	11.0
2	0	5.0	5.0
3	0	23.5	23.5
4	0	0.0	0.0
5	0	n/a	n/a
Control — lagoon	0	25	25
Control — river	0	0.0	0.0



At the 2008 Thallon carp competition, six tagged fish were recaptured, mostly from the one site. Angler tag returns ranged from 0% to 3.7% with an overall return of 1.7%. 56 tagged fish were caught in the post-competition electrofishing survey across eight out of the 13 sites sampled. All recaptured tagged fish were caught within the site they had been released. Tag returns ranged from 0% to 33%, with an average across the competition area of 16.3%.

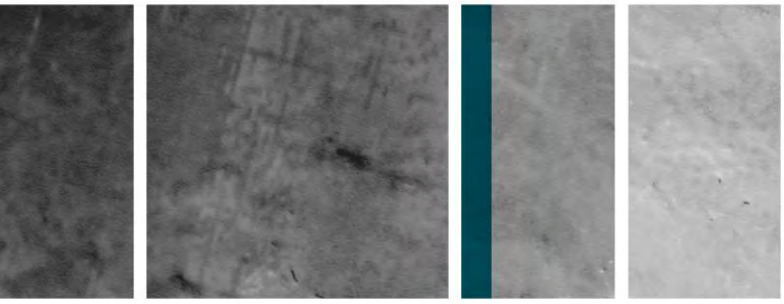
Table 6. Tag returns from angling and electrofishing at the 2008 Thallon Carp Competition.

Site	Angling (%)	Electrofishing (%)	Total (%)
1	3.5	33	36.5
2	0	0	0
3	0	0	0
4	0	0	0
5	0	17	17
6	0	4	4
7	0	4	4
8	0	9	9
9	0	0	0
10	0	5	5
11	0	0	0
12	3.7	4	7.7
Control	0	18	18

In the 2008 Goondiwindi Carp Cull anglers caught eight tagged fish during the competition period, with three from Site 11 and five from Site 1. The overall angler tag return was 1.9%. A further two tagged fish were captured by anglers at Bondi after the event but before the follow-up sampling. A total of 23 tagged carp were recaptured in the follow-up electrofishing surveys from ten of the 12 sites surveyed. Tag returns ranged from 2.6% to 15.4% with an average tag return of 6.9% (excluding the tagged fish from Site 1, which was not resampled) across the competition area.

Table 7. Tag returns from angling and electrofishing at the 2008 Goondiwindi Carp Cull event.

Site	Angling (%)	Electrofishing (%)	Total (%)
1	7	n/a	7
Main reach (2-7)	0	8	8
8	0	3	3
9	0	14	14
10	0	4	4
11	3	9	12
Control — lagoon	0	15	15
Control — river	0	3	3



3.6. Catch per unit effort

The Estimates of the catch per unit effort were required to compare the catch efficiencies of angling and electrofishing. Calculations of angling effort (man hours) were based on the assumption that the average participant fishes for eight hours during daylight and a further two hours during the night for each full day of competition. These assumptions were based on discussions held with numerous anglers.

The 2007 Goondiwindi Carp Cull ran from 10 am on the Saturday to noon on Sunday, a total of 26 hours. Using the above assumptions, it was estimated that the average angler fished for seven hours during the day on Saturday, two hours during Saturday night and a further five hours on the Sunday morning. This would provide a total effort of 14 fishing hours per angler. The number of registered anglers was 169, resulting in a total fishing effort of 2366 angler hours. The combined catch of these participants was 138 carp (only 44 in monitored areas), giving a CPUE of 0.058 carp per angler-hour. In comparison, three people electrofishing for four hours at each site put in a total of 84 man-hours' effort. The post-competition electrofishing catch was 437 carp, giving a CPUE of 5.202 carp per man-hour.

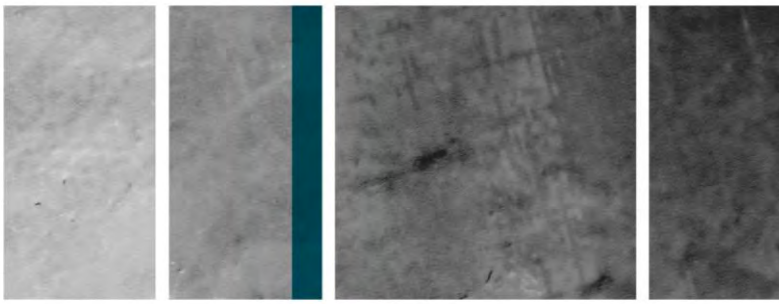
The 2008 Thallon Carp Competition ran from 6 pm on the Friday through to noon on Sunday, a total of 42 hours. So, using the assumptions above, each angler spent on average 18 hours fishing for carp over the two and a half days. The 305 registered anglers therefore put in an estimated 5490 fishing hours. During the competition period 170 carp were caught, giving a CPUE of 0.031 carp per angler-hour. The three-person electrofishing team invested three hours per site at 13 sites for a total of 117 man-hours. The post-competition removal was 1179 carp, giving a CPUE of 10.076 carp per man-hour.

The 2008 Goondiwindi Carp Cull ran from 8 pm Friday through to noon on Sunday. Each of the 266 registered anglers averaged 18 hours fishing for a total angler effort of 4068 angler-hours. The total carp catch was 149 carp giving a CPUE of 0.037 carp per angler-hour. The three-person electrofishing team again invested three hours per site for a total of 117 man-hours. The post-competition carp removal was 667 carp resulting in a CPUE of 5.701 carp per man-hour.

3.7. Population estimates and reduction efficiencies

Population estimates for each monitored site in the carp competitions are in Table 8. Populations were estimated to range from 98 through to 3480 carp per site. The total population estimate for the surveyed areas at Goondiwindi 2007 was 3823 ± 828 carp. At Thallon the entire competition area was surveyed so the estimated carp population in the competition area was 5936 ± 748 carp. At the 2008 Goondiwindi Carp Cull the total population estimate for the surveyed areas was 8021 ± 1672 carp. Approximately 75% of the competition area was surveyed, suggesting an estimated population of 10 694 ± 2229 carp in the entire competition site.

Mean carp population reductions across competition areas for angling and electrofishing followed a similar trend in all competitions. Angling pressure only reduced carp populations by 0.5–1.8%, while electrofishing resulted in reductions of almost an order of magnitude greater (8.3–16.1%). At individual sites population reductions as high as 8.3% were observed from angling, and as high as 32.1% from electrofishing (Figure 5).



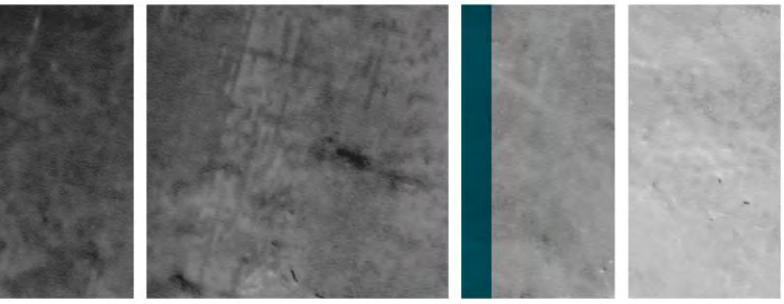
Site 1 at Thallon provides an excellent case study. This site had angling pressure of more than 40 anglers fishing the small enclosed water body (150-m long, 50-m wide and 1.5-m deep) for two and a half days. The carp population here was estimated to be 2201 ± 264 fish. The intense angling pressure only resulted in a population reduction of 4%. In contrast, electrofishing removed 32.1% of the carp population. Numerically, the removal by electrofishing was rather low (706 carp), despite occurring in the ideal scenario presented by the site. This provides an accurate representation of actual electrofishing efficiency. Single-pass electrofishing efficiency was only around an 8% reduction of the population. Additional time at the site could have reduced the population further as carp were still being caught at the end of the three-hour electrofishing session.

Table 8. Summary of carp tagging, recaptures and population estimates for each site of the carp competition areas.

Site	Number tagged	Competition catch	Competition recaptures	Post-comp catch	Post-comp recaptures	Total catch	Total recaptures	Population estimate	Standard error (±)
Goondiwindi 2007 total	**233**	**44**	**2**	**437**	**23**	**481**	**25**	**3823**	**828**
1	45	39	2	164	3	203	5	1,548	743
2	20	0	0	16	1	16	1	178	157
3	17	0	0	32	4	32	4	118	68
4	25	5	0	22	0	27	0	727	790
5	45	0	0	-	n/a	n/a	n/a	n/a	n/a
Control — lagoon	60	0	0	178	15	178	15	681	175
Control — river	21	0	0	25	0	25	0	571	650
Thallon 2008 total	**343**	**143**	**6**	**1036**	**56**	**1179**	**62**	**5936**	**748**
1	143	88	5	706	46	794	51	2201	264
2	10	0	0	8	0	8	0	98	135
3	10	3	0	13	0	16	0	186	263
4	6	11	0	11	0	22	0	160	267
5	12	0	0	30	2	30	2	133	113
6	28	0	0	35	1	35	1	521	436
7	23	7	0	54	1	61	1	743	661
8	11	3	0	43	1	46	1	281	303
9	8	9	0	15	0	24	0	224	343
10	19	4	0	15	1	19	1	199	180
11	29	3	0	9	0	12	0	389	398
12	27	15	1	44	1	59	2	559	402
Control	17	0	0	53	3	53	3	242	166

Table 8. continued…

Site	Number tagged	Competition catch	Competition recaptures	Post-comp catch	Post-comp recaptures	Total catch	Total recaptures	Population estimate	Standard error (±)
Goondiwindi 2008 total	**430**	**127**	**8**	**667**	**25**	**794**	**33**	**8021**	**1672**
Site 1	70	60	5	-	-	60	5	721	310
Main reach (2-7)	118	25	0	87	9	112	9	1344	428
8	38	1	0	25	1	26	1	526	405
9	14	0	0	14	2	14	2	74	57
10	48	0	0	43	2	43	2	718	453
11 - lagoon	96	40	3	397	8	437	11	3540	1077
Control — river	33	1	0	48	1	49	1	849	688
Control — lagoon	13	0	0	53	2	53	2	251	213



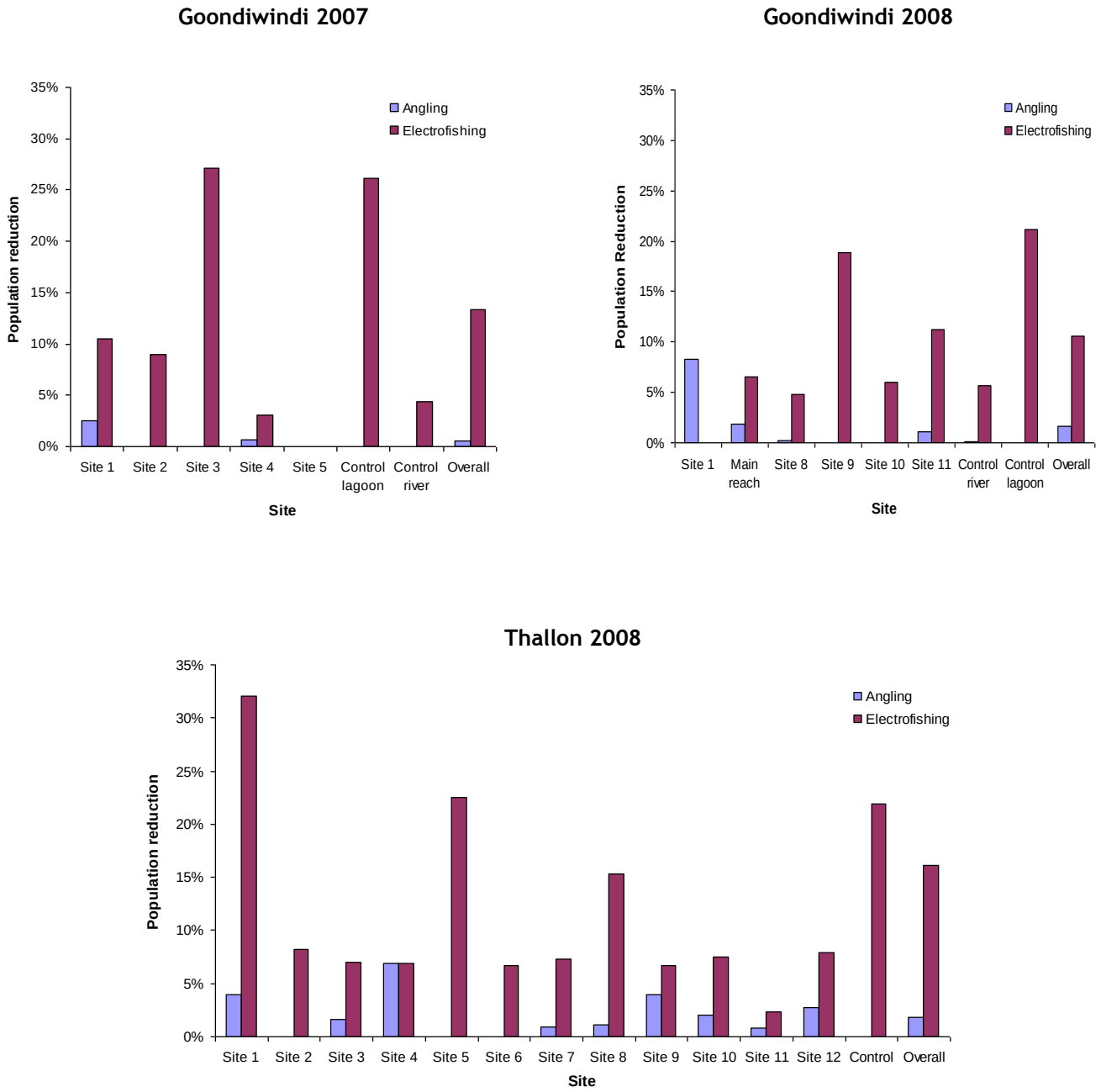
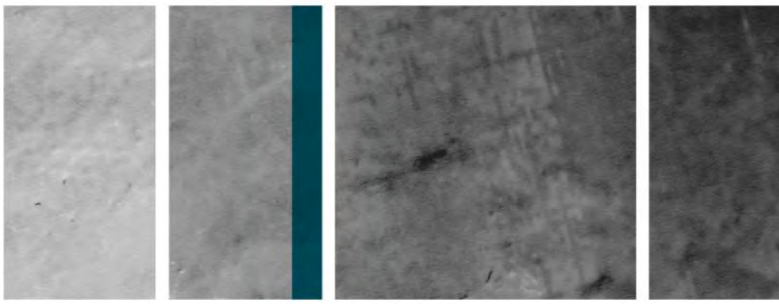


Figure 5. Carp population reductions by angling and post-event boat electrofishing at Goondiwindi in 2007 and 2008, and Thallon in 2008. The 'Overall' column denotes estimated population reductions across the entire competition area.



4. Discussion

4.1. Tag returns

Tagging carp before the competitions served two purposes. Firstly, it targeted angler pressure towards selected locations. The concept of prizes for the capture of tagged carp proved to be very popular with contestants and likely attracted more anglers to register for the competitions. Secondly, tagging provided a means for estimating population sizes that was more reliable and robust than standardised surveys and depletion curves.

The combined tag return for the whole project was 12%. This level of recapture enabled local carp populations to be estimated to an accuracy of ±19%. The project focussed on the relative removal efficiency of angling and electrofishing and thus the return results indicate adequate pre-competition and post competition sampling effort.

Tag returns were highly variable. Low tag returns generally corresponded with river sections with low carp numbers and where the fish were extremely dispersed. In such areas it would have been easier for tagged fish to have avoided recapture. Recaptures were recorded from 78% of the sites assessed with an overall tag return for the project of 12%. The overall tag return would most likely have been greater if post-competition surveys could have been done at the Town Commons site at Goondiwindi. Low water levels prevented boat access to this site both years, but anglers managed to catch tagged fish there during each competition.

The recapture rate decreased slightly between the 2007 Goondiwindi Carp Cull and the 2008 Goondiwindi Carp Cull. This reduction is most likely due to the competition area and monitoring sites shifting from smaller, semi-contained riffle-pool-riffle sites to more open flowing river sites. Carp are less likely to be caught via electrofishing from deeper, more open stretches of river. In such an environment the electrofishing field may not adequately penetrate throughout the water column and fish are more likely to escape from the weaker margins of the field. Electrofishing activity is typically confined to the bank margins and around any woody debris in such areas. Angling can target the entire river profile and still catch fish from the deeper portions but the far lower CPUE limits tag returns.

Tag returns were highest in small closed or semi-closed systems. In such locations, avoidance of the electrofishing units is difficult and a higher proportion of the populations were initially tagged. The large lagoon at Rainbow Reserve, Goondiwindi, only returned moderate numbers of recaptured fish in both 2007 and 2008. The difficulty here was that water levels dropped between the initial and final surveys and the carp became more randomly distributed through the shallow lagoon waters. At higher water levels, the carp were more concentrated around woody debris and were easier to catch around such structures. In shallow waters, the carp were more difficult to catch in large numbers. Fish were seen, but evaded the electrofishing boat, even when close to the anodes. Angling was also restricted to several access points, so tagged fish could roam the large lagoon with a reduced likelihood of coming across an angler's bait during a competition.

At most sites, the majority of carp caught via electrofishing were very strongly associated with fallen timber in the water, particularly dense, complex snags. It remains unclear whether the carp preferentially inhabit these structures or use them as a form of refuge from predation or stress events. Radio-tracking studies in southern Australia on microhabitat use

suggest that carp are only infrequently associated with woody debris. This supports the concept of structure use as a refuge response. It is predicted that fish in the proximity of structure may remain in the near vicinity to these structures resulting in reasonable recapture rates (see below).

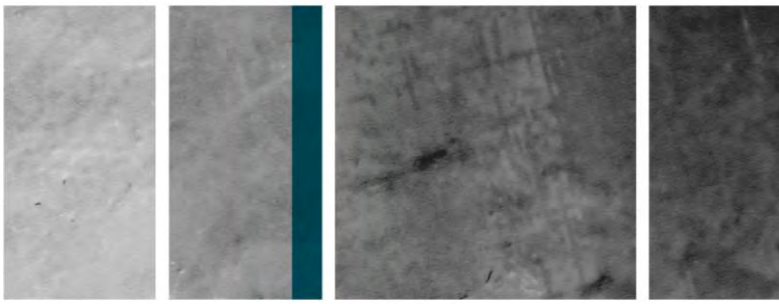
Of the 120 tagged fish recaptured, 117 fish remained in the section where they were originally captured. These observations are similar to those for radio-tracked carp in this catchment. Carp appear to be quite sedentary, with movement mostly occurring during flow events. This lack of frequent migration increases the accuracy of population estimates in open river sites, such as at Goondiwindi. It would also increase the longevity of any impact from fishing competitions and other control techniques, since the area occupied by removed fish would not be immediately re-inhabited.

4.2. Angling pressure

The angler pressures observed in the three competitions were very similar to those seen at most carp fishing events. Except for rare events that target carp in a specific small waterway, most angling effort is dispersed across large competition areas. 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 greatest angling pressure was observed at Site 1 of the Thallon 2008 Competition (**Error! eference source not found.**). At this site, more than 40 anglers fished the 150 m-long enclosed body of water solidly for two and a half days. The area was completely isolated from the rest of the river during the monitoring and competition period, had a very high density of carp and native species and was easy to access. Prior to the competition, 143 carp were tagged in the pool. During the competition, anglers were lined up almost shoulder to shoulder in places to get their lines in and caught 88 carp, including five tagged carp. This sort of fishing pressure is well above average for carp competitions. Even at this high level of fishing pressure, the estimated population reduction rate was low at only 4%.

Figure 6. Many anglers fished the small pool at the Dead End during the Thallon 2007 Carp Competition. Fishing spots were at a premium and very few spots were vacant.



Site 1 of the 2008 Goondiwindi Carp Cull was also heavily fished by anglers. An average of 53 anglers fished this reach over the weekend. The greatest population reduction from angling effort was observed here (8.3%). However, due to extremely low water levels, no post-competition electrofishing survey was conducted and the population estimate had to be based solely upon angler catch. It is anticipated that a follow-up survey would have demonstrated a larger and more precise population estimate for the site. If this was the case, then the population reduction caused by angling would be smaller.

4.3. Catch per unit effort

The carp catch per man-hour was very low for the anglers. Many of the participants were juniors or 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.

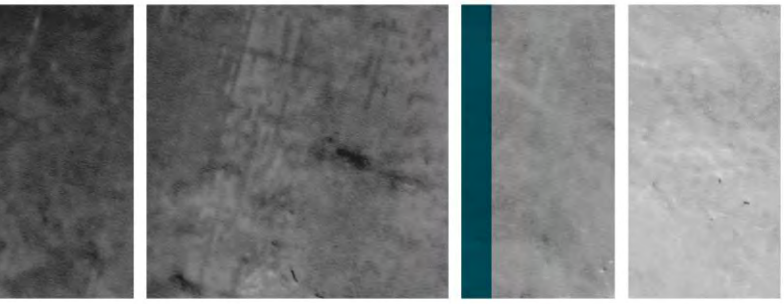
The catch per man-hour was approximately one hundred times greater for the electrofishing team. The electrofishing equipment does not rely on fish actively feeding in order to capture them and can drive fish into designated areas to aid removal. Although electrofishing is more efficient in most environments, there are a few exceptions. Electrofishing has only limited use in waters greater than 4 m deep. The field generated is not strong enough to hold resistant species like carp and stunned fish may also not be seen in turbid waters. In very shallow waters with muddy substrates, the electrofishing equipment also loses its effectiveness. The hull tends to earth out to the substrate, reducing the effective field. This results in fish fleeing from the boat without being stopped. In these scenarios, line fishing may be more effective.

4.4. Population estimates

The population estimates enable a comparison between the control efficiencies of competition angling and electrofishing. Although these estimates are only based on a single mark-recapture process, they do indicate the relative efficiencies of the two techniques.

The assumptions for population estimates using the Lincoln–Peterson methods were quite well met. Generally in river sites, the assumption of no migration will not hold and without knowledge of immigration and emigration rates, population estimates may be approximate. Lagoon sites or sites in river pools will thus have more accurate population estimates. However, as discussed above, it would appear that carp are quite sedentary and only move a small amount in the time frame between surveys.

The assumption of no mortality is also difficult to hold true as estimates of mortality rates are not known for the region. The short time between the pre- and post-competition surveys helps minimise the number of mortalities and mortality impact on the population estimates. Observations from tag retention in tank-held fish, and those from previous studies (eg Stuart and Jones 2002) suggest tag retention is high in carp and thus should not influence population estimates in a significant manner.



4.5. Population reductions

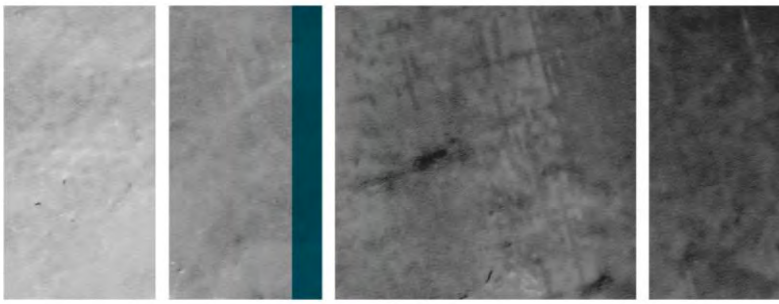
One of the main aims of the organisers of many carp fishing competitions is to reduce the detrimental impact of carp on the environment by reducing numbers in local waterways. Although every carp removed from a waterway potentially lessens the species' impact, meaningful benefits will only arise with substantial population reductions. The extremely high fecundity and relatively long lifespan of carp means that for long-term improvements to occur, significant reductions of local populations are needed. Thresher (1997) estimated that the target population size required to produce a relatively stable, low carp population density in the Murray–Darling River system was less than 10% of the unfished biomass.

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%. Even the electrofishing removals would have only had a small impact, with the mean numerical reduction from this method across competitions being only 12.6%. Although numerical, these figures would be far lower than the required 90% biomass reduction suggested by Thresher (1997). Decreases in carp populations from both of these activities could easily be reversed through a single successful spawning event.

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 over 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 very 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.

Secondly, 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.

Thirdly, angling 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 120 mm are caught by angling. 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 230 mm. Fish escaping an angling event one year can grow from <120 mm to greater than 230 mm FL in good conditions (Smith 2005, personal observation of the author). Thus, small carp may have the opportunity to reproduce between annual competitions.



4.6. Length-frequency – recruitment and size selectivity

The length–frequency histograms of angler-caught fish follow similar patterns to those generated from the electrofishing catch data. The main difference was the lack of small fish caught by anglers. Electrofishing is generally not a size-specific capture technique enabling an accurate snapshot of fish assemblage structure. Thus, angling appears to be equally effective at targeting carp from all sizes above the minimum threshold set by gear constraints. This lower size threshold would be determined by a number of variables including hook size, bait size and type and gear selection.

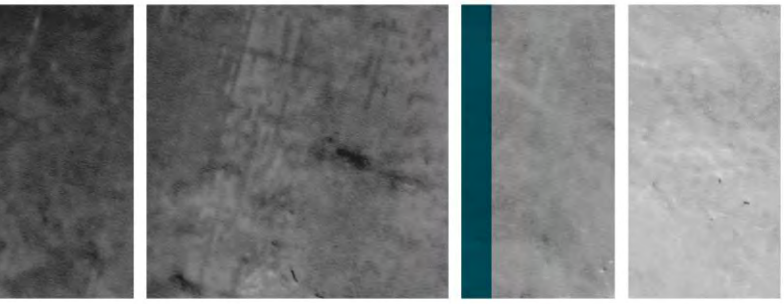
Although a wide size range of carp was caught by anglers during the 2007 Goondiwindi Carp Cull, few small fish were caught except at one site. Low water levels and a lack of recent flow events appear to have impacted carp populations in the area. Recruitment appeared to be poor with small carp only caught in any number at Rainbow Reserve Lagoon (Site 1). Pumping into the lagoon for irrigation purposes increased water levels at this site over the period prior to summer. This resulted in a spawning event around February, as indicated by the abundance of small young-of-year carp (Figure 4). At other survey locations, few or no such small fish were recorded.

The disappearance in 2008 of the length–frequency peak observed in 2007 for Goondiwindi carp of fork lengths between 250 and 300 mm is interesting. A number of factors could have resulted in this observation. A substantial number of carp in this size range were removed from Booberoi Lagoon during the post-competition recapture survey in 2007. The removal of these fish may have reduced the frequency of that size range in 2008. The reduction in the competition area and the resultant changes to survey sites might also explain the observation. The stock reserve sites assessed in 2007 were open river sites with riffle-pool-riffle characteristics. The waters there were generally shallower and flowing at a greater rate than those in the Goondiwindi Town weir-pool. Smaller carp, in the 200–300 mm FL size range, may be more prevalent in such areas. The older and larger fish may prefer deeper, more sedentary waters. Observations from the 2008 Thallon carp competition support this concept. Very few small carp were caught from the larger, deeper portions of the river. The high frequency of carp around the 150 mm FL mark came predominantly from Site 1, which was well vegetated and shallow at one end.

4.7. Competition areas and survey site selection

Evaluating the impacts of fishing competitions is fraught with difficulty when carp numbers are low. The ideal scenario to evaluate has very high carp numbers in discrete populations with little migration. The numbers of carp in the McIntyre River were low to moderate at the times of the carp competitions. Higher carp densities were found in the lagoon at Rainbow Reserve, which also had a greater catch rate. This increased data availability and accuracy as well as capture opportunities and enjoyment for the anglers. The same scenario occurred on the Moonie River at Thallon. In general, carp densities were quite low in the river but extremely high in the one enclosed section at the Dead End (Site 1).

Selection of monitoring and survey sites is one of the most critical aspects in effectively evaluating the impacts of fishing competitions on fish populations. Monitoring sites need to be located in areas exposed to high levels of angling pressure in order to give a maximal impact



estimate. The survey sites were modified at Goondiwindi between 2007 and 2008, to increase the likelihood of anglers fishing in them. This modification was accomplished by significantly reducing the competition area and basing monitoring sites on locations heavily fished in 2007. In 2007, only a low proportion of competition entrants was observed fishing in monitored sites. The reduction of the competition area and reselection of monitoring sites alleviated this issue in 2008, resulting in the majority of anglers fishing within monitored sites.

Several anglers were concerned that the reduced competition area would mean less fish caught per angler. The average angler catch only decreased from 0.8 carp to 0.7 fish per angler with the reduction in competition area, while the mean population reduction nearly tripled from 0.5% to 1.6%. This variation in CPUE for anglers is not huge and cannot be explained by differences in the ratio of senior to junior anglers (based on the assumption that senior anglers are more skilled and thus catch more fish). It is most likely due to different environmental conditions and angler skill levels between the years, rather than changes in the event area.

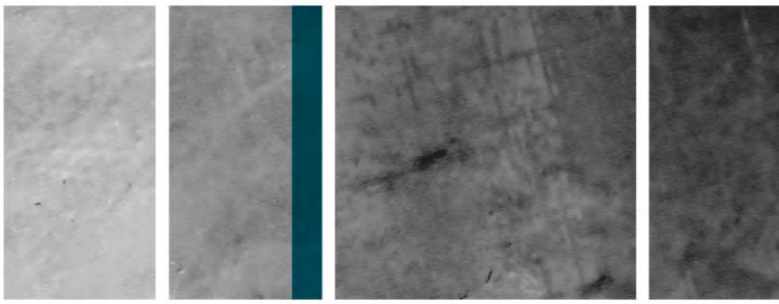
4.8. Survey techniques

In 2007, initial monitoring surveys trialled a number of standardised electrofishing shots at each site, combined with a period of time hunting specifically for carp. Each standard shot generally involved covering a 50-m stretch of water with ten in-and-out manoeuvres with the boat followed by a parallel run. The total 'power-on' time for these shots was typically 300 secs. The low and extremely variable numbers of carp caught using standard shots resulted in data that was difficult to statistically compare (high variance). To overcome these issues, the monitoring regime was simplified and focussed purely on mark-and-recapture data. By spending time actively hunting for carp, as opposed to sampling a designated area, the number of carp caught and tagged before the 2007 Goondiwindi Carp Cull increased from 233 up to 440, and thus increased the pool size for tag returns. Power-on times were kept similar in order to standardise our efforts between areas. This change in strategy was quite effective as seen in the tag-recapture rates and subsequently used for all three competitions discussed in this paper.

4.9. Event benefits

The results clearly indicate that the angling competitions have a negligible impact on the local carp populations. However, that does not necessarily mean that these events cannot be a valuable management tool. Many of the benefits of competitions are intangible.

Pest fishing competitions bring together a cross-sectional group from the local and extended community. This provides an excellent opportunity for government agencies, NRM groups and catchment management authorities to engage in two-way dialogue on environmental issues in the region, particularly aquatic health. The congregation of interested and potentially motivated people enhances the probability of education and extension activities being effective. These events are the ideal venue to set up informative displays on fishing regulations, weeds, pests and a range of other environmental concerns. It was also encouraging to see the number of people who sought clarification on fishing regulations during competitions.

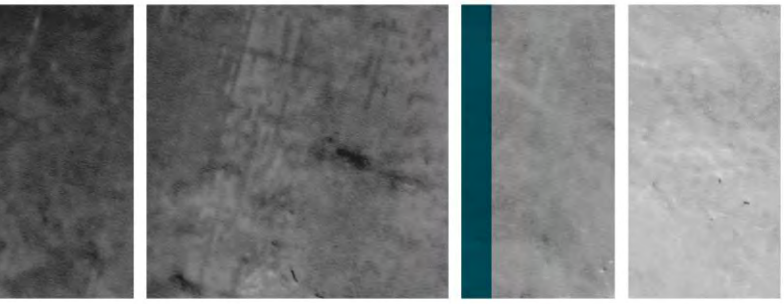


The support for carp fishing events clearly demonstrates that communities are keen to take greater ownership of the carp issue. Of the range of possible carp management options currently available, most require specialised equipment and expertise, and few can be implemented by community groups. The competitions inspired people to believe that individuals could have a positive impact, especially when working together. Some participants, who entered purely to have a good time, were later heard commenting that carp are bad and the local community should/could do something about them. Many people suggested more competitions to increase the pressure on the carp populations.

Some competitions work on a cost-neutral basis, but many raise a profit, which is typically re-invested in local community projects or restocking of native species for recreational angling. The profits raised can be from several hundred up to tens of thousands of dollars, depending upon the number of participants and the prizes on offer. The competitions could be used to raise money to fund organisations to implement carp control. For example, the charge of hiring an electrofishing boat and crew is around $2500 per day. If a competition raised $7500, such a crew could be hired to remove carp for three days at priority sites. Alternatively, the revenue raised could be invested in equipment to aid carp management undertaken with local authorities. For example, the money could assist in installing and maintaining carp separation cages in fishways at weirs, or screening of inlets into carp-free wetlands.

Many events are held in small regional towns and become the social focal point for the region. The Saturday night usually has a bar and some live music, which both locals and visitors seem to enjoy. Attracting entrants from out of town generates significant income for these small towns. Visiting anglers purchase fuel, food, accommodation and many other items that helps stimulate the local economy. This can be an important factor for organisations considering investing in fishing competitions as there can be a broad range of benefits for their investment.

Carp fishing competitions often attract a good deal of media coverage. The events can generate major topics and a source of articles for local newspapers and radio stations. This media coverage helps promote carp-related issues to a broader audience, not just those involved directly with the competition. Interviews with event organisers enable targeted messages to be delivered to people who may not normally be interested in fishing or the health of the aquatic environment. The media coverage increases participation rates, encourages community ownership, disseminates information and attracts visitors to the region. All these factors can be highly useful in an integrated management strategy.



5. Conclusion

This research demonstrates that carp angling competitions are not an effective form of direct carp management. The removal efforts often occur over large areas, resulting in low angling pressure and very low population reductions. When compared to electrofishing, the CPUE of competition angling was found to be nearly 100 times less in terms of carp per man hour. Thus, as these events are currently run, they will not have any significant impact on local carp population numbers.

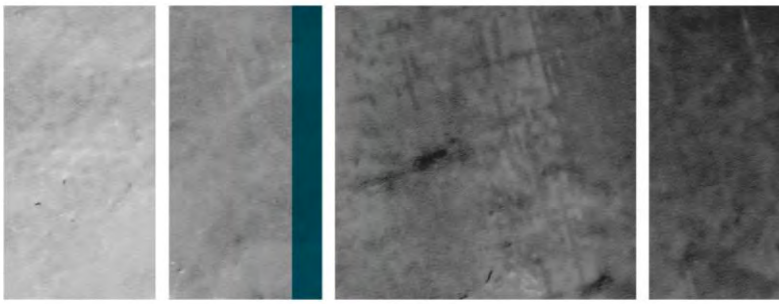
Carp fishing competitions do, however, have a range of less tangible management benefits. The events help educate the wider community about the detrimental impacts of pest fish, raise awareness and ownership of the pest fish issue and provide a social focal point for smaller regional communities. The competitions can generate revenue that can be directed into native fish restocking or pay for contractors to remove carp in high-value areas.

6. Acknowledgements

The authors would like to thank all of the competition organisers for generously giving up their time to talk with us and allowing us to conduct the research at their events. In particular, we would like to thank the people from the Surat Fishing and Restocking Club, Thallon Fishing Club and the Goondiwindi Bowls and RSL Fishing Clubs for all of their efforts and great times.

The research would not have proceeded without the financial support of the Invasive Animals Cooperative Research Centre and Queensland Department of Employment, Economic Development and Innovation (formerly Primary Industries and Fisheries). Many thanks also go to the Queensland Murray Darling Committee Inc who supported and organised the 2008 Regional Carp Series. Lavinnia Fielder did a sterling job in ensuring advertising and event coordination was conducted in an efficient and effective manner.

Lastly, we would like to thank all of the participants in the carp competitions who made this work possible.



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Appendix A: Competition monitoring sites

Goondiwindi Carp Cull 2007

Monitoring sites were selected with the help of competition organisers. Five treatment (fished) sites and two corresponding control sites (not fished) were selected in the region.

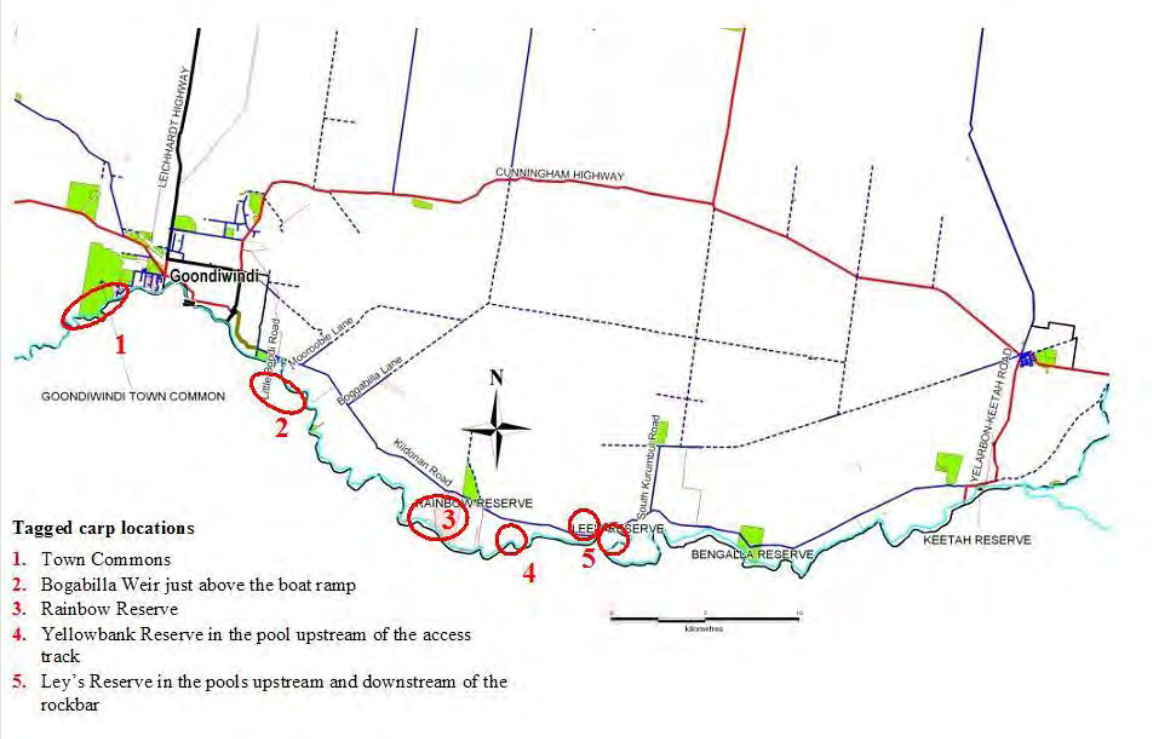
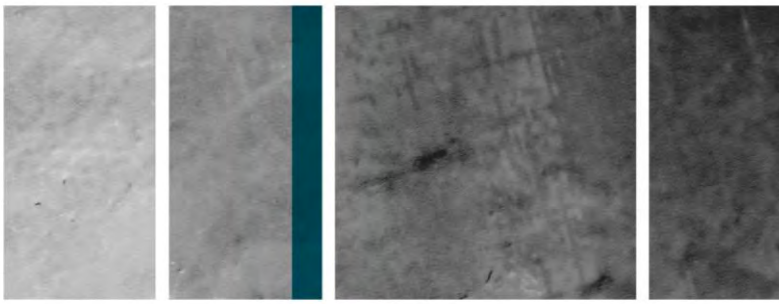


Figure A1. Map of the permitted areas to fish in the 2007 Goondiwindi Carp Cull. Red rings indicate where surveys were conducted and tagged fish were released.

The first treatment site was Rainbow Reserve, a lagoon off the McIntyre River. The lagoon intermittently fills from the main river channel during large flow events, but has been filled via pumping during the recent drought. The lagoon was last filled in February 2007. The water body was approximately 1 km long at the time of the Carp Cull, with an average width of approximately 70–100 m. The banks at low water level are gently sloping, lacking vegetation and composed of extremely soft black soil. The average water depth was less than 1 m, with many of the large woody snags above the water. Half of the lagoon is situated on stock reserve and public access is readily available to this section. The remainder is located on private property, with the land owners relying on the lagoon for irrigation of cotton fields.

The other treatment sites were all located on the McIntyre River. The second treatment site was located at Ley's stock reserve. The river here consisted of two deep pools divided by an emergent rock-bar. The upper pool was approximately 300 m long, while the downstream pool extended for approximately 700 m. The upstream limit of the top pool and the



downstream limit of the bottom pool were both marked by extensive, heavily-timbered shallow runs. Both pools had an average depth of approximately 2.5 m and generally quite steep banks. The margins of both pools were also heavily weeded up to a distance of several metres from the shore and weed free submerged and emergent woody debris was limited.

The third site was located at Yellowbank stock reserve and watering point. An access track crosses the river over a shallow riffle that only flows when the river is running well. Upstream of the access track is a shallow to moderate pool with a large amount of woody debris. The upper limit of the pool is formed by another very shallow riffle section. The pool stretches for approximately 1 km and has an average depth of 1.5 m.

The fourth treatment site was in the Boggabilla weir pool near the boat ramp. The water was quite deep in the middle; however, shallow, muddy banks were present at the margins. A large amount of mostly vertical timber was present in parts of the area sampled. The water depth averaged around 2–2.5 m and the weir pool itself was several kilometres long. The upstream end of the section sampled was formed by the first major run with shallow water.

The last treatment site was along the town commons, below the Goondiwindi town weir. This area of shire owned land has numerous access points and follows a riffle-pool-riffle formation. The waters below the weir's rock-ramp fishway have previously been found to contain carp, particularly when flows occur. The pools in the system have one or two pieces of medium-to-large woody debris, separated by very shallow riffles and runs with a gravely substrate. Typically the current is significantly faster through this site compared to the other treatment areas. The water depths range from less than 1 m up to 2.5 m deep at the large downstream pool with the treatment area extending nearly 2 km. The average width is typically narrow (8–15 m) except for in the larger pools where it reaches up to 40 m.

The first control site was located on Booberoi farm, 30 km west of Goondiwindi. The lagoon at this site was chosen because (1) it has held a large carp population in the past, (2) the land manager is highly amenable to assisting fisheries research and (3) being on private land, it could not be fished by competition participants. At the time of sampling, the water level in the lagoon was very low, with a maximum depth of around 1 m. The lagoon is 400 m long with an average width of 40 m. The substrate is predominantly gravel with several muddy patches and several large fallen trees provide a bit of structure.

The other control site was located in the McIntyre River several kilometres upstream from the Boggabilla weir pool. This area is accessible only by boat and requires the navigation of several shallow runs to reach. Two pool areas either side of a very shallow run were surveyed. Both pools contained moderate to high levels of large woody debris with water depths ranging from 1–2.5 m. The substrate varied between mud and gravel.

Thallon Carp Competition 2008

The competition area stretched approximately 4 km along the Moonie River adjacent to the Thallon township. The downstream margin was located where the river water disappears below the town weir. This area is known to locals as the 'Dead End' (Section 1, Figure A2). The upstream margin was represented by a 1.5-m high causeway with no culverts, making the system essentially closed except during flow events.

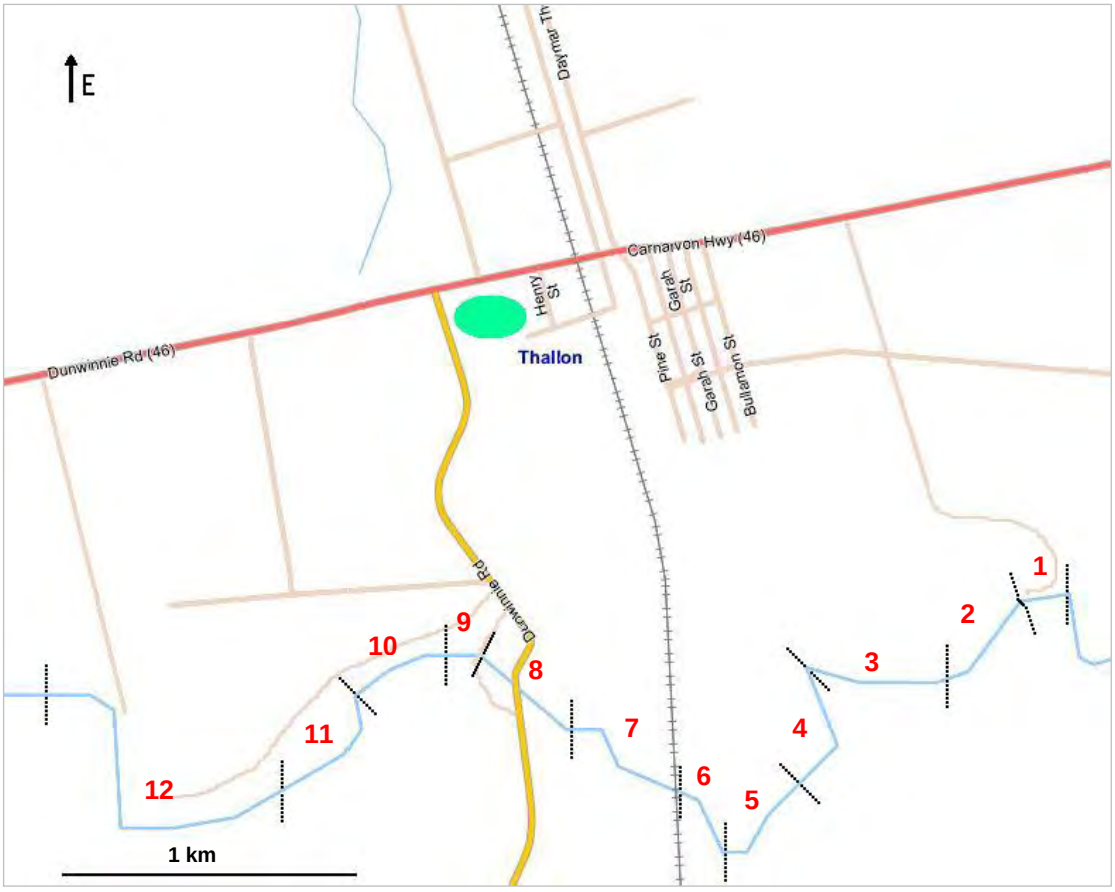


Figure A2. The Thallon carp competition area on the Moonie River. The monitoring sections are labelled 1–12 with the control site approximately 8 km left along Dunwinnie Rd (off the map).

The relatively small size of the competition area enabled the entire stretch of river to be monitored. The river was divided into 12 reaches and an additional control site was located on the river about 10 km upstream of town on private land. Each section required an equal time to survey, except for Section 9, which was located between two closely spaced confining structures (old weir and low bridge). A brief description of each section follows.

Section 1 – The 'Dead End'

The Dead End is a small pool of water below the town weir. It was approximately 50 m wide and 150 m long with an average depth of 1.5–2 m. The downstream end tapers out into a dry gravelly river bed. Several pieces of large woody debris and rocks occurred adjacent to the shores. This small area is the most heavily fished in the region as it is often full of fish prevented from migrating upstream by the weir. The weir wall was approximately 2 m high and water was barely trickling over it.

Figure A3. The 'Dead End' pool looking from the town weir downstream.

Section 2 – Town weir to stock drinking fence

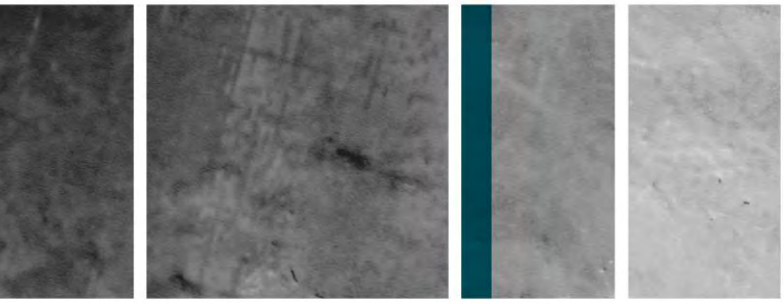
This section encompassed the lower part of the weir pool. The river was consistently 75 m wide with an average depth around 2.5 m. The banks were moderately steep and bare in patches or lined with grass and reeds. There was hardly any large woody debris in the water.

Section 3 – Stock drinking fence to town pump station

The lower reaches of this section were 75 m wide and similar to Section 2. Midway through the reach, the river became narrower and deeper and the amount of submerged woody debris and other structure increased both midstream and on the banks. The water reached a maximal depth of 5 m adjacent to the pump station

Section 4 – Town pump station to fork in river

The river widened again (>75 m) in the lower portion of this reach and the water depth decreased considerably. The banks had a gentle slope on the western shores with a shallow shelf (< 0.5 m deep) extending out 10–25 m. The eastern shore rose more steeply and



contained several large pieces of woody debris. The main channel was around 2 m deep and lined on its western edge with several still standing drowned trees.

Section 5 – Fork in the river to the narrows

The river was wide and shallow in this reach. There were a few standing trees in the shallower margins and width was around 75 m. The western shore had sections of grassy bank extending into the water and the occasional undercut tree.

Section 6 – Narrows to railway bridge

This reach was much narrower than downstream sections. The river formed a channel only 10–15 m wide with one main anabranch. The water depth was 1–2 m and there were fallen tree branches providing structure in the water at numerous places. An area of shallow muddy flats and marshes extended eastwards for about 50 m in the middle of the section. The banks were generally steep, with moderate levels of emergent grass in shallower sections. Towards the railway bridge the river widened and shallowed, with emergent grass dominating the banks.

Section 7 – Railway bridge to gravel wash

The mid-section of this reach was very shallow and dominated by emergent grass island that prevented boat thoroughfare. A small meandering channel bypassed this area along the eastern shore. Beneath the railway bridge the water was deeper and the bank entirely covered by emergent grasses. Towards the gravel the river narrowed to 30 m wide and deepened to around 2 m.

Section 8 – Gravel wash to low concrete bridge

The river was consistently 30 m wide and up to 3 m deep along this stretch. The banks were supported by tree roots with the occasional grassy section. Trees partially shaded large parts of the area. A small section of emergent grass was present just upstream from the highway bridge.

Section 9 – Low concrete bridge to old weir

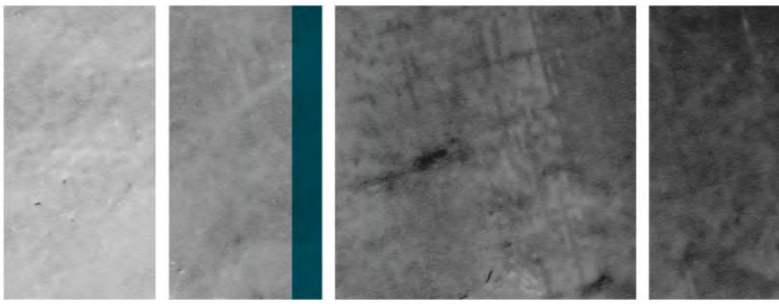
This was a small section. The water below the old weir reached up to 1.5 m in depth and a width or around 40 m. The eastern shore was heavily lined with emergent grass and a verge of aquatic weed beds in parts. The western shore was supported by a tangle of roots. Towards the concrete bridge the river narrowed to 10 m and shallowed to a depth of less than 1 m.

Section 10 – Old weir to Barney's beach

The river was approximately 50 m wide and 2 m deep along most of this reach. There were several pieces of large woody debris and the majority of the bank was stabilised by tree roots. Several large stands on very thick, introduced grass were present.

Section 11 – Barney's beach to homestead on western bank

This section of river was approximately 50– 70 m wide and 2–2.5 m deep. The banks were a mix of grassed areas and parts stabilised with by tree roots. Several large fallen trees stretched nearly across the river. Several dense patches of thick, introduced grass were also present.



Section 12 – Above the homestead on the western bank

The river was initially wide (75 m) for a large part, before turning a corner and narrowing gradually towards the upstream end. The water was 2–3 m deep with several fallen trees providing good structure and banks that gradually flattened towards the upstream end. The section ended in a very narrow reach with overhanging trees grassy verges and a shallow depth. The river continued for a short distance above where boat access was possible, before terminating at a 2-m high weir/causeway wall.

Control site – Bullamon Plains regulator

The control site was located approximately 8 km upstream from Section 12. A pool has been scoured out below regulator at Bullamon Plains. The lower margin of the pool forms a very shallow riffle (<5 cm) while the regulator limits movement further upstream. The pool was generally quite deep, with depths reaching down to 6 m. The banks were all quite steep and the western shore heavily lined with fallen timber. The downstream end finished in shallow water with a large piece of woody debris and grassy banks.

Each section consisted of similar size and took between 2–3 hours of active hunting for carp. Section 9 was somewhat smaller due to the physical constraints of the low concrete bridge and old weir.

Goondiwindi Carp Cull 2008

The competition area extended along the McIntyre River from the Town Commons (below the Goondiwindi town weir) to the base of the Boggabilla Weir (Figure A4), a distance of approximately of 12 km. The area also included the off-river lagoon at Rainbow Reserve, where participants could camp and fishing efficiency be evaluated in a closed environment.

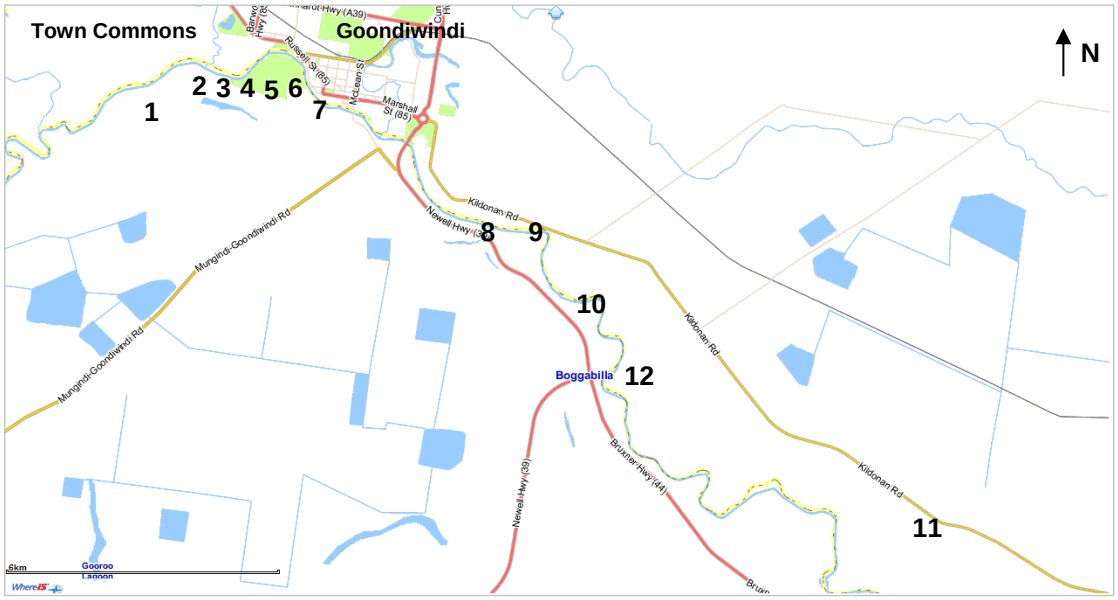
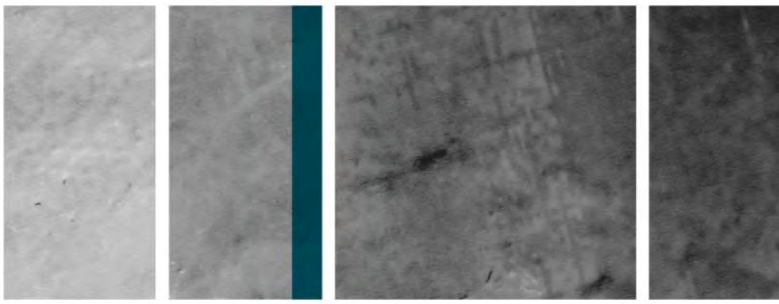


Figure A4. The Goondiwindi Carp Cull competition area on the McIntyre River. The monitoring sections are labelled 1–11 and the river control site is labelled 12. The lagoon control site was located approximately 30 km west of the Goondiwindi township (off the map). Refer to the text for site descriptions.

Monitoring sites were selected with the help of competition organisers. Eleven treatment (fished) sites and two corresponding control sites (not fished) were selected in the region. Each site was based on an area taking three hours of active hunting for carp. All river sites were on the McIntyre River. Prior to the competition, carp were dart tagged in treatment locations during the initial surveys. Captured carp were dart tagged and released to obtain estimates of population sizes and angler efficiencies from recaptures. Prizes were offered for the capture of tagged fish to encourage participants to fish in these areas.

The lagoon treatment site was Rainbow Reserve, a lagoon off the McIntyre River. The lagoon intermittently fills from the main river channel during large flow events, but has been filled via pumping during the recent drought. The lagoon was last filled in early 2008 and currently has moderate water levels. The water body was approximately 2 km long, with an average width of approximately 70–100 m. The banks at the current water level are generally gently sloping, with minimal vegetation and composed of extremely soft black soil. The average water depth was less than 1.5 m, with only a few large woody snags submerged. Half of the lagoon is situated on stock reserve and public access was readily available to this section. The



remainder was located on private property, with the land owners relying on the lagoon for irrigation of cotton fields.

The river treatment sites began at the base of Boggabilla Weir (Site 10). The area consisted of a moderately deep pool (~2 m) immediate below the weir wall, followed by an extremely shallow reach. The site then formed into a typical river reach with very high levels of bankside woody debris.

The next two sites were located above and below the Bondi Bridge, a popular fishing and camping area. The upper Bondi site (Site 9) extended upstream form the bridge, encompassing and area of shallow and/clay substrate before turning into moderately deep water with extensive woody structure. The lower Bondi site (Site 8) extended downstream from the weir and include a large expanse of shallower river (<1 m) followed by a wider stretch with tall grass and treed banks.

The stretch of river between the town weir and the boat ramp formed the majority of the other treatment sites. This reach was divided into six sections, most of which were relatively uniform (Sites 2–7). This area was chosen because many boat and shorebased anglers commonly fish in the area. In general, the river was 50–100 m wide, with a depth of 4 m in the main channel. Banks were steep with areas of submerged grass, tree roots and large woody debris. The bank margins were lined by aquatic plants (*Azolla sp.* and *Myriophyllum sp.*).

The last river site was along the Town Commons (Site 1), below the Goondiwindi town weir. This area of shire owned land has numerous access points and follows a riffle-pool-riffle formation. The waters below the weir's rock-ramp fishway have previously been found to contain carp, particularly when flows occur. The pools in the system have several pieces of medium to large woody debris, separated by very shallow riffles and runs with a gravely substrate. Typically the current was significantly faster through this site compared to the other treatment areas. The water depths ranged from less than 1 m up to 2.5 m deep at the large downstream pool with the treatment area extending nearly 2 km. The average width was typically narrow (8–15 m) except for in the larger pools where it reached up to 40 m.

The river control site was located in the Boggabilla Weir pool near the boat ramp (Site 12). The water level was deep in the middle but shallow, muddy banks were present at the margins. A large amount of timber was present in parts of the area sampled. The water depth averaged around 2–2.5 m and the weir pool itself was several kilometres long. The upstream end of the section sampled was formed by the first major run with shallow water.

The lagoon control site was located on Booberoi Farm (Site 13), 30 km west of Goondiwindi. The lagoon at this site was chosen because it has held a large carp population in the past, the land manager is highly amenable to assisting fisheries research and being on private land the site could not be fished by competition participants. At the time of sampling, the water level in the lagoon was low, with a maximum depth of around 1.5 m. The lagoon was 400 m long with an average width of 40 m. The substrate was predominantly gravel, with several muddy patches and several large fallen trees provide a bit of structure.

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