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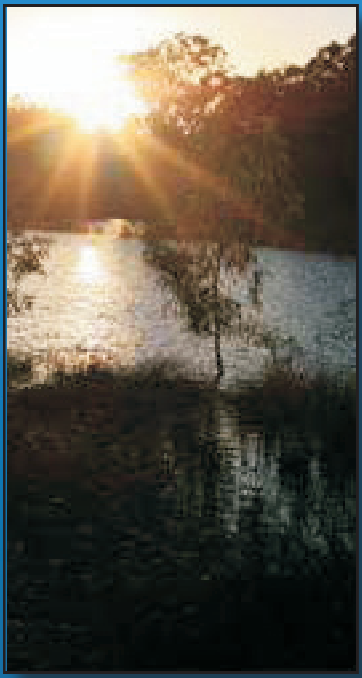
Olive Perchlet (*Ambassis agassizii*) in the Lachlan River: Population Status and Sustainability in the Lake Brewster Region

A report submitted to the Lachlan Catchment Management Authority



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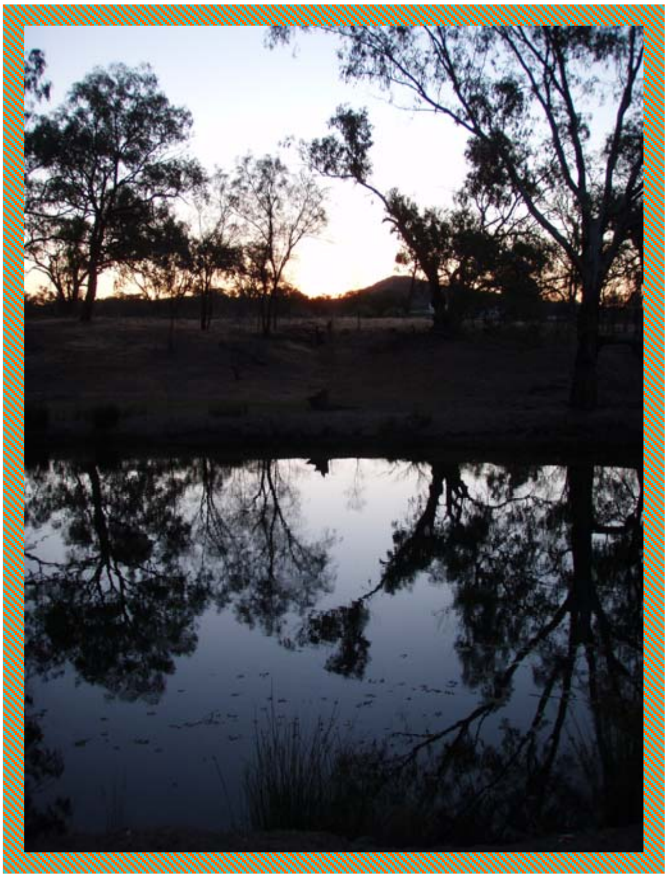

Frontispiece: Benson's Drop Weir pool at sunset.

Executive Summary

A single olive perchlet (*Ambassis agassizii*) was discovered in Mountain Creek, an anabranch of the Lachlan River, during a fish survey in October 2007. A subsequent pilot survey found that a significant population was present in the weir pool above the Benson's Drop Weir in Mountain Creek, which serves as the outlet channel for draining the Lake Brewster Storage into the Lachlan River, a few hundred metres downstream of the weir.

This dedicated follow up survey was conducted for the Lachlan Catchment Management Authority by a collaborative team from SARDI Aquatic Sciences and NSW DPI. The aim of the survey was to determine the status and distribution of the olive perchlet population in the area and to assess the potential risks to the population due to planned improvement works for the Lake Brewster facility. A range of methods were used during the survey, including boat electrofishing, box traps and fyke netting to survey a number of sites in the Lake Brewster region.

The survey found a large population of olive perchlet with almost 5,000 individuals captured during the five-day survey. Whilst many fish were captured from the original discovery site in Mountain Creek, the majority of individuals were captured around the Lake Brewster Weir. These fish were captured both in the weir pool and below the wall, in the main channel of the river and the conduit channel. Olive perchlet were also captured in the Lachlan River upstream of Lake Brewster Weir and in the River near the junction of Mountain Creek, but were not found at sites farther downstream of the junction or below Willandra Weir. It appears that the population is highly localised to the Lake Brewster region.

Ageing and length-frequency distribution analysis concluded that the majority of the population was comprised of young-of-the-year fish spawned over November and December 2007. Spawning occurred at water temperatures above 22-23ºC during a period of summer low flows when there was a wide range of sheltered, shallow and well-vegetated habitats available for spawning. These summer low flow conditions are likely the result of the present drought. Under the resumption of normal river operations, appropriate low-flow spawning habitats are likely to be rare. Therefore the provision of

such habitats (or hydrological conditions) should be a primary management objective for maintaining sustainable perchlet populations. There are also opportunities to recreate these conditions within the Lake Brewster Development and create an ideal perchlet habitat within the operational framework of the Lake.

The failure to detect any perchlet over a year old and the rarity of specific flow conditions leading to the formation of habitat preferred by perchlet at the time of spawning in the summer of 2007/08, suggest that the current abundance of this highly threatened species may represent an exceptional, annual recruitment boom and does not necessarily mean that the population is sustainable in the long term. These results demonstrate that both careful management and ongoing monitoring and research are required to fully understand the factors that will support long-term viability of the population.

It is believed that the distribution of the species around the Lake Brewster area serves to minimise risks to the population that may stem from proposed Lake Brewster Works. As long as a large source population exists outside of Mountain Creek, the risk of widespread impacts from these works remains relatively low. Care must be taken, however, to maintain the habitat value of shallow, well vegetated pools such as those at the Benson's Drop Weir pool that can serve as refuges and spawning sites for the species under less favourable conditions than were present in summer 2007/08.

1 Introduction

1.1 Olive perchlet (Ambassis agassizii)

The olive perchlet is a small-bodied native fish that grows to around 78mm, but is more commonly found around 50mm in length. It is oval shaped and laterally compressed with large eyes and mouth and prominent dorsal fins. The colour ranges from olive green to almost transparent (Ogilby 1910, McDowall 1996, Morris *et al.* 2001, Lintermans 2007).

Olive perchlet inhabit freshwater pools and slower flowing reaches within rivers, streams and swamps (Leggett 1984, Allen & Burgess 1990). They form large schools that are closely associated with macrophyte beds (Arthington *et. al.* 1983, Allen & Burgess 1990), particularly *Vallisneria* and *Nymphoides spp.* (Milton & Arthington 1983). They live for around three years and reach sexual maturity after one year, spawning amongst aquatic vegetation from late spring to mid-summer, depending on the latitude, when water temperatures reach 22-23ºC (Leggett 1984, Milton & Arthington 1983). They are carnivorous, eating micro-crustaceans, insect larvae and some other items (Medeiros 2004, Lintermans 2007).

Olive perchlet were historically widespread across the Murray-Darling Basin (MDB) and coastal catchments of south-eastern Queensland and north-eastern New South Wales (NSW) (Allen & Burgess 1990). Over the past century, however, its range has greatly contracted and it is now extinct in Victoria and presumed extinct in South Australia (SA) and has disappeared from much of southern NSW (Cadwallader 1978, Lloyd & Walker 1986, McNeil & Hammer 2007). Recent records of the species in the MDB have predominantly come from rivers in the Darling catchment in Queensland and northern NSW (Moffat & Voller 2002). Prior to the present study, the southernmost record within the past 47 years was from the Bogan River near Nyngan, approximately 200km north-west of Dubbo (Morris *et al.* 2001). Perchlet were last recorded in the Lachlan catchment near Hillston in 1960 (Australian museum catalogue # 1.25086) (Llewellyn 1983). In inland NSW the distribution of the perchlet population has been reduced so significantly that the NSW Fisheries Scientific Committee has acknowledged it as being in immediate danger of extinction (Morris *et al.* 2001) and has been classified as an

"Endangered population" under Part 2 of schedule 4 of the Fisheries Management Act 1994 (FSC 2001).

Although the exact cause of this broad-scale disappearance of olive perchlet across the MDB is unknown, there can be little doubt that human induced change to riverine flows, habitats and ecosystem processes are integral in their demise (Cadwallader 1978).). The encroachment of urbanisation and related impacts, including the degradation of native habitats, and introduction of exotic competitors, predators and aquatic weeds have been directly implicated in the disappearance of olive perchlet populations in the 1970's and 80's (Arthington *et al.* 1983). The overall impact of river regulation on the NSW population remains unclear and is likely to be scale dependant, leaving small communities within a broadly impacted population (Gehrke & Harris 2001).

In systems with low species diversity, such as the MDB fish fauna, single species possess proportionally high biodiversity value and their loss consequently poses a significant biodiversity impact. The demise of the Victorian olive perchlet population serves as a warning. The population was seen to be 'at risk' due to their patchy distribution, prior to their complete disappearance (Cadwallader *et al.* 1984). Without management intervention, the same fate is likely to befall extant perchlet populations within NSW. Therefore great care should be taken to reduce or reverse anthropogenic impacts, or riverine and catchment management practises that might impact negatively on these populations. NSW DPI has recommended returning natural flow regimes, re-introducing woody debris, facilitating fish passage and eradicating alien fish species as key recovery objectives/management actions required to protect or restore perchlet populations (Morris *et. al.* 2001).

Information about the population structure of olive perchlet, their preferred habitats and interactions with other species is required for management. Although information on population structure can be gathered by length-frequency analysis, surveys coupled with otolith analysis provide greater detail for elucidating early life-history characteristics of fish (Fowler and Short 1996). Otolith analysis has become an invaluable tool for investigating the population dynamics of fish and can be used to determine not only the age of fish but also back-calculate spawning dates (Brothers *et al.* 1976) and determine daily growth rates (Brothers and McFarland 1981, Panella 1971). The information gained from this approach, in addition to field surveying, is integral to guiding the successful management of endangered populations such as the olive perchlet.

1.2 Project background

Olive perchlet were rediscovered in the Lower Lachlan catchment between Lake Cargelligo and Hillston for the first time in 47 years in spring 2007 (Figure 1). Initially an individual perchlet was captured in October 2007 at Benson's Drop in Mountain Creek (Lake Brewster outlet) near the confluence with the Lachlan River (Figure 3). The discovery occurred during the collection of baseline data for the Lachlan River Carp Control program (co-funded by the LCMA and the Invasive Animals Co-operative Research Centre [IACRC]).

Figure 1. A) Olive perchlet captured in the pilot survey conducted at Benson's Drop in October 2007; B) The first olive perchlet was captured in this fyke net at Benson's Drop Weir. This net spanned a gap in the weir that was created during trial construction of a wetland carp separation cage.

After the identification of this individual perchlet was confirmed, a subsequent survey was conducted and a substantial population of perchlet (30 individuals) were captured in the weir pool above Bensons Drop (Figure 3). The following month, two more perchlet were discovered below Benson's Drop, suggesting that the population was not confined to the area upstream of the weir pool and may have been present in the Lachlan River itself.

This discovery of an extant olive perchlet population in NSW was important for a number of reasons, including that it greatly increased the biodiversity value of the habitats in Mountain Creek, as previous evaluation had found these habitats to be of low ecological value (GHD 2006). Furthermore, the planned upgrades to the Lake Brewster facility will involve major construction works within the Mountain Creek channel, directly upstream of the population. The discovery also held possible consequences for the management of water delivery operations by State Water, as the site is the sole outlet channel for draining Lake Brewster. If the Mountain Creek population represents the sole refuge for this very rare species within the catchment then great care should be taken to minimise the potential for any impacts arising from natural resource management or river operational works.

The specific aims of this survey were to:

1) Conduct a fish survey to determine the distribution of olive perchlet (and other fish species) in the Lachlan River catchment.
2) Investigate spatial variations in the relative abundances and population structure of olive perchlet in the region.
3) Assess the spawning and recruitment of this olive perchlet population and examine the relationship between size and age.
4) Explore relative efficiencies of different fishing methodologies.

The results of this survey were then used to:

1) Ascertain the status of the population in Mountain Creek.
2) Determine the spatial distribution of the population in the area, including above Brewster Weir (upstream) and below Willandra Weir (downstream).
3) Evaluate the potential risks to the viability and sustainability of the olive perchlet population, which may arise from the planned construction works.
4) Assess the potential for translocation activities to protect 'at risk' populations of this species.
5) Provide recommendations on the long-term sustainability of the perchlet population in the area.

2 Methods

2.1 Fish community survey

The main field survey was carried out between the 10th and 15th of February 2008, by SARDI and NSW DPI. This survey was focussed around the Lake Brewster area including Mountain Creek and the Lachlan River.

Two separate survey methods were utilised during the present study: For the first surveys, 3mm mesh fyke nets (both single and double-winged) were set within shallow (depth <2m) habitats. In open areas, these were set within each of the major habitat types present (bare banks, emergent macrophyte beds, submerged macrophyte beds, large woody debris). In smaller, shallower pools (depth <0.6m), single nets were placed in the deepest section of the pools as near as possible to those habitats that were most likely to support the highest numbers and diversity of fish. All nets were left for ~24 hours to account for potential diurnal movement of fish. After this time, nets were pulled and fish identified and counted. The total body lengths (TL, mm) of each olive perchlet were measured. All fish were released at the point of capture.

For the second survey method, a boat mounted electrofishing unit was used. Sites were located at the centre-point of a one kilometre stream reach and were chosen randomly following Sustainable Rivers Audit (SRA) protocols (Davies *et al.* 2008). Electrofishing was conducted along both banks of four 1km reaches in the main channel of the Lachlan River. These reaches were separated from each other by at least 2 kilometres. SRA protocols include the deployment of ten box traps (40cm x 24cm x 24cm; 7mm opening) along each reach for the duration of electrofishing operations. For both box traps and electrofishing catch, all fish were identified, counted and lengths measured prior to release at the point of capture.

For each taxon, the mean numbers of individuals captured at each site, and the mean proportion of that taxon as a percentage of the total number of fish captures at each site, were calculated. These data were used to assess changes in both the relative abundances of each fish taxon between sites and the patterns of dominance in the fish community at each site.

For each site, the size distributions of olive perchlet were plotted. A Kolmogorov-Smirnov two-tailed test was used for pairwise comparisons between sites (using SPSS, version 15.0). This test computes the largest difference, at any step, between two length-frequency distributions for pre-determined length groups (McKillup 2005). Water quality parameters, specifically dissolved oxygen, conductivity, pH and water temperature were measured using a TPS-90FLT handheld multimeter at all survey sites.

2.2 Study area

Lake Brewster was naturally an ephemeral lake, which was developed during the 1950's into an off-channel storage for the delivery of irrigation flows to the Lower Lachlan catchment (Thurtell *et al.* 2003). The original artists impression of the developed site can be seen in Figure 2. The study was conducted in the Lake Brewster region, spanning the reach from Lake Brewster Weir pool to the Lachlan Mountain creek Junction (Figure 3). Two sites (Tonto's and below Willandra Weir) were surveyed to evaluate the distribution of perchlet downstream of Brewster Weir. However, the majority of sites were located close to the Lake Brewster inlet and outlet channels and the adjoining reach of the Lachlan River.

Figure 2. Artist's rendition of the Lake Brewster plans showing the study area. Brewster Weir is on the far left and the Mountain Creek/Lachlan Junction on the bottom right. Lake Brewster is in the background with the original route of Mountain Creek crossing the frame in the middle distance dissecting the Lake Brewster inlet channel. This photograph was taken from the original mural in the Lake Cargelligo State Water depot, with permission of State Water.

2.2.1 Netting sites

The fyke netting survey was conducted across ten sites in the Lachlan River and in the adjacent Lake Brewster outlet channel/Mountain Creek complex. (Figure 3) The most upstream site was above Lake Brewster Weir and farthest downstream was below Willandra Creek Weir. Netting was conducted at four sites in the Lachlan River at (in order from upstream to downstream) Lake Brewster Weir, Lake Brewster Weir conduit channel (Below the Weir), the Junction of the Lachlan River and Mountain Creek and downstream of Willandra Weir. A single seine net (3 m in length, 2 mm mesh) was used at the Lake Brewster Weir conduit channel. A single sweep was conducted covering a circular area of approximately 4 m in diameter.

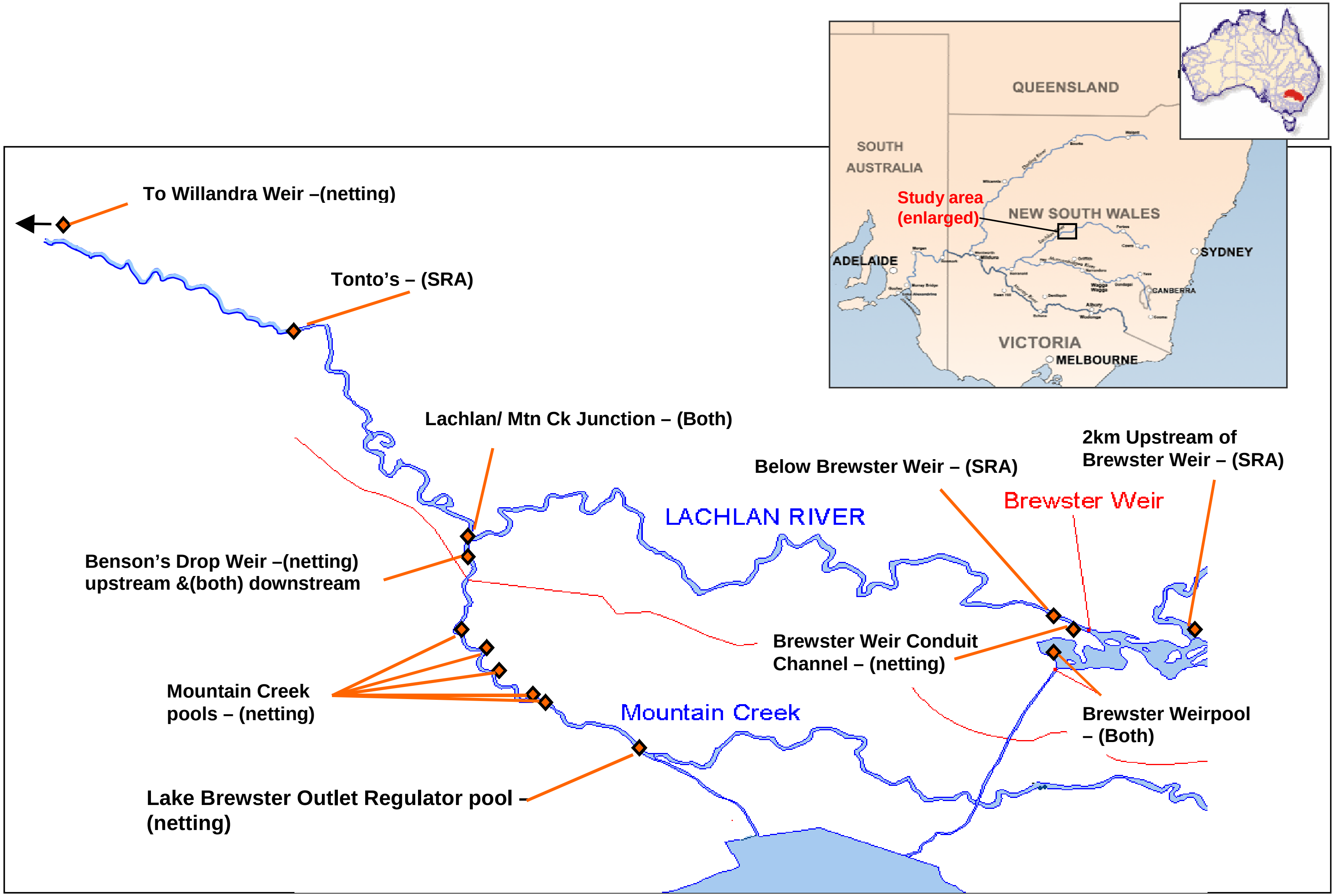

Figure 3. Study area and site locations showing survey methods used at each site.

In addition, eight netting sites were surveyed along the Lake Brewster outlet channel incorporating Mountain Creek. These sites included the Lake Brewster outlet regulator pool, five small pools along the length of Mountain Creek upstream of the Lachlan Valley Way road bridge, and two sites at Benson's Drop, one in the weir pool and the other in the creek below the weir adjacent to the Lachlan junction. Photographs of each sampling site are presented below (Figure 4, Figure 5, Figure 6).

Figure 4. Survey sites A) above Brewster Weir, note complex littoral vegetation and B) Brewster Weir Conduit channel, submerged macrophyte beds are not visible but were extensive.

Figure 5. Lower Mountain Creek sites A) Benson's Drop weir pool, the site of the original discovery, B) Downstream of Benson's Drop adjacent to the Lachlan River junction, C) Benson's Drop looking upstream from below the weir and D) The Lachlan River at the Mountain Creek junction; Setting nets by canoe.

Figure 6. Lake Brewster Outlet Channel and Mountain Creek netting sites. Pictures were taken at time of surveying except for A, which shows water levels slightly higher than those during surveying. A) Brewster Outlet Regulator pool and Mountain Creek pools: B) Pool 1; C) Pool2; D) Pool 3; E) Pool 4; F) Pool 5.

2.2.2 Electrofishing and box trapping sites (SRA methodologies)

Electrofishing was conducted at six sites using SRA protocols (Davies *et al.* 2008). Due to boat access, these sites were confined to deeper reaches, mostly in the Lachlan River. From upstream to downstream, the sites were located: 2 km upstream of Lake Brewster Weir, Lake Brewster Weir (upstream of the inlet regulator), the Lachlan River below Lake Brewster Weir, the Lachlan River across the junction with Mountain Creek, lower Mountain Creek below Benson's Drop and the Lachlan River at Tonto's approximately 10 km downstream of the Mountain Creek junction (see map in Figure 3).

2.2.3 Hydrology of survey area

No flow data was available for the Lachlan River below Brewster Weir during the study period. However, the river height data from the conduit outlet gauge shows a pattern of low water levels throughout October, November and early December 2007, with a sharp peak in late December 2007 that was sustained into early January 2008 (Figure 7). Flow data was available for Benson's Drop over the period and shows similar, but flashier patterns to the conduit hydrograph (Figure 8). The peak in flow resulting from the December flash flood can be clearly seen at Benson's Drop. A smaller flow pulse also occurred in October (the carp control project's experimental flow through Lake Brewster at the time of the original perchlet discovery) and an even smaller flow pulse in late November, probably representing local rainfall.

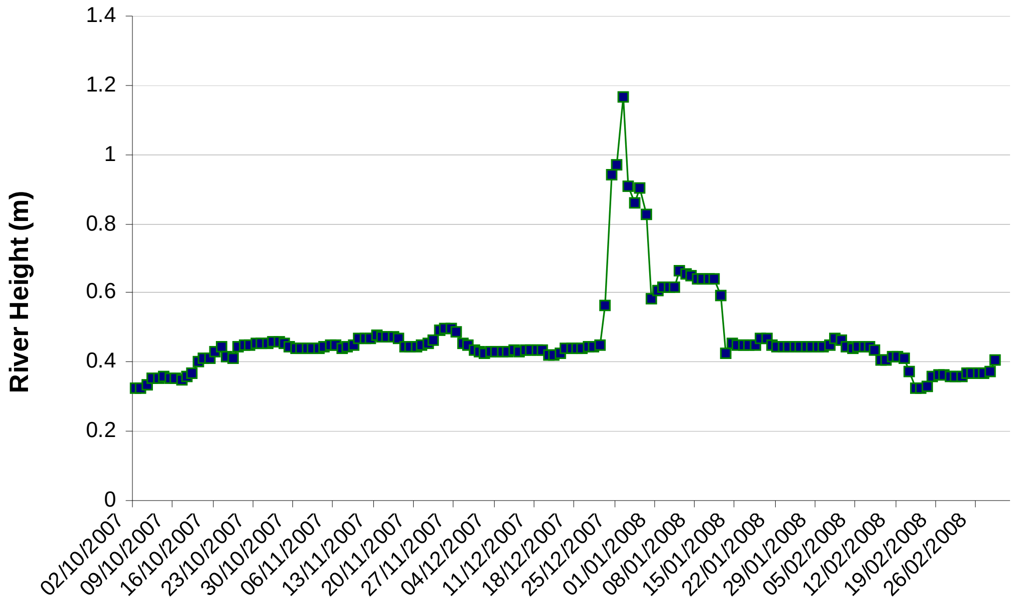

Figure 7. Gauge height at the Lake Brewster Weir Conduit outlet channel from October 2007 to the end of February 2008.

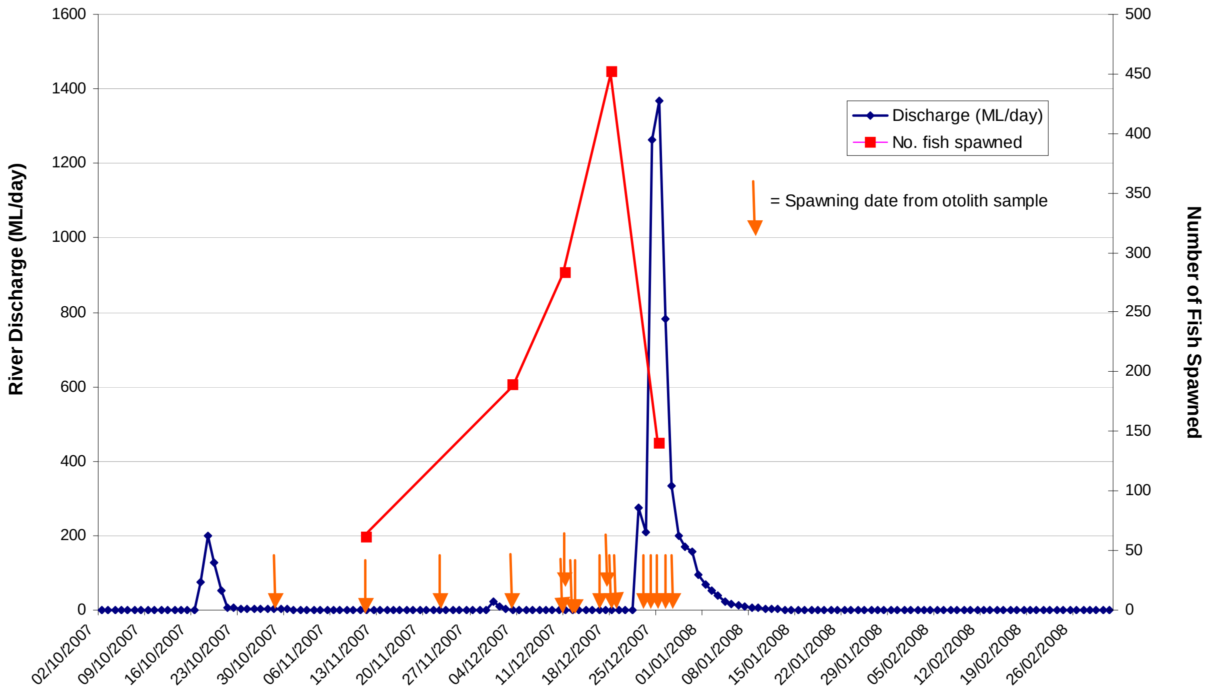

Figure 8. Mean daily discharge over Benson's drop weir overlain with the spawning dates from specimens in the otolith study (orange arrows) and the estimated number of the total fish catch spawned over the period as inferred from the age-size frequency relationship (using only known-age size classes).

2.3 Ageing study

A study was conducted to examine the relationship between age and fish length for the olive perchlet so that the overall age structure of the population and longevity of adult fish could be determined. Fish age was determined using otolith daily growth rings for a small sub-sample (*n* = 17) of fish ranging from 18-44 mm in length. Through an oversight (and due to their rarity), none of the very largest individuals (>44 mm TL) were retained for the aging study.

Otoliths were prepared and measured as described in Molony & Sheaves (1998). This involved the preparation of a transverse section of the sagittal bone from each fish which was fixed to a microscope slide using thermo-plastic cement (Crystalbond©) and ground on 600-1200 grade carbolundum paper until the nucleus was reached. This was polished with a felt pad and 0.3µm alumina powder. The thermo-plastic cement was then re-heated to ~110°C and the otolith re-positioned so that the polished section was face down. This was then repeated for the un-ground side of the otolith. The result is a transverse section approximately 50-100µm thick. This section was then mounted on a microscope slide using thermo-plastic cement (Crystalbond©).

Although there is no available data on otolith analysis from *A. agassizii*, previous studies of the closely related *Ambassis vachelli* have identified clear daily growth rings regardless of diet (Molony & Sheaves 1998) and determined the counting of daily incremental growth rings within each saggitta provided a clear indication of fish age. In the present study counts of saggittal increments were repeated four times at 400 X magnification for each otolith.

Regressions analyses between fish length and estimated fish age indicated that the data fitted an exponential curve. Therefore, a linear regression was performed on the relationship between fish length and (natural) log-transformed fish age data, using the least squares method with Excel software package.

3 Results

3.1 Catch summary

A total of 27,144 fish were captured and processed during the week-long survey conducted in February 2008 (Table 1). Apart from the olive perchlet (*Ambassis agassizii*), eight species of native fish [carp gudgeon (*Hypseleotris spp.*), unspecked hardyhead (*Craterocephalus stercusmuscarum*), flatheaded gudgeon (*Philypnodon grandiceps*), bony herring (*Nematalosa erebi*), golden perch (*Macquaria ambigua*), Murray cod (*Maccullochella peelii*) and Australian smelt (*Retropinna semoni*)] and three species of introduced fish [common carp (*Cyprinus carpio*), Eastern gambusia (*Gambusia holbrooki*) and goldfish (*Carassius auratus*)] were captured (Table 1).

The most dominant taxa were the native carp gudgeons (n=10,336). Two other small-bodied natives, unspecked hardyhead and olive perchlet were also highly abundant (n=5,409 and n=4,912, respectively). European carp were the most abundant introduced species (n=4,571). The vast majority of these were young-of-the-year recruits, with fewer than 100 adults captured (primarily during electrofishing surveys in the main river channel) (Table 1). Introduced Eastern gambusia were somewhat less abundant (n=1502). The native flatheaded gudgeon and bony herring were captured in relatively low numbers (160 & 199 respectively), as was the introduced goldfish (17 in total). The iconic larger bodied, angling species golden perch (n = 33) and Murray cod (n = 4) were captured in reasonable numbers given their relatively low population densities when compared to small-bodied species (Harris & Gehrke 1997) (Table 1).

Table 1. Fish species captured during the surveys conducted in summer 2008, as well as the conservation status and total number of each species caught. The conservation status of each taxon is based on *Fisheries Management Act (1994) and **Morris *et. al.* (2001).

Common Name	**Scientific Name**	**Conservation Status**	**Number Captured**
Carp Gudgeon	*Hypseleotris spp.*	Common	10,336
Unspecked Hardyhead	*Craterocephalus stercusmuscarum*	Common	5,409
Olive Perchlet	*Ambassis agassizii*	Endangered Population*	4,912
Carp	*Cyprinus carpio*	Exotic Pest	4,571
Eastern Gambusia	*Gambusia holbrooki*	Exotic Pest	1,502
Flatheaded Gudgeon	*Philypnodon grandiceps*	Common	160
Bony Herring	*Nematalosa erebi*	Common	199
Golden Perch	*Macquaria ambigua*	Potentially Threatened**	33
Goldfish	*Carassius auratus*	Exotic Pest	17
Murray Cod	*Maccullochella peelii*	Potentially Threatened**	5
Australian Smelt	*Retropinna semoni*	Common	1
Total Catch:			**27,145**

3.3.1 Netting survey

The Lachlan River above Brewster Weir

Of all sites sampled the highest number of fish per net captured was at the site above Brewster Weir (Figure 9). A total of 12,434 fish were caught in three fyke nets at this site, equating to a catch per unit effort (CPUE) of 4,145 fish per net (Table 2). There were seven species present and the community was dominated by native fishes, which made up 98% of the total catch (TC), primarily gudgeons (39% TC), olive perchlet (33% TC) and unspecked hardyheads (26% TC) (Figure 9). Flatheaded gudgeon, carp, Eastern gambusia and bony herring made up the remaining 2% of the catch.

The Brewster Weir Conduit Channel had a CPUE of 161 fish per net (Table 2), with a total catch of 321 fish from 6 species. As with the weir pool, this site was dominated by native species. Olive perchlet accounted for 63% of the catch, with gudgeons accounting for 29%. Eastern gambusia, unspecked hardyhead, carp and flatheaded gudgeon made up the remaining 8%, with introduced species (Eastern gambusia and carp) representing only 5% of the total catch (Figure 9).

At the Mountain Creek Junction in the Lachlan River 1,796 fish in total were captured, equating to a CPUE of 273 fish per net, 99% of which were natives (Table 2). The species richness (n=8) was the highest of any site, with Murray cod the only species collected at other sites that was missing. The catch at this site was dominated by large numbers of carp gudgeons, which made up 70% of the total catch, and unspecked hardyheads made up a further 22%. Of the less dominant species, olive perchlet represented 4% of the total catch and flatheaded gudgeon represented 3% of the total catch, whilst small numbers of large-bodied species including golden perch (0.1%), carp (0.1%) and bony herring (0.1%) were collected. The introduced Eastern gambusia (1%) were also present in low numbers.

Mountain Creek and Brewster Outlet

The fish communities in Mountain Creek pools had low species diversity, with only four species present in four of the pools and five species in Pool 5 (Figure 10). Although there was minimal variation in species richness across all of these pools, they varied greatly in their fish densities, with CPUE between 40 (pool 3) and 1119 (pool 4) fish per net.

Introduced species accounted for 96% of the total catch from Mountain Creek pools. Carp dominated all of the pools, where they contributed between 49% and 89% of the total catch. Additionally, Eastern gambusia represented between 9% and 30% of individual pool catches (Figure 10).

Native fish were much rarer than introduced taxa, but were also captured in the small pools along the Mountain Creek channel. Carp gudgeon (3% TC) and olive perchlet (1% TC) were both present in low numbers in most pools (olive perchlet were captured in all pools except for Pool 3), but contributed up to 18% and 8% of the total numbers of fish captured in some pools, respectively. Golden perch were also captured from the pools in Mountain Creek and comprised 0.4% of the total catch (Figure 9) and up to 3% of the catch from individual pools (Figure 10).

The fish community in the large pool directly below the Lake Brewster Outlet Regulator was more diverse than those in each of the Mountain Creek pools with seven species, including unspecked hardyhead and bony herring in addition to those taxa in the smaller pools. As with the Mountain Creek pools, the catch was dominated by small young-of-year carp, although larger adult carp were also present in this pool. Carp made up 64% of the fish catch (Figure 9 and Figure 10).

There was a relatively high proportion of native fish in the Brewster Outlet Regulator pool compared to the Mountain Creek pools, with gudgeons (16% TC), olive perchlet (13% TC) and hardyhead (4% TC) being the most abundant. This large pool also contained a number of larger native fish species, particularly bony herring (2%) and golden perch (0.4%). Mosquitofish (1%) were also present.

Golden perch were rarely captured in fyke nets at any site; however, the collective outlet channel pools possessed a relatively dense population compared to all other sites. Most of these fish were captured in the large pool below the outlet regulator, but they were also captured downstream in Mountain Creek Pools 3 and 5 (Figure 10) and farther downstream below Benson's Drop. All golden perch captured were adults between 220mm and 552mm in length.

Many of the golden perch from these pools were observed to be in poor health with evidence of bacterial and parasitic infections. A number were also found dead, floating on the surface of the outlet regulator pool.

Benson's Drop

The same seven fish taxa were captured both above and below Benson's Drop. This species richness was higher than that of the pools farther upstream along Mountain Creek, due to the presence of bony herring and flatheaded gudgeon in addition to those species in the pools, and differed from the Brewster Outlet pool in having flatheaded gudgeon rather than golden perch (However, golden perch as well as Murray cod were picked up below Benson's drop in the electrofishing survey).

A total of 3027 fish were captured above Benson's Drop, equating to a CPUE of 378 fish per net (Table 2). As with the Outlet Channel and Mountain Creek pools, however, Benson's Drop Weir pool was dominated by introduced carp (43%) and mosquitofish 13%, but also possessed a very large population of native carp gudgeon (43%). The remainder of the catch consisted of olive perchlet (1%), hardyhead (0.2%), flatheaded gudgeon (0.1%) and bony herring 0.1%) (Figure 9).

Below the weir (Benson's Drop D/S), a total of 2,784 fish were captured with a CPUE of 696 fish per net, the third highest of any site. The fish community differed greatly from the rest of the Mountain Creek/Brewster Outlet Channel sites and instead resembled the riverine catches, in that the capture at this site was dominated by small-bodied native species (over 96%). Hardyhead (50%) and carp gudgeon (42%) were the most common fish taxa captured, with a substantial number of olive perchlet (4%) and mosquitofish (3%), and low numbers of bony herring (1%), carp (0.5%) and flatheaded gudgeon (0.3%) captured at the site.

The Lachlan River below Willandra Weir

The most downstream site surveyed was below Willandra Weir, where 1636 fish were captured representing six species, with a CPUE of 273 fish per net (Table 2). This site differed from the Lachlan River sites adjacent to Lake Brewster in that it was dominated by introduced mosquitofish (44% of the catch) and possessed no olive perchlet (Figure 9). Native fish were present, with relatively high numbers of carp gudgeons (43%) and hardyheads (13%). Less abundant were flatheaded gudgeons (0.1%), carp (0.2%) and a single large Murray cod (660mm).

3.3.2 Water quality impacts

Water quality at almost all sites was well within the normal tolerable ranges of the fish species present and was unlikely to pose serious threats to the survival of these fish. The exception was the outlet regulator pool, where dissolved oxygen concentration at the time of surveying was as low as 3.5 mg/l at the surface and 1.4 mg/l one metre below the surface.

This pool was potentially a harsh environment for large-bodied fish, with temperatures exceeding 27ºC and oxygen dropping to hypoxic levels overnight, even at the water surface. In combination, low dissolved oxygen concentrations and high temperatures have been shown to represent a severe lethal threat to larger bodied native fish (McNeil 2004, Closs *et al.* 2006, McNeil & Closs 2007). A number of dead large golden perch were found floating on the water surface at this site, most likely due to extended periods of hypoxia (low oxygen) at high water temperatures (this pool reached over 27 °C in the afternoon that surveys were conducted).

Sustained poor water quality such as this is also likely to cause ongoing stress, resulting in chronic immune deficiency and other impacts upon fish health (McNeil 2004). Indeed high rates of parasitic and bacterial infection were found on large golden perch captured from this site. Similar low oxygen conditions were recorded at Mountain Creek Pool 2 where no golden perch were captured. In contrast, those pools containing golden perch were well shaded by riparian vegetation and were cooler and more oxygenated than the pools where perch were absent (Table 3). Pools with perch were all shallow, and likely to dry out in the absence of autumn/winter flows.

Table 2. Total Catch and Catch per Unit Effort (CPUE = number of fish per net) across all sites for all fish taxa. Sites are listed in descending order from highest to lowest CPUE using netting data only. The number of nets used and the total species captured at each site are shown.

Site	No. of nets	No. of Species	Total catch	CPUE
Brewster Weir	3	7	12,434	**4,145**
Mountain Ck Pool 4	1	4	1,119	**1,119**
Bensons Drop D/S	4	7	2,784	**696**
Mountain Ck Pool 5	1	5	418	**418**
Bensons Drop Weir pool	8	7	3,027	**378**
Lachlan River/Mt CK Junction	6	8	1,796	**299**
Lake Brewster Outlet Regulator Pool	8	7	2,361	**295**
Willandra Weir D/S	6	6	1,636	**273**
Mountain Ck Pool 2	1	4	189	**189**
Brewster Conduit Channel	2	6	321	**161**
Mountain Ck Pool 1	1	4	129	**129**
Mountain Ck Pool 3	1	4	40	**40**

Table 3. Water Quality Parameters recorded from each site during the survey period. Some sights were tested at 1-metre depth intervals to account for possible stratification. Brewster Outlet pool was surveyed in the morning and evening to account for changes in oxygen stratification that occurred throughout the day.

Site Water Quality	Oxygen (mg/L)	Conductivity (µs)	pH	Temperature (°C)
U/S Brewster Weir (2km) surface	7.6	411	7.8	27.2
U/S Brewster Weir (2km) 1m	5.7	404	7.1	24.8
U/S Brewster Weir (2km) 3m	1.0	414	6.6	24.1
Brewster Conduit Channel	5.5	402	7.3	23.2
Brewster Outlet Regulator - surface (am)	3.5	757	7.1	23.2
Brewster Outlet Regulator - 1m (am)	1.4	753	7.0	23.0
Brewster Outlet Regulator - surface (pm)	10.5	723	8.4	27.3
Mountain Ck - Pool1	5.1	472	7.8	18.5
Mountain Ck - Pool2	3.5	766	7.0	18.4
Mountain Ck - Pool3	5.6	645	7.4	20.6
Mountain Ck - Pool4	5.0	552	7.4	20.1
Mountain Ck - Pool5	7.5	429	7.1	22.5
Benson's Drop Weir - 1	8.0	320	7.8	23.8
Benson's Drop Weir - 2	5.4	472	7.4	25.5
Benson's Drop Weir - 3	3.8	435	7.0	25.3
Benson's Drop Weir - 4	6.0	431	7.3	27.5
Mountain Ck D/S Benson's Drop	9.2	415	7.5	29.4
Benson's Drop (D/S) - surface	5.6	387	7.5	24.3
Benson's Drop (D/S) - 1m	5.3	387	7.2	24.3
Benson's Drop (D/S) - 2m)	5.3	388	7.5	24.3
Lachlan River - surface	7.9	393	8.0	26.8
Lachlan River - 1m	6.1	363	7.2	25.3
Lachlan River - 3m	4.0	366	7.1	24.7
Tonto's - surface	5.8	383	7.4	24.8
Tonto's - 1m	5.2	383	7.1	24.6
Tonto's - 2.5m	4.2	358	6.9	24.4
Willandra Weir	7.9	408	7.1	23.1

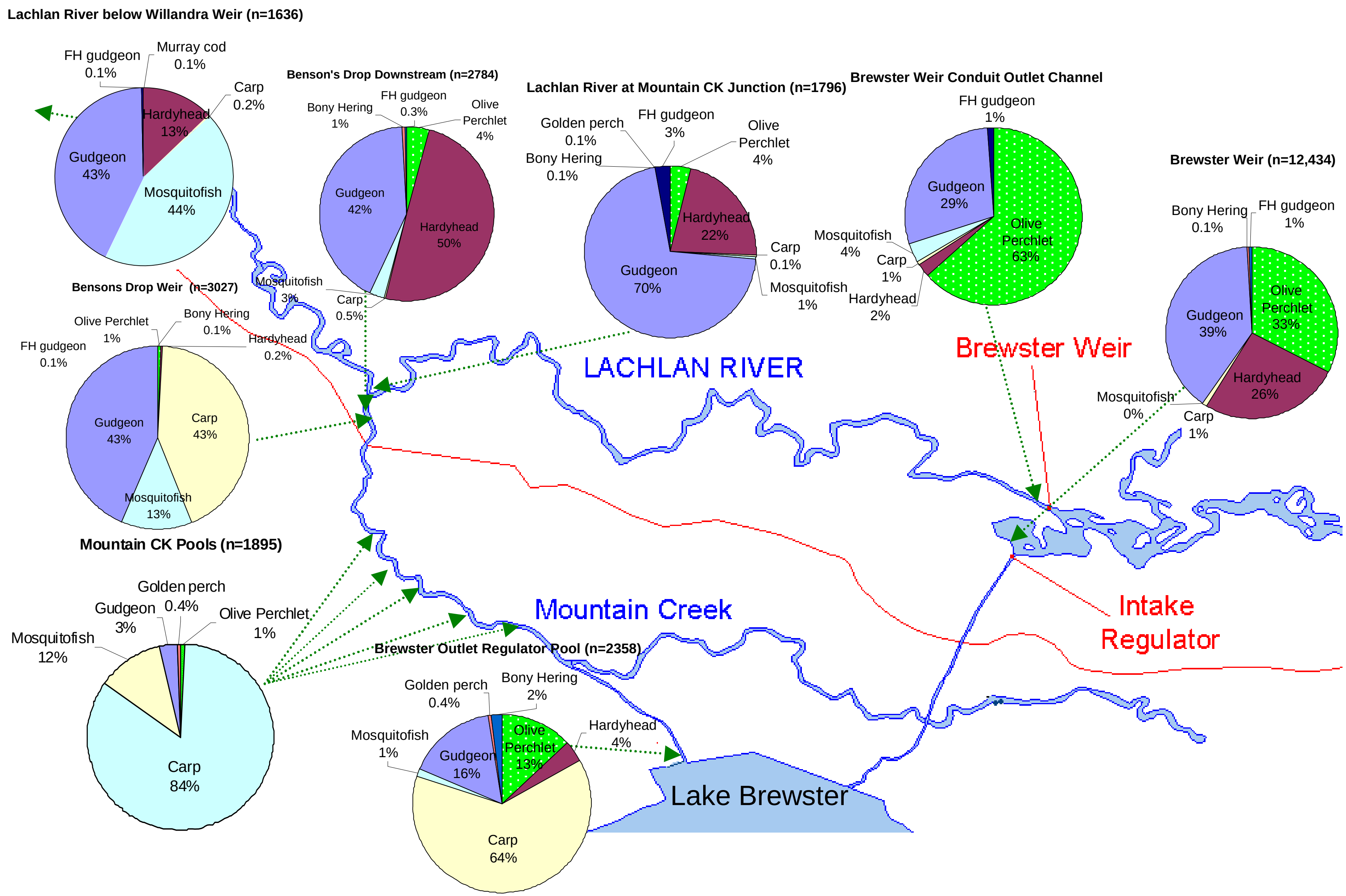

Figure 9. Proportions of fish species across all netting sites (mapped). Note that Mountain Creek pools have been combined here to represent an overall catch for the reach (see Fig. 10 for captures at each individual pool).

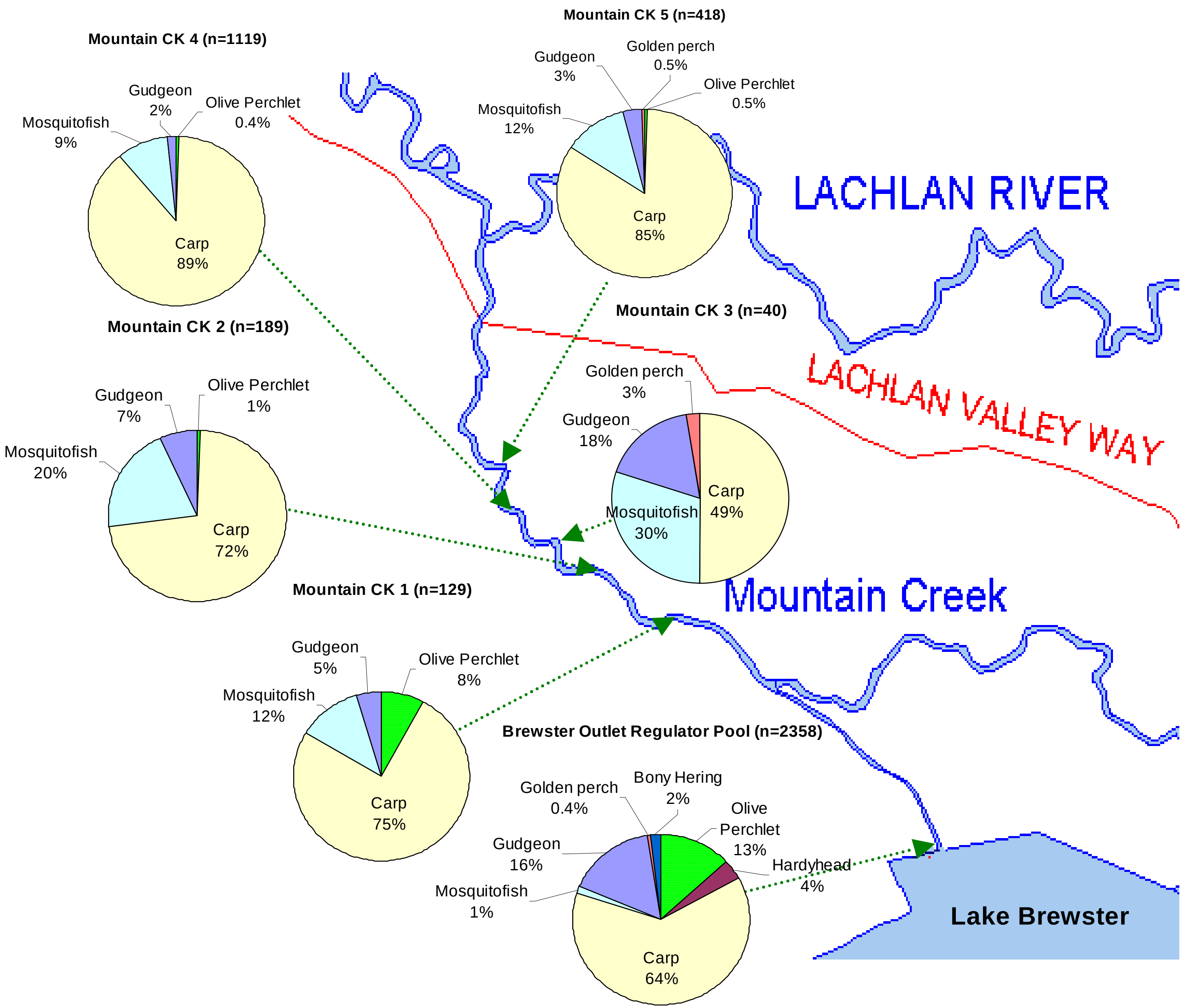

Figure 10. Proportions of fish species across Mountain creek pools (mapped) incorporating the Lake Brewster Outlet Regulator pool (duplicated on Figure 9).

3.1.2 Electrofishing and box trapping sampling (SRA methodologies)

The well-developed methodology of the Sustainable Rivers Audit (MDBC 2004) was utilised for surveying deeper habitats. These surveys were conducted in four sites along the Lachlan River, encompassing an upstream site (2 km upstream of the Brewster Weir), two central sites (Below Brewster Weir and The Lachlan River at the Mountain Creek Junction) and a downstream site (Tontos ~ 5 km downstream of the junction).

At the most upstream reach (U/S Brewster Weir), there was a total of six fish species, 251 individual fish captured (Figure 11). The capture at this reach was dominated by carp gudgeons, which made up 73% of the total catch. The remaining catch was made up of bony herring and carp (10% each), mosquitofish (4%) as well as smaller numbers of flatheaded gudgeon (2%) and olive perchlet (1%) (Figure 11).

Just downstream of Brewster Weir 472 fish were captured which was the highest number of fish captured during the electrofishing surveys. This site possessed all eleven species captured in the Lachlan River catchment during the present study except for Australian smelt, making it the most diverse of all the sites surveyed (Figure 11). The catch was dominated by native species (89% of the catch), particularly olive perchlet (31%), carp gudgeon (28%) and bony herring (18%). The remainder of the catch consisted of the native unspecked hardyhead (8%) and flatheaded gudgeons (1%) and introduced carp (3%) and Eastern gambusia (7%). Two large native species, golden perch (2%) and Murray cod (1%) were also captured whilst electrofishing below the weir. This was the only site at which SRA methodologies were used where any unspecked hardyhead or large numbers of olive perchlet were captured.

At the Lachlan River/Mountain Creek Junction 101 fish, representing five species, were recorded. As in the reach upstream of Brewster Weir, the catch at this reach was dominated by carp gudgeons (79%). Bony herring (9%), golden perch (3%) and the introduced species carp (8%) and goldfish (1%) made up the remainder of the catch (Figure 11).

The fish community in Mountain Creek below Benson's Drop was markedly different from that at the Lachlan River Junction in that no carp gudgeon were captured (the only site this species was absent from) and the catch was dominated by carp (58% of the total). This site yielded the lowest fish abundance with only 17 fish captured. Despite this low number of total captures, golden perch, Murray cod, bony herring and goldfish were all caught (Figure 11).

The catch from Tontos, the most downstream reach surveyed, was low with 51 individuals captured from seven different species. The catch from this reach was dominated by exotics with Eastern gambusia (38%), carp (24%) and goldfish (4%) making up the majority of the catch. Gudgeons dominated the native catch (26%), with golden perch (4%), bony herring (2%) and Murray cod (2%) also captured (Figure 11).

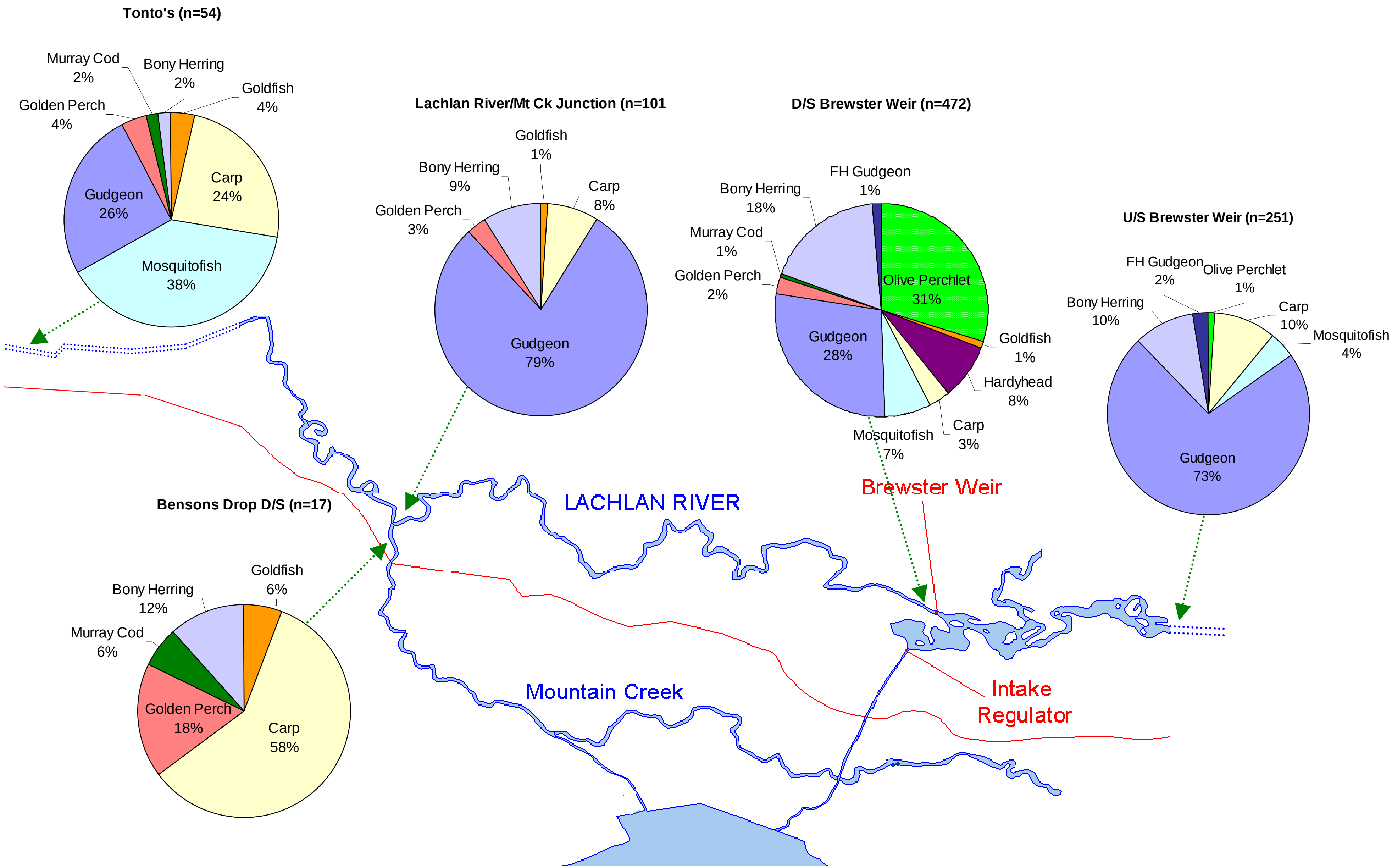

Figure 11. Proportions of each taxa in fish captures across sites using SRA protocols (electrofishing and box traps combined).

3.2 Comparisons of fishing methodologies

The fish species captured were the same for both fyke netting and electrofishing, with the exception of a single smelt which was captured during netting and was absent from all electrofishing catches (Table 4). Fyke netting, however, was more effective than electrofishing in catching large numbers of fish. A total of 26, 254 fish were captured in fyke nets compared to 1090 fish captured using electrofishing and box trapping under the SRA protocols. Seine netting was also effective at catching both large numbers and high diversities of fish, but was only used once. This single pull captured a total of 168 individuals representing five species (olive perchlet, carp gudgeon, hardyhead, flatheaded gudgeon and mosquitofish). This technique was not used more widely as the fyke nets were catching sufficient abundances of fish to make additional collection and processing impractical.

The effectiveness of the different methods in sampling different fish species varied slightly (Table 4). Fyke nets captured much higher numbers of smaller bodied fish including olive perchlet, carp gudgeons, hardyhead, juvenile carp, mosquitofish, and flatheaded gudgeons. For some species, fykes captured up to twenty times more fish than the electrofishing survey. For larger bodied species, however, electrofishing served as a slightly better surveying method, capturing higher numbers of bony herring, golden perch and Murray cod than fyke nets. Goldfish were captured in low numbers using both methods. However, target habitats for the majority of sampling also varied, with fyke nets used more in shallower creeks and pools and electrofishing/bait trapping in deeper riverine areas.

Box trapping captured only five of the twelve species; olive perchlet and carp gudgeons were regularly captured in relatively high numbers, whilst mosquitofish, carp and flatheaded gudgeons were caught only sporadically in low numbers (Table 4).

Table 4. Total catches for each fish species using three different fishing techniques, fyke netting, boat mounted electrofishing (SRA protocols) and box trapping (SRA protocols).

Species	Fyke Netting	Boat Electrofishing	Box Traps
Carp Gudgeon	9,927	298	275
Hardyhead	5,369	45	*
Olive Perchlet	4,769	5	140
Carp*	4,500	70	5
Mosquitofish*	1,441	52	33
Flatheaded Gudgeon	148	9	3
Bony Herring	76	123	*
Golden Perch	14	19	*
Goldfish*	8	8	*
Murray Cod	1	5	*
Smelt	1	*	*
Total:	**26,254**	**634**	**456**

There were three sites where direct comparisons between electrofishing and fyke netting were possible, Brewster Weir, Mountain Creek downstream of Bensons Drop and the Lachlan River at the Mountain Creek junction. Data from these sites showed that fyke netting captured both a higher average number of fish (1688 versus 109), and a higher average number of species (7.6 versus 4.3) than the boat electrofishing survey (Table 5).

Table 5. Comparative catches (total catch and catch per unit effort (CPUE) from netting and electrofishing surveys carried out at the same site on the same day.

	Brewster Weir			**Benson's Drop**			**Mountain CK/Lachlan Junction**		
Species	Fyke total	CPUE (3 fykes)	Electro-fishing	Fyke total	CPUE (4 fykes)	Electro-fishing	Fyke total	CPUE (8 fykes)	Electro-fishing
Gudgeon	4930	1643	*	1175	294	*	1272	159	44
Olive Perchlet	4043	1348	12	117	29	*	68	9	*
Hardyhead	3273	1091	*	1380	345	*	393	49	*
Carp	93	31	5	13	3	11	1	0.1	9
FH gudgeon	85	28	1	9	2	*	48	6	*
Bony Herring	9	3	*	16	4	4	2	0.3	10
Mosquitofish	1	0.3	*	73	18	*	11	1	*
Golden perch	*	*	*	*	*	5	1	0.1	4
Goldfish	*	*	*	*	*	1	*	*	2
Murray cod	*	*	*	*	*	1	*	*	*
Smelt	*	*	*	1	0.3	*	*	*	*
TOTAL:	**12,434**	**4,145**	**18**	**2,784**	**696**	**22**	**1,796**	**224.5**	**69**
No. Species:	**7**		**3**	**8**		**5**	**8**		**5**

3.3 The abundance and distribution of olive perchlet in the Lachlan Catchment

3.3.1 Pre-survey collection of olive perchlet

The initial olive perchlet specimen (44mm length) found in 2007 was captured in a double wing fyke net (3mm mesh) spanning a constructed gap (weir pool raised artificially with sandbags) in the Bensons Drop weir. The site was then surveyed comprehensively using six double wing fyke nets (3mm mesh) placed around the weir pool above Benson's Drop and left for 24 hours. This survey captured a further 30 perchlet from the site.

The habitat in which the population was discovered possessed a dense and diverse macrophyte community. The majority of perchlet (17 individuals) were captured from the large *Vallisneria* bed that covered most of the weir pool where depth was approximately 30cm. Eight perchlet were also captured from an area with a 40% cover of emergent *Eleocharis* and submerged *Vallisneria* and four individuals were captured between *Typha* and a bare bank (four individuals) and Typha and open water (one individual) which was set in the same position as the net which caught the original specimen the previous night. No perchlet were caught in a net placed between a *Potamogeton* bed and *Typha*, although this net was directly adjacent to the net from which the 17 perchlet were captured (Figure 12).

The 30 perchlet captured in this 'pilot' study ranged in size from 24mm to 47mm, with the majority between 25 and 40mm. There was a strong bell-shaped distribution of size classes in this perchlet population, with some smaller and larger individuals and the majority being medium-sized. No individuals captured reached the upper end of the known size range between 50mm and 80mm. To allow comparison between the length frequency distributions at Benson's drop between the pilot and main surveys, this data will not be presented until later in Figure 16: A.

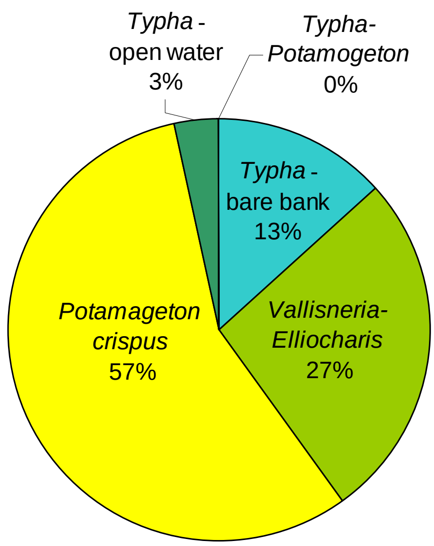

Figure 12. Proportions of olive perchlet catch in different habitat types in Benson's Drop weir in spring 2007. One double winged fyke (3mm) was set in each habitat type for 24h.

3.3.2 Main Survey: Summer 2008

A total of 4,912 olive perchlet were captured during the main survey conducted in summer 2008, representing just over 18% of the total fish catch. These fish were only absent from two of the 13 sites surveyed across the study area (below Willandra Weir and Mountain Creek Pool 5). The highest abundance of olive perchlet was found above Brewster Weir where a total of 4,043 perchlet (82% of the TC) were captured in only three fyke nets, an average of 1,348 per net (less than six perchlet per net (Figure 13).

Figure 13).

A further six fykes were set at this site and whilst all appeared to hold similar quantities of perchlet to the nets which were processed, counting and measuring such a large number of fish was impractical and these catches were released without being processed. The second highest density of olive perchlet was at the Brewster Weir conduit channel, with 101 perchlet captured per net. At the sites below the Lake Brewster outlet regulator and Bensons Drop, 38 and 29 perchlet per net were captured respectively, whilst the Lachlan River Mountain Creek junction had approximately 11 fish captured per net. All other sites had less than six perchlet per net (Figure 13).

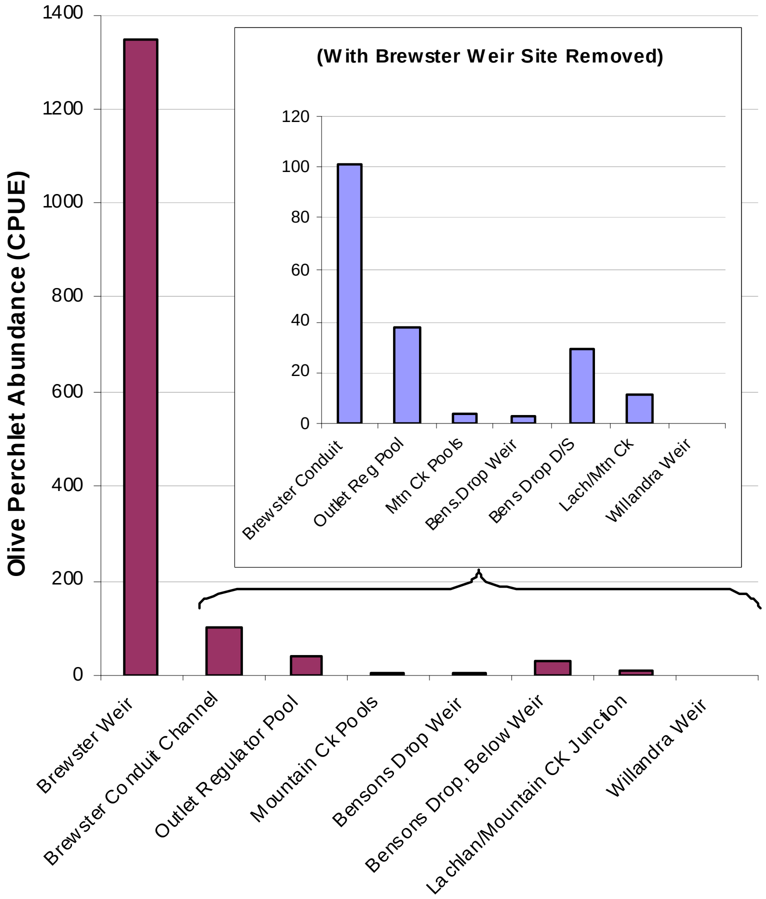

Figure 13. Number of olive perchlet (per net) captured at each sampling site using fyke nets.

Olive perchlet were only found at two sites using the SRA protocols of boat electrofishing and box trapping. A total of five perchlet, three of which were found 2km upstream of Brewster Weir and two below Brewster Weir, were found during electrofishing surveys. From the box-trapping component of the SRA survey, 140 olive perchlet were captured downstream from the Brewster Weir. However, these types of traps failed to catch any perchlet at the Lachlan/Mountain Creek junction, below Benson's drop or at Tonto's.

3.3.3 Comparing the Benson's Drop population 2007 and 2008

Although not comprehensively measured, there was a sharp decline in the density of submerged macrophytes, with the large *Potamageton* and *Vallasneria* beds completely gone by summer 2008 (Figure 14). There was also a decrease in the catch of perchlet at Benson's drop between the pilot study in spring 2007 and the main survey in summer 2008 (Figure 15).

Figure 14. Benson's Drop weir pool; A) in spring 2007 (note dense macrophyte bed) and B) the same site in summer 2008 following summer flooding (devoid of submerged macrophytes). This entire area was densely packed with submerged macrophytes (predominantly *Potamogeton crispus*) prior to the summer flash flood.

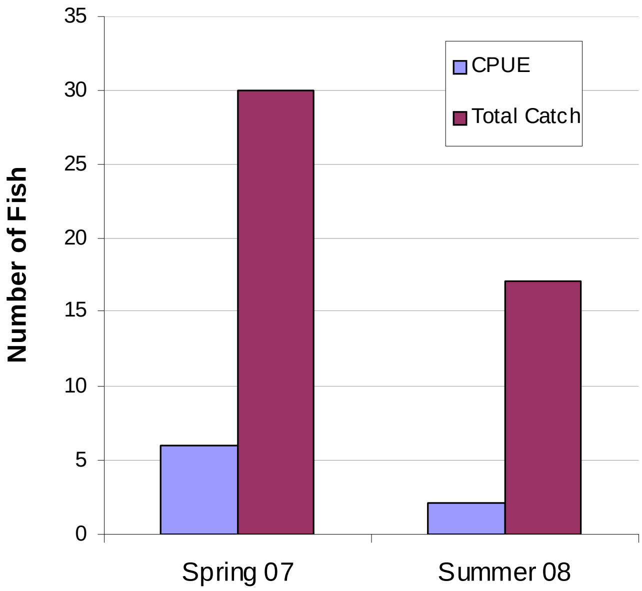

Figure 15. Total catch and catch per net (CPUE) between spring 2007 and summer 2008 netting surveys of Benson's Drop weir pool.

When the Benson's Drop population from spring 2007 is compared only to the summer 2008 data from the same site, there was a significant difference in population structure between seasons (Kolmogorov –Smirnov test ($Z = 1.918$), $P = 0.001$). Only one large fish was captured in the 2008 survey with a distinct lack of fish between 35mm and 50mm indicating that a new cohort of smaller individuals had largely replaced the spring population in 2008 (Figure 16 A & B). Therefore over the summer of 2007/2008 there was both a successful recruitment event and the demise, or dispersal, of older fish at this site. Either of these explanations for the lack of large fish is possible as a large flood in Mountain Creek inundated the site late December 2007 (see Benson's Drop hydrograph in Figure 8) that could have destroyed or flushed the majority of the spring population downstream.

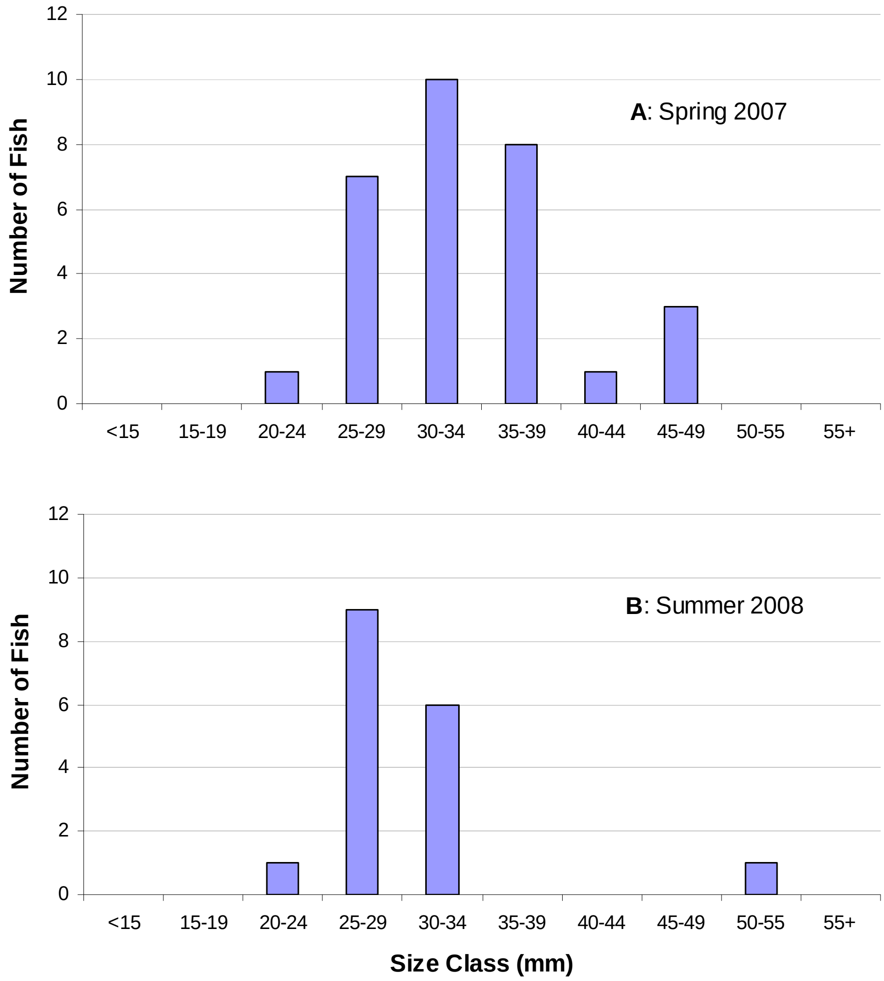

Figure 16. Length frequency distribution of olive perchlet captured from Benson's Drop weir pool in A: spring 2007 and B: summer 2008.

Figure 17. Olive perchlet from the Lake Brewster Weir pool catch.

3.4 Populations structure and spatial variations in the population structure of olive perchlet

3.4.1 Population structure

Olive perchlet measured during this study ranged between 18mm and 57mm in length (total length). The overall size distribution was a 'normal' shaped distribution with the majority of fish being between 25 and 35 mm in length (Figure 18). Of the 1154 perchlet measured during the survey only ten were over 50mm in length. Whilst these individuals were larger than any captured during the pilot survey they represented less than 1% of the individuals captured in subsequent surveys.

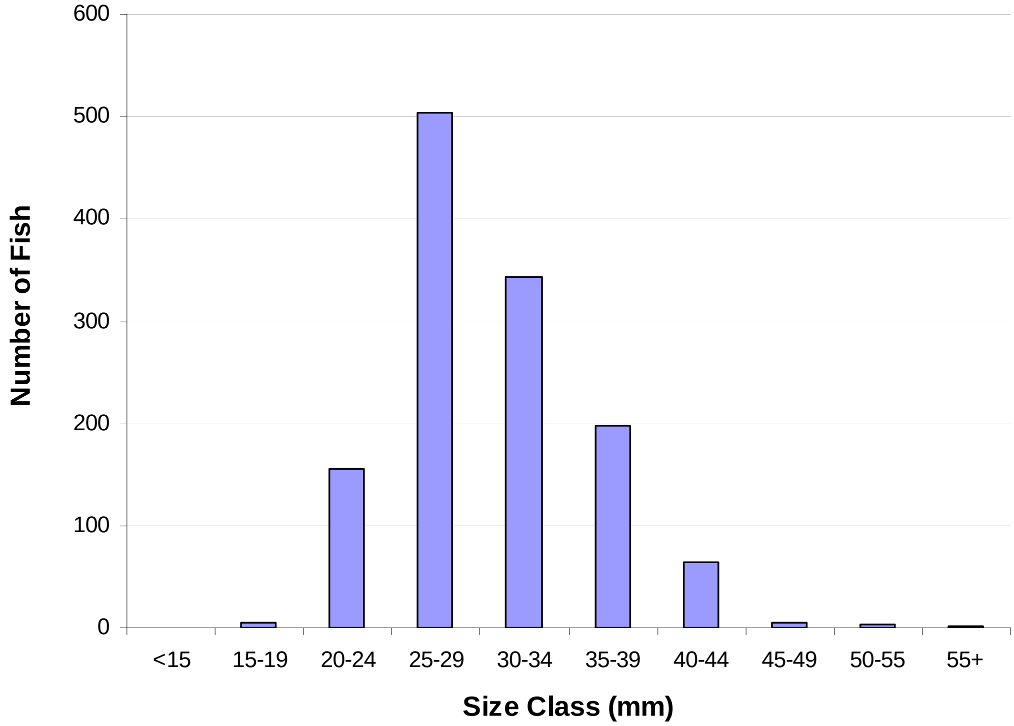

Figure 18. Sizes of olive perchlet across the Lachlan River catchment that were measured during the summer 2008 survey. Measured fish were captured from all sites using both fyke net and electrofishing.

The size distribution of olive perchlet captured during the main survey (summer 2008) was similar to that for the pilot study (spring 2007) (Kolmogorov–Smirnov test (Z = 1.292, P = 0.071). Both smaller and larger individuals were present in the population during each survey (Figure 16: A and Figure 18) with the majority of the population captured in both the summer 2008 study and the pilot study dominated by mid-sized (25-40mm) individuals.

3.4.2. Spatial variations in population structure

There were significant differences in the size structure of perchlet populations across different sites in the Lake Brewster area (Table 6, Figure 19). The large sample sizes used for this analysis, however, has resulted in relatively minor differences in the population structure between sites being identified as significant. Not all of these differences are easily interpretable or necessarily biologically significant.

Table 6. Summary table for pairwise Kolmogorov-Smirnov test results for differences in the length distributions of olive perchlet across survey sites. The two-tailed asymptotic significant value and Kolmogorov-Smirnov Z (in parentheses) values are shown for each pairwise comparison.

Pairwise Site Comparisons	Brewster Weir	D/S Bensons drop	Lake Brewster Outlet Regulator	Brewster Weir Conduit Channel	Mountain Ck Pools	Mountain Ck - Lachlan Junction
Brewster Weir *(n = 386)*						
Benson's drop D/S *(n = 134)*	**0.000 (4.802)**					
Brewster Outlet Regulator *(n = 195)*	**0.000 (7.530)**	**0.000 (7.836)**				
Conduit Channel *(n = 203)*	**0.004 (1.779)**	**0.000 (3.603)**	**0.000 (8.119)**			
Mountain Ck *(n = 17)*	0.400 (0.895)	**0.000 (2.731)**	**0.000 (2.374)**	**0.041 (1.394)**		
Mt Ck/Lachlan Junction *(n = 68)*	**0.000 (4.464)**	0.696 (0.709)	**0.000 (6.778)**	**0.000 (3.518)**	**0.000 (2.983)**	
Bensons drop *(n = 30)*	**0.025 (1.479)**	**0.003 (1.783)**	**0.000 (4.014)**	0.463 (0.851)	**0.013 (1.589)**	**0.005 (1.736)**

Overall, across the whole catchment the population consisted primarily of smaller or medium sized individuals at each site, with a small number of larger fish, predominantly in the Lachlan River sites (Figure 18). The most biologically significant difference in population structure is the very small size of perchlet captured from below the Lake Brewster outlet regulator, where only a handful of individuals were over 30mm in length and the majority of perchlet were between 20 and 30mm. Other Mountain Creek sites contained predominantly smaller to medium sized fish with very few fish (only two individuals) over 40mm in length.

Most large fish (40mm+) were captured downstream of Benson's Drop and the adjacent junction with the Lachlan River. Benson's Drop D/S possessed a high proportion of large fish, with the majority of the population over 35mm in length. Some larger fish were also captured in the Brewster and Benson's Drop weirs and the conduit channel below Brewster Weir (Figure 19).

3.4.3. Fishing methodology comparison.

A significant difference was detected between the size range of olive perchlet captured in the netting and electrofishing surveys (Kolmogorov –Smirnov test; Z = 2.594, P = 0.000)

(Figure 20). Fyke netting was most effective for catching both the largest numbers of fish and also the entire range of fish sizes (Figure 20).

Data from electrofishing surveys underestimated the proportion of both large and small fish in the Lachlan River olive perchlet population. This has serious implications for detecting the true structure of small remnant populations of small-bodied fish. This may be particularly relevant for the olive perchlet population in the Lachlan River catchment as this population may often consist primarily of larger adults between large recruitment events.

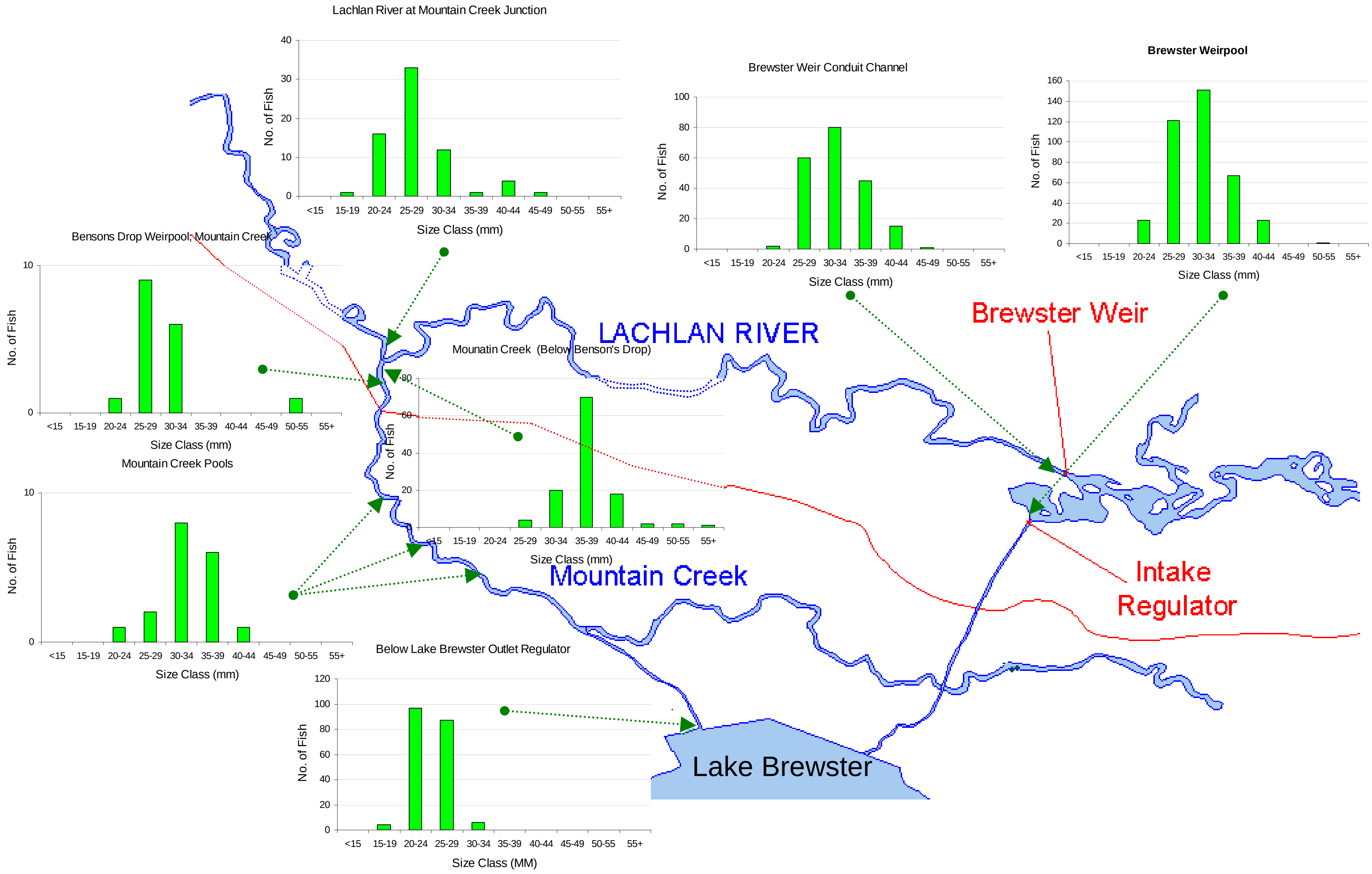

Figure 19. Size range of olive perchlet captured across various sites in the Lake Brewster Area (mapped).

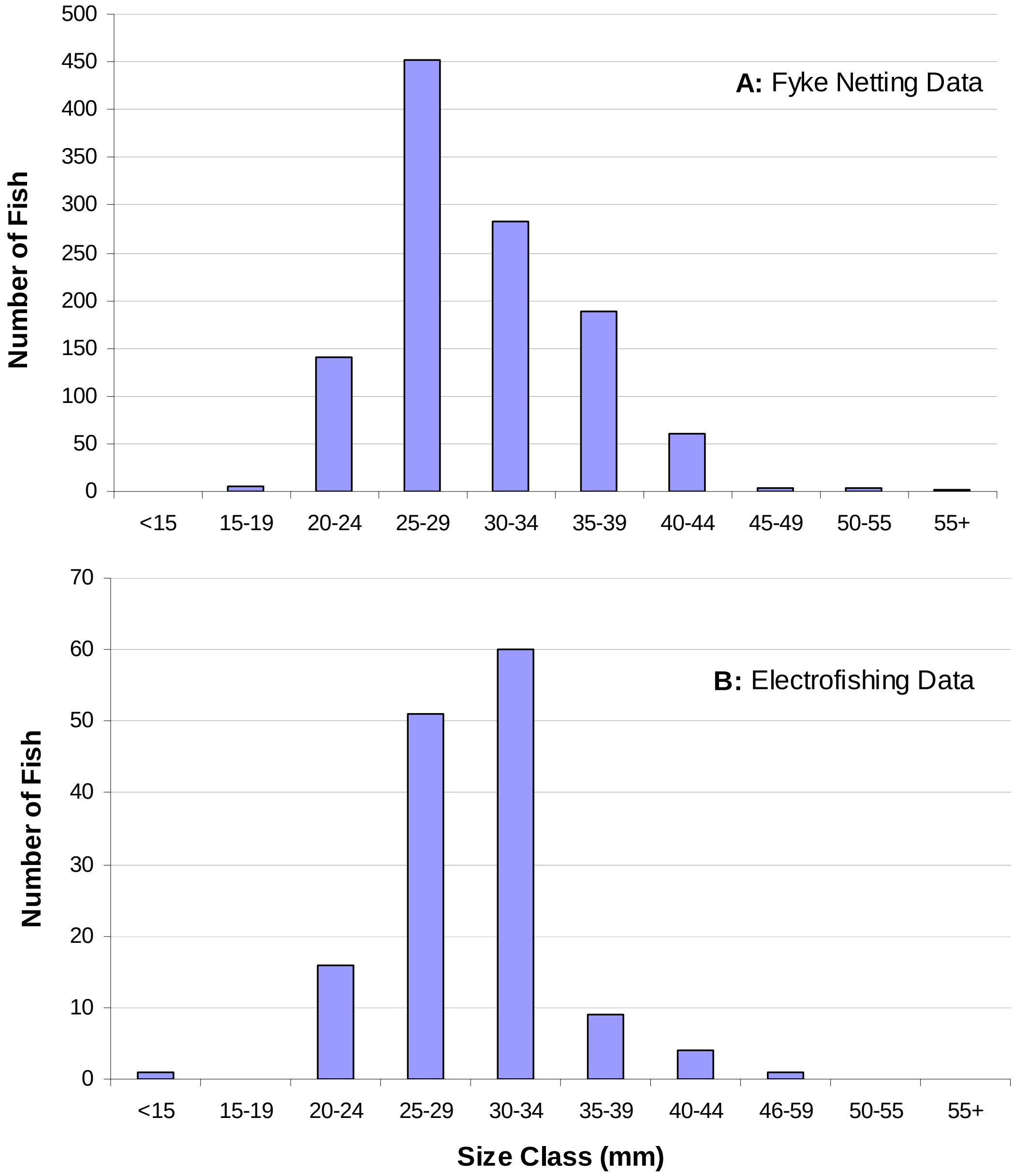

Figure 20. Length Frequency plots for olive perchlet captured using a: fyke netting and B: boat mounted electrofishing. Note differences in scale used for each of the two datasets.

3.5 Spawning and recruitment of olive perchlet

3.5.1 Otolith aging

Prepared olive perchlet otoliths were exceptionally easy to read, displaying clearly visible daily growth rings (Figure 21). The relationship between estimated age, from counts of daily otolith growth rings, and fish length followed an exponential curve. Linear regression showed that a significant linear relationship also existed between length and estimated age (R^2=0.92, F=172.88 P<0.001, n= 17) (Figure 22). All 17 fish that were aged were young of the year (i.e. spawned in the same year as they were captured, there were no annual growth bands to indicate that any fish were over a year old). Otoliths possessed very clear daily growth bands that suggest incredibly fast development early in life. The smallest specimen of 18mm in length grew to this size in only 52 days and the largest fish, at 44mm, was only 104 days old.

Figure 21. A transverse-sectioned otolith (saggitta) taken from a Lachlan River perchlet, showing distinctive daily growth rings.

Given that all test fish were captured and sacrificed on the 13th February 2008, the estimated spawning period for the vast majority of olive perchlet was in December 2007, whilst the largest size fish had spawned during November 2007 (Figure 23).

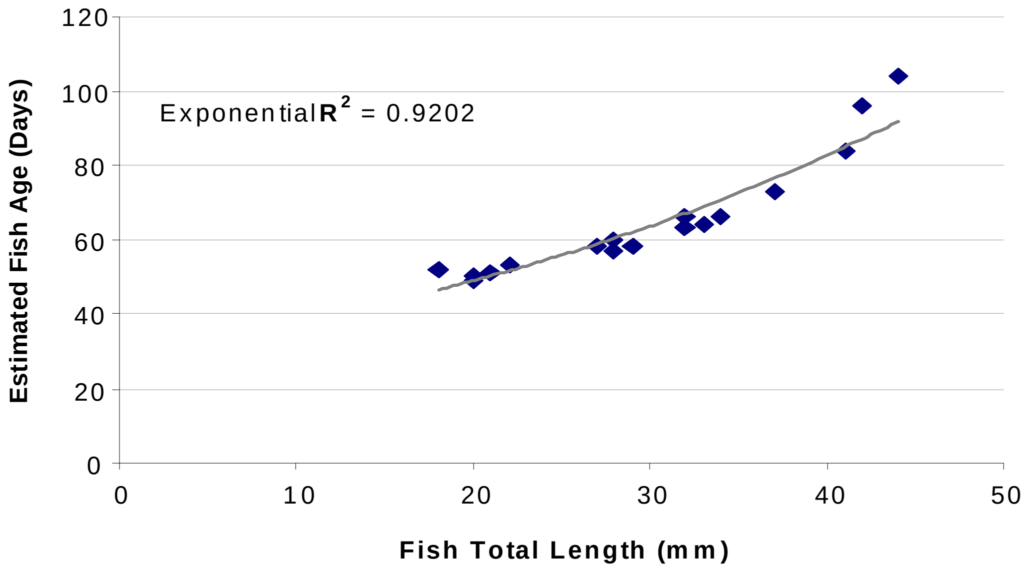

Figure 22. Length-age relationship for olive perchlet based on counts of daily growth rings within fish otoliths showing a strong exponential relationship.

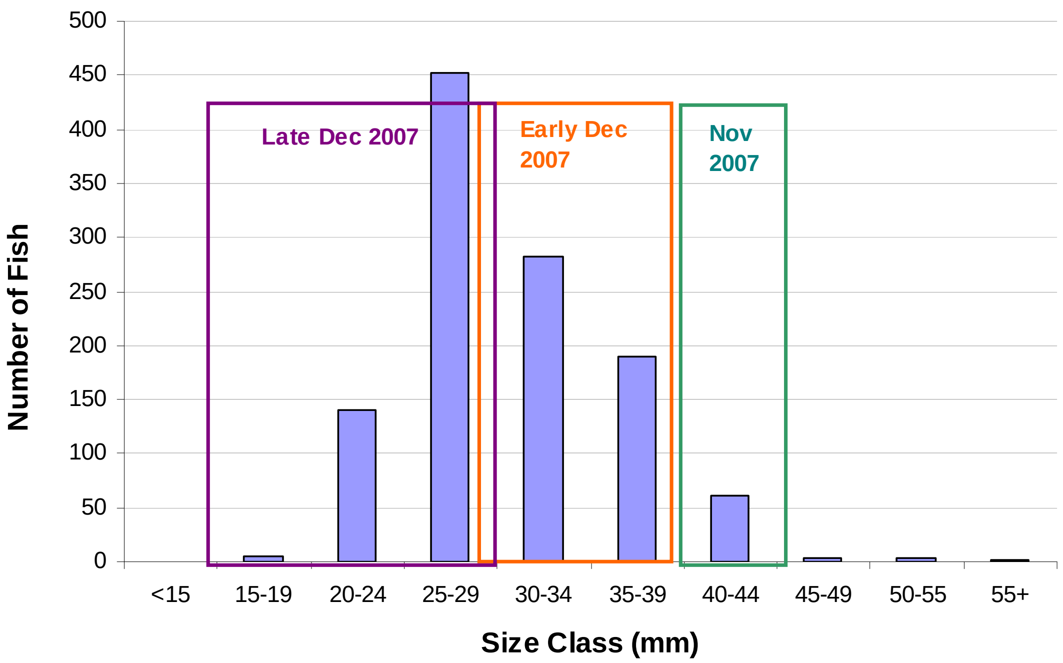

Figure 23. Spawning periods for olive perchlet captured during the 2008 netting survey. The relative numbers of fish spawned during November, early December and late December 2007 were calculated based on otolith growth rings.

3.5.2 Hydrology, Temperature and perchlet spawning

The vast majority of perchlet measured during the 2008 survey were spawned under the summer low flow conditions throughout December 2007, but a large number also spawned during the high rainfall period and flash flood that occurred at the end of that month (see hydrograph in Figure 8). Spawning also coincided with water temperatures reaching around 22°C in early November 2007 (

Figure 24). The peak of spawning occurred around mid November when water temperatures exceed 23°C, and continued through November and December whilst temperatures remain between 23°C and 27°C. There was a rapid decline in the water temperature associated with the high flows in late December 2007. This drop in temperature to 22ºC coincided with a final boom in spawning, but no perchlet were spawned following this high-flow period.

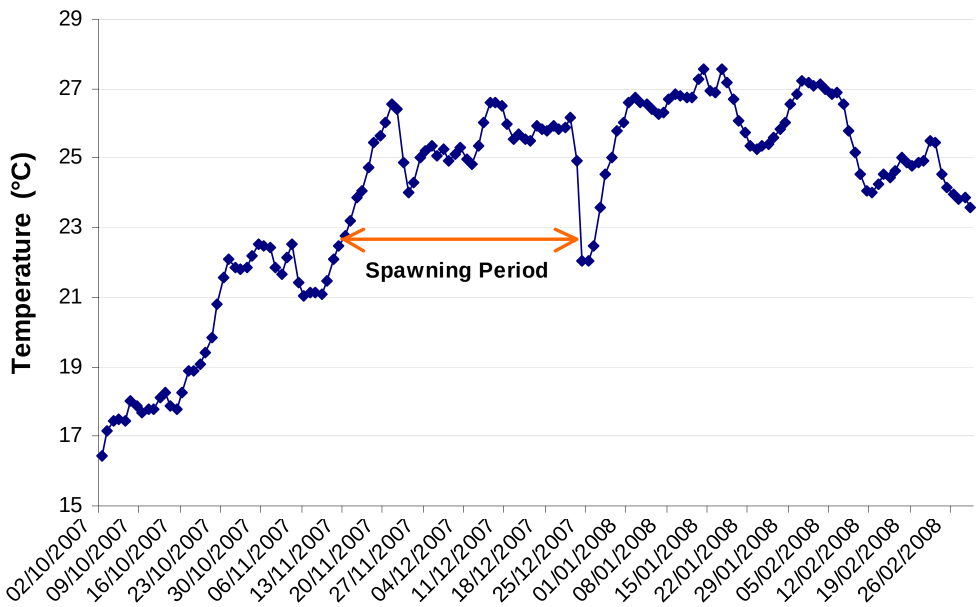

Figure 24. Water temperature in the Lachlan River upstream of Willandra weir over spring and summer 2007/08.

4 Discussion

4.1 General Fish Survey

In general the fish community in the Lachlan River catchment was similar to that reported to occur throughout the Murray Darling basin (MDBC 2004). However, redfin perch (*Perca fluviatilis*), Murray catfish (*Tandanus tandanus*) and silver perch (*Bidyanus bidyanus*) have been reported in the region previously, but were not captured during the present surveys (Harris & Gehrke 1997, Growns 2001, Kerezsy 2005). With the exception of redfin perch, these three taxa are rarely captured in riverine systems of NSW (Growns *et al.* 2003). The failure to catch redfin perch (an introduced predator) in the area is a good sign as native predators, Murray cod and golden perch, were present. If native species can continue to dominate, introduced predator populations will find it harder to compete for resources and become established in the area in the future (Schulze *et al.* 2006). Large booms in redfin recruitment can occur during winter under drought low flow conditions (McNeil, Wilson and Reid *In Prep*) and should have been detected if they were present in the system at the time that the 2007 surveys were conducted. If such a recruitment boom in redfin recruitment were to occur in the future, it could severely threaten the perchlet population.

The dominance of small-bodied native fish (gudgeons, hardyhead and perchlet) over similar sized exotic taxa at many of the sites surveyed is an indicator that the native fish population is in good condition. Most significantly, a massive population of olive perchlet was detected. This population will be discussed further in subsequent sections of this report.

Although a very large number of young-of-year carp were captured, it is known that this recruitment event stemmed from an experimental flow diverted through the Lake Brewster Channel and down Mountain Creek, as part of the Lachlan carp clean-up baseline study. A key purpose of the carp control study was to determine the impact of flow releases on carp spawning responses. The present study clearly shows that the spawning event associated with the flow (McNeil, Conallin and Stuart *in prep* [B]) translated into a high number of young-of-year carp, predominantly in the Mountain Creek pools. This adds a significant level of information to that project and future surveys will be required to determine how this boom in the number of juveniles translates into longer term recruitment and survival of the local carp population.

4.1.1 Fishing methodology

At a broad spatial scale, as covered by the entire survey, the SRA methodologies were good at identifying the fish species assemblage present. However, at more localised scales, such as within a single SRA site (1km reach, both sides), fyke nets were better at picking up a more complete range of the species present, especially regarding smaller-bodied fish species. Seine nets may also be useful, but were only used once and area restricted to shallow areas with low structural complexity.

This is an important result as the majority of fish surveys carried out by NSW DPI in recent years has been conducted using SRA style electrofishing methodology. When these surveys are relied upon to determine the distribution of rare, patchily distributed or small-bodied species such as olive perchlet this approach is likely to be insufficient (Lloyd & Walker 1986).

A pilot SRA audit conducted in 2002/2003 to refine & trial methods failed to find olive perchlet or unspecked hardyheads in the Lachlan catchment (MDBC 2004). During the present study, both of these species were regularly captured using fyke nets in SRA sites but were rarely captured during extensive electrofishing surveys.

Long-term fish monitoring programs that employ only electrofishing, such as the SRA, are not reliable for determining the distribution or population status of such small-bodied rare or threatened populations as the olive perchlet population of western NSW. Instead, dedicated surveys using netting techniques across a range of sites, such as used in this study, will give a far more accurate and detailed picture of the distribution and population structure of small-bodied fishes.

It is often claimed that electrofishing provides the least biased method for capturing all fish species likely to be present in a given reach (Harris & Gehrke 1997, Growns *et al.* 2003). However, the current surveys show that small meshed fyke nets, if placed in high enough numbers across all habitat types, provide as good, if not better, detection of the full range of species and body sizes of fish present. In addition to being most useful for the capture of smaller bodied species, fyke netting is also the best method in small to medium sized pools where boat or backpack electrofishing is impossible, whereas electrofishing is most appropriate in deep reaches where nets cannot be set.

The effort involved in surveying each site was lower using nets than for using the SRA protocols. Two staff worked for five days on each method, but ten sites were completed by the team using nets whereas only six sites were completed by the electrofishing team (despite more fish being captured in nets). Certainly fyke netting is recommended for future surveys of small-bodied fish such as threatened olive perchlet or hardyheads. Whilst electrofishing from boats is effective in large rivers and small fresh streams, fyke nets are able to sample complex, disconnected, highly conductive and shallow habitats where electrofishing is ineffective.

4.2. Status and Conservation of the Olive Perchlet Population

The identification of a substantial population of olive perchlet in the Lake Brewster area during the present study comes only three years before the species would have been declared extinct within the Lachlan catchment: given the last official record of the species in the catchment occurred in 1960 (Australian Museum record I.25086). Several surveys in the Lachlan catchment over the past 10 years have failed to locate olive perchlet (Llewellyn 1983, Harris & Gehrke 1997, Growns 2001, MDBC 2004, Kerezsy 2005).

The Lachlan olive perchlet population extended from Mountain Creek, well into the Lachlan River and upstream beyond Brewster Weir pool. However, with no perchlet found below Willandra Weir or in indeed below the junction with Mountain Creek, it is likely that the population is confined to the triangular area of roughly 10-15 km encompassing Lake Brewster Weir, Mountain Creek, Lake Brewster and the Lachlan River between the divergence and reconvergence of Mountain Creek.

This is the single largest known perchlet population anywhere within the western NSW region (FSC 2001, Morris *et al.* 2001), and is also the most southern natural population of the species in the Murray-Darling Basin or indeed Australia. As a result, this population has an extremely high biodiversity value that is of great significance to the conservation and future widespread recovery of this species. Its discovery highlights the need to carefully manage the riverine environment within the area so as to minimise any potential threats to the population through current and future water and land management and development.

4.2.1 Population connectivity

Lake Brewster inlet and outlet regulators and Brewster Weir itself form significant barriers to the free movement of perchlet across all of the sites where they were found. However, under scenarios in which both Brewster inlet and outlet regulators are both open, perchlet may move through this channel, linking the habitats upstream and downstream of Brewster Weir.

Perchlet may also move from above Brewster Weir through the underground conduit channel and into the Lachlan River downstream of the weir. Upstream movement through the conduit is unlikely due to high velocities within the conduit pipe. Similarly, high flow velocities moving through the regulators may present barriers to upstream movement.

Furthermore, when Mountain Creek is inundated during high flows, the creek itself links up the Lachlan River above and below Brewster Weir. There is one potential barrier to fish movement along this route, as Mountain Creek passes through a culvert beneath the Brewster inlet channel. If perchlet were capable of moving through this culvert then connectivity between sites above and below Brewster Weir would be facilitated through this route during high flows.

Potential connectivity between known sites where olive perchlet currently exist may add to the long-term viability of the population as genetic intermixing can potentially occur by movement between sites. Further studies into the movement of perchlet between locations will be required to support this hypothesis. Methods for assessing this population connectivity include the tracking of marked fish (using polymer tags or otolith dye markers) and genetic studies to determine the degree to which genes are shared between discrete populations from different locations.

4.2.2 Perchlet spawning

In the Lachlan River catchment, perchlet spawned during November/ December, slightly later than that recorded for coastal Queensland populations (October/November) (Milton & Arthington 1985). In Queensland the spawning dates were believed to be dependant on water temperature. Specifically, perchlet spawn as water temperatures reach between 22°C and 23°C (Milton & Arthington 1985). As these temperatures are reached later in the year in southern states, southern perchlet populations spawn later than those in the north (Cadwallader & Backhouse 1983; Milton & Arthington 1985; FSC 2001).

The results from the present study concur, with perchlet spawning began immediately as water temperatures exceeded 23°C and was sustained in water temperatures approaching 27°C, until a sudden drop in temperature associated with flows in late December 2007 brought water temperatures back below this required temperature range. Spawning was not resumed in January, even though water temperatures moved above 23°C. The cessation of spawning coinciding with the summer flood may be inconsequential as spawning is not believed to continue throughout summer, regardless of flow or water temperature (Milton & Arthington 1985).

Our estimation of spawning periods and timing is based on data taken from length frequency distributions linked with preliminary otolith aging. The patterns outlined above suggest that our aging and spawning data fit very well with known information about perchlet populations, but there are a number of key differences between the patterns we observed and those from the previous study in coastal Queensland (Milton & Arthington 1984; 1985). Firstly, the strongly exponential growth rate determined using daily otolith growth ring counts from the current study differs from the linear growth rate back-calculated using the length of known age fish scale radius data for Queensland populations (Milton & Arthington 1984; 1985). Secondly, Milton & Arthington (1985) found that in coastal Queensland populations, the mean length of young of year (0+) perchlet was around 26mm. Perchlet over one year old reached a mean size of ~37mm, whilst two-year-old fish averaged 47mm in length and 3+-year-old fish an average length of 52.6mm. In the current study, young-of-the-year perchlet (100% of specimens) averaged 31.2mm in length. The largest specimen analysed for age was 44mm long and was aged at only 104 days old, the size of a 2 to 3 year-old fish in the Queensland population (Milton & Arthington 1985).

This evidence demonstrates that the Lachlan perchlet population are exceptionally fast growing, compared to their northern relations, reaching adult size within a single season. The Lachlan River catchment population consisted of a single yearly cohort spawned during a recruitment boom and with little or no surviving adults from previous years, rather than a multigenerational population possessing relatively slower growth rates as in Queensland populations, where females live for three years and males two (Milton & Arthington 1984). The planned aging of 50mm+ fish collected from the Lachlan in future studies will provide essential information regarding the survival and age of adults in the population.

Although it was known that a reasonable adult population was present before spring 2007 (at least above Brewster Weir), this generation was barely represented in the summer 2008 catch, if at all. Overall, the pattern suggests a strong annual pattern of recruitment, similar to that identified for Australian smelt in the lower Murray River (Leigh 2002). It is likely that almost the entire population of perchlet surveyed were young-of-the-year fish, which were spawned from the same generation of adult fish which were caught at Benson's Drop in October 2007.

Large annual spawning events over a short duration, fast growth rates and the lack of adult survival over multiple years may represent an evolutionary response to the harsh and highly variable conditions present in the Lachlan Catchment, as opposed to the higher and more dependable rainfall falling in catchments of coastal Queensland.

Sexual maturity is reached after the first year in Queensland populations of olive perchlet (Milton & Arthington 1985), but rapid growth in the first year may allow earlier attainment of sexual maturity in the Lachlan population. Sexual development has not been investigated in the present study and appearance of stronger environmentally driven R selection in the Lachlan population compared to more stable coastal habitats is a hypothesis that will require further detailed testing and reproductive analysis.

The alternative explanation is that the methodology used to assess the age/growth relationship in the previous study was somehow flawed, in which case the Queensland populations may also represent more annually based recruitment dynamics than estimated during the 1980s, prior to reliable otolith aging techniques being widely applied to the aging of small native fish (see Milton & Arthington 1984 and 1985). This could be resolved by aging of fish from the Queensland population using validated aging methodology comparable to the present study.

Neither the present study, nor the past work of Milton and Arthington (Angela Arthington *pers. comm.*) has carefully validated aging techniques or length age relationships for olive perchlet. A short validation study is suggested to match otolith ring counts with fish of known age in the laboratory. This can be done using stains that mark otoliths at a known time and then matching proposed daily rings to known number of days since staining. This study will be relatively inexpensive but highly valuable to our understanding of perchlet growth and aging.

The annual recruitment strategy observed in the Lachlan population might help to explain the fact that perchlet are rarely found above 50mm across the Murray-Darling Basin (McDowall 1996, Lintermans 2007). If only few adults persist from year to year, most fish sampled will represent young-of-the-year fish and although fast growing, it appears that 50mm represents the upper possible limit of annual growth. If perchlet do not reach maximum size until their second or third year, fish of maximum size (<78mm, Lintermans 2007) would be rare in annual populations.

It was very notable that less than 10 perchlet (less than 1%) of the 1311 fish measured during the entire survey were over 50mm in length. Although none of these large fish were aged, it is possible that they represent adults, which had survived from the past year. Fish this large are very likely to represent 1yr+ fish even with the exceptional fast growth rate of perchlet found during the present study.

This information about the population structure of olive perchlet in the Lachlan River catchment is significant to understanding the ecology of the species and also in identifying parameters useful for conservation management. It is likely that failure to meet the fish's requirements for spawning during any single year and, especially for consecutive years, could lead to a population collapse. With the widespread extent of local anthropogenic modification of riverine habitats and catchment-scale impacts on flow regime and other important ecosystem processes that occur across most of the Murray Darling Basin (Cadwallader 1978, Arthington *et. al.* 1983), it is possible that failure of this annual population boom may have already happened on a large spatial scale. This may be a major contributor to the broad scale demise of the species observed across the basin over the past 60 years (FSC 2001).

4.2.3 Climatic factors

The data suggests that olive perchlet may respond strongly to boom-bust cycles and most likely will have highly variable population structure from year to year reflecting variability in climate, flow, and availability of suitable habitat. The 2007 population boom coincided with the longest run of consistently low summer flows in the Lachlan in the last 30-40 years, as summer flow allocations have ceased due to the drought (Figure 25). More stable hydrographic conditions, such as the sustained high water levels regularly experienced in the Lachlan River catchment due to heavily regulated flows, may be counterproductive to the long-term sustainability of olive perchlet populations.

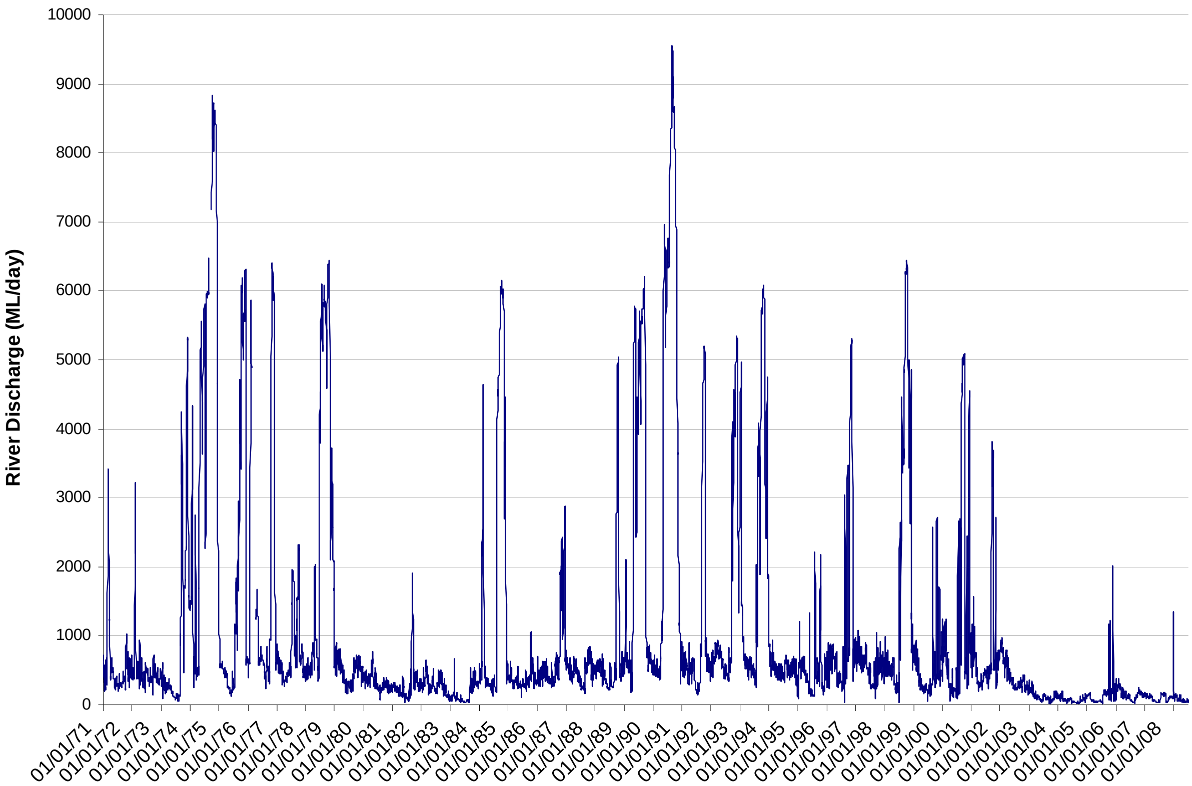

Figure 25. Historical flows from the Lachlan River (since 1971) at Hillston Weir showing the exceptionally low flows occurring over the past five to six years.

Summer low flows are most often prevented from occurring in the Lachlan due to the delivery of summer irrigation allocations, but it was during these 'summer low flows' that the vast majority of the olive perchlet population were spawned during 2007. Low flows appear to be ideal for perchlet spawning and recruitment as they are conducive to the growth of extensive macrophyte beds that provide ideal perchlet habitat and vital food sources for perchlet survival (Arthington *et al.* 1983, Allen & Burgess 1990, Moffat & Voller 2002, Medeiros 2004). This finding adds olive perchlet to the list of native fish that show low flow recruitment patterns (Humphries, King and Koehn 1999).

Olive perchlet may persist not only in the Lachlan, but also in other isolated pockets where summer low flow conditions and good habitat co-occur. Interestingly, the site of the original discovery at Benson's Drop Weir is more likely to enjoy regular periods of low flow during summer as it is separated from the river and will only flow on release of water from Lake Brewster or during big floods. It also possesses ideal perchlet habitat being relatively shallow with dense macrophyte beds. More extensive surveys would be required to identify other extant populations throughout similar habitats in the Lachlan and across western NSW.

The overall hydrological pattern associated with the present perchlet population boom is that summer low flow conditions (due to drought) in the main channel, followed by high flows (due to a summer storm) that connected the river and off channel habitats. This connectivity likely allowed the free movement of perchlet across habitats, potentially spreading from previously isolated refuges like Benson's drop Weir. Whilst this is a somewhat complex combination of hydrological events and spawning requirements, it is likely that perchlet recruitment patterns would be well adapted to the highly variable natural flow regime present in Australia's inland rivers (Puckridge *et al.* 1998). The results highlight the need for careful integration of flow regime and the spawning and recruitment requirements for the sustainable management of native fish. Under the resumption of more 'normal' river operations in the Lachlan, the perchlet population is likely to contract back into those isolated pockets where low flow habitats and spawning sites are available each summer (or at least most summers), such as Benson's Drop Weir.

It is essential for the management of the population that monitoring is continued, as contraction into small isolated pockets will increase the importance of these specific sites as refuges for the threatened population. Further surveys are also needed to provide additional information on the fate of the current cohort and to determine whether adult perchlet are able to persist for successive years in the Lachlan or whether the population is truly annual and requires strong recruitment each year to persist.

The occasional occurrence of large volume flows as water from Lake Brewster is released through Bensons Drop may be inconsequential to the long-term survival of the population at this site, as demonstrated by their persistence through the flash flood of late December 2007. In fact it is possible that perchlet (and golden perch) present within these pools may have moved into these habitats from downstream (Benson's Drop/Lachlan River) during this high flow event.

Both perchlet and golden perch are known to migrate upstream in response to river flows (McDowall 1996, Lintermans 2007). For perchlet, this migration was previously only recorded from coastal streams (Moffat & Voller 2002). Schools of small perchlet were observed schooling into the flow below the Brewster conduit outlet during the present study, suggesting a desire for upstream movement. Furthermore, perchlet directly below the Lake Brewster outlet regulator were all very small and likely to have been spawned immediately prior to the flood, suggesting a possible upstream migration of very young (1-2 weeks old) individuals. Their tolerance to such high flow conditions are further emphasized by maintenance of the outlet channel population within Benson's Drop Weir pool, which is historically subject to large flows and very poor water quality during the emptying of Lake Brewster.

4.3. Lake Brewster Works and emergency translocation

The initial discovery of perchlet in the Lake Brewster outlet channel raised concerns about imminent works under the Lake Brewster Improvement Project (GHD 2006). This project is a major initiative to improve the wetland function, habitat value and water quality within this important off channel storage. Early stages of planned works included earthworks to reconfigure the outlet channel from the outlet regulator to a point approximately 2.6km downstream. This work was targeted at the 'constructed' channel and does not extend to the area that was historically the 'natural' course of Mountain Creek, which converges with the outlet channel downstream of this point.

A key focus of this survey was to identify any perchlet habitats that existed within the planned works area and if necessary, to translocate these fish to a safe refuge (i.e. Brewster Weir pool). Although perchlet were present in the large pool directly below the old outlet regulator, no other habitats existed directly within the proposed works area. As a result, it is not envisaged that planned works will have a direct impact on the olive perchlet population. Nevertheless, it was found that perchlet were present in moderate numbers within remnant pools downstream of the planned works. These areas may be at risk to sedimentation and other impacts associated with upstream works, particularly following heavy rains, or the resumption of flows through the outlet channel. A number of factors influence the level of risk this poses to the perchlet population upstream of the Benson's Drop Weir pool.

1. These pools were shallow (less than 0.6m) and are likely to dry up naturally prior to winter rainfall.

2. These pools were already subjected to extremely high and turbid channel flows following the local storm event and associated flash flood in December 2007. This indicates that the communities in these pools are likely to tolerate high turbidities that might arise from fine sediment inputs from works following flow resumption, as long as this is not associated with additional pollutants.

3. The perchlet within these pools represent only a tiny proportion of the overall Lachlan population. Much larger numbers of perchlet were present in the Brewster Weir pool and in the main channel of the Lachlan than in the high-risk area directly downstream of the works.

Emergency protection of olive perchlet may be required in the future if major threats to the population arise. Under these circumstances, it is recommended that a basic action plan be agreed to with NSW DPI and other relevant agencies. The development of this plan should involve specific recommendations for the removal and translocation of the threatened fish to a safe location nearby. This will require permission from NSW DPI and it may be prudent to pre-arrange permission for such actions so that an immediate emergency response can be enacted if need arises. Special permission for translocation is not required if NSW DPI staff are involved with the exercise, so continued close liaison with the department is necessary. This will ensure that equipment and expertise required for capturing and transporting fish safely will be available if needed.

4.4. Summary

4.4.1. Status of the native fish in the Lake Brewster Region

Overall, a healthy native fish community existed throughout the Lake Brewster region, including a high diversity of small-bodied native fishes as well as large bodied species including golden perch and Murray cod.

4.4.2. Status of the olive perchlet population

Olive perchlet were found across most sites in very high numbers and formed one of the most abundant components of the fish community in the region. The population constitutes a very significant remnant population within the endangered western NSW population (FSC 2001) and is the southernmost remnant of this once widespread species.

The study suggest however, that is an annual population that may be vulnerable to impacts and threats that cause recruitment failure in any given year. The population spawn during summer low flows provided under drought conditions but may be severely impacted by the resumption of high summer flows in the Lachlan. Careful year-to-year management ids required to sustain the population.

4.4.3. Spatial distribution of the population.

The perchlet population was not restricted to Benson's Drop Weir, and was widely distributed throughout the Lake Bre4wster region. The downstream distribution of the species appears limited, however, with no perchlet captured in the Lachlan downstream of the junction or in the pool below Willandra Weir.

4.4.4. Risk of planned works impacting heavily upon population viability and sustainability and assess the potential for translocation activities to protect 'at risk' populations.

The potential impact of planned works for the deepening of the Lake Brewster outlet channel was considered to be minimal due to the extensive distribution of olive perchlet throughout various habitats in the region. As a result, no immediate translocation of the species is recommended in the Lachlan catchment whilst this wider distribution remains. Any impact such as the drying of Benson's drop weirpool will, however, require a translocation from the wider population back into Mountain Creek to protect against the impact of resumed high summer flows in the Lachlan River. Other future impacts may also require emergency translocations.

4.4.5. Recommendations on the long-term sustainability of the perchlet population in the area.

A long-term fish management plan should be produced for the Lake Brewster region to identify and manage any possible impacts that may extend from the works and from the long-term operation of the Lake Brewster storage. This plan should include a process for maximising the utility of the lake as a refuge habitat for the threatened perchlet population.

The current boom in perchlet numbers may be due to drought related low-flow conditions. The resulting increase in low flow habitats is ideal for perchlet, but will disappear following the resumption of more normal water delivery practises following the drought. Refuges where habitat and summer low flow conditions continue to be available are likely to be extremely important to the long-term viability of the olive perchlet population. As such, every measure should be taken to protect these perchlet habitats, especially permanent off channel habitats such as Benson's Drop and Lake Brewster and Lake Brewster weir.

It is highly recommended that continuous monitoring of the perchlet population be undertaken to provide information about its long-term sustainability. Further research is needed to validate aging, to determine the survival of adult perchlet beyond a year, to determine critical carrying capacities and critical refuge habitats that enable the population to survive in the long term.

4.4.6. Survey methodology.

Appropriate netting methodologies must be incorporated into all monitoring and research surveys. Current reliance on electrofishing and box trapping through the SRA and other state surveys are likely to miss or underestimate populations of olive perchlet.

4.5. Key threats to the olive perchlet population

1. Flow regulation and potential loss of summer low flows necessary for perchlet spawning.
2. Drying of critical refuge habitats due to drought
3. Predation of perchlet in refuge habitats (particularly by exotic redfin perch)
4. Loss of macrophyte habitat availability in refuges.
5. Sustained poor water quality (i.e. high turbidity, low dissolved oxygen, high temperatures and high conductivity).
6. Land management and development.
7. Barrier structures restricting movement and connectivity of perchlet populations.
8. Population collapse if spawning requirements are not met in consecutive years.

4.6. Specific management and research recommendations:

1. Determine the role of fish greater than 1 year in age in maintaining the perchlet population.
2. Identify critical refuge habitats for the population if/when the population contracts.
3. Continue monitoring of the population across sites to enable rapid management response if the population contracts or fails or if as yet unforseen impacts become apparent in the future.
4. Undertake marking and genetic studies to determine the spatial and genetic connectivity between different perchlet populations or sites.
5. Determine other possible remnant populations of perchlet throughout the Lachlan Catchment to ascertain the full significance of the Lake Brewster population to the overall threatened western NSW population.
6. Ensure that the population is included in NSW threatened species recovery plans and assessment activities.
7. Incorporate perchlet and other native fish into long-term management plans under future operations of the Lake Brewster Storage and other local river management issues. This will ensure that Lake Brewster itself can be utilised as an important habitat for the threatened olive perchlet population.
8. Develop a rapid response plan with NSW DPI in case translocation is necessary in the future.

9. Conduct an ageing validation study for olive perchlet.
10. Develop a captive breeding program to assist with the future re-stocking of the species.

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The field team; A) Phillipa Wilson with a Murray cod from below Willandra Weir and B) Zach Dawson, Dean Hartwell (NSW DPI) and Dale McNeil (SARDI) with fyke nets.