An evaluation of fyke nets as a sampling tool for the Murray-Darling Basin Fish Survey in turbid northern Basin rivers

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Cover photos: *Neosilurus hyrtlii* captured in a fyke net. A pair of fykes set in the Balonne River. Setting fykes in turbid water in the Balonne River near St George. Images by David Nixon and Andrew Norris, Department of Agriculture and Fisheries.

Summary

The Murray-Darling Basin (MDB) Fish Survey is currently reliant on electrofishing and un-baited bait traps to sample fish populations. Water clarity can impact on the efficiency of these methods. Highly turbid waters are prevalent across much of the Condamine, Warrego and Paroo systems. Therefore, it was considered some key species or life stages could be missed by electrofishing and bait traps in these catchments. In response to this, a comparison of fish catches using the current MDB sampling techniques with fish catches in fine meshed fyke nets (a method perhaps less affected by turbidity) was carried out to evaluate the extent to which fyke nets could add value to the current survey techniques in highly turbid northern Basin rivers.

During the 2015/16 MDB Fish Survey use of day-set fykes and overnight-set fykes was trialled at fixed MDB Fish Survey sites in Queensland sections of the Condamine, Warrego and Paroo River Valleys. The fixed sites in these river valleys are characterised by highly turbid water; the majority of sites sampled had Secchi depths of 10 cm or less. Fyke netting was run in conjunction with the standard MDB Fish Survey techniques of electrofishing and unbaited bait traps. The fyke nets used in this study were of the same dimensions as those used in the Sustainable Rivers Audit (SRA) pilot work, but the mesh size used in the current survey was 1 mm square (or 2 mm stretched), in contrast to the 10 mm mesh used in the SRA pilot. At each site fyke nets were set in three back-to-back pairs in water less than 1 m deep.

The fine-meshed fykes used in this survey captured species of fish not captured by electrofishing, whereas bait traps did not capture any additional species to those captured by electrofishing. Additional species detected by fykes on a site by site basis included Freshwater catfish, Silver perch, Australian smelt and Hyrtl's tandan. Overnight set fykes were also very effective at detecting juvenile Golden perch and large numbers of Carp gudgeons at sites where few or none were detected by electrofishing or bait traps. Juvenile Golden perch detected by overnight set fykes were too small to have been stocked fish, and therefore are evidence of natural recruitment. Most size classes of Golden perch detected by electrofishing would require genetic fingerprinting or calcein tagging of stocked individuals for reliable conclusions of natural recruitment. Overnight set fykes also detected significantly more Un-specked hardyhead than electrofishing. Overnight set fykes indicated that Hyrtl's tandan was a common species at some sites, yet electrofishing and bait traps failed to detect any.

Electrofishing was better than overnight set fyke nets at capturing large Golden perch, Bony bream, Carp, Murray cod and Eastern gambusia. Overnight fyke netting and electrofishing therefore complement each other well. Day set fykes also detected additional species to electrofishing, but at fewer sites than overnight set fykes. With the exception of Carp gudgeons, total captures of fish were usually higher in overnight set fykes than in day set fykes, especially in the case of Hyrtl's tandan and juvenile Golden perch.

It is concluded that reliance on electrofishing and bait traps alone in turbid waters provides a biased estimate of the fish assemblage and population structure. Addition of overnight set fine meshed fykes to MDB fish surveys in turbid sites may substantially improve estimates of relative abundance of native fish, native fish biomass and native fish recruitment.

It is recommended that overnight set fine mesh fykes be added to the sampling regime for the three highly turbid northern Murray-Darling Basin river valleys. Use of overnight fyke nets will increase sampling time and slightly increase operational costs, but will also significantly improve the detection

of key fish species and life history stages that are essential for evaluating the success of environmental watering strategies such as those proposed under the Basin Plan.

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Introduction

The Murray-Darling Basin Authority (2015) described the Murray-Darling Basin (MDB) Fish Survey as a program that monitors Basin-scale fish condition and supports tracking of the high-level fish targets identified in Schedule 7 of the Basin Plan (Murray-Darling Basin Authority 2012), as well as more specific targets identified in the basin-wide environmental watering strategy (Murray-Darling Basin Authority 2014). However, targeted programs are also required to evaluate certain aspects of the strategy's outcomes. Data collected by the MDB Fish Survey are used to calculate various metrics and indicators that provide a measure of the health of the fish assemblage in key river valleys. These metrics were initially used in the Sustainable Rivers Audit. Metrics include proportion of native fish abundance, proportion of native species and proportion of native biomass, recruitment by proportion of taxa, recruitment by proportion of sites and recruitment by proportion of abundance. These metrics in turn are used to form indices of fish nativeness and fish recruitment. There are also metrics that are used to calculate an expectedness indicator, based on species actually caught compared to what would be expected to be caught in a hypothetical pre-European reference condition (Robinson 2012).

The MDB Fish Survey has monitoring sites in all of the major catchments (river valleys) of the Murray-Darling Basin, including five sites in each of the Paroo, Warrego and Condamine river valleys respectively. These are the three most northern river catchments in the Murray-Darling Basin. The three catchments are characterised by intermittent flow and turbid waters. These systems contain a number of fish species that are uncommon or absent in more southern catchments including Hyrtl's tandan *Neosilurus hyrtlii* and Spangled perch *Leiopotherapon unicolor* (Lintermans 2009).

Current sampling methods for the MDB fish survey include the use of electrofishing (boat and/or back pack) and unbaited bait traps (Murray-Darling Basin Authority 2015). Unbaited bait traps caught very few fish in the Paroo, Warrego and Condamine valleys in the 2014/15 round of sampling for the MDB Fish Survey. Unbaited traps have apparently been effective at catching small fish at sites in other catchments (Faragher and Rodgers 1997; Murray-Darling Basin Commission 2004). It is possible that the highly turbid waters of the northern Murray-Darling Basin rivers may be reducing the effectiveness of unbaited traps as a sampling tool. Turbidity is also known to reduce the effectiveness of electrofishing (Reynolds 1983: Lyon et al. 2014). Highly turbid water can make it difficult for netters to detect stunned fish, especially those that remain below the surface. Secchi depths of less than 10 cm are common in the northern basin. High turbidity associated with river discharge negatively influenced the capture probability of four large-bodied species by electrofishing in the southern Murray-Darling Basin (Lyon et al. 2014). Increasing fish length up to 500 mm increased the detection of Murray cod, after which detectability decreased (Lyon et al. 2014). Reynolds (1983) suggested a dome-shaped relationship between turbidity and efficiency of electrofishing capture. In very clear waters fish may move to deeper water where they are less susceptible to electrofishing or they may be more able to see the boat and avoid capture. With some turbidity fish may sit shallower or be less likely to see the boat and avoid capture (Kirkland 1962), whereas at high turbidity levels stunned fish are less visible to dip netters.

To counter the effects of high turbidity on electrofishing efficiency Hutchison et al. (2008) used continuous blind sweeps of nets in figure-of-eight movements, alternating between near the surface and the bottom substrate. This resulted in captures of fish not seen by the netter, thereby increasing total catch. Fish that were visible to the netter were deliberately targeted between blind sweeps. The MDB Fish survey does not use blind sweeping during electrofishing and therefore netters only net what they can see. However, even blind netting is still not effective at detecting certain species of fish in highly turbid water. Blind netting during electrofishing has been used extensively in the northern

Basin during various Queensland Department of Agriculture and Fisheries (DAF) research projects. Some species, most notably *N. hyrtlii* and *Porochilus rendahli* were occasionally caught by electrofishing in turbid waters, using blind netting, but were more frequently captured in fyke nets DAF catch data).

In the 2014/15 round of sampling of the MDB Fish Survey, no *N. hyrtlii* or *P. rendahli* were captured in the Paroo, Warrego or Condamine valleys using the existing MDB Fish Survey techniques of electrofishing (without blind netting) and unbaited traps. The catfish *P. rendahli* is restricted to the Condamine Valley in the Murray-Darling Basin, and is quite rare (Lintermans 2007 and DAF catch records), thus the non-capture of this species is to be expected. However, *N. hyrtlii* is considered relatively common in the lowland zone and to a lesser degree in the foothill zone of northern Murray-Darling Basin catchments (Moffatt and Voller 2002). Therefore, non-capture of this species by the MDB fish survey could either indicate non-representative sampling or a decline in this species.

The main fish objectives in Schedule 7 of the Basin Plan (Murray-Darling Basin Authority 2012) relate to no loss or degradation in recruitment up until 2019 and improvements in recruitment beyond 2016. More specific targets in the Basin-wide environmental watering strategy (Murray-Darling Basin Authority 2014) include:

- For short-lived species:
  - Restored distribution and abundance levels recorded pre-2007 (prior to major losses caused by extreme drought). This will require annual or biennial recruitment events depending on species.
- For moderate to long-lived species (which includes *N. hyrtlii*):
  - Improved population structure (i.e. range of size/age classes and stable sex ratios where relevant).
  - A 10-15% increase of mature fish (of legal take size) for recreational target species in key populations.
  - Annual detection of species and life stages representative of the whole fish community through key fish passages.
- By extending the range of existing populations and establishing additional populations, expanded distributions of key species are expected by 2024 including
  - A doubling of current (mostly restricted) distributions of key species in the northern Basin.

Given the apparent difficulty for electrofishing and unbaited traps to detect some key species (including *N. hyrtlii*) in turbid northern rivers, it was decided to evaluate the effectiveness of fyke nets as a supplementary fish sampling technique for northern Basin turbid rivers. If fykes could improve the detection of some species or life stages, then addition of fyke nets to the sampling protocol may improve assessment of how well the objectives and targets of the Basin Plan and Basin-wide environmental watering strategy are being met.

Objectives for this study included

a) Determining if fykes improved detectability of *N. hyrtlii*
b) Determining if fykes improved detection rates of additional species
c) Determining if fyke nets improved detection of juvenile life stages of some species

Methods

One constraint of using fykes is that they must be set for at least several hours duration. This is because fykes are a passive sampling method relying on fish to move into them. Traditionally fykes

have been set overnight (from late afternoon to early morning). However, from a time management perspective, it could be useful to set fykes for just a few hours during the day so that they operate concurrently with electrofishing activities. For this reason it was decided to evaluate both day time fyke net sets and overnight fyke net sets in this study. Fyke net sampling was carried out concurrently with electrofishing and bait trap sampling for the MDB Fish survey in the 2015-16 sampling round in the Paroo, Warrego and Condamine river valleys.

Sampling period and sites

The Condamine Valley was sampled in April 2016 and the Warrego and Paroo Valleys were sampled in May 2016. Fykes were set at MDB Fish Survey sites only in the Queensland section of the river valleys because prior Animal Ethics approvals and permits for use of fykes were in place in Queensland. Given the rapid turn-around time for this project there was insufficient time to organise Animal Ethics and Fisheries permit approvals for use of fykes in the New South Wales (NSW) sites. Five sites were sampled by fyke netting, electrofishing and trapping in the Warrego valley, four sites were sampled in the Condamine valley and two sites in the Paroo valley. The sites are listed in Table 1. MDB Fish survey sites in the NSW parts of the valleys were sampled by electrofishing and bait traps only, as per the Murray-Darling Fish Survey Protocol (Murray-Darling Basin Authority 2015). However, the NSW sites are not included in this document.

Table 1- MDB Fish Survey sites used for assessment of fyke netting in comparison with existing MDB Fish Survey Techniques.

Valley	Site name	Site code	Latitude	Longitude
Condamine	St George Reserve	66784	-28.07319	148.57560
Condamine	Lower Plains	66787	-28.33060	148.38647
Condamine	Kings Creek Aides Bridge	66813	-27.92699	151.86162
Condamine	Surat Weir	72902	-27.14816	149.06075
Warrego	Cunnamulla Weir	70501	-28.11224	145.68675
Warrego	Tickleman Gardens	64271	-27.86651	145.66999
Warrego	Glenco Waterhole	64285	-28.20121	145.70705
Warrego	Bakers Bend	70531	-26.69224	146.12953
Warrego	Ward River Waterhole	64304	-26.47991	146.10105
Paroo	Caiwarro Waterhole	64332	-28.73724	144.73874
Paroo	Eulo Bridge	64346	-28.16109	145.03784

Sampling gear and gear operation

Sampling at each site consisted of a combination of boat electrofishing, bait trapping, day-time fyke netting and overnight fyke netting. Both electrofishing and bait trapping are outlined in the current MDB Fish Survey protocol (Murray-Darling Basin Authority 2015), whereas fyke netting does not currently form part of the protocol. For that reason fyke sampling is described in more detail than electrofishing and bait trapping.

Electrofishing

All electrofishing followed the methods outlined in the Murray-Darling Basin Fish Survey Protocol MDB2 (Murray-Darling Basin Authority 2015). At all Queensland MDB Fish Survey sites all habitat types were accessible to electrofishing boats. Therefore back-pack electrofishing was not necessary according to the Fish Survey protocol. Kings Creek was sampled by small electrofishing boat, using a single netter and all other Queensland sites were sampled by a large electrofishing boat using two netters. Twelve ninety-second (accumulated power on time) boat electrofishing shots were used at each site. Netters dip-netted all stunned fish that they could see or detect in the water from cues such as splashing and swirls. These were placed into a 150 L live well for processing at the end of each shot.

Bait traps

Use of bait traps followed the Murray-Darling Basin Fish Survey protocol (Murray-Darling Basin Authority 2015). At each site 10 bait traps were deployed in water less than 1 m depth. Traps were set in slow flowing or backwater areas independent from electrofishing. Traps were not baited and trap captures were pooled as a single event in each site. Traps were set for the duration of the electrofishing sampling period and were cleared after approximately 2.5 hours. Any captured fish were placed into a 20 L bucket of river water for processing. Traps were cleared before retrieval of day-set fykes.

Fykes

Fykes rely on fish movements to passively capture fish. Wings are used to guide fish into an entrance and then through a series of funnels into a holding chamber called a cod end. Fyke nets used in this study had a 60 cm D entrance. A stainless steel wire grid fitted to the first ring behind the D in each fyke was used to exclude most turtles, although smaller specimens could still enter. The first ring had a diameter of 55 cm. Vertical grids were spaced 70 mm apart and horizontal grids 170 mm apart (Figure 1). This satisfied Animal Ethics requirements and also prevented large turtles from damaging the net and preying on fish in the fyke net. The grids allowed most size classes of fish to pass into the fyke nets, but would have prevented larger Murray cod and carp from entering.

Each fyke had two 5 m wings with a 60 cm drop; the top of each wing was fitted with floats and the bottom of each wing was threaded with a leaded cord. Fyke nets consisted of 1 mm thick knotless mesh with 1 mm spaces between rows (Figure 1). Mesh openings were 1 mm square or 2 mm on a stretched diagonal. The fine mesh allowed adequate water exchange and prevented gilling or meshing of small fish. This design maximises survival of fish in the fyke. Coarser netting tends to mesh some species (including rainbowfish and olive perchlet), while small juveniles and small species like Carp gudgeon can easily escape. Cone entries were fitted to the first two rings after the D entrance, leading into a cod end (Figure 1). The cones minimise the chance of fish escaping from the cod end. A float was placed in the cod-end of each fyke to provide an air pocket for any air breathing animal that may have accidentally entered the fyke (Figure 2). Six fykes were set per site in three back to back pairs in water less than 1 m deep and greater than 40 cm deep at the D (Figure 2). Cod ends were tied to a labelled stake. Back to back pairing meant that fish moving either upstream or downstream could be caught.

Fyke wings were set approximately 5 m wide. In still water, fyke wings were fixed in place with snapper leads attached to the outer lower end of each wing. In flowing waters wings were staked for additional stability. In flowing waters fykes were set in locations sheltered from the main current to reduce the risk of wings becoming dislodged and to reduce the potential impact of debris.

Day time fyke sets were set prior to the onset of electrofishing and cleared at the end of all electrofishing activity and after clearing of all bait traps; a set period of approximately three hours. Overnight fyke sets were set late in the afternoon and cleared the next morning. Electrofishing did not occur within 30 m of fyke nets. As far as was possible, day fyke sets were set in different locations to night fyke sets to avoid sampling interference. Most sites had ample sandbank, backwater and shallow marginal habitat for this to be possible. However, this was not the case at the Kings Creek site or the Surat site, where only narrow shelves of suitable depth or low velocity water were available for fyke netting. In these cases fyke net pairs were reset at the same point locations. At the Surat site overnight fykes were set first, and at the Kings Creek site day-time fykes were set first.

A fyke net was cleared by drawing the wings into the D frame, then untying the cod end from the stake. The fyke was then dragged horizontally through the water towards the shore or boat for processing. The dragging motion created a current to wash all fish towards the rear of the cod end.

The fyke cod-end was then dropped vertically into a 20 L bucket of river water or into a 60 L plastic tub (Nally bin) of river water. The cod end was opened up to allow fish to enter the water. Gentle shaking of the cod end was used to dislodge fish into the water. The cod end was also visually examined and any remaining fish were picked out by hand and placed into the container of water.

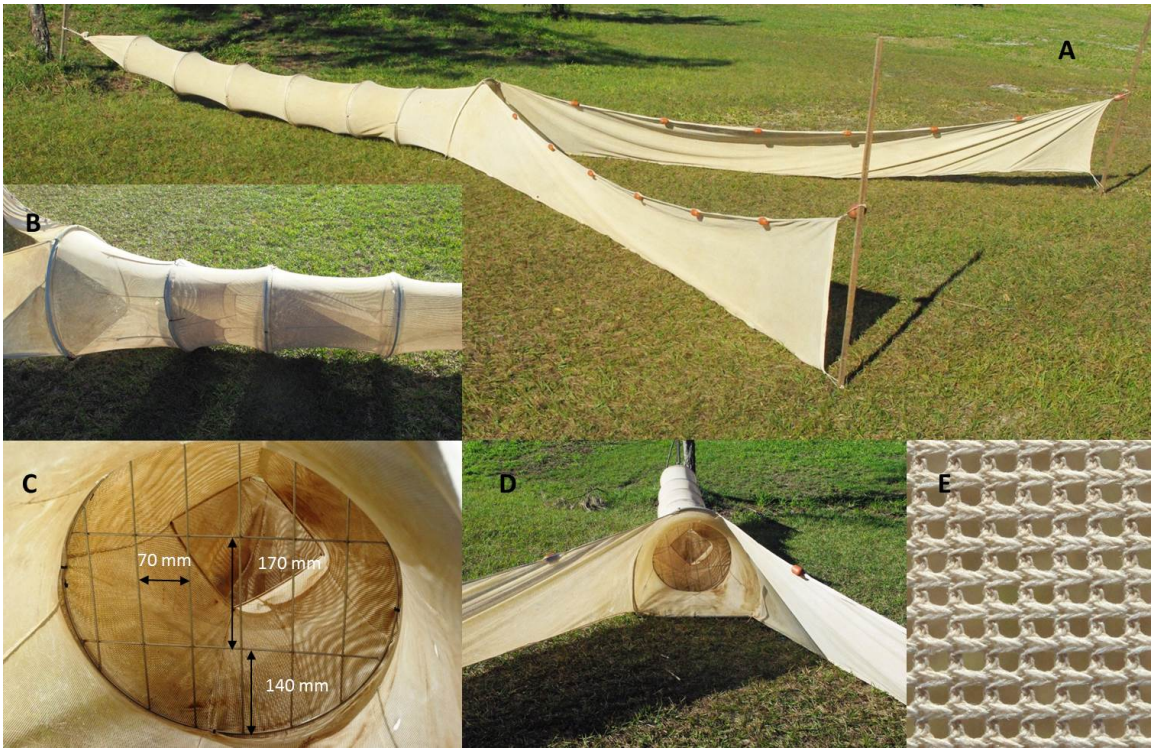

Figure 1- Fyke net showing: A) Fyke with two 5 m wings and cod end. B) Entrance tunnel profile with two internal cones C) Turtle excluder on the first ring with dimensions of grids labelled. D) 60 cm D-shaped entrance to fyke. E) Close up of fyke net mesh. Openings between rows of fibre are approximately 1 mm (2mm on a stretched diagonal).

Figure 2- A pair of fyke nets set back to back near Eulo in the Paroo River. Note the floats in the cod-ends providing an air pocket. Also note the highly turbid water.

Water quality

The water quality parameters turbidity, conductivity and water temperature were recorded at all sites. All three parameters can influence the efficiency of electrofishing (Reynolds 1983). Conductivity and water temperature were recorded at each site at 10 cm depth using a YSI water quality meter. Conductivity was recorded as micro Siemens per cm ($\mu S.cm^{-1}$). Higher conductivity readings indicate higher salinity levels. Turbidity was recorded as Secchi depth. Secchi depth was determined using a Secchi disc. A Secchi disk is marked with black and white quadrants. The disc is lowered into the water by a cord with depth markings. The depth at which the black and white quadrants are no longer visible from the surface is the Secchi depth. Secchi depth was recorded to the nearest centimetre. As turbidity increases, Secchi depth decreases.

Recording of the fish catch

Identification, measurement and counting of fish captured by electrofishing and bait traps followed the procedures outlined in the Murray-Darling Basin Fish Survey protocol MDB2 (Murray-Darling Basin Authority 2015). All fish captured by bait trap and electrofishing were identified and counted. For bait traps the catch is pooled at each site and the first 50 of each species are measured. Total catch of individual fish by bait traps was well below 50 at all sites sampled. In electrofishing at each site the sub-sampling began with the first individual captured of each species and continued to the 50th individual. For electrofishing, in the shot where the 50th individual of a species was found, all individuals of that species in the shot were measured to avoid sampling bias. After that shot, any further individuals of that species that were captured were counted, but not measured.

Measurement and counting of fish from fykes (both day and night sets) followed similar protocols to those described for electrofishing shots in MDB2, where the first 50 fish of a species caught by fykes were measured. If the 50th fish fell within a particular fyke shot then all fish of that species were measured in that shot to avoid size sampling bias, then just counted in all following shots. However, at one Condamine Valley site, fykes captured several thousand individuals of Carp gudgeons. It was not practical to measure all fish past a count of 50 in the first fyke, both from a time management perspective and fish welfare perspective. In that instance, an additional 10 fish were measured beyond 50 to reduce sampling bias, but no more were measured as it was feared holding such large numbers of fish in containers for the duration of measuring many hundreds of individuals could lead to oxygen stress.

In cases where catches of small fish (mainly Carp gudgeons) in fykes were estimated to exceed 500 individuals in a shot, accurate counts were made of 100 individuals of the most abundant species and then volumetric sub-samples in soft mesh dip nets were used to estimate abundances of that species to speed up processing times and reduce stress on fish. Less abundant species were picked from the sub-samples for counting and measurement. Such estimation techniques were not required for electrofishing or bait traps as numbers captured per shot were much lower.

Data presentation and statistical analyses

All individual species captured were tabulated by site captured and sampling method used. The number of species (species richness) captured by each method at each site was also tabulated.

All statistical analyses were carried out using the software package GenStat (16th edition). The total number of species caught by each of the sampling methods was evaluated by a generalised linear model (GLM) using a normal distribution, with identity link function and with sampling event and method as fixed effects. This was followed by a post hoc pairwise comparison of sampling methods with Fisher's least significant difference (LSD) test. The number of additional species detected by adding day set fykes or night set fykes to the existing MDB Fish survey methods (electrofishing and unbaited bait traps) were also analysed by GLM, using a normal distribution and identity link function, with fyke method and sampling event as fixed effects.

For the more common species, abundance of each species captured by each gear type was also examined by GLM, using a Poisson distribution (to account for large numbers of zero values) with a log link function. The dispersion parameter set in each model used the estimate function and was based on residual mean deviance. Sampling event and method were used as factors in the models. For most species bait traps captured no individuals at all sites. Therefore, bait traps were excluded from most analyses of abundance by gear type. For any given species, any sampling method that recorded zero captures across all sites was excluded from any analyses for that species, but the raw data are still presented in tabular form in this report. If a sampling method had zero captures across all sites for a relatively common species, then it was assumed that method was not effective for that species. Temperature, conductivity and Secchi depth were initially run as covariates in the GLM models, but were not found to have any significant effect and were therefore dropped from the final analyses.

For any GLM model that showed a significant effect for sampling method, a post hoc pairwise LSD test was run for sampling method. Catch rates are presented as back-transformed means.

Unspecked hardyheads *Craterocephalus stercusmuscarum fulvus* were only captured at one site (Kings Bridge). They were relatively abundant at this site, even though absent at all other sites. Sampling gear was compared within this site using the Chi-square test for equal proportions.

Length frequency histograms were generated for pooled data across all sites for the more abundant species captured by fykes and/or electrofishing. Length frequency distributions were compared between pairs of sampling methods with the non-parametric Kolmogorov-Smirnoff test. This was to determine if different capture methods were biased towards certain size classes. Bait traps did not capture enough individuals of any species for length frequency analyses to be meaningful, therefore bait traps were not included in length frequency analyses.

Results

Water quality data

Table 2 shows water quality data by site. Secchi depth ranged from 5 to 49 cm. Therefore all sites would be classified turbid. Nine of the eleven sites used in this study had Secchi depths of 10 cm or less, which is highly turbid. Conductivity ranged from 60 to 1168 $\mu S.cm^{-1}$. Boat electrofishers can operate in this range, but the effective field for stunning small fish would be reduced at 1168 $\mu S.cm^{-1}$ compared to the other conductivity levels observed. Water temperatures ranged from 16.9 to 25.8º C. Water temperature can affect activity levels of fish, but the temperatures observed were not extreme.

Table 2- Representative water quality samples from the study sites at the time of survey

Valley	Site	Representative water quality samples from time of fish survey		
		Temperature °C	**Conductivity µS.cm^{-2}**	**Secchi depth cm**
Paroo	64332	16.9	82	5
Paroo	64346	19.1	72	8
Warrego	64271	19.5	122	10
Warrego	64285	16.9	114	8
Warrego	64304	21.2	125	6
Warrego	70501	21.6	102	29
Warrego	70531	21.4	121	8
Condamine	66813	25.8	1168	49
Condamine	72902	23.2	60	6
Condamine	66784	24.5	196	9
Condamine	66787	24.1	173	10

Species detected

Table 3 shows species captured by sampling method, valley and site. A total of 15 fish species, 12 native and three non-native species were captured across the eleven sites. Note the *Hypseleotris* species complex is treated as if a single species in this context, although it is likely several species of *Hypseleotris* were captured. The Environment Protection and Biodiversity Conservation Act (EPBC)-listed species Murray cod *Maccullochella peelii peelii* was captured only by electrofishing. The EPBC-listed Silver perch *Bidyanus bidyanus* (a single specimen) was captured only by overnight set fykes. Hyrtl's tandan *Neosilurus hyrtlii* was captured only by day and night set fyke nets. Night set fykes captured this species at six sites, whereas day set fykes captured this species at just four sites. Freshwater catfish *Tandanus tandanus* was captured at only two sites, one specimen by electrofishing and one individual by overnight set fykes.

Table 3- Species of fish captured by valley, site and sampling method

Valley	Paroo	Paroo	Warrego	Warrego	Warrego	Warrego	Warrego	Condamine	Condamine	Condamine	Condamine
Site	**64332**	**64346**	**64271**	**64285**	**64304**	**70501**	**70531**	**66813**	**72902**	**66784**	**66787**
NEMERE	E, FON,FYD	E, FON, FYD	E, FON, FYD	E, FON, FYD	E, FON, FYD	E, FON, FYD	E, FON	E,	E, FON	E, FON, FYD	E, FON, FYD
RETSEM		E, FYD	E, FYD	E, FON, FYD				FYD	E	FON	
NEOHYR	FON, FYD	FON, FYD		FON, FYD					FON, FYD	FON	FON
TANTAN						FON		E			
CRASTE								E, FON, FYD			
MELFLU								E, FON, FYD		E	E, FON
MELSPL	E	E, FON, FYD	E	E		E					
MACAMB	E, FON,FYD	E, FON,FYD	E, FON		E, FON	E, FON, FYD	E, FON, FYD	E, FYD	E, FON, FYD	E, FON, FYD	E, FON, FYD
MACPEE			E				E				E
BIDBID	FON										
LEIUNI	E, FYD	E, FON, FYD		E, FON, FYD	E, FON, FYD	E, FON, FYD	E	E	FON, FYD	FON	E, FON
HYPSPP		E, FON	E, FON, FYD	E, FON, FYD	FON, FYD	E, FON, FYD, T	FON, FYD	E, FON, FYD, T	E, FON, FYD	E, FON, FYD, T	E, FON, FYD
CYPCAR	E, FON	E	E	E, FON	E	E	E	E	E	E, FON	E, FON
CARAUR		E		E		E, FON		E			
GAMHOL	E		E	E	E	E	E	E	E, FON, FYD	FON, FYD	E, FYD

Key. Species codes: NEMERE *Nematalosa erebi* Bony bream, RETSEM *Retropinna semoni* Australian smelt, NEOHYR *Neosilurus hyrtlii* Hyrtl's tandan, TAN TAN *Tandanus tandanus* Freshwater catfish, CRASTE *Craterocephalus stercusmuscarum fulvus* Un-specked hardyhead, MELFLU *Melanotaenia fluviatilis* Murray-Darling rainbowfish, MELSPL *Melanotaenia splendida tatei* Desert rainbowfish MACAMB *Macquaria ambigua ambigua* Golden perch, MACPEE *Maccullochella peelii peelii* Murray cod, BIDBID *Bidyanus bidyanus* Silver perch, LEIUNI *Leiopotherapon unicolor* Spangled perch, HYPSPP *Hypseleotris spp* Carp gudgeons, CYPCAR *Cyprinus carpio* Carp CARAUR *Carassius auratus* Goldfish, GAMHOL *Gambusia holbrooki* Eastern gambusia
Sampling methods code: E electrofishing, FON Fyke overnight set, FYD Fyke day-time set, T bait trap.

Murray-Darling rainbowfish *Melanotaenia fluviatilis* was captured only in Condamine Valley sites by all methods except bait traps and the Desert rainbowfish *Melanotaenia splendida tatei* was captured only in Warrego and Paroo Valley sites. The latter species was captured by electrofishing at five sites and by day and night set fykes at just one site. Unspecked hardyhead *C. s. fulvus* was recorded at just one Condamine valley site by electrofishing, and by both fyke sampling methods.

The only species (or species group) captured by bait traps was the Carp gudgeon species complex *Hypseleotris* spp. But this species group was also captured by electrofishing, day set fykes and night set fykes and was recorded at 10 of the 11 sites sampled.

The pest fish species carp *Cyprinus carpio* was captured at every site sampled. Carp were captured by electrofishing at every site and also by overnight set fykes at four sites. Eastern Gambusia or mosquitofish *Gambusia holbrooki* were recorded at 10 of the 11 sites sampled. They were mainly captured by electrofishing, but were also captured by day set and overnight set fykes at three and two sites each respectively.

Golden perch *Macquaria ambigua* were captured at ten sites. This species was captured by all sampling methods except bait traps. Bony bream *Nematalosa* erebi were recorded at every site and like golden perch were captured by electrofishing, day set fykes and overnight set fykes. Spangled perch *Leiopotherapon unicolor* was recorded from ten sites. This species was captured by electrofishing, day set fykes and night set fykes.

Table 4- Number of fish species detected at each site by different sampling methods. Numbers in brackets in the two right hand columns show additional species detected when combining fyke data with existing MDB Fish survey (electrofishing and bait trap) sampling method data.

Valley	Site	Number of fish species captured by sampling method					
		Electrofishing boat	Bait trap	Day set fyke (FYD)	Overnight set fyke (FON)	Fish Survey method + FYD	Fish Survey method + FON
Paroo	64332	6	0	4	5	7 (+1)	8 (+2)
Paroo	64346	8	0	6	6	9 (+1)	9 (+1)
Warrego	64271	8	0	3	3	8 (0)	8 (0)
Warrego	64285	9	0	6	7	10 (+1)	10 (+1)
Warrego	64304	5	0	3	4	6 (+1)	6 (+1)
Warrego	70501	8	1	4	6	8 (0)	9 (+1)
Warrego	70531	6	0	2	3	7 (+1)	7 (+1)
Condamine	66813	10	1	5	3	11 (+1)	10 (0)
Condamine	72902	6	0	5	6	8 (+2)	8 (+2)
Condamine	66784	5	1	3	8	5 (0)	9 (+4)
Condamine	66787	8	0	4	7	8 (0)	9 (+1)

Table 4 shows the number of species captured by each sampling method at each site. It also includes information on how many species were captured when combining either day or night fyke data with

electrofishing and bait trap (the current MDB fish survey method) data. Values in brackets indicate the number of additional species detected by adding the fyke methods. Additional species detected by day set fykes ranged from zero to two per site, with additional species being detected at seven of eleven sites. Additional species detected per site by overnight set fykes ranged from zero to four, with additional species being detected at nine of eleven sites.

The GLM for number of species caught by method and sampling event (site) was significant for method ($p<0.001$) (3 d.f.) but not for sampling event (site) (10 d.f.). Table 5 shows the results of Fisher's least significant difference test. Numbers of species caught were significantly different between all sampling methods. Electrofishing captured the highest mean number of species, followed by overnight set fykes, then day set fykes and then bait traps.

Table 5- Mean number of species captured per site by different sampling methods. Means not sharing a letter in common are significantly different from each other (p<0.05).

Sampling method	Mean number of species captured per site
Bait trap (unbaited)	0.273 a
Fyke (day set)	4.091 b
Fyke (overnight set)	5.273 c
Electrofishing boat	7.182 d

A mean of 0.7273 extra species were detected per site by the addition of day set fykes to the MDB fish survey sampling regime. Addition of overnight set fykes to the MDB fish survey method added a mean of 1.272 extra species detected per site. However, the difference between day and overnight set fykes in additional species detected was not significant ($p=0.173$). Comparison of the increased species catch by the two fyke methods had fewer degrees of freedom than comparison of numbers of species caught for each of the four sampling methods.

Hyrtl's tandan *N. hyrtlii*

Table 6 shows the numbers of Hyrtl's tandan *N. hyrtlii* captured by the different sampling methods. Some relatively high numbers were captured at some sites by fykes set overnight, whereas none were captured at the same sites by electrofishing or bait traps. Day set fykes also detected *N. hyrtlii* but in lesser numbers and at fewer sites (Table 6).

Table 7 shows a summary of the GLM model used to compare Hyrtl's tandan catch rates for day set fykes and overnight set fykes at 11 sites. The model was significant ($p<0.001$). Estimates of parameters (not shown in Table 7) showed both method ($p<0.001$) and sampling event (site) contributed significantly to the model, with some sites being significantly different to the reference level of site 66784 ($p<0.01$). The latter reflects between-site differences in abundance of Hyrtl's tandan. Given that method was a significant parameter in the model and only two methods were tested, post-hoc pairwise comparisons were not required. The mean capture rate of Hyrtl's tandan by overnight fyke was 19.00± 2.258 (SEM) per site, whereas the mean catch by day set fyke was 5.45±1.210, demonstrating that overnight fykes were more effective at capturing Hyrtl's tandan.

Table 6- Numbers of Hyrtl's tandan captured by valley, site and method

Valley	Site	Numbers of Hyrtl's tandan captured by sampling method			
		Electrofishing boat	Bait trap	Day set fyke	Overnight set fyke
Paroo	64332	0	0	5	64
Paroo	64346	0	0	32	57
Warrego	64271	0	0	0	0
Warrego	64285	0	0	15	73
Warrego	64304	0	0	0	0
Warrego	70501	0	0	0	0
Warrego	70531	0	0	0	0
Condamine	66813	0	0	0	0
Condamine	72902	0	0	8	9
Condamine	66784	0	0	0	4
Condamine	66787	0	0	0	2

Table 7- Summary of analysis for GLM of Hyrtl's tandan catch by day set fykes and overnight set fykes. Sampling method and sampling event (site) were factors in the model. The model used a Poisson distribution with log link function.

	Degrees of freedom	Deviance	Mean deviance	Deviance ratio	Approx. F pr.
Regression	11	648.97	58.998	19.98	<0.001
Residual	10	29.53	2.953		
Total	21	678.51	32.310		

Figure 3 shows length frequency distributions for Hyrtl's tandan captured by day set and overnight set fykes. The Kolmogorov-Smirnov two-sample test showed there were significant differences in the size distribution of Hyrtl's tandan captured by the two different fyke methods (p=0.011, 2 d.f.). Interpretation of Figure 3 suggests that overnight set fykes not only captured more fish overall, but also captured a wider size range (65-274 mm vs 75 -224 mm) than day set fykes. Overnight set fykes caught far more juveniles in the 85-99 mm size range and far more large adult fish than day set fykes. The length frequency distribution of day set fykes appears more like a normal distribution, whereas the distribution of fish captured in the overnight set fykes is more deviated from normal and more suggestive of different year class strengths.

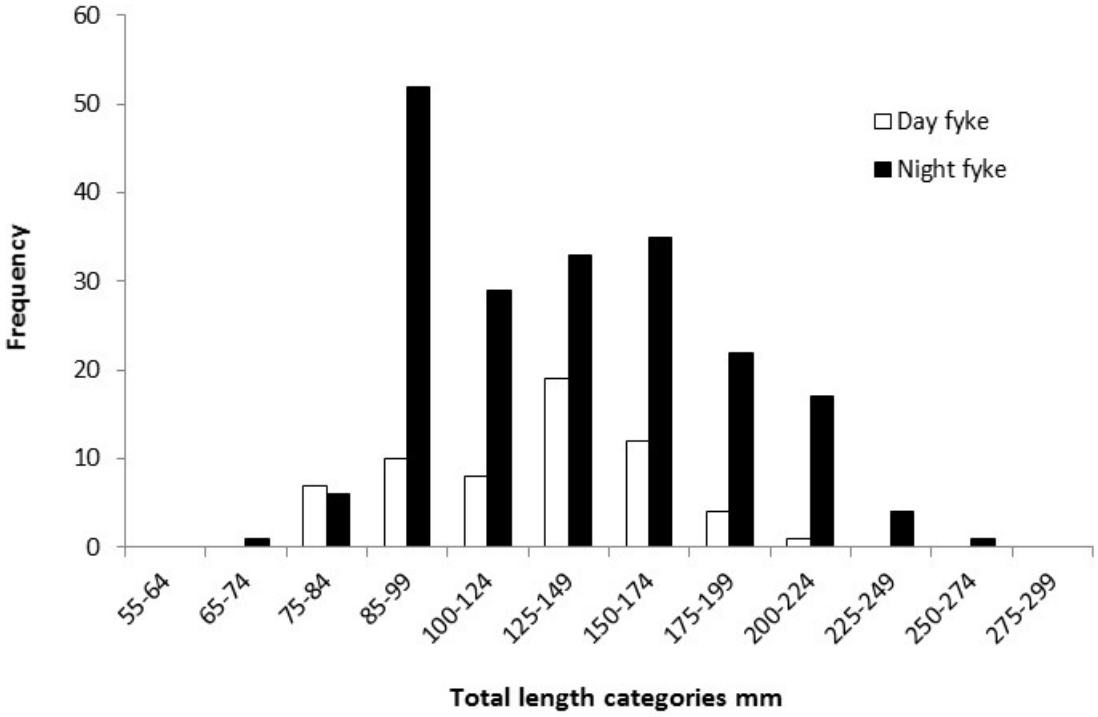

Figure 3- Length frequency distributions of Hyrtl's tandan captured by day set and overnight set fykes.

Golden perch *M. ambigua*

Table 8 shows the catch rates of Golden perch *M. ambigua* by the different sampling methods across the 11 sites sampled. At some sites electrofishing captured higher numbers of Golden perch than either fyke netting method, whereas at other sites fyke nets captured more Golden perch than electrofishing. The highest number of Golden perch captured at any one site (130) was by overnight set fykes. Bait traps failed to capture any Golden perch.

The GLM model used to evaluate Golden perch catch rates for electrofishing, day set fykes and overnight set fykes across the 11 sites is shown in Table 9. The model was significant ($p=0.009$). Estimates of parameters (not shown in Table 9) showed that some parameters within sampling event (site) ($p<0.05$) and method ($p=0.05$) were significantly different than reference levels. Parameters within site were compared to the reference level for site 66784 and parameters within method were compared to the reference level for electrofishing. The model therefore suggests between-site differences in abundance, but also variation in catch effectiveness between the methods. Post hoc pairwise LSD testing for the parameter method is summarised in Table 10. Mean catch rates by electrofishing and overnight set fykes were significantly greater than catch rates by day set fykes ($p< 0.05$) but mean catch rates for electrofishing and overnight set fykes were not significantly different from each other.

Table 8- Numbers of Golden perch* M. ambigua *captured by valley, site and method

Valley	Site	Numbers of Golden perch captured by sampling method			
		Electrofishing boat	Bait trap	Day set fyke	Overnight set fyke
Paroo	64332	42	0	4	8
Paroo	64346	30	0	3	10
Warrego	64271	11	0	0	5
Warrego	64285	22	0	2	3
Warrego	64304	11	0	0	9
Warrego	70501	1	0	3	4
Warrego	70531	11	0	1	6
Condamine	66813	3	0	1	0
Condamine	72902	3	0	12	50
Condamine	66784	6	0	15	130
Condamine	66787	9	0	1	8

Table 9- Summary of analysis for GLM of Golden perch catch by electrofishing, day set fykes and overnight set fykes. Sampling method and sampling event (site) were factors in the model. The model used a Poisson distribution with log link function.

	Degrees of freedom	Deviance	Mean deviance	Deviance ratio	Approx. F pr.
Regression	12	501.2	41.76	3.31	0.009
Residual	20	252.3	12.62		
Total	32	753.5	23.55		

Table 10- Mean number of Golden perch captured per site by different sampling methods. Means not sharing a letter in common are significantly different from each other (p<0.05). Errors are one standard error of the mean.

Sampling method	Mean number of Golden perch captured per site
Electrofishing boat	13.55 ± 3.94 a
Fyke (day set)	3.82 ± 2.09 b
Fyke (overnight set)	21.18 ± 4.93 a

Figure 4 shows length frequency distributions for Golden perch captured by boat electrofishing, day set and overnight set fykes. The Kolmogorov-Smirnov two-sample test showed there were significant differences in the size distribution of Golden perch captured by boat electrofishing and day set fykes ($p<0.001$, 2 d.f.), and also between the two different fyke methods ($p=0.007$, 2 d.f.). There were also significant differences between the length frequency distribution of Golden perch captured by boat electrofishing and overnight set fykes ($p < 0.001$, 2 d.f.). Figure 4 shows that overnight set fykes captured far more juvenile fish than any other method and that boat electrofishing captured far more medium to large fish than any other method. Sites where juvenile Golden perch were abundant would be those where high catches of golden perch were made by overnight set fykes and sites where adult Golden perch were abundant is where high catches of Golden perch were made by boat electrofishing (see Table 8). Excluding bait traps, electrofishing was the least effective method for detecting small juvenile Golden perch.

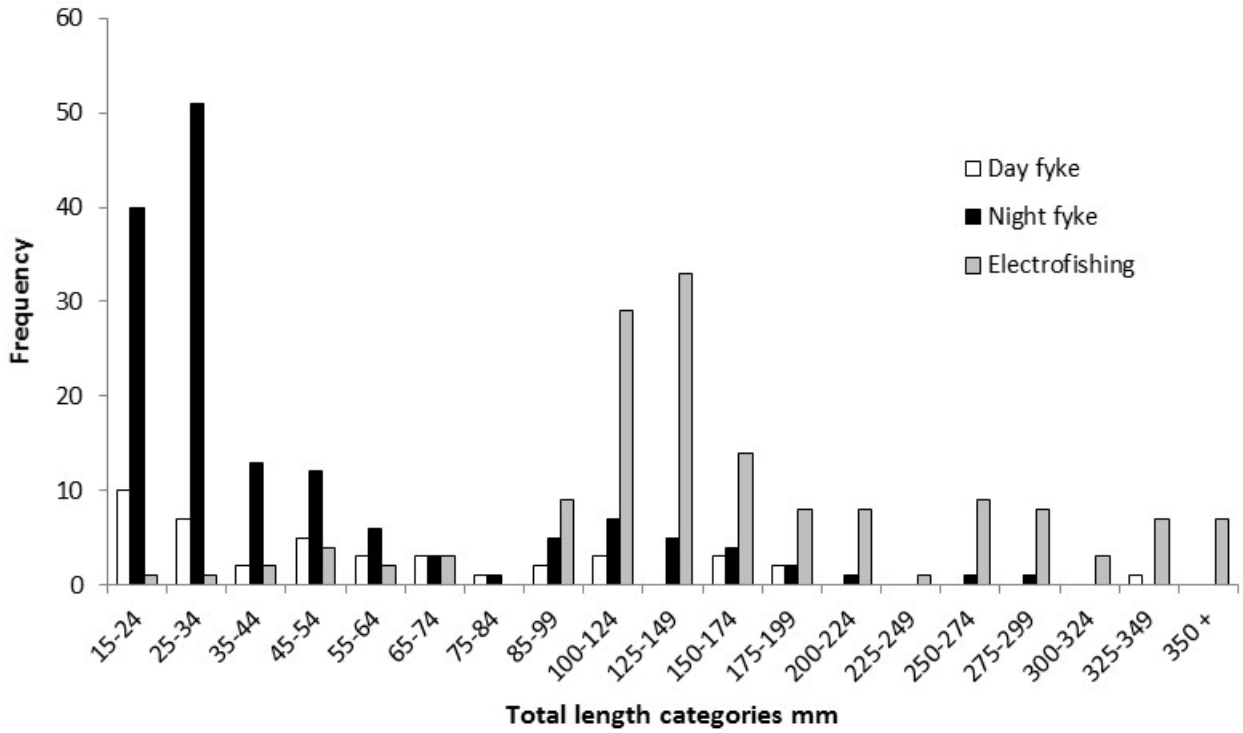

Figure 4- Length frequency distributions of Golden perch captured by boat electrofishing, day set fykes and overnight set fykes.

Carp gudgeons *Hypseleotris* spp.

Table 11 shows the numbers of Carp gudgeons captured by boat electrofishing, bait traps, day set fykes and overnight set fykes across the 11 sample sites. At most sites day and night set fykes captured more Carp gudgeons than bait traps and boat electrofishing. Day set fykes generally captured more Carp gudgeons than night set fykes. At site 66813 both fyke net methods detected thousands of Carp gudgeons, whereas bait traps and boat electrofishing only detected four each.

Table 11- Numbers of Carp gudgeons Hypseleotris spp. captured by valley, site and method

Valley	Site	Numbers of Carp gudgeons captured by sampling method			
		Electrofishing boat	Bait trap	Day set fyke	Overnight set fyke
Paroo	64332	0	0	0	0
Paroo	64346	1	0	0	11
Warrego	64271	8	0	71	27
Warrego	64285	1	0	21	26
Warrego	64304	0	0	18	10
Warrego	70501	15	2	242	153
Warrego	70531	0	0	4	1
Condamine	66813	4	4	3962	2635
Condamine	72902	2	0	5	3
Condamine	66784	5	1	108	135
Condamine	66787	7	0	92	59

The GLM model for Carp gudgeon catch rates for electrofishing, day set fykes and overnight set fykes across the 11 sites is shown in Table 12. The model was significant ($p<0.001$). Estimates of parameters (not shown in Table 12) showed some significant differences between the parameters for sampling event (site) ($p<0.001$) and method ($p<0.001$). Parameters for site were compared to the reference level 66784 and parameters for method were compared to the reference level for electrofishing. The model suggests between-site differences in abundance, but also variation in catch effectiveness between the methods. Post hoc pairwise LSD testing for the factor method is summarised in Table 13. Mean catch rates by electrofishing and bait traps were not significantly different. Mean catches by day set fykes were significantly higher than all other methods ($p<0.05$) and mean catch rates by overnight set fykes were significantly greater than those by electrofishing and bait traps ($p<0.05$).

Table 12- Summary of analysis for GLM of Carp gudgeon catch by electrofishing, day set fykes overnight set fykes and bait traps. Sampling method and sampling event (site) were factors in the model. The model used a Poisson distribution with log link function.

	Degrees of freedom	Deviance	Mean deviance	Deviance ratio	Approx. F pr.
Regression	13	35571.8	2736.29	378.46	<0.001
Residual	30	216.9	7.23		
Total	43	35788.7	832.295		

Table 13- Mean number of Carp gudgeons captured per site by different sampling methods. Means not sharing a letter in common are significantly different from each other (p<0.05). Errors are one standard error of the mean.

Sampling method	Mean number of Carp gudgeons captured per site
Electrofishing boat	3.9 ± 1.60 a
Fyke (day set)	411.2 ± 16.44 b
Fyke (overnight set)	244.1 ± 12.67 c
Bait trap	0.6 ± 0.65 a

Figure 5 shows length frequency distributions for Carp gudgeons captured by boat electrofishing, day set fykes and overnight set fykes. The Kolmogorov-Smirnov two-sample test showed significant differences in length distribution of captured carp gudgeons between boat electrofishing and overnight set fykes (p=0.027), between boat electrofishing and day set fykes (p<0.001) and between day set fykes and overnight set fykes (p=0.008).

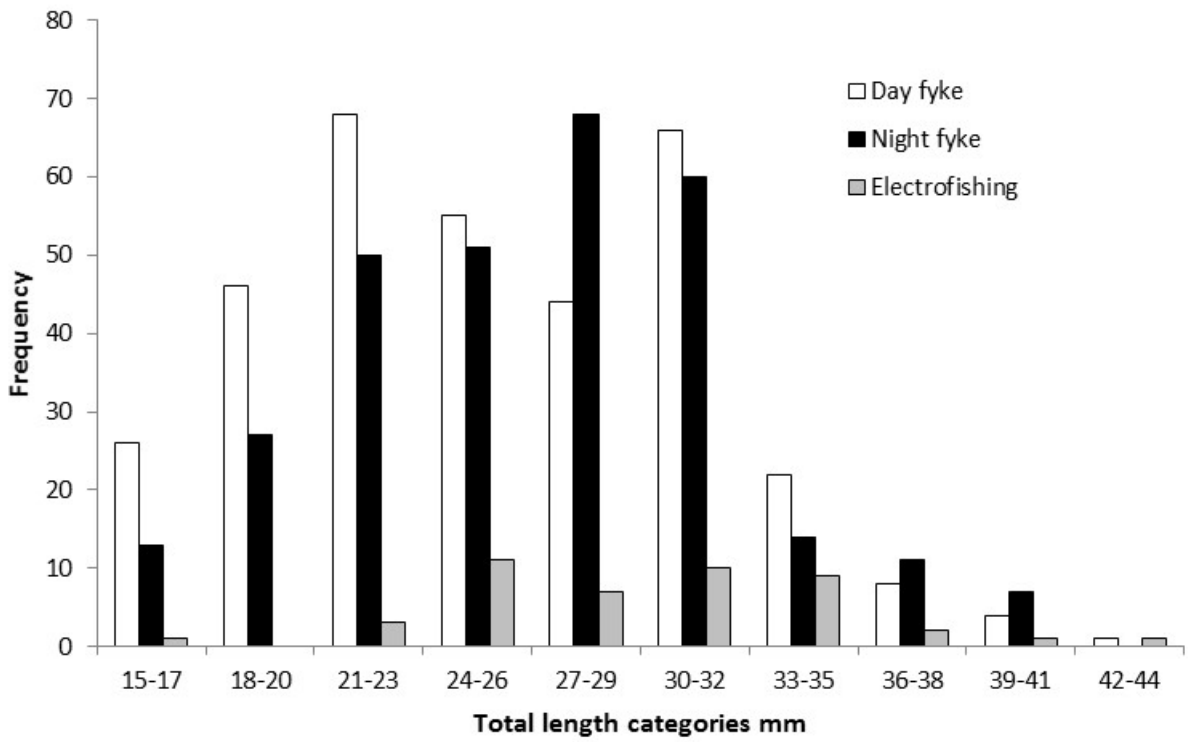

Figure 5- Length frequency distributions of Carp gudgeons captured by boat electrofishing, day set fykes and overnight set fykes.

The length frequency plot (Figure 5) suggests fyke nets (both day and night set) were more effective at capturing smaller size classes of carp gudgeons than boat electrofishing. In general, length distributions of carp gudgeons seem to follow a similar pattern between the two fyke methods, except

overnight set fykes were probably more effective at capturing some medium to large size classes and day set fykes better at capturing some of the smaller size classes.

Spangled perch *L. unicolor*

Table 14 shows the numbers of Spangled perch captured by boat electrofishing, bait traps, day set fykes and overnight set fykes across the 11 sample sites. Spangled perch were caught at ten of the sites. Bait traps did not catch any spangled perch. The other sampling methods all captured Spangled perch, but none of the methods captured very high numbers and none of the methods appeared to dominate catches.

Table 14- Numbers of Spangled perch captured by valley, site and method

Valley	Site	Number of Spangled perch captured by sampling method			
		Electrofishing boat	Bait trap	Day set fyke	Overnight set fyke
Paroo	64332	3	0	1	0
Paroo	64346	2	0	3	1
Warrego	64271	0	0	0	0
Warrego	64285	16	0	2	9
Warrego	64304	1	0	3	2
Warrego	70501	1	0	2	3
Warrego	70531	2	0	0	0
Condamine	66813	6	0	0	0
Condamine	72902	0	0	2	4
Condamine	66784	0	0	0	1
Condamine	66787	3	0	1	0

The GLM model for Spangled perch captures by method and sampling event (site) was significant (Table 15). However, none of the method parameters in the model was significantly different from the reference level boat electrofishing. Most sites, excluding site 64285 ($p<0.05$), were not significantly different to the reference level of site 66784. Post hoc LSD testing confirmed there were no significant differences in catch rates of Spangled perch between sampling methods excluding bait traps (Table 16).

Table 15- Summary of analysis for GLM of Spangled perch catch by electrofishing, day set fykes and overnight set fykes. Sampling method and sampling event (site) were factors in the model. The model used a Poisson distribution with log link function.

	Degrees of freedom	Deviance	Mean deviance	Deviance ratio	Approx. F pr.
Regression	12	71.77	5.981	2.96	0.015
Residual	20	40.36	2.018		
Total	32	112.13	3.504		

Table 16- Mean number of Spangled perch captured per site by different sampling methods. Means not sharing a letter in common are significantly different from each other (p<0.05). Errors are one standard error of the mean.

Sampling method	Mean number of Spangled perch captured per site
Electrofishing boat	3.091 ± 0.75 a
Fyke (day set)	1.273 ± 0.48 a
Fyke (overnight set)	1.818 ± 0.58 a

Figure 6 shows the length frequency distribution for spangled perch captured by boat electrofishing, day set fykes and overnight set fykes. Analyses by the Kolmogorov-Smirnov two-sample test found no significant differences between length distributions of spangled perch captured by any of the methods tested.

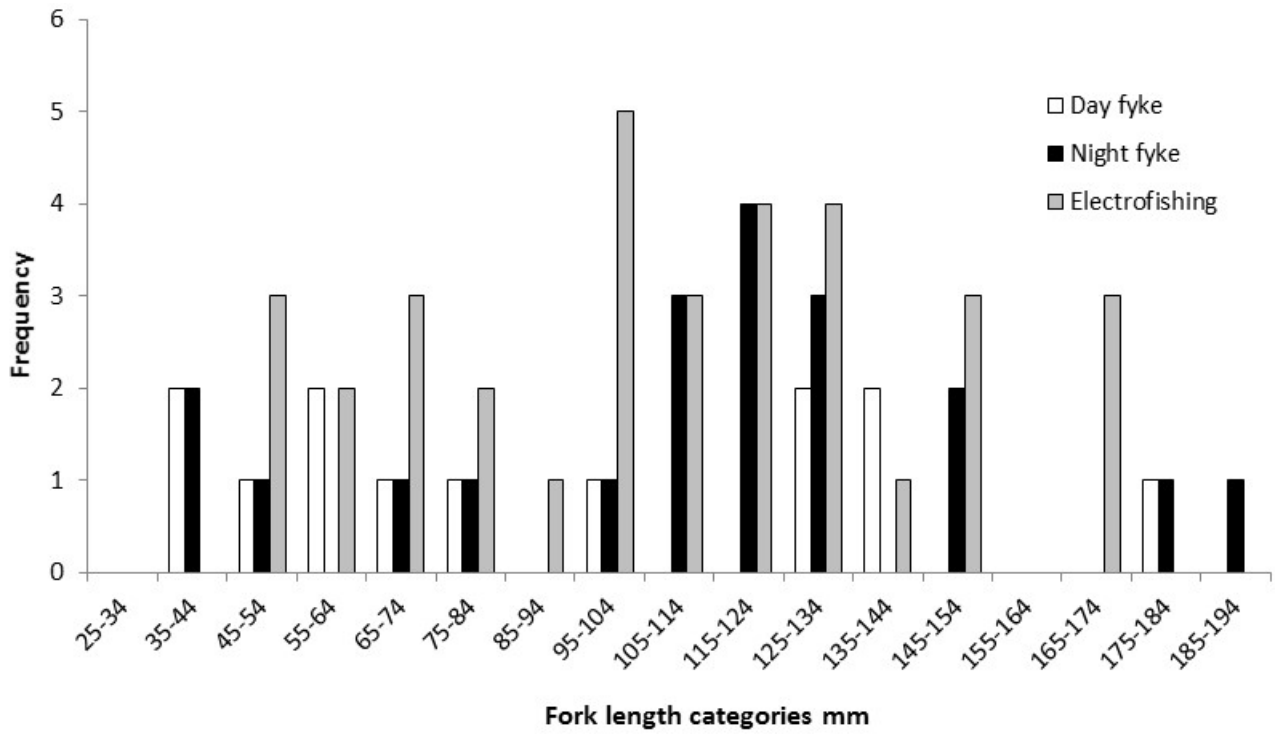

Figure 6- Length frequency distributions of Spangled perch captured by boat electrofishing, day set fykes and overnight set fykes.

Bony bream *N. erebi*

Bony bream *N. erebi* were captured at every site sampled. The majority of fish were captured by boat electrofishing and none were captured in bait traps (Table 17).

Table 17- Numbers of Bony bream captured by valley, site and method

Valley	Site	Number of Bony bream captured by sampling method			
		Electrofishing boat	Bait trap	Day set fyke	Overnight set fyke
Paroo	64332	98	0	8	11
Paroo	64346	51	0	15	3
Warrego	64271	72	0	10	3
Warrego	64285	119	0	16	17
Warrego	64304	110	0	2	4
Warrego	70501	61	0	4	1
Warrego	70531	84	0	0	1
Condamine	66813	94	0	0	0
Condamine	72902	7	0	0	2
Condamine	66784	130	0	47	24
Condamine	66787	69	0	21	15

The GLM model for Bony bream captures by method and sampling event (site) was significant (Table 18). The method parameters in the model were significantly different ($p<0.001$) from the reference level parameter boat electrofishing (not shown in Table 19). Several sites were significantly different ($p<0.05$) from the reference level of site 66784, suggesting variable abundance of Bony bream between sites. Post hoc LSD testing confirmed there were significant differences in mean catch rates of Bony bream between boat electrofishing and the two fyke sampling methods. However, day set fykes and overnight set fykes were not significantly different from each other (Table 19).

Table 18- Summary of analysis for GLM of Bony bream catch by electrofishing, day set fykes and overnight set fykes. Sampling method and sampling event (site) were factors in the model. The model used a Poisson distribution with log link function.

	Degrees of freedom	Deviance	Mean deviance	Deviance ratio	Approx. F pr.
Regression	12	1361.1	113.424	14.13	<0.001
Residual	20	160.6	8.029		
Total	32	1521.7	47.552		

Table 19- Mean number of Bony bream captured per site by different sampling methods. Means not sharing a letter in common are significantly different to each other (p<0.05). Errors are one standard error of the mean.

Sampling method	Mean number of Bony bream captured per site
Electrofishing boat	81.36 ± 7.71 a
Fyke (day set)	11.18 ± 2.85 b
Fyke (overnight set)	7.36 ± 2.32 b

Figure 7 shows the length frequency distributions of Bony bream captured by boat electrofishing, day set fykes and overnight set fykes. Even though electrofishing captured far more fish, there were no significant differences detected in size distributions by Kolmogorov-Smirnov two-sample testing between each pair of the sampling methods.

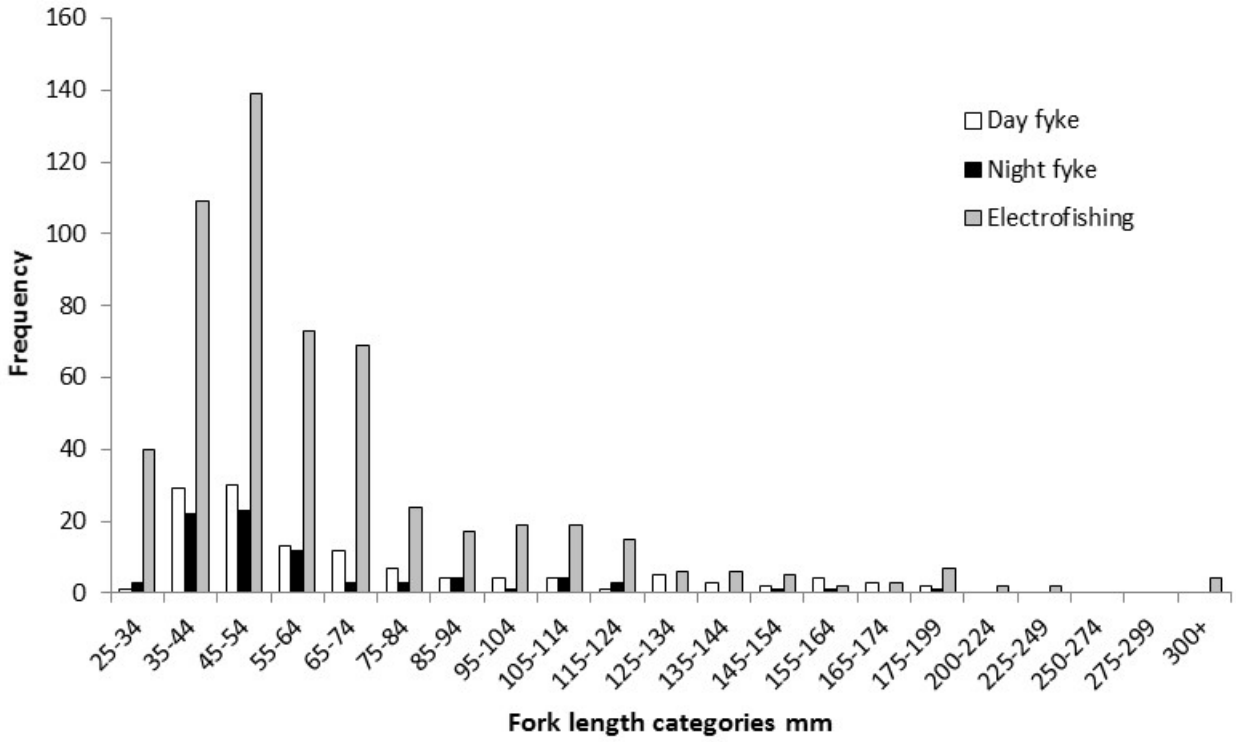

Figure 7- Length frequency distributions of Bony bream captured by boat electrofishing, day set fykes and overnight set fykes.

Un-specked hardyhead *C. s. fulvus*

Un-specked hardyheads were only recorded from one site, site 66813 in the Condamine Valley. At this site three hardyheads were captured by boat electrofishing, none by bait traps and 43 and 41 by day set and overnight set fykes respectively. Analysis of the fyke and boat electrofisher catch data by Chi-square testing for equal proportions showed a probability of <0.001 for the null hypothesis of

equal proportions, from which it is concluded that the two fyke methods were significantly more effective than electrofishing at capturing Un-specked hardyhead.

Figure 8 shows the length frequency distributions of Un-specked hardyheads captured by the two fyke methods. Kolmogorov-Smirnov twosample testing showed no significant difference between the two methods (p=0.499, 2 d.f.).

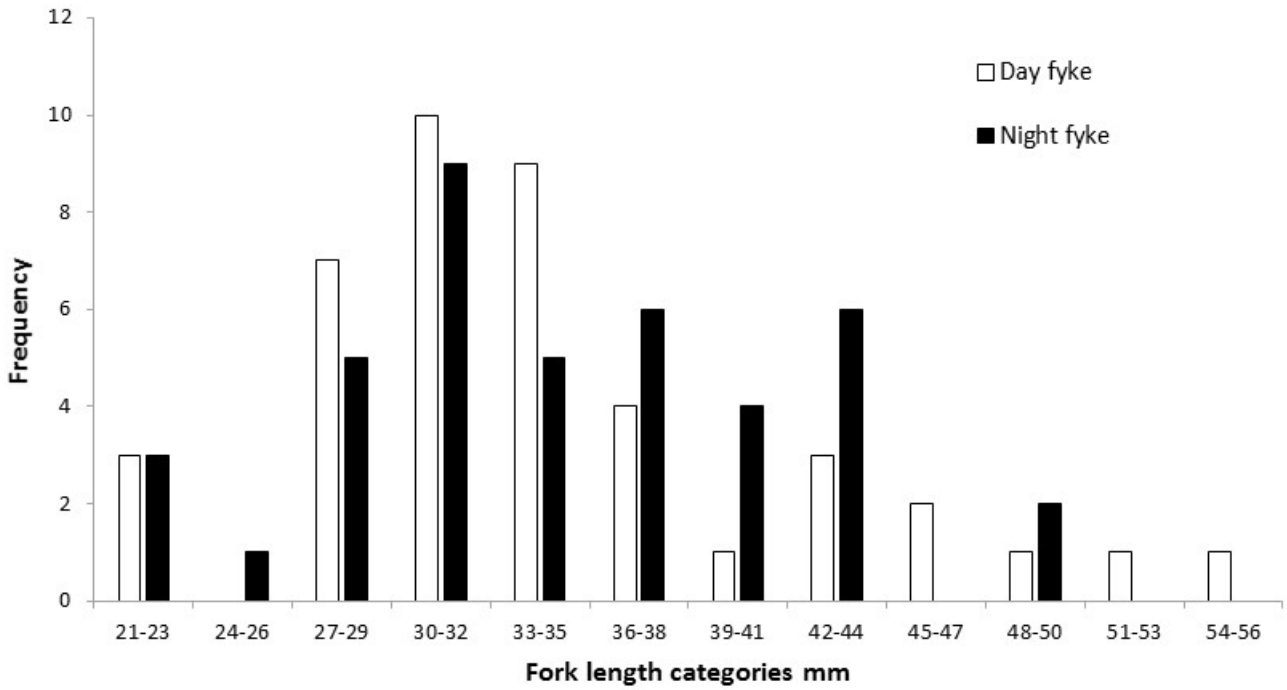

Figure 8- Length frequency distributions of Un-specked hardyheads captured by boat electrofishing, day set fykes and overnight set fykes.

Rainbowfish *M. s. tatei* and *M. fluviatilis*

Data for the two rainbowfish species have been amalgamated for the analysis of catchability by gear type. The desert rainbowfish *M. s. tatei* was only recorded in the Paroo and Warrego valleys, whereas the Murray-Darling rainbowfish *M. fluviatilis* was only recorded in the Condamine valley. For this analysis it was assumed the behaviour and catchability of the two rainbowfish species were essentially the same. Table 20 shows the catch of Rainbowfish spp. by valley site and sampling method. Rainbowfish were captured more consistently by electrofishing (i.e. at more sites).

The GLM model for Rainbowfish spp. captures by method and sampling event (site) was significant (Table 21). However, method parameters in the model were not significantly different ($p<0.001$) from the reference level parameter boat electrofishing (not shown in Table 21). One site, 66813 was significantly different ($p<0.01$) from the reference level of site 66784, reflecting the higher abundance of Rainbowfish at site 66813 relative to the other sites. Post hoc LSD testing confirmed there were no significant differences in mean catches of rainbowfish between any of the sampling methods.

Table 20- Numbers of rainbowfish captured by valley, site and method

Valley	Site	Number of Rainbowfish captured by sampling method			
		Electrofishing boat	Bait trap	Day set fyke	Overnight set fyke
Paroo	64332	4	0	0	0
Paroo	64346	7	0	5	1
Warrego	64271	2	0	0	0
Warrego	64285	3	0	0	0
Warrego	64304	0	0	0	0
Warrego	70501	1	0	0	0
Warrego	70531	0	0	0	0
Condamine	66813	19	0	21	26
Condamine	72902	0	0	0	0
Condamine	66784	10	0	0	0
Condamine	66787	6	0	0	1

Table 21- Summary of analysis for GLM of Rainbowfish spp. catch by electrofishing, day set fykes and overnight set fykes. Sampling method and sampling event (site) were factors in the model. The model used a Poisson distribution with log link function.

	Degrees of freedom	Deviance	Mean deviance	Deviance ratio	Approx. F pr.
Regression	12	244.39	20.366	8.36	<0.001
Residual	20	48.75	2.437		
Total	32	293.13	9.160		

A length frequency histogram was produced for captures of Murray-Darling rainbowfish by electrofishing, day set fykes and overnight set fykes. Too few Desert rainbowfish were captured for any analysis of length frequencies to be meaningful. Kolmogorov-Smirnov two-sample tests showed there were significant differences between the length distribution of Murray-Darling rainbowfish captured by boat electrofishing and fykes set overnight. (p=0.001, 2 d.f.). Electrofishing seems to have captured a wider size range (Figure 9).

No significant differences were detected by the Kolmogorov-Smirnov two-sample test between boat electrofishing and day set fykes (p=0.226, 2 d.f.) or between day set fykes and overnight set fykes (p=0.247, 2 d.f.). The non-significant result for day set fykes may in part be related to the smaller sample size (n=21), compared to boat electrofishing (n=35) and overnight set fykes (n=27).

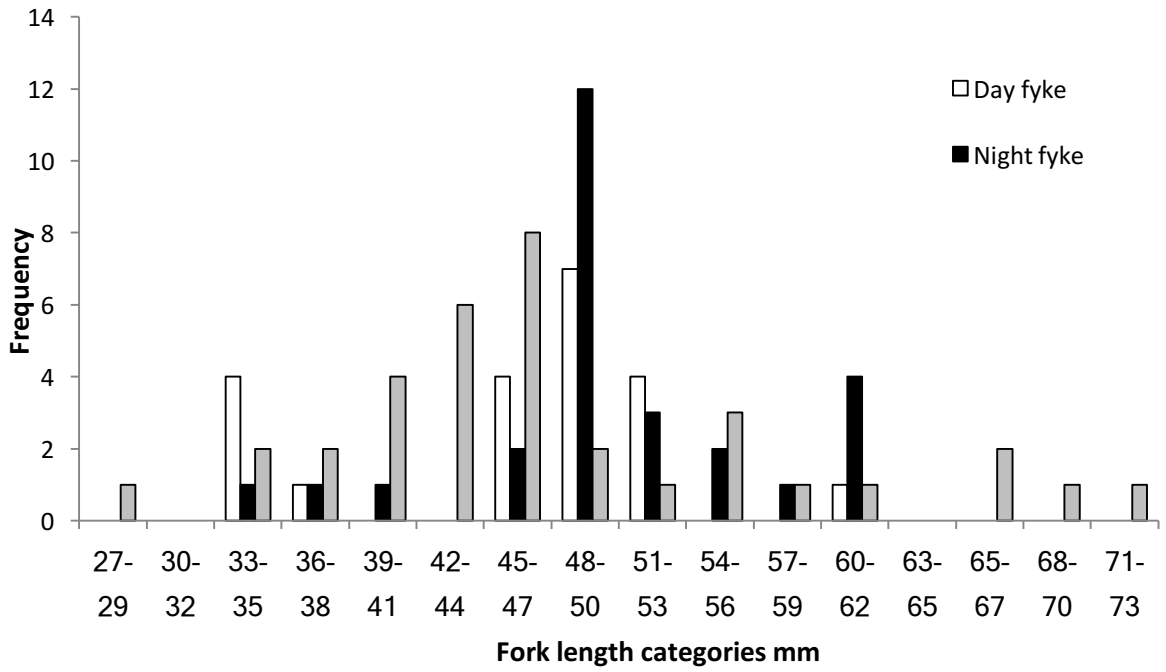

Figure 9- Length frequency distributions of Murray-Darling rainbowfish captured by boat electrofishing, day set fykes and overnight set fykes.

Carp *C. carpio*

Table 22 shows the number of Carp *C. carpio* captured by method valley and site. Electrofishing captured carp at every site, whereas bait traps and day set fykes captured no arp. Overnight set fykes captured carp at only 4 sites and in very low numbers.

Table 22- Numbers of carp captured by valley, site and method

Valley	**Site**	**Number of Carp captured by sampling method**			
		Electrofishing boat	Bait trap	Day set fyke	Overnight set fyke
Paroo	64332	1	0	0	2
Paroo	64346	5	0	0	0
Warrego	64271	6	0	0	0
Warrego	64285	19	0	0	1
Warrego	64304	6	0	0	0
Warrego	70501	6	0	0	0
Warrego	70531	7	0	0	0
Condamine	66813	15	0	0	0
Condamine	72902	7	0	0	0
Condamine	66784	2	0	0	2
Condamine	66787	7	0	0	1

Based on Table 22, statistical analysis was not really essential to show a difference in the sampling methods for carp. Nevertheless, a GLM for carp catch by method (boat electrofishing and overnight fyke) and by sampling event (site) was run. The GLM is summarised in Table 23. The overall model was significant, but none of the parameters for sampling event (site) were significantly different from the reference level of Site 66784 ($p>0.1$). Overnight set fyke catches were significantly different from the boat electrofishing ($p=0.002$). This reflects the generally higher and more consistent catch of carp by boat electrofishing than by overnight set fykes. Not enough carp were captured by overnight set fykes to warrant a length distribution comparison with carp captured by boat electrofishing.

Table 23- Summary of analysis for GLM of Carp catch by electrofishing and overnight set fykes. Sampling method and sampling event (site) were factors in the model. The model used a Poisson distribution with log link function.

	Degrees of freedom	Deviance	Mean deviance	Deviance ratio	Approx. F pr.
Regression	11	104.21	9.474	4.66	0.011
Residual	10	20.33	2.033		
Total	21	124.55	5.931		

Discussion

The sites sampled in this survey were highly turbid. Secchi depths recorded in some southern riverine and anabranch sites include an average Secchi depth of 50 cm in the lower Murray, 48 cm between Mildura and Euston, 57 cm in the Great Darling Anabranch and 78 cm in the lower Darling River in 2005/06 (Gilligan 2007). In 2006/07 average Secchi depth reported for the lower Murray River downstream of Mildura was 76 cm and for the Murray River between Euston and Mildura the average Secchi depth was 68 cm. The lower Darling River had an average Secchi depth of 42 cm and the Great Darling anabranch an average Secchi depth of 55 cm (Gilligan 2009). These readings contrast with the northern river sites in this current survey, where Secchi depths were generally 10 cm or less and where the least turbid site had a Secchi reading of only 49 cm. Turbidity can therefore be expected to have had a major influence on sampling efficiency of electrofishing and potentially bait traps. In clearer water fish may enter bait traps for cover, but in highly turbid waters there would be little to attract fish into unbaited bait traps.

The SRA Pilot report (Murray-Darling Basin Commission 2004) stated the following: “because electrofishing under-represented several rare (few individuals per site) and small (in length) fish species, there is potential for improving representation of these fish at some sites by setting bait traps for a short period. It is recommended to assess the results from setting ten bait traps for two hours at each site in the first round of the full SRA.” However, it is clear from the results of this current report that bait traps are ineffective in northern turbid rivers for detecting fish. As a group Carp gudgeon are a widespread and abundant small fish species in the northern Basin (Moffatt and Voller 2002), yet this was the only species detected by bait traps and detected at only three of the eleven trial sites for a total of seven individuals. At site 66813 (the least turbid site) where ten bait traps captured just four Carp gudgeons (the highest catch by bait traps at any of the 11 sites), thousands of individual Carp gudgeons were captured by both day set and overnight set fykes.

Electrofishing captured far fewer Carp gudgeons than fykes and tended to catch mainly larger individuals.

The Sustainable Rivers Audit (SRA) was the precursor to the current Murray-Darling Basin Fish survey. Fyke nets were trialled in the SRA pilot in the Condamine catchment, but not in the Paroo or Warrego catchments (Murray-Darling Basin Commission 2004). Fyke nets were also trialled in several more southern catchments. The fyke nets used in the SRA pilot were of the same dimensions as the fyke nets used in the current study; however, the mesh size used in the SRA pilot was 10 mm (Murray-Darling Basin Commission 2004) compared to 1 mm squares (or 2mm stretched diagonal) in the current study. Fyke nets were dropped from the SRA program after the pilot work.

The use of coarser meshed fykes in the SRA pilot may have led to an underestimation of the effectiveness of fykes in detecting small fish assemblages like Carp gudgeons. Use of fine mesh fykes can clearly alter nativeness indices based on abundance. Use of just electrofishing and bait traps could lead to a large underestimation of the abundance of the Carp gudgeon species group in northern turbid rivers. The fine-mesh fyke nets used in this study were also effective at detecting a range of other species that were not detected by bait traps in the northern turbid rivers.

Use of fyke nets in the current study increased the number of species detected at the majority of sites. In contrast, use of bait traps did not increase the number of species detected at any site. Although unbaited bait traps may be of some value in detecting additional species in more southern, less turbid rivers, there is no evidence for them adding anything of significance to catches in northern turbid rivers.

Overnight set fykes captured significantly more species than day set fykes and detected additional species at more sites than day set fykes. Although the mean increase in number of species detected by addition of overnight set fykes was greater than the mean increase gained from use of day set fykes, the increase was not statistically significant at the 5% level. Day set fykes captured significantly more carp gudgeons than overnight set fykes, but both methods captured significantly more Carp gudgeons than electrofishing and bait traps. However overnight set fykes captured significantly more Golden perch and Hyrtl's tandan than day set fykes

Hyrtl's tandan was a key species of interest in this study. This species is one of the target species for the Basin-wide environmental watering program (Murray-Darling Basin Authority 2014). This species was only detected by fyke nets across the eleven sites sampled in the current study. During the SRA pilot Hyrtl's tandan were also captured in fyke nets. The related *Porochilus rendahli* (Rendahl's tandan) was only captured by fyke nets and only at reference locations in the SRA pilot (Murray-Darling Basin Commission 2004). With its decision to drop fyke nets from the SRA, the Murray-Darling Basin Commission seems to have concluded that Hyrtl's tandan was a rarer species just detected by chance, and it was just as likely it could be detected by electrofishing. This conclusion may have been reached because the pilot work was conducted in the Condamine River, where Hyrtl's tandan is probably less abundant than in the Warrego or Paroo rivers. The current study shows clearly that Hyrtl's tandan are detected at multiple sites by fykes, but remain undetected by electrofishing, even when detected in relatively high numbers by fykes (especially overnight set fykes). It should be noted that at two NSW sites on the Paroo, where fykes were not set in the 2015/16 round of MDB Fish Survey sampling, Hyrtl's tandan were detected by electrofishing (one and two individuals respectively). It is likely that had fykes been set at those sites, much higher numbers of Hyrtl's tandan would have been caught. Use of fykes will add statistical power to any evaluation of Hyrtl's tandan populations. Also, since Hyrtl's tandan is a medium sized species (Figure 10), the

current MDB Fish Survey method is likely to underestimate relative biomass of native species at sites where Hyrtl's tandan are abundant if fykes are not included as a sampling method.

The results of the current study show that overnight set fykes detect Hyrtl's tandan at more sites and in greater numbers than day set fykes. Overnight set fykes also detect more juveniles and a greater size range of fish than day set fykes.

Figure 10- Part of a Hyrtl's tandan catch from a fyke set in the Paroo River.

It is interesting to note that since fyke nets were dropped from the SRA, Rendahl's tandan were not detected again in any subsequent SRA survey. However, they were detected in a range of other surveys during the same period in both tributary systems and wetland systems. All those surveys used fykes in addition to other methods (Hutchison 2014).

Overnight fykes significantly increase detection rates of small juvenile golden perch. Golden perch in the 15-34 mm size range were a feature of overnight set fyke captures. Within Queensland, Golden perch are generally stocked at 50 mm in length. Golden perch captured at less than 40 mm total length would all have been of wild origin. Detection of golden perch of less than 40 mm enables immediate confirmation of natural recruitment. Any larger juveniles would require either genetic fingerprinting analyses or lethal sampling to check for calcein marks in otoliths to confirm if they are natural recruits or stocked fish.

In contrast to overnight set fyke nets, electrofishing detected very few golden perch of less than 40 mm, but electrofishing was more effective at detecting adult Golden perch than either of the fyke net techniques. Electrofishing and overnight set fykes therefore complement each other well for the monitoring of golden perch. Continued reliance on just electrofishing and bait traps in very turbid

rivers is likely to lead to a failure to detect recent recruitment events by Golden perch. Addition of overnight set fykes to the MDB fish survey in northern turbid rivers would result in greater certainty of detecting recruitment events by Golden perch. Increased recruitment is one of the key objectives of the Basin Plan (Murray-Darling Basin Authority 2012) and the Basin-wide environmental watering strategy (Murray-Darling Basin Authority 2014).

Various studies have found fykes to be a useful sampling tool. Overnight set fykes have been shown to be an effective sampling tool for small sized fish. For example, the largest catches of Golden galaxias *Galaxias auratus* were made by night set fykes, rather than day set fykes or electrofishing (Hardie et al. 2006). Fyke nets have also been found to be more useful than electrofishing boats for characterising fish assemblages in wetlands of the Lower Great Lakes region (Chow-Fraser et al. 2003). In a review of data from various projects in the Condamine-Balonne catchment, Hutchison (2014) found that addition of fykes to a survey was more effective than electrofishing alone at detecting a number of species, including Hyrtl's tandan, Rendahl's tandan, Olive perchlet and Dwarf flathead gudgeon. The latter two species did not appear in the current study. However, the key reaches of the Condamine River and its tributaries where these species are most abundant (between Dogwood Creek junction and Cecil Plains) were not sampled. This represents a significant portion of the Condamine-Balonne catchment that isn't currently surveyed in the MDB Fish Survey.

Different environmental conditions can impact the effectiveness of sampling gears (Hubert 1983; Reynolds 1983). Different sampling gears have different sampling biases (Hubert 1983; Reynolds 1983; Porreca et al. 2013). As demonstrated in the current survey electrofishing can be more effective than fyke netting for detecting certain species of fish or particular size classes within some species. For example, in the current study electrofishing was more effective than fyke nets for sampling Bony bream, Carp, Murray cod, Eastern Gambusia and large Golden perch. Conversely, electrofishing was not effective at detecting Hyrtl's tandan, and less effective than fykes for detecting Carp gudgeons (especially smaller size classes), Un-specked hardyheads and small size classes of Golden perch. Use of both overnight set fykes and electrofishing were complementary and in combination created a broader description of the fish species assemblage and fish population structure at the sites sampled.

Conclusions and recommendations

Addition of overnight set fykes would be of far more value in northern turbid rivers than continued use of un-baited bait traps. The fine-meshed fykes used in this survey detected additional species of fish to those captured by electrofishing, whereas bait traps did not. Additional species detected on a site by site basis included Freshwater catfish, Silver perch, Australian smelt and Hyrtl's tandan. Hyrtl's tandan were shown by overnight fyke sets to be common at some sites, yet none were detected by electrofishing or bait traps. Overnight fykes were also very effective at detecting juvenile Golden perch and large numbers of Carp gudgeons at sites where few or none were detected by electrofishing or bait traps. Overnight set fykes also detected significantly more Un-specked hardyhead at a site where they were only detected in small numbers by electrofishing and not by bait traps.

Electrofishing was better at detecting large Golden perch, Bony bream, Carp, Murray cod and Eastern gambusia. Overnight fyke netting and electrofishing complement each other well. Although day set fykes also detected additional species, this was at fewer sites than overnight set fykes. With the exception of Carp gudgeons, total captures of fish were usually higher in overnight set fykes, especially in the case of Hyrtl's tandan and juvenile golden perch.

Continued reliance on just electrofishing and bait traps in northern turbid rivers will produce misleading information on fish assemblages and fish population structure. Addition of overnight set fine meshed fykes to surveys will lead to improved estimates of nativeness of fish assemblages and relative proportions of biomass of native species. Overnight set fine-meshed fykes will also improve the probability of detecting recruitment of key species, including Golden perch and Hyrtl's tandan. It is therefore **recommended** that overnight set fine mesh fykes be added to the sampling regime for the three highly turbid northern Murray-Darling Basin river valleys. Bait traps could be dropped from the northern valleys' sampling regime with little consequent effect on the overall result or sampling time. Use of overnight fyke nets will increase sampling time and slightly increase operational costs, but will also significantly improve the detection of key fish species and life history stages that are essential for evaluating the success of environmental watering strategies.

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