# The Benefits of Community and Stakeholder Driven Fish Monitoring Projects in a Murray-Darling Basin River

Adam Kerezsy[1]

**Abstract**

River and catchment management in Australia's Murray-Darling Basin underwent a transformation in the latter part of the twentieth century, from being focused on delivering water predominantly for human and agricultural needs to also considering environmental considerations. The main driver of this change was the realisation that a comparatively long period of river regulation and associated alterations to natural systems had resulted in negative consequences. Native fish communities, in particular, have been considered to be in a poor or degraded condition. The centrally located Lachlan River, in New South Wales (NSW), is a poignant example, as the fish community has been rated as 'extremely poor' in both of the basin-scale Sustainable Rivers Audit reports in 2008 and 2012. River management can generally be regarded as a top-down process, with the Murray-Darling Basin Authority and state-based agencies simultaneously relied on and looked to for advice, but also blamed for any perceived problems and inequities. However, neither the federal nor state governments and their agencies have the capacity to undertake accurate monitoring of individual catchments at localised scales. In order to achieve this, local communities and stakeholders can make a difference to the management of their catchments by actively sponsoring and participating in sampling and monitoring projects that can then inform broader catchment management. This process has begun with positive results within the Lachlan catchment, and offers a representative case study that can be applied to other areas within the Murray-Darling Basin.

**Keywords:** Lachlan River, off-river areas, Lake Cargelligo, Booberoi Creek, community involvement, fish surveys, endangered species

[1] *Dr Fish Contracting, Lake Cargelligo, NSW 2672, Australia (kerezsy@hotmail.com)*

## Introduction

In Australia's heavily modified Murray-Darling Basin (M-DB) in the nation's south-east, rivers were historically managed (from the mid-1800s) in order to ameliorate the effects of Australia's unpredictable weather systems and ensure that water could be supplied for towns and agriculture and – somewhat later – for the establishment and sustenance of irrigation districts and the generation of hydroelectricity.

Due to Australia's dry climate, the principal tools for controlling flows in the M-DB were (and remain) large headwater dams that enabled flows from the highest-rainfall areas to be harvested and stored, and a series of smaller weirs or other structures situated at various points downstream that similarly enabled water to be prevented from following riverine channels until it was required (Water Conservation and Irrigation Commission, 1971). Today, there are very few rivers in the M-DB that are unaffected by such regulation (a notable exception is the Paroo River in far western Queensland and New South Wales; Kingsford & Thompson, 2006).

By the latter part of the twentieth century, and facilitated by evolving areas of study within applied science and ecology, it became obvious that the regulated rivers of the M-DB were affected by

a range of negative issues, including damming of rivers preventing natural flows, the introduction and spread of alien species, over-allocation of water, riparian denudation, pollution, and the decline of native fish species and stocks (Arthington, 1991; Walker et al., 1995; Humphries et al., 1999; King et al., 2003; Koehn, 2004). However, these issues were also complicated by geographic location, for the basin occupies four Australian states and one territory: Queensland, New South Wales, Victoria, South Australia and the Australian Capital Territory. Within each jurisdiction, agencies with associated responsibilities (water, planning, natural resources and fisheries) worked autonomously to develop 'their' rivers and associated infrastructure. However, within 100 years it became necessary to create an over-arching organisation, first called the Murray-Darling Basin Commission (MDBC) and then the Murray-Darling Basin Authority (MDBA), as it became obvious that addressing basin issues at basin scale was essential.

The observed problems were also confounded by a general absence of historical records that documented these perturbations in a quantitative manner (the survey work of J. O. Langtry, in Cadwallader, 1977, being a notable exception). Given that fish are the ecological focus of this paper, a dataset that illustrates native fish decline in the M-DB is the commercial catch data from New South Wales (Reid et al., 1997). From 1947 (when records commenced) the catch records for three of the four native species targeted by commercial fishers (Murray cod, *Maccullochella peelii*; silver perch, *Bidyanus bidyanus*; and freshwater catfish, *Tandanus tandanus*) plummeted by the 1970s (Reid et al., 1997). Following a peak in 1960 (80 tonnes), Murray cod capture fell rapidly and stabilised to less than 10 tonnes per year within seven years. Silver perch peaked in 1958–1959 with a catch of 44 tonnes, but the fishery was exhausted by 1984–1985. Catfish were similar: 43 tonnes in 1974–1975 and complete decline by 1990. This compelling evidence led to the closure of the inland riverine commercial fishery for native species in September 2001 and is indicative of the wider problems within the basin by that time (Lintermans, 2007).

The imposition of a top-down framework to manage the M-DB (including the MDBA and state government agencies, supported by research by universities and other groups) has often led to friction between jurisdictions and – most noticeably – anger within local riverine communities who sometimes feel affronted by this approach. Graphic examples include irrigators in Griffith, New South Wales publicly burning copies of the draft Murray-Darling Basin Plan in 2010 (Australian Broadcasting Commission, 2010), and the worldwide media reaction to fish kills in the Darling River near Menindee in the summer of 2018–2019 (*The Guardian*, 2019). A more consultative approach to managing these rivers is therefore clearly desirable.

The Lachlan catchment is the geographic focus of this paper and is centrally located in the basin within NSW (Figure 1). It is the northernmost catchment in the southern M-DB, the fourth-longest river in Australia, and somewhat unique within the M-DB as it most usually reaches a terminus in the Great Cumbung Swamp (near Oxley), so is essentially an isolated catchment. The Lachlan rises in the Great Dividing Range west of Sydney, and the headwater reservoir – Wyangala Dam – harvests water from both the upper Lachlan and Abercrombie Rivers.

With the exception of the native species caught by commercial fishers and targeted by recreational and illegal fishing (those mentioned above and golden perch or yellowbelly, *Macquaria ambigua*), there is limited historical knowledge of the fish communities within the Lachlan catchment (Roberts & Sainty, 1996; Trueman, 2011). Indeed, the first published record of species within the Lachlan did not occur until Llewellyn's survey (1983), where nine native and four alien species were detected.

In response to the realisation that fish communities within the M-DB (in particular) were declining, NSW Fisheries and the Cooperative Centre for Freshwater Ecology conducted the NSW Rivers Survey (Harris & Gehrke, 1997) in an effort to generate baseline river health data across the state. The Lachlan delivered poor results, with only six native fish species present.

The urgency of the M-DB problems prompted the MDBC/MDBA to initiate a large-scale and ambitious project – the Sustainable Rivers Audit (SRA) – in an effort to measure several indicators (fish, macroinvertebrates, vegetation and hydrology) in all major M-DB catchments. However, against

the SRA criteria, the fish theme presents sobering reading, as the Lachlan fish community consistently rates as 'extremely poor' (Davies et al., 2008; Davies et al., 2012).

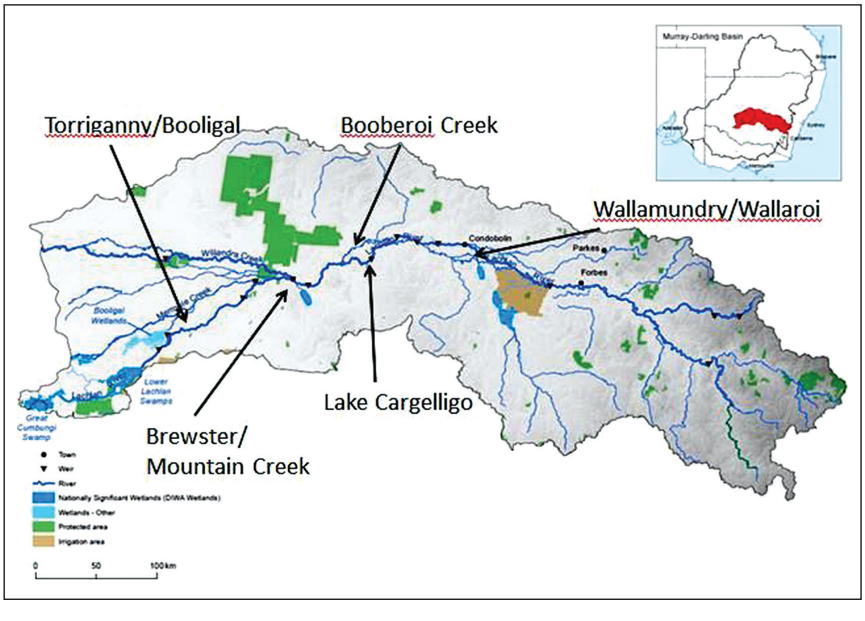
The data presented in this paper relate to fish from multiple surveys at multiple locations in the mid-Lachlan (i.e. roughly between Condobolin and Booligal; Figure 1), conducted at various times and for many different reasons between 2017 and 2020. These data have not been collected as part of a large-scale study, but instead have been sponsored and supported by local and/or regional groups – both government and not-for-profit – with an interest in auditing and then contributing to improvement of the riverine environment at local scales. The data are presented and then discussed under five headings that highlight the benefits of this 'bottom-up' approach to river management: the involvement, interest and education of local participants; the delivery of records for unknown or poorly known areas that can inform riverine management; the ecological relevance of sampling off-river areas away from the main stem of M-DB rivers; the longevity and flexibility afforded by localised monitoring; and the creation of new projects that can ensue following initial engagement. The results and discussion may, therefore, be relevant to other systems throughout the M-DB and are intended to inform future monitoring programs and management strategies.

## Materials and Methods

### Study Area

All fish sampling described in this paper was undertaken in what could be termed the 'mid-Lachlan' between 2017 and 2020. The sampling area stretches from Condobolin (elevation 220 m) in the east to Booligal (elevation 83 m) in the south-west, across a distance of approximately 253 km (Figure 1). As such, the mid-Lachlan represents a typical meandering, low-gradient river valley that is similar to many of the longer M-DB rivers such as the Murrumbidgee, Darling and Macquarie. The principal land use within this stretch of the Lachlan is dryland agriculture (cereal cropping combined with livestock production); however, irrigated systems are also common, with concentrations around Hillston and Condobolin producing cotton and tree crops (nuts and citrus). The climate of the mid-Lachlan is mediterranean, with long, hot summers (temperatures frequently exceed 40°C between November and March) and short, cold winters with multiple frosts.

**Figure 1.** Map of the Lachlan catchment. Arrows indicate areas where the fish sampling described herein has occurred between 2017 and 2020.



The mid-Lachlan is characterised by a deep (frequently deeper than 10 m) and incised main channel, and several creeks and off-river areas that are generally regulated by weirs and lock gates managed by WaterNSW. The majority of sampling was undertaken in these off-channel areas, such as the Wallamundry Creek complex close to Condobolin, Booberoi Creek between Condobolin and Lake Cargelligo, Torriganny Creek between Hillston and Booligal, and within the Lake Cargelligo system (Figures 1 & 2). Constructed from 1902–1904 by excavating channels to link low-lying areas, the Lake Cargelligo storage comprises three connected lakes that hold 36,000 ML when full. The Lake Cargelligo storage is used in conjunction with Wyangala Dam and the Lake Brewster storage to supply water to the lower sections of the Lachlan. Sampling was also undertaken at main channel sites close to the Booberoi Creek offtake and re-entry points; in the Brewster weir pool; and in Mountain Creek, which drains Lake Brewster back to the main channel of the Lachlan (Figure 1).

**Sampling Rationale and Timing**

The data presented do not derive from a discrete project but are the cumulative data collected from several projects that have occurred within the mid-Lachlan since 2017. As such, some sites have been sampled on multiple occasions, whereas others have been sampled only once or twice. Nevertheless, the same sampling methodology (described below) has been used during all sampling events, thus allowing the data to be used to infer general trends regarding the fish communities in this section of the Lachlan catchment.

Booberoi Creek was sampled on eight occasions between November 2017 and January 2020. The purpose of this sampling was to monitor the short- and long-term changes in the fish community following environmental flow releases by state and/or national water holders, who also enabled/sponsored the monitoring (NSW Department of Primary Industries and Environment (DPIE) and Commonwealth Environmental Water Office (CEWO)). Main channel sites in the vicinity of Booberoi Creek were sampled as an addition to Booberoi Creek sites in September–October 2019.

The Lake Cargelligo system was sampled on seven occasions between December 2017 and January 2020. The purpose of this sampling was to provide basic inventory information to a local not-for-profit group, the Cargelligo Wetlands and Lakes Council, in order to inform their management of an island (Robinson Crusoe Island) which they lease and manage for conservation.

The weir pool above Brewster Weir was sampled in both February and March 2019 and also in February 2020 in order to monitor the population of the endangered olive perchlet (*Ambassis agassizii*) that is known to inhabit this area. This work was undertaken in conjunction with volunteers from NSW ANGFA (Australia and New Guinea Fishes Association). Mountain Creek, which drains Lake Brewster back to the main channel of the Lachlan River, was also sampled in February 2019 in order to monitor the population of olive perchlet.

Yarrabandai Creek and Wallamundry Creek (both close to Condobolin) were sampled in October 2019 in order to provide basic inventory information and monitor an environmental flow (NSW DPIE/CEWO), and Torriganny Creek (close to Booligal) was also monitored in October 2019 for the same reasons.

In all areas, a minimum of three sites were sampled on each sampling occasion.

**Fish Sampling Methods**

Fish populations were sampled at all sites and on all sampling occasions using a combination of large and small fyke nets. These methods successfully capture fish of all body sizes and life stages in Australian inland waterways (Arthington et al., 2005; Balcombe et al., 2007). Large double-winged fyke nets with a 13 mm stretched mesh and 8 m wings (1 m deep) were set parallel to the bank with their openings facing in opposite directions upstream and downstream from a central post. Cod-ends were secured above the water surface in order to allow air-breathing vertebrates to survive if they became entrapped. Small double-winged fyke nets with a stretched mesh of 2 mm and a wing width of 3 m (1 m deep) were set in an identical manner. All fyke nets were set in the afternoon (as close as possible to 4.00 pm) and retrieved the following morning (as close as possible to 9.00 am). Following the clearing of fyke nets, all fish were held in shaded water-filled buckets prior to processing.

**Figure 2.** Habitats sampled between 2017 and 2020 ranged from areas of open water in the Lake Cargelligo system (top) to channelised riverine environments such as Booberoi Creek (bottom) (Photos: Adam Kerezsy).

Fish species were identified using a combination of published literature relating to fishes of the Murray-Darling Basin (Allen et al., 2002; Lintermans, 2007). All sampled fish were measured from the tip of the snout to the caudal peduncle to obtain a standard length (SL) measurement in millimetres. Following identification and measurement for standard length, all native fish were returned to the water alive and alien species were euthanised using a dilute solution of Aqui-S (as per OEH Animal Research Authority AEC Approval No. 171017/01).

### Data Presentation and Comparison with Previous Studies

Owing to the large number of sites and the fact that some sites were sampled on multiple occasions whereas others were only sampled once over the extended seasonal sampling timeframe, analysis of the entire dataset was neither envisaged nor attempted.

Overall total catches were calculated and tabulated for each site and species. Totals were calculated by adding all results from all sampling events in a particular area, with the number of sampling occasions also noted.

Totals were used in areas sampled multiple times (Lake Cargelligo and Booberoi Creek) in order to graph and compare fish community composition and provide a visual representation of the contribution of common and alien species in such areas.

Fish species' presence/absence was compared to previous sampling data within the Lachlan catchment (Llewellyn, 1983; Harris & Gehrke, 1997; Growns, 2001; Kerezsy, 2005; MDBC, 2004a; Davies et al., 2008; Price, 2009; Davies et al., 2012) in order to permit discussion of the current state of fish communities within the mid-Lachlan catchment.

## Results

### Total Fish Results, 2017–2020

Close to 30,000 individual fish were sampled at all sites in the mid-Lachlan between 2017 and 2020, with the vast majority (84%) being native species (Table 1). Small gudgeons of the genus *Hypseleotris* were the most commonly sampled species and were found at all sites except in the main channel of the Lachlan (Table 1). Bony herring (*Nematolosa erebi*) were also sampled in large numbers (>10,000; Table 1); however, their range was generally concentrated in the open water habitats (such as Lake Cargelligo and the Brewster Weir pool; Table 1).

Small-bodied native species such as un-specked hardyhead (*Craterocephalus stercusmuscarum fulvus*), Australian smelt (*Retropinna semoni*) and flathead gudgeon (*Philypnodon grandiceps*) were sampled in reasonable numbers; however, they were generally detected more often in Lake Cargelligo and Booberoi Creek, the two areas that were sampled on multiple occasions.

Large-bodied native species such as yellowbelly and Murray cod were sampled in small numbers, and only from Lake Cargelligo, and the endangered population of olive perchlet was detected within its known range in the Brewster Weir pool (Figure 1; Table 1).

Freshwater catfish – classified as a listed endangered population within the M-DB – was found at four locations, including Booberoi Creek, Mountain Creek, Wallamundry Creek and Lake Cargelligo. At each location, one adult catfish was sampled (Figure 1; Table 1).

The most commonly sampled alien species was gambusia (*Gambusia holbrooki*), which was present at all sites except the main channel of the Lachlan River and Yarrabandai Creek (Figure 1; Table 1). Carp were similarly distributed, occurring at all sites except Wallamundry Creek. Goldfish and redfin were sampled in far lower numbers and at a more limited number of sites (Table 1).

### Fish Communities in Different Areas

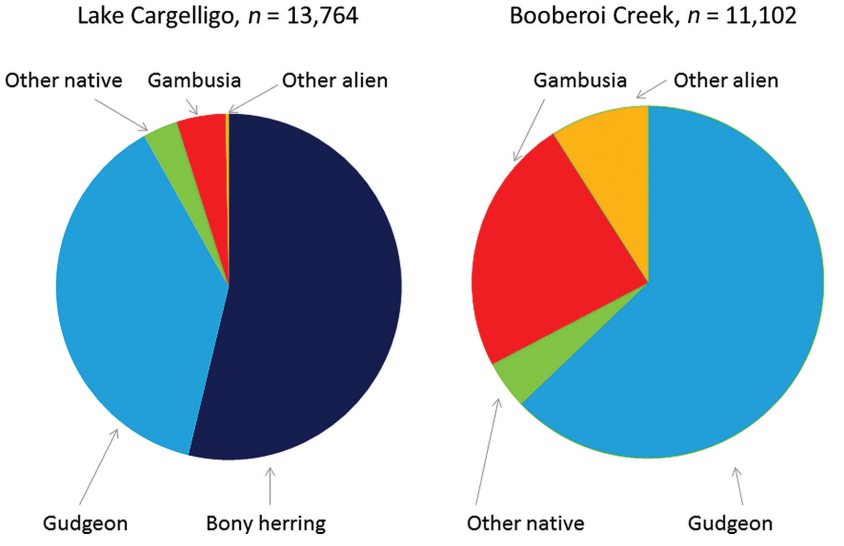
The fish community in the meandering and riverine Booberoi Creek (summed from eight sampling occasions) was dominated by small species such as gudgeons and gambusia, whereas the open-water habitat of Lake Cargelligo was dominated by bony herring (Figure 3).

In Booberoi Creek, gudgeons and gambusia were sampled during all surveys (eight) and carp were sampled during seven. Goldfish were sampled during five surveys, and un-specked hardyhead and flathead gudgeon during four. All other species in Booberoi Creek (bony herring, freshwater catfish, Australian smelt and redfin) were sampled during one survey.

**Table 1.** Total numbers of fish sampled at sites throughout the mid-Lachlan catchment from 2017–2020, including number of times each site was sampled.

| Scientific name | Common name | Booberoi Creek (sampled eight times) | Lake Cargelligo (sampled seven times) | Brewster Weir Pool (sampled three times) | Mountain Creek (sampled once) | Wallamundry Creek (sampled once) | Yarrabandai Creek (sampled once) | Torriganny Creek (sampled once) | Lachlan main channel (sampled once) | Totals |
|---|---|---|---|---|---|---|---|---|---|---|
| ***Native species*** | | | | | | | | | | |
| *Nematolosa erebi* | Bony herring | 7 | 7400 | 1690 | 1569 | — | — | — | — | **10666** |
| *Retropinna semoni* | Australian smelt | 79 | 131 | — | — | 3 | — | — | — | **213** |
| *Tandanus tandanus* | Freshwater catfish | 1 | 1 | — | 1 | 1 | — | — | — | **4** |
| *Craterocephalus stercusmuscarum fulvus* | Un-specked hardyhead | 140 | 52 | 1 | — | — | — | — | — | **193** |
| *Ambassis agassizii* | Olive perchlet | — | — | 11 | — | — | — | — | — | **11** |
| *Macquaria ambigua* | Yellowbelly | — | 18 | — | — | — | — | — | 1 | **19** |
| *Maccullochella peelii peelii* | Murray cod | — | 3 | — | — | — | — | — | — | **3** |
| *Philypnodon grandiceps* | Flathead gudgeon | 269 | 245 | 12 | — | — | — | — | — | **526** |
| *Hypseleotris* spp. | Carp gudgeons | 6981 | 5242 | 712 | 97 | 25 | 149 | 25 | — | **13231** |
| ***Alien species*** | | | | | | | | | | |
| *Cyprinus carpio* | Carp | 976 | 22 | 6 | 73 | — | 17 | 13 | 3 | **1110** |
| *Carassius auratus* | Goldfish | 28 | 1 | — | — | — | 1 | 2 | 5 | **37** |
| *Gambusia holbrooki* | Gambusia | 2620 | 631 | 259 | 89 | 6 | — | 125 | — | **3730** |
| *Perca fluviatilis* | Redfin | 1 | 18 | — | — | — | — | — | — | **19** |

**Figure 3.** Proportional representation of summed totals of all fish sampled in Lake Cargelligo (left) and Booberoi Creek (right) between 2017 and 2020.




In Lake Cargelligo, gudgeons and bony herring were sampled during all surveys (seven), carp and gambusia during six, flathead gudgeon during five, and yellowbelly, redfin and Australian smelt during four. Un-specked hardyhead were sampled during three surveys, Murray cod during two, and both freshwater catfish and goldfish were sampled during one survey.

The population of native fish sampled in Booberoi Creek represented 67% of the total, whereas in Lake Cargelligo native fish comprised 95% of the total.

### Comparison with Existing Surveys in the Lachlan Catchment

Two native species (yellowbelly and *Hypseleotris* gudgeons) and three alien species (carp, goldfish and gambusia) have been detected during nine surveys in the mid-Lachlan since 1983 (Tables 1 & 2).

Two native species (bony herring and flathead gudgeon) have been detected during eight of the nine surveys, and two native species (Murray cod and Australian smelt) and one alien species (redfin) have been detected during seven (Tables 1 & 2). Native species detected in fewer surveys include un-specked hardyhead (five surveys), freshwater catfish (four surveys), silver perch (three surveys) and olive perchlet (two surveys; Tables 1 & 2). Southern pygmy perch, flathead galaxias, Murray-Darling rainbowfish, southern purple-spotted gudgeon and trout cod have not been detected by any of the surveys of freshwater fish in the mid-Lachlan (Tables 1 & 2).

## Discussion

### Fish Records for Unknown or Poorly Known Areas Can Inform Management

River and catchment management relies on accurate records such that decisions can be made in relation to restoration works or the provision of flows that may have ecological benefit. During the monitoring studies presented here, both NSW DPIE and CEWO have used the fish survey results from specific areas to inform the timing and volume of environmental flows (J. Lenehan, DPIE, pers. comm.).

Following the detection of endangered freshwater catfish in Booberoi Creek, environmental flows were directed down this off-river system, and during subsequent sampling events populations of small native species such as un-specked hardyhead and flathead gudgeon were also recorded (Table 1). Subsequent sampling of other off-river creeks such as Wallamundry and Mountain Creeks also found catfish present and may become target areas for future environmental flows (J. Lenehan, NSW DPIE, pers. comm.).

**TTable 2.** Records of fish species in the mid-Lachlan catchment during surveys undertaken since 1983. Empty squares indicate absence.

| Family | Scientific name | Common name | Llewellyn | Harris & Gehrke | Growns | MDBC SRA Pilot Study | Kerezsy | SRA 1 Davies et al. | MDFRC Price | SRA 2 Davies et al. | Recent surveys |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1983 | 1997 | 2001 | 2004 | 2005 | 2008 | 2009 | 2012 | 2017–1920 |
| ***Native species*** | | | | | | | | | | | |
| *Clupeidae* | *Nematolosa erebi* | Bony herring | | * | * | * | * | * | * | * | * |
| *Retropinnidae* | *Retropinna semoni* | Australian smelt | * | * | * | * | * | * | | | * |
| *Plotosidae* | *Tandanus tandanus* | Freshwater catfish | * | | * | | * | | | | * |
| *Atherinidae* | *Craterocephalus stercusmuscarum fulvus* | Un-specked hardyhead | * | | | | * | * | * | | * |
| *Ambassidae* | *Ambassis agassizii* | Olive perchlet | * | | | | | | | | * |
| *Percichthyidae* | *Macquaria ambigua* | Yellowbelly | * | * | * | * | * | * | * | * | * |
| *Percichthyidae* | *Maccullochella peelii peelii* | Murray cod | * | | * | * | | * | * | * | * |
| *Terapontidae* | *Bidyanus bidyanus* | Silver perch | * | * | | | * | | | | |
| *Eleotridae* | *Philypnodon grandiceps* | Flathead gudgeon | * | * | * | * | * | | * | * | * |
| *Eleotridae* | *Hypseleotris* spp. | Carp gudgeons | * | * | * | * | * | * | * | * | * |
| ***Alien species*** | | | | | | | | | | | |
| *Cyprinidae* | *Cyprinus carpio* | Carp | * | * | * | * | * | * | * | * | * |
| *Cyprinidae* | *Carassius auratus* | Goldfish | * | * | * | * | * | * | * | * | * |
| *Poecilidae* | *Gambusia holbrooki* | Gambusia | * | * | * | * | * | * | * | * | * |
| *Percidae* | *Perca fluviatilis* | Redfin | * | * | * | * | * | | | * | * |

In Lake Cargelligo, the presence of most expected species in the Robinson Crusoe Island area similarly prompted the managers of this reserve (Cargelligo Wetlands and Lakes Council) to ask the water provider (WaterNSW) to consider altering their traditional management of the lake as a storage to also factor in the ecological and social benefits of more regular water delivery (P. Skipworth, CWLC, pers. comm.). The result has been that some water that normally would have flowed down the Lachlan has been diverted through the Lake Cargelligo system, and this appears to have had a positive effect on aquatic fauna (Tables 1 & 2).

In both of these cases, locally sponsored monitoring provided survey results that have then been used by managers to make informed decisions regarding catchment management.

**The Biological Relevance of Repeated Sampling in Off-river Habitats**

Broad-scale river surveys provide a snapshot of fish community composition in a catchment but are generally restricted to main channel sites, as opposed to lotic or lentic sites that are situated in creeks, lakes and floodplains (Davies et al., 2008; Davies et al., 2012; Price, 2009). Localised sampling has the potential to fill knowledge gaps with regard to catchment fish communities by augmenting broad-scale surveys with monitoring in a wider range of off-river habitat types. Furthermore, the repeated nature of some of this sampling (for example in Booberoi Creek and Lake Cargelligo) may deliver more informative and useful fish community data from which to inform river and water management.

Results from the mid-Lachlan between 2017 and 2020 compare favourably with all previous surveys with regard to species present (Table 2) and suggest that these off-river areas may provide valuable habitat and ecosystem services, particularly as potential refuge or nursery areas (Datry et al., 2017).

The Lake Cargelligo system (Figures 1 & 2) was essentially altered from an ephemeral wetland to a permanent storage from the early 1900s (Kerezsy, 2005). This has created large areas of shallow, open water and provided ideal habitat for pelagic schooling species such as bony herring, Australian smelt and un-specked hardyhead. The numerical dominance of bony herring in this habitat is exemplified by the survey results from 2017 onwards (Table 1), and unsurprisingly, the species also favours the similar lacustrine environment created by the Brewster Weir (Table 1).

In contrast, in the channelised and riverine habitat that occurs in Booberoi Creek (Figure 2), bony herring are uncommon and the community is dominated by small generalists such as gudgeons (*Hypseleotris* spp.) and alien gambusia (Table 1).

Carp are generally present in off-river habitats of the mid-Lachlan. However, it is notable that commercial carp fishers have been operating in Lake Cargelligo since 1 May 2018 and estimate they have removed approximately 180 tonnes of carp from the system in the intervening period (Steve Hounsell, pers. comm). It is therefore possible that sustained carp removal may be contributing to the positive results for all native species recorded from Lake Cargelligo since mid-2018 (Table 1).

Monitoring undertaken in the mid-Lachlan between 2017 and 2020 has confirmed the presence of endangered species such as freshwater catfish in four areas (Table 1) and has similarly confirmed the presence of olive perchlet within the Lake Brewster weir pool (Table 1) following the discovery of this isolated population approximately 10 years earlier (McNeill et al., 2008).

However, five species remain elusive in the mid-Lachlan, despite predictions that they were historically present and may still occur (Davies et al., 2008; Davies et al., 2012). Flathead galaxias (*Galaxias rostratus*), Murray-Darling rainbowfish (*Melanotaenia fluviatilis*), trout cod (*Maccullochella macquariensis*), southern pygmy perch (*Nannoperca australis*) and southern purple-spotted gudgeon (*Mogurnda adspersa*) have not been recorded in mid-Lachlan surveys since 1983 (Table 2), and museum records do not exist for any of these species except for a single record of a rainbowfish from Hillston in 1950 (Amanda Hay, Australian Museum, pers. comm.).

**The Longevity and Flexibility Associated with Localised Monitoring Projects**

Localised and locally supported fish sampling can be timed to coincide with and/or inform environmental watering events, and can be tailored and expanded to meet desired project management goals where necessary. For example, all of the

sampling that has occurred in Booberoi Creek has been targeted with a view to obtaining before, during and after samples of fish populations relative to the timing and volume of environmental water deliveries (J. Lenehan, DPIE, pers. comm.), and the sampling in Wallamundry Creek was initiated for the same reason. It is envisaged that long-term monitoring of Booberoi Creek is likely to continue (J. Lenehan, NSW DPIE, pers. comm.), and commencing in late 2020, another project aimed at mid-Lachlan creeks in the Forbes/Condobolin area is also planned (Mary Ewing, Lachlan Valley Water, pers. comm.).

In Lake Cargelligo, the local not-for-profit Cargelligo Wetlands and Lakes Council made a decision to continue fish monitoring in the Robinson Crusoe Island reserve area on a regular basis from 2019–2020 onwards. This decision was based on the early fish survey results and the need to create a longer-term dataset upon which to base environmental watering management plans (P. Skipworth, CWLC, pers. comm.).

This flexible approach to sampling and monitoring can have unintended benefits, with a good example being the detection of freshwater catfish in Mountain Creek (Table 1), which was initially sampled (along with the Brewster weir pool) for the purposes of auditing the Lachlan population of the endangered olive perchlet.

Locally sponsored sampling can complement established long-term monitoring projects (Dyer et al., 2019) by expanding the overall sampling area within a catchment and focusing on specific habitats or areas that are beyond the scope of larger projects.

**Involvement, Interest and Education of Local Participants**

Monitoring that is sponsored and supported by community and/or stakeholder groups – by its very nature – encourages the participation of local communities, and in the mid-Lachlan numerous examples relating to the work that has been carried out between 2017 and 2020 suggest that the flow-on effects regarding community engagement are beneficial.

During two of the Booberoi Creek monitoring events (spring 2018 and spring 2019), fish sampling took place as part of stakeholder engagement weekends/overnight trips that included local landholders, representatives from the local Aboriginal community and government agents (from NSW DPIE and CEWO). The majority of participants – but most notably the landowners – expressed interest (and surprise) at both the variety and abundance of small-bodied native fish, and most commented that although they had lived adjacent to the creek for extended periods, they were somewhat ignorant of (but keen to learn about) the local biodiversity (landowners D. Stewart, J. Ireland, pers. comms).

In April 2019, as part of routine sampling of the Robinson Crusoe Island area sponsored by Cargelligo Wetlands and Lakes Council, two coordinators and six Aboriginal teenagers from the Down The Track youth-at-risk program attended and assisted with both fish sampling and bird counts, as well as staying overnight and helping with general chores associated with bush camping (Figure 4). Coordinator Lana Masterson commented that the participants were all completely engaged with the activities, and – as soon as they were heading back to the 'mainland' by boat – enquired as to when they would be repeating the exercise (L. Masterson, Down The Track, pers. comm.).

Similarly, interest in ecological projects and associated work has become an accepted and possible career/occupation pathway for school-aged students, with one Year 10 student working on fish sampling within Lake Cargelligo as part of the local 'School to Work' work experience program (T. Kendall, careers advisor, Lake Cargelligo Central School, pers. comm.).

**The Creation of New Projects Following Initial Engagement**

Fish monitoring work undertaken in the mid-Lachlan from 2017 onwards has yielded some encouraging results regarding native fish, particularly for the areas that have been sampled on multiple occasions (Table 1; Figure 3). The communication of results from this work – mainly through informal networks and word of mouth – appears to have had a positive influence within the catchment, and as a consequence, monitoring of other areas, sponsored by different stakeholders, has commenced or will be commencing from 2020.

**Figure 4.** Members of the Down The Track program for at-risk youth participating in fish sampling at Robinson Crusoe Island, Lake Cargelligo, in March 2020 (Photo: Mal Carnegie).

From mid-2020, the ongoing monitoring of the Robinson Crusoe Island area within Lake Cargelligo will be funded and supported by a partnership between Cargelligo Lakes and Wetlands Council (a local not-for-profit group) and Lachlan Shire Council (P. Skipworth, CWLC, pers. comm.). This is an important development as it indicates that local governments have the ability to contribute positively to community-based projects that have a broad utilitarian goal (i.e. better management of the catchment for the benefit of all parties).

Commencing in spring 2020, a three-year project will commence in the Belubula catchment, and this work will be supported by Newcrest Mining (T. Thornberry, Newcrest, pers. comm.). The Belubula, which rises in high country between Bathurst and Orange and joins the Lachlan close to Gooloogong, can be considered an upstream tributary of the Lachlan, as opposed to the majority of sites discussed and sampled to date (Table 2). However, the Belubula is also poorly known regarding fish communities; thus, there is demonstrated interest from local landholders and government agencies (G. Fitzhardinge, M. Martin, C. Dunhill, J. Sanders, M. Payten, C. Proctor, pers. comms), and the results from these surveys are also likely to contribute to management of both the Belubula and Lachlan Rivers.

In a similar fashion, Lachlan Valley Water – a water users group with a focus on irrigation – will sponsor the aforementioned fish monitoring in another poorly known area of the Lachlan (from Jemalong, downstream of Forbes, to Wallamundry, in the vicinity of Condobolin) commencing in spring 2020.

Lastly, based on the success of the community-based monitoring workshops held at Booberoi Creek (spring 2018 and spring 2019), NSW DPIE is planning to repeat this model (incorporating fish sampling, bird sampling and other ecological information) in the lowland section of the Lachlan in the area close to Booligal, again commencing in spring 2020 (J. Lenehan, NSW DPIE, pers. comm.).

## Conclusions

Monitoring specific or targeted areas within a catchment is beset by the same problems that apply to broad-scale monitoring, because not all areas are likely to be sampled, and some important areas will inevitably be missed. However, if this monitoring is supported by a broad range of local and regional groups – as the surveys presented and discussed here have been – the chances of obtaining accurate information that can guide catchment management can certainly be improved.

Contrary to the results from broad-scale riverine surveys (Davies et al., 2008; Price, 2009; Davies et al., 2012), the results from specific areas within the mid-Lachlan (for example Booberoi Creek and Lake Cargelligo) indicate that off-river areas are likely to provide habitat for the majority of extant native species. The importance of these habitats can be confirmed by targeted fish surveys, especially if sampling is carried out on multiple occasions. Replicating surveys such as those documented herein, both within individual catchments and across the M-DB, would undoubtedly provide enhanced records and reliable information upon which fishery and catchment managers can base decisions.

Though desirable, monitoring at these scales is beyond the capacity of state agencies and the MDBA. However, the work cited demonstrates that there is both capacity and intent within local riverine communities to learn about and improve river management with a view to enhancing biodiversity and overall catchment health. The diversity of interested community and stakeholder groups – encompassing a local not-for-profit, a local council, a mining company, an irrigation group, Indigenous owners, and state and federal agencies charged with delivering environmental flows – is indicative, perhaps, of a changing mood within riverine communities in the M-DB, and bodes well for the future.

A bottom-up approach to catchment management, where local and regional people can invest in monitoring programs that seek to document the biota and health of their rivers and waterways, could be an extremely effective way of sharing the considerable load associated with making informed management decisions. The template that has evolved – and is evolving – in the Lachlan catchment in New South Wales could easily be adapted and replicated in other catchments across the M-DB and elsewhere.

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## Literature Cited

Allen, G. R., Midgley, S. H., & Allen, M. (2002). *Field Guide to the Freshwater Fishes of Australia*. Western Australian Museum.

Arthington, A. H. (1991). Ecological and Genetic Impacts of Introduced and Translocated Freshwater Fishes in Australia. *Canadian Journal of Fisheries and Aquatic Sciences, 48*(Suppl. 1), 33–43.

Arthington, A. H., Balcombe, S. R., Wilson, G. A., Thoms, M. C., & Marshall, J. (2005). Spatial and temporal variation in fish assemblage structure in isolated waterholes during the 2001 dry season of an arid-zone river, Cooper Creek, Australia. *Australian Journal of Marine and Freshwater Research*, *56*, 25–35.

Australian Broadcasting Commission. (2010). Copies of guide to Murray-Darling Basin plan burnt. *ABC News*. https://www.abc.net.au/news/2010-10-14/young-men-burn-copies-of-the-guide-to-the-murray/2298002?nw=0

Balcombe, S. R., Bunn, S. E., Arthington, A. H., Fawcett, J. H., McKenzie-Smith, F. J., & Wright, A. (2007). Fish larvae, growth and biomass relationships in an Australian arid zone river: links between floodplains and waterholes. *Freshwater Biology*, *52*, 2385–2398.

Cadwallader, P. (1977). *J.O. Langtry's 1949-50 Murray River Investigations* (Fisheries and Wildlife paper, Victoria, No. 13). Fisheries and Wildlife Division, Victoria.

Datry, T., Bonada, N., & Boulton, A. (Eds.). (2017). *Intermittent Rivers and Ephemeral Streams: Ecology and Management*. Academic Press/Elsevier.

Davies, P., Harris, J., Hillman, T., & Walker, K. (2008). *SRA Report 1: Report on the Ecological Health of Rivers in the Murray-Darling Basin, 2004–2007.* Prepared by the Independent Sustainable Rivers Audit Group for the Murray-Darling Basin Ministerial Council.

Davies, P., Stewardson, M., Hillman, T., Roberts, J., & Thoms, M. (2012). *Sustainable Rivers Audit 2: The ecological health of rivers in the Murray-Darling Basin at the end of the Millenium Drought (2008–2010)*. Prepared by the Independent Sustainable Rivers Audit Group for the Murray-Darling Basin Ministerial Council.

Dyer, F., Broadhurst, B., Tschierschke, A., Higgisson, W., Allan, H., Thiem, J., Wright, D., & Thompson, R. (2019). *Commonwealth Environmental Water Office Long Term Intervention Monitoring Project: Lower Lachlan River System 2018–2019 Annual Report*. https://www.environment.gov.au/water/cewo/publications/ltim-lachlan-annual-report-2018-19

Growns, I. (2001). *An Assessment of the status of Native Fish and Fish Habitats in the Lachlan River.* NSW Fisheries Office of Conservation.

Harris, J., & Gehrke, P. (1997). *Fish and Rivers in Stress – the NSW Rivers Survey.* NSW Fisheries Office of Conservation; Cooperative Research Centre for Freshwater Ecology, Canberra.

Humphries, P., King, A. J., & Koehn, J. D. (1999). Fish, flows and flood plains: Links between freshwater fishes and their environment in the Murray-Darling River system, Australia. *Environmental Biology of Fishes*, *56*, 129–151.

Kerezsy, A. (2005). *The distribution and abundance of fish in the Lake Cargelligo system, New South Wales* [Honours thesis]. Charles Sturt University, North Wagga, New South Wales.

King, A. J., Humphries, P., & Lake, P. S., (2003). Fish recruitment on floodplains: the roles of patterns of flooding and life history characteristics. *Canadian Journal of Fisheries and Aquatic Sciences*, *60*, 773–786.

Kingsford, R., & Thompson, J. (2006). Desert or dryland rivers of the world: an introduction. In R. T. Kingsford (Ed.), *Ecology of Desert Rivers* (pp. 3–10). Cambridge University Press.

Koehn, J. D. (2004). Carp (*Cyprinus carpio*) as a powerful invader in Australian waterways. *Freshwater Biology*, *49*, 882–894.

Lintermans, M. (2007). *Fishes of the Murray-Darling Basin: An introductory guide* (MDBC Publication No. 10/07). Murray-Darling Basin Authority.

Llewellyn, L. C. (1983). *The distribution of fish in New South Wales* (Australian Society for Limnology Special Publication No. 7). Australian Society for Limnology.

McNeill, D., Wilson, P., Hartwell, D., & Pellizarre, M. (2008). *Olive perchlet (*Ambassis agassizii*) in the Lachlan River: Population Status and Sustainability in the Lake Brewster Region* (SARDI Research Report Series No. 309; F2008/000846-1). South Australian Research and Development Institute (Aquatic Sciences).

Murray-Darling Basin Commission. (2004). *Fish Theme Pilot Audit Technical Report – Sustainable Rivers Audit* (MDBC Publication No. 06/04). Murray-Darling Basin Authority.

Price, A. (2009). *Distribution and Recruitment Patterns of Fish in the Lower Lachlan River* (Final Report prepared for the Lachlan Catchment Management Authority by The Murray-Darling Freshwater Research Centre; MDFRC Publication 17/2010). Murray-Darling Freshwater Research Centre.

Reid, D., Harris, J., & Chapman, D. (1997). *NSW inland commercial fishery data analysis* (Fisheries Research and Development Corporation Project No. 94/027 Report). Fisheries Research and Development Corporation.

Roberts, J., & Sainty, G. (1996). *Listening to the Lachlan*. Sainty and Associates.

The Guardian. (2019, 28 January). Menindee fish kill: another mass death on Darling River 'worse than last time'. *The Guardian*. https://www.theguardian.com/australia-news/2019/jan/28/menindee-fish-kill-another-mass-death-on-darling-river-worse-than-last-time/

Trueman, W. (2011). *True Tales of the Trout Cod: River Histories of the Murray-Darling Basin*. Murray-Darling Basin Authority.

Walker, K., Sheldon, F., & Puckridge, J. (1995). A Perspective on Dryland River Ecosystems. *Regulated Rivers: Research and Management*, *11*, 85–104.

Water Conservation and Irrigation Commission. (1971). *Water Resources of New South Wales*. Government Printer, Sydney.

## Author Profile

Adam Kerezsy completed his PhD at Griffith University (Brisbane) on the distribution and recruitment of fish in far western Queensland, and then worked for the not-for-profit Bush Heritage Australia, principally on the conservation of endangered fish at Edgbaston Reserve in central western Queensland. He is the author of many scientific papers and the natural history book *Desert Fishing Lessons: Adventures in Australia's Rivers*. In 2016 he returned to his home in western New South Wales, and now works as a consultant on the ecology of inland rivers and springs in New South Wales and Queensland.