
by

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NON-TECHNICAL SUMMARY


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OBJECTIVES:

1. Determination of the progress toward the LMD Riverine Health Catchment Target in relation to improvements in the native to introduced fish ratio (55% improvement in species ratio, 25% improvement in abundance ratio, 25% improvement in biomass ratio).

2. Determination and analysis of trends in fish species & communities throughout the LMD catchment in terms of species richness, total abundance, total biomass, proportion native species, proportion native abundance, proportion native biomass, proportion recruits and proportion with a health condition.

The Lower-Murray Darling Catchment Action Plan (CAP) identifies Riverine Health as a Catchment Target: An identifiable nett improvement in riverine health across the Lower Murray Darling Catchment by 2015. The CAP states that this will be determined by:

- an improvement in the native to introduced fish ratio (55% improvement in species ratio, 25% improvement in abundance ratio, 25% improvement in biomass ratio);
- a 20% reduction in the number of days subject to blue green algal alerts; and
- the reinstatement of more natural flow patterns as modelled in each of five river management zones.

SUMMARY:

This annual summary reports on progress towards the fish community catchment targets up until the end of the 2008/09 financial year. The fish community was benchmarked at a number of sites established and sampled in 2004 (Gilligan 2005). These were re-sampled in 2006 (Gilligan 2007), 2007 (Gilligan 2008) and again in 2009 (this report) to gauge progress towards the CAP targets. In 2009, fish sampling was undertaken at 30 sites between 2 June and 15 July.

At a catchment level, all the fish species collected in 2004, 2006 and 2007 were also collected in 2009, and no new fish species were recorded. Nine native species formerly resident in the Lower Murray Darling CMA area remain undetected since at least 2004. At an individual species level, two native fish species, bony herring and carp-gudgeon species have declined in abundance since 2004, with bony herring declining from an average abundance of 110 individuals per site in 2004 to 56 individual per site in 2009, and carp-gudgeon species declining from an average abundance of 20 individual per site in 2004 to 3 individuals per site in 2009. Native silver perch, un-specked hardyhead and flat-headed gudgeon and alien goldfish and eastern gambusia were found at more sites in 2009 than in 2004, whilst native carp-gudgeon species and Murray-Darling rainbowfish were collected at fewer sites.
The CAP target of a 55% improvement in the native : alien species ratio was not met in any catchment management zone in 2009. In fact, there was a significant decline in the native : alien species ratio in all individual catchment management zones apart from the Darling River. Since 2004, alien species have been expanding in distribution within the CMA area while the distribution of native fish has not changed. The species richness ratio has declined from 4 native species per alien species in 2004 to 2.7 in 2009.

The CAP target of a 25% improvement in the native : alien abundance ratio was exceeded in both the upper Murray River management zone and floodplain wetlands in 2009, but not across the catchment overall or within the Lakes & Reservoirs, Darling River or lower Murray River management zones. Although the median native : alien abundance ratios in the upper Murray River zone and floodplain wetlands exceed the CAP targets, the changes are not yet statistically significant improvements above the CAP target level, although they are obviously trends in a positive direction. Those species that contributed most to the increased native fish abundance within the upper Murray River zone were Australian smelt, un-specked hardyhead and bony herring. However, the overall trend across the catchment area as a whole is a decline in the ratio of native : alien fish between 2004 and 2009 resulting from a decline in the abundance of native fish while the abundance of alien fish has remained stable.

The CAP target of a 25% improvement in the native : alien biomass ratio was not met in any catchment management zone in 2009. In fact, there has been a significant decline in the native : alien biomass ratio across the catchment area between 2004 and 2009. The total biomass of both native and alien fishes has declined since 2004, and the decreasing native : alien biomass ratio was driven by a 42% decrease in the biomass of native fish since 2004, while the total biomass of alien fishes declined by only 12%. The biomass ratio has declined from 792 grams of native fish to every 1 kg of alien fish in 2004 to 347 grams of native fish in 2009.

As at 2009, only two of 30 sites (7%) exceeded the CAP targets for all three ‘nativeness’ ratios, Imperial Lake near Broken Hill and Lelma on the Darling River. Nativeness was improving at a further five sites (17%), was stable at one site (3 %), but had declined at thirteen sites (43 %) and deteriorated substantially at nine sites (30 %). Therefore, conditions are getting worse at around three quarters of the sites monitored.

Other fish assemblage variables monitored indicate that within individual catchment zones the proportion of native fish recruits had declined in the Lakes & Reservoirs management zone, total species richness had declined in the Darling River management zone and total biomass had declined and the proportion of fish suffering a health condition had increased in the upper Murray River management zone since 2004. None of the fish assemblage parameters analysed had changed significantly between 2004 and 2009 in the lower Murray River management zone.

These data suggest that the management actions implemented up until June 2009, and/or the extent of the works involved, have not been sufficient to result in acceptable progress towards the three Lower Murray Darling CMA CAP targets for fish community ‘nativeness’. At the current, rate of change, the Lower Murray Darling CMA will not meet its riverine health catchment management targets by 2015. Recovery actions for threatened species, ‘fish-appropriate’ wetland watering activities, utilising environmental water allocations to initiate recruitment of riverine fishes, investigating and remediating the lack of golden perch recruitment in the CMA area and implementing carp control activities are recommended as strategies to make progress towards achieving CAP targets by 2015.
1. INTRODUCTION

The Lower-Murray Darling Catchment Action Plan (CAP) identifies Riverine Health as a Catchment Target: An identifiable nett improvement in riverine health across the Lower Murray Darling Catchment by 2015. The CAP states that this will be determined by:

- an improvement in the native to introduced fish ratio (55% improvement in species ratio, 25% improvement in abundance ratio, 25% improvement in biomass ratio);
- a 20% reduction in the number of days subject to blue green algal alerts; and
- the reinstatement of more natural flow patterns as modelled in each of five river management zones.

This annual summary reports on progress towards the fish community catchment targets within the catchment area, including rivers, lakes & reservoirs and wetlands, with riverine sites stratified within five pre-determined catchment management zones (Figure 1):

1. Lakes & Reservoirs (Menindee Lakes plus Lake Victoria, Euston Lakes and Broken Hill Reservoirs).
2. Darling River.
3. Great Darling Anabranch.
5. Murray River downstream of the Darling junction (Murray II).

And a sixth additional category:

6. Floodplain wetlands (combined across zones 2 – 5 above).

The objectives of the fish monitoring program are:

1. Determination of the progress toward the LMD Riverine Health Catchment Target in relation to improvements in the native to introduced fish ratio (55% improvement in species ratio, 25% improvement in abundance ratio, 25% improvement in biomass ratio).
2. Determination and analysis of trends in fish species & communities throughout the LMD catchment in terms of species richness, total abundance, total biomass, proportion native species, proportion native abundance, proportion native biomass, proportion recruits and proportion with a health condition.

The fish community was benchmarked at a number of sites established and sampled in 2004 (Gilligan 2005). Progress up until 2006 and 2007 were reported in Gilligan (2007) and Gilligan (2008) respectively. This document reports on progress up until 2009.
2. METHODS

The sampling procedure used for all the riverine, lake and reservoir sites was identical to that used for the benchmarking surveys undertaken in 2004 and described in Gilligan (2005). The sampling procedure at wetland sites was also consistent with these, but unlike in previous rounds of sampling, the additional netting methods formerly used in wetlands were not used in 2009 as they did not add significantly to the data.

In the 2009 season, the first sample was collected on 2 June and sampling had been completed by 15 July.

As in 2005/06 and 2006/07, the continued drought limited our ability to sample the full complement of sites benchmarked in 2004 (Gilligan 2005). All seven core sites in each of the Darling, Murray I and Murray II zones were re-sampled as per the benchmarking survey in 2004 and the 2006 and 2007 annual surveys. In the Lakes & Reservoirs zone, Lake Wetherell, Lake Victoria, Copi Hollow and Imperial Lake were also re-sampled as per previous surveys, but the water level in Lake Pamamaroo has been so low since 2007 that despite containing some water in the central basin of the lake, it has remained inaccessible to sampling and no data were collected. Because of the need to minimise evaporative losses in an effort to secure critical water needs and ongoing urban water supplies in the face of the ongoing drought, both Lake Benanee and Dry Lake were isolated from the Murray River in August 2007 and have remained dry since that time. Lake Menindee and Lake Cawndilla have remained totally dry throughout the study period. The Great Darling Anabranch river management zone has also remained dry. Therefore, as previously, only a single sample was collected from the Great Darling Anabranch at a site immediately upstream of its junction with the Murray River in 2009, as this was the only location in that waterway (and zone) that contained water.

Four wetland sites were sampled in 2009. Peacock Creek (Murray I zone) is the only wetland that has been sampled during all four surveys. Pomona wetland (Darling zone), which had been sampled in 2006 and 2007, but not in 2004, was also re-sampled in 2009. Two wetlands that had not been sampled in either 2004 or 2006, but where in 2007, Ned’s Corner anabranch (Murray II zone) and Frenchman’s Creek wetland (Murray II zone) were also re-sampled in 2009. Although Tareena Wetland (Murray II zone) contained water, it was extremely saline (4,500 µS/cm) and precluded the use of electrofishing and was not sampled in 2009. All other wetlands within a 5 km radius of riverine sampling sites were dry. This included Thegoa Lagoon (Murray II zone), which had been sampled in both 2004 and 2006 but was dry during the sampling period in 2009 and Cliffhouse wetland (Murray II zone), which contained water in 2006 but was also dry 2009.

In total, 30 fish community samples were collected in 2009.

Data from 2004 were collected during the benchmarking surveys (Gilligan 2005).

Data from 2005 were collected for the Murray-Darling Basin Authority’s Sustainable Rivers Audit (SRA) IP1 sampling round. The data from Murray I zone was collected from six of the seven LMD CMA sampling locations (excluding Nangiloc) and a single new SRA site (Gol Gol). The data from the Darling zone were collected from three of the seven LMD CMA sampling locations (Downham Farm, Pooncarrie and Lethero) and four new SRA sites (Mararo, Chalky Well, Bellevue and Tolaro). Only three SRA sites were sampled in the Murray II zone, one of the seven LMD CMA sites (Upper Kulnine) and two new SRA sites (Kulcurna Station and Moorna Station). No SRA sites exist within the Lakes & Reservoirs zone or the Great Darling Anabranch zone and therefore no data are available from these zones in 2005. Although the sampling locations for the SRA in 2005 were not entirely consistent with those established for the LMD CMA monitoring program,
both projects used a similar random site selection process and aim for the same site density per zone (only three sites were present in the Murray II zone as the zone boundary for the SRA straddles the NSW-SA border, and four of the seven SRA sites lay within SA).

Data from 2006 and 2007 were collected under Lower Murray Darling CMA project No. MD122.05 and were presented in Gilligan (2007) and Gilligan (2008).

Data from 2008 were collected for the Murray-Darling Basin Authority’s Sustainable Rivers Audit (SRA) IP4 sampling round and the NSW governments MER program. Data from Murray I zone was collected from eight sites, three of the seven LMD CMA sampling locations (Cowana Bend, Wemen and Carina Bend) and five new randomly selected locations. Data from the Darling zone were collected from two of the seven LMD CMA sampling locations (Downham Farm, Pooncarrie) and five new randomly selected locations. Only two sites were sampled in the Murray II zone, one of the seven LMD CMA sites (Upper Kulnine) and one new randomly selected location. No SRA sites exist within the Lakes & Reservoirs zone or the Great Darling Anabranch zone and therefore no data are available from these zones in 2008. Although the sampling locations for the SRA in 2008 were not entirely consistent with those established for the LMD CMA monitoring program, both projects used a similar random site selection process and aim for the same site density per zone (only two sites were present in the Murray II zone as the zone boundary for the SRA straddles the NSW-SA border, and five of the seven SRA sites lay within South Australia).

Data collected in 2009 were compared at an overall catchment level with those collected from 2004 and 2007 using paired $t$-tests. Prior to analysis, total abundance and total biomass were $\log_{10}$ transformed, the proportion of total abundance that was native was arcsine transformed and the proportion of individuals suffering a health condition was square-root transformed in order to normalise the data and/or equalise the variances. All other parameters were suitable for parametric analysis without transformation.
Sites sampled within each of five catchment zones in the Lower Murray-Darling CMA catchment area. The four shaded sites in the Lakes & Reservoirs zone were not sampled during the benchmarking surveys in 2004 (Gilligan 2005), but are part of the ongoing annual monitoring program.

Table 1.

<table>
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<th>Site name</th>
<th>Waterway</th>
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<tr>
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<td></td>
<td>Easting</td>
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* The conductivity at Tareena Wetland was 4,500 µS/cm which was too high for electrofishing to be used effectively.
Table 1 (cont.)

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<thead>
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<th>Waterway</th>
<th>UTM zone 54</th>
<th>Sampled in 2009</th>
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<td><strong>Lakes and Reservoirs</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Imperial Lake</td>
<td>Broken Hill reservoir</td>
<td>546811</td>
<td>6465397</td>
</tr>
<tr>
<td>Copi Hollow</td>
<td>Menindee Lakes</td>
<td>630090</td>
<td>6428815</td>
</tr>
<tr>
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<td>634010</td>
<td>6428878</td>
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<tr>
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<td>6423500</td>
</tr>
<tr>
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<td>Lake Victoria</td>
<td>526500</td>
<td>6233500</td>
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<td>Menindee Lakes</td>
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<td>6427300</td>
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<td>6409000</td>
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<td>6177800</td>
</tr>
<tr>
<td>Dry Lake</td>
<td>Euston Lakes</td>
<td>670446</td>
<td>6177572</td>
</tr>
</tbody>
</table>

* This site was sampled as it was the only part of the Great Darling Anabranch containing water in 2009. It is not one of the seven randomly selected fish monitoring sites designed to represent this zone.
Figure 1. The locations of fish survey sites sampled in the 2009 season.
3. PROGRESS TOWARD THE LOWER MURRAY DARLING CATCHMENT ACTION PLAN FISH ‘NATIVENESS’ TARGETS FOR RIVERINE HEALTH

The CAP riverine health catchment targets related to the fish community are:
- A 55% improvement in the native to introduced fish species ratio.
- A 25% improvement in the native to introduced fish abundance ratio.
- A 25% improvement in the native to introduced fish biomass ratio.

To test progress towards these targets, data collected in 2004 (Gilligan 2005) were used as the benchmark for each of the target ratios.

As suggested in Gilligan (2005), ratios are problematic indices given that a zero value in the denominator, as occurs when no alien fishes are collected at a site, results in an invalid value. Further, the ratio can be very large if the number of natives exceeds the number of aliens, violating the assumption of normality important for many standard statistical tests. There have been six instances of fish community samples that did not collect any alien species that prevent the calculation of ratios at those sites. These are Imperial Lake in 2004, Copi Hollow and Lake Pamamaroo in 2006, Imperial Lake and Dry Lake in 2007 and Imperial Lake in 2009. The only option to enable assessment of the three ratio targets was to use the median rather than the mean values for assessment. Variance around the median was estimated via bootstrap re-sampling of the data-set with 1,000 iterations with replacement and calculating the average standard deviation of the bootstrap replicates. However, because of the alien-free sites within the Lakes & Reservoirs zones, it was not possible to estimate the standard deviation of the median in this zone. Changes between the benchmarking survey (2004) and present (2009) and recent changes between 2007 and present (2009) were compared using z tests.

3.1. Native : Alien species ratio

The CAP target of a 55% improvement in the native : alien species ratio was not met in any catchment zone in 2009 (Figure 2). In fact, there was a significant decline in the native : alien species ratio across the catchment area between 2004 and 2009 ($p < 0.001$). This trend was driven by an increase in the average proportion of sites occupied by alien species (38% in 2004 versus 48% in 2009) while the average proportion of sites occupied by native species did not change (52% in 2004 versus 51% in 2009). This indicates that since 2004, alien species have been expanding in distribution within the CMA area. The 2004 – 2009 decline in the native : alien species ratio was significant ($p < 0.001$) in all individual catchment zones apart from the Darling River, where a recent significant improvement in the species ratio (since 2007, $p < 0.001$) has increased the ratio enough to lead to the non-significant five year result in this zone ($p = 0.174$). However, the recent trend over the catchment as a whole was for a significant catchment-wide decline since 2007 ($p = 0.035$).

As at 2009, the native : alien species ratio was significantly lower than the CAP target in all zones ($p < 0.001$).
3.2. Native : Alien abundance ratio

The CAP target of a 25% improvement in the native : alien abundance ratio was exceeded in both the upper Murray River zone and floodplain wetlands in 2009, but not across the catchment overall or within the Lakes & Reservoirs, Darling River or lower Murray River zones (Figure 3). Although the median native : alien abundance ratios in the upper Murray River zone and floodplain wetlands exceed the CAP targets, the changes are not yet statistically significant improvements above the CAP target level, although they are obviously trends in a positive direction. In contrast, the changes in the abundance ratio in the lower Murray River zone and across the catchment area overall between 2004 and 2009 represent statistically significant declines ($p < 0.001$) in fish community composition. The only significant recent (since 2007) change was an improvement in the native : alien abundance ratio in the upper Murray River zone ($p = 0.005$). This improvement was driven by a slight increase in the average abundance of native species per site (127 individuals per site in 2007 versus 162 per site in 2009) rather than a decline in the abundance of alien species, which has remained relatively constant (24 individuals per site in 2007 versus 23 per site in 2009). Those species that contributed most to the increased native fish abundance within the upper Murray River zone were Australian smelt, un-specked hardyhead and bony herring.
Figure 3. Comparison of the median (+ SD) native : alien abundance ratio observed in 2006, 2007 and 2009 with the benchmark (2004) and target (25% improvement) ratios.

3.3. Native : Alien biomass ratio

The CAP target of a 25% improvement in the native : alien biomass ratio was not met in any catchment zone in 2009 (Figure 4). In fact, there has been a significant decline in the native : alien biomass ratio across the catchment area between 2004 and 2009 ($p < 0.001$). The total biomass of both native and alien fishes has declined since 2004. The decreasing native : alien biomass ratio was driven by a 42% decrease in the biomass of native fish since 2004 while the total biomass of alien fishes declined by only 12%. Therefore, not only has there not been any progress towards the CAP target, but the trend has been for a substantial reduction in the condition of the fish community in the catchment. Although the native : alien biomass ratio declined in all catchment management zones between 2004 and 2009, the decline was only statistically significant within floodplain wetlands ($p < 0.001$). Data from the lower Murray River zone (Murray II) in 2009 was very variable due to a very large increase in the ratio at a single site (Frenchman’s Creek) and illustrates the undesirable properties of ratios as targets. More recent changes (since 2007) include significant declines in the native : alien biomass ratio in both the upper Murray River zone and within floodplain wetlands.

As at 2009, the native : alien biomass ratio was significantly lower than the CAP target in all zones ($p < 0.001$) apart from the lower Murray River (where the lack of significance is affected by the high variance).
Figure 4. Comparison of the median (± SD) native : alien biomass ratio observed in 2006, 2007 and 2009 with the benchmark (2004) and target (25% improvement) ratios.

The following Report Card figures (Figures 5, 6 and 7) are provided to gauge progress towards meeting CAP targets at individual sites as at 2008/09. Progress is quantified as the change in the proportion observed since 2004, divided by the change that would be required to meet the CAP target. For example, a change in the proportion native biomass of + 0.13 (0.44 in 2004 to 0.57 in 2009) would equal a 59% achievement of the CAP biomass target, which is a change of 0.22 (eg. 0.13/0.22 = 59%). In each of the report cards, progress towards the targets at each site are presented as one of five categories:

1. **CAP target exceeded** – The ratio of native : alien fish is greater than the CAP target value (progress > +100% of CAP target).

2. **Good** – The ratio of native : alien fish has increased since 2004 but has not yet exceeded the CAP target (progress +25 to +99% of CAP target).

3. **Stable** – The ratio of native : alien fish has not changed substantially since 2004 (progress -25 to +25% of CAP target).

4. **Poor** – The ratio of native : alien fish has decreased since 2004 (-25 to -99% of CAP target).

5. **Very Poor** – The ratio of native : alien fish has changed by more than the change required to meet the CAP target, but in the opposite direction, since 2004).
To present an overall assessment that amalgamates the three nativeness indices (Figure 8), a score was assigned to each of the progress categories defined above for each ratio, where: CAP target exceeded = 3 points, Good = 1 point, Stable = 0 points, Poor = -1 point and Very poor = -3 points. These points were summed across the three nativeness ratios. Overall progress towards the CAP targets was defined based on the summed scores according to the following bands:

- \( \text{Score} = 9 \): All CAP targets exceeded
- \( \text{Score} > 5 \): Very good progress
- \( \text{Score} > 1 \): Good progress
- \( \text{Score} = 0 \): No progress
- \( \text{Score} < -1 \): Progress poor
- \( \text{Score} < -5 \): Progress very poor
Figure 5. Progress towards the CAP target of a 55% improvement in the ratio of native : alien species as at 2009.
Figure 6. Progress towards the CAP target of a 25% improvement in the ratio of abundance of native : alien species as at 2009.
Figure 7. Progress towards the CAP target of a 25% improvement in the ratio of biomass of native : alien species as at 2009.
Figure 8. Overall progress towards the Lower Murray-Darling CMA CAP Riverine health targets for fish nativeness as at 2009.
4. FISH ASSEMBLAGE PARAMETERS USEFUL FOR UNDERSTANDING THE ‘HEALTH’ OF FISH COMMUNITIES

4.1. Species richness

Species richness is the total number of different species occurring at a site, including native and alien species. A significant decline in the average species richness at sites in the Darling River since 2007 ($p = 0.038$) has resulted in a statistically significant decrease in species richness from 6.3 to 5.6 species per site since the benchmark data was collected in 2004 ($p = 0.047$) (Figure 9). None of the other catchment management zones have suffered a similar decline in species richness, with various minor increases or decreases in species richness not found to be statistically significant (Figure 9). Across the catchment area as a whole, average species richness has increased only very slightly since the benchmarking surveys in 2004.

4.2. Total abundance

Total abundance is the total number of individuals sampled from a site, including native and alien fish. There was no significant change in total abundance across the catchment area as a whole, or within any individual management zone between 2004 and 2009 (Figure 10). The significant decline in total abundance observed in the lower Murray River zone between 2004 and 2007 (Gilligan 2008) has been countered by a slight increase in total abundance between 2007 and 2009, which itself was a non-significant increase, but has been sufficient to improve the condition of total abundance within the zone (Figure 10).

4.3. Total biomass

Total biomass is the total weight of all individuals sampled at a site, including native and alien fish. There was no significant change in the total biomass across the catchment area as a whole between 2004 and 2009 (Figure 11). The only statistically significant change in total biomass since benchmark sampling in 2004 was a decrease in total biomass in the upper Murray River management zone (Murray I) ($p = 0.01$) (Figure 11). The significant decrease in total biomass in the lower Murray River management zone (Murray II) observed between 2006 and 2007 (Gilligan 2008) has been counter-acted by an increase in total biomass within this zone between 2007 and 2009 (Figure 11) and the total biomass in the lower Murray River zone is no longer significantly lower than it was during the benchmarking surveys. No significant changes in total biomass were observed within any other individual catchment management zone, or across the catchment area as a whole between 2004 and 2009 although the trend has been for a decline in total biomass in riverine zones and an increase in Lakes & Reservoirs and floodplain wetlands sites (Figure 11).

4.4. Proportion of total species richness that are native species

The proportion of total species richness that is native is the number of different native species collected at a site divided by the total species richness (native plus alien species). Within the Darling River management zone, there has been a significant recent increase in the proportion of native species richness between 2007 and 2009 ($p = 0.038$), but because of prior decreases up until 2007, the resulting proportion of total species that are native is not significantly different from benchmark condition. There were no statistically significant recent or longer term changes within any other catchment management zone. However, there has been a consistent decline ($p = 0.009$) with the proportion of native species richness across the catchment area as a whole, with the proportion declining from an average of 0.78 native species per site in 2004 to 0.72 in 2009 (Figure 12).
Figure 9. Total species richness for fish in the Lower Murray Darling River system.

Figure 10. Total abundance of fish in the Lower Murray Darling River system.
Figure 11. Total biomass of fish in the Lower Murray Darling River system.

Figure 12. Proportion of total fish species richness that are native species in the Lower Murray Darling River system.
4.5. **Proportion of total abundance that is native species**

The proportion of total abundance that is native is the total number of individuals collected at a site that are native species, divided by the total number of individuals (native plus alien species) collected at the site. There were no significant changes in proportion of total abundance that were native species within any individual catchment management zone, or across the catchment area as a whole between 2004 and 2009 (Figure 13), but the proportion of total abundance that is native species has declined slightly from 86% native in 2004 to 81% in 2009.

4.6. **Proportion of total biomass that is native species**

The proportion of total biomass that is native is the total weight of fish collected at a site that are native species, divided by the total weight of fish (native plus alien species) collected at the site. There were no significant changes in proportion of total biomass that were native species within any individual catchment management zone or across the catchment area as a whole (Figure 14), but the proportion of total biomass that is native species has declined slightly from 44% native in 2004 to 31% native in 2009.

4.7. **Proportion of total catch that are native fish recruits**

Recruits are young juvenile fish that represent the recent breeding activity of the population. For this study, we assumed recruits to be fish less than one year old for larger long-lived species and immature individuals for smaller species that mature at less than one year of age. Individuals were identified as recruits if they were smaller than the length cut-offs as provided in Gilligan (2005). For all native species combined, there has been a significant recent decrease in the amount of native fish recruitment with the Darling River management zone, with the proportion of native fish recruits declining from 0.33 in 2007 to 0.09 in 2009 (p = 0.033). This decrease does not represent a decline from benchmark conditions, but counter-acts increased recruitment in the Darling River observed between 2005 and 2007 (Figure 15). However, the decrease in native fish recruitment from 0.6 in 2004 to 0.09 in 2009 in the Lakes & Reservoir management zone does represent a significant decline in native fish recruitment since benchmark sampling in 2004 (p = 0.03) (Figure 15). Across the catchment area as a whole, native fish recruitment has increased slightly since the benchmarking surveys in 2004, largely through slight increases in the upper and lower Murray River management zones, but the change has not been significant. The level of recruitment of individual species are presented in Figures 23 to 37.

4.8. **Proportion of total catch suffering from a health condition**

The proportion of the total catch suffering from a health condition across the catchment as a whole had increased significantly from an average of 2.0 % of individuals in 2004 to 8.9 % in 2009 (p = 0.002) (Figure 16). Zone based increases were significant in the upper Murray River management zone (p = 0.009) from 0.8 % in 2004 to 3.2 % in 2009 and in the Darling River (p = 0.006) from 6.0 % in 2007 to 15.7 % in 2009 (Figure 16). The proportion of affected individuals was not consistent across species. As in previous years (Gilligan 2005, 2007, 2008), the most affected species were golden perch, Murray cod, goldfish, silver perch and common carp (Figure 17). It is likely that smaller species are also affected to similar extents to the larger species, but as they are more prone to predation when suffering a health condition, they do not remain in the population for very long and are not detected. The proportion of individuals affected by the parasitic anchor worm (*Lerneae* spp), fin damage (physical and pathogenic), wounds and deformities was higher in 2009 than observed during any previous round of sampling (Figure 18).
Figure 13. Proportion of total fish abundance that is made up of native species in the Lower Murray Darling River system.

Figure 14. Proportion of total fish biomass that is made up by native species in the Lower Murray Darling River system.
Figure 15. Proportion of total catch that is native fish recruits in the Lower Murray Darling River system.

Figure 16. Proportion of total fish catch that is suffering from a health condition in the Lower Murray Darling River system.
Figure 17. The proportion of each fish species affected by a health condition.

Figure 18. The proportion of individual fish affected by each of the five health conditions observed.
The proportion of individuals parasitised by externally visible anchor worm has increased significantly ($p = 0.015$) across the catchment area as a whole between 2004 and 2009 (Figure 19). Recent increases in the proportion of individuals affected (between 2007 and 2009) were significant in the Darling River ($p = 0.009$) and across the broader catchment ($p = 0.034$) (Figure 19). The high variance in the proportion of individuals parasitised by anchor worm in the floodplain wetlands in 2009 was driven by the very high incidence in Pomona wetland relative to the other three wetland sites.

Similarly, the proportion of individuals suffering fin damage was significantly higher in 2009 than it was during the benchmark sampling in 2004 across the catchment area as a whole ($p = 0.002$), increasing from 0.0 % in 2004 to 0.7 % of individuals in 2009 (Figure 20). At a zone level, the increase was only significant in the upper Murray River zone (Murray I) ($p = 0.033$). Those individuals observed with fin damage in the Darling River had suffered physical damage to the caudal fin consistent with a predator biting a section of fin. Those individuals observed to be suffering fin damage in the upper and lower Murray River zones were primarily individuals suffering some type of infection resulting in inflammation and erosion of dorsal or anal fin tissue.

The proportion of wounded fish (bird strikes, scale loss or hook wounds) and fish suffering from deformities were low, but the changes in the proportion of individuals observed to be affected were statistically significant. The proportion of deformed individuals had increase from 0 % in 2004 to 0.2 % in 2009 across the catchment area as a whole. The deformities observed in 2009 included bony herring and Australian smelt with scoliosis (Figure 21) and golden perch and carp with deformed fin rays (which could be attributed to fin scarring following recovery from fin damage). The proportion of wounded individuals had not changed across the whole catchment area but had declined significantly from 0.9 % to 0.0 % within the lower Murray River zone ($p = 0.031$). Both changes could be suggestive of reduced predation pressure, as there are fewer signs of predation related damage (wounds) and more deformed individuals in the population (which would probably be predated if predator densities were high).
Figure 19. The distribution of individual fish affected by parasitic anchor worm (*Lerneae* spp.) in 2009. The relative size of the circles reflects the proportion of individuals affected.

Figure 20. The distribution of fish suffering fin damage in 2009. The relative size of the circles reflects the proportion of individuals affected.
Figure 21. A bony herring collected from Copi Hollow (Lakes & Reservoirs zone) suffering scoliosis (curvature of the spine).
5. TRENDS IN ABUNDANCE AND RECRUITMENT OF INDIVIDUAL FISH SPECIES

At a catchment level, all the fish species collected in 2004 (Gilligan 2005), 2006 (Gilligan 2007) and 2007 (Gilligan 2008) were also collected in 2009 and no new fish species were collected. SRA sampling in the LMD CMA area in 2005 collected a single Murray hardyhead at Upper Kulnine in the lower Murray zone. However, no Murray hardyhead have been collected in subsequent rounds of sampling (Gilligan 2007, 2008).

The proportional change in the abundance of each species across the catchment between 2004 and 2007 and 2009 are presented in Table 2. The changes between 2004 and 2009 were statistically significant at the catchment level for only two of the fourteen species. Bony herring declined from an average abundance of 110 individuals per site in 2004 to 56 individual per site in 2009 ($p = 0.029$) and carp-gudgeon species had declined from an average abundance of 20 individual per site in 2004 to 3 individuals per site in 2009 ($p = 0.011$). The decline in abundance of carp-gudgeons was a recent event, occurring between the 2007 and 2009 sampling rounds ($p = 0.041$).

Table 2. The proportional change in the abundance of each species (across the whole catchment) between the benchmark surveys in 2004 (Gilligan 2005), the 2007 annual survey (Gilligan 2008) and 2009 (this survey). * statistically significant changes in abundance.

<table>
<thead>
<tr>
<th>Species</th>
<th>Change between 2004 and 2009</th>
<th>Change between 2007 and 2009</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eastern gambusia</td>
<td>3,483 % increase</td>
<td>162 % increase</td>
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<tr>
<td>Silver perch</td>
<td>700 % increase</td>
<td>700 % increase</td>
</tr>
<tr>
<td>Un-specked hardyhead</td>
<td>457 % increase</td>
<td>44 % decrease</td>
</tr>
<tr>
<td>Murray cod</td>
<td>17 % increase</td>
<td>18 % decrease</td>
</tr>
<tr>
<td>Goldfish</td>
<td>16 % decrease</td>
<td>67 % decrease</td>
</tr>
<tr>
<td>Golden perch</td>
<td>17 % decrease</td>
<td>51 % increase</td>
</tr>
<tr>
<td>Common carp</td>
<td>28 % decrease</td>
<td>3 % decrease</td>
</tr>
<tr>
<td>Flat-headed gudgeon</td>
<td>29 % decrease</td>
<td>30 % increase</td>
</tr>
<tr>
<td>Bony herring</td>
<td>47 % decrease*</td>
<td>55 % increase</td>
</tr>
<tr>
<td>Redfin perch</td>
<td>50 % decrease</td>
<td>No change</td>
</tr>
<tr>
<td>Australian smelt</td>
<td>53 % decrease</td>
<td>177 % increase</td>
</tr>
<tr>
<td>Murray Darling rainbowfish</td>
<td>80 % decrease</td>
<td>16 % decrease</td>
</tr>
<tr>
<td>Carp-gudgeon species complex</td>
<td>85 % decrease*</td>
<td>90 % decrease*</td>
</tr>
<tr>
<td>Freshwater catfish</td>
<td>91 % decrease</td>
<td>90 % decrease</td>
</tr>
</tbody>
</table>

Those species that increased in prevalence by more than 10% (in terms of the proportion of sites at which they were sampled) between 2004 and 2009 were goldfish (21%), silver perch (20%), un-specked hardyhead (17%), eastern gambusia (16%) and flat-headed gudgeon (12%) (Figure 22). Those species that decreased in prevalence (by more than 10% of sites) were carp-gudgeons (35%) and Murray-Darling rainbowfish (17%) (Figure 22).
Figure 22. The proportion of sites across the Lower Murray Darling catchment where each species was collected during each sampling round.

The following native and alien species known to have historically occurred within the Lower Murray Darling CMA area (see Gilligan 2005: Table 1.1) have not been detected by the CMAs monitoring program since sampling commenced in 2004:

- Brown trout (*Salmo trutta*) – alien (Murray only).
- Congoli (*Pseudaphritis urvillii*) – vagrant.
- Dwarf flat-headed gudgeon (*Philypnodon macrostomus*).
- Flat-headed galaxias (*Galaxias rostratus*) – critically endangered.
- Hyrtl’s tandan (*Neosilurus hyrtlii*) – vagrant (Darling only).
- Macquarie perch (*Macquaria australasica*) – endangered.
- Murray hardyhead (*Craterocephalus fluviatilis*) – critically endangered.
- Olive perchlet (*Ambassis agassizii*) – endangered population.
- Short-headed lamprey (*Mordacia mordax*).

1 However, a single Murray hardyhead was detected in the Lower Murray River (Murray II zone) during Sustainable Rivers Audit sampling in 2005.
• Southern purple spotted gudgeon (*Mogurnda adspersa*) – endangered.
• Southern pygmy perch (*Nannoperca australis*) – endangered.
• Spangled perch (*Leiopotherapon unicolor*) – vagrant.
• Spotted galaxias (*Galaxias truttaceus*) – alien.
• Tench (*Tinca tinca*) – alien.
• Trout cod (*Maccullochella macquariensis*) – endangered.

The following figures (Figures 23 to 37) present four types of data for each fish species currently present in the catchment area (in order of greatest to least biomass across the whole catchment); 1) The distribution of each species within the catchment area in 2009, 2) the abundance of each species at each site in 2009, 3) The distribution and abundance of recruits at each site in 2009 and 4) trends in abundance since 2004 in each catchment zone.

1. Distribution is reflected by the presence of white (absent) versus black or green dots (present) at each sampling location.
2. Abundance is reflected by the size of the dot (black and/or green) at each sampling location. The size scaling of the dots varies across species and can be gauged relative to the legend in the bottom right corner of each figure.
3. Recruits are defined as those individuals smaller than the length cut-offs presented in Gilligan (2005: Table 3.1) which represent fish less than 1 year of age (0+) or size at sexual maturity for species that mature rapidly. The distribution and abundance of recruits is reflected by the distribution and size of green dots at each sampling location. The absence of a green dot at a site means that no recruits of that species were sampled in 2009. If recruits were present, the size of the green dot matches the abundance scale described by the legend.
4. Trends in abundance from 2004 through to 2009 are presented for each catchment zone and for the catchment as a whole as a bar graph. The height of the bar reflects the average abundance across all sites in that zone and the error bars represent the standard error of the mean.
Figure 23. Common carp (Cyprinus carpio) – alien pest.

Figure 24. Golden perch (Macquaria ambigu).
Figure 25.  Bony herring (*Nematalosa erebi*).

Figure 26.  Murray cod (*Maccullochella peelii*).
Figure 27. Silver perch (*Bidyanus bidyanus*) – vulnerable.

Figure 28. Goldfish (*Carassius auratus*) – alien pest.
Figure 29.  Freshwater catfish (*Tandanus tandanus*).

Figure 30.  Redfin perch (*Perca fluviatilis*) – alien pest.
Figure 31. Australian smelt (*Retropinna semoni*).

Figure 32. Un-specked hardyhead (*Craterocephalus stercusmuscarum*).
Figure 33. Murray Darling rainbowfish (*Melanotaenia fluviatilis*).

Figure 34. Flat-headed gudgeon (*Philypnodon grandiceps*).
Figure 35. Eastern gambusia (*Gambusia holbrooki*) – alien pest.

Figure 36. Carp-gudgeon species complex (*Hypseleotris* spp.).
Figure 37. Murray hardyhead (*Craterocephalus fluviatilis*) – critically endangered.
6. WATER QUALITY AND HABITAT PARAMETERS COLLECTED FROM EACH SITE DURING FISH SAMPLING

6.1. Water quality

The following water quality parameters were recorded at each site at the time of fish community sampling; temperature (°C), pH, dissolved oxygen (mg/L), conductivity (μS/cm) and turbidity (NTU and secchi depth). For each parameter, two measurements were taken at 20 cm below the surface. Then single measurements were taken at each 1 metre depth interval. These depth profile measurements were recorded in the deepest part of the sampling site. Data presented are the average of the two measurements taken 20 cm below the surface as no stratification of water quality parameters was observed at any site.

Despite being important parameters for fish, the temperature (Figure 38) and dissolved oxygen (Figure 39) data presented are un-informative in the context of monitoring long term changes, as both parameters fluctuate on a daily as well as longer-term basis. For these parameters, long-term data continuously collected from instream data loggers is the most reliable means to detect long-term change. No sites had sub-optimal dissolved oxygen concentrations at the time of sampling in 2009 (Figure 39).

Figure 38. Average surface (20 cm) temperature recorded at each fish sampling site in 2009.
Although pH, conductivity and turbidity can also vary widely as a result of the immediate climatic and hydrological conditions, they are a little more indicative of the conditions in the weeks or months preceding fish community sampling and have the ability to drive changes in the composition of fish communities.

In contrast to the observation that the Darling River sites tended towards being slightly more acidic (lower pH) than the other zones in 2006 (Gilligan 2007), in both 2007 (Gilligan 2008) and now in 2009, both the Darling River sites and Lakes & Reservoir sites tended towards being slightly more basic (higher pH) (Figure 40). All but five sites had pH values in the “normal” range of 6 – 8 (Figure 40). Copi Hollow, Imperial Lake, Bono, Lelma and Pomona Wetland had slightly higher pH values ranging between 8 and 9.

No site had conductivity readings above 1,500 μS/cm at the time of sampling. Only a single site, Imperial Lake, had a conductivity reading above 800 μS/cm. And three sites, Copi Hollow, Pomona and Pomona Wetland had conductivity readings above 400 μS/cm (Figure 41). However, the conductivity did not exceed the catchment target of 463 μS/cm at any of these three sites (Figure 41).
Figure 40. Average surface (20 cm) pH recorded at each fish community sampling site at the time of sampling in 2009.

Figure 41. Average surface (20 cm) conductivity (μS/ cm) recorded at each fish community sampling site at the time of sampling in 2009.
Turbidity was recorded using both a Horiba Model U10 water quality meter and a secchi disk. The Horiba water quality meter is useful in that it enables the recording of turbidity at various depths throughout the water column and can record the turbidity of clearer waters at shallow depths, but its turbidity probe is notoriously prone to malfunction. In contrast, secchi depth (the depth at which a secchi disk can be seen from the surface) is robust in that it is simple and straightforward to use, but it can be limited in that it cannot be used when the water is clear enough that the disk can be seen when it has reached the bottom of the water column (usually only a problem at very shallow sites). In Figure 42, turbidity readings from the Horiba (NTUs) are presented as the bar graph while the colour codes used for dots on the map represent secchi depth readings. Inconsistencies between the secchi disk reading and NTU value at Lelma suggest a potential error in the NTU reading, with the secchi depth more typical of other sites in the Darling River than the high NTU value suggests.

There was a broad range of turbidity recorded amongst sites within the catchment area and many of the high turbidity readings were localised to specific sites or site clusters (Figure 42). Averaged across sites, the most turbid to least turbid zones in 2009 were the Darling River (secchi depth = 22 cm (versus 78 cm in 2006 and 42 cm in 2007)), Lakes & Reservoirs (45 cm (versus 31 cm in 2006 and 42 cm in 2007)), Great Darling Anabranch (50 cm (versus 57 cm in 2006 and 55 cm in 2007)), lower Murray (52 cm (versus 46 cm in 2006 and 68 cm in 2007)), floodplain wetlands (61 cm (versus 25 cm in 2006 and 43 cm in 2007)) and the upper Murray (83 cm (versus 48 cm in 2006 and 76 cm in 2007)). The Darling River and lower Murray River zones have become slightly more turbid, the upper Murray River zone has become less turbid and the turbidity in the Lakes & Reservoirs zone and floodplain wetlands have not changed.

Figure 42. Average surface (20 cm) turbidity (NTU) recorded at each fish community sampling site at the time of sampling in 2009. The high turbidity (NTU) at Lelma appears suspiciously high and is inconsistent with the secchi disk reading at this site.
6.2. Habitat

Aquatic habitat features were recorded as present or absent within each of the replicate electrofishing operations, each corresponding to a transect of 53 ± 2 m (mean ± SE). The presence/absence data is presented as the proportion of operations at each site where each habitat feature was present (i.e., if native trees were present in 9 of the 12 replicate operations, then they would be scored as 9 / 12 = 0.75). Additionally, the depth and width were recorded for each electrofishing operation and averaged across operations. Flow velocity was assessed as either no flow, slow, medium or fast for each operation and the modal velocity (the value that occurs most frequently) is presented. Only those habitat features that changed by more than 0.2 at a zone level are discussed below.

6.2.1. Substrate

Mud-silt and clay substrates are the most predominant substrates within the catchment area, with lower proportions of sand substrates and cobble and boulder substrates only found at a single site, Imperial Lake, where they constitute artificial rip-rap walls (Figure 43). Mud-silt was the dominant substrate in the Darling River management zone and upper reaches of the upper Murray River management zone and combined mud-silt and clay substrates predominant elsewhere (Figure 43).

Since 2004, there has been a decrease in sandy substratum in the Lakes & Reservoirs zone, Darling River and both upper and lower Murray River management zones, an increase in mud-silt substratum in the Lakes & Reservoirs zone and an increase in clay substratum in the lower Murray River zone and floodplain wetlands, but a decrease in clay at the Great Darling Anabranch site. These changes are more likely to reflect a change in the availability of substrate types because of changes in water level rather than changes in the frequency of the substrate types themselves.

Figure 43. The proportion of operations at each sampling site where each substrate category was present.
6.2.2. *Riparian and instream vegetation*

Native riparian trees were present at a majority of reaches fished, but were rare or absent at most Lakes & Reservoirs sites (Figure 44). Alien trees and shrubs were present but rare at only one site each and were absent from all remaining sites (Figure 44). Native riparian shrubs and terrestrial grass were most common in the upper Murray River zone and were only present at occasional scattered sites within other zones (Figure 44).

Native riparian trees had declined in the Lakes & Reservoirs management zone. This was probably as a result of the omission of the two Euston Lakes sites, which both had abundant riparian tree cover when sampled in 2007. Native riparian shrubs and riparian grasses have increased in the upper Murray River management zone. In contrast, native riparian shrubs have decreased at the Great Darling Anabranch site and at floodplain wetlands, and terrestrial grass had declined in the Lakes & Reservoirs zone, lower Murray River management zone and at floodplain wetlands.

Instream aquatic vegetation was uncommon or absent at most Lakes & Reservoirs sites apart from Imperial Lake which had moderate coverage of both submerged macrophytes and filamentous algae and Lake Wetherell where emergent macrophytes were common (Figure 45). Aquatic vegetation was uncommon or absent within the Darling River management zone (Figure 45). In contrast, instream aquatic vegetation was common and diverse within the two Murray River management zones, but particularly in the lower Murray River (Figure 45).

Submerged macrophyte cover has declined in the Darling River zone but increased in the upper Murray River zone since 2007. These changes could possibly be a response to the increasing and decreasing turbidity in the Darling River and upper Murray River management zones respectively. Emergent macrophyte cover has increased in floodplain wetlands. Floating macrophytes have increased at the Great Darling Anabranch site. Filamentous algae has increased in floodplain wetlands and the Great Darling Anabranch. Biofilms have declined in all catchment zones, but have increased in floodplain wetlands.

6.2.3. *Structural fish habitat*

The availability of timber cover (snags) has increased in the lower Murray River and Darling River zones since 2007. Like the changes in substrate availability, this is likely to have resulted from changes in water levels, inundating exposed snag habitats, rather than snags having been added to the river reaches. Macrophyte beds have declined in the lower Murray River zone and in the Darling River. There were no substantial changes in the availability of rocky cover, plant litter or undercut banks within any zone since 2007.

6.2.4. *Stream characteristics (meso-habitat)*

By their nature, sites in the Lakes & Reservoirs and floodplain wetlands were entirely non-flowing pool habitats (Figure 47). Sites within the upper Murray River zone were primarily flowing run meso-habitats, the lower Murray River zone sites were primarily non-flowing pool habitats and those in the Darling comprised both run and pool habitats (Figure 47).
Figure 44. The proportion of operations at each sampling site where each riparian vegetation category was present.

Figure 45. The proportion of operations at each sampling site where each instream vegetation category was present.
Figure 46. The proportion of operations at each sampling site where each structural habitat types was present.

Figure 47. The proportion of operations at each sampling site where each meso-habitat types was present.
7. DISCUSSION

Management actions undertaken in an effort to achieve an ‘identifiable nett improvement in riverine health across the Lower Murray Darling Catchment by 2015’ include (Troy Muster, Lower Murray Darling CMA, pers. comm.):

   - February 2005: 33,475 Murray cod released at three locations in the Darling River.
   - February 2007: 27,000 Murray cod and 60,000 golden perch released at four locations in the Murray (2) and Darling (2) Rivers.
   - February 2008: 125,000 Murray cod and 125,000 Golden perch released at 17 locations on the Murray (13) and Darling (4) Rivers.
   - February 2009: 11,100 Murray cod and 11,100 Golden perch released at 11 locations in the Murray River between Euston and the Murrumbidgee junction and an additional four locations on the Murrumbidgee River downstream of Balranald (Club Marine Insurance and Coastcare).

2. The NSW Murray Wetlands Working Group, NSW Department of Water & Energy and NSW Department of Environment, Climate Change & Water used a combined total of 8,900 ML of environmental water allocations to inundate.
   - 17 wetlands in the upper and lower Murray River floodplain (Murray I and Murray II zones), totalling 228 ha of wetland habitat in 2004.
   - 6 wetlands in the lower Murray River floodplain (Murray II zone), totalling 113 ha in 2005.
   - 4 wetlands in the lower Murray River floodplain (Murray II zone), totalling 52 ha in 2006.
   - 5 wetlands in the lower Murray River floodplain (Murray II zone) and 2 wetlands in the upper Murray River floodplain (Murray I zone), totalling 118 ha in 2008. This included the re-wetting of Thegoa Lagoon (MWWG ID No. 367: wetted in 2005, 2006 and again in 2008) and two wetlands at Cliffhouse (MWWG ID No.s 3938 and 128: wetted in 2005/2006 and again in 2008). These wetlands are associated with the riverine sites Upper Kulnine and Hancock Hill – Wompinni respectively and have been sampled previously under the LMD CMA’s fish monitoring program. However, no LMD CMA fish sampling was undertaken in 2008 and all three wetlands had dried prior to the sampling period in June – July 2009.
   - 1 wetland in the upper Murray River floodplain (Murray I zone) and 1 wetland on the Darling River floodplain, totalling 21.5 ha in 2009.

3. In 2008, the Lower Murray Darling CMA completed works at nine wetlands of the lower Darling River and one wetland on the lower Murray River (Murray II zone) to improve flows and fish passage to wetlands. The works included the replacement of pipe culverts with box culverts, the installation of regulators at some sites and the removal or lowering of levee banks.

4. In 2007, 19 snags were placed in the lower Darling River upstream of Burtundy Weir by the NSW Department of Primary Industries.

5. The Lower Murray Darling CMA installed a nine cell vertical-slot fishway at Burtundy Weir that became operational in August 2008. The CMA are currently constructing similar fish passage facilities at Pooncarrie Weir and at Weir 32. These three fishways will provide
un-interrupted fish passage along the entire main channel of the Darling River from Menindee Main Weir to the Murray River junction.

6. The **Pomona Reach Habitat Management Plan** implementation project was undertaken by the LMD CMA on four properties at Pomona on the Darling River between March and June 2009. Works involved removal of 39 willows, erection of 2,103 m of riparian fencing, weed removal, provision of 2 off-stream stock watering points and riparian revegetation with 150 plants each of River Cooba, Tangled Lignum and River Red Gum, 170 black box and 30 Old Man Saltbush. The works are being undertaken about 13 km downstream of the Pomona sampling site. This distance, plus the fact that the works were only completed immediately prior to fish sampling in 2009 means that it is unlikely that any benefits of the works will be detected by the fish monitor program.

7. The **River Frontage Action Strategy** implementation project was undertaken by the LMD CMA at three sites (Pooncarie Mission and the Menindee Aboriginal Reserve on the Darling River and Boston Bend on the Murray River) between May and July 2009. Works intended to protect and preserve 11.7 km of river frontage included archaeological surveys, installation of stock grids and gates, fence repair, track construction and traffic exclusion, rubbish and machinery removal, targeted rabbit and weed control and signage. The Menindee works were being undertaken ~40 km upstream of the Bono sampling site, the Pooncarrie Mission works 10 km upstream of the Pooncarrie sampling site and the Boston Bend works at the Cowana Bend sampling site. However, due to both the large distances from sampling sites and the nature of the works involved, none of these projects are likely to lead to changes in fish communities apart from possibly the vehicle exclusion from river banks at Boston Bend.

In addition:

8. The Murray-Darling Basin Commission’s **Sea to Hume Dam** fish passage program has completed construction of functional vertical-slot fishways on each of Locks 7 (in 2004), 8 (2003), 9 (2005), 10 (2006) and a denil fishway on Euston weir (Lock 15) (in 2004) on the Murray River (Barrett and Mallen-Cooper 2006, Stuart *et al.* 2008). Lock 10 also has an additional denil fishway which only provides fish passage under conditions of high tailwater. The only remaining Murray River weir within the Lower Murray Darling CMA area that does not have a fishway installed is Mildura Weir (Lock 11). This fishway is scheduled for construction in 2011 as the last of the fishways in the program. The existing fishways have been demonstrated to provide fish passage for > 1,000 fish per day, for 13 species of fish and for individuals ranging from 31 mm – 1040 mm (Stuart *et al.* 2008).

9. Within the Lower Murray Darling CMA area, William’s Carp Separation Cages (Stuart *et al.* 2006) have been constructed and installed at the Euston Weir fishway in early 2006 and at Lock 10 in April 2008 (Stuart 2008). Automated Mark V carp separation cages have also been provided at Locks 7, 8 and 9, however use of the carp traps at these sites will be dependant on the development of a cost-effective disposal strategy for remote locations. Such a strategy is currently being developed by Peter Jackson on behalf of the Murray Darling Basin Authority. To date, there has been limited removal of carp (< 1 tonne) from either Lock 10 (Benny Bourke, pers. comm.) or Euston Weir (Phillip Cocks, pers. comm.) carp separation cages due to unresolved disposal difficulties. In comparison, at Lock 1 in South Australia, more than 36 tonnes of carp have been removed since the fishway and carp trap were opened in November 2007 (Lee Baumgartner, pers. comm.).

Despite implementation of these management actions, CAP targets have deteriorated across the catchment as a whole since 2004. In 2009, only two sites (7%) exceeded the CAP targets for all three ‘nativeness’ ratios, Imperial Lake near Broken Hill and Lelma on the Darling River.
Nativeness was improving at a further five sites (17%), was stable at one site (3 %), but had declined at thirteen sites (43 %) and deteriorated substantially at nine sites (30 %) (Figure 8). Therefore, conditions are getting worse at 73% of sites. Two of the three native : alien ratios, species richness and biomass, had declined significantly at a whole of catchment level, with the species richness ratio declining from a median of 4 native species per alien species in 2004 to 2.7 in 2009 (Figure 2) and the biomass ratio declining from a median of 792 grams of native fish to every 1 kg of alien fish in 2004 to 347 grams of native fish in 2009 (Figure 4).

Fish assemblage parameters that have changed significantly at a catchment level over the five years since benchmark sampling in 2004 are the proportion of total species richness that is native, which declined from an average of 0.78 native species per site in 2004 to 0.72 in 2009 (Figure 12) and the proportion of the total catch suffering from a health condition, which had increased significantly from an average of 2.0 % of individuals in 2004 to 8.9 % in 2009 (Figure 16). The proportion of individuals affected by the parasitic anchor worm (Lerneae spp), fin damage (physical and pathogenic), wounds and deformities was higher in 2009 than observed during any previous round of sampling (Figure 18). None of the other parameters assessed; total species richness, abundance or biomass, the proportion of total abundance or biomass that was native fish or the proportion of native fish recruits have changed at a whole of catchment level between 2004 and 2009.

Within individual catchment management zones, the proportion of native fish recruits had declined significantly in the Lakes & Reservoirs management zone, total species richness had declined in the Darling River management zone, and total biomass had declined and the proportion of fish suffering a health condition had increased in the upper Murray River management zone since 2004. None of the fish assemblage parameters analysed had changed significantly between 2004 and 2009 in the lower Murray River management zone.

At an individual species level, two native fish species, bony herring (Figure 25) and carp-gudgeon species (Figure 36) had declined in abundance, with bony herring declining from an average abundance of 110 individuals per site in 2004 to 56 individual per site in 2009, and carp-gudgeon species declining from an average abundance of 20 individual per site in 2004 to 3 individuals per site in 2009. Native silver perch, un-specked hardyhead and flat-headed gudgeon and alien goldfish and eastern gambusia were found at more sites in 2009 than in 2004, whilst native carp-gudgeon species and Murray-Darling rainbowfish were collected at fewer sites.

These data suggest that the management actions implemented up until June 2009, and/or the extent of the works involved, have not been sufficient to result in acceptable progress towards the three Lower Murray Darling CMA CAP targets for fish community ‘nativeness’. In contrast, the persistent drought in this part of the Murray Darling Basin may have contributed to the observed declines in most fish assemblage parameters.

The release of ~ 382,000 Murray cod and golden perch fingerlings since 2005 has not resulted in significant increases in the population sizes of either of these species. Despite releasing 11,100 Murray cod and 11,100 golden perch fingerlings at sites throughout the upper Murray River management zone in February 2009, no young golden perch were collected at any site throughout the CMA area and only a single young Murray cod was collected from those sites within 25 km of release points. This suggests that either the survival of the released fingerlings was very poor or that they rapidly dispersed long distances from the release points (and possibly outside the CMA area for golden perch). Further, the lack of any golden perch recruits at any site throughout the CMA area since monitoring commenced in 2004 indicates a serious problem for this species in the catchment. However, the capture of several one year old fish in the Darling River in 2009 and the 51% increase in golden perch abundance over the 2 years since data was last collected in 2007 suggests that the release of golden perch fingerlings in the Darling River in 2008 may have temporarily stabilised the decline in abundance of this species. However, without assessing the
origin of the 2008 through otolith microchemical analysis, it cannot be determined whether the 2008 cohort in the Darling River resulted from stocking as opposed to natural recruitment. There were fewer Murray cod recruits collected from fewer sites in 2009 than they had been in 2007, and there is a continued absence of Murray cod recruitment in the lower Murray River management zone. Some unknown factor which promoted Murray cod recruitment in this zone in 2004 and 2006 (perhaps a flow variable or water quality parameter) had changed in 2006/07 to become less favourable. Despite this, the catchment-wide level of natural Murray cod recruitment has been sufficient to lead to non-significant increase in abundance of Murray cod across the catchment as a whole since 2004. But the combined level of natural recruitment plus the input of stocked Murray cod fingerlings released in 2005 and 2007 – 2009 has not been sufficient to result in significant increases in the abundance of Murray cod.

The environmental watering of wetland systems between 2004 and 2009 has similarly not led to a detectable improvement in native fish assemblages in these catchment zones. However, as most of the water delivered was pumped or siphoned, the opportunity for fish to enter the wetlands was limited. Fish passing through pumps have been demonstrated to suffer substantial mortality (Baumgartner et al. 2007) and data exists demonstrating that some species have an aversion or inhibition to passing voluntarily through or into dark passages or pipes (Mallen-Cooper 1996; Mallen-Cooper 2001; Harris et al. 2007). Even more pertinent is the fact that once the wetlands were filled, there would have been no or only a limited opportunity for fish to escape back to the river before the wetland dried and any food-web responses resulting from the wetting of the wetland (plankton blooms etc) would not have contributed to the riverine fish community. In summary, wetland inundation activities will only lead to a positive response in fish communities if a) fish are allowed unimpeded access to the wetland during the filling phase and b) that the wetland is subsequently re-opened to the river at a later date (with adequate fish passage provided) so that fish recruited in the wetland can re-enter the river before the wetland dries and so that the bio-production from the wetland has an opportunity to contribute to the riverine ecosystem. Wetland habitats are particularly important for several species of fish native to the CMA area, especially the threatened species; Murray hardyhead, southern purple spotted gudgeon, olive perchlet, southern pygmy perch, flat-headed galaxias and freshwater catfish. Implementing ‘fish-appropriate’ wetland rehabilitation activities will be essential in the recovery of these species in the CMA area.

Fish-appropriate wetland watering can only be achieved by natural gravity feeding water to wetlands, as occurs at Thogoa Lagoon. Water should be delivered to wetlands by either raising the river level above the natural commence-to-fill sill within the wetland inlet, or by excavating the inlet sill to below base-flow river level and installing a culvert and regulator gates that provide adequate fish passage both into and out of the wetland (see Mallen-Cooper 2001; Fairfull & Witheridge 2003; Nichols and Gilligan 2004). Further, sufficient environmental water should be allocated to initially fill the wetland and then to reconnect the wetland to the river at a later date (12 – 18 months after filling) before the wetland is allowed to return to its dry state. Lastly, wetland wetting-drying cycles should be coordinated among neighbouring wetland systems so that at any point in time at least some wetland habitat is available to wetland specialists. Under natural hydrology, dry phases resulting in natural wetland drying would have coincided with low river levels, which resulted in lentic pseudo-wetland habitats being available in drying main river channels. However, under current river management regimes, river channels persist as lotic systems even during drought and wetland specialist fishes have no or few refugia within which they can persist. Therefore, fish-appropriate wetland management must ensure that wetland specialist fishes have an opportunity to evacuate drying wetlands and re-populate filling ones without having to spend long periods of time trying to survive in potential hostile riverine (lotic) environments. A high priority for the recovery of the large number of threatened wetland specialist fishes is the development of such a ‘fish appropriate’ wetland wetting-drying management strategy.
Despite data indicating that each of the fishways constructed in the Murray River is providing effective fish passage past Locks 7, 8, 9, 10 and 15 (Stuart et al. 2008), fishway construction has not led to a detectable improvement in any fish community parameter or the increase in abundance of any fish species in the Lower Murray Darling CMA reaches of the Murray River. A potential explanation may be that although the fishways are in place at Locks 7, 8, 9, and 10, and providing free fish passage within the lower Murray River zone, substantial improvements in the fish communities may be dependent on the provision of fish passage at Locks 1 – 6, that would enable fish to migrate into the Lower Murray-Darling CMA area from the lower Murray River in South Australia. Fishway construction has been completed at Lock 1 and 3 in South Australia and will be completed at Lock 6 by November 2009. It could be hypothesised that a response in fish communities in the lower Murray River management zone will not eventuate until fishway construction has also been completed at Locks 2, 4 and 5. Alternatively, the rate of recovery of a fish community following provision of fish passage has been demonstrated to take several years in a coastal catchment (Gilligan 2003) and a similar time frame may be required to detect fish community responses in the Murray River.

In contrast to the Murray River fishways, the achievement of all three fish nativeness CAP targets at Lelma (~16 km upstream of the fishway) in 2009, and very good progress towards achieving all three CAP targets at Lethero could possibly be a direct result of the provision of fish passage within the Darling River at Burtundy Weir, although this can not be conclusively proven with existing data.

In order for the Lower Murray-Darling CMA to make progress towards meeting its CAP targets for riverine health, it is recommended that the CMA invests its resources into the following aquatic rehabilitation programs, each of which could contribute substantially to meeting the CMAs aquatic health CAP targets:

- Threatened species recovery actions such as those described in the NSW DPI Priorities Action Statement for threatened fish and marine vegetation. Murray hardyhead, southern purple spotted gudgeon, olive perchlet, southern pygmy perch, flat-headed galaxias and freshwater catfish would all benefit from fish-appropriate wetland management, habitat rehabilitation and pest fish exclusion at key wetlands in the system. For all six of these species, recovery would require substantial reintroduction programs as four of the six species are likely to be locally extinct in the Lower Murray Darling CMA area and therefore natural recolonisation of rehabilitated habitats is unlikely to occur. It is specifically recommended that the LMD CMA liaise with Michael Hammer (Aquasave Consultants) regarding potential for reintroduction of the endangered Southern purple-spotted gudgeon (Hammer et al. 2009) and Iain Ellis (Murray-Darling Freshwater Research Centre) regarding potential for reintroduction of critically endangered Murray hardyhead to specific sites that meet their habitat requirements and can be carefully managed to ensure ongoing survival of the reintroduced populations. It is also recommended that the LMD CMA purchase endangered freshwater catfish fingerlings in addition to Murray cod and golden perch as part of the catchments ongoing fish stocking activities. Further, vulnerable silver perch populations may also benefit from a stocking program. The goal of these threatened species recovery actions is to increase the ‘proportion of total species richness that is native’ across the catchment, which is one of the Lower Murray Darling riverine health CAP targets.

- Developing ‘fish-appropriate’ wetland watering programs to aid the recovery of non-threatened wetland specialist fishes and also to ensure that wetlands maintain food-web and nutrient transfer linkages with the riverine ecosystem.

- Utilising Environmental Water Allocations to initiate natural in situ spawning and recruitment events for riverine species such as Murray cod, golden perch, silver perch, bony herring and Australian smelt.
• Promoting the maintenance of stable populations of large adult Murray cod, golden perch, silver perch and freshwater catfish in order to maximise the biomass of native fish in fish communities and improve the ‘proportion of total biomass that is native’ (one of the Lower Murray Darling riverine health CAP targets).

• Investigating the reasons for the lack of golden perch recruitment in the catchment area and implementation of management actions aimed at increasing golden perch recruitment.

• Implementing carp control programs to reduce their biomass within the CMA area and consequently improving the ‘proportion of total biomass that is native’, which is one of the Lower Murray Darling riverine health CAP targets. This could begin with facilitation of ongoing use of the William’s Carp Separation Cages at Locks 7, 8, 9, 10 and 15, and the installation of carp separation cages at Burtundy Weir, Pooncarrie Weir and Weir 32.
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