Monitoring and assessment of Gunbower and Thompson's weir fishways

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EXECUTIVE SUMMARY

Restoring longitudinal fish passage along the ~120 km main channel of Gunbower Creek is an important component of recovery for native fish populations. Accordingly, fish passage works have commenced at main-channel weirs on the Gunbower Creek. Fishways have been constructed at Thompson's and Gunbower weirs and others are planned for Cohuna Weir, Koondrook Weir and the National Channel Offtake Regulator and regulators proposed for the Living Murray Hipwell Road Channel package of works. The aim of the present project was to collect technical and biological information concerning migratory fish in Gunbower Creek to determine if the fishways enable upstream and downstream passage of the full range of target fish species and size classes. The information collected will also be used to inform the design of the new fishways proposed under the new Living Murray program and for the existing weirs.

In March and November 2011, fish were trapped and electrofished at the Gunbower Weir vertical-slot fishway and Thompson's Weir rock fishway. In 8-sample days a total of 931 fish from nine species (six native) were collected in Gunbower Weir fishway, while boat electrofishing collected 2447 fish below both of the weirs. Catches were dominated by small-bodied fish species (25-55 mm long) with few large bodied fishes collected. Accordingly, provision of fish passage for small bodied species at main channel weirs on the Gunbower Creek is an important management consideration. Thus, for Gunbower Weir fishway, several refinement opportunities are identified to optimise its function for small bodied fish species, and weir operating protocols may also be clarified and improved to further improve utilisation of the fishway. The Thompson's Weir rock fishway requires rectification to meet basic functionality requirements for fish passage

The November/December 2011 sampling coincided with an environmental flow in Gunbower Creek, which created a pulse in flows over Gunbower Weir. Monitoring during this flow pulse was important to clarify that for large-bodied fish re-colonisation of juvenile golden perch and silver perch from the Murray River is required to restore Gunbower Creek populations. Hence, fishways at Koondrook and Cohuna weirs are ecological priorities, along with restoration of end of system flow.

Assessment of the Gunbower and Thompson's weir fishways has provided the necessary data to emphasise the provision of passage for small (30+ mm long) bodied fish and crustaceans in the design objectives for future fishways on the Gunbower Creek. For new fishways we recommend inclusion of river operators, designers, fish ecologists and North Central CMA staff in the design and operation guidelines of new fishways to maximise their effectiveness in the restoration of migratory fish populations in Gunbower Creek. We also suggest that landscape fishway prioritisation include the Kow Swamp system and therefore there is a need to strengthen links with the NVIRP regulator upgrade process.

Recommendations

Gunbower Weir

1. Align fish passage objectives for all fishways on Gunbower Creek for small and large fish (from 30-1000 mm long) and crustaceans.
2. Consider optimising the function of the Gunbower weir vertical-slot fishway for small fish by constructing (i) middle sills, (ii) modified slots and (iii) floor rocks within the fishway.
3. Clarify Gunbower Weir operational protocols with G-MW to optimise fish attraction, adopt a maximum 50 ML/d protocol for Gate 1 (the adjacent gate).
4. Draft and assess new operational protocols for Upper Gunbower Lagoon (UGL) flow releases (e.g. UGL regulator turned off for 24h per week) to improve fish attraction at the Gunbower fishway.
5. Consider a small-scale strategic habitat restoration below Gunbower Weir to provide cover for migrating native fish.

Thompson's Weir

1. Rectify Thompson's Weir rock fishway to meet basic functionality and ensure a partnership approach with engineers, fish scientists, operators and North Central CMA.
2. Include a commissioning phase to adjust the rocks within the new fishway to achieve optimal hydraulics over the design flow range.
3. Assessment of the biological and hydraulic function of any new rock fishway at Thompson's Weir.

Gunbower Creek

1. Restore full landscape connectivity with fishways at Koondrook and Cohuna weirs.
2. Environmental flows will be important in restoring fish populations. Components of the hydrograph character may be: (i) restore regular end of system flow at Koondrook Weir, (ii) spring/summer pulsing and small daily variations (i.e. 0.15 m) to stimulate movement and re-colonisation of Gunbower Creek by juvenile golden perch and silver perch from the Murray River, through Koondrook fishway (when built), (iii) restore winter base flows.

Kow Swamp

1. North Central CMA to liaise with NVIRP to ensure any opportunities to enhance fish passage at upgraded regulators on the Kow Swamp/Taylors Creek/Pyramid system are capitalised upon.

CONTENTS

1 INTRODUCTION

1.1 Background

Since European settlement, native fish have declined across the Murray-Darling Basin (MDB) and this is, in part, due to the construction of barriers to movement and migration (NFS 2004). Barriers such as weirs, levees, causeways and dams impede migration pathways and movement to and from spawning and natal areas (Mallen-Cooper and Brand 2007; Stuart *et al.* 2008; Baumgartner et al. 2010), disrupt feeding patterns (Baumgartner 2007) and increase predation pressure when migrating fish accumulate below impassible barriers (Baumgartner 2006; Jones and Stuart 2008). Fishways, including vertical-slot and rock ramp designs, are designed to mitigate the effects of impeded passage by passing a broad diversity of fish species and sizes (ranging from 40 -1000 mm). Over the past two decades, fishways have been incorporated into the design and operation of new and existing flow regulation structures throughout the MDB. Their construction has been shown to restore migration pathways for many thousands of small and large bodied fish (Mallen-Cooper and Barrett 2006; Stuart et al. 2008; Baumgartner et al. 2010).

Twelve native fish species are commonly collected in Gunbower Creek, and most of these are considered to be migratory at various stages in their life-cycle. Flow in Gunbower Creek is regulated by a series of barriers and restoring fish passage along the entire ~120 km of main channel is an important component for recovery of native fish populations in the region. To achieve this aim, fishways have been constructed at Gunbower and Thompson's weirs and three additional fishways are proposed for Cohuna Weir, Koondrook Weir and the National Channel Inlet Regulator (Figure 1). Two new regulators are also proposed under the Living Murray Hipwell Road Channel Package of Works. One of these new regulators will be constructed in Gunbower Creek and the other on an inlet channel that will divert environmental water from Gunbower Creek to Gunbower Forest. The new regulator in Gunbower Creek will incorporate a vertical-slot fishway and the new regulator on the inlet channel will incorporate a fish lock. The results of this monitoring project will assist in the design of these proposed fishways.

The aim of the present project was to collect technical and biological information concerning migratory fish in Gunbower Creek. The monitoring was then interpreted to determine if the fishways enable upstream and downstream passage of the full range of target fish species and size classes. The information collected will also be used to inform the design of the new fishways proposed under the new Living Murray program and for the existing weirs.

An additional project objective was to determine if a managed flow pulse during spring stimulated a significant increase in the number of fish migrating upstream in Gunbower Creek. Information gathered during the flow pulse may then be used to determine future flow management in Gunbower Creek and the operating strategy for the Living Murray works at Gunbower Forest (Hipwell Road works).

During the November 2011 field sampling, an opportunity to survey additional locations (Figure 1) was also taken advantage of at the following locations:

- Immediately downstream of Cohuna weir
- Immediately downstream of the National Channel Offtake Regulator
- Immediately downstream of Spittles Regulator on Taylor's Creek

2 METHODOLOGY

2.1 Site description

2.1.1 Gunbower Weir vertical-slot fishway

Gunbower Weir fishway was designed by SKM and constructed in 2008/09 by Goulburn-Murray Water (G-MW). The fishway operates over a range of 2.5 m, or flows from 150 - 1650 ML/day. The fishway was constructed on a 1v:20h gradient (5% slope) with 3 m long by 2 m wide pools, a minimum operating depth of 1 m and 0.3 m wide vertical-slots (SKM 2008). The fishway contained several larger (2.5 standard pool volume) pools at each 180^o bend and the head difference between the pools was 0.165 m, creating a maximum water velocity of 1.7 $m.s^{-1}$ and an average turbulence of 88 $W.m^3$. A continuous layer of floor rocks (0.2 m diameter) was to be included to enhance the passage of crustaceans and lampreys, both of which migrate at Torrumbarry Weir fishway (Mallen-Cooper 1999). However, no rocks were observed in the de-watered upper fishway channel during the present study.

2.1.2 Thompson's Weir rock fishway

Design

A rock ramp fishway for Thompson's Weir was designed by SKM and constructed in November 2010 by G-MW. Construction of the rock ramp fishway in 2010 enabled potentially unimpeded fish passage along 65 km of Gunbower Creek, from Cohuna Weir to the National Channel offtake regulator. The fishway has a slope of 1v:30h with large rocks placed throughout the rock-ramp to create pools and enable fish passage (Figure 2). The fishway is designed for a minimum of 150 ML/d (0.92 m head over weir crest; SKM 2008). The fishway is designed to pass fish from 90 - 1000 mm in length (SKM 2008).

Figure 1. Study area, showing Gunbower system, weirs and fishways. Adapted from North Central CMA (2011).

On-site modifications

During commissioning of the rock fishway there was concern that overall discharge ability of the weir had been reduced due to the reduced cross-sectional area of the rock chute, caused by the new ridge rocks (Ross Stanton, G-MW, pers. comm.). To reinstate the previous discharge magnitude, most of the central ridge rocks were removed, resulting in high flow and turbulence in the centre of the ramp. Nevertheless, some large rocks were retained on the rock ramp margins where fish could potentially ascend. In summary, the final fishway constructed was substantially altered from the original design in a compromise with the discharge requirements of the site. The present project assed the modified Thompson's Weir rock ramp fishway.

a).

b).

c).

d).

Figure 2. Thompson's Weir rock fishway a) and b) after construction with ridge rocks, c) after removal of ridge rocks and d) original weir.

2.2 Gunbower Creek fish community

Fish community

Thirteen native fish species and six non-native fish have been recently recorded in Gunbower Creek with the fish community dominated by small bodied fish species less than 100 mm in length (Douglas and Shirley 1996, Douglas *et al.* 1998, Richardson *et al*. 2005, Sharpe 2009, Rehwinkel and Sharpe 2009; Table 1). These include carp gudgeons, unspecked hardyhead, Australian smelt and flat-headed gudgeons. Most fish species recorded in the Gunbower system are considered common in other lowland areas of the Murray catchment (Lintermans 2007). The large and medium- bodied fish species recorded in Gunbower Creek generally occur in low abundance but include four threatened species; Murray cod, silver perch, trout cod and freshwater catfish (Rehwinkel & Sharpe, 2009). Of the six non-native species, carp and gambusia are the most abundant.

Gunbower Creek movement model

Little is known of the migration habits of fish in Gunbower Creek but the conceptual understanding predicts that several species and life-stages would move upstream and downstream particularly in spring and summer. This includes adult and juvenile golden perch, silver perch and Murray cod but only the latter are considered to recruit in Gunbower Creek. These species of large-bodied fish are generally considered to have a migration period from late August to March. In the Gunbower Creek, the majority of fish collected in routine surveys are small bodied species (< 100 mm long) and these are likely to be moving upstream and downstream between November (spring) and April (autumn). The fish movement season broadly matches the irrigation season in the Gunbower region, and the period of maximum flow in the fully regulated Gunbower Creek of ~1200 ML/d.

Table 1. Fish species present or may recover in Gunbower Creek and their migratory habits as adults, juveniles and young-of-the-year.; threatened species are denoted by an asterisk.

Abundance: ✓✓✓✓ Very abundant, ✓✓✓ Abundant, ✓✓ Common, ✓ Rare, - Absent,? Unknown

	Present abundance	Migratory as adults	Migratory as juveniles	Migratory as young of year
NATIVE				
Large-bodied (500-1000 mm)				
Murray cod*	✓✓	▲	▲	▲
Trout cod*	✓	▲	▲	▲?
Medium-bodied (90-500mm)				
Golden perch	✓✓	▲	▲	▲
Silver perch*	✓	▲	▲	▲
Freshwater catfish*	✓	▲	▲	
Bony herring	✓	▲	▲	▲
River blackfish	possible	**local**	**?**	**?**
Small-bodied (20-100 mm)				
Carp gudgeons	✓✓✓✓	▲	▲	▲
Flat-headed gudgeon	✓✓✓	▲	▲	▲
Un-specked hardyhead	✓✓✓	▲	▲	▲
Australian smelt	✓✓	▲	▲	▲
Dwarf flat-headed gudgeon	✓✓	▲	▲	**?**
Murray–Darling rainbowfish	✓	▲	▲	▲
NON-NATIVE				
Carp	✓✓✓	▲	▲	▲
Eastern gambusia	✓✓✓✓	▲	▲	▲
Goldfish	✓✓	▲	▲	▲
Redfin perch	✓	▲	▲	▲
Oriental weatherloach	✓✓	**?**	**?**	?
Tench	✓	**?**	**?**	?

Table modified from Mallen-Cooper et al. 2011.

2.3 Gunbower Weir fishway trapping

A cage incorporating a funnel-trap was manufactured to sample fish from the Gunbower vertical-slot fishway (Figure 3). The cage can be situated near the entrance or exit and is 2 m long by 1.75 m wide and 1.8 m high. The funnel is 1.2 m long with exit dimensions of 0.4 m high and 0.3 m wide; is covered in 4 mm perforated aluminium sheet. For improved cost-efficiency, the sampling cage was also designed to fit the Kerang Weir vertical-slot fishway.

At Gunbower Weir vertical-slot fishway, the number, size-range and species composition of fish entering and exiting the fishway was assessed with paired-day cage samples at the fishway entrance and exit. Sampling both the exit and entrance of the fishway was required to quantitatively assess its performance. Each cage sample was 24-hrs in duration and the first location (exit or entrance) randomised within each trap pair. Two independent trap catches (48-hrs total) is a standard method for comparing the proportion of different fish species and size classes that successfully ascend (Stuart and Mallen-Cooper 1999). For the entrance sample, the attraction flow (head loss) was reduced from the design standard of 150 mm to 40 mm, to give any small migrating fishes the opportunity to enter the fishway.

Cage trapping was conducted over 2 weeks (two paired day samples in each week) in March and November 2011. March represents the end of the fish migration season (autumn), however earlier sampling was delayed due to 'black water' event and flooding issues in Gunbower Creek (North Central CMA unpubl. data 2011). A second 'spring' sample was undertaken in November (2011) to coincide with the fish migration period, and was timed to occur in conjunction with an environmental flow in Gunbower Creek.

Seven GL of environmental water was allocated from Living Murray environmental water entitlements and designed to deliver a series of freshes and base flows, with the aim of building the resilience of native fish populations in Gunbower Creek (Anna Chatfield, North Central CMA pers. com 2011). The delivery schedule for the environmental water consisted of a flow peak at Gunbower Weir on 22 November 2011, with 30 day rise and fall.

All fish sampled were identified, counted, measured and released upstream of the fishway, into the Gunbower Weir pool. In the case of large catches, a sub-sample of 50 individual fish per species were measured.

2.4 Boat electrofishing at Gunbower and Thompson's weirs

Sampling rock ramp fishways can be a difficult process and at Thompson's Weir nets could not be set at the fishway exit due to very high water velocities during both autumn and spring 2011 samples. As such, the effectiveness of the Thompson's Weir fishway was measured using indirect indices. These were (i) the relative abundance of fish and species/size composition of fish migrating upstream and accumulating immediately below the weir and (ii) the relative abundance of fish 1 km downstream of the fishway. This paired design enabled the effectiveness of the fishway to be evaluated by detecting any aggregation of fish below the fishway. Three paired samples of the sites were undertaken on three contiguous days in late March 2011 and another paired sample was completed in November 2011.

At Gunbower Weir, the vertical-slot fishway was assessed with a cage trap to avoid disturbing migrating fish (Figure 3). Boat electrofishing was conducted on one occasion at the end of each sampling week (31/3/2011 and 25/11/2011) to assess the occurrence of fish aggregation (i) immediately below the new Gunbower Weir and fishway, (ii) immediately below Upper Gunbower Lagoon outlet Regulator, and (iii) approximately 500 m to 1 km downstream of the Gunbower Weir, in Gunbower Creek (Figure 4).

A boat electrofisher was used to sample fish downstream of Gunbower and Thompson's Weirs. The electrofishing system consisted of an onboard mounted 4800 Watt University of Wisconsin MBS-2D pulsator (ETS Electrofishing, Verona, Wisconsin). During each sample, electrofishing began at the designated starting point and fishing was undertaken in an upstream direction with the electrofishing elapsed time recorded. All fish were collected by dip-net and placed into a live well to recover. Fish were identified, measured for total length (TL), or fork length (FL) for fork-tailed species. Any positively identified fish which could not be dip-netted were recorded as 'observed'. In instances where large numbers of individual species were collected, a random sub-sample (50 individuals) were measured.

2.5 Additional measurements

Backpack electrofishing and water velocity at Thompson's Weir fishway

A one-off sample of fish on the left margin (looking downstream) of Thompson's Weir rock fishway was undertaken on 30 March 2011 using a backpack electrofisher (model LR 24; Smith Root Inc, Vancouver, WA, U.S.A.). Collecting this sample involved wading from downstream to upstream, electrofishing behind the larger rocks and in the relatively slow water margins near the bank edge. Fish were dip-netted, identified and processed as per the boat electrofishing method.

A water velocity meter (Flo-Mate^{TM} 2000-51) was used to characterize hydraulics along the left bank of the rock fishway on 1 April 2011. Instantaneous water quality measurements were

Figure 3. Cage trap for Gunbower Weir vertical-slot fishway.

Figure 4. Electro-fishing below the Upper Gunbower Lagoon Regulator.

undertaken downstream of Thompson's and Gunbower weirs with a Horiba® U-52 multi-probe and included dissolved oxygen, temperature, pH, turbidity and conductivity.

Surveys downstream of Cohuna Weir, National Channel offtake regulator and Spittles Weir (Taylors Creek).

From November 21st-25th 2011, boat electrofishing sampling was undertaken immediately downstream of National Channel Offtake regulator and Cohuna weirs (Gunbower Creek) and downstream of Spittles Weir (Taylors Creek) in order to identify any fish accumulations, particularly in response to the environmental flow. This information was collected in order to enhance the conceptual understanding of fish movement throughout the Gunbower/Taylors Creek systems. One sample was completed at each of the three weirs. Sampling was conducted following the same protocols as for Gunbower and Thompson's weirs (described above).

3 RESULTS

3.1 Gunbower Creek discharge, March 2011

Discharge from Gunbower Weir during the March 2011 (28/3/2011-1/4/2011) sampling is shown in Figure 5. Discharge increased from 299 Ml/d on Monday 28 March to 899 Ml/d on Friday 1 April (Figure 5). Discharge tended to be distributed evenly across the four radial gates of the weir and peaked at 224 ML/d per gate during the sampling. Discharge from the adjacent Upper Gunbower Lagoon Regulator decreased from 126 ML/d to 87 ML/d over the same period.

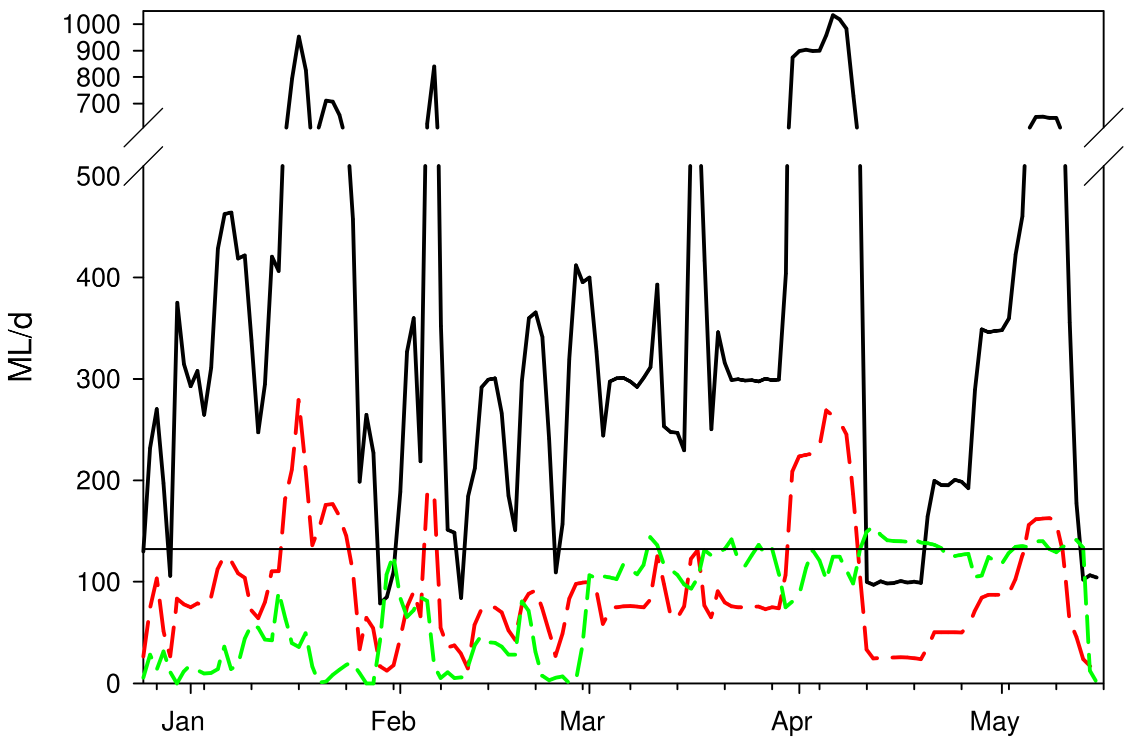

Figure 5. Discharge (ML/d) in Gunbower Creek for the period January-May 2011 (black), from radial Gate 1 (red) and from Upper Gunbower Lagoon Outlet Regulator (green). The horizontal black line represents the maximum discharge (100 ML/d) recommended for radial Gate 1 to optimise fish attraction to the fishway entrance (Mallen-Cooper 2008).

3.2 Gunbower fishway trapping, March 2011

A total of 904 individuals representing six fish species were collected in the Gunbower Weir fishway over four sample days in March 2011 (Table 2, Figures 6 & 7). The fish community was dominated by small-bodied species (902 of 905 individuals) and the majority (99%) were collected at the entrance (Table 2). Most small fish (891 of 895) at the entrance were collected in the first sampling period (29-30 March 2011). By contrast, on the second sampling period (30-31 March 2011) flows had risen substantially and the fishway entrance appeared subject to significantly more turbulence than the previous sampling day and few fish were collected (four individuals). The size-frequency of fish from the exit and entrance of the fishway could not be reliably compared due to the lack of fish in the sample at the exit of the fishway. Figure 8 indicates the size-frequency of the four most common small-bodied species that were collected at the fishway entrance. Most small-bodied fish were among adult size classes rather than juvenile, which may reflect the timing of sampling (autumn), which was outside the known breeding period for those species.

3.3 Fish community and abundance below Gunbower Weir, March 2011

In the boat eletrofishing sample below Gunbower Weir, 1151 individual fish constituting four native and four non-native fish species were collected (Table 3). Gambusia and unspecked hardyhead dominated the catch. There were considerably more gambusia and unspecked hardyhead collected below Upper Gunbower Creek Lagoon Regulator compared to both immediately below Gunbower Weir and 1km downstream of the Gunbower Weir (Figures 6 & 7). The remaining species (Table 3) were either collected at similar relative densities at each location, or were collected at too low abundance to compare.

3.4 Fish community and abundance below Thompson's Weir March 2011

In the three separate electrofishing samples below Thompson's Weir, 1024 individual fish constituting six native and four non-native fish species were collected (Table 4). Unspecked hardyhead and gambusia dominated at each site (Table 4). For unspecked hardyhead and Australian smelt there were five and eight times more fish (respectively) collected below Thompson's Weir as compared to the site 1 km downstream of the weir. The remaining species were either collected at similar relative densities at each location or too few fish were collected to enable relevant comparisons.

Table 2. Total numbers of fish collected at Gunbower Weir vertical-slot fishway in two-paired days (four days total) of trapping in March 2011. Each catch (number of individuals collected) for the two separate days of sampling at the fishway entrance and exit is indicated in brackets.

	Exit sample (150 mm head)	**Entrance sample (40 mm head)**	**TOTAL individuals**	**Length range (mm)**
Species				
Carp gudgeons	(0,0)	(36,0)	**36**	32 – 52
Australian smelt	(6,0)	(800,3)	**809**	38 – 55
Unspecked hardyhead	(0,0)	(31,1)	**32**	30 – 50
Bony herring	(1,0)	(0,0)	**1**	147
Carp*	(2,0)	(0,0)	**2**	107 - 447
Gambusia*	(0,0)	(24,0)	**24**	31 - 45
Freshwater crustaceans	3,12	3.541 kg (30shrimp,11 prawn), 650 g (40 prawn, 20 shrimp)	Thousands	
TOTAL	**9**	**895**	**904**	

*Non-native species

Figure 6. Catch of small-bodied fish and crustaceans in Gunbower Weir vertical-slot fishway.

Figure 7. Fish electrofished below the Upper Gunbower Lagoon Regulator.

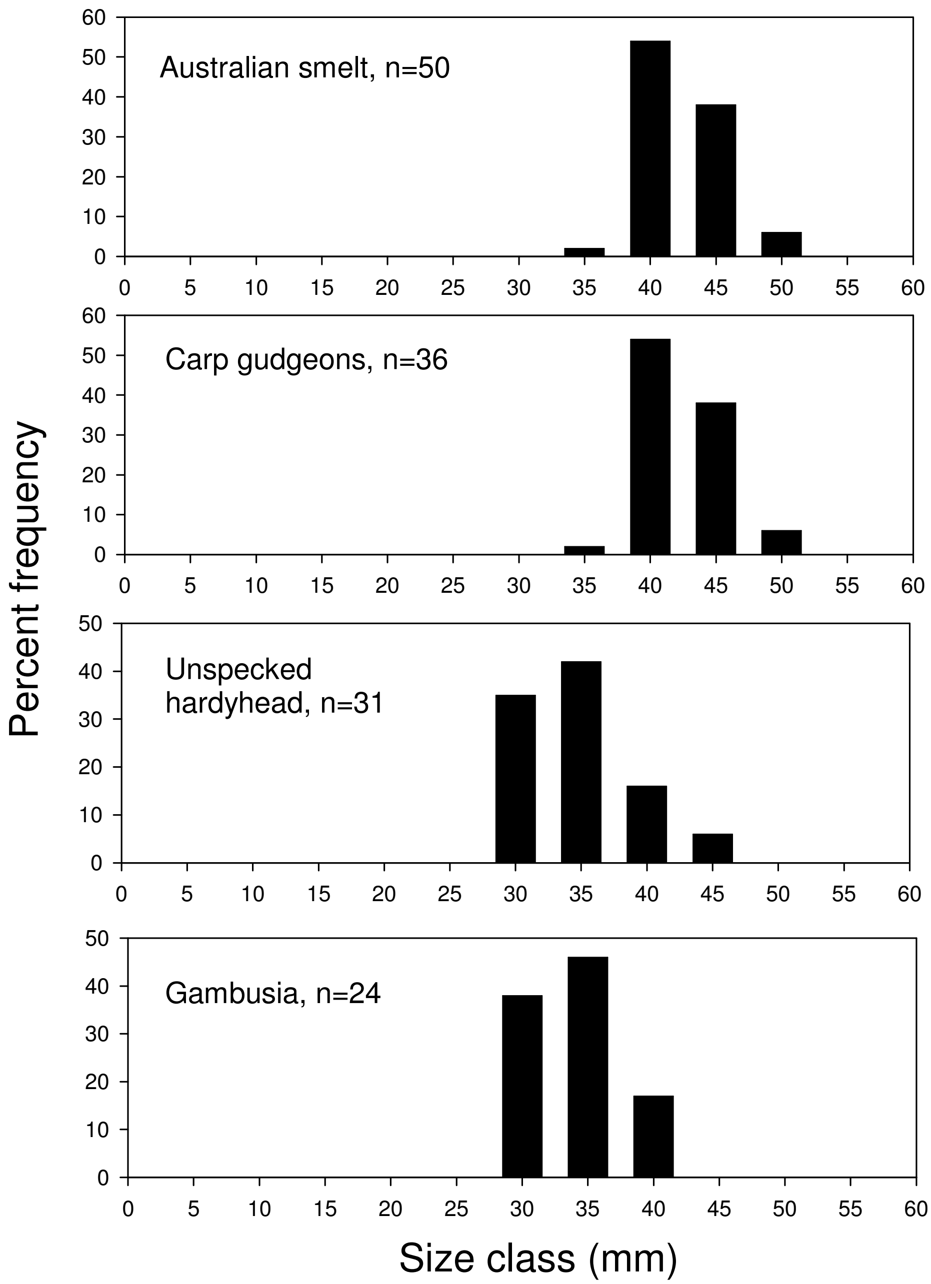

Figure 8. The size-frequency of small-bodied fish collected in the entrance of the Gunbower vertical-slot fishway in March 2011.

Table 3. Fish collected by boat electrofishing at Gunbower Weir on one occasion at three sites (immediately below weir, Upper Gunbower Lagoon Regulator and 1 km downstream) in March 2011.

	Beneath Gunbower weir	**Beneath UGL Regulator**	**1 km d/s**	**TOTAL individuals**	**Length range (mm)**
Species					
Carp gudgeons	0	6	0	**6**	24-47
Australian smelt	5	19	12	**36**	32-51
Unspecked hardyhead	0	202(hundreds)	17	**219**	25-44
Silver perch	1	0	0	**1**	226
Carp*	0	3	5	**8**	132-285
Goldfish*	0	0	3	**3**	161-207
Gambusia*	106	755	17	**1739**	19-42
weatherloach*	0	1	0	1	89
crustaceans	350g	150g	100g		
TOTAL	**112**	**986(hundreds)**	**54**		

*Non-native species

Table 4. Fish collected by boat electrofishing at Thompson's Weir on three occasions at two sites (immediately below weir and 1 km downstream) in March 2011. Brackets indicate observed fish.

Species	Beneath weir	Effort mins)	Fish/min	1 km d/s	Effort (mins)	CPUE	Length range (mm)
		(14m47s)			16min		
Carp gudgeons	1,7,1		0.55				23-47
Flat-headed gudgeon	1		.07	1		0.06	70-74
Australian smelt	26,52(4),42(4)		8.85	2		0.12	29-52
Unspecked hardyhead	61(7),56(148), 45(52)		25.5	30,20(14),5		4.31	20-45
Bony herring	2		0.13				180-294
Murray cod	1		0.07				425
Carp*	(2),2(1),1		0.41	3(6),1		0.6	136-731
Goldfish*	1,1,1		0.21	2,6,4(1)		0.8	75-240
Gambusia*	87(8),38(11),16(2)		11.2	17,20(52),18		6.7	17-35
Redfin*				1		0.06	152
Observed small-bodied fish	(20),(70)			(25),(30)			
TOTAL	**771**		**5.22**	**253**	**1.8**		

*Non-native species

3.5 Backpack fishing in Gunbower rock fishway

In March 2011, two Australian smelt and one gambusia were collected within the rock fishway from 40 seconds of power-on electrofishing sampling on 30/3/2011.

3.6 Water velocity in Gunbower rock fishway

In March 2011, 12 water velocity measurements were collected from within the Thompson's Weir rock fishway and these ranged from 0.33 - 4.29 m/s. Water velocity was fastest at the downstream end of the fishway and slowest along the shallow bank margins and behind large rocks.

3.7 Water quality measurements

In March 2011, water quality measurements indicated that the water temperature range during sampling was 17.80-19.80°C and dissolved oxygen 10.59-11.63 mg/L.

3.8 Gunbower Creek discharge, November 2011

In November 2011, a flow pulse at Gunbower Weir from 100- 491- 130 ML/d over 14 days was followed by a larger flow pulse of 140- 616- 480 ML/d over a 20 day period (Figure 9). Fishway sampling was timed (21st-25th November) to occur in conjunction with this second flow pulse. During the second flow pulse and for the duration of fishway sampling, discharge over radial Gate 1 (adjacent to the fishway) was reduced to 50 ML/d.

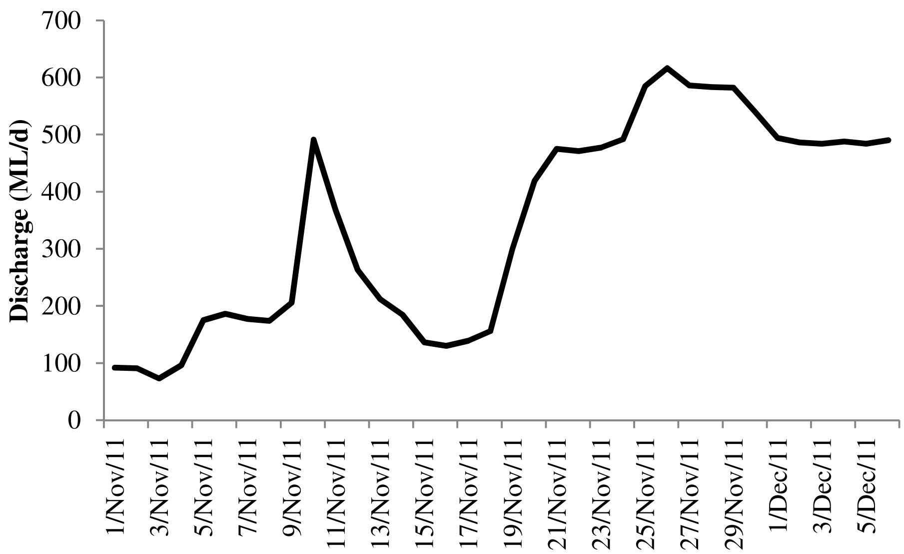

Figure 9. Discharge at Gunbower Weir in November 2011, highlighting the environmental flow pulse in Gunbower Creek. Fishway sampling was from 21-25 November.

3.9 Gunbower fishway trapping, November 2011

A total 27 fish from six species were collected in trapping of the Gunbower Weir fishway over four sampling days during November 2011. Each species was collected at very low abundance relative to abundances observed earlier in March 2011 (Table 5). Both of the silver perch were juveniles and the individual golden perch was a large pre-spawning female.

Table 5. Total numbers of fish collected at Gunbower Weir vertical-slot fishway in 2-paired days (4d total) of trapping in November 2011. Each catch (number of individuals collected) for the 2 separate days of sampling at the fishway entrance and exit is indicated in brackets.

	Exit sample (150 mm head)	**Entrance sample (40 mm head)**	**TOTAL individuals**	**Length range (mm)**
Species				
Carp gudgeons	(0,1)	(0,2)	**3**	36 – 45
Australian smelt	(12,1)	(0,6)	**19**	25 – 58
Carp*	(0,0)	(0,1)	**1**	90
Silver perch	(0,1)	(0,1)	**2**	105-118
Golden perch	(0,0)	(1,0)	**1**	600
Redfin*	(0,0)	(1,0)	**1**	65
Freshwater crustaceans	(5 prawn)	(60 prawn)		
TOTAL	**15**	**12**	**27**	

*=non-native species

3.9 Fish community and abundance below Gunbower Weir, November 2011

In November 2011, boat electrofishing below Gunbower Weir resulted in six carp, one golden perch and two silver perch for a total of 3min 40s electrofishing on-time (Figures 10 & 11). Carp ranged in size from 334- 644 mm (FL). The majority of carp (five individuals) were collected downstream of the upper Gunbower Lagoon outlet regulator, together with the two silver perch (345 and 314 mm long FL), the larger of which was a running ripe female, extruding mature eggs. One golden perch and one carp were collected downstream of Gunbower Weir. The golden perch was 280mm long. There were no small bodied species collected or observed downstream of Gunbower Weir.

Figure 10. A 600 mm long, pre-spawning female golden perch from Gunbower fishway.

Figure 11. Adult silver perch electrofished from below the Upper Gunbower Lagoon regulator in November 2011.

3.10 Fish community and abundance below Thompson's Weir autumn 2011

Boat electrofishing immediately below Thompson's Weir during spring 2011 resulted in 33 fish from five species: three native and two non-native (Table 6). Overall abundance was much lower in November compared to March and non-native Eastern gambusia were not observed. There were twice as many fish surveyed immediately downstream of Thompson's Weir (4.3 fish/minute) compared to 1 km downstream (2.14 fish/minute) (Table 6). A single golden perch was collected at the downstream site (580 mm long) as well as a goldfish. Carp and unspecked hardyhead were collected at similar abundances at Thompson's Weir and 1 km downstream. Australian smelt were twice as abundant at Thompson's Weir compared to one km downstream.

Table 6. Total number of fish species collected downstream of Thompson's Weir by boat electrofishing in November 2011.

Species Position	Abundance	CPUE Fish/minute
Carp		
1km downstream	**4**	**0.8**
Downstream Weir	**3**	**0.6**
Goldfish		
1km downstream	**1**	**0.2**
Golden perch		
Downstream Weir	**1**	**0.2**
Australian smelt		
1km downstream	**3**	**0.6**
Downstream Weir	**16**	**3.2**
Unspecked hardyhead		
1km downstream	**3**	**0.6**
Downstream Weir	**2**	**0.4**

3.11 Cohuna Weir

Boat electrofishing was undertaken immediately downstream of Cohuna Weir on 23/11/2011. A total of 154 fish representing seven species were collected for a total of 7 min and 9s electrofishing on-time, or 21.5 fish/minute. Australian smelt and unspecked hardyhead were the most abundant species (12 and 7.5fish/minute respectively; Table 7). The three golden perch collected were most likely large pre-spawning females, ranging in size from 485- 510 mm long (TL; Figure 12). The three adult silver perch collected ranged in size from 340- 365 mm (FL), with the largest a running-ripe male.

Figure 12. Adult golden perch electrofished from below Cohuna Weir in November 2011.

Table 7. Total numbers of each fish species collected downstream of Cohuna Weir by boat electrofishing during November 2011. Brackets indicate observed fish.

Species	Abundance	CPUE Fish/minute
Carp	5	0.7
Golden perch	3	0.4
Carp gudgeons	2	0.3
Silver perch	3	0.4
Australian smelt	17 (69)	12.0
unspecked hardyhead	40 (14)	7.6
Weatherloach	1	0.1
TOTAL	154	21.5

3.12 National Channel Offtake Regulator

Boat electrofishing was undertaken downstream of National Channel offtake regulator on 24/11/2011. Overall, a total of 63 fish representing four species were collected from a total of 11 minutes 35s electrofishing on-time (Table 8). The 50 Australian smelt recorded were observed at the left hand abutment (looking downstream) of the structure and these were unable to be collected due to high water velocities. The four golden perch ranged in size from 335- 484 mm (TL), the smallest was a running ripe male and the others might have been pre-spawning females. The single silver perch collected was 294 mm long and another was observed.

Table 8. Total numbers of fish collected downstream of National Channel offtake regulator by boat electrofishing in November 2011. Brackets indicate observed fish.

Species	Abundance	CPUE Fish/minute
Carp	7	0.6
Golden perch	4	0.4
Silver perch	1 (1)	0.2
Australian smelt	(50)	4.5
TOTAL	**63**	**5.6**

3.13 Spittle's Weir

Boat electrofishing downstream of Spittles Weir (Taylors Creek) was undertaken on 24/11/2011. A total of 132 fish from four species were collected from 4 mins 3s electrofishing on-time (Table 9). Adult carp ranged in size from 399- 500 mm (FL). The individual golden perch collected was 354 mm (TL) and silver perch 268- 335 mm (FL). There were no small bodied species observed.

Table 9. Total numbers of fish collected downstream of Spittle's Weir by boat electrofishing in November 2011.

Species	Abundance	CPUE Fish/minute
Carp	8	2.0
Golden perch	1	0.2
Goldfish	1	0.2
Silver perch	3	0.7
TOTAL	**13**	**3.2**

4 DISCUSSION

4.1 Gunbower Weir

4.1.1 Fishway efficacy

The small-bodied fish species, including unspecked hardyhead, carp gudgeons and Australian smelt collected in the Gunbower Weir vertical-slot fishway confirms the migratory nature of these species. Small bodied fish species dominated the catch within the fishway during the March 2011 sampling but were in much lower abundance in November 2011. The reduction in numbers probably reflects a seasonal population dynamic (fluctuating seasonal abundance) reported for small bodied fish species in Gunbower Creek by others (Richardson et al. 2005; Rehwinkel and Sharpe 2009)

The ecological objective of the Gunbower Weir fishway was to provide passage of fish greater than 90 mm long. This excludes almost all unspecked hardyhead, Australian smelt, flat headed gudgeons and carp gudgeons, as these species are generally < 90 mm in length (Lintermans 2007). These species were not considered migratory until recently when large numbers were detected attempting to ascend a low slope (1v:32h) vertical-slot fishway on the River Murray at Lock 8 (Stuart et al. 2008).

The presence of small-bodied fish (<90 mm long) at the entrance but with significantly fewer at the exit of the fishway indicates that water velocity and/or turbulence within the fishway was too great for those small bodied species to negotiate. In the Gunbower vertical-slot fishway these factors also prevented the complete ascent of two species of crustaceans (*Paratya* and *Macrobrachium*). Hence, a main recommendation of the present report is for the provision of small fish passage in future fishway designs within Gunbower Creek.

Inclusion of small-bodied fish species as targets for fish passage aligns Gunbower Weir with the passage objectives of other new and or planned fishways for Gunbower Creek (e.g. National Channel offtake Regulator and fishways proposed as part of the Hipwell Road Channel package of works); all of which have an expanded ecological target that includes small fish (25+ mm long). Over the past decade, provision of passage for the whole fish community in fishway design objectives has become national best-practice (Mallen-Cooper 1999; Stuart and Mallen-Cooper 1999).

4.1.2 Improving passage of small-bodied fish

The Gunbower Weir vertical-slot design included installation of a contiguous layer of rocks (0.2 m diameter) on the fishway floor specifically to extend the ecological range of the fishway to crustaceans and for small-bodied and demersal fish species (e.g. flat headed gudgeons). These rocks do not appear to have been installed. Nevertheless, crustaceans were abundant in the entrance of the Gunbower fishway, though they were almost absent at the exit. This observation confirms their inability to ascend this type of fishway in the absence of rocks, which increase roughness to facilitate the passage of demersal taxa (Stuart et al. 2008). Installation of floor rocks as specified in the original SKM (2008) design, including through each vertical-slot, is therefore recommended as a high priority for the Gunbower Weir fishway.

Another possible way to significantly improve the passage of small bodied fish in the Gunbower vertical-slot fishway is the modification of the shape of the vertical-slot baffles (blocking the middle section; see Figure 13) to reduce the turbulence in each pool. Turbulence is a major factor that governs ascent of small fish and reducing turbulence, by reducing the area of the vertical-slot, can improve passage of small-bodied fish by up to an order of magnitude in abundance (Mallen-Cooper at al. 2008).

For the Gunbower Weir vertical-slot fishway, a concept of baffle modifications is shown in Figure 13. Under the proposed modifications each baffle, including at the entrance, would have a middle sill blockout (e.g. 0.35 m high) and the upper slot-width would be reduced to 0.1 m wide (height 0.25 m) with metal plates. Such modifications were effective at a similar fishway at Lock 8 on the lower Murray River for increasing passage of a variety of small bodied fish species (Mallen-Cooper et al. 2008). The advantages of modified baffles and middle sills include:

- Reduced turbulence in the fishway pools (from average of 88 W m^3 to ~30 W m^3);
- Knife-edge flow around the metal plates which enhances the passage of small fish;
- Greatly extend ecological range of the fishway to the abundant small-bodied fish species;

The disadvantages of the modified baffles and middle sills are:

- With narrow slots the attraction discharge at the entrance is less (approximately half) which may slightly reduce the attraction ability of the fishway.
- The 0.3m slot-width at the bottom of the slot is retained but there is a 0.4 m high gap to the middle sill. Therefore, the reduced height gap may inhibit the passage of large Murray cod but evidence from the old submerged orifice fishway at Euston Weir suggests that this is unlikely (Mallen-Cooper and Brand 2007).

To scope the applicability of proposed design options, a fishway specialist/engineer could be consulted to develop concepts for the middle sills and modified baffles in order to extend the ecological range of the fishway.

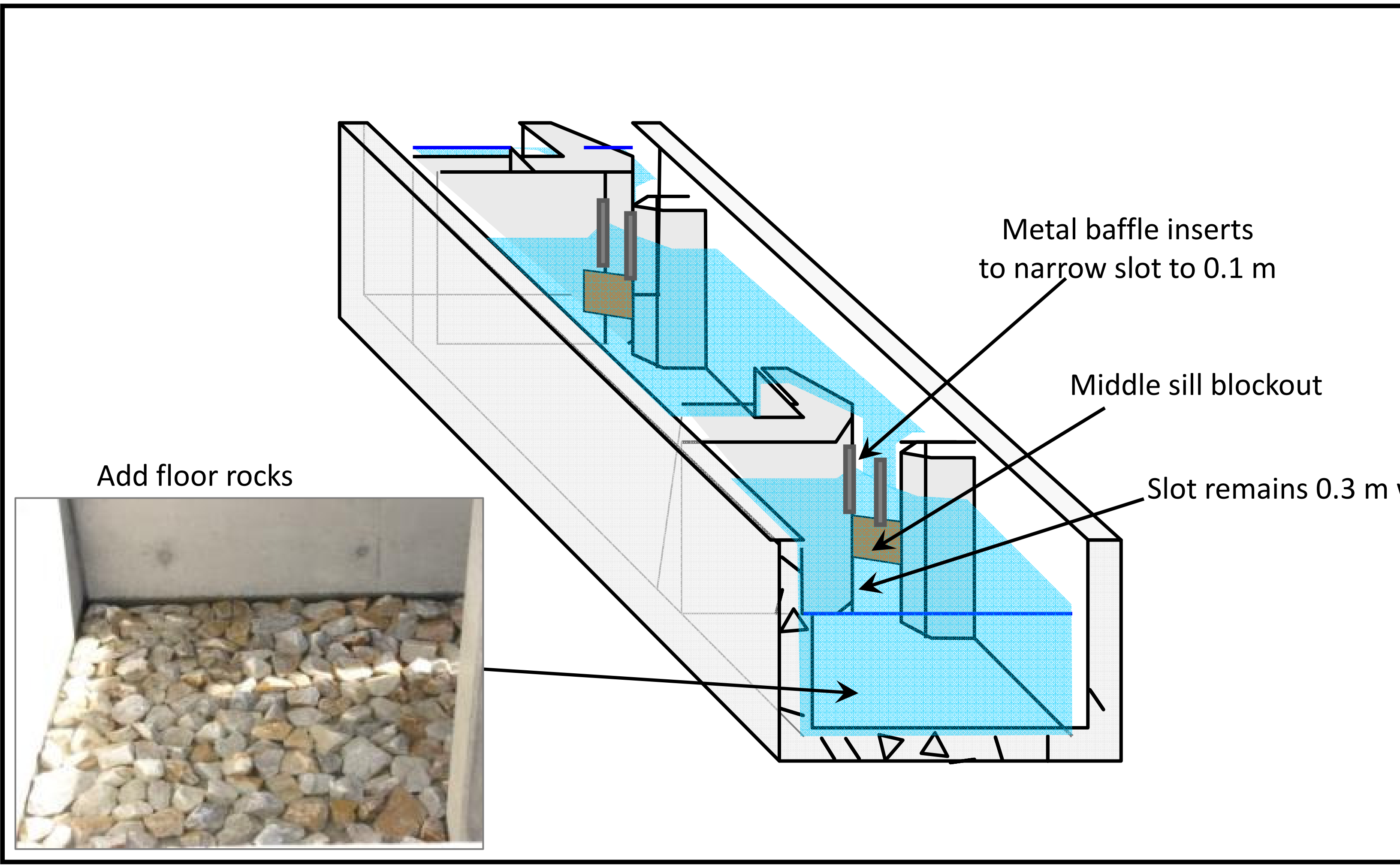

Figure 13. A concept of potential modifications to Gunbower Weir vertical-slot fishway. These include: i) addition of middle sills, ii) narrowing of the top of the slot, and iii) addition of floor rocks. These modifications will reduce pool turbulence and greatly facilitate ascent of the abundant small fish (30+ mm long). Drawing modified with permission from Dr. M. Mallen-Cooper, Fishway Consulting Services.

4.1.3 Entrance attraction at Gunbower Weir fishway

For any fishway, the location and hydraulic conditions of the entrance is crucial to attract fish with minimal delay. The boat electrofishing in the present study collected data which can partly address the major question of what proportion of fish below the weir found the fishway entrance. When Upper Gunbower Lagoon Regulator was open, some fish species, particularly unspecked hardyhead in March 2011 and silver perch in November 2011 were attracted. Hence, these fish were distracted away from the fishway and this may be partly related to flow or the water chemistry of the lagoon discharge water.

The issue of effectively attracting fish to the fishway entrance may best be resolved operationally. One solution is to limit the continuous time the Upper Lagoon Regulator discharges water. For example, regularly turning the Lagoon regulator off for 24 hrs once per week will likely improve fish being able to detect the fishway and complete their migration. This type of operational plan needs to be considered in the context of local operations and water quality objectives for the Upper Lagoon.

Physical habitat is an important life-history criterion for native migratory fish however at Gunbower Weir it appears that all in-stream habitat has been removed. Consideration of replacing a strategic log or snag below the Gunbower Weir would likely provide cover and a holding position for native fish. Available habitat is likely to attract fish to the vicinity of the fishway from which they can complete their migration. We recommend that North Central CMA and G-MW consider an appropriate snag in the deeper scour pool approximately 20-30 m downstream of the vertical-slot fishway.

4.1.4 Entrance hydraulics

The design of the Gunbower Weir fishway included physical modelling of the entrance to optimise attraction of fish. From this modelling two major recommendations were made: i) an offset training wall with the entrance 6 m downstream of the weir and ii) restricting flow through the adjacent gate (Gate 1) to 100 ML/d when total flow exceeds 400 ML/d (Mallen-Cooper 2008). Despite these recommendations, the 100 ML/d maximum discharge criterion (SKM 2008; Mallen-Cooper 2008) through Gate 1 was regularly exceeded (224 ML/d during March 2011 sampling) and very likely reduced trapping rates in the fishway entrance during the present study (Figure 14). It is important that weir operators are aware of the 100 ML/d restriction and that during the spring irrigation season, which coincides with the period that fish migrate most, optimising gate operations and fish attraction to the fishway is particularly important. In November 2011, field observations confirmed that a discharge of approximately 50 ML/d (not 100 ML/d) provided optimal entrance hydraulics for fish passage (Figure 15).

Figure 14. Entrance of Gunbower Weir fishway (31/3/2011) subject to high turbulence from Gate 1 spill flow (209 ML/d).

Figure 15. Optimised attraction with a reduced Gate 1 spill of 50 ML/d (23/4/2011).

4.5 Environmental flow and fish migration

Flow in Gunbower Creek is fully regulated and one of the aims of this project is to describe any differences between fish migration under normal operational flows (March 2011) and a spring environmental flow pulse (November 2011). During the March sampling flow rates in Gunbower Creek gradually increased however there was no apparent increase in capture rates of fish. The reasons why large bodied fish were absent from our March sampling were unclear as adult golden perch were migrating at Torrumbarry fishway at the same time (I. Stuart pers. obs.). In November 2011, large-bodied fish were largely absent from the Gunbower fishway, though they were migrating at Torrumbarry Weir fishway.

The reasons why large-bodied fish were absent became more apparent after the additional boat electrofishing, conducted in November 2011, at the National Channel offtake regulator, Spittle's Weir, Cohuna Weir, Koondrook Weir (Sharpe 2011) in addition to Thompson's and Gunbower weirs. That sampling found very few golden perch and silver perch in Gunbower Creek. The low abundance of these species is also supported by previous electrofishing studies (Rehwinkle and Sharpe 2009; 2010). Hence, the environmental flow was important in clarifying that few large-bodied fish were migrating in Gunbower fishway because of their comparative rarity along the entire Gunbower Creek.

The one exception was Koondrook Weir where end of system flow is uncommon due to any flow passing Koondrook Weir being considered a loss to G-MW under current water accounting rules. However, a minimum passing flow of 100ML/d at Koondrook weir was implemented during the 30 day environmental flow in November/December 2011.

This enabled a major piece of ecological information to be collected. During the passing flow, there was a relatively high accumulation of 1+ juvenile golden perch and silver perch (e.g. 150-200 mm long) below Koondrook Weir (Sharpe 2011). These size classes are highly migratory (Mallen-Cooper 1999) and appeared to be trying to re-colonise Gunbower Creek from the Murray River, where presently they are largely absent (Rehwinkle and Sharpe 2010). Hence, restoring end of system flow and a fishway at Koondrook Weir appear to be major ecological priorities for rehabilitating golden perch and silver perch populations.

Golden perch and silver perch appear to move, spawn and recruit at a landscape scale and are unlikely to form a functioning population until full longitudinal connectivity is restored in Gunbower Creek (Mallen-Cooper et al. 2011). Once a fishway is built at Koondrook Weir, annual spring/summer re-colonisation of juvenile golden perch and silver perch can be expected. Hence, end of system flow pulses in spring and summer can trigger re-colonisation movement and this can be easily monitored in the Koondrook fishway. Consideration of PIT tag readers on the fishways at the downstream (Koondrook Weir) and upstream end (Gunbower Weir) of the system might be cost-effective. Additionally, the rehabilitation of these species might also be demonstrable with the strong historic sampling data set (Rehwinkle and Sharpe 2009; 2010).

4.6 Kow Swamp system

The Kow Swamp system (including Pyramid Creek and Taylors Creek) is anecdotally reported to also have high abundances of golden perch. For example, fish accumulations occurred in late 2010 at Box Creek regulator and in late 2011 at Spittle's regulator (Ross Stanton, G-MW, pers. com.). These fish accumulated on elevated flows but the origin of the fish was unclear. They could be from: (1) Kow Swamp stocking, (2) local natural recruits, (3) larval drift from the Murray River into Kow Swamp, (4) downstream migrating fish from the Murray River en-trapped into the National channel system, (5) from the Loddon/Pyramid system. Further work to understand the ecology of the Kow Swamp system is required.

The authors are also aware of various NVIRP regulator upgrades proposed for the Kow Swamp system. This study and others are gathering further ecological information on the current and potential status of native fish populations in the system. This information should be incorporated into the NVIRP regulator structure upgrades to ensure opportunities to enhance fish passage through the system are not lost.

4.7 Conceptual model of golden perch and silver perch life-history

This study has increased the understanding of movement and recruitment of large bodied native fish within the Gunbower Creek and Kow swamp system. The knowledge can be applied to a conceptual model of golden perch, silver perch and possibly with some application to bony herring and Murray cod. A summary of the key learnings are:

- Adult fish are in low abundance in Gunbower Creek because they cannot complete landscape-scale movements and spawning to close their life-cycle loop.
- During spring/summer when flows rise (irrigation season) adult and sub-adult fish congregate below weirs (i.e. Cohuna Weir) within Gunbower Creek in relatively low abundance or pass through weirs with fishways (e.g. Thompson's and Gunbower).
- Larger numbers of adult and sub-adult golden perch accumulate below weirs associated with Kow Swamp (e.g. Spittles and Box Creek weirs), usually in response to elevated flow. The origin of these fish is unclear and requires further research. Possible sources include Loddon River/Pyramid Creek system, Kow Swamp stocking, or larval recruits drifting downstream from the Murray River and recruiting in Kow Swamp area.
- Relatively large numbers of sub-adult and some adult fish from recruitment in the Murray River congregate below Koondrook Weir when there is end of system flow.
- Following installation of a fishway at Koondrook Weir annual spring/summer re-colonisation of Gunbower Creek by juvenile golden perch and silver perch from the Murray River can be expected.

4.8 Management implications

The priority management implications that can be drawn from the conceptual model for the Gunbower Creek and Kow Swamp is that full longitudinal connectivity through the system is needed if populations of fish species with landscape scale life histories are to be rehabilitated. To achieve longitudinal connectivity fishways are required at the National Channel Offtake regulator, Koondrook Weir and Cohuna Weir (Mallen-Cooper et al. 2011). Restoring end of system flow at Koondrook Weir (including summer flows) to encourage migration of new recruits into the Gunbower system is also a high management priority. Implementing these management recommendations will likely make a significant contribution to rehabilitation of native fish populations within the system.

4.9 Thompson's Weir rock fishway

One measure of the effectiveness of a fishway is the relative density of fish in the creek immediately downstream of a weir compared to further downstream. The accumulation of small-bodied migratory fish (mainly Australian smelt and unspecked hardyhead) below Thompson's Weir is strong evidence that the fishway does not efficiently pass these size-classes. Although evidence suggests that some fish ascend the shallow rock ramp margins, the overall fishway hydraulics exceed fish swimming capacity.

The main reason why fish cannot use the fishway is the removal of most large rocks from the centre of the fishway. The rocks were removed to reduce the cross-sectional area of the stream and reduced the discharge capacity. This altered the design hydraulics and significantly impaired the ecological function of the fishway. For example very high water velocities (up to 4.29 m/s) were recorded within the centre of the fishway. The function of the large rocks was to break up flow, maximise roughness, and provide low velocity/turbulence zones for fish to rest interspersed with short faster flowing drops for fish to ascend (Figure 16). Hence, there is a need for engineering re-design of the fishway and hydraulic review.

4.9.1 Commissioning a new rock fishway

After construction, rock fishways need to be tested and modified because each rock fishway is hydraulically unique, unlike vertical-slot fishways where the internal hydraulics are consistent. Optimising the hydraulics to achieve suitable flows should be conducted by making small adjustments to the rock layout and testing over the design flow range. The commissioning phase is considered part of the rock ramp design process and is necessary to achieve an excellent fishway.

Figure 16. A well-designed lateral ridge rock fishway with large pools and small drops for fish to ascend a weir. These design features could be incorporated into the Thompson's Weir rock fishway. Commissioning the fishway by making small adjustments to the rocks over the design flow range was an important aspect in achieving an excellent fishway.

To restore the ecological functionality of the Thompson's Weir rock fishway, we recommend a hydraulic analysis of the fishway with appropriate conceptual and detailed design input from a fishway biologist. Some conceptual re-design elements have already been recommended by Dr. Martin Mallen-Cooper (Fishway Consulting Services) (see Figure 17) and these provide a strong starting point for rectifying the existing structure. These recommendations and additional ones are summarised below:

- a fish biologist and an engineer are engaged to review the design and performance of the rock ramp fishway;
- large (>1 m) rocks to be installed on the rock ramp margins;
- key smaller (0.2-0.5 m) rocks into the central and medium channel;
- undertake a full hydraulic review of the design to ensure the that the discharge capacity of the weir is maintained. Based on field observations this will likely indicate that the fishway needs to be widened to maintain an appropriate cross-sectional area for creek flow after the installation of large rocks;
- field assessments of the hydraulic/ecological function of the fishway following any further modifications.
- Inclusion of a commissioning phase for the new rock fishway to make small adjustments to the rock layout and achieve optimal hydraulics. This is an important part of the design/construction process for Thomson's Weir fishway.

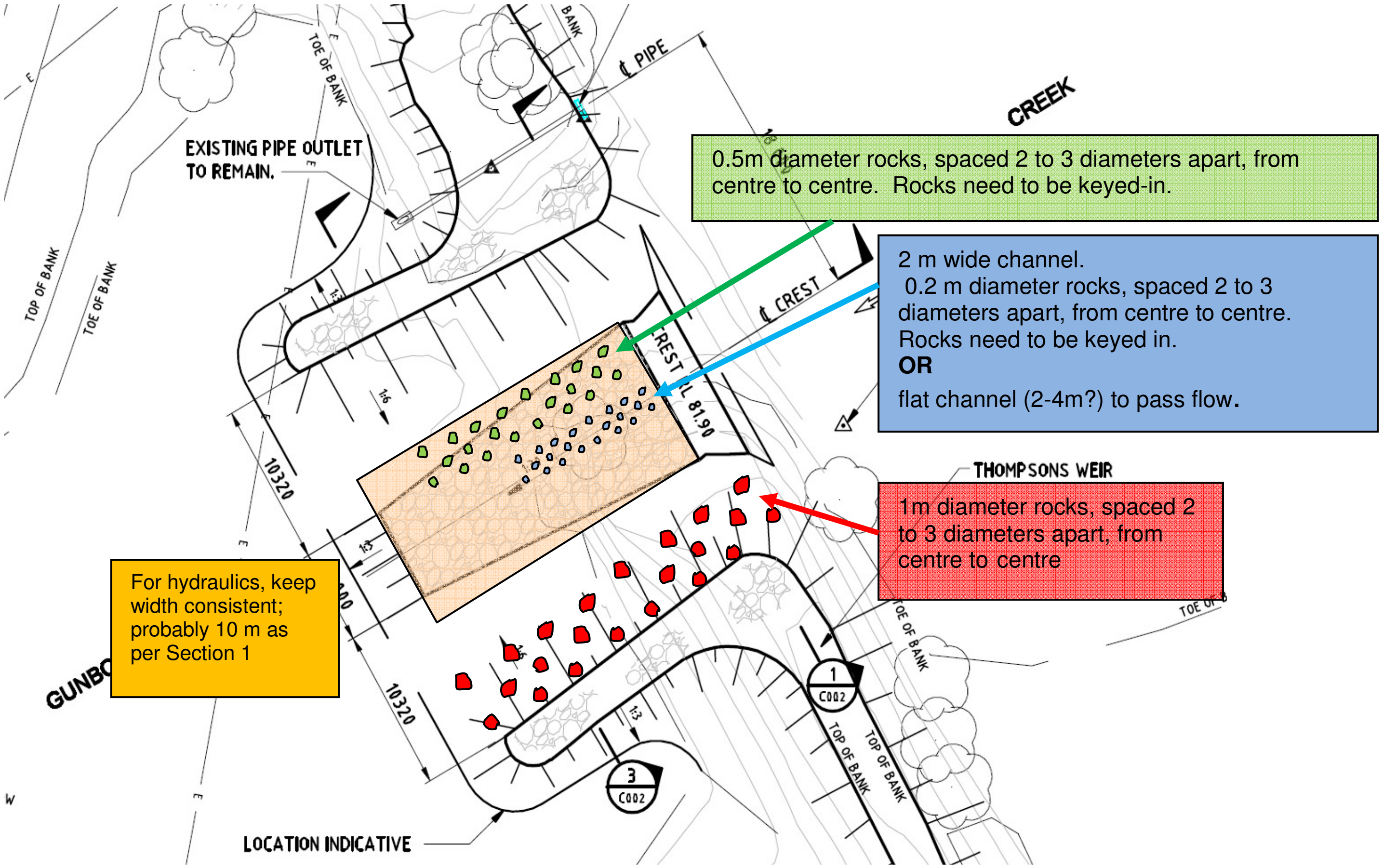

Figure 17. Red-design recommendations for Thompson's Weir rock fishway, provided by Martin Mallen-Cooper (Fishway Consulting Services).

5 CONCLUSION

The Gunbower Weir fishway and Thompson's weir fishways in Gunbower Creek are an essential step in a broader program to restore migratory pathways for native fish through the Gunbower Creek system. Assessment of these two fishways has provided the necessary data to validate the inclusion of small (>25-30 mm long) fish and crustaceans in the design objectives for future fishways. Incorporation of the knowledge gained from this project is vital for new fishways. For Gunbower Weir fishway, several refinement opportunities are identified to optimise its function for small fish. This study has also highlighted the need for clarifying and improving the weir operating protocols. Thompson's Weir rock ramp fishway needs modifications in order to meet the basic functionality requirements for fish passage.

The operational changes at Gunbower Weir fishway and the non-optimal functioning of Thompson's Weir fishway strongly suggests a partnership approach is required to design, construction and operation.

The November 2011 environmental flow was important to clarify that it is re-colonisation of fish from below Koondrook Weir that will help restore golden perch and silver perch populations. Hence, fishways at Koondrook and Cohuna weirs are ecological priorities, along with restoration of end of system flow. For new fishways involving operators, designers, fish experts and North Central CMA will maximise the development of effective fishways and restoration of migratory fish populations.

6 RECOMMENDATIONS

Gunbower Weir

1. Consider optimising the function of the Gunbower weir vertical-slot fishway for small fish by constructing (i) middle sills, (ii) modified slots and (iii) floor rocks within the fishway.
2. Clarify Gunbower Weir operational protocols with G-MW to optimise fish attraction, adopt a maximum 50 ML/d protocol for Gate 1 (adjacent gate to fishway entrance).
3. Draft and assess new operational protocols for Upper Gunbower Lagoon flow releases to (e.g. UGL regulator turned off for 24h per week) to improve fish attraction to the Gunbower fishway.
4. Consider a small-scale strategic habitat restoration below Gunbower Weir to provide cover for migrating native fish.

Thompson's Weir

1. Rectify Thompson's Weir rock fishway to meet basic functionality and ensure a partnership approach with engineers, fish scientists, operators and North Central CMA.
2. Include a commissioning phase to adjust the rocks within the new fishway to achieve optimal hydraulics over the design flow range.
3. Assessment of the biological and hydraulic function of any new rock fishway at Thompson's Weir.

Gunbower Creek

1. Align fish passage objectives for all fishways on Gunbower Creek for small and large fish (from 30-1000 mm long) and crustaceans.
2. Restore full landscape connectivity with fishways at Koondrook and Cohuna weirs and National Channel offtake regulator.
   Continue to release environmental flows. Recommended components of the hydrograph character include: (i) restore regular end of system flow at Koondrook Weir, (ii) spring/summer pulsing and small daily variations (i.e. 0.15 m) to stimulate movement and re-colonisation of Gunbower Creek by juvenile golden perch and silver perch from the Murray River, through Koondrook fishway (when built).

Kow Swamp

4. North Central CMA to liaise with NVIRP to ensure any opportunities to enhance fish passage at upgraded regulators on the Kow Swamp/Taylors Creek/Pyramid system are capitalised upon and new ecological knowledge is incorporated into NVIRP structures.

7 ACKNOWLEDGMENTS

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