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Lower Goulburn Fish Communities Project 2009 Annual Report

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Arthur Rylah Institute for Environmental Research

Client Report

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Front cover photo: Goulburn River at Cable Hole.

All photos by Wayne Koster/David Dawson

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Acknowledgements

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Summary

This report documents the findings of a study of fish populations in the lower Goulburn River, to provide information on (1) species distribution, abundance and population structure using boat electrofishing surveys, (2) spawning of key native species, Murray Cod (*Maccullochella peelii peelii*), Trout Cod (*Maccullochella macquariensis*), Golden Perch (*Macquaria ambigua*), and Silver Perch (*Bidyanus bidyanus*) using drift net surveys, and (3) Golden Perch movement dynamics and links to spawning and recruitment patterns in the lower Goulburn River using acoustic telemetry. The study was funded by the Goulburn–Broken Catchment Management Authority (2006–2009) and the Victorian Recreational Fishing Licence Fund (2003–2006).

Major findings of the study were:

- The lower Goulburn River has a diverse native fish population, which includes several species of recreational angling value and/or conservation significance (e.g. Murray Cod, Trout Cod, Silver Perch, Golden Perch, and Freshwater Catfish (*Tandanus tandanus*).
- Murray Cod are the most abundant large-bodied native species in the lower Goulburn River, but few fish exceed the minimum legal size. The minimum legal size for Murray Cod was recently increased from 500 to 600 mm. The data collected in this study suggest that there has been a slight increase in the number of fish collected in this size range in the lower Goulburn River the last year, although further sampling is needed to confirm this trend.
- Murray Cod spawn regularly in the lower Goulburn River. Larvae were collected in every year of the study (2003–2009) under a range of flow conditions, including low flows. This finding is similar to the results of previous studies, which suggests that Murray Cod can spawn irrespective of flow conditions.
- Trout Cod were collected occasionally in low numbers in the electrofishing surveys. Of particular significance was the collection of Trout Cod larvae in several years, which suggests that the lower Goulburn River supports a breeding population of this threatened species. As with Murray Cod, Trout Cod larvae were collected under a range of flow conditions, including low flows.
- Trout Cod were not found in the electrofishing or drift net surveys for several years following the fish kill in the lower Goulburn River below Nagambie in January 2004. However, it appears that the population has re-established in recent years, as several individuals were collected in the 2008 electrofishing surveys and larvae were collected in the 2007–08 and 2008–09 drift sampling.
- A single Freshwater Catfish larva was collected in the 2007–08 drift net surveys and a juvenile catfish was collected in the autumn 2008 electrofishing surveys. These individuals may have originated from upstream lakes (e.g. Lake Nagambie), but it is also possible that a breeding population of this threatened species exists in the lower Goulburn River.
- Spawning by Golden Perch is extremely limited in the lower Goulburn River, with only four Golden Perch larvae collected in the lower Goulburn River in the study. This result might be related to flow conditions in the lower Goulburn River. Increased flows are thought to initiate spawning by this species, but such flow events were either absent, or only of limited duration/magnitude, during the spawning period in each year of the study. Sampling over periods with high flow events would be needed to test whether increased flow events stimulate spawning of Golden Perch in the lower Goulburn River. This

information will provide evidence to support the implementation of recommended environmental flows for Golden Perch spawning in the lower Goulburn River.

- The lack of Golden Perch spawning could also indicate that the lower Goulburn River is naturally not an important spawning ground for the species. Previous studies have suggested that Golden Perch might move to specific areas to spawn and that increased flows initiate movement. The results of the telemetry study showed that Golden Perch moved from the Goulburn River into the Murray River at various times, but movements were most concentrated in the spawning period in late 2007 – early 2008 and coincided with increased flows in the lower Goulburn River (e.g. from about 300 to 3500 ML/day). An important step now is to test whether similar flow events are again associated with Golden Perch movement, to strengthen the suspected link between movement, flow and spawning.
- A number of exotic fish species occur in the lower Goulburn River — Carp (*Cyprinus carpio*), Redfin (*Perca fluviatilis*), goldfish (*Carassius auratus*), Oriental Weatherloach (*Misgurnus anguillicaudatus*), and Eastern Gambusia (*Gambusia holbrooki*).
- Carp are the most abundant large-bodied fish in the lower Goulburn River. There was only limited evidence of spawning by Carp in the lower Goulburn River in the study, although the drift net surveys may not be effective for collecting the early life stages of carp. In contrast, large numbers of young-of-year Carp were collected occasionally in the electrofishing surveys. Recent research suggests that a large proportion of young-of-year Carp in the lower Goulburn River may originate from areas outside of the Goulburn River.
- Redfin, once common in the lower Goulburn River, were collected only in low numbers in this study. The abundance of Redfin has, however, been higher in the last few years compared to the first few years of the study. The recent increase in numbers of Redfin may indicate that the species is re-emerging in the lower Goulburn River, but further sampling is needed to confirm this.
- Oriental Weatherloach was collected in the last few years of this study in the mid to lower reaches of the lower Goulburn River. This species is also abundant in the Murray River around Barmah and is rapidly expanding its range. Prior to this study, there were no documented records of this species in the lower Goulburn River. It is possible that this species is more widespread than the surveys indicate, as it is a bottom-dweller and therefore generally difficult to see and capture in the lower Goulburn River.

1 Introduction

In 2003 the Goulburn Valley Association of Angling Clubs commissioned the Arthur Rylah Institute for Environmental Research to examine the status of native fish communities in the lower Goulburn River. The project, funded from 2003 to 2006 under the Victorian Recreational Fishing Licence Fund, included boat electrofishing surveys to provide information on the distribution, abundance and population structure of recreational fish species and the status of threatened fish species and pest fish species, and drift net surveys to detect spawning of key native species, Murray Cod (*Maccullochella peelii peelii*), Trout Cod (*Maccullochella macquariensis*), Golden Perch (*Macquaria ambigua*) and Silver Perch (*Bidyanus bidyanus*). Major findings of the study included a lack of spawning and recruitment of Golden Perch, low numbers of large Murray Cod (i.e. > 500 mm in length), and the collection of small numbers of the nationally threatened Trout Cod (Koster et al. 2004, 2005, 2006, King et al. 2005, Crook and Koster 2006).

In 2006 funding to continue the project was provided by the Goulburn–Broken Catchment Management Authority (GBMCA) and has continued through to 2009. In addition to the electrofishing and drift surveys, GBCMA provided funding over this period for a project to investigate the movements of Golden Perch in the lower Goulburn and mid-Murray rivers using acoustic telemetry. The telemetry study aims to provide an understanding of Golden Perch movement dynamics and links to spawning and recruitment patterns in the lower Goulburn River. This report documents the results of the surveys and telemetry study conducted from 2006 to 2009. Data from the 2003–2006 surveys is also presented for comparison. The results of the telemetry study should be considered preliminary only at this stage, as the transmitters in many of the tagged fish will continue to transmit for the next few years.

2 Methods

2.1 Electrofishing

A total of six sites were selected for sampling on the lower Goulburn River (Table 1, Figure 1). Surveys of the fish assemblages were conducted at each site using a Smith–Root model 5 GPP boat-mounted electrofishing unit (Figure 2). Electrofishing was conducted in all habitats within the river channel. At each site the total time during which electrical current was applied to the water was recorded to determine catch per unit effort (number of fish per electrofishing hour). All fish collected were identified, counted and measured for length (caudal fork or total length). The weight of large-bodied species was also recorded. Sampling was conducted during spring and autumn in each year since spring 2003 at five of the six sites. The sixth site (Kotupna) was added to the program in spring 2006.

2.2 Drift sampling

Samples of fish eggs and larvae were collected at three of the lower Goulburn River sites using a single drift net at each site (Table 1, Figure 1). Samples were also collected from one site on the Murray River for comparison with the Goulburn River. A more comprehensive investigation of fish spawning in the mid-Murray River region has been undertaken as part of a separate study (King et al. 2008). The drift nets consisted of 500 µm mesh, were 500 mm in diameter and had flow meters fitted to the mouth of the net to measure the volume of water filtered (Figure 3). The nets were set in late afternoon and retrieved the following morning. The nets were attached to snags in areas with relatively high flow velocity. Sampling was conducted approximately fortnightly between September and February. The drift samples collected were briefly inspected in the field to obtain eggs so that these could be taken to the laboratory for hatching to assist identifications. The remaining samples of drifting eggs and larvae and associated debris were collected and preserved in ethanol and taken to the laboratory for sorting. Fish were removed from the samples by sorting through the debris under a dissecting microscope, and identified using an authoritative identification guide (Serafini and Humphries 2004).

Table 1. Location details for sites sampled on the Goulburn and Murray rivers.

River	Site Code	Location	Latitude	Longitude	Sampling technique
Goulburn	CH	Cable Hole	–36.69	145.23	Boat EF, Drift net
Goulburn	CB	Cemetery Bend	–36.51	145.33	Boat EF
Goulburn	PR	Pyke Road	–36.45	145.36	Boat EF, Drift net
Goulburn	CA	Shepparton	–36.38	145.40	Boat EF
Goulburn	KO	Kotupna	–36.16	145.20	Boat EF
Goulburn	YA	Yambuna	–36.13	145.01	Boat EF, Drift net
Murray	EC	Echuca	–36.10	144.82	Drift net

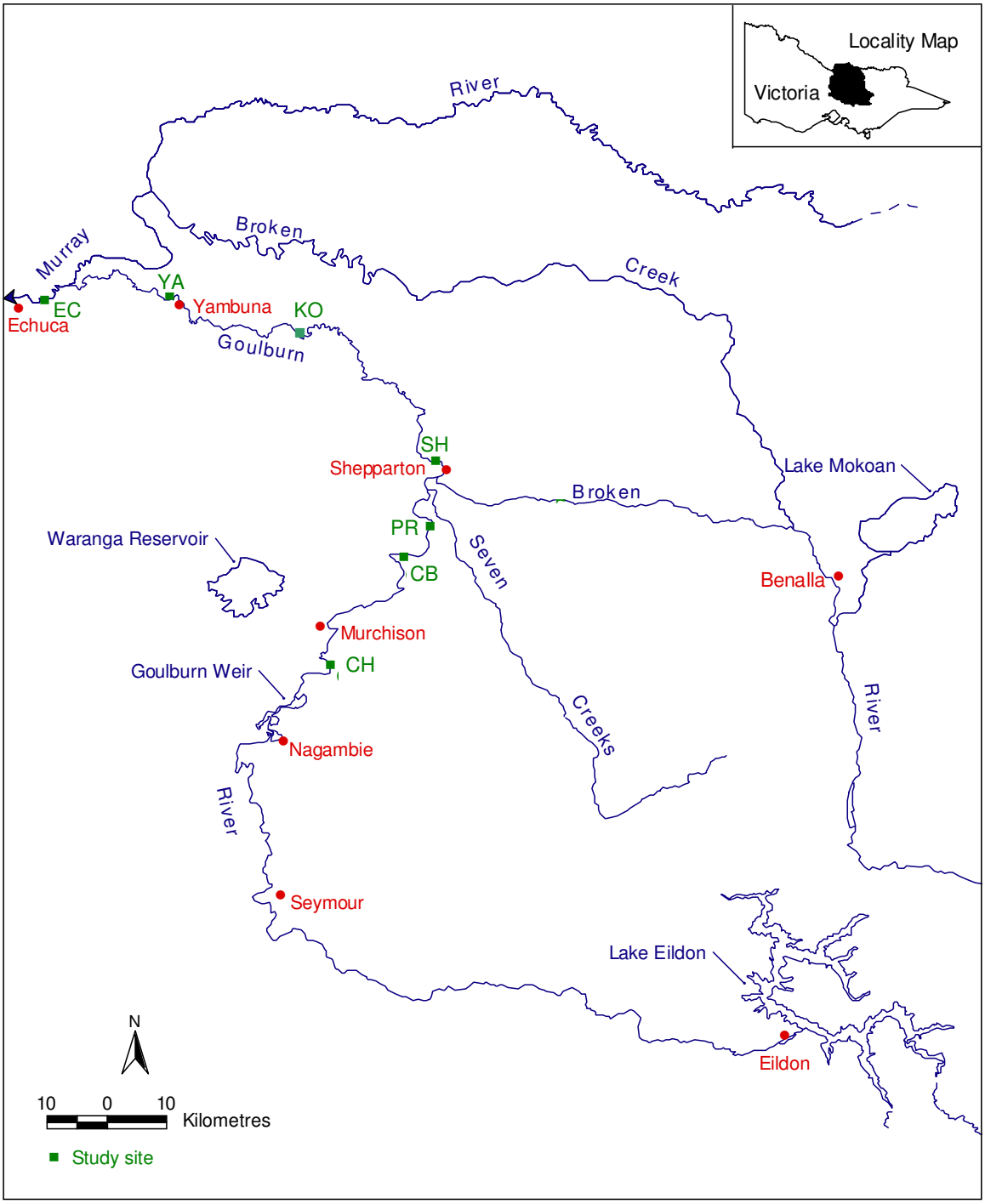

Figure 1. Study area, showing locations of survey sites (green squares). Site name abbreviations shown in Table 1.

Figure 2. Boat-electrofishing on the lower Goulburn River.

Figure 3. Setting drift net on the lower Goulburn River.

Figure 4. The Goulburn River at Cable Hole.

Figure 5. The Goulburn River at Cemetery Bend.

Figure 6. The Goulburn River at Pyke Road.

Figure 7. The Goulburn River at Shepparton.

Figure 8. The Goulburn River at Kotupna.

Figure 9. The Goulburn River at Yambuna.

2.3 Acoustic tracking of Golden Perch

Golden Perch (mean TL 422 ± 73 mm SD, mean weight 1457 ± 707 g SD) were collected in the lower Goulburn and mid-Murray rivers by boat electrofishing in April 2007, 2008 and 2009. Thirty Golden Perch were tagged in the lower Goulburn (n = 15) and mid-Murray (n = 15) rivers in April 2007. A further 30 Golden Perch were tagged in April 2008 (Goulburn n = 16, Murray n = 14) and 27 Golden Perch were tagged in April 2009 (Goulburn: n = 14, Murray: n = 13). Acoustic transmitters with a battery life of about 610–880 days, depending on the year of manufacture (Vemco model V13–1L, dimensions 36 × 13 mm, weight 11 g in air) were implanted into the body cavity of the fish through an incision of approximately 15 mm, adjacent to the pectoral fin and anterior to the anal vent. The transmitter weight compared to the fish body weight was approximately 2% or less. Each fish was released near its point of capture immediately after recovery from the transmitter implantation procedure (Figure 10).

Fourteen listening stations (acoustic receivers, Vemco model VR2W) were deployed in the lower Goulburn (n = 6) and mid-Murray (n = 8) rivers (Figure 11). The listening stations were deployed using a length of chain and plastic-coated stainless steel cable with logs as anchor points (Figure 12). Data was downloaded from the listening stations using wireless communication technology and a laptop computer approximately every three months throughout the study. At the time of writing, the most recent download was April 2009. As there is only limited data currently available for the fish tagged in April 2009, data from these fish has not been presented in this report. Assessment of the movements of these fish will be conducted and made available once sufficient data has been collected. The transmitters implanted in these fish and the fish tagged in 2008 will continue to transmit for approximately the next two years and one year, respectively.

Figure 10. Releasing a Golden Perch following tagging.

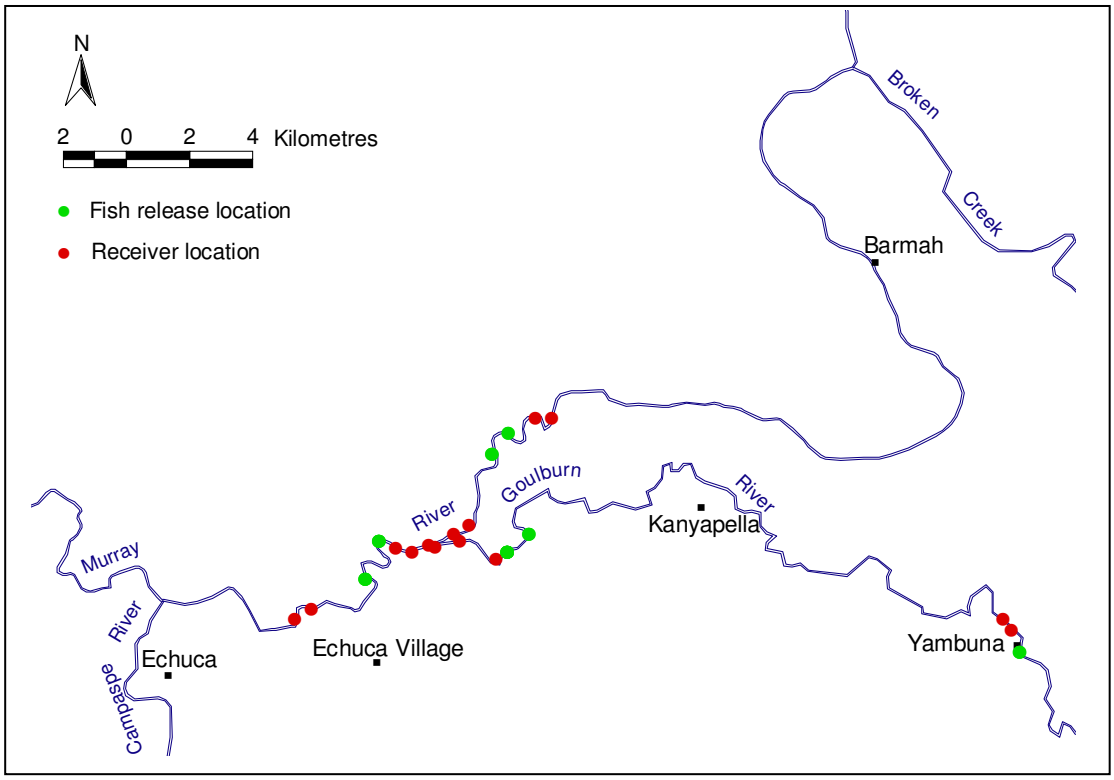

Figure 11. Study area showing listening station and fish release locations.

Figure 12. Listening station being deployed in the Murray River.

3 Results

3.1 Electrofishing

3.1.1 Species diversity and abundance

Over 4000 individuals representing twelve native and five exotic species were collected from the lower Goulburn River between 2003 and 2009 (Table 2). Australian Smelt (*Retropinna semoni*) (Figure 13) was the most abundant species, comprising about 38% of the total abundance for all species. Murray River Rainbowfish (*Melanotaenia fluviatilis*) was the next most abundant species, comprising about 34% of the total abundance, followed by the exotic Carp (*Cyprinus carpio*), which comprised about 11% of the total abundance. A number of species of conservation significance were collected, including Murray Cod (Figure 14), Silver Perch (Figure 15), Trout Cod and Freshwater Catfish (*Tandanus tandanus*), comprising about 6%, 0.3%, 0.2% and 0.1% of the total abundance, respectively.

Table 2. Numbers of individual fish species collected from each site in the Goulburn River in electrofishing surveys from 2003-2009.

Species	CAH	CEB	PYR	SHE	KOT	YAM	TOTAL
Native							
Australian Smelt *Retropinna semoni*	984	268	201	73	42	45	1613
Murray River Rainbowfish *Melanotaenia fluviatilis*	90	343	341	565	111	17	1467
Murray Cod *Maccullochella peelii peelii*	14	68	79	37	39	32	269
Flat-headed Gudgeon *Philypnodon grandiceps*	133	11	8	1	1		154
Golden Perch *Macquaria ambigua*	26	33	33	20	20	14	146
Carp Gudgeon *Hypseleotris klunzingeri*	1	2	13	13	12	14	55
Silver Perch *Bidyanus bidyanus*	2	3	5	2	1	1	14
River Blackfish *Gadopsis marmoratus*	12						12
Trout Cod *Maccullochella macquariensis*	2	3	3				8
Unspecked Hardyhead *Craterocephalus fulvus*					1	1	2
Freshwater Catfish *Tandanus tandanus*	1						1
Bony Herring *Nematalosa erebi*						1	1
Exotic							
Carp *Cyprinus carpio*	61	67	54	43	34	209	468
Goldfish *Carassius auratus*		2	2	2	1	35	42
Redfin *Perca fluviatilis*	5	3	1				9
Eastern Gambusia *Gambusia holbrooki*	4			1		3	8
Oriental Weatherloach *Misgurnus anguillicaudatus*			1		1	1	3
TOTAL	1335	803	741	757	263	373	4272

CAH = Cable Hole, CEB = Cemetery Bend, PYR = Pyke Road, SHE = Shepparton, KOT = Kotupna, YAM = Yambuna

Figure 13. The most abundant species collected, Australian smelt.

Figure 14. A large Murray Cod being released following capture by electrofishing.

Figure 15. A Silver Perch collected by electrofishing.

3.1.2 Spatial and temporal variation in fish assemblages

The fish assemblages in the lower Goulburn River varied both spatially and temporally (Table 3, Figures 16–19). The most upstream site, Cable Hole, was characterised by large numbers of Australian Smelt. Cable Hole was also the only site where River Blackfish (*Gadopsis marmoratus*) and Freshwater Catfish were collected, and one of only three sites were the nationally threatened Trout Cod was collected. At the two next downstream sites, Cemetery Bend and Pyke Road, the fish assemblages were similar to each other, being dominated by Australian Smelt and Murray River Rainbowfish and to a lesser extent Murray Cod. Trout Cod was also collected at these sites.

The next downstream site, Shepparton, was characterised by large numbers of Murray River Rainbowfish. The fish assemblage at the next downstream site, Kotupna, was generally similar to Cemetery Bend and Pyke Road, although abundances of Australian Smelt and Murray River Rainbowfish were lower at Kotupna. The most downstream site, Yambuna, was characterised by large numbers of the exotic Carp and Goldfish (*Carassius auratus*). Yambuna was also one of only three sites where the exotic Oriental Weatherloach (*Misgurnus anguillicaudatus*) was collected.

The last three to four years have been characterised by generally higher abundances of Flat-headed Gudgeon (*Philypnodon grandiceps*), Carp Gudgeon (*Hypseleotris klunzingeri*), Silver Perch and Goldfish. Several species have also been recorded in the last few years but were not recorded in the first few years of the study, e.g. Freshwater Catfish, Unspecked Hardyhead (*Craterocephalus fulvus*), and Bony Herring (*Nematalosa erebi*).

3.1.3 Size structure

Length frequency histograms are presented for the large-bodied native species that were collected in relatively high numbers. For Murray Cod, the population in the lower Goulburn River includes few fish above the minimum legal size of 600 mm (Figure 20). Young-of-year fish (YOY) were collected in most years, but were most abundant in autumn 2004, 2005 and 2007. The collection of YOY fish may indicate natural recruitment into the population, but could also be a result of fish stocked into the river. In contrast to Murray Cod, the Golden Perch population in the lower Goulburn River consists of larger, older fish, with few individuals below the minimum legal size of 300 mm (Figure 21). There has been a slight increase, however, in the number of smaller fish (e.g. 200–250 mm in length) collected in recent years. Only a single YOY Golden Perch was collected in the study, at Pyke Road in autumn 2007. Whether these smaller fish are natural recruits or stocked is unknown. The population of Carp in the lower Goulburn River consists of predominantly large fish (e.g. 400–600 mm in length), although YOY fish occasionally comprised a large proportion of the population (e.g. autumn 2006, 2008 and 2009) (Figure 22).

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Table 3. Numbers of individual fish species collected from the Goulburn River in each season in electrofishing surveys from 2003-2009.

Species	Spring 03	Autumn 04	Spring 04	Autumn 05	Spring 05	Autumn 06	Spring 06	Autumn 07	Spring 07	Autumn 08	Spring 08	Autumn 09	TOTAL
Native													
Australian Smelt	42	140	110	65	92	349	104	118	82	175	206	130	1613
Murray River Rainbowfish	59	110	31	87	11	177	23	280	50	180	109	350	1467
Murray Cod	18	36	22	29	16	6	22	26	14	28	21	31	269
Flat-Headed Gudgeon	5	3	1	3	2	26	7	25	6	16	19	41	154
Golden Perch	18	13	8	9	11	14	13	14	7	14	11	14	146
Carp Gudgeon	2	7		1		2	4	8	4	6	10	11	55
Silver Perch								3	2	4	2	3	14
River Blackfish	7				1			2		2			12
Trout Cod	3									4	1		8
Unspecked Hardyhead										2			2
Freshwater Catfish										1			1
Bony Herring												1	1
Exotic													
Carp	46	40	28	34	38	63	52	30	26	29	27	55	468
Goldfish	2		3			1	5	9	7	1	1	13	42
Redfin				1				1		6	1		9
Eastern Gambusia						5		3					8
Oriental weatherloach								2		1			3
TOTAL	202	349	203	229	171	643	230	521	198	469	408	649	4272

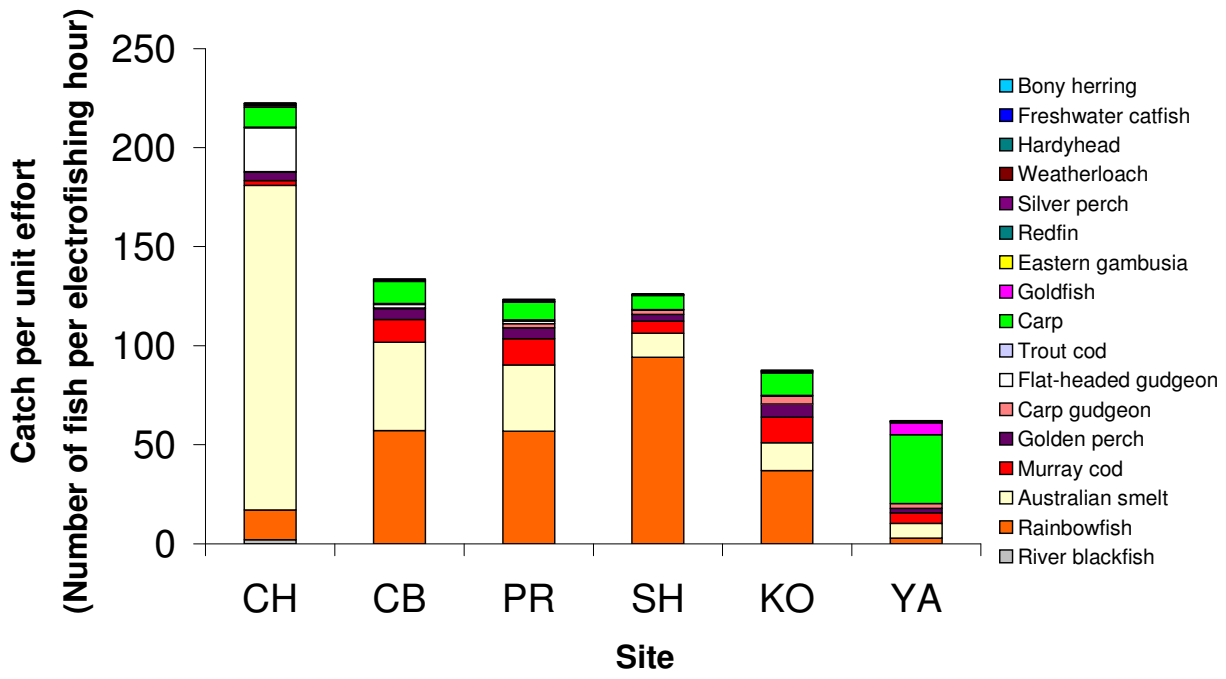

Figure 16. Abundance of all species collected from the lower Goulburn River at each site by electrofishing from 2003-2009.

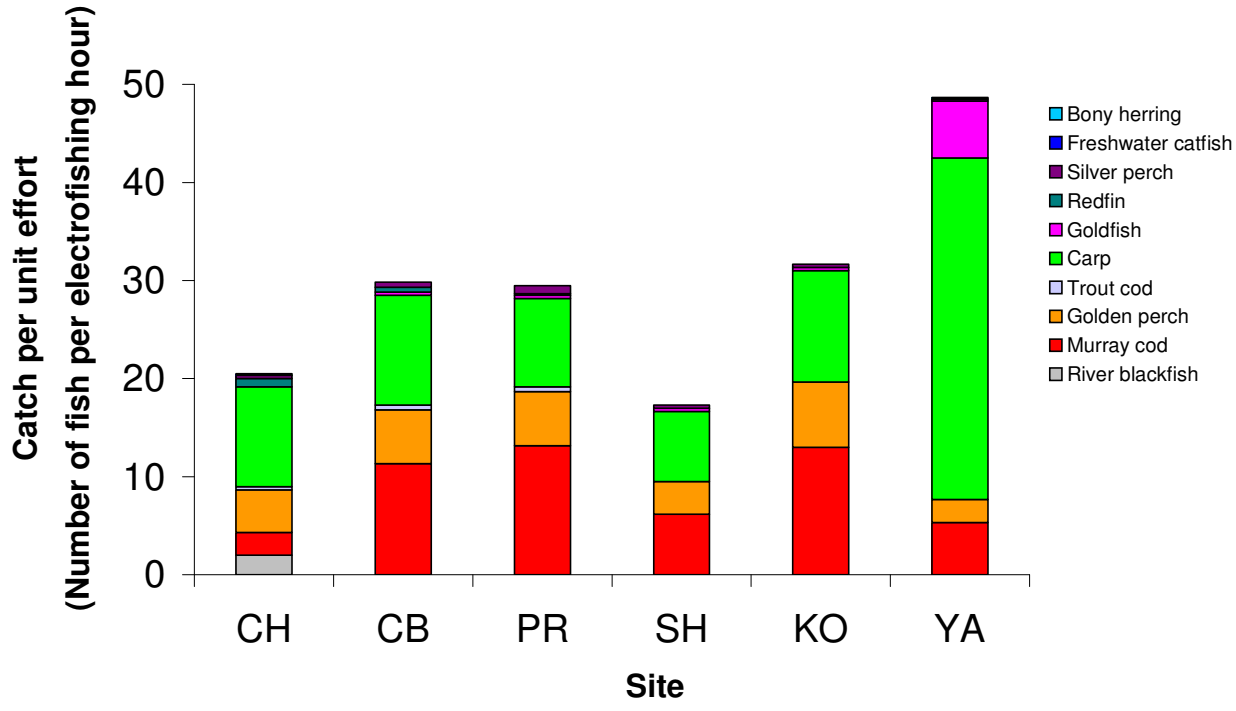

Figure 17. Abundance of large-bodied species collected from the lower Goulburn River at each site by electrofishing from 2003-2009.

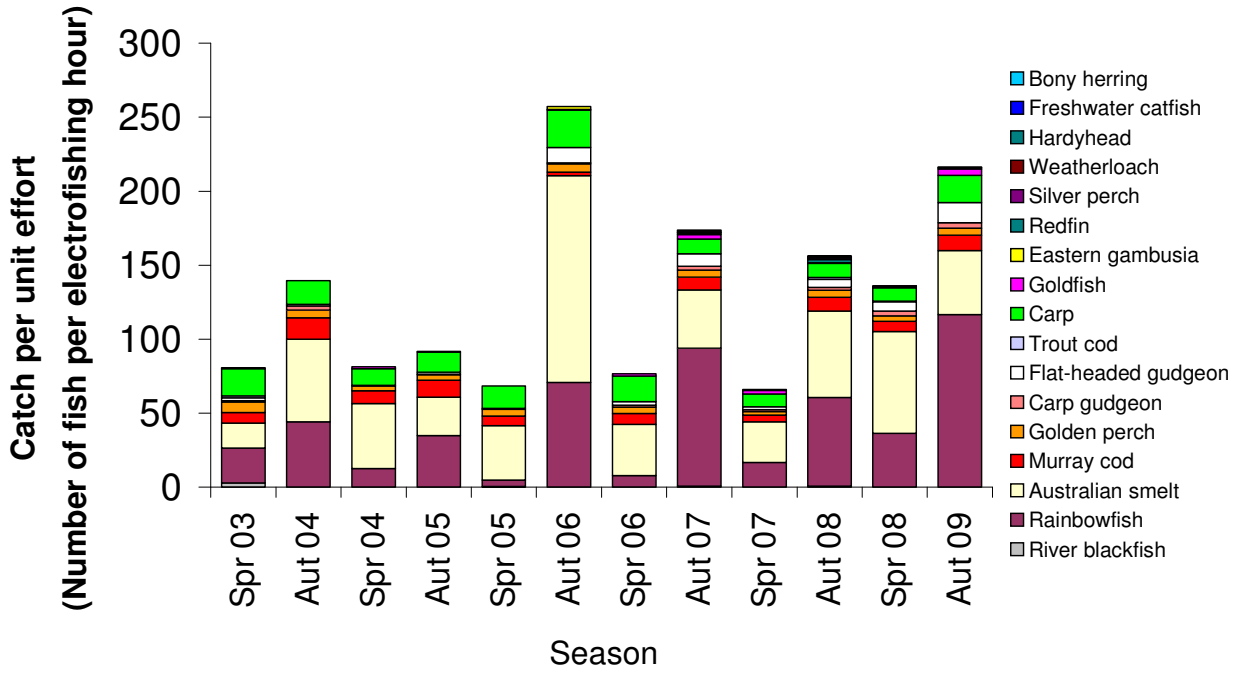

Figure 18. Abundance of all species collected from the lower Goulburn River in each season by electrofishing from 2003-2009.

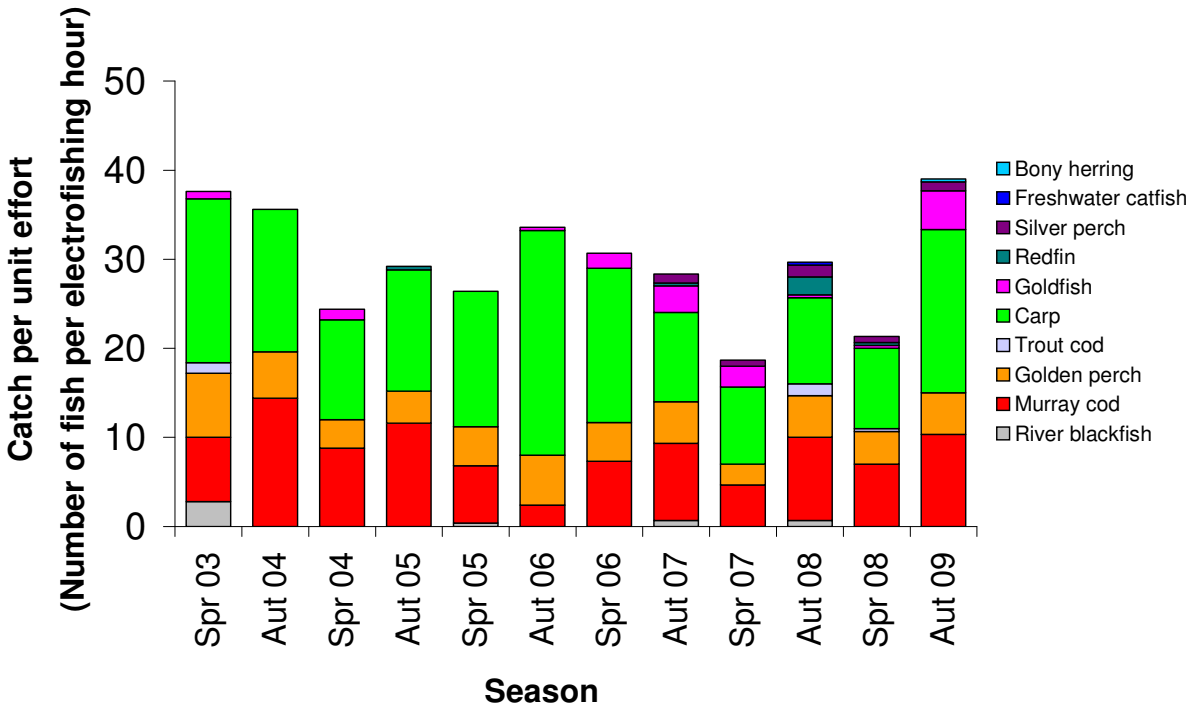

Figure 19. Abundance of large-bodied species collected from the lower Goulburn River in each season by electrofishing from 2003.

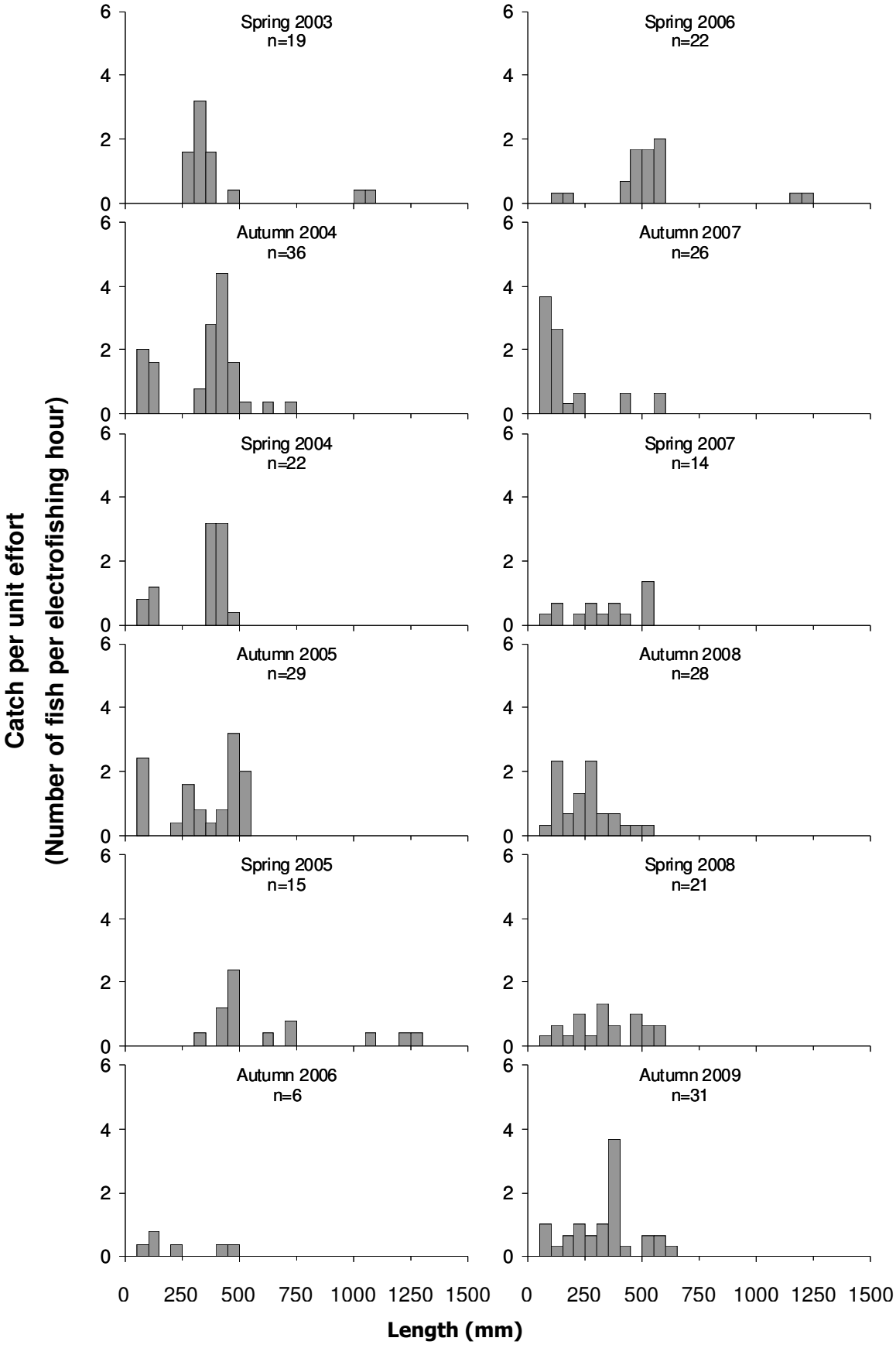

Figure 20. Length frequency of Murray Cod in the Goulburn River.

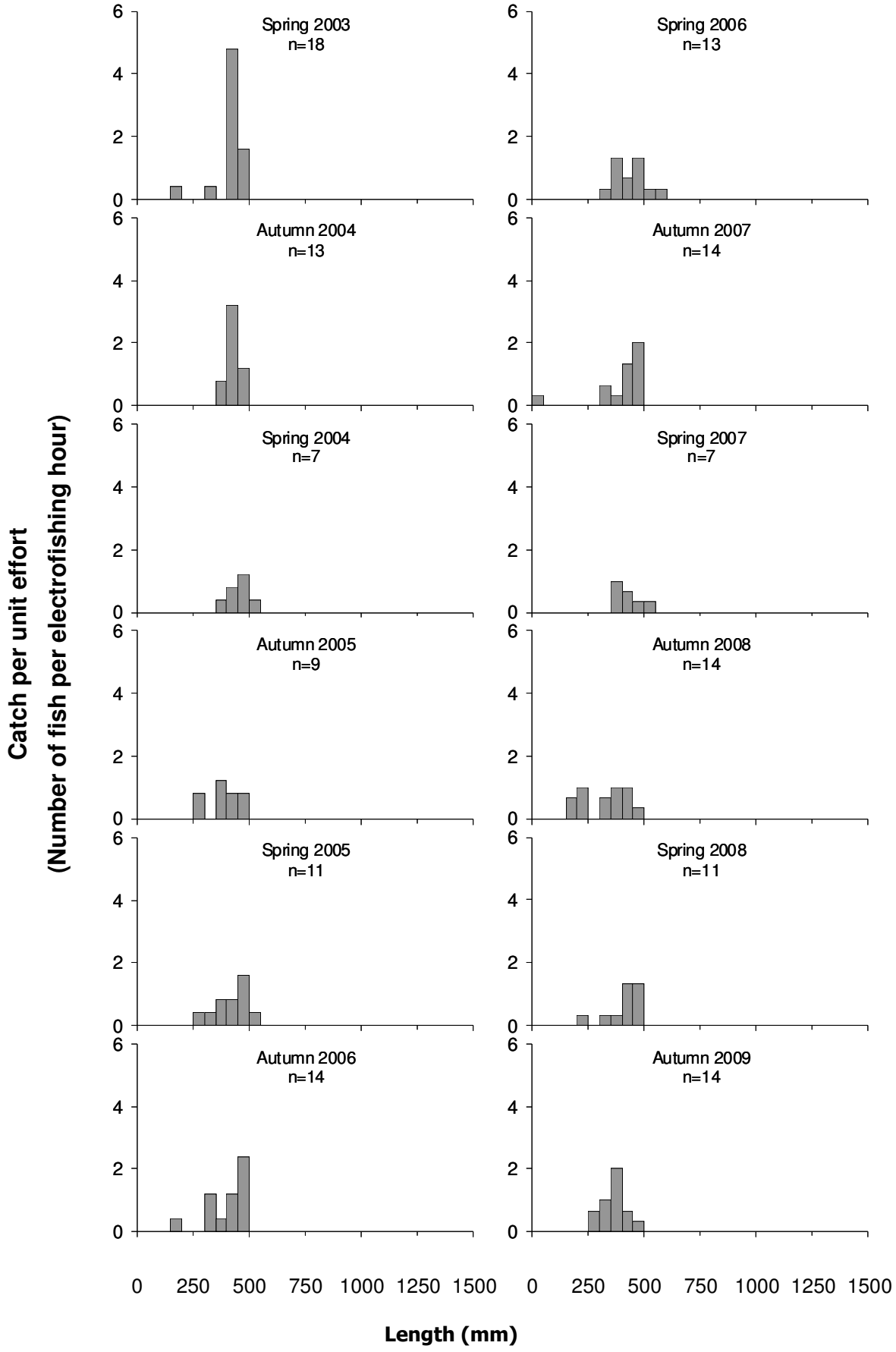

Figure 21. Length frequency of Golden Perch in the Goulburn River.

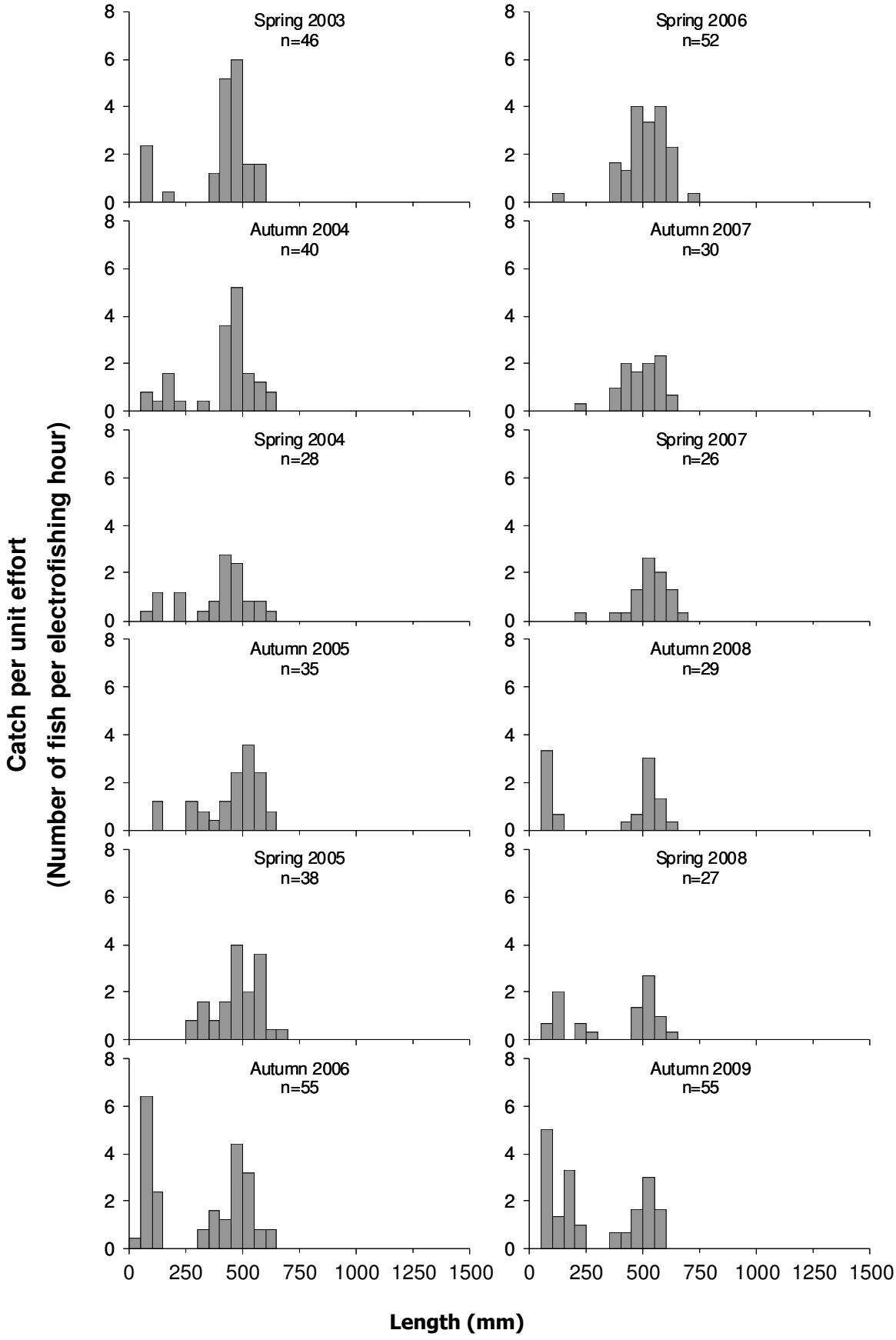

Figure 22. Length frequency of carp in the Goulburn River.

3.2 Drift sampling

3.2.1 Goulburn River

Over 12 000 individuals representing eight native and two exotic species were collected in drift sampling from the Goulburn River between 2003–04 and 2008–09 (Table 4). Flat-headed Gudgeon was the most abundant species, comprising about 90% of the total abundance for all species. Murray Cod (Figure 23) and Australian Smelt were the next most abundant species, each comprising about 3% of the total abundance.

Murray Cod larvae were collected in all years, but densities were higher in 2007–08 and 2008–09 compared to other years (Table 4, Figure 24). Murray Cod larvae were generally collected in the lower Goulburn River from around mid November to mid December (Figure 18). In most years the flow in the lower Goulburn River around this time was relatively low and stable, while water temperatures were around 20–24°C (Figure 24).

Figure 23. A Murray Cod collected in drift surveys in the Goulburn River.

Trout Cod larvae were only occasionally collected (i.e. 2003–04, 2007–08, 2008–09) in the lower Goulburn River, but like Murray Cod their densities were highest in 2007–08 (Figure 25). Trout Cod larvae were collected around mid November to early December. Around the times Trout Cod larvae were collected the flow in the lower Goulburn River was low and stable, while water temperatures were around 22–24°C (Figure 25).

Golden Perch larvae were collected in very low numbers only in 2005–06 and 2006–07 in the lower Goulburn River (Figure 26). In both of these years, larvae were collected in mid November. In late October and mid November 2007 the flow in the lower Goulburn River increased from approximately 500 to 3000 ML/day and 1100 to 4000 ML/day, respectively. In contrast, a single Golden Perch larva was collected in November 2006 during a period of low and stable flow in the lower Goulburn River (Figure 20). Water temperature at these times was around 18–22°C (Figure 26).

Apart from Murray Cod and Trout Cod, one other species of conservation significance, a single Freshwater Catfish larva, was collected in 2007–08 in the lower Goulburn River (Table 4).

3.2.2 Murray River

The composition of catches in the Murray River was very different to that in the Goulburn River (Table 4). Over 1900 individuals representing seven native and one exotic species were collected from the Murray River between 2003–04 and 2008–09 (Table 4). Golden Perch was the most abundant species, comprising about 48% of the total abundance. Silver Perch was the next most

abundant species, comprising about 24% of the total abundance, followed by Australian Smelt, comprising about 18% of the total abundance.

The most abundant species in the Murray River, Golden Perch, was collected only in low numbers in the Goulburn River, while the second most abundant species in the Murray River, Silver Perch, was not collected in the Goulburn River. Unspecked Hardyhead, collected in low numbers in the Murray River, was also absent from the Goulburn River. Trout Cod was collected in the Goulburn River but not in the Murray River. River Blackfish, Freshwater Catfish and the exotic Redfin (*Perca fluviatilis*), collected in low numbers in the Goulburn River, were also absent from the Murray River. For a more detailed assessment of fish spawning in the mid-Murray River region, see King et al. (2008).

Table 4. Numbers of eggs and larvae of fish species in drift samples collected from the Goulburn and Murray rivers between 2003–04 and 2008–09.

		Goulburn							Murray						
		03–04	04–05	05–06	06–07	07–08	08–09	Total	03–04	04–05	05–06	06–07	07–08	08–09	Total
Golden Perch	Eggs								47	428	432	1		37	945
	Larvae			3	1			4		9					9
Silver Perch	Eggs								72	37	25	41	60	262	497
	Larvae									10				2	12
Murray Cod	Larvae	8	14	31	58	158	156	425	1	17				4	22
Trout Cod	Larvae	31				60	1	92							
River blackfish	Larvae				1			1							
Australian smelt	Eggs	27	29	15	10	34	32	147		4		3		4	11
	Larvae	33	4	7	2	32	301	379	45	9		13	179	100	346
Flat-headed gudgeon	Eggs	3						3							
	Larvae	92	1267	343	1061	736	7902	11401	2	8	2	3	3	17	35
Carp gudgeon	Eggs														
	Larvae		14	38		4	19	75		1			3	6	10
Carp	Eggs								3	2			2	4	11
	Larvae	1	1				10	12	9	5	87	3	4	5	113
Freshwater catfish	Larvae					1		1							
Unspecked hardyhead	Eggs												3		3
Redfin	Larvae					1		1							
	TOTAL	195	1329	437	1133	1026	8421	12541	179	530	546	64	254	441	2014

Note: Three sites were sampled in the Goulburn River and one in the Murray River

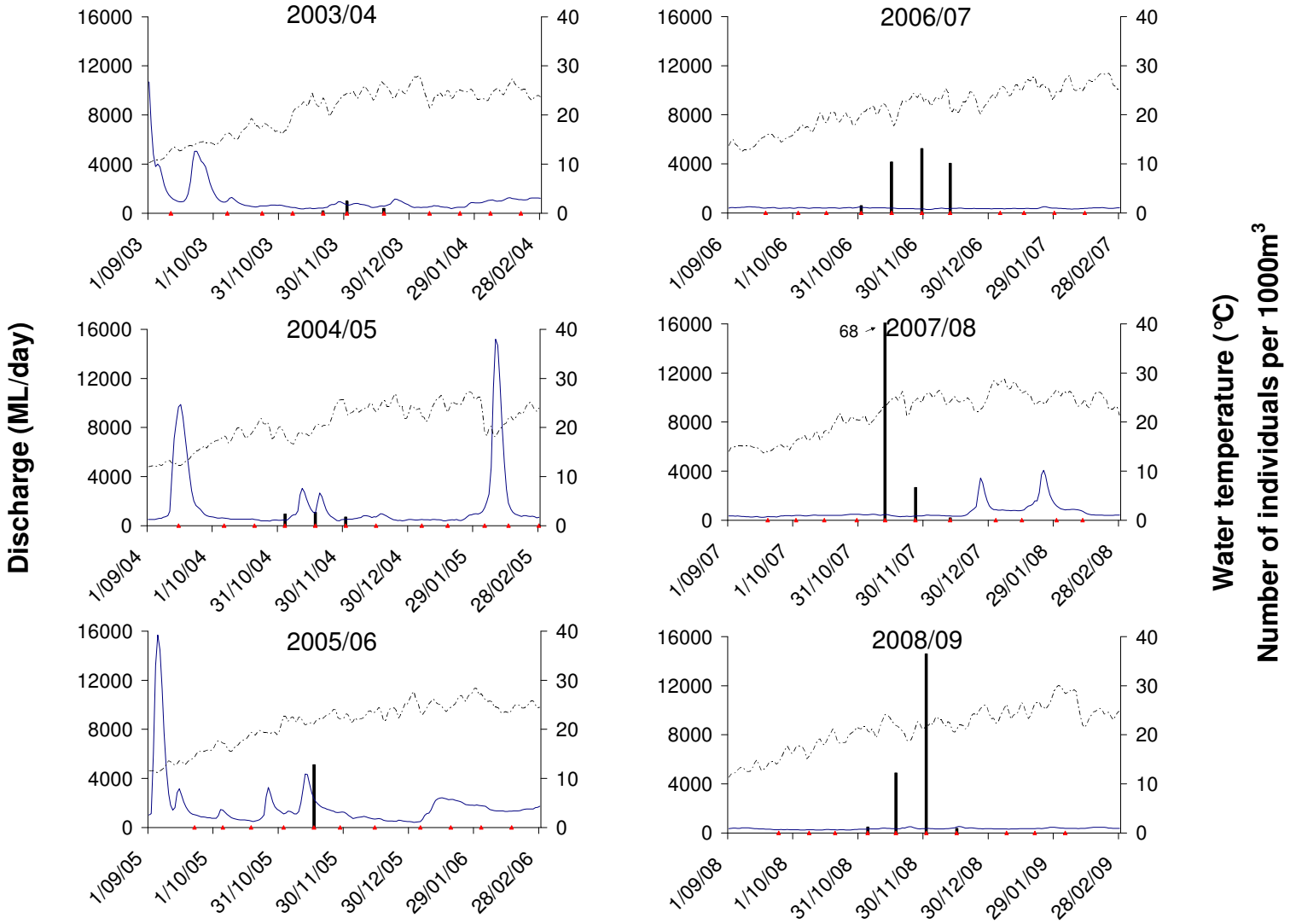

Figure 24. Total adjusted abundance of Murray Cod larvae, water temperature (on same vertical axis) and discharge in the Goulburn River. Data pooled across sites. Triangles on horizontal axis indicates sampling events.

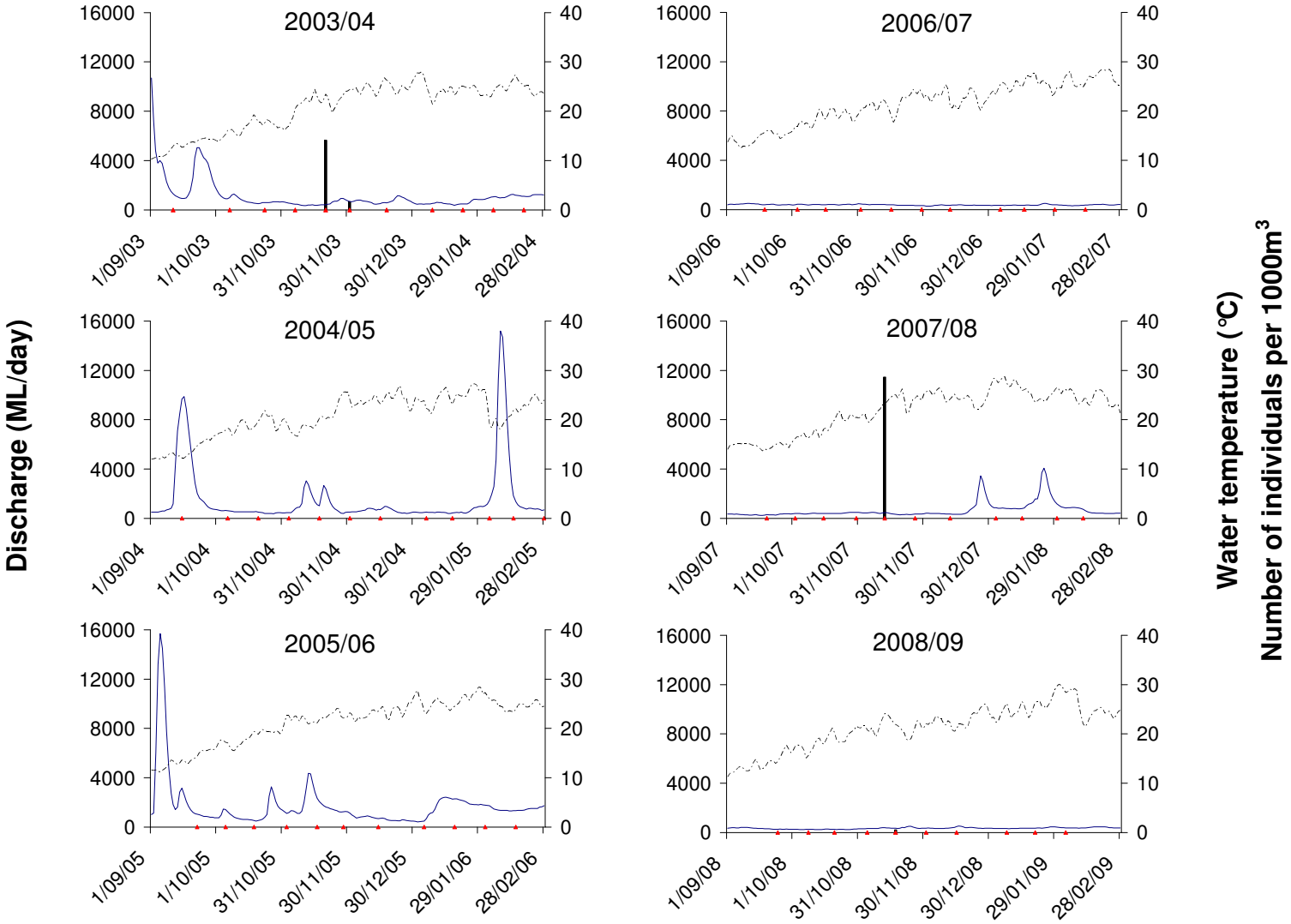

Figure 25. Total adjusted abundance of Trout Cod larvae, water temperature (on same vertical axis) and discharge in the Goulburn River. Data pooled across sites. Triangles on horizontal axis indicates sampling events.

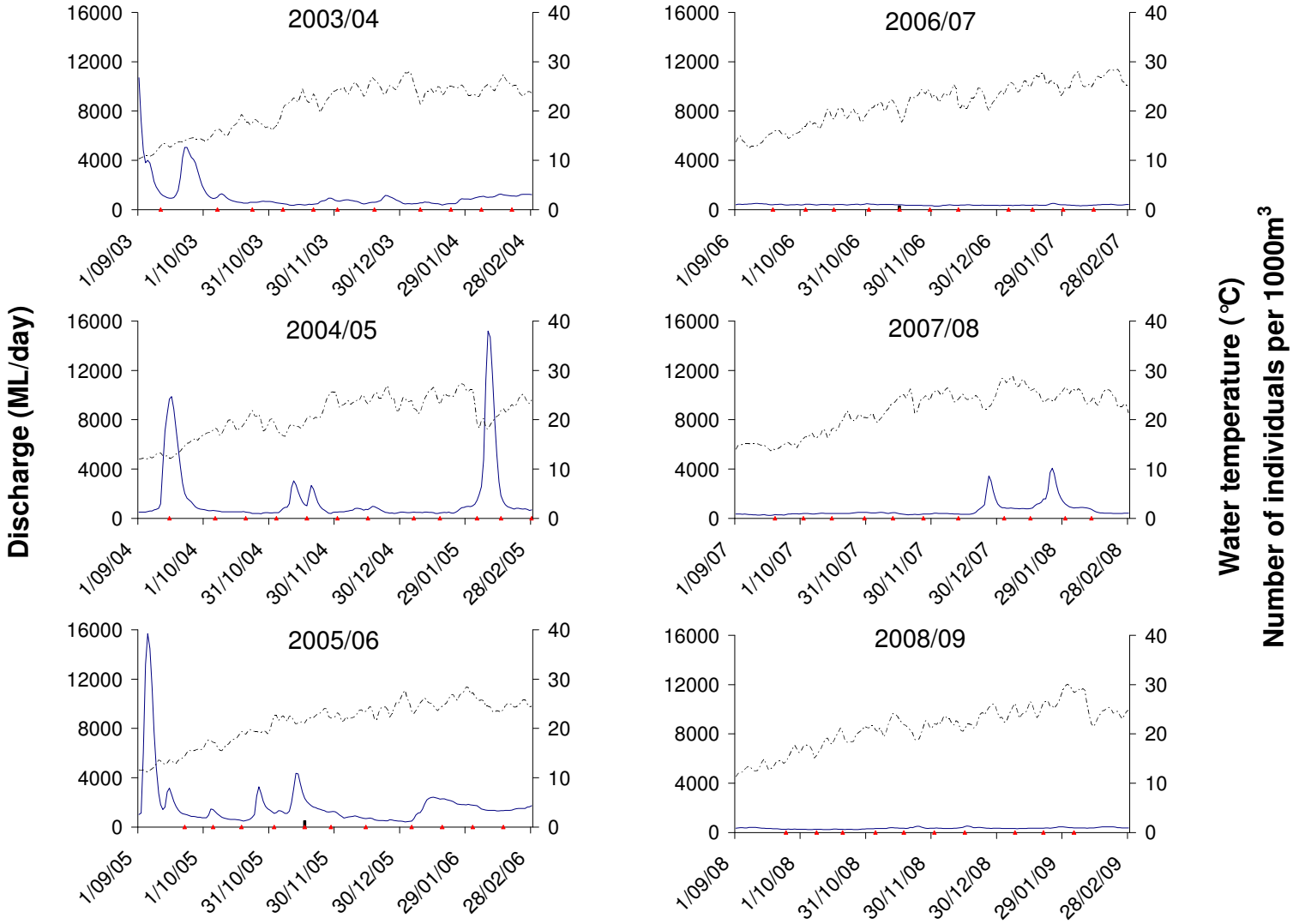

Figure 26. Total adjusted abundance of Golden Perch larvae, water temperature (on same vertical axis) and discharge in the Goulburn River. Data pooled across sites. Triangles on horizontal axis indicates sampling events.

3.3 Acoustic tracking of Golden Perch

3.3.1 Goulburn River tagged fish

Fish tagged in 2007 in the Goulburn River

Of the 15 fish tagged in the Goulburn River in 2007, nine were detected on the listening stations (Table 5). The fate of the other six fish is unknown. Seven of the nine fish detected moved into the Murray River (Figure 27). Only one of these fish (fish 3475)[1] did not return to the Goulburn River (Figure 27). Details of individual fish movements are given below.

The earliest time that a fish was detected moving into the Murray River was mid May 2007, about one month after tagging. Movement by this fish (3480) into the Murray River followed a rise in flow in the Goulburn River from about 300 to 550 ML/day. The timing of movement was associated with relatively low water temperature (17°C). This individual (3480) was recorded only for a short period (< 7 days) in the Murray River before returning to the Goulburn River.

Five of the seven fish that moved into the Murray River did so in late December 2007 (Figure 27). These movements into the Murray River occurred during a sharp increase in flow in the Goulburn River, from about 300 to 3500 ML/day. Four of these fish (3476, 3485, 3489, 3490) returned to the Goulburn River in early January 2008 and one of the fish (3475) returned in late January 2008. Two of these fish (3489, 3490) moved back into the Murray River in mid January 2008 during another sharp increase in flow in the Goulburn River from around 800 to 4000 ML/day, before returning to the Goulburn River in late January 2008. The timing of these movements was associated with relatively high water temperature (22–29°C). In the Murray River, flow was relatively moderate around these times (approximately 7300 ML/day) and water temperature relatively high (22–28°C).

Later in the year in mid August 2008, one of the fish (3475) returned to the Murray River. Around this time, flow and water temperature in the Goulburn River were relatively low. This individual is the only fish tagged in 2007 not to have returned to the Goulburn River.

Around late November 2008, another two fish (3490, 3494), including one of the fish that visited the Murray River in late December 2007 (3490), moved into the Murray River. This movement followed a rise in flow in the Goulburn River from about 250 to 350 ML/day. The timing of these movements was associated with relatively high water temperature (19–24°C). Both fish were recorded only for a short period (< 7 days) in the Murray River before returning to the Goulburn River. In the Murray River, flow was relatively low around these times (i.e. approximately 6200 ML/day) and water temperature relatively high (19–23°C).

Fish tagged in 2008 in the Goulburn River

Of the 16 fish tagged in the Goulburn River in 2008, eight were detected on the listening stations (Table 5). The fate of the other eight fish is unknown. Six of the eight detected fish moved into the Murray River (Figure 28). Only one of these fish (fish 10791) has not returned to the Goulburn River (Figure 28). Details of individual fish movements are given below.

Two of the fish (10795, 10791) were detected in the Murray River in May 2008, about one month after tagging. The movement of fish 10791 into the Murray River followed a rise in flow in the Goulburn River from about 340 to 400 ML/day, while the movement of fish 10795 occurred during a period of relatively low and stable flow. The timing of these movements was associated with relatively low water temperature (11–15°C). One of these fish (10795) remained in the Murray River until mid November 2008, before returning to the Goulburn River. The return of this

[1] Number refers to individual fish ID code

fish to the Goulburn River coincided with a rise in flow in the Goulburn River from about 340 to 400 ML/ day. The movement also followed a sharp rise in flow in the Murray River from about 5600 to 6800 ML/day. Water temperatures around this time were relatively high (19–24°C). The other fish (10791) has remained in the Murray River.

One fish (10797) moved into the Murray River in late September 2008. Flow and water temperature in the Goulburn River around these times was relatively low (approximately 260 ML/day, 14°C). Between September 2008 and March 2009, this fish made numerous visits back and forth between the Goulburn and Murray rivers. Flow in the Murray River during this period gradually increased, while flow was relatively low and stable in the Goulburn River. This fish was last detected in the Murray River.

Two fish (10793, 10800) moved into the Murray River in mid November 2008. These fish were recorded only for a short period (< 2 days) in the Murray River before returning to the Goulburn River. The movements of these fish into the Murray River and back to the Goulburn River coincided with a small increase in flow in the Goulburn River, from about 340 to 400 ML/day. The movements also followed a sharp rise in flow in the Murray River from about 5600 to 6800 ML/day. Water temperatures around this time were relatively high (19–24°C).

Another fish (10796) moved into the Murray River in mid October 2008. This fish was recorded only for a short period (< 2 days) in the Murray River before returning to the Goulburn River. This fish moved back into the Murray River in early November 2008, but returned to the Goulburn River within a few days. Flow in the Goulburn River around this time was relatively low (approximately 260 ML/day), while water temperature was high (19–24°C). Flow and water temperature in the Murray River around these times were gradually increasing.

In contrast to the fish tagged in 2007, half of the fish tagged in 2008 that moved from the Goulburn River into the Murray River spent a large proportion of their time (> 40%) in the Murray River and two of these fish (10797, 10791) had not returned to the Goulburn River at the time of writing.

3.3.2 Murray River tagged fish

Fish tagged in 2007 in the Murray River

All 15 of the Golden Perch tagged in the Murray River in 2007 were detected on the listening stations (Table 5). Four moved into the Goulburn River (Figure 29), and two of these four fish (fish 3477, 3493) did not return to the Murray River (Figure 29). Details of individual fish movements are given below.

The earliest time that a fish was detected moving into the Goulburn River was mid April 2007, several days after tagging. Flow in the Murray River had steadily decreased over several months prior to this fish (3477) moving into the Goulburn, while flow in the Goulburn River around this time was relatively low (approximately 320 ML/day). Water temperatures in both rivers were steadily decreasing. This fish has not returned to the Murray River.

Another two fish (3478, 3493) moved into the Goulburn River in early June and early July 2007, respectively. The movement of these fish coincided with rapid and large increases in flow in the Murray River, from about 1800 to 5900 ML/day for fish 3478 and 2000 to 6900 ML/day for fish 3493. Flows in the Goulburn River also increased around these times, from about 400 to 550 ML/day for fish 3478 and 350 to 1900 ML/day for fish 3493. Water temperatures in both rivers were relatively low (7–9°C). Fish 3493 has not returned to the Murray River. Fish 3478 returned to the Murray River in late August 2007. This movement occurred during a decrease in flow in the Murray River from about 5900 to 3900 ML/day. This fish back moved into the Goulburn River on several other occasions for short periods (< 14 days) between February and

August 2008. On two occasions, the movements into the Goulburn River coincided with rapid and large increases in flow in the Murray River (e.g. from about 1800 to 4100 ML/day). Flow in the Goulburn River around these times was relatively low. Water temperatures in both rivers were relatively low around the time of these movements.

One fish (3467) moved into the Goulburn River for short periods (< 7 days) before returning to the Murray River on several occasions between late November 2007 and early January 2008. This fish displayed a similar pattern of movement about one year later between early November and late December 2008. Flow and water temperature in the Murray River around the time of these movements were steadily increasing. Flow in the Goulburn River was relatively low, while water temperature was increasing.

Fish tagged in 2008 in the Murray River

Eight of the 14 Golden Perch tagged in the Murray River in 2008 were detected on the listening stations (Table 5). Three (38%) of these eight fish moved into the Goulburn River (Figure 29). The earliest time that a fish was detected moving into the Goulburn River was in mid April 2008. This fish (10787) has not returned to the Murray River. Flow in the Murray River had steadily decreased over several months prior to fish 10807 moving into the Goulburn River, while flow in the Goulburn River around this time was relatively low and stable. Water temperatures in both rivers were gradually decreasing. One fish (10807) moved into the Goulburn River in mid October 2008, but returned to the Murray River within a few days. Flow in both rivers around this time was relatively low, while water temperatures were gradually increasing. One fish (10808) moved into the Goulburn River on several occasions between mid November 2008 and late December 2008. Flow and water temperature in the Murray River around the time of these movements were steadily increasing. Flow in the Goulburn River was relatively low, while water temperature was increasing.

Table 5. Summary of the movement data for Golden Perch collected in the Goulburn River.

Fish ID Code	Collection site	Date tagged	Date of 1st detection	Date of last detection	No. of detections	No. visits to Murray	% time spent in Murray	% time spent in Goulburn	Last location
3471	Stewarts Bridge	12/04/2007	24/10/2007	27/10/2007	140	0	0.0	100.0	Goulburn
3475	Stewarts Bridge	12/04/2007	22/12/2007	20/08/2008	361	2	24.8	75.2	Murray
3476	Stewarts Bridge	12/04/2007	27/12/2007	30/12/2007	80	1	0.7	99.3	Goulburn
3480	Stewarts Bridge	12/04/2007	9/05/2007	19/05/2007	2066	1	0.8	99.2	Goulburn
3485	Stewarts Bridge	11/04/2007	24/12/2007	20/11/2008	217	4	1.6	98.4	Goulburn
3486	Yambuna	13/04/2007	22/12/2007	28/01/2008	639	0	0.0	100.0	Goulburn
3489	Stewarts Bridge	12/04/2007	3/10/2007	5/02/2008	1302	2	0.7	99.3	Goulburn
3490	Stewarts Bridge	12/04/2007	21/12/2007	22/11/2008	564	6	3.8	96.2	Goulburn
3494	Stewarts Bridge	12/04/2007	30/10/2007	25/11/2008	129	1	1.0	99.0	Goulburn
10791	Stewarts Bridge	22/04/2008	23/04/2008	15/10/2008	3972	1	88.7	11.3	Murray
10792	Stewarts Bridge	22/04/2008	27/04/2008	2/11/2008	5129	0	0.0	100.0	Goulburn
10793	Stewarts Bridge	22/04/2008	3/10/2008	26/02/2009	769	1	0.6	99.4	Goulburn
10795	Stewarts Bridge	22/04/2008	3/05/2008	1/02/2009	29333	3	58.2	41.8	Goulburn
10796	Stewarts Bridge	22/04/2008	25/04/2008	4/03/2009	27957	1	0.9	99.1	Goulburn
10797	Stewarts Bridge	22/04/2008	21/09/2008	4/03/2009	20806	54	43.1	56.9	Murray
10799	Stewarts Bridge	22/04/2008	30/04/2008	25/01/2009	144	0	0.0	100.0	Goulburn
10800	Stewarts Bridge	22/04/2008	20/11/2008	22/11/2008	656	1	0.9	99.1	Goulburn

Table 6. Summary of the movement data for Golden Perch collected in the Murray River.

Fish ID Code	Collection site*	Date tagged	Date of 1st detection	Date of last detection	No. of detections	No. visits to Goulburn	% time spent in Goulburn	% time spent in Murray	Last location
3467	Upstream	10/04/2007	19/10/2007	8/12/2008	2629	6	2.1	97.9	Murray
3468	Downstream	11/04/2007	19/04/2007	15/06/2007	58	0	0.0	100.0	Murray
3469	Downstream	11/04/2007	1/05/2007	15/02/2008	654	0	0.0	100.0	Murray
3472	Upstream	10/04/2007	13/05/2007	6/11/2007	198	0	0.0	100.0	Murray
3473	Downstream	11/04/2007	28/05/2007	2/07/2008	31408	0	0.0	100.0	Murray
3474	Upstream	11/04/2007	11/04/2007	20/11/2008	31	0	0.0	100.0	Murray
3477	Upstream	10/04/2007	12/04/2007	17/04/2007	2299	1	99.8	0.2	Goulburn
3478	Downstream	11/04/2007	4/06/2007	21/11/2008	30887	7	16.4	83.6	Murray
3479	Upstream	11/04/2007	30/10/2007	2/11/2007	103	0	0.0	100.0	Murray
3482	Downstream	11/04/2007	23/10/2007	22/01/2008	18	0	0.0	100.0	Murray
3483	Downstream	11/04/2007	17/10/2007	12/11/2008	1383	0	0.0	100.0	Murray
3487	Downstream	11/04/2007	10/10/2007	10/10/2007	183	0	0.0	100.0	Murray
3488	Downstream	11/04/2007	23/04/2007	27/10/2008	770	0	0.0	100.0	Murray
3492	Downstream	11/04/2007	13/05/2007	1/11/2008	492	0	0.0	100.0	Murray
3493	Downstream	11/04/2007	7/07/2007	21/07/2007	2	1	86.1	13.9	Goulburn
10786	Downstream	21/04/2008	20/11/2008	21/11/2008	325	0	0.0	100.0	Murray
10787	Downstream	21/04/2008	29/04/2008	1/05/2008	2	1	97.8	2.2	Goulburn
10788	Downstream	21/04/2008	15/05/2008	8/10/2008	2017	0	0.0	100.0	Murray
10789	Downstream	21/04/2008	2/10/2008	20/12/2008	1800	0	0.0	100.0	Murray
10806	Downstream	23/04/2008	23/04/2008	15/06/2008	2442	0	0.0	100.0	Murray
10807	Downstream	23/04/2008	23/04/2008	4/03/2009	27646	2	0.6	99.4	Murray
10808	Upstream	23/04/2008	13/10/2008	25/12/2008	3810	4	4.1	95.9	Murray
10809	Upstream	23/04/2008	28/04/2008	31/10/2008	820	0	0.0	100.0	Murray

* upstream or downstream of junction with Goulburn River

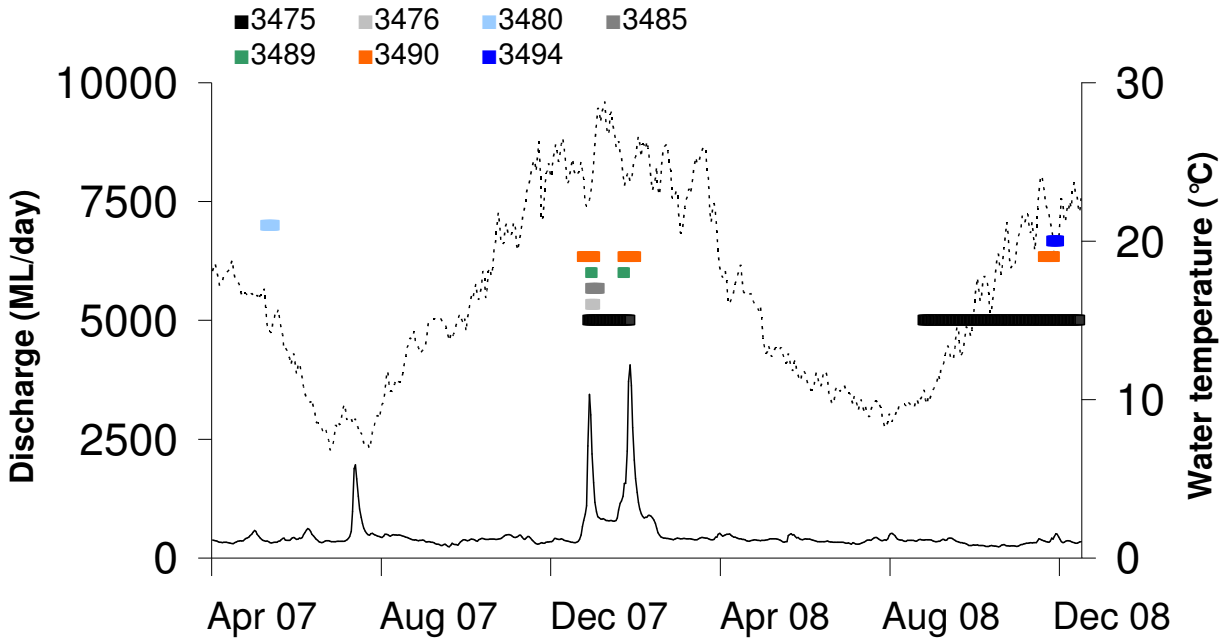

Figure 27. Times (coloured bars) during which fish tagged in 2007 in the Goulburn River were detected in the Murray River. At all other times fish were in the Goulburn River. Coloured bars refer to individual fish and associated numbers refer to fish ID code. Discharge (solid line) and water temperature (dotted line) for Goulburn River at McCoys Bridge.

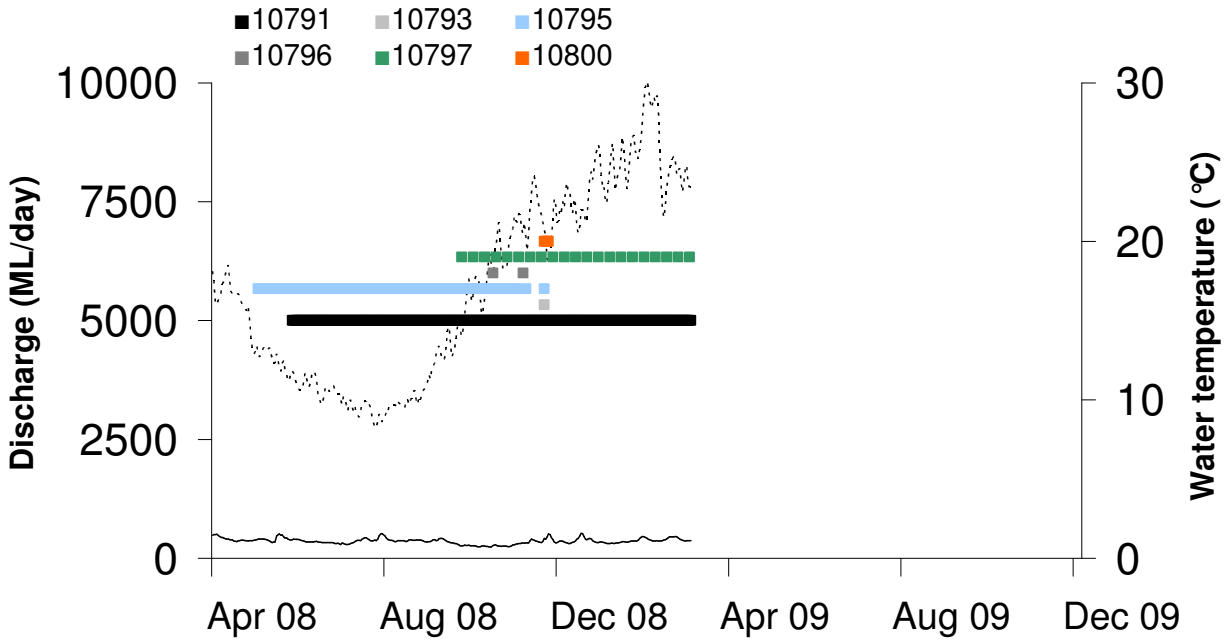

Figure 28. Times (coloured bars) during which fish tagged in 2008 in the Goulburn River were detected in the Murray River. At all other times fish were in the Goulburn River. Coloured bars refer to individual fish and associated numbers refer to fish ID code. Discharge (solid line) and water temperature (dotted line) for Goulburn River at McCoys Bridge.

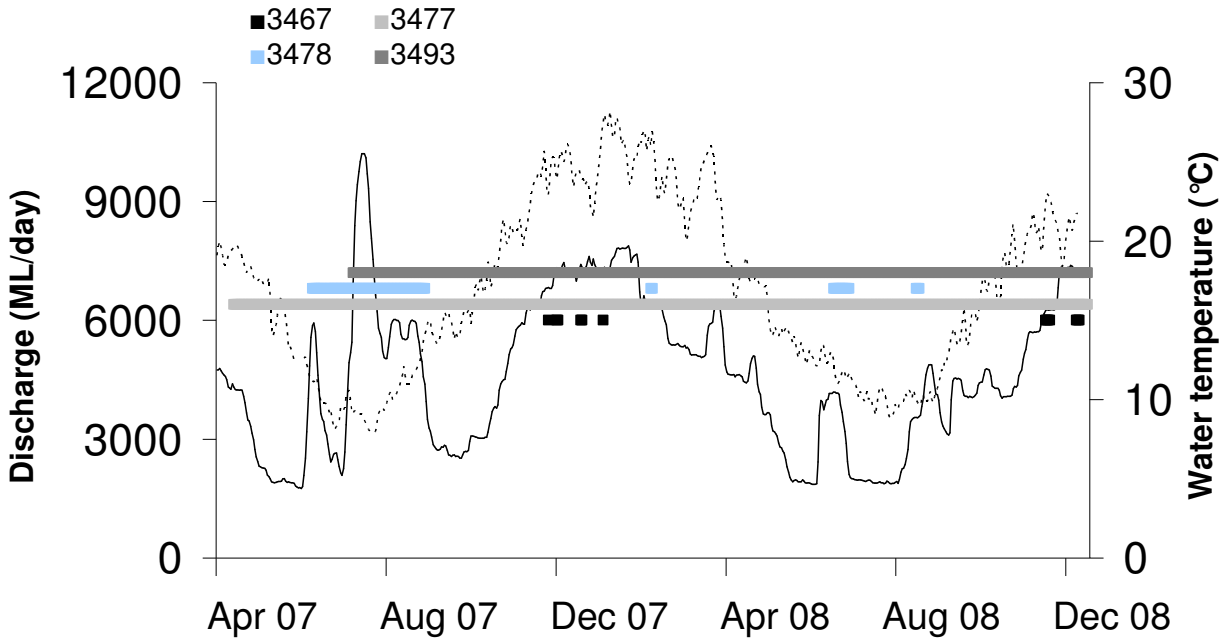

Figure 29. Times (coloured bars) during which fish tagged in 2007 in the Murray River were detected in the Goulburn River. At all other times fish were in the Murray River. Coloured bars refer to individual fish and associated numbers refer to fish ID code. Discharge (solid line) and water temperature (dotted line) for Murray River at Tocumwal.

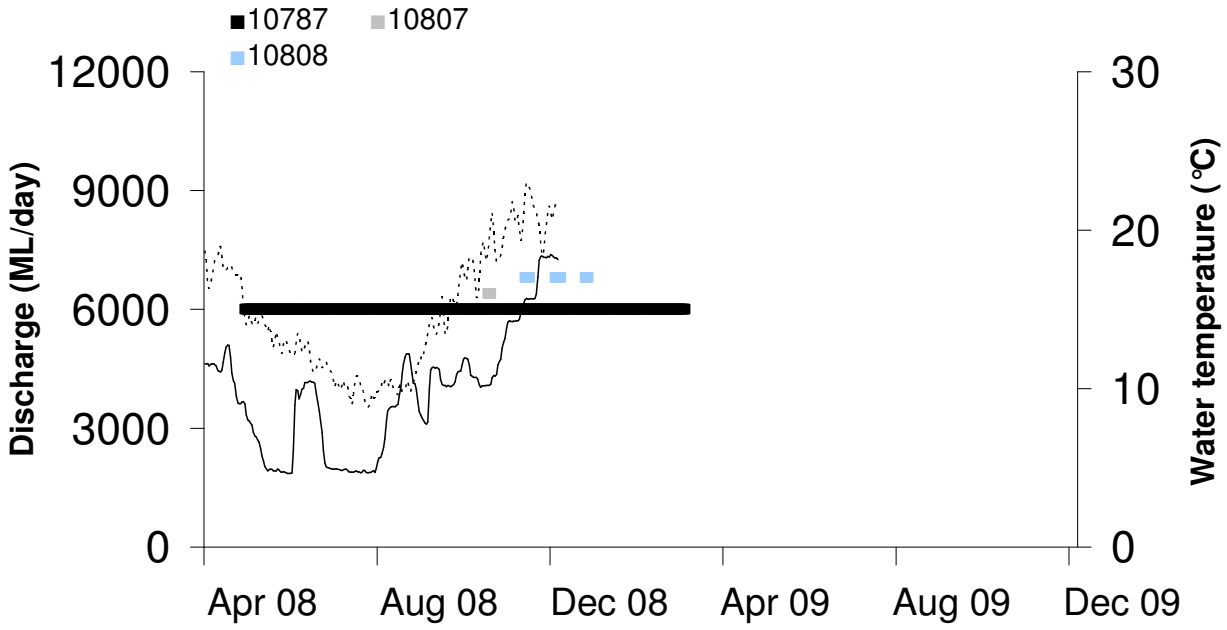

Figure 30. Times (coloured bars) during which fish tagged in 2008 in the Murray River were detected in the Goulburn River. At all other times fish were in the Murray River. Coloured bars refer to individual fish and associated numbers refer to fish ID code. Discharge (solid line) and water temperature (dotted line) for Murray River at Tocumwal.

4 Discussion

The results of this study demonstrate that the lower Goulburn River supports a diverse native fish population, including several species of recreational angling value or conservation significance (or both), such as Trout Cod, Murray Cod, Silver Perch, Freshwater Catfish and Golden Perch. Of particular importance is the collection of Trout Cod larvae in the 2003–04, 2007–08 and 2008–09 drift sampling, which suggests that the lower Goulburn River supports a breeding population of this nationally threatened species. Although no Trout Cod were collected in the electrofishing and drift net surveys for several years following the fish kill in the lower Goulburn River in January 2004 (Koster et al. 2006), it appears that the population has re-established in recent years. In the study period the flow was relatively low and stable in the lower Goulburn River around the times when Trout Cod larvae were collected. This result supports previous research that has indicated that Trout Cod are able to spawn under a range of flow conditions (Koehn and Harrington 2006, King et al. 2008a).

Murray Cod was the most abundant large-bodied native species in the electrofishing surveys, although few fish above the minimum legal size were collected. The minimum legal size for Murray Cod in Victoria was recently increased from 500 mm to 600 mm. The data collected in this study suggest that there has been a slight increase in the number of fish collected in the 500–600 mm size range in the lower Goulburn River in the last year, although further sampling is needed to confirm this trend. The data collected through this project will provide a basis for monitoring the population size structure of Murray Cod.

The results of the study show that natural spawning of Murray Cod occurs regularly in the lower Goulburn River. Murray Cod larvae were collected there every year in the drift samples, during periods of both low and high flows. This result supports previous studies that indicated that Murray Cod are able to spawn under a range of flow conditions (Humphries et al. 2002, Humphries 2005, Koehn and Harrington 2006 King et al. 2007, 2008a), although flows were relatively low and stable around the times when the greatest densities were collected (e.g. mid November 2007, early December 2008) in this study.

High densities of Murray Cod larvae (e.g. 2007–08, 2008–09) were not necessarily followed by high numbers of YOY fish in the electrofishing surveys in the following autumn. In fact, the greatest numbers of YOY fish were collected in autumn 2004, 2005 and 2007, which were years that had some of the lowest densities of Murray Cod larvae in the preceding spawning season. The reason for a greater abundance of YOY fish in these years is unclear. Before autumn 2004 and 2005 there had been several flow increases in the previous spring/summer, while before autumn 2007 the flow in the previous spring/summer was low and stable. It is possible that YOY fish collected in the surveys are derived from Murray Cod fingerlings that have been released regularly into the lower Goulburn River as part of stocking programs. Unfortunately we are unable to distinguish between YOY Murray Cod natural recruits and stocked fish.

Golden Perch was the second most abundant large-bodied native species collected in the electrofishing surveys. In this study though, only one juvenile Golden Perch and only limited evidence of spawning by this species was detected in the Goulburn River, with three larvae collected in 2005–06 and one larva collected in 2006–07. In contrast to the lack of spawning by this species in the Goulburn River, Golden Perch eggs and/or larvae were collected at the Murray River drift site in all years except 2007–08. Golden Perch eggs and/or larvae have also been collected at several other sites in the mid-Murray in all years between 2003–04 and 2006–07, but not in 2007–08 or 2008–09, as part of a separate study (King et al. 2008a, Tonkin pers. comm.).

Previous research has indicated that spawning by Golden Perch is associated with rises in flow and water temperature (Lake 1967), and is enhanced during flood events (King et al. 2007, 2008b). In the current study, evidence of spawning was detected during a period of low and stable flows in the Goulburn River in November 2006, although only a single Golden Perch larva was collected at this time. The greatest number of larvae, although only three individuals, was collected in November 2005, shortly after increases in flow (from approximately 500 to 3000 ML/day and 1100 to 4000 ML/day in late October and early November 2005, respectively) and water temperature. This result provides support for the link between flows, water temperature and spawning, although no evidence of spawning was detected during a number of other similar increases in flow coupled with increasing water temperature in the lower Goulburn River during the spawning period (e.g. December 2007 and January 2008). Apart from one relatively large flow increase (from approximately 600 to 15 000 ML/day) in February 2005, which was associated with low water temperatures (< 20°C), the increased flows in the Goulburn River during the spawning period have been of relatively short duration (e.g. < 1 week) or magnitude (e.g. peak discharges between 3000 and 4000 ML/day), which may explain the lack of any significant spawning events by Golden Perch in the Goulburn River in this study. Further sampling under higher flow conditions during the spawning season is needed to improve our understanding of the factors that influence spawning success in the Goulburn River.

The lack of spawning by Golden Perch in the Goulburn River could also indicate that the Goulburn River is naturally not an important spawning ground. Golden Perch are thought to make spawning migrations (Reynolds 1983), possibly to specific areas within a river system (e.g. near river junctions) (O'Connor et al. 2005). In the current study, about one third of the fish tagged in the Goulburn River moved downstream during the spawning season and entered the Murray River. Most of these fish stayed within 10 km of the junction before returning to the Goulburn River within the next few weeks. Similarly, O'Connor et al. (2005) found that Golden Perch moved close to river junctions during the spawning season, then returned to pre-movement locations. Whether these movements are related to spawning is unclear. No Golden Perch eggs or larvae were collected at the Murray River drift site, located several kilometres below the Goulburn River junction, in 2007–08, and only low numbers were collected in 2008–09. Similarly, there has been only limited evidence of spawning by Golden Perch at several other sites in the mid-Murray River region in the 2007–08 and 2008–09 spawning seasons (King et al. 2008a, Tonkin pers. comm.). However, unfavourable environmental conditions (e.g. low flows) may have limited spawning by Golden Perch in the Murray River in the last two years. Regardless of the purpose of the movements, movement by Golden Perch from the Goulburn River into the Murray River was most prevalent during December 2007 – January 2008, which coincided with increased flows in the Goulburn River. Many of the fish tagged in the Murray River that moved into the Goulburn River also did so during increased flows in the Murray River. These findings support previous studies which suggest that increased flows initiate movement by Golden Perch (Reynolds 1983, O'Connor et al. 2005).

The results of this study so far show that the Murray River acts as a source of new emigrants to the lower Goulburn River, with about one quarter of the fish tagged in the Murray River moving into the Goulburn River, although most of these individuals returned to the Murray River. It is possible that the low flow conditions in the Goulburn River over the last few years have been unfavourable for promoting fish movement into the Goulburn River. Further investigation of fish movement between the systems is needed, particularly under increased flow conditions, to better understand the role of the Murray River as a source of recruitment of Golden Perch to the Goulburn River. It should also be noted that most of the Golden Perch collected and tagged in this study were adult fish. Mallen-Cooper (1994) observed large numbers of juvenile Golden Perch migrating upstream

through a fishway on the mid-Murray River. It is possible that juvenile Golden Perch in the Murray River also acts as source of recruits to the Goulburn River, but this requires further investigation.

As with Golden Perch, this study has revealed a lack of spawning and recruitment by Silver Perch in the Goulburn River. This result contrasts with the regular collection of Silver Perch eggs and/or larvae over the last six years at the Murray River drift site and at other sites upstream in the mid-Murray region (King et al. 2008a, Tonkin pers. comm.). The lack of evidence of spawning by Silver Perch in the Goulburn River may be due to unfavourable environmental conditions (e.g. low flows). The result may also be related to low abundances of adult Silver Perch in the Goulburn River. The numbers of Silver Perch collected in the electrofishing surveys have, however, increased in the last few years of this study. It is possible that Silver Perch have moved into the Goulburn River from the Murray River.

Another significant finding of this study was the collection a Freshwater Catfish larva in the 2007–08 drift sampling and a juvenile catfish several months later in the electrofishing surveys in autumn 2008. Freshwater Catfish was once common throughout the Goulburn River, but is now rare and thought to be confined to a small number of wetlands and lakes, including Lake Nagambie and Tahbilk Lagoon. The collection of a Freshwater Catfish larvae and juvenile in this study may indicate that a breeding population of this threatened species exists in the Goulburn River. Alternatively, these individuals may have originated from upstream lakes (e.g. Lake Nagambie). Although few Freshwater Catfish have been collected in this study, the species is a bottom-dweller and could be difficult to see and capture using electrofishing in the relatively turbid waters of the Goulburn River. The use of other sampling techniques (e.g. netting) may improve the chances of detecting this species.

A number of exotic fish species occur in the Goulburn River, including Carp, Goldfish, Eastern Gambusia (*Gambusia holbrooki*), Redfin and Oriental Weatherloach. Carp are the most abundant large-bodied fish in the Goulburn River. There was limited evidence of spawning by carp in the Goulburn River however, with only low numbers of carp larvae collected in 2003–04, 2004–05 and 2008–09, although the drift net surveys may not be effective for collecting the early life stages of carp. In contrast, YOY carp were collected in almost every electrofishing survey and at times (e.g. autumn 2006 and 2009) comprised a large proportion of the total carp abundance. A study of the otolith chemical signatures of the YOY Carp collected in autumn 2006 estimated that 86% originated from recruitment sources outside the Goulburn River basin (Macdonald and Crook 2006).

Redfin, Oriental Weatherloach, Eastern Gambusia, and Goldfish have only been collected in relatively low numbers. The numbers of Redfin, Oriental Weatherloach, and Goldfish, however, have been higher in the last few years compared to the first few years of the study. Redfin were common in the lower Goulburn River in the 1980s, but only low numbers have been collected in this study. The recent increase in numbers of Redfin may indicate that the species is re-emerging in the lower Goulburn River, but further surveys would be needed to confirm this. Oriental Weatherloach were collected in the last few years of this study in the mid to lower reaches of the lower Goulburn River. This species is also abundant in the Murray River around Barmah and is rapidly expanding its range. Prior to this study, there were no documented records of Oriental Weatherloach in the lower Goulburn River. It is possible that this species is more widespread than the surveys indicate, as it is a bottom-dweller and generally difficult to capture using electrofishing. Eastern Gambusia is also difficult to capture using electrofishing because of its small size and preference for shallow littoral zones. As a result, the abundance of this species is likely to be underestimated in the lower Goulburn River.

Conclusion

This project has provided important information about the fish assemblages in the Goulburn River. In particular, the electrofishing surveys have shown that the Goulburn River has a diverse fish population, which includes several species of recreational angling value and/or conservation significance. The collection of several fish species only in the last few years of the study (e.g. Freshwater Catfish, Bony Herring, and Oriental Weatherloach) also demonstrates the value of a long-term monitoring program to describe fish assemblage composition accurately. Continuing these surveys will provide a valuable baseline to detect any future changes in fish species presence, abundance, and population structure in the Goulburn River. The larval drift sampling has provided critical information regarding the spawning of several important species such as Murray Cod, Trout Cod, Golden Perch, Silver Perch and Freshwater Catfish. One of the major findings of these surveys has been the lack of spawning by Golden Perch in the Goulburn River. This result is perhaps not unexpected, given that flows were generally low and stable throughout the spawning period in each year of the study. An important step now is to determine whether high flow events stimulate spawning of Golden Perch in the Goulburn River. The role of high flows in stimulating the movement of Golden Perch in the Goulburn River also requires further investigation. The acoustic tracking has demonstrated links between Golden Perch movements and increased flows in the Goulburn River. Further monitoring of fish movement is required to strengthen our understanding of Golden Perch movement dynamics and links to flow, spawning and recruitment.

References

Crook, D.A. and Koster W.M. (2006). Temporal change in fish communities in the lower Goulburn River, south-eastern Australia: comment on Pollino et al. 2004. *Marine and Freshwater Research* **57**, 303–308.

Humphries, P. (2005). Spawning time and early life history of Murray Cod, *Maccullochella peelii peelii* (Mitchell) in an Australian river. *Environmental Biology of Fishes* **72**, 393–407.

Humphries, P, Serafini, L. and King, A.J. (2002). River regulation and fish larvae; variations through space and time. *Freshwater Biology* **47**, 1303–1331.

King, A.J., Crook, D.A., Koster, W.M., Mahoney, J. and Tonkin, Z. (2005). Comparison of larval fish drift in the lower Goulburn and mid-Murray rivers. *Ecological Management and Restoration* **6**, 136–138.

King, A.J., Tonkin, Z. and Mahoney, J. (2007). Assessing the effectiveness of environmental flows on fish recruitment in Barmah-Millewa Forest. Prepared by Arthur Rylah Institute for Environmental Research, DSE. MDBC Project No. BMF 2004.09

King, A.J., Tonkin, Z. and Mahoney, J. (2008a). Assessing the effectiveness of environmental flows on fish recruitment in Barmah-Millewa Forest – 2007/2008 Annual Report. Arthur Rylah Institute for Environmental Research. Unpublished report. Department of Sustainability and Environment, Heidelberg.

King, A.J., Tonkin, Z. and Mahoney, J. (2008b). Environmental flow enhances native fish spawning and recruitment in the Murray River, Australia. *River Research and Applications* DOI: 10.1002/rra.

Koehn, J.D. and Harrington D.J. (2006). Environmental conditions and timing for the spawning of Murray Cod (*Maccullochella peelii peelii*) and the endangered Trout Cod (*M. Macquariensis*) in southeastern Australian rivers. *River Research and Applications* **22**, 327–342.

Koster, W., Crook, D., and Fairbrother, P. (2004). Surveys of fish communities in the lower Goulburn River. Annual Report 2003/2004. Report to Goulburn Valley Association of Angling Clubs. Arthur Rylah Institute for Environmental Research, Department of Sustainability and Environment, Heidelberg, Victoria.

Koster, W., Crook, D., and Fairbrother, P. (2005). Surveys of fish communities in the lower Goulburn River. Annual Report 2004/2005. Report to Goulburn Valley Association of Angling Clubs. Arthur Rylah Institute for Environmental Research, Department of Sustainability and Environment, Heidelberg, Victoria.

Koster, W., Crook, D., O'Mahony, D. and Fairbrother, P. (2006). Surveys of fish communities in the lower Goulburn River. Final Report. Report to Goulburn Valley Association of Angling Clubs. Arthur Rylah Institute for Environmental Research, Department of Sustainability and Environment, Heidelberg, Victoria.

Lake, J.S. (1967). Rearing experiments with five species of Australian freshwater fishes. I. Inducement to spawning. *Australian Journal of Marine and Freshwater Research* **18**, 155–173.

Macdonald, J.I. and Crook, D.A. (2006). Using chemical signatures in post-larval carp otoliths to estimate the contribution of recruitment sources in the mid-Murray River. Final report to Murray-Darling Basin Commission. Arthur Rylah Institute for Environmental Research, Department of Sustainability and Environment, Heidelberg, Victoria.

O'Connor, J.P., O'Mahony, D.J. and O'Mahony, J.M. (2005) Movements of *Macquaria ambigua*, in the Murray River, south-eastern Australia. *Journal of Fish Biology* **66**, 392–403.

Reynolds, L.F. (1983) Migrations patterns of five fish species in the Murray-Darling River system. *Australian Journal of Marine and Freshwater Research*, **34**, 857–871.

Serafini, L.G. and Humphries, P. (2004). Preliminary guide to the identification of larvae of fish, with a bibliography, from the Murray-Darling Basin. Cooperative Research Centre for Freshwater Ecology Identification and Ecology Guide No. 48. Cooperative Research Centre for Freshwater Ecology, Murray-Darling Freshwater Research Centre, Albury and Monash University, Clayton.