

Broken River Rehabilitation Project 2009



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Final Report

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A report prepared for the Goulburn Broken Catchment Management Authority by The Murray-Darling Freshwater Research Centre.

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Introduction

The abundance of large woody debris (LWD) within lowland river channels is a major driver of both primary productivity and community structure of fish and invertebrates as well as other associated biota (Nicol et al. 2002). In Australian lowland rivers the substratum generally consists of sand, silt or clay. In general these substrates are colonized by few invertebrates (Humphries et al. 1998). The principle substratum for biofilm development and macroinvertebrate colonization is large woody debris (Crook and Robertson 1999). Large woody debris supports a more diverse invertebrate community in comparison to other instream sediments (Humphries et al. 1998; Grown et al. 1999) and increases instream habitat complexity (Pusey and Arthington 2003).

The presence of LWD influences fish habitat at a number of scales. The number of fish in a river is often related to the quality and heterogeneity of instream habitat (Koehn and O'Connor 1990). The presence and complexity of LWD assists in the creation of scour pools and slackwaters promoting habitat diversity for fish and refuge from flow and predators. Fish communities in streams with a poor diversity of habitat are usually dominated by fish species that are tolerant of a wide variety of habitats. These generalists are most often introduced species (Koehn and O'Connor 1990), which compete with native fish species for food resources.

Between 1960 and 1975 "river improvement" works were carried out in the Broken River in an effort to decrease the frequency of flooding. Works undertaken included the construction of levees and removal of LWD. In 2006 work was commenced to re-snap the Broken River.

This report builds on the fish data collected during 2006-2008 following the introduction of the LWD.

Objectives

The objective of this program is to re-snap the Broken River and to determine the impacts of re-snagging on the ecology of the river by monitoring fish and macroinvertebrates. As macroinvertebrates were not surveyed during 2008-2009 this report builds on the information obtained from previous fish surveys undertaken between 2006 and 2008. The specific aim is to determine whether there are temporal changes in the species richness, species composition, and age structure of fish as a result of re-snagging.

Methods

Site Selection

In December 2005 site assessments were undertaken along the Broken River to identify nine reaches approximately 500 m in length with either high (3 sites) or low (6 sites) existing wood densities. To be included, the study sites had to have a defined set of criteria (Table 1). Wood would then be added to 3 of the sites with low wood densities with the aim of eventually achieving a density of wood of 1 m^3 per 10 m^2 of reach. The remaining reaches would act as reference reaches. Sites were selected based on:

- Site visit
- Survey by Earthtech
- Data from previous MDFRC & CRCFE projects
- Site accessibility

The nine sites selected are located within 3 reaches of the Broken River. Benalla to Casey's weir (Reach 1); Casey's weir to Gowangardie weir (Reach 2); Gowangardie weir to Shepparton (Reach 3) (Table 2).

Table 1. Re-snagging treatments

Treatment	Condition
Reference 1	These sites will have a reasonable density of LWD, in good condition, which will be used to determine the natural density of LWD. This will establish the density of snags to be added to the treatment sites. No snags will be added to these sites. They should also have an intact riparian zone.
Reference 2	These sites will have a low density of snags, possibly in poor condition. No snags will be added to these sites. They may have a degraded or rehabilitated riparian zone.
Re-snagged	These sites will have a low density of snags, possibly in poor condition. Preferably they will also be, or have been, targeted for riparian zone rehabilitation.

Table 2. Selected sites within Broken River

Site	Wood density	Reach
Morago	high	Benalla – Casey’s weir
Scholes Rd	re-snag	(Reach 1)
Mokoan Park	low	
Quinn Rd	high	Casey’s weir – Gowangardie weir
Burnells Rd	re-snag	(Reach 2)
Goomalibee Bridge	low	
Cosgrove Rd	high	Gowangardie weir – Shepparton
Pine Lodge Rd	re-snag	(Reach 3)
Keats Rd	low	

Over the period of 2007 – 07 approximately 1262 m³ of wood was placed in the Broken River at Scholes Road, 1067 m³ at Burnells Road and 735 m³ at Pine Lodge Road.

Fish

Fish were surveyed in December 2009, February 2010 and March 2010. Surveys were undertaken using a Smith-Root LR-24 backpack electrofisher employing the Sustainable River Audit sampling protocol (MDBC 2005). This meant that within each 500 meter reach of river, 8 shots of 150 seconds accumulated power-on time were undertaken, resulting in a total survey of 20 minutes active fishing. Fishing targeted the full range of habitats available at each site, increasing the chance of catching fish within each reach. Collected fish were identified, measured and returned to the river at or close to their point of capture. Declared noxious fish were euthanased and disposed of appropriately.

Electrofishing was complimented at each site with the deployment of 10 unbaited bait traps set along the length of the site. Bait traps were employed to catch small bodied fish that may not be targeted with the electrofisher. Collected fish from bait traps were processed in the same manner as outlined above.

Results and Discussion

For the purpose of this document we have selected comparable sample dates from previous years sampling to compare to the current samples. Multivariate analysis using PRIMER (V6) (Clarke & Warwick 2001) and PERMANOVA+ for PRIMER (Anderson et al. 2008) is used to determine if any differences in fish communities were occurring between years, reaches and treatments. PERMANOVA is a multivariate equivalent of analysis of variance.

The experimental design is a randomised block design, with treatments randomly selected within reaches (blocks). A 3 factor model (time, reach and treatment) was analysed. Results indicated that there were significant differences ($P < 0.050$) between *Years*, *Reaches* and for the interaction terms *Year x Reach* and *Reaches x Treatments*. There was not a significant effect for treatment (Table 4).

Table 3. Survey dates used in the analysis

Year A	Year B	Year C	Year D
13 October 2006	12 November 2007	17 November 2008	16 December 2009
18 December 2006	21 January 2007	5 January 2009	2 February 2010
19 February 2007	26 March 2008	17 March 2009	30 March 2010

Table 4. PERMANOVA results

Source	df	SS	MS	Pseudo-F	P(perm)	Perms
Year	3	19124	6375	4.926	<0.001	998
Reach	2	75541	37771	29.184	<0.001	998
Treatment	2	4781	2390	1.847	0.078	999
Year x Reach	6	15510	2585	1.997	<0.050	999
Year x Treatment	6	6183	1031	0.796	0.729	999
Reach x Treatment	4	24342	6086	4.702	<0.001	998
Year x Reach x Treatment	12	14653	1221	0.943	0.569	999
Res	72	93186	1294			
Total	107	253320				

Fish communities between years

Not unexpectedly there are significant differences in fish communities between all sampling years across all sites ($P < 0.001$). The exception to this was the years 2007/08 and 2008/09 between which there were no significant differences between fish communities (pairwise comparison $P = 0.408$) (Table 5; Figure 1). In the first sampling year rainbow fish, smelt, gudgeons and European carp were more abundant and in the following years Murray cod have become increasingly more abundant (Table 6).

Table 5. PERMANOVA pair wise comparisons of fish communities between years

Year pairs	t	P(perm)	permutations	
2006/07	2007/08	1.945	<0.050	997
2006/07	2008/09	1.914	<0.050	998
2006/07	2009/10	3.191	<0.001	999
2007/08	2008/09	1.025	0.408	998
2007/08	2009/10	1.915	<0.050	999
2008/09	2009/10	2.545	<0.050	998

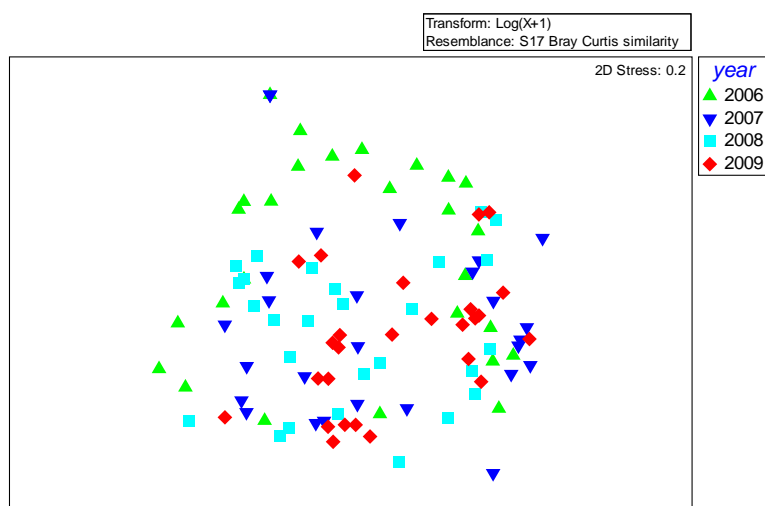


Figure 1. nMDS of fish communities across the four sampling periods (year A = summer 2006-07; year B = summer 2007-2008; year C = summer 2008-09, year D summer 2009-10)

Table 6. Fish species contributing 90% to the within year similarity (SIMPER analysis) (year A = summer 2006-07; year B = summer 2007-2008; year C = summer 2008-09, year D summer 2009-10)

Species	Year			
	2006/07	2007/08	2008/09	2009/10
<i>Hypseleotris</i> spp.	1.1	1.17	0.84	1.32
<i>Maccullochella peelii peelii</i>	0.48	0.77	1.07	1.1
<i>Macquaria ambigua</i>		0.47	0.57	
<i>Melanotaenia fluviatilis</i>	0.62	1.07	1.02	1.33
<i>Retropinna semoni</i>	0.77			
<i>Carassius auratus</i>				0.75
<i>Cyprinus carpio</i>	0.93	0.52	0.65	0.94
<i>Gambusia holbrooki</i>		0.81		1.32

Fish communities between reaches

There are significant differences in fish community structure between all pairs of reaches ($P < 0.001$) (Figure 2). Typically the reach above Casey's weir can be characterised as being dominated by small bodied fish. Reach 2 immediately downstream of Casey's weir is typified by a more diverse fish community consisting of primarily large bodied fish whereas the reach below Gowangardie weir is a less diverse community also consisting of large bodied fish (Table 7).

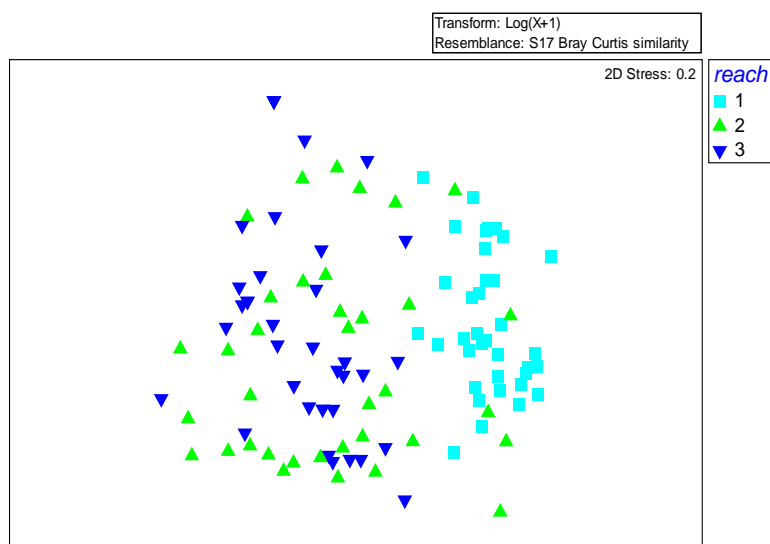


Figure 2. nMDS of fish communities surveyed from each reach (reach 1 = Benalla to Casey's weir; reach 2 = Casey's weir to Gowangardie weir; reach 3 = Gowangardie weir to Shepparton)

Table 7. Fish species contributing 90% to the within reach similarity (SIMPER analysis)

Species	Reach 1	Reach 2	Reach 3
<i>Hypseleotris</i> spp.	2.73		
<i>Maccullochella peellii peellii</i>		1.27	1.20
<i>Macquaria ambigua</i>	0.62	0.54	
<i>Melanotaenia fluviatilis</i>	1.45	0.74	0.85
<i>Carassius auratus</i>	0.54		
<i>Cyprinus carpio</i>	0.84	0.53	0.90
<i>Gambusia holbrooki</i>	1.21		

Differences in fish communities between treatments within reaches

As already noted there is no differences between fish communities between the three treatments (high wood density, low wood density and re-snagged wood) which is the primary aim of this study ($P = 0.078$) (Table 4). There are however some differences occurring between treatments within reaches over time. Pairwise comparisons of treatments within each reach indicates that there were no differences between treatments within reach 1 (Benalla to Casey's weir) but differences are occurring between treatments in the two reaches below Casey's weir (Table 8).

Table 8. Pairwise comparisons of treatment pairs within each reach for each year

Reach	Treatment pair	Year A	Year B	Year C	Year D
1	High density - Low density	0.839	0.513	0.635	0.952
1	Re-snagged - High density	0.425	0.489	0.457	0.598
1	Re-snagged - Low density	0.868	0.835	0.649	0.510
2	High density - Low density	0.194	0.525	0.684	0.452
2	Re-snagged - High density	0.184	0.055	0.020	0.046
2	Re-snagged - Low density	0.693	0.094	0.098	0.030
3	High density - Low density	0.837	0.264	0.297	0.029
3	Re-snagged - High density	0.492	0.040	0.250	0.153
3	Re-snagged - Low density	0.405	0.085	0.378	0.387

In reach 2 - Casey’s weir to Gowangardie weir – significant differences in fish communities were occurring between the re-snagged treatment and both the low and high density wood treatments in 2009 (Table 8, Figure 3). Typically the high wood treatment and low wood treatments had similar numbers of taxa. The re-snagged treatment has a lower diversity of fish but the greatest number of Murray cod (Table 9).

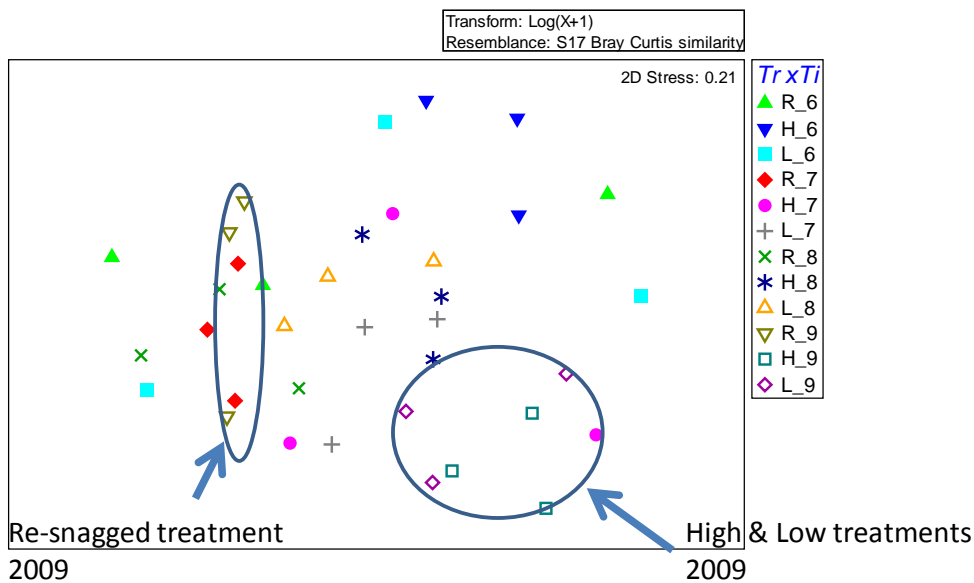


Figure 3. nMDS of fish communities in reach 2 – Casey’s weir to Gowangardie weir

Table 9. Species of fish that typify the fish community within each treatment in reach 2 at each sampling time (Casey’s weir to Gowangardie weir) (SIMPER analysis)

Treatment	Species	2006	2007	2008	2009
High density	<i>Hypseleotris</i> spp.	0.92			1.45
	<i>Maccullochella peelii peelii</i>		0.83		0.96
	<i>Macquaria ambigua</i>	0.83	1.25	0.83	
	<i>Melanotaenia fluviatilis</i>			1.52	
	<i>Retropinna semoni</i>	1.43			
	<i>Carassius auratus</i>		0.96	0.92	1.30
	<i>Cyprinus carpio</i>	0.46			1.00
	<i>Gambusia holbrooki</i>		0.69		1.50
Low density	<i>Hypseleotris</i> spp.				
	<i>Maccullochella peelii peelii</i>	0.77	1.56	1.42	0.83
	<i>Macquaria ambigua</i>	0.60	1.13	0.73	
	<i>Melanotaenia fluviatilis</i>			1.52	
	<i>Retropinna semoni</i>				
	<i>Carassius auratus</i>			1.29	
	<i>Cyprinus carpio</i>		1.06		1.61
	<i>Gambusia holbrooki</i>		0.46		2.17
Re-snagged	<i>Hypseleotris</i> spp.				
	<i>Maccullochella peelii peelii</i>	1.13	1.99	2.58	2.71
	<i>Macquaria ambigua</i>				
	<i>Melanotaenia fluviatilis</i>	0.46			1.45
	<i>Retropinna semoni</i>				
	<i>Carassius auratus</i>				
	<i>Cyprinus carpio</i>				
	<i>Gambusia holbrooki</i>				

In reach 3 - Casey’s weir to Gowangardie weir – there was differences in fish communities between the re-snagged treatment and the high density wood treatment (Table 8; Figure 4). Typically the re-snagged treatment had lower abundance of Murray Cod and higher abundances of European carp and mosquito fish (Table 10).

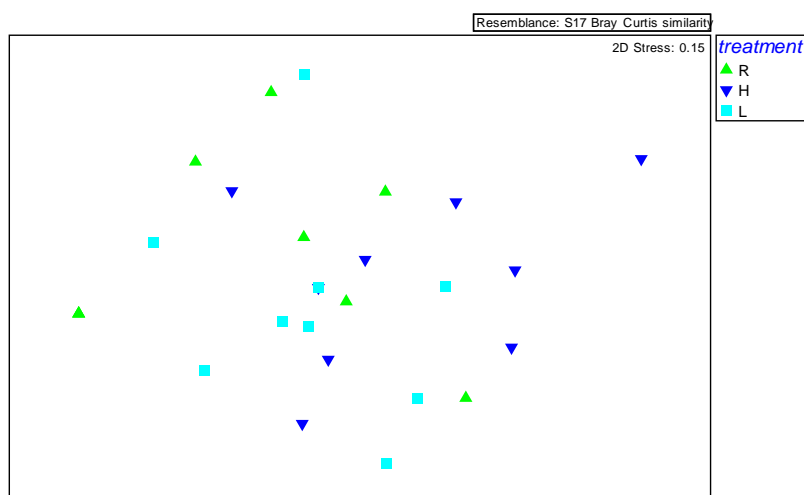


Figure 4. nMDS of fish communities in reach 2 –Gowangardie weir to Shepparton.

Table 10. Species of fish that typify the fish community within each treatment in reach 3 at each sampling time (Gowangardie weir to Shepparton) (SIMPER analysis)

Treatment	Species	2006	2007	2008	2009
High density	<i>Hypseleotris</i> spp.			0.46	
	<i>Maccullochella peellii peellii</i>	1.16	1.52	1.13	1.66
	<i>Melanotaenia fluviatilis</i>		2.10	1.50	2.56
	<i>Retropinna semoni</i>				
	<i>Cyprinus carpio</i>	1.34		0.69	
	<i>Gambusia holbrooki</i>				0.92
Low density	<i>Hypseleotris</i> spp.				0.69
	<i>Maccullochella peellii peellii</i>	0.60	1.06	1.56	2.29
	<i>Melanotaenia fluviatilis</i>		0.46		1.44
	<i>Retropinna semoni</i>	0.69			
	<i>Cyprinus carpio</i>	0.60	0.83	1.19	
	<i>Gambusia holbrooki</i>				
Re-snagged	<i>Hypseleotris</i> spp.	0.69			
	<i>Maccullochella peellii peellii</i>				1.52
	<i>Melanotaenia fluviatilis</i>				1.65
	<i>Retropinna semoni</i>				
	<i>Cyprinus carpio</i>	0.77	1.00	1.25	1.36
	<i>Gambusia holbrooki</i>				1.19

Size distributions

Size distributions and contingency tables were calculated for Murray Cod, Carp gudgeons, and Rainbow fish in those reaches in which they were in abundant numbers. Pearson's Chi-square was calculated to determine if the frequency of each fish within any size class at each sampling season occurred by chance.

Murray Cod

Size distributions and contingency tables for the reaches from Casey's weir to Gowangardie weir and Gowangardie weir to Shepparton were calculated (Table 11, Figure 5). Of these six reaches only the re-snagged reach at Burnell's Road had a significant Chi-square value (31.607, 6df, $P < 0.001$). This indicates that Murray cod in the size class 100 to 250 mm are utilising this site more than can be explained by chance occurrence, suggesting that this re-snagged site may be providing habitat for juvenile Murray Cod.

Although no significant differences occurred at the other re-snagged site at Pine Lodge road there does appear to be increasing numbers of Murray cod less than 100 mm in length sampled over time (Table 11, Figure 5).

Carp-gudgeons

Size distributions and contingency tables were calculated for the reach between Benalla and Casey's weir for each sampling season (Table 12; Figure 6). This fish species was sampled in abundant numbers at all sites across all sampling seasons and numbers do not appear to have been influenced by the addition of LWD at Scholes Road.

Rainbow fish

Size distributions and contingency tables were calculated for the reach between Benalla and Casey's weir for each sampling season (Table 13; Figure 7). This fish species was sampled in abundant numbers at all sites across all sampling seasons and numbers do not appear to have been influenced by the addition of LWD at Scholes Road.

European carp

Size distributions and contingency tables were European carp were calculated for all sites (Table 14; Figure 8; Figure 9; Figure 10). In general the numbers of European carp were low in all reaches and at all sampling times. The addition of LWD has had no impact (either positively or negatively) the numbers of European carp present.

Management Implications

- Many effects of the re-snagging are potentially being masked by the differences in fish communities within the 3 reaches of the river. There still remains no significant differences in fish communities between any of the treatments suggesting that re-snagging is not having an impact on fish communities within the Broken river.
- There is evidence that juvenile Murray Cod are utilizing the two re-snagged reaches below Casey's weir particularly at Burnell's Road and Pine Lodge road. The data indicates that the reach at Burnell's Road is providing habitat for Murray Cod. There is a consistent trend of increasing numbers of Murray Cod occurring over the 4 sampling seasons in all age classes less than 500 mm.
- The data from Pine Lodge road is less conclusive but is showing a similar pattern to Burnell's Road with increasing numbers of juvenile cod (<100mm) occurring across the four sampling seasons suggesting that Murray Cod are utilizing this habitat. However, it should be noted that there were also increases in the abundances of larger Murray Cod at Keats Road.

Table 11. Chi-squared contingency tables for Murray cod surveyed at each site

Reach	Year	Size (mm)				Total fish	value	df	P
		<100	101-250	251-500	>500				
Burnell's Rd (re-snagged)	2006-07	8	2	0	1	11	57.85	9	<0.001
	2007-08	1	14	4	0	19			
	2008-09	3	25	9	0	37			
	2009-10	31	8	9	0	48			
Goomalibee (low wood)	2006-07	2	0	2	0	4	10.79	9	0.291
	2007-08	0	3	8	1	12			
	2008-09	2	4	4	1	11			
	2009-10	2	0	2	1	5			
Quinns Rd (high wood)	2006-07	0	1	1	0	2	6.75	9	0.663
	2007-08	2	2	0	1	5			
	2008-09	1	1	2	1	5			
	2009-10	2	0	1	0	3			
Pine Lodge (re-snagged)	2006-07	1	1	1	0	3	6.69	4	0.153
	2007-08	0	0	0	0	0			
	2008-09	4	7	0	0	11			
	2009-10	7	2	2	0	11			
Keats Rd (low wood)	2006-07	1	1	1	0	3	10.26	9	0.330
	2007-08	1	0	4	1	6			
	2008-09	6	3	4	0	13			
	2009-10	5	11	10	1	27			
Cosgrove Rd (high wood)	2006-07	0	4	3	0	7	11.321	6	0.079
	2007-08	0	2	6	3	11			
	2008-09	0	1	6	0	7			
	2009-10	0	6	3	4	13			

Table 12. Chi-squared contingency tables for Carp-gudgeons surveyed at each site between Benalla and Casey's weir

Reach	Year	Size (mm)						Total fish	Value	df	p-value
		<10	11-20	21-30	31-40	41-50	>50				
Scholes Rd (re-snagged)	2006-07	0	9	12	12	9	3	45	81.73	12	<0.001
	2007-08	0	0	7	35	12	1	55			
	2008-09	0	0	2	6	22	0	30			
	2009-10	0	0	1	39	19	2	61			
Mokoan Park (low wood)	2006-07	0	7	64	19	3	4	97	199.10	12	<0.001
	2007-08	0	0	6	52	11	0	69			
	2008-09	0	0	0	13	34	0	47			
	2009-10	0	0	1	24	13	0	38			
Morago (high wood)	2006-07	0	0	10	12	5	0	27	62.82	9	<0.001
	2007-08	0	0	5	55	13	0	73			
	2008-09	0	0	1	5	23	1	30			
	2009-10	0	0	3	29	15	1	48			

Table 13. Chi-squared contingency tables for rainbow fish surveyed between Benalla and Casey's weir at each site

	Year	<10	11-20	21-30	31-40	41-50	>50	Total fish	Value	df	p-value
Scholes Rd (re-snagged)	2006-07	0	1	15	26	4	1	47	66.04	12	<0.001
	2007-08	0	1	3	8	12	6	30			
	2008-09	0	8	3	4	0	3	18			
	2009-10	0	0	6	13	9	4	32			
Mokoan Park (low wood)	2006-07	0	0	2	2	5	0	9	8.61	9	0.474
	2007-08	0	0	2	12	9	3	26			
	2008-09	0	0	2	5	4	0	11			
	2009-10	0	0	0	3	3	2	8			
Morago (high wood)	2006-07	0	1	3	3	3	1	11	15.16	12	0.233
	2007-08	0	2	0	1	3	0	6			
	2008-09	0	1	0	4	1	3	9			
	2009-10	0	0	1	1	3	3	8			

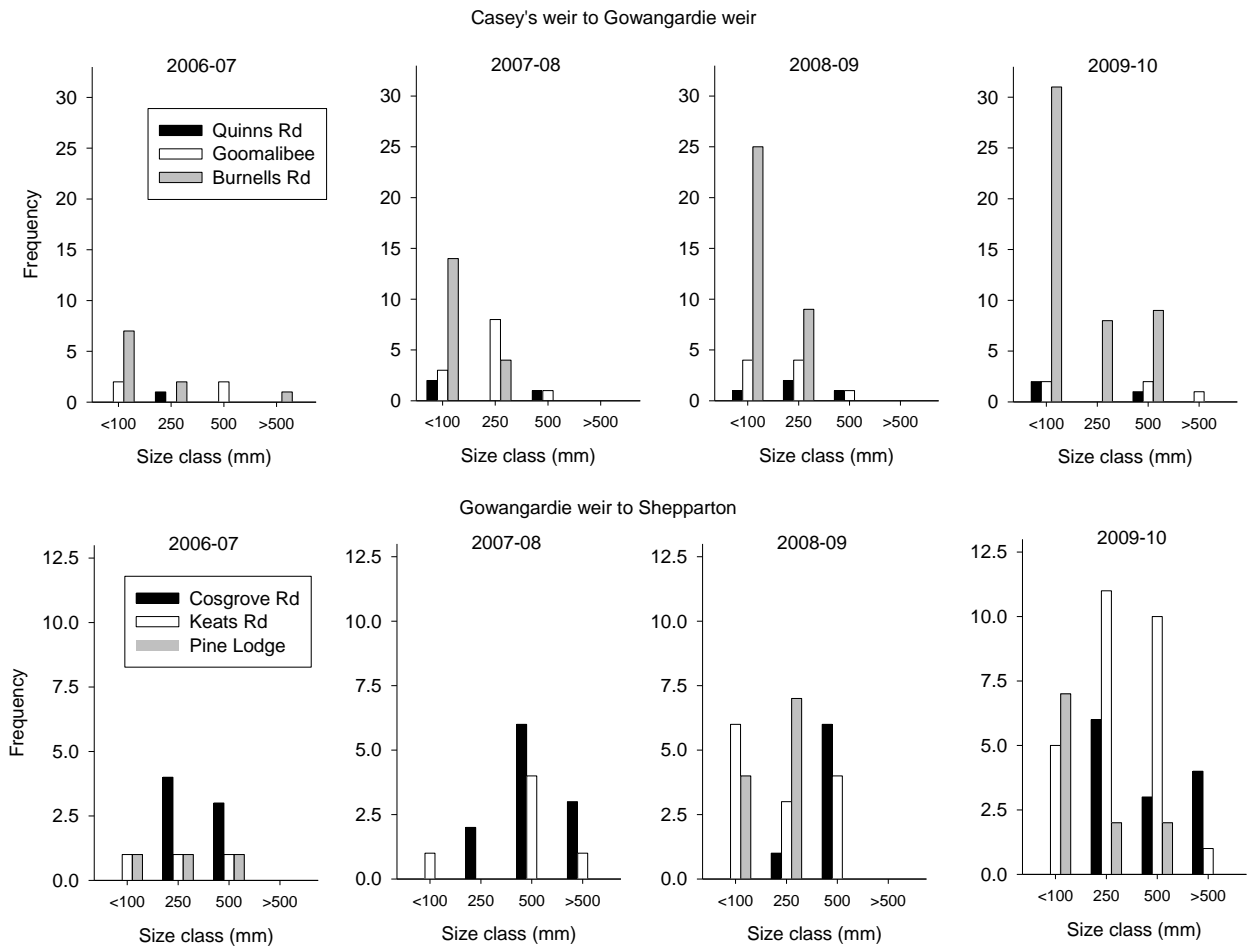


Figure 5. Size class distributions of Murray cod collected from reaches below Casey's weir during the summers of 2006-07, 2007-08, 2008-09 and 2009-10

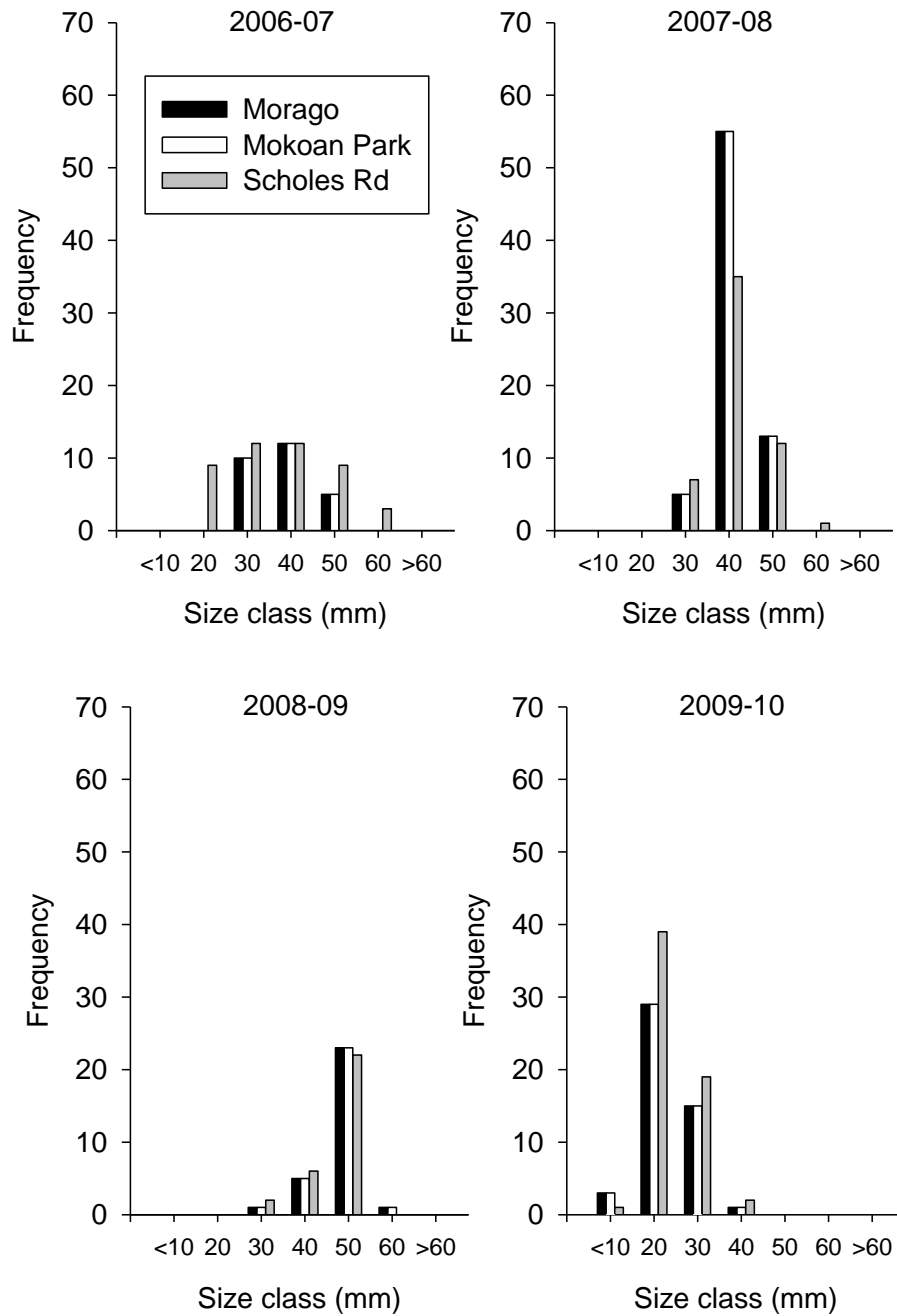


Figure 6. Size class distributions of Carp-gudgeons collected from reaches Benalla and Casey's weir during the summers of 2006-07, 2007-08, 2008-09 and 2009-10

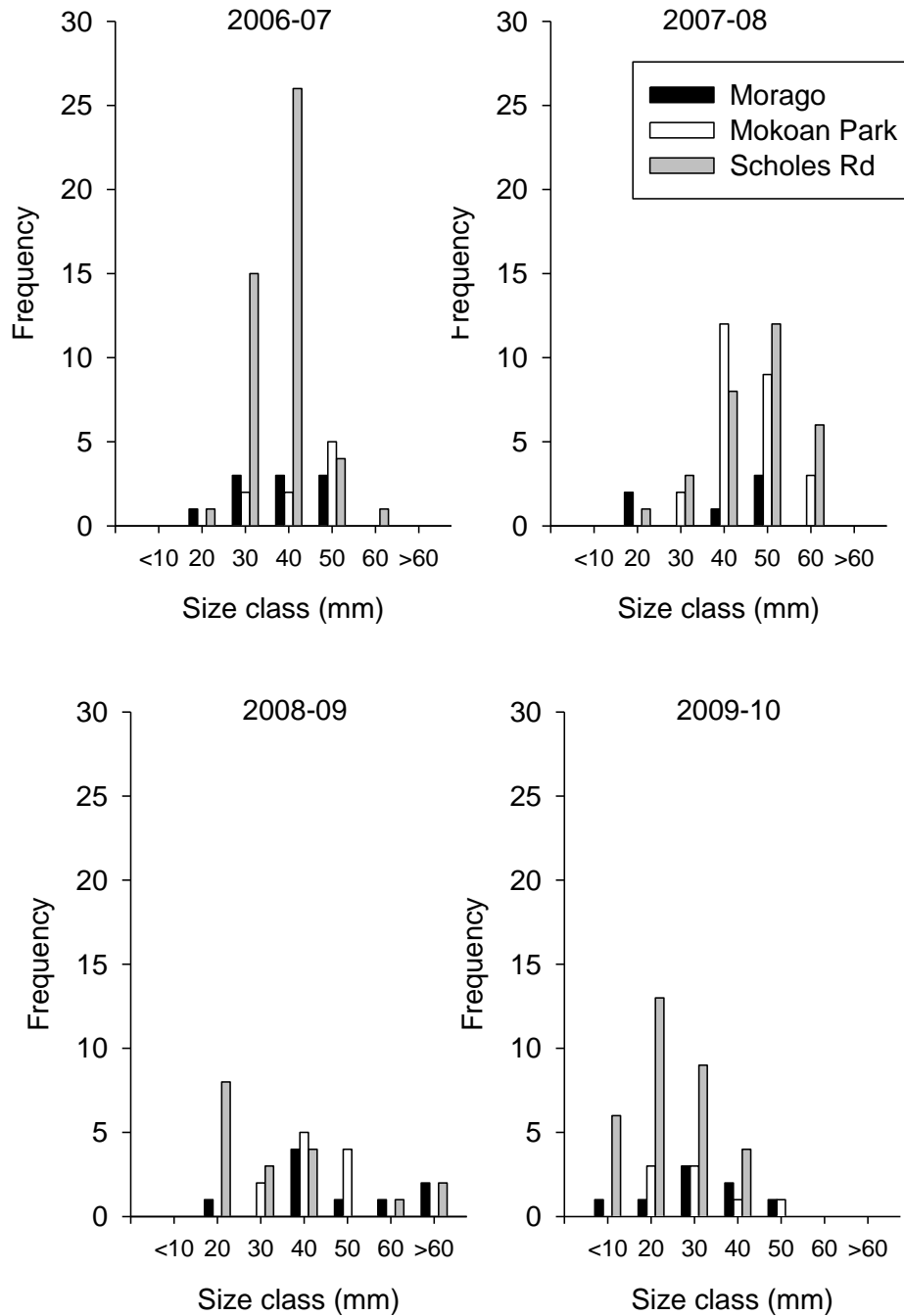


Figure 7. Size class distributions of Rainbow fish collected from reaches between Benalla and Casey's weir during the summers of 2006-07, 2007-08, 2008-09 and 2009-10

Table 14. Chi-squared contingency tables for European carp surveyed from all sites

Reach	Year	Size (mm)				Total fish	value	df	P
		<100	101-250	251-500	>500				
Burnells Rd (re-snagged)	2006-07	0	0	0	1	1	1.33	2	0.513
	2007-08	0	0	0	1	1			
	2008-09	0	1	0	1	2			
	2009-10	0	0	0	0	0			
Goomalibee (low wood)	2006-07	0	0	0	3	3	21.38	6	<0.050
	2007-08	3	0	0	5	8			
	2008-09	0	0	0	3	3			
	2009-10	13	2	0	0	15			
Quinns Rd (high wood)	2006-07	1	0	0	0	1	10.00	4	<0.050
	2007-08	0	0	0	0	0			
	2008-09	0	0	1	1	2			
	2009-10	7	0	0	0	7			
Pine Lodge (re-snagged)	2006-07	2	0	1	2	5	31.26	9	<0.001
	2007-08	2	1	3	0	6			
	2008-09	0	7	2	0	9			
	2009-10	6	0	6	0	12			
Keats Rd (low wood)	2006-07	0	0	1	1	2	10.48	9	0.313
	2007-08	2	0	3	0	5			
	2008-09	0	1	4	2	7			
	2009-10	0	0	5	2	7			
Cosgrove Rd (high wood)	2006-07	0	0	4	4	8	6.82	6	0.338
	2007-08	1	0	2	0	3			
	2008-09	0	0	2	2	4			
	2009-10	0	0	1	0	1			
Scholes Rd (re-snagged)	2006-07	17	0	0	0	17	31.61	6	<0.001
	2007-08	0	0	0	0	0			
	2008-09	2	0	1	1	4			
	2009-10	1	6	2	0	9			
Mokoan Park (low wood)	2006-07	21	0	1	1	23	23.37	9	<0.050
	2007-08	1	0	0	0	1			
	2008-09	1	0	0	1	2			
	2009-10	2	3	1	0	6			
Morago (high wood)	2006-07	25	1	0	4	30	24.03	9	<0.050
	2007-08	2	2	0	1	5			
	2008-09	0	0	0	1	1			
	2009-10	1	3	1	3	8			

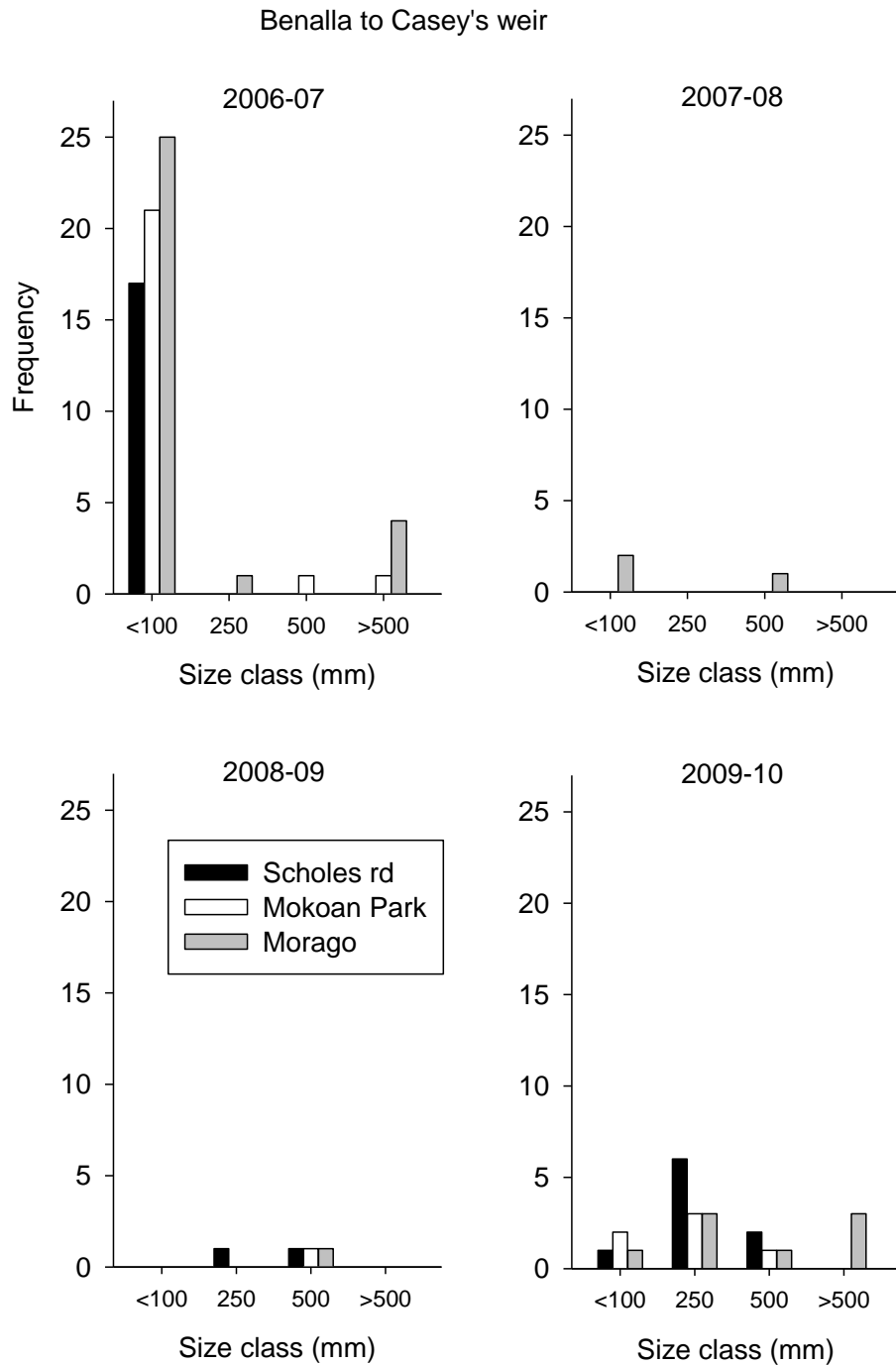


Figure 8. Size class distributions of European carp collected from reaches between Benalla and Casey's weir during the summers of 2006-07, 2007-08, 2008-09 and 2009-10

Gowangardie weir to Shepparton

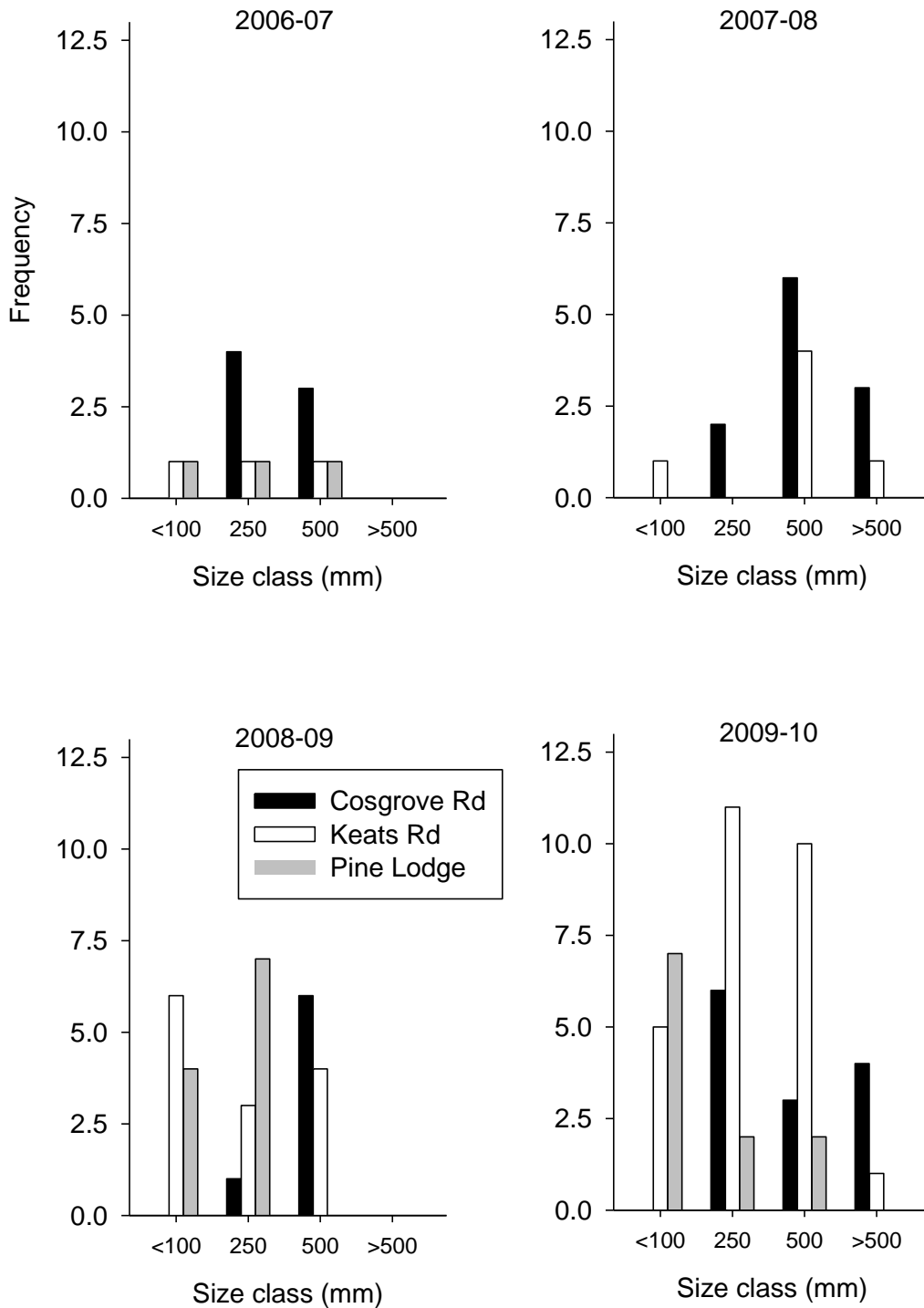


Figure 9. Size class distributions of European carp collected from reaches between Casey's weir and Gowangardie weir during the summers of 2006-07, 2007-08, 2008-09 and 2009-10

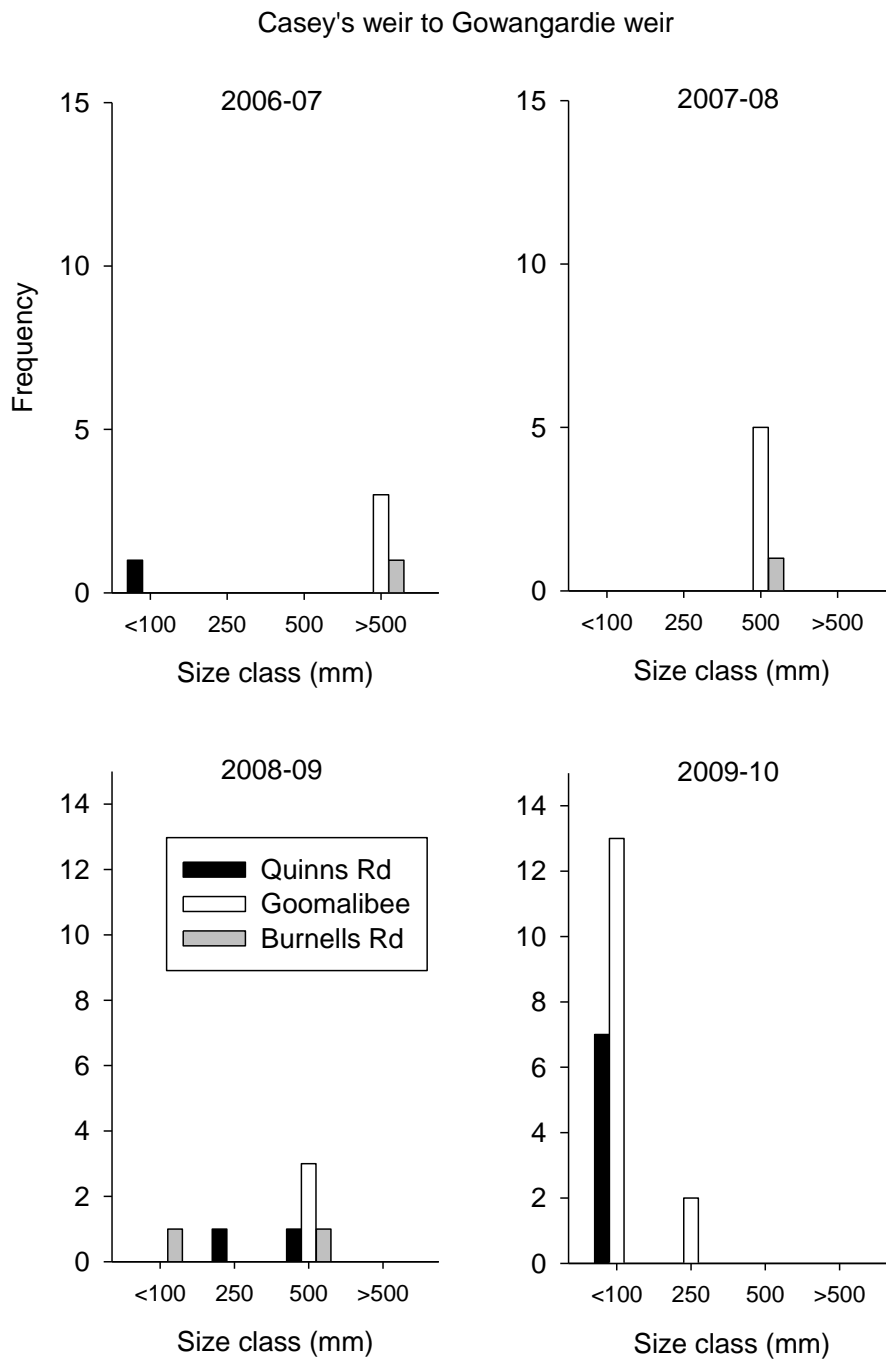


Figure 10. Size class distributions of European carp collected from reaches between Gowangardie weir and Shepparton during the summers of 2006-07, 2007-08, 2008-09 and 2009-10

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