Department of Sustainability and Environment

Assessment of the Freshwater Fish Community and Riverine Habitat in the Yarra River (with Reference to Macquarie perch, *Macquaria australasica*)

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Summary

This report summarises the results of a comprehensive fish survey of the freshwater reaches of the Yarra River. It provides a snapshot of the status of the fish community and the available aquatic habitat during a period of relatively low stream flow from January to March 2007. Forty three sites from immediately below Dights Falls to Millgrove were surveyed. The distribution patterns and habitat utilisation of important fish populations, such as Macquarie perch (*Macquaria australasica*), are described in more detail and future management research directions are discussed.

Considering the severity of catchment alteration, the aquatic habitat and riparian condition of the Yarra River is of a high standard and supports a diverse community of aquatic fauna. A total of 10,016 individuals, from 22 species of fish and two species of crayfish were recorded during the survey. The total fish catch was dominated by Australian smelt, roach (exotic), common galaxias and short-finned eels. Other species with high total abundances included Macquarie perch, common carp, redfin (exotic) and brown trout (exotic). The diversity of all fish species was highest at the two sites below Dights Falls with a number of species not found upstream, including the estuarine species black bream, blue spot goby, yellowfin goby (exotic), Australian bass, flat-headed gudgeon and tupong. The diversity of native species was also highest downstream of Dights Falls, and was consistently around 4-5 species up to the end of the Warrandyte Gorge reach, and declined in the upper reaches. Total fish abundance and abundance of natives was highly variable along the river, but consistently lower in the weir pool and lowland floodplain reaches.

While the fish community varied with the broad landscape zones along the river, the biggest influence on abundance and diversity of fish was the restricted fish passage caused by Dights Falls. An aggregation of migratory fish (common galaxias and short-finned eel) below, and an absence of other migratory species (spotted galaxias, broad-finned galaxias and Australian grayling) upstream of Dights Fals, is in part associated with the inability of these species to move upstream through the fishway during the low water conditions experienced in recent years. The absence of Australian grayling in this survey, although recently captured in other Yarra River surveys, may in part be due to the methods employed during the study, and therefore we suggest that a survey be conducted using targeted methodologies to determine the status of Australian grayling in the Yarra River.

The survey confirmed that a number of significant self-sustaining populations of native species occur in the Yarra River, particularly the nationally threatened species Macquarie perch and Murray cod. The population of Macquarie perch, although translocated into the Yarra River, now probably represents the most significant population in Victoria, and perhaps Australia. Macquarie perch were distributed over 130 km of the Yarra River from below Dights Falls to above Healesville in the upper reaches, and were positively associated with higher proportions of bedrock and vegetated banks. Macquarie perch and Murray cod were recorded in higher abundance in the Warrandyte gorge reach where there was an abundance of rock, wood and submerged macrophyte cover. This reach also contained the best quality riparian zone along the river. Over 60 % of Macquarie perch were found in the Warrandyte Gorge, where they were mainly caught in moderately deep water (0.5 -1.5 m) below riffles and cascades. In comparison, very low numbers of Macquarie perch in the upper floodplain section of the river which corresponded with an increase in shallow run and riffle habitats, an increase in silt and sand substrata, reduced habitat cover and greater abundances of exotic predatory species (brown trout and redfin). Habitat quality improves in the upland reach of the Yarra River and this would be more suitable to Macquarie perch.

The absence of Macquarie perch in the upland reaches is most likely to be due to the barrier created by degraded habitat downstream in the upper floodplain section and to the effects of exotic species, particularly brown trout and redfin.

Exotic fish represented only 29% of the total abundance of fish, less than half of the species diversity and dominated the catch at only eight sites. The Dights Falls weir pool was dominated by common carp, gambusia and oriental weatherloach. Roach were the most abundant exotic species captured in the survey, and dominated the fish community in the Warrandyte reach. Redfin and brown trout were found to be more prevalent in the upper reaches of the catchment (upstream of Healesville), where they were likely to represent a significant threat to smaller native species such as mountain galaxias, juvenile river blackfish and Macquarie perch.

A high standard of riparian vegetation, instream habitat and sustained minimum environmental flows has provided an abundance and diversity of aquatic habitat in the river. Throughout the River, it was found that fluctuations in the quality of the riverine habitat influenced the diversity and abundance of fish that occur in the different reaches. A high diversity and abundance of native species was found in the Warrandyte reach due to the improved quality and abundance in instream habitat and riparian cover. In contrast, a decline in the overall quality of riverine habitat upstream of Warrandyte Gorge, associated with a decline in riparian cover and instream habitat diversity and deposition of fine sediment, resulted in a decline in species diversity.

This study identified a number of future research requirements and management recommendations, including:

1. There is a need to assess and remedy the effectiveness of the Dights Falls fishway, particularly during low flow conditions.
2. Considering the importance and quality of instream habitat and the native fish community of the Yarra River, targeted research should be conducted on the flow and habitat requirements of key species (eg. Macquarie perch, Australian grayling, common galaxias) at all life stages to improve the management of environmental flows and habitat within the River.
3. Targeted surveys should be conducted to determine the status of Australian grayling in the Yarra River system.
4. Investigations should be conducted into the sources and possible remediation of the increased sedimentation observed in the mainstem River and its ecological effects on instream fauna.
5. Surveys should be conducted to determine the association of native and exotic fish and macroinvertebrates with dense waterweed. Research should also be conducted to investigate potential control options for the waterweed.
6. As the Yarra River has an abundant and healthy Macquarie perch population, further ecological research should be conducted on this population to better inform the conservation of this species in this catchment and also to guide management of the existing remnant populations throughout its natural range.
7. Given the national significance of the Yarra River Macquarie perch population, further consideration should be given to the overall management of the population, including: a public awareness campaign to educate local and regional managers of the significance of the population, and a review of the current fishing regulations and

fisheries management in the Yarra River should be conducted. Additionally, in areas of the River where Macquarie perch are not present, but that contain bedrock, increasing the amount of native riparian cover through targeted tree plantings and reservation of land should be encouraged to eventually increase the abundance of perch.

8. This study was designed in a repeatable manner, and regular assessments of the fish communities in Yarra River, preferably following a period of good spring and summer rainfall, would provide important information regarding trends in the fish community and river health, and also provide empirical support for any restoration activities undertaken in the system.

1 Introduction

The Yarra River drains a catchment of 3,766 km^2, of which 703 km^2 are in protected high altitude, forested, sub-catchments impounded for Melbourne's water supply (Walsh *et al.* 2007). However, most of the floodplain vegetation in the lower reaches has been cleared for agriculture and human living. The main landuse in the catchment is agriculture, including market gardens, vineyards and cattle grazing. Importantly about 500km^2 of the catchment is heavily urbanized (Walsh *et al.* 2007). Despite its proximity to a major population centre, the River supports an abundant and unique fish assemblage consisting of native, translocated (ie. native species that have established outside of their natural range) and exotic species.

The management of the overall health of the Yarra River is currently a topical issue and is the focus of a number of management strategies concentrating on environmental flows, water quality and recreational use. What has been lacking in many of these strategies is a demonstrated understanding of how the proposed management scenarios would impact the freshwater fish communities in the Yarra River. This omission is largely due to a lack of recent comprehensive fish surveys.

1.1 Project objectives

The main aim of this study was to assess the current status of the freshwater fish community and riverine habitat conditions of the Yarra River between Dights Falls to Warburton, to help guide future management of the river. The overall objectives of this survey were to:

- document the distribution and relative abundance of the fish communities in the Yarra River from Dights Falls to Warburton
- assess the presence of in-stream and riparian habitat features in relation to occurrence of key fish species such as Macquarie perch
- identify and assess potential risks to native fish species and key habitat features in the Yarra River
- make recommendations for short and long-term research, monitoring and management

1.2 Background Information

1.2.1 Previous fish surveys

Considering the importance of the River and its proximity to Melbourne, comparatively few studies have investigated the fish community in the Yarra River. The majority of fish surveys have been conducted from 10 to more than 20 years ago (1985, 1992-1998) and have been opportunistic and of limited spatial context (see Aquatic Fauna Database DEPARTMENT OF SUSTAINABILITY AND ENVIRONMENT 2007). More recently, Zampatti *et al.* (2003) conducted frequent assessments of the Dights Falls fishway in 2001 and 2002, and limited surveys

were conducted from Warrandyte to Wonga Park in 2003 and 2004 (Ryan and O'Mahony 2004).

Nineteen native freshwater fish species have been recorded in the Yarra River system since 1970 (DEPARTMENT OF SUSTAINABILITY AND ENVIRONMENT 2007, Zampatti *et al.* 2003) (Table 1). Native species previously found to be abundant and widespread include common species such as short-finned eel (*Anguilla australis*), common galaxias (*Galaxias maculatus*) and Australian smelt (*Retropinna semoni*). Species found in lower abundance but in all river reaches include short headed lamprey (*Mordacia mordax*) and Australian grayling (*Prototroctes maraena*). Other species appear to have a more limited distribution such as broad-finned galaxias (*Galaxias brevipinnis*), spotted galaxias (*Galaxias truttaceus*), Australian mudfish (*Neochanna cleaveri*), flat-headed gudgeon (*Philypnodon grandiceps*) and tupong (*Pseudaphritis urvillii*), being found mostly in the lower reaches near Dights Falls.

Species found further upstream include river blackfish (*Gadopsis marmoratus*), Murray cod (*Maccullochella peelii peelii*), Macquarie perch (*Macquaria australasica*) and freshwater catfish (*Tandanus tandanus*). Only two angler records were recorded for freshwater catfish in the middle reaches of the Yarra River, indicating a relatively low abundance. Golden perch (*Macquaria ambigua*) have only been recorded from below Dights Falls to Warrandyte. There has only been one recorded capture of a single Australian mudfish in 1991.

The majority of the native freshwater fish species recorded in the lower reaches of the Yarra River have a diadromous life cycle and migrate between freshwater, estuarine and marine habitats. Two other fish species (golden perch and Murray cod) are known to make potamodromous migrations solely within freshwater habitat (Table 1). Five of the native species recorded in the Yarra River (Australian bass, golden perch, Murray cod, Macquarie perch, freshwater catfish) are not indigenous to the river and have been translocated from other river systems in the early 1900's (Table 1).

Five of the fish species recorded in the Yarra River since 1970 have state and national conservation significance, including Australian grayling, Australian mudfish, Macquarie perch, freshwater catfish and Murray cod. All five species are listed and protected under the *Victorian Flora and Fauna Guarantee (FFG) Act 1988*. Additionally, Macquarie perch and Murray cod are considered 'endangered' nationally, Australian grayling are considered 'vulnerable' nationally and all are protected under the *Commonwealth Environment Protection and Biodiversity Conservation (EPBC) Act 1999*.

Eight exotic species have been previously recorded in the freshwater reaches of the Yarra River, with most species recorded to be in relatively high abundances and are widely distributed throughout the catchment (Table 1). Brown trout, a popular angling species, were regularly stocked into the Yarra River from 1987 to 1996, including 30,000 fingerlings at Launching Place from 1987 to 1989, approximately 30,000 at Eltham and Studley Park from 1989 to 1992 and a further 16,000 below Eltham from 1993 to 1996 (DEPARTMENT OF PRIMARY INDUSTRIES 2007).

A number of estuarine species have also been previously recorded downstream of Dights Falls, including 16 native species and one exotic species. The yellowfin goby (*Acanthogobius flavimanus)* has been recently introduced into the Yarra from Asia, and has been recorded from below Dights Falls to the Yarra River mouth (Zampatti *et al.* 2003).

Table 1. Fish species and broad scale distribution in the Yarra River based on previous surveys (DEPARTMENT OF SUSTAINABILITY AND ENVIRONMENT 2007).

Native freshwater species		Downstream of Dights Falls	Dights Falls to Warrandyte	Upstream of Warrandyte
Short-finned eel [D]	*Anguilla australis*	■	■	■
River blackfish	*Gadopsis marmoratus*		■	■
Broad-finned galaxias [D]	*Galaxias brevipinnis*	■		
Common galaxias [D]	*Galaxias maculatus*	■	■	■
Mountain galaxias	*Galaxias olidus*			■
Spotted galaxias [D]	*Galaxias truttaceus*	■		
Pouched lamprey [D]	*Geotria australis*	■		■
Murray cod [P T]	*Maccullochella peelii peelii*		■	■
Golden perch [P T]	*Macquaria ambigua*	■	■	
Macquarie perch [T]	*Macquaria australasica*		■	■
Australian bass [D T]	*Macquaria novemaculeata*	■	■	
Short-headed lamprey [D]	*Mordacia mordax*	■	■	■
Southern pygmy perch	*Nannoperca australis*		■	■
Australian mudfish [D]	*Neochanna cleaveri*	■		
Flat-headed gudgeon	*Philypnodon grandiceps*	■		
Australian grayling [D]	*Prototroctes maraena*	■	■	■
Tupong [D]	*Pseudaphritis urvillii*	■		
Australian smelt	*Retropinna semoni*	■	■	■
Freshwater catfish [T]	*Tandanus tandanus*		■	■
Exotic species				
Goldfish	*Carassius auratus*	■	■	■
Carp	*Cyprinus carpio*	■	■	■
Eastern gambusia	*Gambusia holbrooki*	■	■	■
Oriental weatherloach	*Misgurnus anguillicaudatus*	■	■	■
Rainbow trout	*Oncorhynchus mykiss*	■	■	■
Redfin	*Perca fluviatilis*	■	■	■
Roach	*Rutilus rutilus*	■	■	■
Brown trout	*Salmo trutta*	■	■	■
Yellowfin goby	*Acanthogobious flavimanus*	■		
Native estuarine species				
Black bream	*Acanthopagrus butcheri*	■		
Yellow-eye mullet	*Aldrichetta forsteri*	■		
Bridled goby	*Arenigobius bifrenatus*	■		
Mulloway	*Argyrosomus hololepidotus*	■		
Australian salmon	*Arripis spp.**	■		
Small-mouthed hardyhead	*Atherinosoma microstoma*	■		
Australian anchovy	*Engraulis australis*	■		
Tamar River goby	*Favonigobius tamarensis*	■		
Glass goby	*Gobiopterus semivestitus*	■		
Sea mullet	*Mugil cephalus*	■		
Sand flathead	*Platycephalus bassensis*	■		
Silver trevally	*Pseudocaranx dentex*	■		
Blue spot goby	*Pseudogobius olorum*	■		
Greenback flounder	*Rhombosolea tapirina*	■		
Pilchard	*Sardinops neopilchardus*	■		
Lagoon goby	*Tasmanogobius sp. 2*	■		

[D –] Diadromous native species, [T –] Translocated native species, [P –] Potamodromous native fish, * - unsure if record is western or eastern Australian Salmon. Grey squares indicates previously recorded

1.2.2 Importance of investigating Macquarie perch in the Yarra River

Macquarie perch are a medium-sized native fish that naturally occur throughout the southern Murray-Darling Basin, and in some coastal catchments in New South Wales (McDowall 1996). Macquarie perch were once abundant in Victoria and were a highly sought after angling species. However, by the 1970's they had undergone a serious decline in both range and abundance. Habitat degradation and the various effects of river regulation are thought to have contributed to these declines (Cadwallader 1981, Appleford *et al.* 1998). The species is now listed as 'endangered' nationally and 'threatened' in Victoria (Table 2).

In Victoria, only three self-sustaining populations are known to exist including Lake Dartmouth and its tributaries, the Goulburn/Broken catchment and the translocated Yarra River population. The Lake Dartmouth population has been noted as under serious decline (Douglas *et al.* 2002) and the Goulburn-Broken River population has recently been observed to be fragmented and vulnerable to the impacts of prolonged low flow periods (J. Pritchard, personal communication, NSW DEPARTMENT OF PRIMARY INDUSTRIES Fisheries, 2007).

Macquarie perch were first translocated from the Goulburn River catchment to the Yarra River between 1912 and the 1940's (Cadwallader 1981). The current Yarra River population of Macquarie perch appears to be self-sustaining (Ryan and O'Mahony 2004), and probably represents the strongest population of the species remaining in Victoria. The success of the Yarra population provides a unique opportunity to gain a better understanding of the biological requirements of Macquarie perch, which will inturn improve our ability to manage the remnant riverine populations in the Yarra River and across its current distribution.

Table 2. Conservation status of Macquarie perch.

Government	Conservation Status	Reference
Federal	Endangered	*Environment Protection and Biodiversity Conservation Act 1999*
	Endangered	ASFB 2004
Victoria	Threatened	*Flora and Fauna Guarantee Act 1988*
	Endangered	DEPARTMENT OF SUSTAINABILITY AND ENVIRONMENT 2003
New South Wales	Vulnerable	*Fisheries Management Act 1994*
ACT	Endangered	*Nature Conservation Act 1980*
International	Endangered	IUCN Redlist (IUCN 2007)

2 Methods

2.1 Study area

The study was conducted across approximately 150 km of the Yarra River, beginning immediately below Dights falls and ending just downstream from the township of Warburton (Figure 2). This study reach included a range of habitat types and geologies including undulating lowland floodplain river, incised midway by one large gorge (Warrandyte Gorge) and two smaller gorges (Yering and Healesville Gorges) and a rocky upland reach near Warburton.

The lowland floodplain section of the Yarra River begins just upstream of the Little Yarra River (Figure 2), after which the floodplain widens to 0.8 to 1.5km. This floodplain section continues approximately 80 km to the Warrandyte Gorge section, only interrupted by two small gorges at Healesville and Yering. Through the gorge section, the river has predominantly steep banks with very little floodplain for approximately 28 km, and is surrounded by low-density residential landuse and forested riparian reserves. As the river flows towards Melbourne, it widens and is merged by a number of different tributaries. The riparian floodplains in this region are mostly reserved as parkland and have intermittent forest cover (Walsh *et al.* 2007).

2.2 Stream discharge

Average daily discharge information over the last seven years (supplied by Melbourne Water) was selected from gauging sites at Warburton, Millgrove, Yarra Glen, Warrandyte, Templestowe and Chandler Highway (Figure 1). Overall stream discharge increases downstream with contributions from major tributaries such as the Little Yarra River, Woori Yallock Creek, Hoddles Creek, Mullum Mullum Creek, Diamond Creek and Plenty River. For example, the maximum peak flow in spring 2000 was 2,834 ML/day at Warburton and increased downstream to 3,209 ML/day at Millgrove, 9,099 ML/day at Yarra Glen, 7,648 ML/day at Warrandyte, 7,849 ML/day at Templestowe and 12,773 ML/day at the Chandler Highway. Similar peak flows in winter and spring were observed in subsequent years from 2001 to 2005. During the last seven years, 2004 was the wettest year with peak flows of 2,414 ML/day at Millgrove to 17,893 ML/day at the Chandler Highway, and average flows of 305 ML/day at Millgrove and 1,390 ML/day at the Chandler Highway.

However, another notable feature of the flow record of the last seven years is the predominance of low flows, and the lack of significant spring and summer flow spikes during 2006 and 2007. Yarra River discharge in 2006 and 2007 has been the lowest for sometime (at least since 1990), due to the continued drought condition across south-eastern Australia. Notably, there appears to be a distinct lack of flushing flows since March 2005.

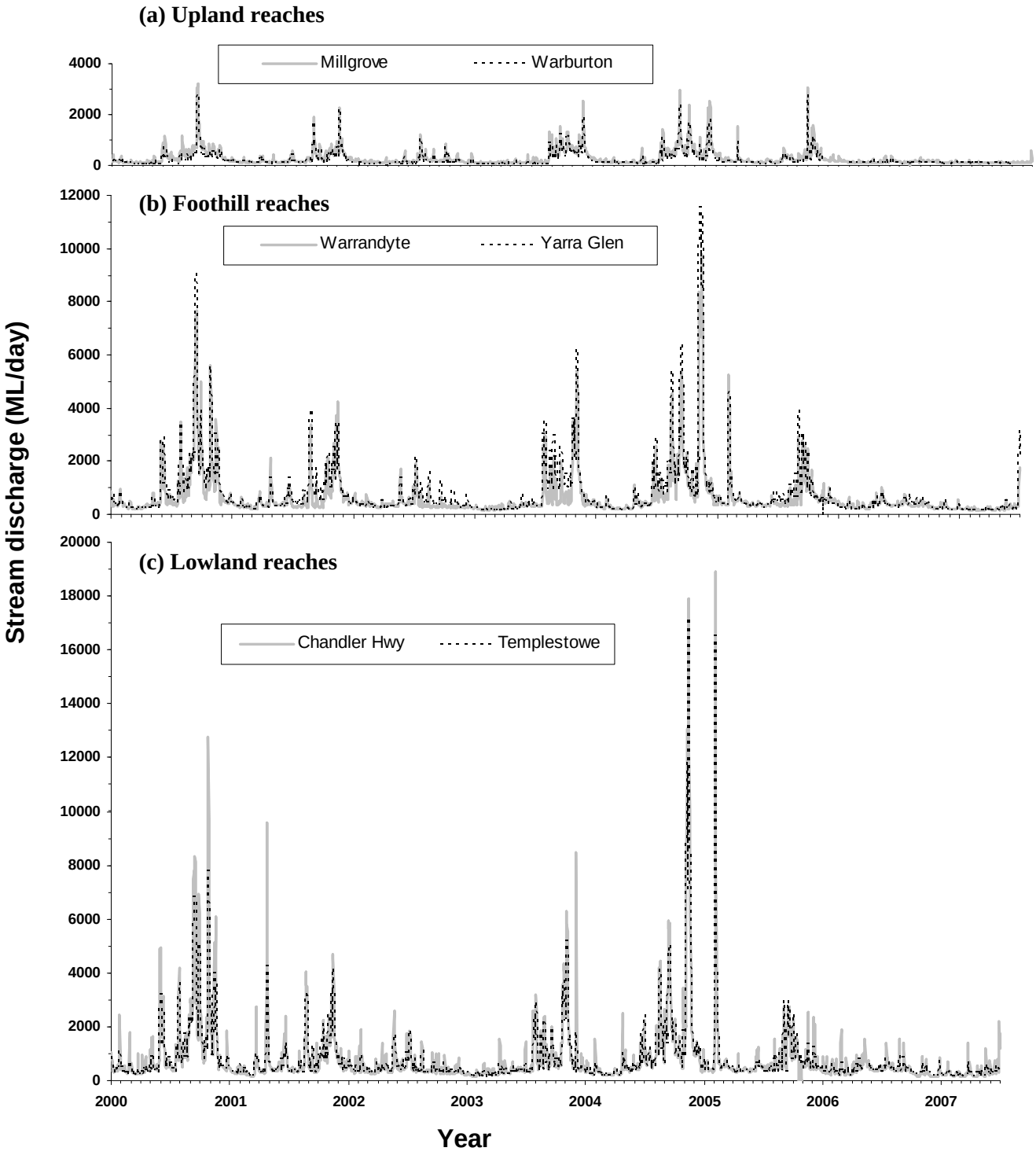


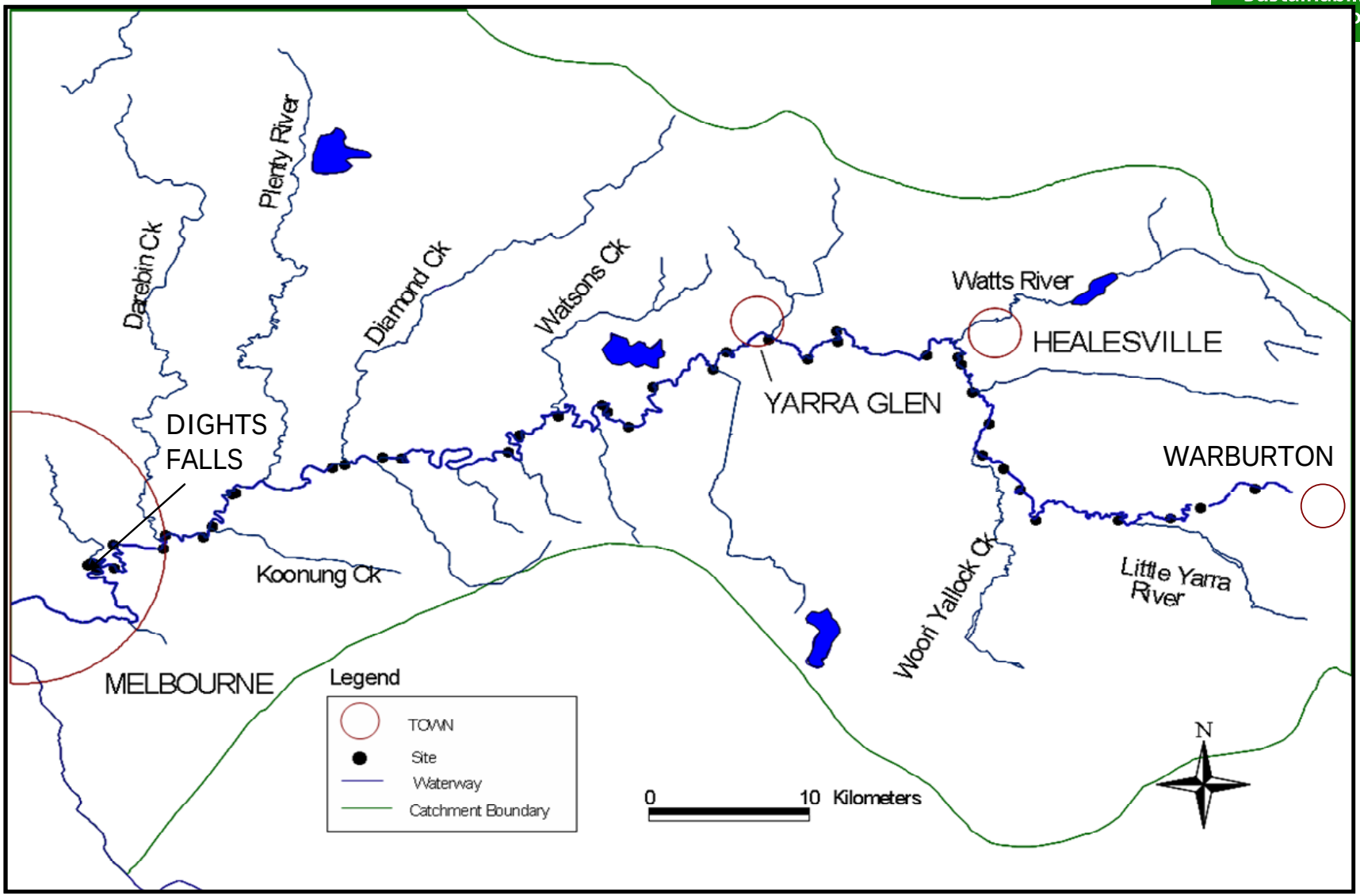
Figure 1. Average daily discharge of gauging sites on the Yarra River (January 2000 to June 2007). Note different y-axis scales. Plots include: (a) Upland reaches at Warburton (black dashed line) and Millgrove (grey solid line); (b) Foothill reaches at Yarra Glen (black dashed line) and Warrandyte (grey solid line) and (c) Lowland reaches at Templestowe (black dashed line) and the Chandler Highway at Alphington (grey solid line).

2.3 Site selection

The primary aim of the site selection process was to encompass as much of the sample reach, and to include as many different habitat zones, as possible. A total of 43 sites were sampled from below Dights Falls to Millgrove (Table 3, Figure 2). Sites were selected using information from previous surveys such as fish surveys near Warrandyte by Ryan and O'Mahony (2004) and a number of known access points used in a broad-scale macroinvertebrate study by Walsh *et al.* (2007). Additional sites were selected in areas where data was lacking, resulting in a preliminary final list of approximately 50 sites. These sites were then ground-truthed for boat launching access and safety considerations and the final 43 were chosen. All sites were accessed through private property, local Council and/or through Parks Victoria managed properties.

Where possible, sites were spaced along the river at regular intervals and spread over the survey reach with an average distance between sites of approximately 3.5 km. Accessibility to the river was a restricting factor and in some cases once a single boat launch was located, a number of sites were accessed by boating upstream and downstream from this point. Interactive helicopter aerial footage of the Yarra River (supplied by Melbourne Water) was used to assess whether the sites selected in that particular reach were representative of the habitat available in that reach. In most cases, all reaches were adequately represented by the sites chosen. However, the Healesville Gorge was not able to be sampled due to difficult access and is not represented in the survey sites.

Broad landscape types were distinguished along the River using both observations during site visits and by reviewing relevant literature on the Yarra River. For this study, the Yarra River was therefore categorised into: lowland (below Dights Falls), weir pool (above Dights Falls), lowland floodplain, gorges (Warrandyte Gorge and Yering Gorge), midland floodplain, upland floodplain and upland (Table 3). These seven broad zones were then used to compare fish communities and habitat characteristics across landscapes.



Produced by Freshwater Ecology, Arthur Rylah Research Institute

Figure 2. Map of the Yarra River survey area showing sampling sites, tributaries, major towns and gorges.

Table 3. Site details for Yarra River fish survey 2007.

Site No.	Location	Easting (GDA 94)	Northing (GDA 94)	Zone
1	500m below Dights Falls	324368	5814344	Lowland
2	Just below Dights Falls	323900	5814800	Lowland
3	Above Dights Falls	324073	5814797	Weir pool
4	1.5 km above Dights Falls	325222	5814485	Weir pool
5	Fairfield boathouse - upstream	325122	5816107	Weir pool
6	La Trobe Golf Club, Alphington	327578	5815854	Lowland floodplain
7	Darebin creek to Wilsons Reserve	327462	5816195	Lowland floodplain
8	Burke road to 500m upstream	329560	5816655	Lowland floodplain
9	Yarra Flats Park - upstream	329968	5817383	Lowland floodplain
10	Footy oval in Warringal Parklands	330939	5819546	Lowland floodplain
11	Plymouth St - downstream	331135	5819656	Lowland floodplain
12	Finns Reserve, Templestowe	333621	5819670	Lowland floodplain
13	Upstream of Fitzsimmons Bridge	335834	5821356	Lowland floodplain
14	Below Griffin Park	336459	5821558	Lowland floodplain
15	Reynolds Road, Templestowe	338324	5822090	Warrandyte Gorge
16	Alexander Road access, downstream	339282	5822013	Warrandyte Gorge
17	Alexander Road access, upstream	339602	5822294	Warrandyte Gorge
18	Black Flat Reserve	344540	5822525	Warrandyte Gorge
19	Jumping Creek Reserve	345167	5823818	Warrandyte Gorge
20	Private property off Oxley Road	347112	5825164	Warrandyte Gorge
21	Wonga Park	349163	5825772	Warrandyte Gorge
22	Lower Homestead Road, downstream	349400	5825300	Warrandyte Gorge
23	Lower Homestead Road, upstream	350472	5824317	Midland floodplain
24	'Windsor Park', Yering Gorge	351630	5827001	Yering Gorge
25	Tarcoola, downstream	354584	5828248	Midland floodplain
26	Tarcoola, upstream	355232	5829413	Midland floodplain
27	Yarra Glen Showgrounds, upstream	357348	5830348	Midland floodplain
28	Tarrawarra Road, downstream	359247	5829047	Midland floodplain
29	Tarrawarra Road	360721	5830206	Midland floodplain
30	Tarrawarra Road, upstream	360643	5830954	Midland floodplain
31	Yarra Grange, upstream	362300	5829389	Midland floodplain
32	Maroondah Hwy, downstream	366748	5829269	Midland floodplain
33	Maroondah Hwy bridge, upstream	366889	5828772	Midland floodplain
34	Private property off Hexam Road	367444	5826915	Upland floodplain
35	'Eyton on Yarra', downstream	368327	5824872	Upland floodplain
36	'Eyton on Yarra', upstream	367998	5822743	Upland floodplain
37	Private property 'Binalong'	369090	5821897	Upland floodplain
38	Private property 'Congelton'	369911	5820517	Upland floodplain
39	Healesville-Koo Wee Rup Road	370731	5818500	Upland floodplain
40	Private property - Gary Pie	374826	5818613	Upland floodplain
41	Doonside Caravan Park	377384	5818783	Upland
42	Station Road bridge	378895	5819493	Upland
43	River Road, Millgrove	381571	5820799	Upland

2.4 Fish sampling

Fish surveys were undertaken from mid-January to late March 2007, during record low summer flows and water clarity, which aided sampling effort. All sites were sampled using electrofishing and 11 sites were also sampled using fyke nets.

A standardised sampling regime was used to ensure that survey techniques were repeatable and comparable between sites. Sampling techniques were adapted from the current methodology used for the nationally accredited Sustainable Rivers Audit (SRA) (MDBC 2004). The methods used have been found to be very effective in sampling fish communities (Growns *et al.* 1996). However, it is not always a reliable method to target specific species such as fast swimming Australian grayling.

Single-pass electrofishing was conducted in all habitats within the river channel. The electrofishing effort included 12 x 90 second "on-time" shots per site with a medium electrofishing boat (Smith-Root® Model 5 GPP) or 150 second "on-time" shots with a backpack electrofisher unit (Smith-Root® Model 12). The boat electrofishing settings varied from 500 to 1000 volts, 120 pulses per second, duty-cycle 40-60% of range and 5 to 8 amps, and the backpack electrofisher settings consisted of 500 to 1000 volts, 120 pulses per second and 1 to 1.2 amps. At five sites, pool size restricted the use of the boat electrosfishing unit, and backpack electrofishing was used to make-up the remaining effort at that site. Four of these sites were in the upper section of the river, and backpack electrofishing was also undertaken directly below Dights Falls, as a boat was unable to negotiate the shallow riffle zone 100 m downstream.

After capture, all fish collected were identified, measured to total length (or fork length for species with forked caudal fins) and released at the capture location. Where large numbers of fish were collected, sub-samples of 20 fish were measured. Counts were also made of fish observed and not captured during the survey. Due to the difficulty and potential damage caused by prolonged handling, lengths of short-finned eels were only estimated. The larger native species caught, including all Macquarie perch and Murray cod over 250 mm total length, were externally tagged with uniquely numbered dart tags (Hall tags®) between the first and second dorsal spines, before release. Tag recapture information is directed to the toll free number and answering service at ARI. The collection of this information will provide data on the movement, angler capture information and growth of these species in the future.

2.5 Habitat information

Habitat data was collected within each site to gain an understanding of the variation in habitat along the length of the Yarra River and how fish communities respond to those variations. Habitat variables were collected at each individual electrofishing operation (twelve per site) and included: depth; stream flow; channel width; channel type; riparian bank cover, composition of native and exotic species and width; substrate characteristics; instream habitat type; and bank type (Table 4). Water quality was assessed at each site using a TPS (FL 90) multiprobe water quality unit to measure temperature (°C), pH, electrical conductivity (uS/cm), dissolved oxygen (mg/L) and turbidity (NTU).

Table 4. Habitat variables recorded at each replicate sample (shot) at each site.

Habitat variable	Unit
Wetted area	
Mean depth	m
Max depth	m
Velocity	Fast (3), medium (2), slow (1)
wetted width	m
riffle	%
run	%
pool	%
backwater	%
Substrate composition	
Clay	%
silt	%
sand	%
gravel	%
pebble	%
cobble	%
rock	%
bedrock	%
Instream habitat (expressed as a rank of abundance, 1 – Abundant (>90%), 2 – Frequent (50 to 90%), 3 – Occasional (10 to 50%), 4 - Rare (>10%) and Absent (0%))	
undercut bank	0, 1, 2, 3, 4
emergent macrophytes	0, 1, 2, 3, 4
submerged macrophytes	0, 1, 2, 3, 4
rock cover	0, 1, 2, 3, 4
root mass	0, 1, 2, 3, 4
small woody debris	0, 1, 2, 3, 4
large wood debris	0, 1, 2, 3, 4
Riparian vegetation	
Overhead vegetation	% (Expressed as % of wetted surface of river)
Riparian vegetation	%
Riparian vegetation - native	%
Riparian vegetation - exotic	%
Riparian vegetation mean width	m
Rocky bank	%
Steep bank (gorge) (>10m)	%
Flat bank (<10m)	%
Bare (eroded or beach)	%

2.6 Data analysis

Total catch data from each sample (shot) within a site were combined to describe the fish community assemblage at each of the 43 survey sites. A range of assessment techniques were used to address the survey objectives, including:

- collation and description of general fish data
- distribution and abundance maps based on site locations and river zones
- proportional assessment of native and exotic species captured
- assessment of multiple age classes for key species
- comparisons of fish catch and available habitat
- multivariate analysis to determine fish community structure and related habitat variables

Non-metric multidimensional scaling (NMDS) was performed separately on both the fish and habitat data to describe changes in the fish community structure and available habitat throughout the survey reach. The total abundance of each species per site was log (x+1) transformed, and a Bray-Curtis similarity matrix constructed before NMDS was performed. A euclidean distance similarity matrix was constructed from the untransformed habitat and water quality dataset per site before NMDS was performed. Following NMDS for both datasets, one way ANOSIM's were conducted to test among reach differences, based on 999 permutations. SIMPER analysis was also conducted to determine which species and habitat variables best described the predefined groups, with the species and habitat variables that contributed more than 10% of the within group similarity said to define that group. NMDS and other associated multivariate statistics were conducted using the statistical package Primer (Clarke and Warwick 2001).

To explore which habitat variables influenced the occurrence and abundance of the fish community, fish CPUE data were also subject to redundancy analysis (RDA), a multivariate analysis where the matrix ordination of fish densities was regressed with an ordination of environmental variables. All variables were standardized by subtracting column means and then dividing by the column standard deviation (after centering). Rather than fit all possible environmental variables in the analysis, a series of models were fitted by grouping environmental variables into logical groupings (eg. water flow variables, stream bank characteristics, stream bed characteristics, water chemistry and instream cover. The explanatory power of each model grouping was calculated as the percentage of the inertia (redundancy) explained by the constraining variables, compared with the unconstrained variables (all the other variables). The significance of any particular variable used in the constraints was estimated using F ratio statistics calculated using Monte-Carlo techniques (using 500 permutations).

3 Results

A total of 10,016 individuals, from 22 species of fish and two species of crayfish were recorded during the survey (Table 5). The total fish catch was dominated by Australian smelt, roach, common galaxias and short-finned eels. Other species with high total abundances included Macquarie perch, common carp, redfin and brown trout. The remaining fish species were captured in low abundances, with most representing less than 1% of the total catch. A summary of the fish captured using electrofishing techniques at each site is provided in Appendix 1.

Table 5. Total number of individuals and number of sites recorded of fish and crustaceans captured in the Yarra River. E = estuarine, M= migratory.

Common name	Scientific name	Total catch	% of total	No. of sites	% of sites
Native species					
Black bream [E]	*Acanthopagrus butcheri*	73	0.73	2	4.65
Short-finned eel [M]	*Anguilla australis*	1090	10.88	43	100.0
River blackfish	*Gadopsis marmoratus*	47	0.46	11	25.58
Common galaxias [M]	*Galaxias maculatus*	1273	12.71	24	55.81
Mountain galaxias	*Galaxias olidus*	4	0.04	3	6.97
Macquarie perch	*Macquaria australasica*	289	2.88	27	62.79
Murray cod	*Maccullochella peelii peelii*	68	0.68	10	23.25
Golden perch	*Macquaria ambigua*	4	0.04	3	6.98
Australian bass	*Macquaria novemaculata*	3	0.03	1	2.32
Short headed lamprey [M]	*Mordacia mordox*	10	0.10	5	11.63
Flat-headed gudgeon	*Philypnodon grandiceps*	48	0.48	3	6.98
Tupong [M]	*Pseudaphritis urvilii*	1	0.01	1	2.32
Blue spot goby [E]	*Pseudogobius sp. 9*	7	0.07	2	4.65
Australian smelt	*Retropinna semoni*	3927	39.21	40	93.02
Exotic species					
Yellowfin goby [E]	*Acanthogobius flavimanus*	8	0.08	2	4.65
Common carp	*Cyprinus carpio*	429	4.28	40	93.02
Goldfish	*Carassius auratus*	37	0.37	16	37.21
Gambusia	*Gambusia holbrooki*	455	4.54	15	34.88
Oriental weatherloach	*Misgurnus anguillicaudatus*	80	0.79	14	32.56
Redfin	*Perca fluviatilis*	527	5.26	36	83.72
Brown trout	*Salmo trutta*	221	2.21	17	39.53
Roach	*Rutilus rutilus*	1415	14.12	35	81.39
Invertebrates					
Gippsland spiny cray	*Euastacus kershawi*	3	0.03	3	7.0
Southern Victoria spiny cray	*Euastacus yarraensis*	11	0.11	3	7.0
	TOTALS	**10,016**			

The most widely distributed species included short-finned eel (collected at all 43 sites), Australian smelt (40 of the 43 sites) and common carp, which only represented 4.6 % of the total catch but were collected at 40 of the 43 sites.

Of all species captured, short-finned eels represented the greatest overall biomass, with approximately 360 kg (with an average weight of 0.3 kg). In order of overall biomass other abundant species included common carp, Macquarie perch, brown trout, roach, redfin, common galaxias and Australian smelt.

The diversity of fish species was highest at the two sites below Dights Falls with a number of species not found further upstream, including the estuarine species black bream, blue spot goby, yellowfin goby, Australian bass, flat-headed gudgeon and tupong. The diversity of native species was also at its highest downstream of Dights Falls, and was consistently around 4-5 species up to the end of the Warrandyte Gorge, and then was reduced in the upper reaches (Figure 3).

Total abundance per site ranged from 47 to 829 individuals, and averaged 232 fish per site. The total fish abundance and the abundance of natives was highly variable along the river, and was highest below Dights Falls, and consistently low in the weir pool and lowland floodplain reaches (Figure 3). Other than the lowland reach, fish abundances were higher in the Warrandyte Gorge (sites 17 to 21) and in the upper floodplain reach (sites 29 to 32), compared with other reaches. The higher total abundance at Warrandyte Gorge was associated with increased catches of roach, Australian smelt, short-finned eel and Macquarie perch; while the higher total abundance in the upper floodplain reach was associated with Australian smelt, roach, short-finned eel and redfin.

Overall, native fish species (mainly Australian smelt, short-finned eels and common galaxias) were the most abundant group (6,400 fish), having over twice as many individuals as exotic fish (3,164 fish), this was followed by native translocated fish (364 fish) and estuarine fish (88 fish) (Figure 4). Exotic fish dominated the catch at some sites particularly at sites in the upper Warrandyte Gorge and in sites 25, 28, 33 and 43 (Figure 4). In the weir pool; common carp, gambusia and oriental weatherloach dominated the total catch, while roach dominated the sites in the upper Warrandyte Gorge and sites 24 and 33. Common carp were common in most sites and brown trout dominated sites 41 and 43. Native translocated fish species (mainly Macquarie perch and Murray cod) were restricted to the Warrandyte gorge and lowland floodplain reaches.

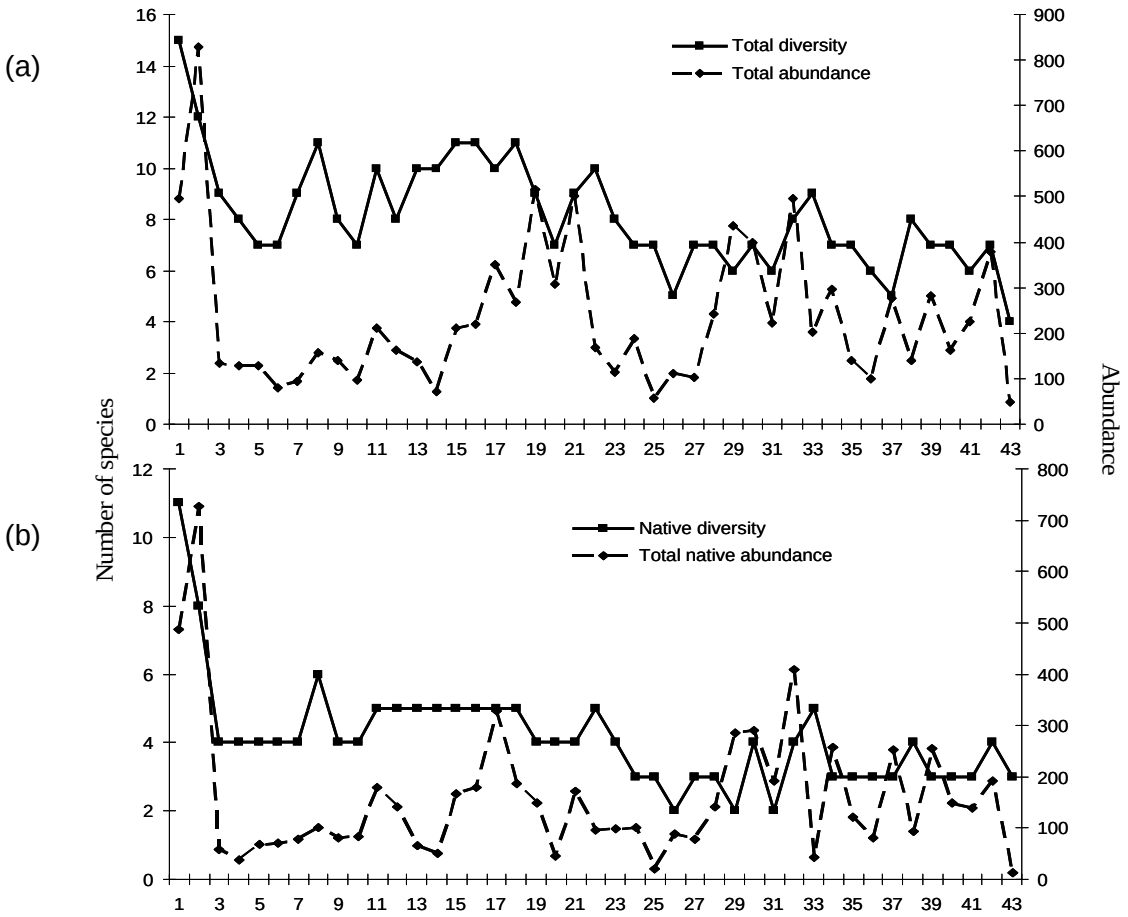


Figure 3. (a) Species diversity and total abundance and (b) native species diversity and native total abundance across sites in the Yarra River.

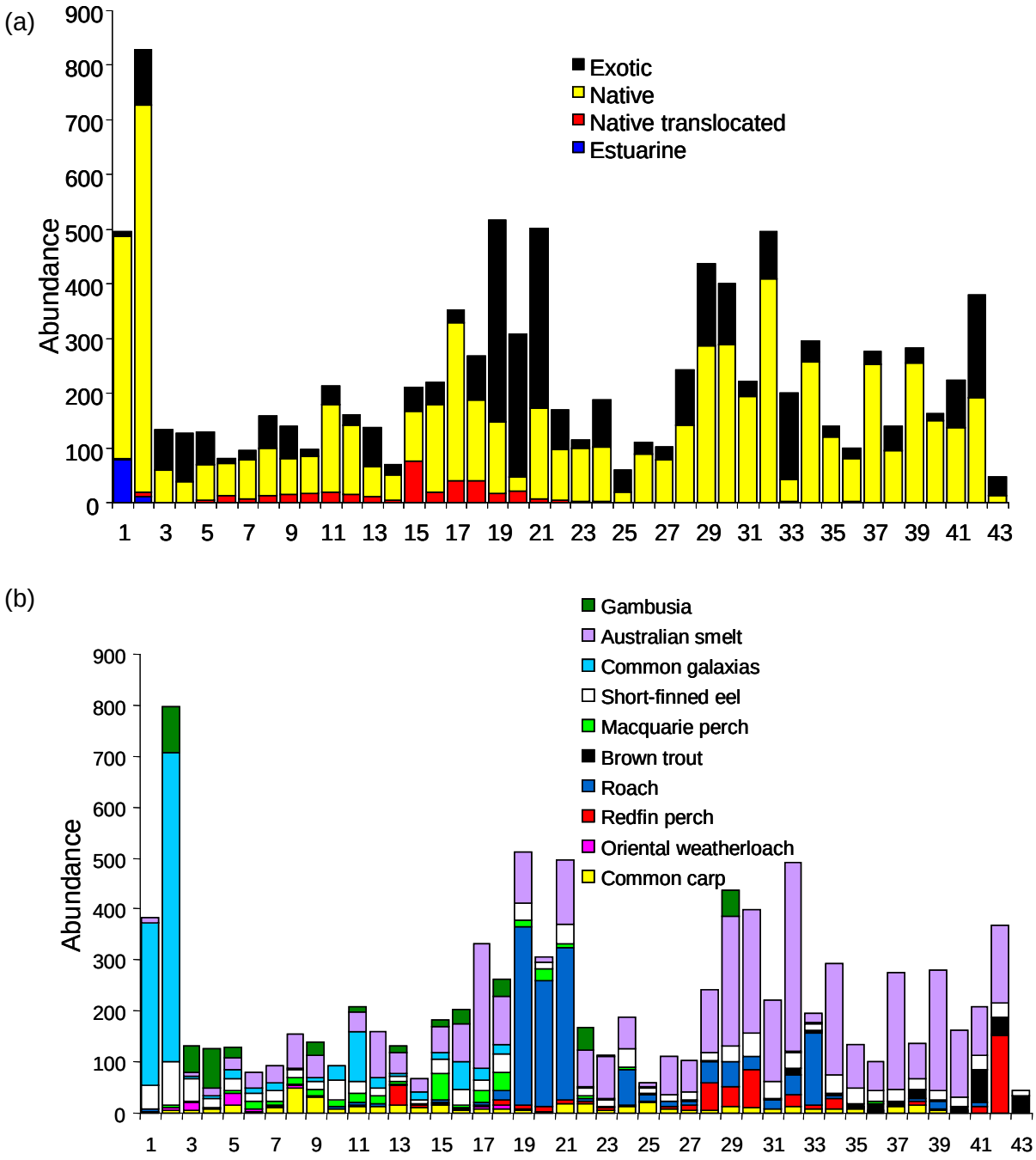


Figure 4. (a) Abundance of fish groups (exotic, native, native translocated and estuarine) and (b) abundance of the overall top ten species across sites along the Yarra River.

Southern Victorian spiny crays and Gippsland spiny crays were recorded at the higher altitude sites; with southern Victoria spiny crays captured at sites 32, 42 and 43, while Gippsland spiny crays were captured at sites 39 and 40.

Other aquatic fauna observed included four platypus (*Ornithorhynchus anatinus*) at sites 26, 27, 28 and 40 and three long-necked turtles (*Chelodina longicollis*) at sites 26, 27 and 34.

3.1 Distribution and abundance of key native species

3.1.1 Macquarie perch

A total of 289 Macquarie perch were collected during the survey, from 27 of the 43 sites. The abundance of Macquarie perch varied substantially along the river, and was roughly related to the defined zones (Figure 5). The Warrandyte Gorge region had the highest abundances of Macquarie perch recorded for the survey, particularly at site 15 (Figure 6). However, they were also consistently recorded at about 10 fish per site in the lowland floodplain zone. Macquarie perch were not found in the upland zone, and only in low abundances in the lowland area, the weir pool and in the midland floodplain.

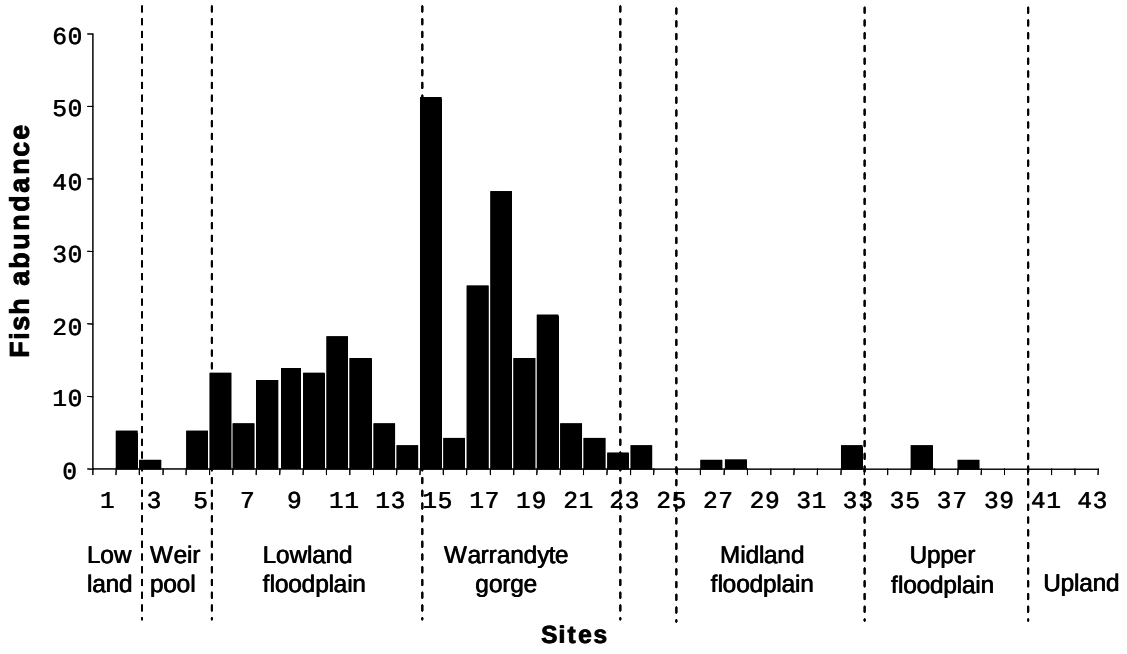


Figure 5. The distribution and abundance of Macquarie perch along the Yarra River.

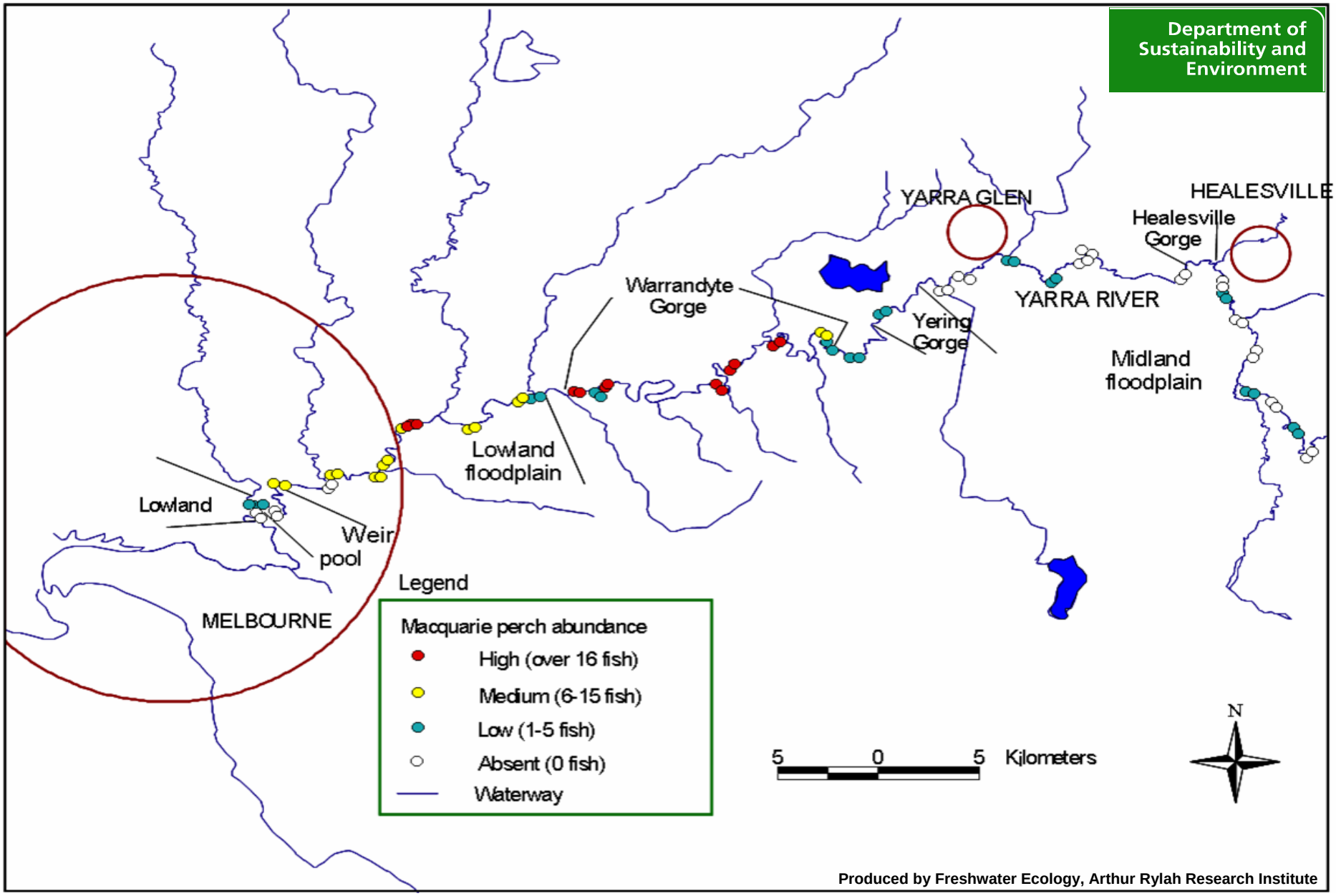


Figure 6. Macquarie perch abundance along the Yarra River, showing zonation of different landscape types. Sampling sites are denoted by two dots which mark upstream and downstream limits.

A range of size classes of Macquarie perch were present in the Yarra River indicating a number of successful recruiting events over past years. Sizes ranged from 18 mm (young-of-year) up to 395 mm. There were some differences in the presence and abundances of size classes between the three different areas (Figure 7). Both the lowland and the gorge sections had strong size classes of adult fish, while few adults were caught in the upland region. The gorge section also contained the highest abundances of small fish (<75 mm), few young fish were recorded in the lowland region and only a single small fish was captured in the upland section. The higher proportion larger adult fish and abundance smaller fish in the gorge section suggests that recruitment is particularly successful in this river zone.

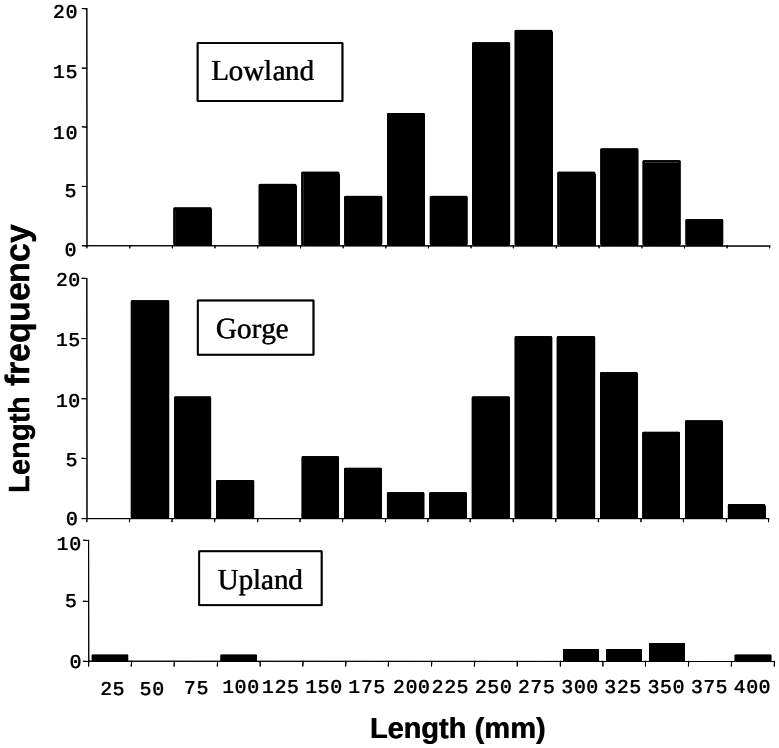


Figure 7. Length frequency distributions of Macquarie perch within three river zones. Plots include: a) lowland section (sites 2 - 14, n=91), b) Gorge section (sites 15 - 25, n=112) and c) midland - upland section (sites 26 - 38, n=10).

3.1.2 Murray cod

A total of 68 Murray cod were caught at 10 of the 43 sites, with an average of six fish per site (Table 5). Murray cod were only present from the lowest site below Dights Falls to Warrandyte Gorge (Figure 8 and 9). The majority of Murray cod were observed in the Warrandyte Gorge reach, although a few were found in the lowland and lowland floodplain reaches. No Murray cod were found in the weir pool, upper floodplain and upland reaches (Figures 8 and 9).

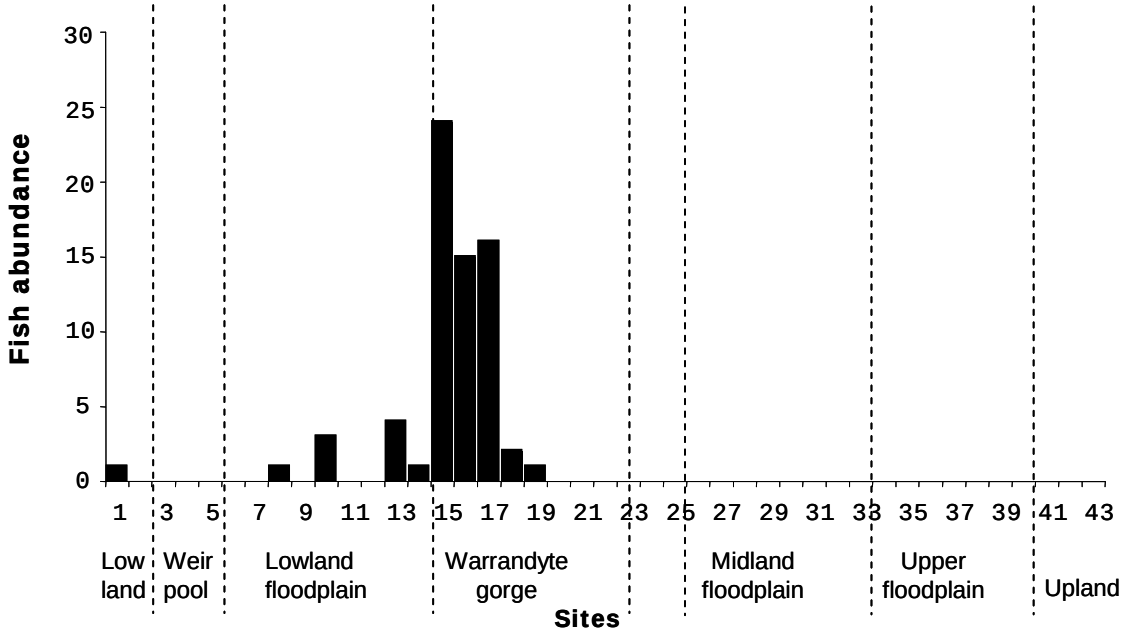


Figure 8. The distribution and abundance of Murray cod along the Yarra River.

A wide range of Murray cod size classes were caught in the sampled in the River, ranging from 66 to 742 mm. Although more Murray cod were captured in the Warrandyte Gorge section compared to the lowland section, the length structure was similar in both reaches (Figure 10). The most frequent size collected was 250 to 300 mm fish, which represent at least two year old fish. Records of some large Murray cod over 500 mm and juvenile fish less than 100 mm suggests recent recruitment success, or that illegal stocking is occurring.

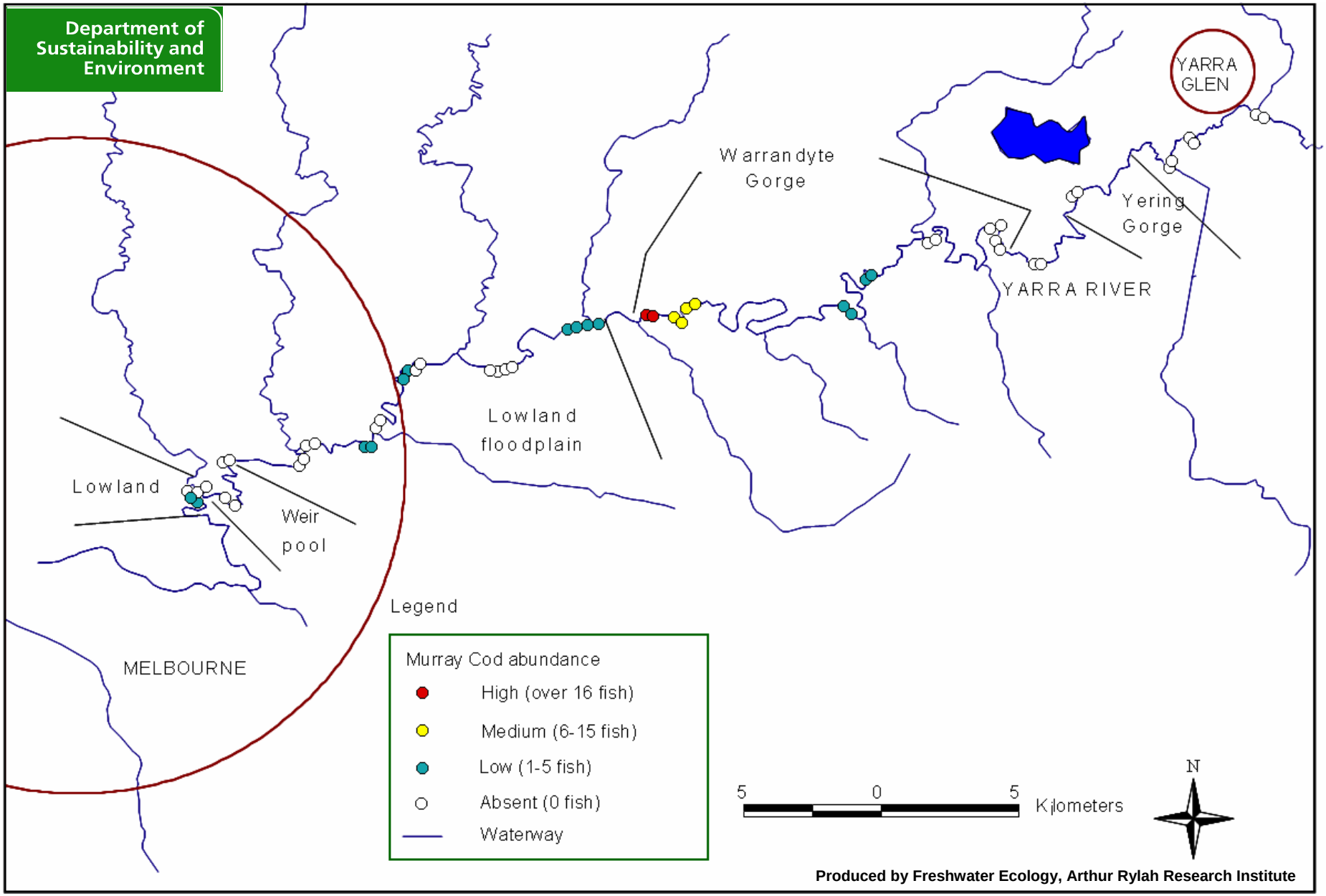


Figure 9: Murray Cod abundance along the Yarra River, showing zonation of different landscape types. Sampling sites are denoted by two dots which mark upstream and downstream limits

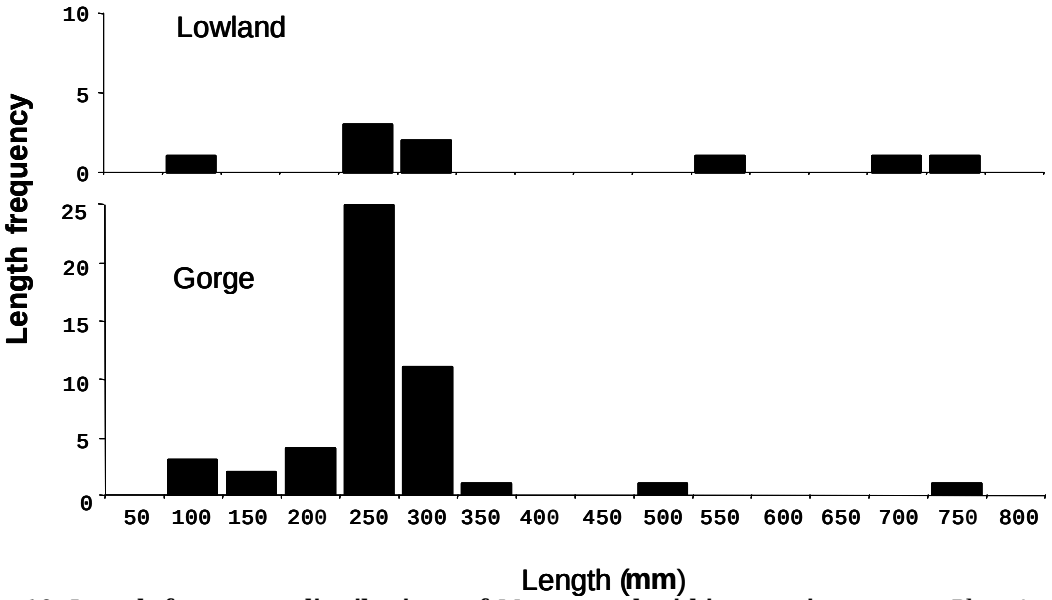


Figure 10. Length frequency distributions of Murray cod within two river zones. Plots include: A) lowland section (sites 1 - 13, n=9) and B) Warrandyte Gorge section (sites 14 – 19, n=48).

3.1.3 River blackfish

A total of 47 river blackfish were caught at 11 of the 43 sites (Table 5). River blackfish were located from Warrandyte Gorge to the upland reaches as high as Warburton (Figures 11 & 12) and were most abundant in the upland section of the river at sites 41 and 42, with up to 15 being captured at site 41.

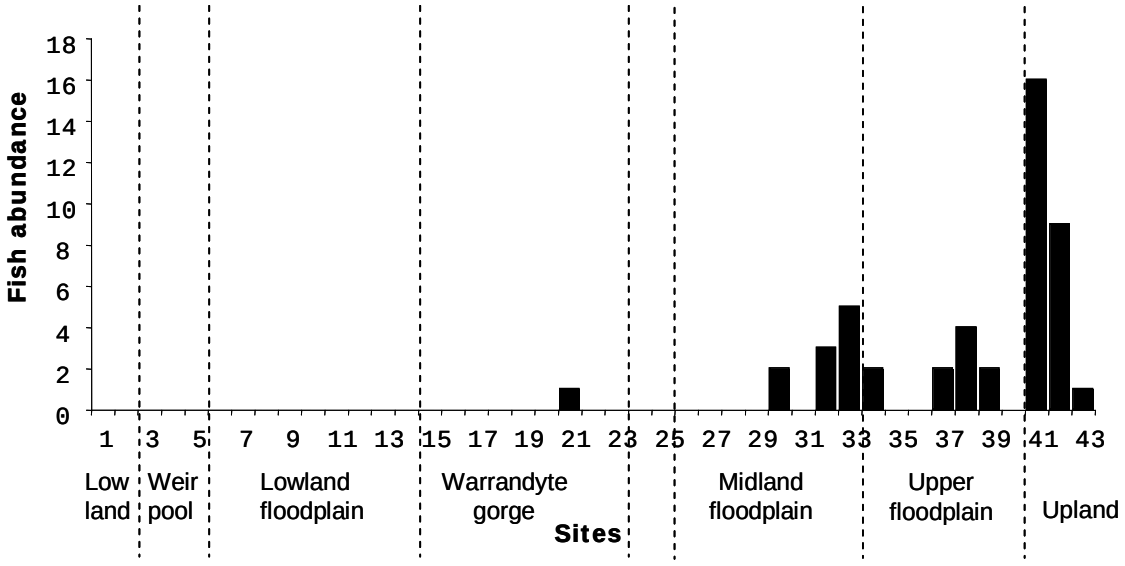


Figure 11. The distribution and abundance of river blackfish along the Yarra River.

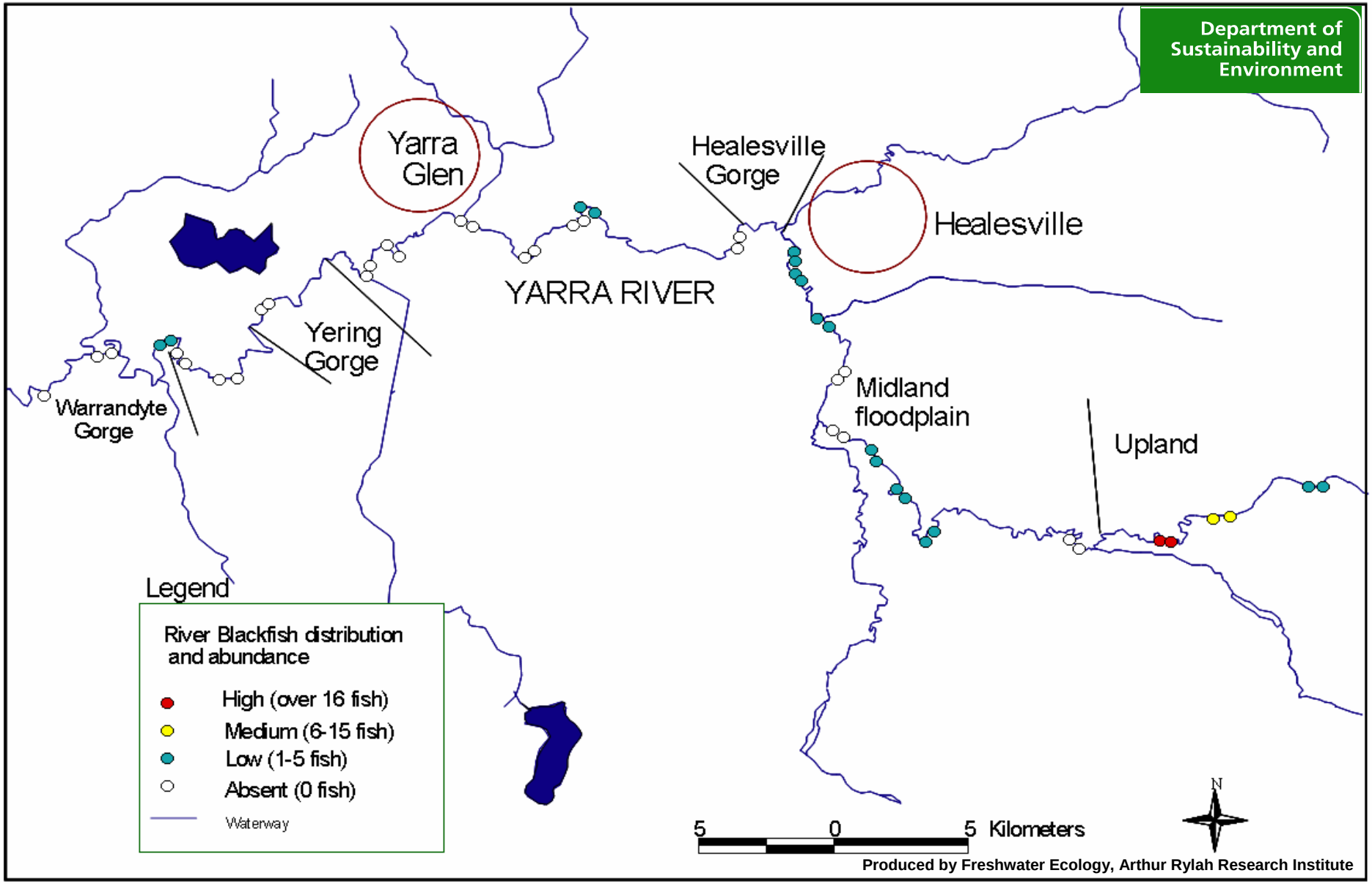


Figure 12. River blackfish abundance along the Yarra River, showing zonation of different landscape types. Sampling sites are denoted by two dots which mark upstream and downstream limits.

3.1.4 Common galaxias

A total of 1,273 common galaxias were caught at 24 of the 43 sites (Table 5). Common galaxias were more abundant below Dights Falls but were also found in reasonable numbers up to Warrandyte gorge (Figure 13).

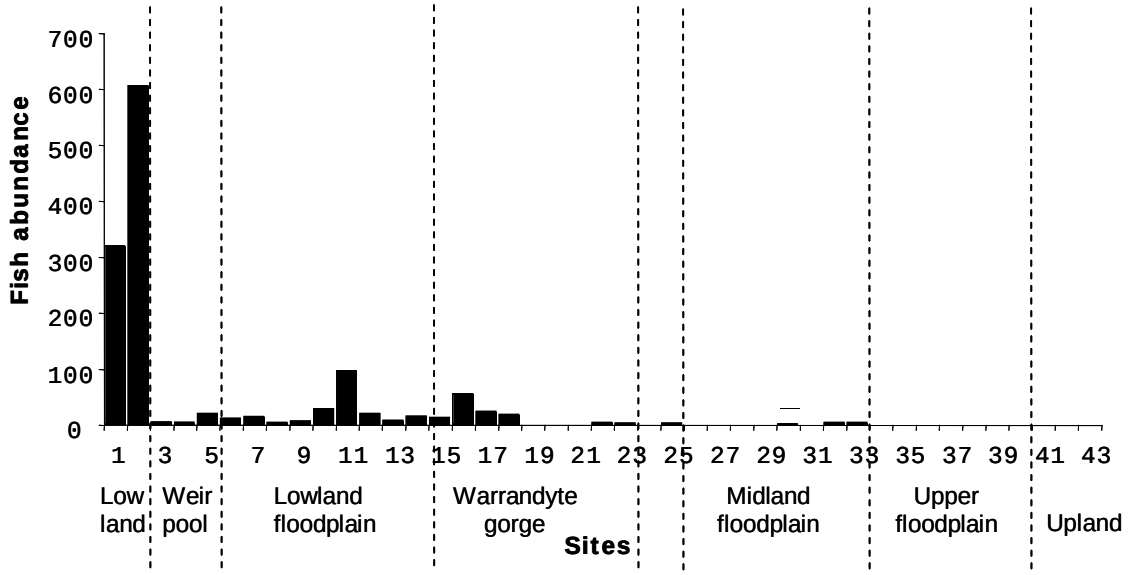


Figure 13. Distribution and abundance of common galaxias along the Yarra River.

3.2 Distribution and abundance of exotic species

Eight exotic species were recorded in the Yarra River. Yellowfin goby, goldfish and oriental weatherloach were recorded in low numbers and at fewer sites than the other exotic species (see Table 5). Some smaller species, such as oriental weatherloach and gambusia may have been underestimated in the sampling, as they are difficult to reliably sample with boat electrofishing, and therefore their abundance and distribution in the Yarra River is likely to be higher than recorded here.

Roach were the most abundant exotic species collected in the Yarra River (Table 5). They were also collected at a high number of sites (81.4% of sites). Roach were distributed from below Dights Falls to the upland sites, but were highly abundant in the upper section of the Warrandyte gorge (Figure 14 & 16).

Carp were the second most widely distributed fish in the River being found in all but three sites in the upland region (Figure 15). The relative abundance of carp was consistent throughout, however the highest abundance was recorded at two sites (site 8 and 9, upstream of Heidelberg) in the lowland floodplain reach.

A wide range of size classes of carp were present in the Yarra River ranging from 34 to 650 mm. The carp population was dominated by larger adults (500-650 mm), with few 150 to 400 mm fish present. However, there were relatively high abundances of 50-100mm carp caught in the mid to lower regions of the river and are indicative of recent recruitment success.

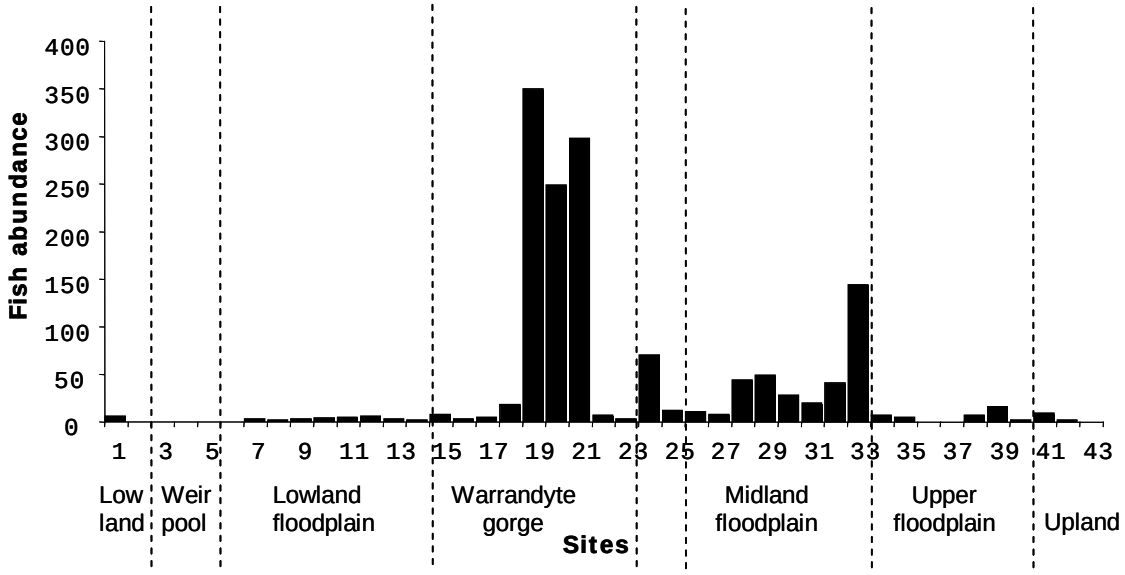


Figure 14. The distribution and abundance of roach along the Yarra River

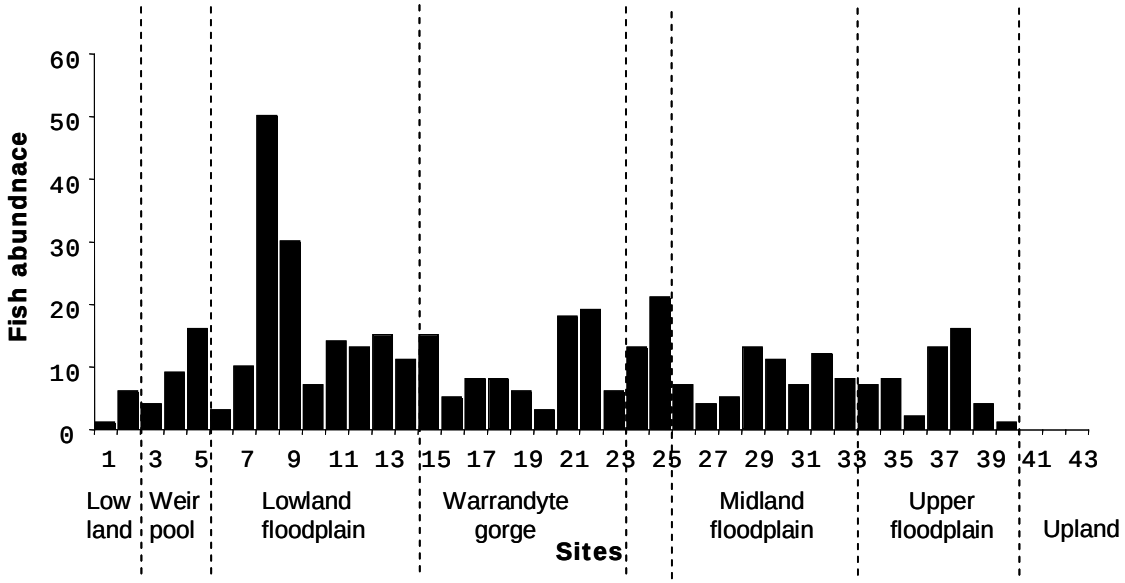


Figure 15. Distribution and abundance of carp along the Yarra River.

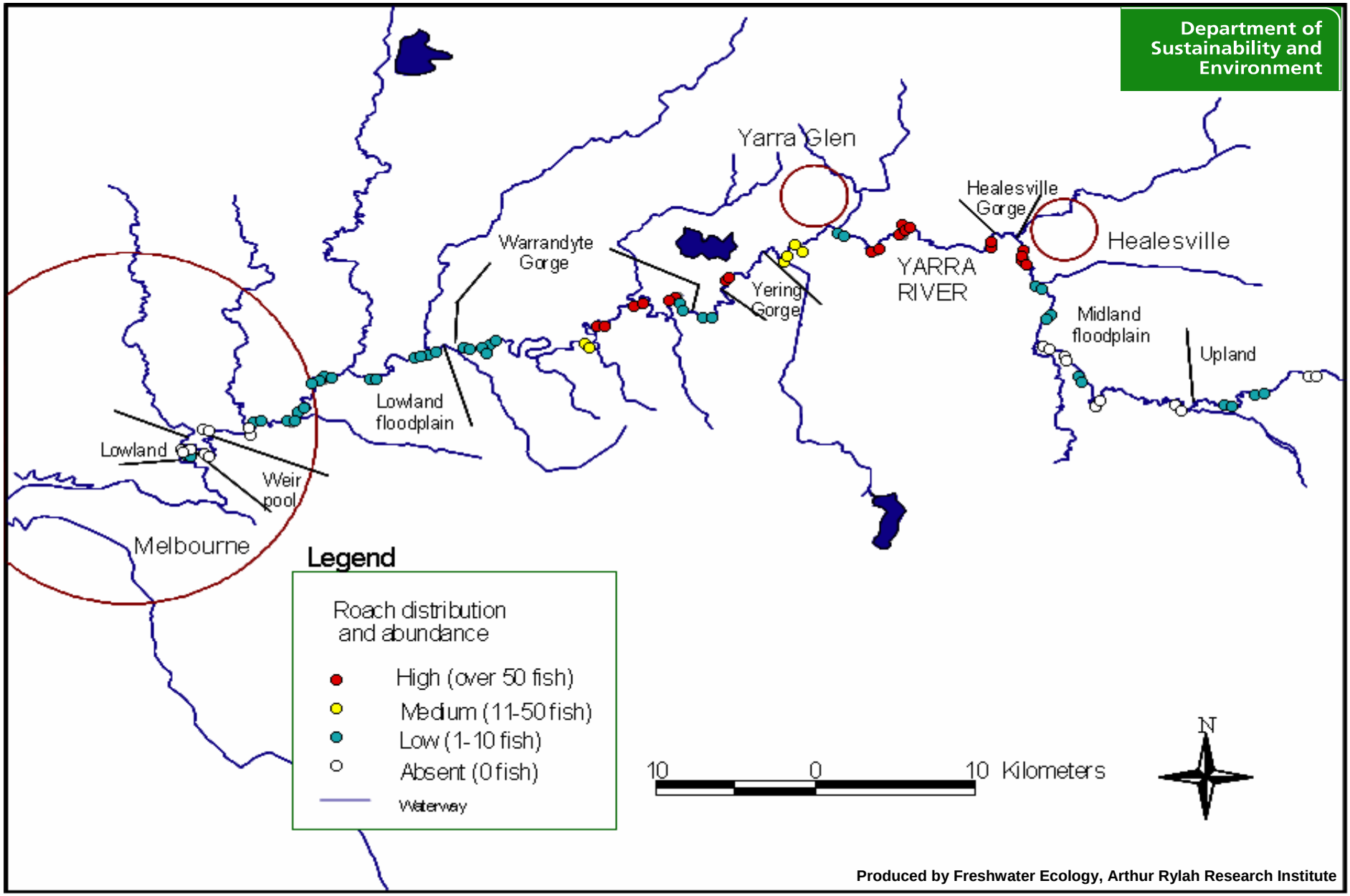


Figure 16. Roach abundance along the Yarra River, showing zonation of different landscape types. Sampling sites are denoted by two dots which mark upstream and downstream limits.

A total of 221 brown trout were collected at 17 sites (Table 5). While they were found in the mid - upper sections of the river, not surprisingly they were in high abundances in the cooler and clearer upper floodplain and upland reaches (Figure 17 & 19).

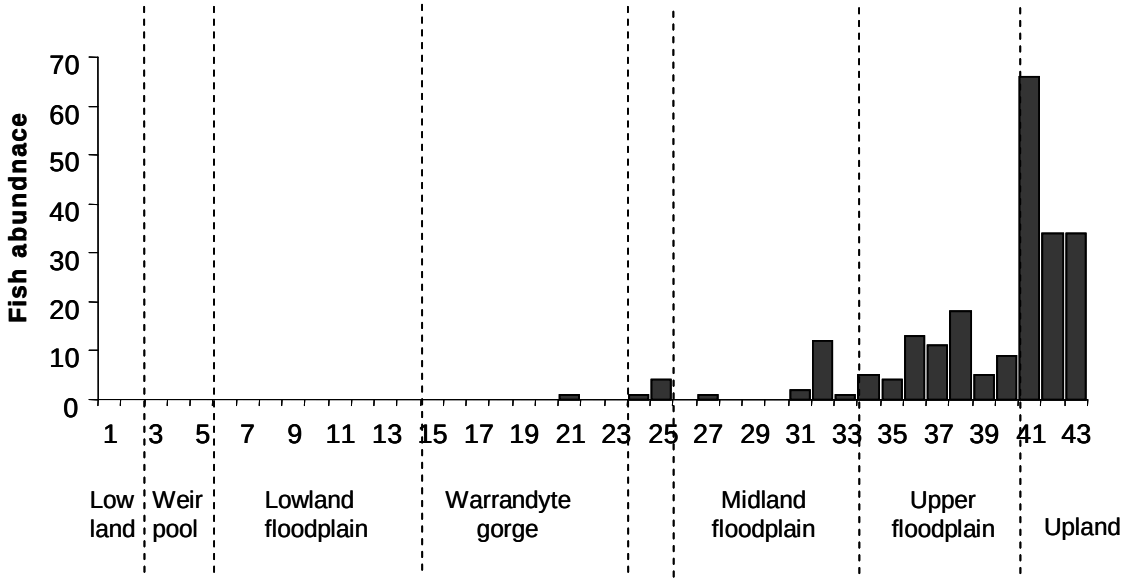


Figure 17. The distribution and abundance of brown trout along the Yarra River.

Redfin were widely distributed and relatively abundant along the Yarra River, and were collected 83.7% of sites (Table 5). They were only absent in eight of the lower sites and four sites in the upper region of the river (Figure 18). They were recorded in much higher abundance at site 42 than any of the other sites.

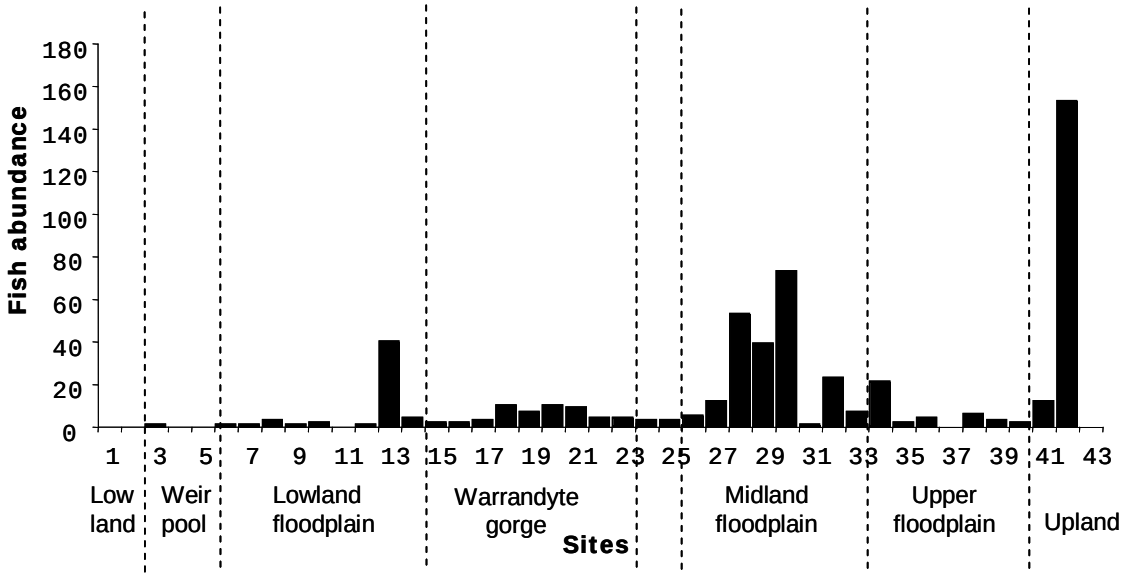


Figure 18. Distribution and abundance of redfin along the Yarra River.

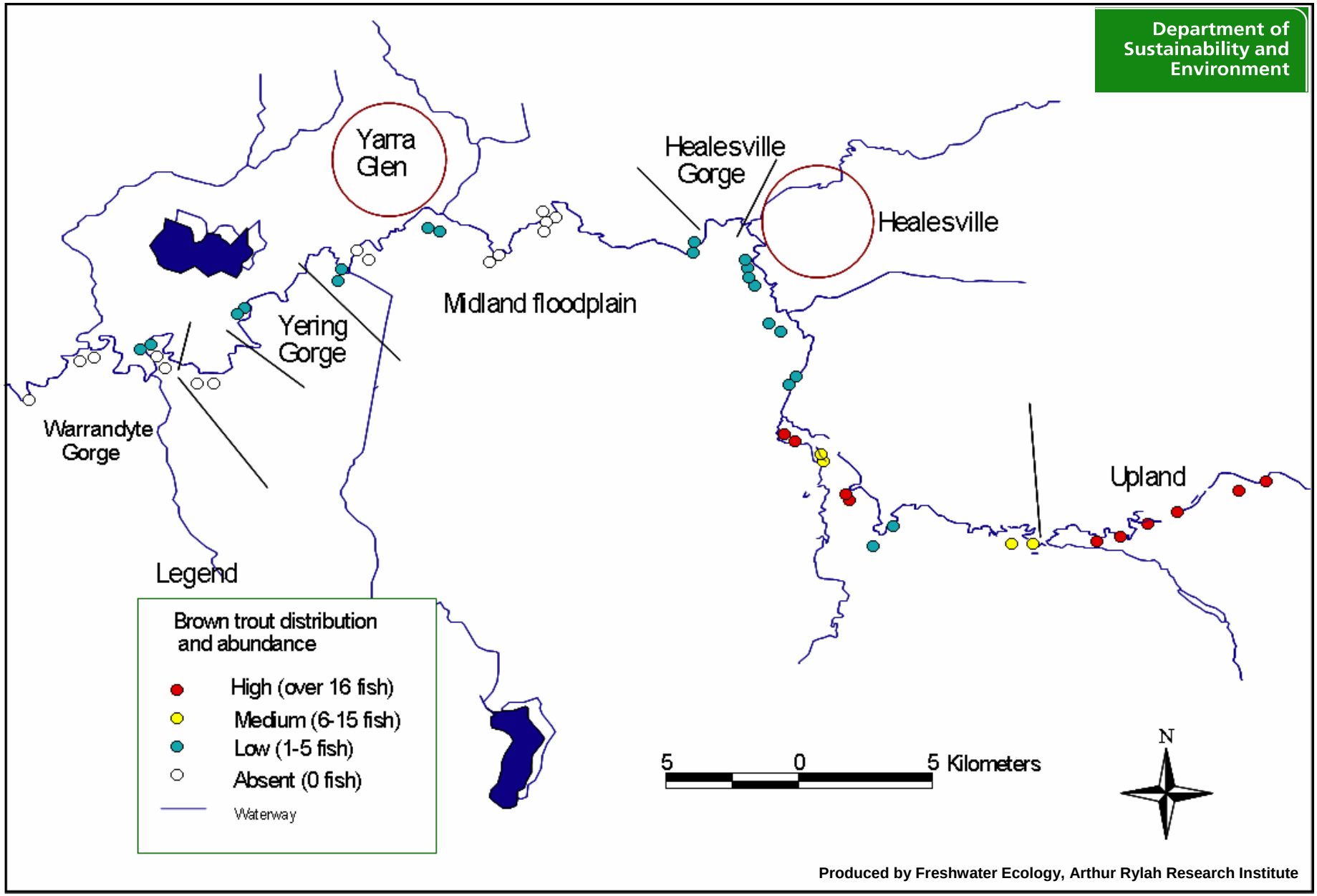


Figure 19. Brown trout abundance along the Yarra River, showing zonation of different landscape types. Sampling sites are denoted by two dots which mark upstream and downstream limits.

3.3 Water quality

Basic water quality parameters at all of the survey sites indicated that conditions were suitable for aquatic biota (Appendix 6). Water conductivity decreased with distance upstream from 273 µS/cm below Dights Falls, approximately 200 µS/cm upstream of Dights Falls, 120 µS/cm at Yarra Glen, and less than 50 µS/cm at Millgrove. Peaks in stream conductivity were recorded at Finns Reserve (site12) and at Yering Gorge (Site 24). Stream temperature also decreased, albeit slightly, with distance upstream from an average of 23°C downstream of Yarra Glen to an average of 20°C upstream of Yarra Glen. Maximum stream temperatures were recorded at shallow riffle reaches upstream of Warrandyte (site 19 to 22) and open water reaches near Tarcoola (site 25 and 26). Water pH ranged from 6.1 at Templestowe (site 11) and at Burkes Road (site 8) to 8.5 at Yarra Glen (site 27). Turbidity varied by site from a low of 1.8 NTU at Wonga Park (site 22) to a high of 20.8 NTU at Burke Road (site 8). Notably, turbidity above 10 NTU was recorded between Alphington and Templestowe (sites 6 to 11).

Dissolved oxygen varied from 5.2 mg/L (62% saturation) at Wonga Park (site 22) to a maximum of 13.1 mg/L (113% saturation) at Tarcoola (site 25). Sites downstream of Yarra Glen had an average dissolved oxygen concentration of 7.7 mg/L (80% saturation), while sites downstream had a higher average of 9.0 mg/L (92% saturation). Lower dissolved oxygen levels were associated with deeper, slower flowing environments, while higher dissolved oxygen levels were likely to be related to nutrient runoff and/or excessive aquatic macrophyte and algal growth.

3.4 Spatial variation in habitat

Habitat information recorded as a summary for each site is provided in Appendix 2 to 5.

The mean wetted width was related to the mean depth within sites of the Yarra River, with an increase in river width roughly corresponding to an increase in mean depth (Figure 21). The depth and width of the river throughout the survey reach was highly variable, although it was wider and deeper in the weir pool section and in the Warrandyte Gorge (Figure 21). The floodplain sections of the river were shallower and relatively constricted due to the accumulation of deposited sediment.

The most dominant broad habitat feature in the Yarra River was pool habitats (Figure 22). Pool habitats represented >50% of the proportion of available habitat at sites in the weir pool, lowland floodplain and some sites in the midland floodplain reaches. Conversely, run and riffle habitats were the major feature in the Warrandyte gorge, upper floodplain and upland reaches.

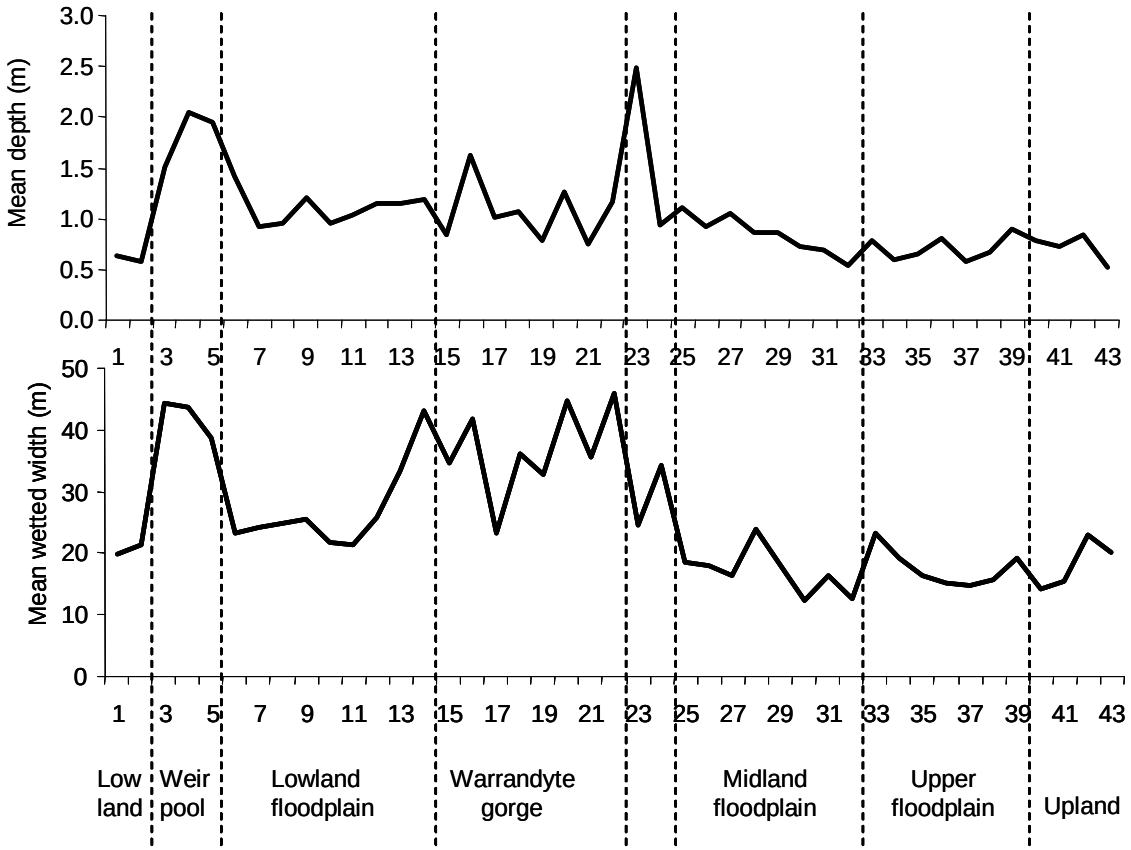


Figure 21. Mean wetted width (m) and mean depth (m) of sites along the Yarra River.

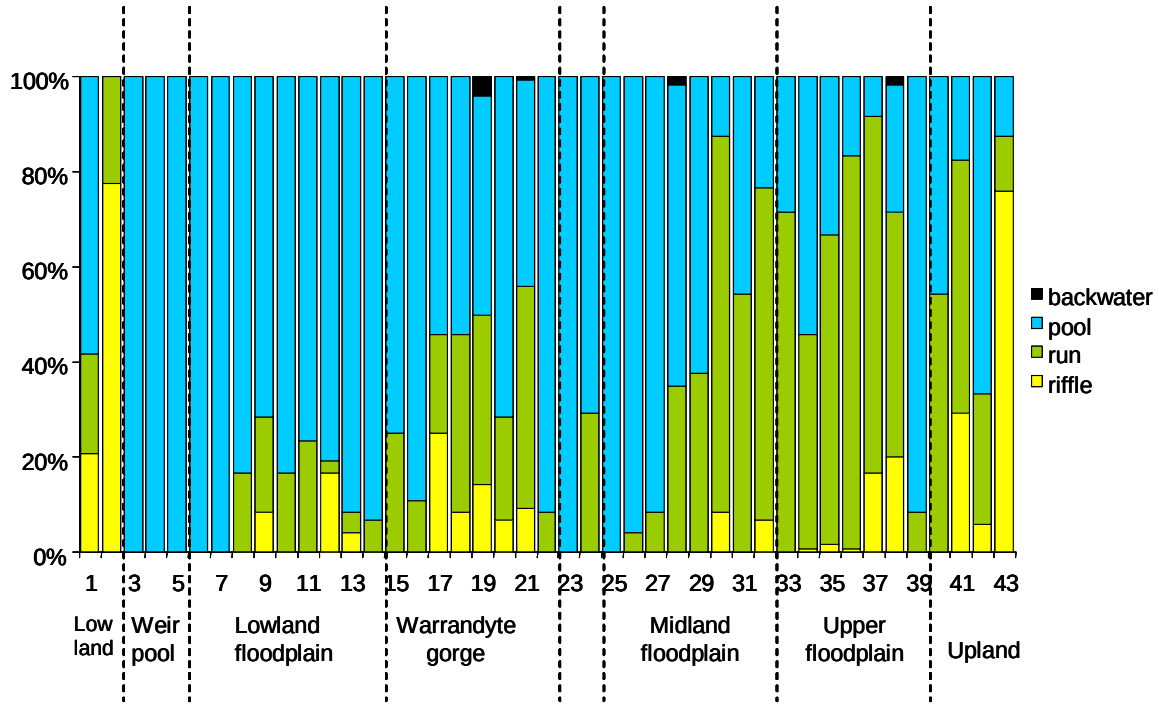


Figure 22. Proportion of broad habitat features at each site along the Yarra River.

In general, the most common substrate in the Yarra River was sand and silt (Figure 23). Rock and/or bedrock substrates were an important feature below Dights Falls and in the Warrandyte gorge reach. Interestingly, an increase in the percent cover of sand and silt was observed immediately downstream of major tributaries (Figure 23). This effect was more pronounced in the upper part of the river, particularly below Olinda Creek, Watts River, Woori Yallock Creek and the Little Yarra River.

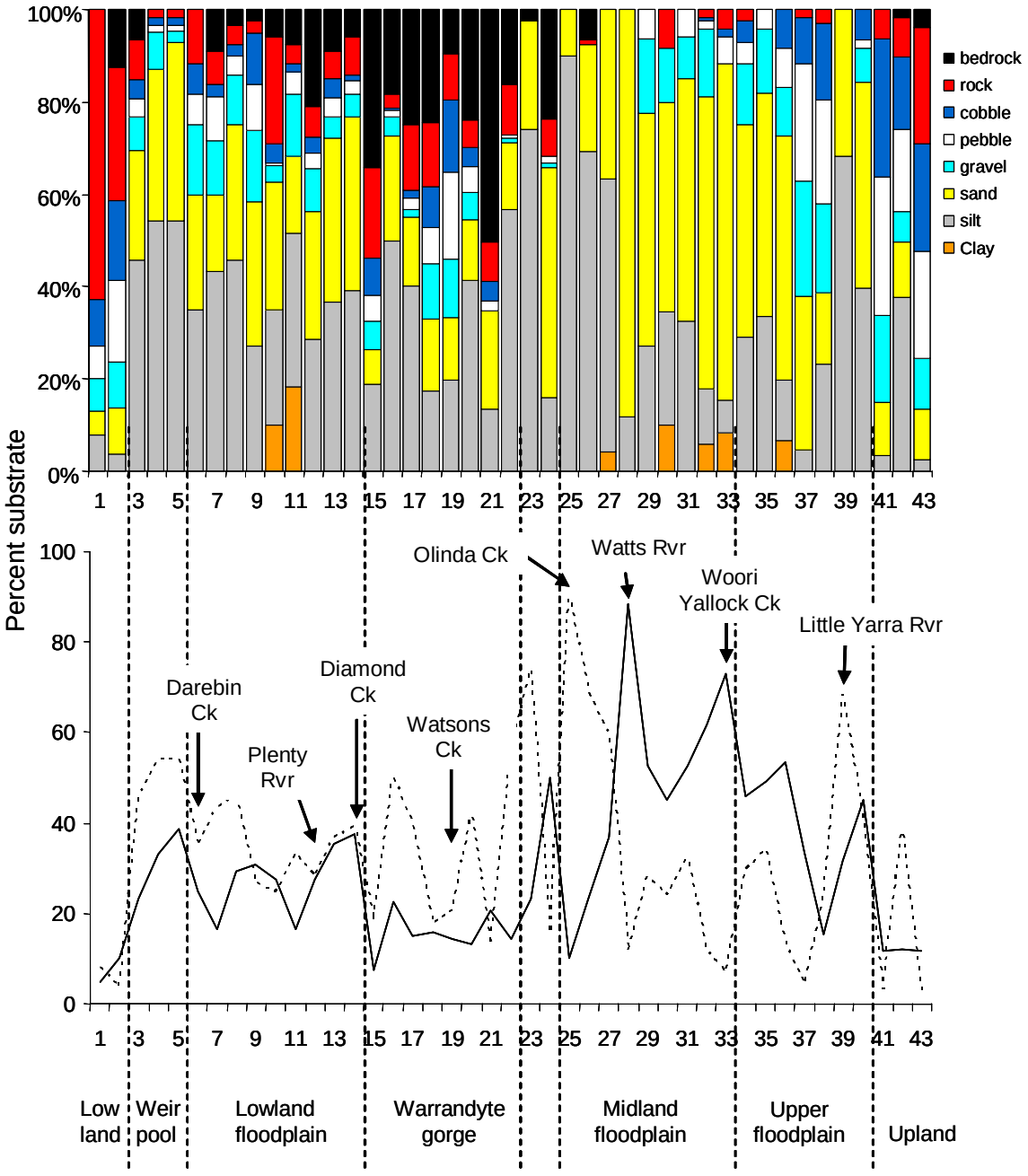


Figure 23. Percent cover of each substrate type along the Yarra River, and percent cover of silt and sand at each site indicating approximate location of major tributaries.

Stream habitat features for fish varied considerably along the study reach (Figure 24 & 25). The highest cover scores commonly came from sites in and near the Warrandyte Gorge (sites 15, 17, 19, 20, 21, 22 and 24), where most of the sites had a high proportion of rock cover, submerged vegetation, root mass and emergent vegetation.

Undercut banks were a common feature at the majority of sites, but were not present in the two sites below Dights Falls (Figure 24a). Emergent macrophytes had a patchy distribution and abundance throughout the River, being most common in some of the lower sites (sites 1-8) and the Warrandyte Gorge reach (sites 15-24) (Figure 24b). They were also in high densities in Site 42. Submerged macrophytes were very patchy and were generally recorded in low coverage (<10% cover) at most sites, however they were recorded in higher densities at five sites (Figure 24c). The introduced submerged macrophyte, dense waterweed (*Egeria densa)*, was also recorded at a number of sites.

Rock cover was present in low densities at most sites, apart from in the Warrandyte gorge reach and below Dights Falls (Figure 25c). Woody cover and root masses were generally in high densities throughout the study reach (Figure 25). There was a lower density of woody cover (both small and large) at sites below Dights Falls (sites 1 & 2) and at the upmost site (site 43), compared with the higher densities of wood recorded at other sites along the River.

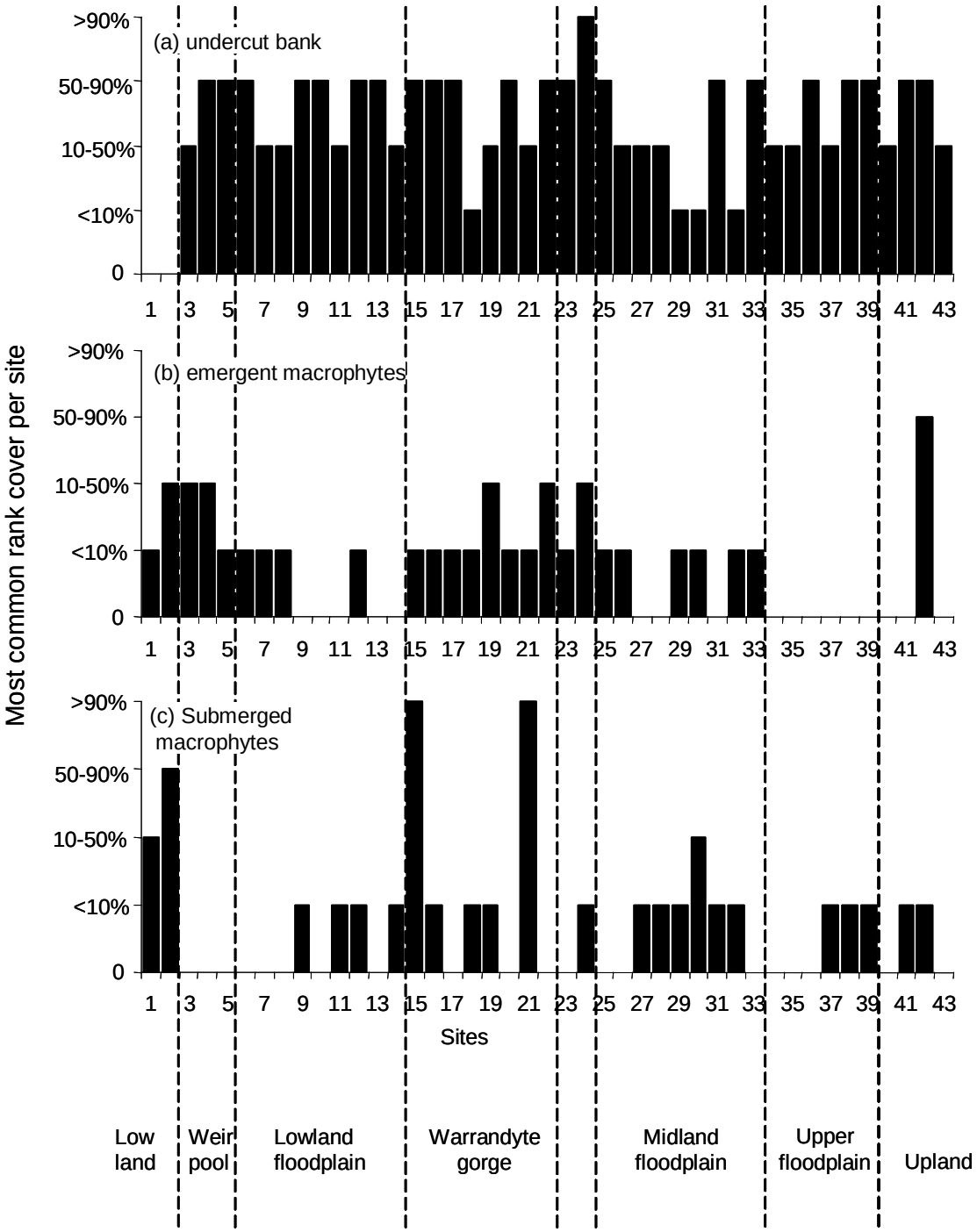


Figure 24. Spatial variation of (a) undercut banks, (b) emergent and (c) submerged macrophytes along the Yarra River.

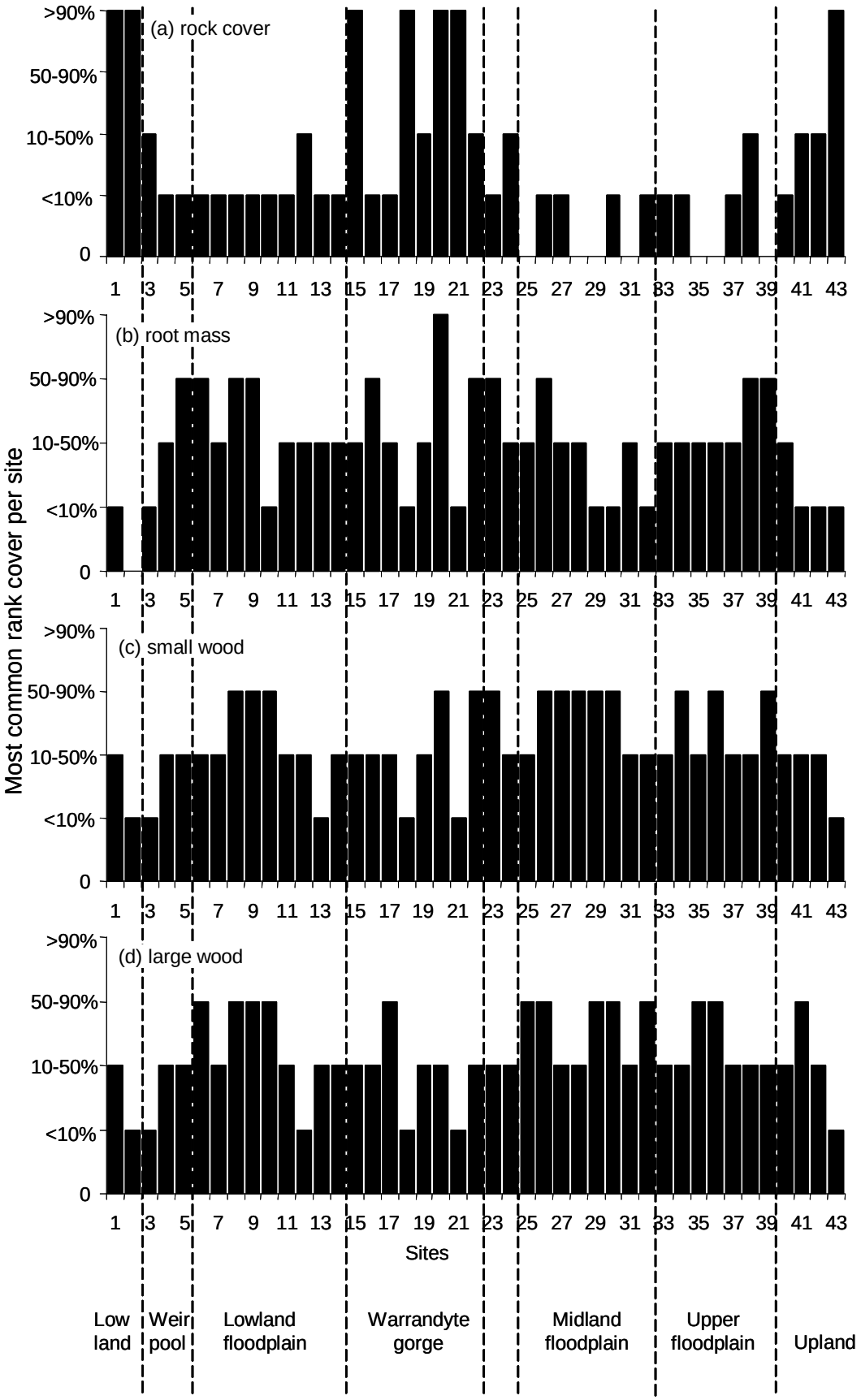


Figure 25. Spatial variation of (a) rock cover, (b) root mass, (c) small woody debris and (d) large woody debris along the Yarra River.

3.5 Riparian characteristics

The lowland region had the lowest average riparian cover throughout the river, however there were some individual sites in other reaches where riparian cover was less than 50% (Figure 26). However, riparian cover was patchy and highly site dependant. The highest proportion of riparian cover was at a number of sites in the Warrandyte Gorge section of the river, where riparian width of greater than 50m was commonly recorded. Other wide riparian zones were recorded upstream of Dights Falls near Fairfield (sites 3, 4, 5), at Yering Gorge (site 24) and in the upper floodplain reach, upstream of Yarra Grange (sites 31, 34) (Figure 26).

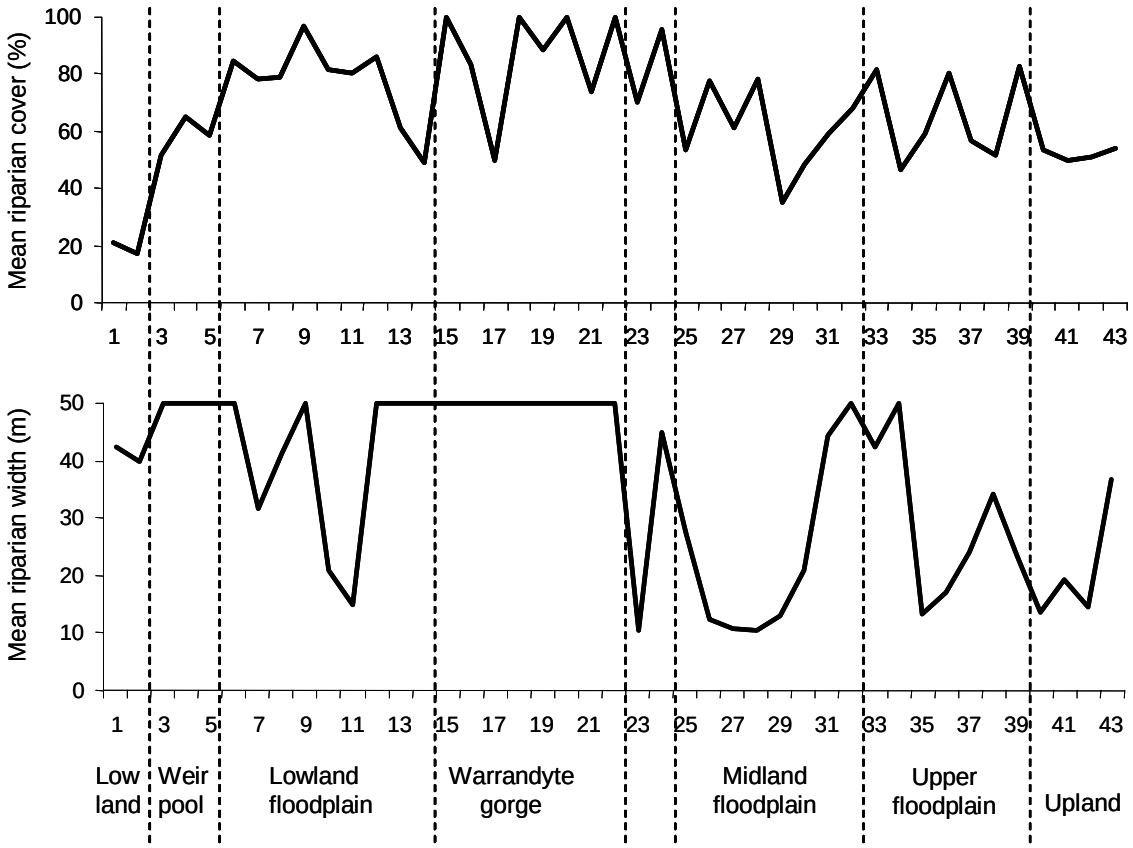


Figure 26. Mean riparian width (m) and mean percent riparian cover at sites along the Yarra River.

Exotic vegetation in the riparian zone occurred throughout much of the survey reach, but represented greater than 50% cover at only three sites (Figure 27). The proportion of exotic vegetation in the riparian zone was high in the upland reaches from sites 39 to 42, and consisted mostly of blackberries (*Rubus spp.*) and willows (*Salix spp.*). Willows were present at a number of sites, but were particularly dense near Heidelberg (sites 8, 9 and 10), at Alexander Road (site 17) and at 'Eyton on Yarra' (sites 35 and 36).

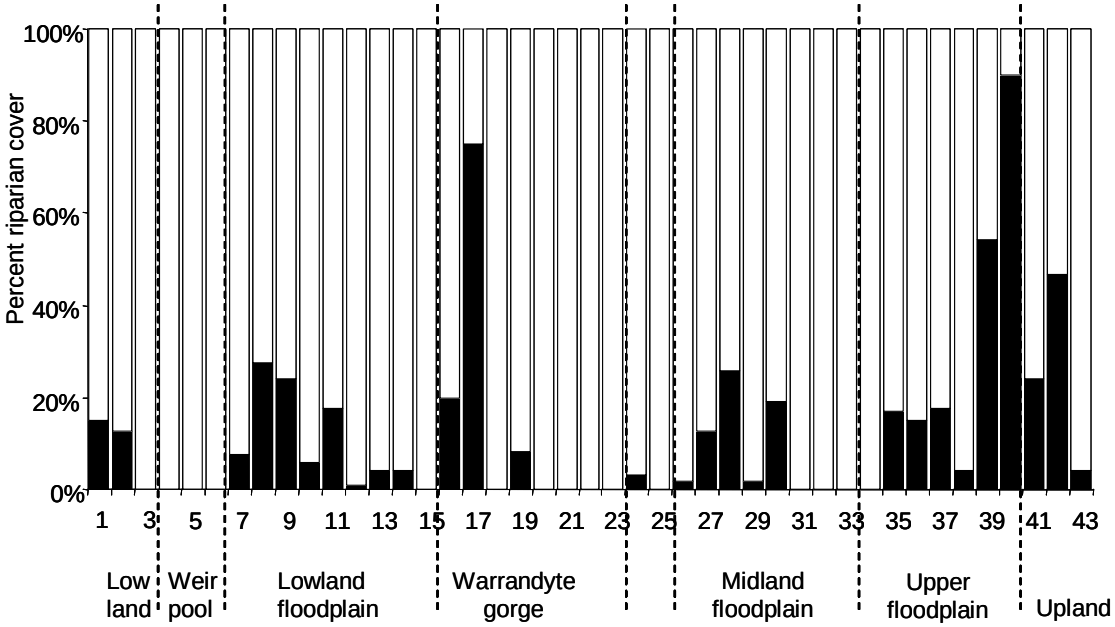


Figure 27. Percent cover of exotic (black) and native (white) vegetation in the riparian zone along the Yarra River.

3.6 Fish community and habitat structure

Multivariate analysis using NMDS demonstrated that the fish community of the Yarra River gradually changed along a clear altitudinal gradient (upstream to downstream), and differed significantly in their composition amongst the seven defined reaches (Global R=0.721, $p<0.01$) and within all pairwise comparisons ($p<0.05$) (Figure 28). Each defined river reach had distinctly different fish communities (Table 6). For example, the lowland reach, below Dights Falls, was characterised by common galaxias, short-finned eel and flathead gudgeons; while the next reach upstream (the weirpool) was characterised by these species and gambusia, carp, weatherloach and Australian smelt.

Redundancy analysis on the Yarra River fish community revealed strong associations with the habitat variables measured. The “water flow” model (explaining 23.12% of the overall variance) was mainly explained by the variable wetted area, and to a lesser extent mean depth, velocity and riffle (Table 7). Wetted area was positively associated with Macquarie perch, oriental weatherloach, goldfish and gambusia, while the abundance of the introduced species roach was associated with increasing mean depth. Increased riffle habitats and velocity was associated with the estuarine and diadromous species mostly captured below Dights Falls, and brown trout was strongly associated with increasing water velocity (Figure 29a).

Table 6. Species characterising defined river zones. Percent contribution of species contributing 10% or more to within group similarities. Average similarity scores within groups in brackets.

	Lowland (62.79)	Weir pool (78.25)	Lowland floodplain (73.62)	Gorge (71.15)	Mid floodplain (74.85)	Upper floodplain (78.82)	Upland (63.34)
Common galaxias	30.41	11.47	15.67				
Short-finned eel	20.30	20.67	18.47	17.11	20.56	23.54	28.67
Flathead gudgeon	15.79						
Gambusia		23.23					
Australian smelt		17.37	19.22	21.36	27.19	33.95	20.74
Common carp		12.68	15.70	10.83	14.82	12.70	
Oriental weatherloach		11.44					
Macquarie perch			15.05	12.30			
Roach				12.55	20.07		
Redfin perch					13.41		
Brown trout						14.41	31.02

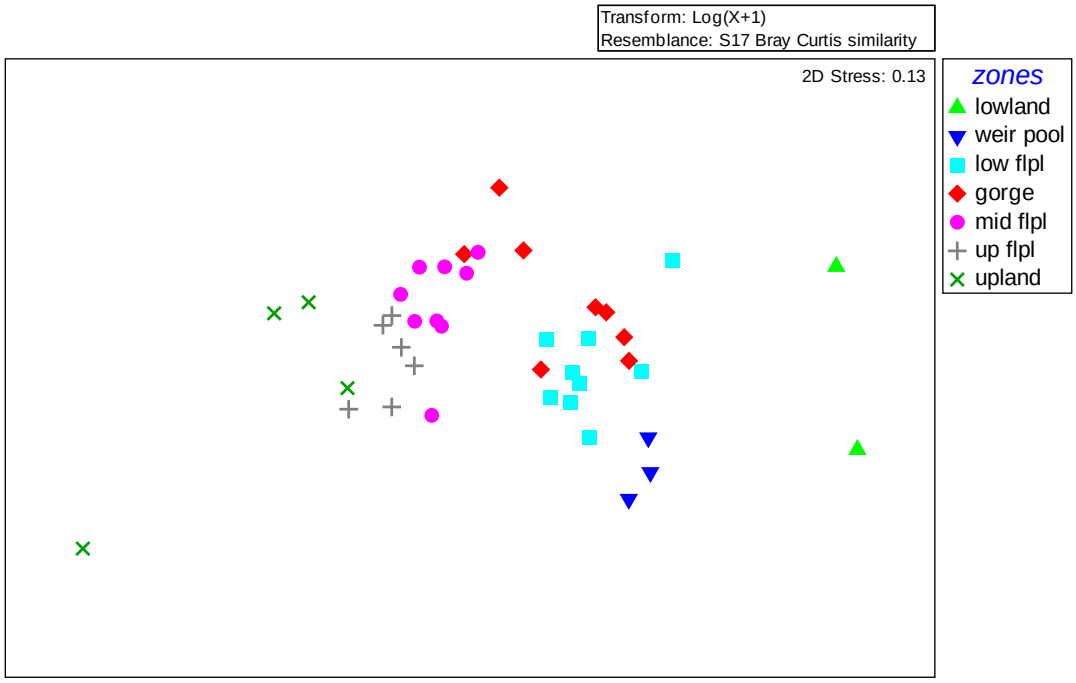


Figure 28. Two-dimensional solution for NMDS ordination of the total number of individuals of each species per site. The ordination is presented to show groupings of seven pre-defined river reaches. (25 random starts, maximum of 200 iterations and minimum stress of 0.13).

Table 7. Redundancy analysis model fit results

(a) Water flow (explaining 23.12%)

	Df	Var	F	Pr(>F)
mean_depth	1	0.97402	1.09417	0.072
max_depth	1	0.33673	0.37827	0.46
velocity	1	1.0959	1.23108	0.058
wetted	**1**	**1.14722**	**1.28873**	**0.012**
riffle	1	0.82426	0.92593	0.074
run	1	0.24148	0.27127	0.786
pool	1	0.46676	0.52433	0.358
Residual	19	16.91364		

(b) Stream bed (explaining 43.22%)

	Df	Var	F	Pr(>F)
clay	1	0.11791	0.17936	0.972
silt	**1**	**0.99084**	**1.50719**	**0.01**
sand	**1**	**1.28325**	**1.95199**	**0.004**
gravel	**1**	**0.7484**	**1.13841**	**0.04**
pebble	**1**	**1.73056**	**2.63241**	**<0.002**
cobble	1	0.40969	0.6232	0.292
rock	**1**	**3.53835**	**5.3823**	**<0.002**
bedrock	1	0.6903	1.05004	0.128
Residual	19	12.4907		

(c) Stream bank characteristics (explaining 32.25%)

	Df	Var	F	Pr(>F)
rocky_bank	1	0.52075	0.66379	0.262
bare	1	0.47396	0.60415	0.306
Ohveg	1	0.50629	0.64535	0.276
steep_bank	1	0.75494	0.96231	0.086
flat_bank	1	1.62259	2.06829	0.032
bank_veg	**1**	**1.66015**	**2.11616**	**<0.002**
bank_width	1	0.5599	0.71369	0.224
bank_native	1	0.3485	0.44422	0.468
bank_exotic	1	0.64725	0.82504	0.144
Residual	19	14.90567		

(d) Water chemistry (explaining 31.08%)

	Df	Var	F	Pr(>F)
EC	**1**	**3.13321**	**3.92651**	**<0.002**
temp	**1**	**1.27801**	**1.60159**	**0.004**
DO	1	0.05204	0.06522	0.974
DO_sat	1	0.25216	0.31601	0.774
ph	**1**	**1.18917**	**1.49026**	**0.02**
turb	**1**	**0.93411**	**1.17062**	**0.046**
Residual	19	15.1613		

(e) Instream habitat (explaining 30.92%)

	Df	Var	F	Pr(>F)
undercut	**1**	**2.48198**	**3.10312**	**<0.002**
macro_em	1	0.82475	1.03115	0.054
macro_sub	1	0.88345	1.10454	0.078
rock_cover	1	0.98091	1.22639	0.072
root	1	0.80789	1.01007	0.09
wood_sm	1	0.46522	0.58165	0.314
wood_lrg	1	0.35894	0.44876	0.56
Residual	19	15.19685		

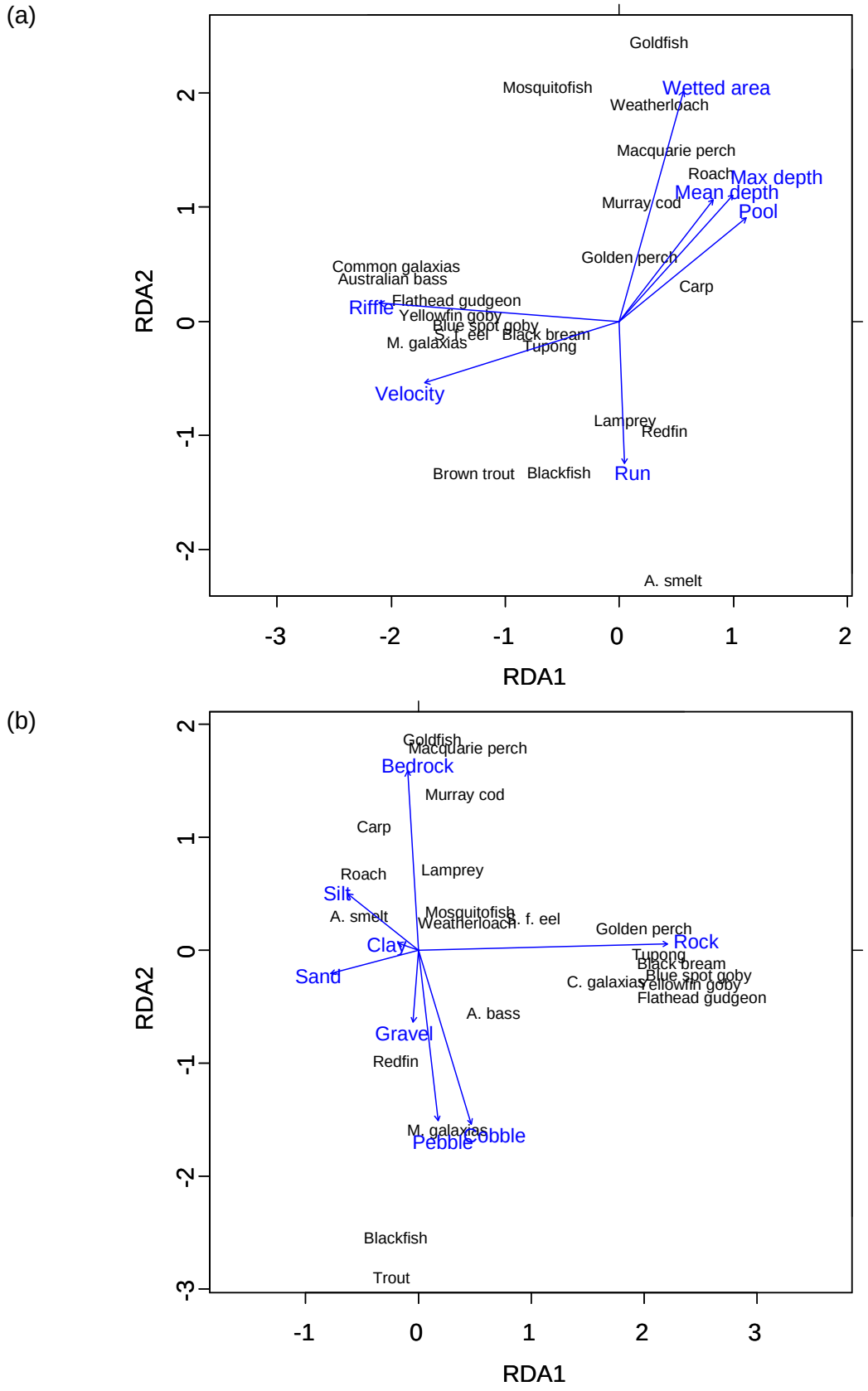


Figure 29. Two-dimensional solution for Redundancy Analysis models on the total number of individuals of each species per site for (a) water flow and (b) stream bed characteristics.

The “steam bed characteristics” model (explaining 43.22% of the overall variance) was the best fit of all the models, and was strongly explained by the variables; rock, pebbles, gravel, sand and silt (Table 7). The fish community found below Dights falls was again separated out from the rest of the community by its strong association with the dominance of rock at these sites (Figure 29b). The abundance of the upland species trout, blackfish and mountain galaxias was strongly associated with increased proportions of pebble and cobble substrates, while the abundance of more typical lowland species such as Australian smelt and roach was associated with the occurrence of silt. The proportion of bedrock, although not contributing a large amount to explaining the model, was strongly associated with the abundance of Macquarie perch, goldfish and Murray cod.

The “stream bank characteristics” model (explaining 32.24% of the overall variance) was explained by mostly two variables; the percentage of bank vegetated and the percentage of flat bank (Table 7). The percentage of bank vegetated, along with riparian zone width, the steepness of the bank and the proportion of native vegetation in the riparian zone was strongly associated Macquarie perch, goldfish, roach, carp and Murray cod (Figure 30a). While Australian smelt, common galaxias, redfin, trout and blackfish were associated with flat banks and an increased proportion in exotic vegetation.

The “water chemistry” model (explaining 31.08% of the overall variance) was largely explained by EC, and to a lesser extent temperature, turbidity and pH (Table 7). Again, the fish community below Dights falls was separated out from the rest of the community, and was associated by both EC and pH (Figure 30b). Increased water temperature and turbidity was associated with Macquarie perch and carp. Increased dissolved oxygen, although not contributing a large amount to explaining the model, was strongly associated with the abundance of trout, mountain galaxias, blackfish, Australian smelt and redfin.

The “instream cover” model (explaining 30.92% of the overall variance) was mostly associated with one variable, undercut bank (Table 7). The proportion of undercut bank and rock cover was strongly associated with a large group of species including Macquarie perch, cod, goldfish, roach, trout, blackfish and Mountain galaxias (Figure 31). There was also a strong grouping of the fish species that occurred below Dights Falls, and they were associated with the occurrence of emergent macrophytes.

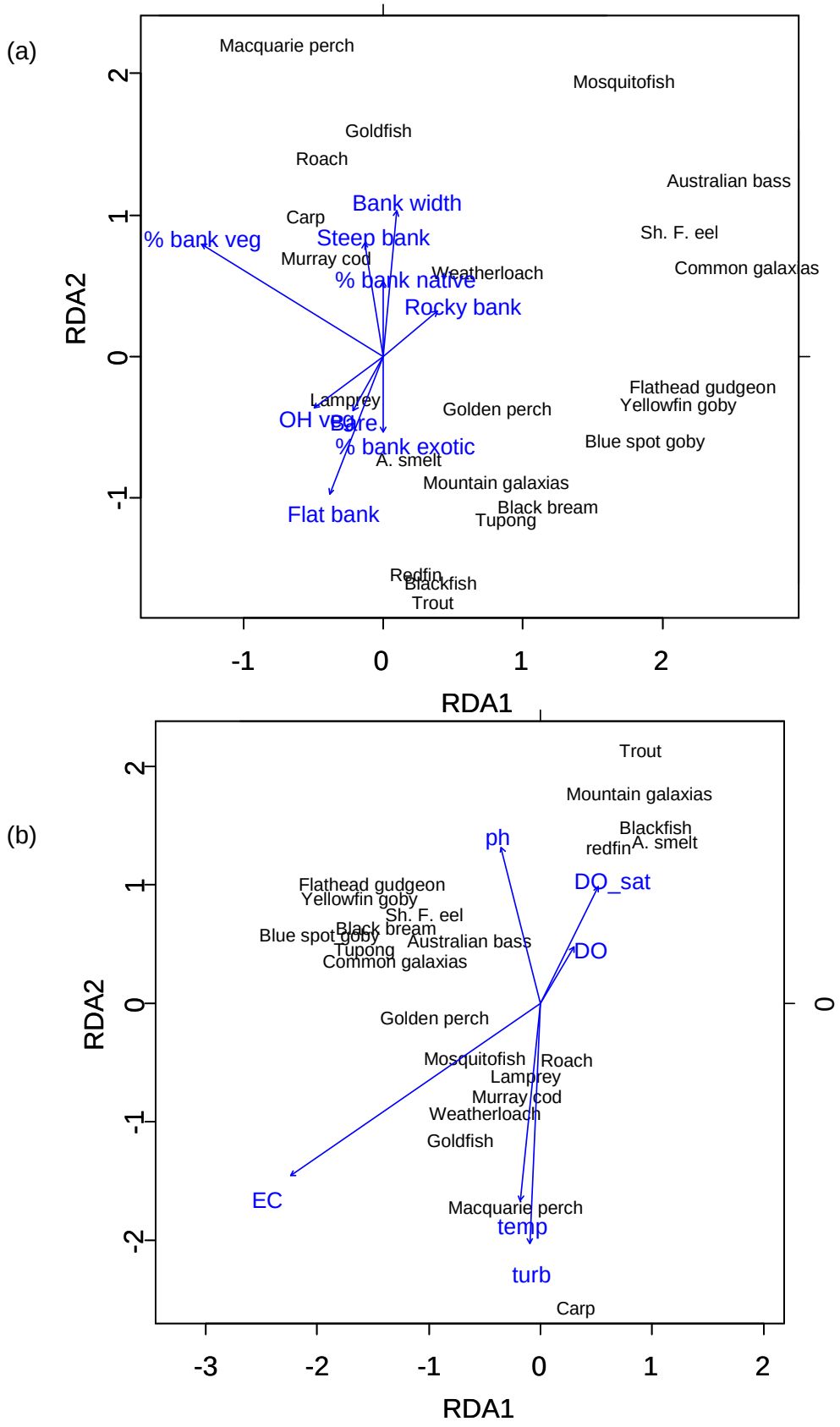


Figure 30. Two-dimensional solution for Redundancy Analysis models on the total number of individuals of each species per site for (a) stream bank characteristics and (b) water chemistry.

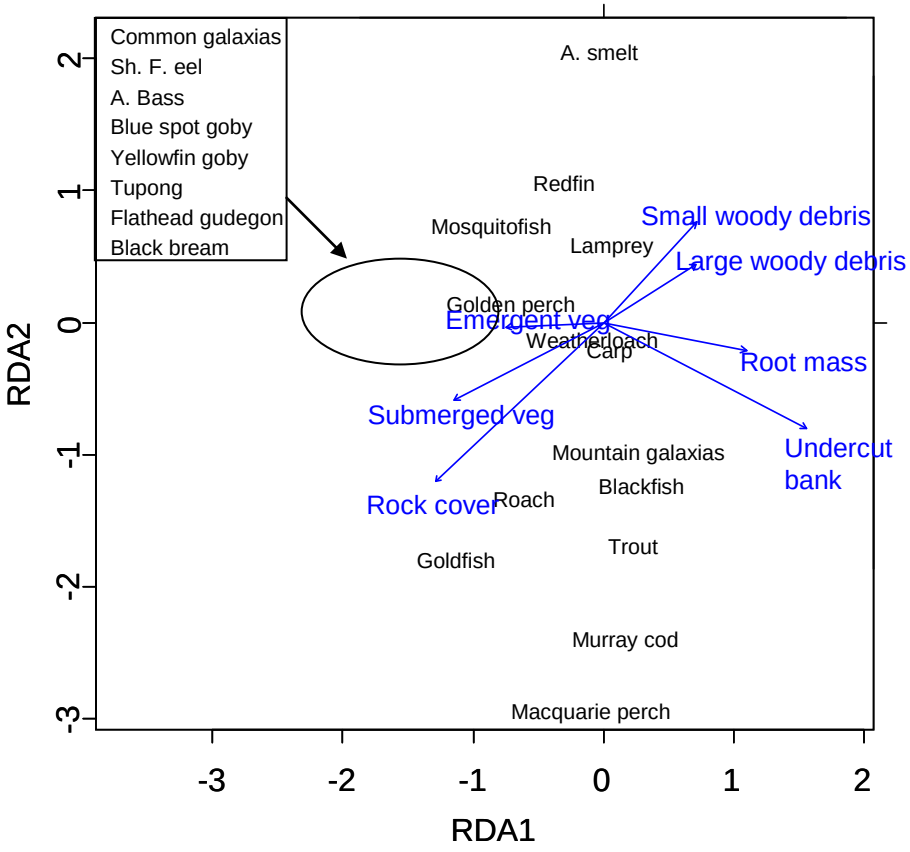


Figure 31. Two-dimensional solution for Redundancy Analysis models on the total number of individuals of each species per site for instream cover.

The Redundancy Analysis graphs can also be used to explore the variables most strongly associated with a particular species. Of particular interest was the habitat variables associated with higher abundances of Macquarie perch. Redundancy analysis showed that Macquarie perch was strongly associated with increasing wetted area, bedrock, proportion of bank vegetated, proportion of native riparian cover, steep banks, increased temperature and turbidity, and rocky cover and undercut banks. However, normal correlation analysis showed that an increase in the abundance of Macquarie perch was most strongly associated with increasing proportions of bedrock and vegetated bank at a site (bedrock: $r=0.606$, $p<0.05$; vegetated bank: $r=0.52$, $p=0.65$) (Figure 32).

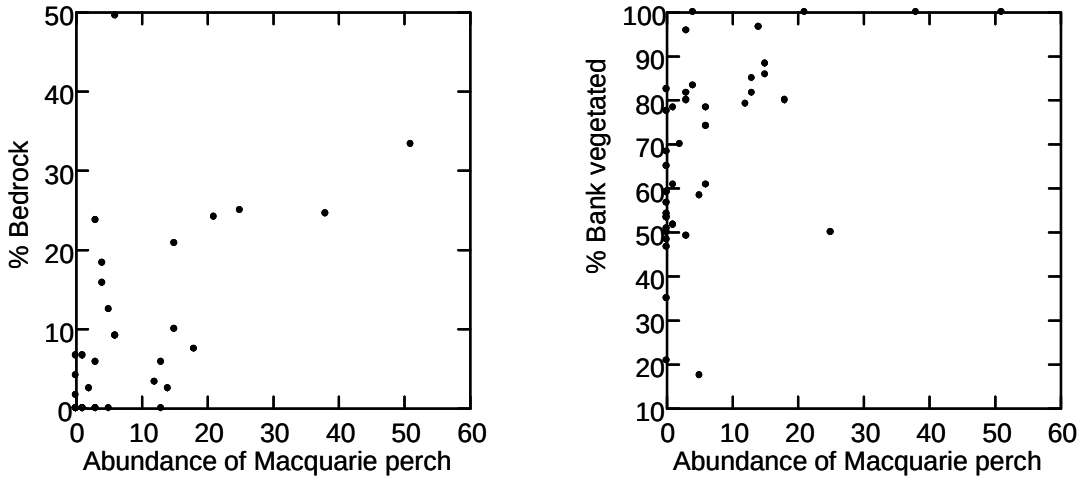


Figure 32. Relationship between the abundance of Macquarie perch and the proportion of bedrock and stream bank vegetated across all sites.

4 Discussion

4.1 Fish diversity and abundance

This survey represented the first known comprehensive survey of the fish community in the Yarra River. Considering the high degree of land clearing, urbanisation and habitat modification that has occurred in the catchment, the fish community was found to be highly diverse with 22 species recorded, 14 of which were native. This included four species of native fish (Australian bass, golden perch, Murray cod and Macquarie perch) that represent successful translocations into the system.

The survey suggests that the Yarra River supports a healthy and diverse native fish community, with a relatively high (19:8) ratio of native to exotic freshwater fish. The diversity of native species was highest at the two sites below Dights Falls with a number of species not found upstream, including the estuarine species black bream, blue spot goby, yellowfin goby, and freshwater species such as Australian bass, flat-headed gudgeon and tupong. The diversity of native species upstream of the weir remained at an average of four

to five species up to the end of the Warrandyte Gorge reach, however, the average diversity decreased in the upper floodplain and upland reaches.

In terms of overall abundance, indigenous native fish (mostly Australian smelt, short-finned eel and common galaxias) were twice as abundant as the exotic fish species. The total abundance of all fish was also considerably higher downstream of Dights Falls compared to the other sites. While this in part is related to the higher diversity of species present at these sites compared to the upstream sites, it also likely to be due to the inability of fish to move upstream through Dights Falls (see discussion below). In the freshwater reaches, fish abundances were higher in the Warrandyte Gorge (sites 17 to 21) and in the upper floodplain reach (sites 29 to 32), compared with other reaches. The higher total abundance at Warrandyte Gorge was associated with increased catches of roach, Australian smelt, short-finned eel and Macquarie perch; while the higher total abundance in the upper floodplain reach was associated with Australian smelt, roach, short-finned eel and redfin.

4.2 Macquarie perch

This survey has confirmed the regional and national significance of the Macquarie perch population in the Yarra River. Although the population has been translocated into the River, it represents probably the most stable and healthy population of the species in Victoria. They were found to be distributed along approximately 130 km of the Yarra River from below Dights Falls in the heart of Melbourne to above Healesville. The presence of young-of-year fish at a number of sites also indicates that the population is spawning and recruiting successfully within the system.

The majority of Macquarie perch were captured in the lowland and gorge reaches. Interestingly, the abundance of Macquarie perch was strongly positively associated with the occurrence of bedrock and proportion of the bank which was vegetated by trees and shrubs. This suggests that in areas of the River where Macquarie perch are not present, but that contain bedrock, increasing the amount of native riparian cover through targeted tree plantings and reservation of land may eventually increase the abundance of perch. It was also noted that in the lowland reach, the abundance of Macquarie perch was associated with complex woody debris and relatively narrower channel widths. This pattern may be an artefact of the natural accumulation of woody debris toward the tail end of larger pools and a lack of other instream habitat features in this section of the Yarra River. However, in the gorge reaches the majority of Macquarie perch were caught in moderately deep water (0.5 - 1.5 m), generally below riffles and cascades.

At three different locations in the Warrandyte Gorge reach, aggregations of 10 to 20 adult fish were also observed apparently attempting to move upstream through shallow riffle sections. The low flows during this survey period and over the last few years, may be restricting their movements across shallow rifle environments, and perhaps having important consequences for the species' feeding and spawning success. Both the small scale and large scale movement requirements for Macquarie perch are not currently known, and require further investigation. This survey also demonstrated that Macquarie perch are obviously spawning and recruiting successfully within the River. Juveniles were collected at a number of sites, particularly in the gorge reach. Due to the conservation significance of the species, investigations should be conducted into their spawning cues, larval and nursery habitat requirements.

In the upper part of the river, Macquarie perch were mostly absent, however this region generally contained similar habitat characteristics to sites downstream where they were collected. Macquarie perch have been collected at higher altitudes from other populations throughout the State, and therefore their distribution in the Yarra River maybe limited by three possible factors. Firstly, it is possible that a large section of degraded stream habitat may represent a significant barrier to the upstream colonization of Macquarie perch. It may also be that Macquarie perch colonise new habitats slowly and that their distribution will expand slowly over time. And thirdly, high abundances of predatory brown trout and redfin recorded in this reach may be impacting Macquarie perch recruitment. Juvenile Macquarie perch have previously been noted to be vulnerable to predation, forming large aggregations in pool habitat, such as in the Cotter River (ACT) (B. Ebner, ACT Fisheries, personal communication, 2007). Predation of juvenile Macquarie perch has also been previously raised as a potential cause of the decline in Macquarie perch populations in Lake Eildon (Wharton, 1968; Cadwallader and Rogan, 1977) and in Lake Dartmouth (Douglas *et al.* 2002). Further studies investigating the extent of any possible interaction between these species needs to be conducted, before any management interventions could be considered. Research could include dietary studies, habitat use and behaviour and movement interactions.

4.3 Other significant native fish

Short-finned eels were an abundant and widely distributed native fish in the Yarra River. However, there had been some concern about the number of eels remaining in the system, since approximately 500 short-finned eels were found dead in the lower Yarra River (upstream and downstream of Dights Falls) between January and February 2005 (N. Bate, personal communication, Environment Protection Authority, 2007). Whilst this is a large number of eels to have been removed from the system at one time, short-finned eels still remain abundant throughout the Yarra River.

Other migratory species, however, were not well represented in the survey, including short-headed lamprey, tupong and Australian Bass. Additionally, a number of other native migratory species that could be expected to be collected in the Yarra River, were not captured in this survey, including Australian grayling, Australian mudfish, pouched lamprey, broad-finned galaxias and spotted galaxias.

While Australian grayling can be difficult to capture and often require specific sampling techniques and effort to capture them, their absence in this survey, including at sites where they have previously been captured in the Warrandyte Gorge, suggests that the species is in low numbers within the system. Nine Australian grayling from two distinct size classes (100-120 mm and 160-180 mm) were captured in the Warrandyte Gorge section in 2003 using similar techniques employed during this survey (Ryan and O'Mahony 2004). It is also possible that low flow conditions over the last two years have reduced the recruitment of Australian grayling and prevented an upstream migration of juveniles into the system. Australian grayling are thought to have the ability to reabsorb eggs if river and flow conditions are not conducive for spawning (O'Connor and Mahoney 2004). Low spring rainfall and river flows over the last two years would have significantly reduced the available spawning habitat and period for Australian grayling. Zampatti *et al.* (2003) reported that grayling were in the proximity of Dights Falls from October to December 2001, corresponding with the tail end of two large flow peaks (3000 and 5000 ML/day). Similar flow events have not occurred since 2005 and may have impacted the upstream migration of

Australian grayling, and other migratory species. Further surveys particularly targeted at sampling Australian grayling should be conducted to determine the status of this nationally threatened species in the Yarra River.

Only 10 short-headed lamprey were captured at a range of sites from the lowland reach to the upper floodplain reach. The low abundance of short-headed lamprey appears to represent a decline in occurrence compared to previous surveys (DEPARTMENT OF SUSTAINABILITY AND ENVIRONMENT 2007). Additionally, only one tupong was captured 500 m downstream of Dights Falls (site 1). A combination of low flow, lack of fish passage and a high abundance of predatory fish below Dights Falls are likely to be contributing to the low abundances observed.

Common galaxias were captured in high numbers in the study however, 74% of all individuals recorded were captured at only the two sites below Dights Falls. This again suggests that upstream passage of fish through Dights Falls was impeded during and prior to the time of the survey. Given that this species is short-lived (mostly annual), upstream recolonisation needs to occur regularly to sustain the population.

Interestingly, a large number of Murray cod, a species that is naturally restricted to the Murray-Darling Basin, were recorded in the Yarra River. Murray cod were caught at 10 of the 43 sites, mostly in the lower half of the Warrandyte Gorge and the lowland floodplain reaches. A wide size range of Murray cod were caught in the lowland and Warrandyte Gorge reaches of the Yarra River ranging from 66 to 742 mm, with the majority between 250 to 300 mm in length, which represent at least two year old fish. Young of the year fish (60 to 100 mm) were also captured in the lowland and Warrandyte Gorge reaches indicating the occurrence of natural recruitment within the system or that illegal stocking is occurring. This data supports anecdotal accounts from fisherman of a significant Murray cod population occurring in the lower reaches of the Yarra. Further research is required to determine the strength of the natural recruitment of Murray cod in the Yarra River, and also determine if illegal stocking is occurring.

4.4 Exotic species

Exotic fish are thought to be favoured by disturbed and altered environments (Arthington *et al.* 1983), and hence the Yarra River would be expected to contain a high diversity and biomass of exotic fish. However, exotic fish only represented 29% of the total abundance of fish and represented less than half of the species diversity. Exotic fish dominated the catch at only eight sites (sites 3 and 4 in the weir pool, sites 19, 20 and 21 in the upper Warrandyte Gorge, sites 25 and 33 in the upland floodplain reach and sites 42 and 43 in the upland reach). The weir pool was dominated by a combination of common carp, gambusia and oriental weatherloach. Roach dominated the Warrandyte reach, and brown trout dominated the upland reach.

Roach were the most abundant exotic species and dominated the catch at five sites (19, 20, 21, 24 and 33). They were widespread, but varied in abundance between sites, being more common in sites with submerged aquatic vegetation, such as in the Warrandyte Gorge reach. This link is probably related to the foraging and spawning preferences of the species (McDowall, 1996) and may indicate that an abundance of dense waterweed (*E. densa*) may be favouring this species in this River reach. Sizes ranged from 31 to 410 mm with the majority

of fish being between 40 and 100 mm, suggesting that roach have recruited successfully over the last one to two years.

Common carp were widely distributed throughout the Yarra River, being found in all but the three sites in the upland region. Higher abundances were noted in the more degraded habitats upstream and downstream of the Warrandyte Gorge reaches in deeper channel reaches. Common carp populations were dominated by large adults between 400 and 650 mm. However, there were also good representations of 50-100 mm fish in the mid to lower reaches of the river. The low flow conditions over the last two years, therefore, appear to have been suitable for some recruitment of common carp.

Redfin were widely distributed along the Yarra River (33 of 43 sites) and were recorded in the highest abundances throughout the upper floodplain reach. A large size range of redfin were captured (from 45 to 430 mm), including a good representation of smaller fish from 70 to 80 mm, suggesting some recruitment over the last year. Brown trout were collected at only 17 sites surveyed, and were highly restricted to the upland and upper floodplain reaches, obviously relating to their habitat preference of cool, clear waters. Redfin and trout are aggressive exotic species that readily prey on smaller fish, and may therefore represent a significant threat to native species in the catchment, including Macquarie perch.

4.5 Fish community and available habitat

The Yarra River fish community shows a clear gradual change in composition with altitude, and the defined zones contained significantly different fish communities. For example, the lowland reach, below Dights Falls, was characterised by common galaxias, short-finned eel and flathead gudgeons; while the next reach upstream (the weir pool) was characterised by these species and gambusia, carp, weatherloach and Australian smelt. The middle reaches were characterised by roach, Macquarie perch, carp and Australian smelt; while the upland reach consisted of a simple community of eels, smelt and trout.

While the fish communities in all of the defined zones did not form distinct groups associated with habitat variables; the community downstream of Dights Falls, the community in the mid-reaches that included roach and Macquarie perch, and the community present in the upland reaches; were associated with particular habitat variables.

4.6 Spatial variation in riverine habitat

Considering the large proportion of the Yarra River's catchment which is now a highly altered landscape, the quality the River's instream habitat was very good and the types of aquatic habitat present for fish varied considerably throughout the River. Immediately below Dights Falls, the river consists of cascades, run and riffles sequence with predominantly rock cover and little woody debris. From Dights Falls to the Warrandyte gorge region, pool habitats were the dominant feature of the lowland zone where the river was wide and the surrounding floodplains were generally flat. Warrandyte gorge was quite distinct from other regions, containing a large proportion of bedrock and macrophytes. Upstream of the Warrandyte gorge, the river was dominated by broad run-riffle sequences and sections with a dominance of silt and sand substrates.

Woody cover and root masses were generally in high densities at most sites (except below Heidelberg and a section immediately downstream of Yering Gorge). Its occurrence is likely to be due in part to the high quality of the riparian zone throughout much of the river, especially in the Warrandyte gorge and lower floodplain region. Bank erosion control works were noted within sampling shots at a number of sites along the Yarra River. Banks reinforced with rock (rip rap) were noted at sites 1, 2, 6, 8, 27, 29, 33, 40 and 41, and wooden retaining walls were noted at sites 7 and 33. These structures provide some habitat for numerous fish species depending on their location within the river system. However, most species seemed to have a preference for the natural habitat provided by undercut banks, larger rocks and snag piles of woody debris.

The Warrandyte Gorge reach had the highest average proportion of most habitat cover variables across the surveyed river reach, and this also corresponded with a relatively high total fish abundance (ie including exotic) and native fish diversity and abundance. This is probably due to the better quality riparian zone (width and nativeness) and diversity of habitat types present in this reach. This highlights the importance of this river reach, and suggests that any external factors that may impact on the health of the River in this reach should be viewed with extreme caution and mitigated if possible.

Emergent and submerged vegetation habitats were often present together and were usually associated with depositional zones. Conversely, a distinct lack of emergent vegetation in some of the upper floodplain region appeared to correspond with unfenced banks and extensive cattle grazing (particularly at sites 23, 25, 26, 27, 28 and 31). Of concern is the widespread occurrence of the introduced species, dense waterweed (*Egeria densa)*, along the river. Dense waterweed is an introduced weed from South America and is considered an aquatic pest in many countries around the world. It thrives in slow flowing waters or in lakes containing high nutrient loads (Sainty and Jacobs, 2003), where it forms dense mats of growth and can out compete native plants and degrade fish habitat. It can rapidly colonise aquatic environments via downstream propagation of broken segments (Riis and Jensen, 2006). Observations during the survey suggest that the largest beds of dense waterweed coincided with depositional zones. While dense waterweed beds appeared to provide habitat for some smaller native fish, exotic species such as oriental weatherloach, roach and goldfish were also commonly collected from beds of the waterweed. Surveys should be conducted to determine the extent of the infestation in the Yarra, possible control options and the use of the waterweed beds as habitat by native fish species.

A notable feature of the aquatic habitat of the River was the heavy sedimentation immediately downstream from a number of the major tributaries, particularly in the upper part of the river. Sediment input into the river is probably mainly from bank and gully erosion, and runoff from horticulture and urban gardens. The accumulation of sediment maybe higher than previous years due to the lack of flushing flows over the last two years. However, whatever its source, siltation has been identified as a major threat to riverine systems and their aquatic inhabitants. Increased sediment into streams can severely alter the riverine channel and available habitat by burying woody debris and macropyhtes, reducing channel volume, alter water depth and substrate complexity (Bond and Lake, 2003). A high level of suspended sediments also increases the turbidity of the water column which can in turn reduce aquatic productivity. High levels of suspended sediment can also be harmful to fish, by potentially smothering developing eggs, particularly of those species that have demersal eggs (eg. river blackfish, Murray cod) and semi-demersal eggs (eg. Macquarie perch, Australian grayling) (Merrick and Schmida, 1984; Koehn and O'Connor, 1990; Jackson *et al.*

1996). River blackfish had a patchy distribution and relatively low abundance within the Yarra River. An absence of river blackfish at sites 21 to 29, 35, 36 and 40, loosely corresponded with a relatively high proportion of fine sediment. The potential impact of sand and silt concentrations on river blackfish abundances should be further investigated via the exploration of river blackfish occurrence and sedimentation rates in the riverine environment in conjunction with laboratory experiments on sediment and fertilization success of exposed eggs.

4.7 Impact of Dights Falls

This study documented a large congregation of native migratory species, particularly common galaxias, downstream of Dights Falls. Additionally, a number of other native migratory species that were expected to be collected in the Yarra River were not captured in this survey, including Australian grayling, Australian mudfish, pouched lamprey, broad-finned galaxias and spotted galaxias.

The presence of this congregation below Dights Falls, and the absence of a number of expected migratory species, suggests that upstream fish passage through Dights Falls was severely impeded before and at the time of these surveys. A fishway does exist on Dights Falls to aid in the upstream passage of fish however, the effectiveness of the fishway is known to vary over a range of flow conditions (Zampatti et al. 2003). Zampatti et al. (2003) found that while a high proportion of broad finned galaxias appeared to negotiate the fishway, only one spotted galaxias was caught upstream of Dights Falls from August 2001 to February 2002. Broad finned galaxias are capable of climbing rocks and resting even in high velocity flows. In contrast, species such as spotted galaxias, tupong and Australian grayling rely on fast burst swimming to move through one rapid at a time, but also require suitable zones to rest. Zampatti et al. (2003) concluded that a number of problems existed with the fishway at that time, and we believe that these problems largely still exist today and have contributed to the inability of fish to negotiate Dights Falls successfully. The key issues required to be addressed at Dights Falls continue to be the reduction of turbulence, provision of suitable resting zones, maintenance of sufficient attraction flow through the fishway during a range of flow events and the existence of large vertical drops in the fishway during low flow conditions.

5 Conclusion

This report summarises the results of a comprehensive fish survey of the freshwater reaches of the Yarra River. It provides a snapshot of the status of the fish community during a period of relatively low stream flow at 43 sites from immediately below Dights Falls to Millgrove. Considering the severity of catchment alteration, the fish community and the aquatic habitat and riparian condition of the Yarra River was surprisingly good.

While the fish community varied with the broad landscape zones along the river, the biggest influence on abundance and diversity of fish was the limited fish passage provided by Dights Falls. An aggregation of migratory fish (common galaxias and short-finned eel) below Dights Falls and an absence of other migratory species (spotted galaxias, broad-finned galaxias and Australian grayling) upstream recorded in this study, is likely to be at least in part due to the inability of these species to move upstream through the fishway in recent years.

The river also contained a number of significant populations of native species, particularly the nationally threatened species Macquarie perch and Murray cod. The population of Macquarie perch in the Yarra River is probably the most significant population in Victoria, and perhaps Australia, and as such has national conservation significance. Macquarie perch and Murray cod were mainly recorded in the Warrandyte gorge reach where there was an abundance of rock, wood and submerged macrophyte cover present. This reach also contained the best quality riparian zone along the river. Over 60% of Macquarie perch were found in the Warrandyte Gorge, where they were mainly caught in moderately deep water (0.5 -1.5 m) below riffles and cascades. Low numbers of Macquarie perch in the upper section of the river corresponded with an increase in shallow run and riffle habitats, cooler water temperatures, an increase in silt and sand substrata, reduced habitat cover and greater abundances of exotic predatory species (brown trout and redfin). The absence of Macquarie perch in the upland reaches is most likely to be due to a barrier of degraded habitat downstream and the effects of the exotic species, rather than a lack of suitable habitat.

A high standard of riparian vegetation and instream habitat and sustained minimum environmental flow has provided an abundance of high quality and diverse range of aquatic habitats in the river. Throughout the River, it was found that fluctuations in the quality of the riverine habitat influenced the diversity and abundance of fish that occur in the different reaches. A high diversity and abundance of native species was found in the Warrandyte reach which was related to improved quality and abundance in instream habitat and riparian cover. A decline in the overall quality of riverine habitat upstream of Warrandyte Gorge, associated with a decline in riparian cover and instream habitat diversity and deposition of fine sediment, resulted in a decline in species diversity.

6 Recommendations

1. Dights Falls represents the most influential feature on fish distribution in the Yarra River, and there is a need to assess and remedy the effectiveness of the fishway, particularly during low flow conditions.
2. Considering the importance and quality of instream habitat and the native fish community of the Yarra River, targeted research should be conducted into the flow and habitat requirements of key species (eg. Macquarie perch, Australian grayling, common galaxias) at all life stages to improve the management of environmental flows and habitat within the River.
3. Targeted surveys should be conducted to determine the status of Australian grayling in the Yarra River system.
4. Investigations should be conducted into the sources and possible remediation of the increased sedimentation observed in the mainstem River. This should also include:
    a. Investigating the relationship between sediment accumulation of riverine flow, particularly in light of a lack of flushing flows in the last two years;
    b. Investigating the source of sediment from major tributaries and actively undertake sub-catchment sediment runoff management programs;
    c. Investigating the impacts of sedimentation on river blackfish eggs with laboratory experiments of exposure of fertilised eggs to sedimentation.

5. Surveys should be conducted to determine the association of native and exotic fish and macroinvertebrate with dense waterweed in the Yarra River. Research should also be conducted to investigate potential control options for the waterweed.
6. As the Yarra River has an abundant and healthy Macquarie perch population, further ecological research on this population should be conducted to better inform the conservation and management of this species in this catchment and also to help better manage the existing remnant populations throughout its natural range. Studies in the Yarra catchment should include:
    a. Determine the extent, timing and location of spawning events
    b. Determine the adult and nursery habitat requirements, including the identification, protection and development of management strategies to help preserve and enhance important nursery habitats
    c. Determine the whether the species undergoes spawning migrations and also small scale movement requirements for foraging and residence
    d. Investigate the interaction of Macquarie perch and exotic predatory species such as redfin and brown trout
7. Given the national significance of the Yarra River Macquarie perch population further consideration should be given to the overall management of the population, including:
    a. A review of the current fishing regulations in the system
    b. A public awareness campaign should be conducted to educate the public, local and regional managers on the significance of the population
    c. In areas of the River where Macquarie perch are not present, but that contain bedrock, increasing the amount of native riparian cover through targeted tree plantings and reservation of land should be encouraged to eventually increase the abundance of perch.
    d. Given the potential damage of exotic predatory species such as brown trout and redfin and the relatively success of native fish populations, consideration should be given to managing the Yarra River as a completely native fishery
8. This study was conducted in a period of prolonged low flows and provided a baseline on the status of fish communities and riverine conditions during this time. However, as the survey was designed in a repeatable manner, and it would be beneficial to conduct further surveys using the same methodology and design, and for it to be conducted after good spring flushes to determine their potential to alter the fish community assemblage of the Yarra River. This would provide important information regarding trends in the fish community and river health, and also provide empirical support for any restoration activities undertaken in the system.

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Appendix 1. Summary of fish caught by electrofishing.

Site	ACA FLA	ACA BUT	ANG AUS	CAR AUR	CYP CAR	GAL MAC	GAM HOL	GAD MAR	GAL OLI	MAC PEE	MAC AMB	MAC AUS	MAC NOV	MIS ANG	MOR MOX	PER FLU	PHI GRA	PSE URV	PSE sp. 9	RET SEM	RUT RUT	SAL TRU
	est	est	nat	exo	exo	nat	eco	nat	nat	nat trans	nat trans	nat trans	nat trans	exo	nat	exo	nat	nat	est	nat	exo	exo
1	5	68	46	1	1	319	0	0	0	1	2	0	0	1	1	0	28	1	5	11	5	0
2	3	5	86	1	6	605	90	0	0	0	0	5	3	4	0	0	19	0	2	0	0	0
3	0	0	43	3	4	5	49	0	0	0	0	1	0	17	0	1	0	0	0	10	0	0
4	0	0	18	1	9	4	77	0	0	0	1	0	0	2	0	0	0	0	0	15	0	0
5	0	0	22	0	16	19	21	0	0	0	0	5	0	23	0	0	0	0	0	23	0	0
6	0	0	17	0	3	11	0	0	0	0	0	13	0	5	0	1	0	0	0	30	0	0
7	0	0	22	1	10	14	0	0	0	0	0	6	0	3	0	1	0	0	0	35	2	0
8	0	0	16	0	50	3	1	0	0	1	0	12	0	3	2	3	0	0	0	66	1	0
9	0	0	16	0	30	6	25	0	0	0	0	14	0	0	0	1	0	0	0	45	2	0
10	0	0	40	0	7	28	0	0	0	3	0	13	0	0	0	2	0	0	0	0	3	0
11	0	0	25	3	14	96	10	0	0	0	0	18	0	2	1	0	0	0	0	39	4	0
12	0	0	16	0	13	19	0	0	0	0	0	15	0	0	2	1	0	0	0	90	5	0
13	0	0	8	1	15	7	13	0	0	4	0	6	0	0	0	40	0	0	0	41	2	0
14	0	0	7	1	11	15	2	0	0	1	0	3	0	0	0	4	0	0	0	25	1	0
15	0	0	28	4	15	12	12	0	0	24	0	51	0	3	0	2	0	0	0	52	7	0
16	0	0	31	3	5	55	27	0	0	15	0	4	0	2	0	2	0	0	0	74	2	0
17	0	0	19	3	8	23	0	0	0	16	0	25	0	5	0	3	0	0	0	245	4	0
18	0	0	36	4	8	18	33	0	0	2	0	38	0	8	0	10	0	0	0	94	17	0
19	0	0	33	4	6	0	0	0	0	1	0	15	0	2	0	7	0	0	0	99	349	0
20	0	0	14	0	3	0	0	0	0	0	0	21	0	0	0	10	1	0	0	10	248	0
21	0	0	39	5	18	0	0	1	0	0	0	6	0	0	0	9	0	0	0	126	297	1
22	0	0	15	1	19	3	43	0	0	0	1	4	0	0	0	4	0	0	0	73	6	0
23	0	0	13	0	6	2	2	0	0	0	0	2	0	0	0	4	0	0	0	82	2	0
24	0	0	37	0	13	0	0	0	0	0	0	3	0	0	0	3	0	0	0	61	69	1
25	0	0	11	0	21	2	0	0	0	0	0	0	0	0	0	3	0	0	0	6	11	4
26	0	0	13	0	7	0	0	0	0	0	0	0	0	0	0	5	0	0	0	75	10	0
27	0	0	16	0	4	0	0	0	0	0	0	1	0	0	0	12	0	0	0	61	7	1
28	0	0	17	1	5	0	0	0	0	0	0	1	0	0	0	53	0	0	0	123	43	0
29	0	0	30	0	13	0	50	0	0	0	0	0	0	0	0	39	0	0	0	256	48	0
30	0	0	46	0	11	1	0	2	0	0	0	0	0	0	0	73	0	0	0	240	27	0
31	0	0	33	0	7	0	0	0	0	0	0	0	0	0	0	1	0	0	0	160	19	2
32	0	0	32	0	12	3	0	3	0	0	0	0	0	0	0	23	0	0	0	370	40	12
33	0	0	12	0	8	3	0	5	0	0	0	3	0	0	0	7	0	0	0	19	143	1
34	0	0	35	0	7	0	0	2	0	0	0	0	0	0	0	21	0	0	0	220	6	5
35	0	0	30	0	8	0	0	0	0	0	0	0	0	0	4	2	0	0	0	87	4	4
36	0	0	23	0	2	0	0	0	0	0	0	3	0	0	0	4	0	0	0	55	0	13
37	0	0	23	0	13	0	0	2	0	0	0	0	0	0	0	0	0	0	0	227	0	11
38	0	0	21	0	16	0	0	4	0	0	0	1	0	0	0	6	0	0	0	68	6	18
39	0	0	17	0	4	0	0	2	0	0	0	0	0	0	0	3	0	0	0	237	15	5
40	0	0	18	0	1	0	0	0	1	0	0	0	0	0	0	2	0	0	0	130	1	9
41	0	0	28	0	0	0	0	16	0	0	0	0	0	0	0	12	0	0	0	94	8	66
42	0	0	28	0	0	0	0	9	1	0	0	0	0	0	0	153	0	0	0	153	1	34
43	0	0	10	0	0	0	0	1	2	0	0	0	0	0	0	0	0	0	0	0	0	34

Appendix 2. Summary of riparian characteristics.

Riparian characteristics of all sites. All values are expressed as a mean percentage. Overhanging vegetation is expressed as a percentage of the wetted surface of the river.

Site No.	Mean riparian cover %	Mean width %	Native Veg %	Exotic Veg %	bare (eroded or beach) %	OH veg %	Steep bank (>10m) %	Flat bank (<10m) %
1	20.83	42.50	85.00	15.00	0.00	5.00	0.00	100.00
2	17.50	40.00	87.50	12.50	0.00	0.00	0.00	50.00
3	51.67	50.00	100.00	0.00	0.00	5.00	25.00	75.00
4	65.00	50.00	100.00	0.00	0.00	11.25	16.67	83.33
5	58.33	50.00	100.00	0.00	0.00	17.92	0.00	100.00
6	85.00	50.00	100.00	0.00	0.00	24.58	0.00	100.00
7	78.33	31.67	92.50	7.50	0.00	22.50	0.00	100.00
8	79.17	41.25	72.50	27.50	0.00	14.17	0.00	100.00
9	96.67	50.00	75.83	24.17	0.00	16.67	0.00	100.00
10	81.67	20.83	94.17	5.83	0.00	15.00	0.00	100.00
11	80.00	15.00	82.50	17.50	0.00	18.33	0.00	100.00
12	85.83	50.00	99.17	0.83	0.00	16.25	0.00	100.00
13	60.83	50.00	95.83	4.17	0.00	5.00	0.00	100.00
14	49.17	50.00	95.83	4.17	0.00	10.00	0.00	100.00
15	100.00	50.00	100.00	0.00	0.00	5.00	0.00	100.00
16	83.33	50.00	80.00	20.00	0.00	15.00	0.00	100.00
17	50.00	50.00	25.00	75.00	0.00	8.33	0.00	100.00
18	100.00	50.00	100.00	0.00	0.00	14.58	100.00	0.00
19	88.33	50.00	91.67	8.33	0.00	14.17	41.67	58.33
20	100.00	50.00	100.00	0.00	0.00	10.00	0.00	100.00
21	74.17	50.00	100.00	0.00	0.00	6.67	66.67	33.33
22	100.00	50.00	100.00	0.00	0.00	9.58	58.33	41.67
23	70.00	10.42	100.00	0.00	5.00	19.17	0.00	100.00
24	95.83	45.00	96.67	3.33	0.00	87.50	54.17	45.83
25	53.33	27.50	100.00	0.00	20.83	30.00	0.00	100.00
26	77.50	12.50	98.33	1.67	0.00	35.00	0.00	100.00
27	60.83	10.83	87.50	12.50	18.33	70.00	0.00	100.00
28	78.33	10.42	74.17	25.83	10.00	66.67	0.00	100.00
29	35.00	12.92	98.33	1.67	30.00	13.33	0.00	70.00
30	48.33	20.83	80.83	19.17	10.83	28.33	0.00	100.00
31	59.17	44.17	100.00	0.00	16.67	34.58	0.00	100.00
32	68.33	50.00	100.00	0.00	4.17	15.83	12.50	87.50
33	81.67	42.50	100.00	0.00	13.33	55.00	12.50	87.50
34	46.67	50.00	100.00	0.00	4.17	23.33	0.00	79.17
35	59.17	13.33	85.00	17.50	5.83	20.00	0.00	100.00
36	80.00	17.00	85.00	15.00	29.17	24.17	0.00	95.83
37	56.67	24.17	82.50	17.50	0.00	10.42	14.17	85.83
38	51.67	34.17	95.83	4.17	0.00	15.00	0.00	100.00
39	82.50	23.33	45.83	54.17	5.83	21.67	5.83	94.17
40	53.33	13.75	10.00	90.00	5.00	0.00	0.00	75.00
41	50.00	19.17	75.83	24.17	0.00	16.25	0.00	100.00
42	50.83	14.58	53.33	46.67	0.00	13.33	0.00	100.00
43	54.17	36.67	95.83	4.17	0.00	9.17	0.00	100.00

Appendix 3. Summary of instream habitat cover.

Most common rank habitat cover per site. Values in table are expressed as a rank cover abundance with 1 – Abundant (>90%), 2 – Frequent (50 to 90%), 3 – Occasional (10 to 50%), Rare (>10%) and Absent (0%). Rocky bank is expressed as % cover of bank.

Site No.	Undercut bank	Emergent macrophytes	Submerged macrophytes	Rock cover	Root mass	Small wood	Large wood	Rocky* bank
1	0	1	2	4	1	2	2	0.00
2	0	2	3	4	0	1	1	31.25
3	2	2	0	2	1	1	1	25.00
4	3	2	0	1	2	2	2	0.00
5	3	1	0	1	3	2	2	0.00
6	3	1	0	1	3	2	3	6.67
7	2	1	0	1	2	2	2	16.67
8	2	1	0	1	3	3	3	0.00
9	3	0	1	1	3	3	3	0.00
10	3	0	0	1	1	3	3	25.00
11	2	0	1	1	2	2	2	0.00
12	3	1	1	2	2	2	1	0.00
13	3	0	0	1	2	1	2	0.00
14	2	0	1	1	2	2	2	0.00
15	3	1	4	4	2	2	2	0.00
16	3	1	1	1	3	2	2	0.00
17	3	1	0	1	2	2	3	0.00
18	1	1	1	4	1	1	1	0.00
19	2	2	1	2	2	2	2	0.00
20	3	1	0	4	4	3	2	0.00
21	2	1	4	4	1	1	1	58.33
22	3	2	0	2	3	3	2	40.00
23	3	1	0	1	3	3	2	0.00
24	4	2	1	2	2	2	2	53.33
25	3	1	0	0	2	2	3	0.00
26	2	1	0	1	3	3	3	0.00
27	2	0	1	1	2	3	2	0.00
28	2	0	1	0	2	3	2	0.00
29	1	1	1	0	1	3	3	0.00
30	1	1	2	1	1	3	3	42.50
31	3	0	1	0	2	2	2	0.00
32	1	1	1	1	1	2	3	0.00
33	3	1	0	1	2	2	2	3.33
34	2	0	0	1	2	3	2	11.67
35	2	0	0	0	2	2	3	0.00
36	3	0	0	0	2	3	3	0.00
37	2	0	1	1	2	2	2	4.17
38	3	0	1	2	3	2	2	0.00
39	3	0	1	0	3	3	2	0.00
40	2	0	0	1	2	2	2	11.67
41	3	0	1	2	1	2	3	25.00
42	3	3	1	2	1	2	2	0.00
43	2	0	0	4	1	1	1	0.00

Appendix 4. Summary of instream and flow characteristics.

Mean habitat characteristics of mesohabitat within sites. All values are expressed as a measurement in metres or as a mean percentage, except Velocity which is a mean rank value, where 1 refers to slow water velocity, 2 refers to – medium water velocity and 3 refers to fast water velocity.

Site No.	Velocity (rank)	Mean depth (m)	Max depth (m)	Wetted width (m)	Riffle %	Run %	Pool %	Back water %
1	2	0.63	0.79	19.75	20.83	20.83	58.33	0.00
2	3	0.58	0.98	21.25	77.50	22.50	0.00	0.00
3	1	1.52	2.03	44.25	0.00	0.00	100.00	0.00
4	1	2.05	2.79	43.75	0.00	0.00	100.00	0.00
5	1	1.94	2.62	38.75	0.00	0.00	100.00	0.00
6	1	1.42	2.01	23.42	0.00	0.00	100.00	0.00
7	1	0.92	1.48	24.33	0.00	0.00	100.00	0.00
8	1	0.95	1.61	24.88	0.00	16.67	83.33	0.00
9	2	1.20	1.56	25.50	8.33	20.00	71.67	0.00
10	1	0.95	1.55	21.67	0.00	16.67	83.33	0.00
11	1	1.03	1.53	21.50	0.00	23.33	76.67	0.00
12	1	1.15	1.57	25.67	16.67	2.50	80.83	0.00
13	1	1.15	1.78	33.33	4.17	4.17	91.67	0.00
14	1	1.19	1.73	43.08	0.00	6.67	93.33	0.00
15	1	0.83	1.40	34.50	0.00	25.00	75.00	0.00
16	1	1.63	2.25	41.83	0.00	10.83	89.17	0.00
17	2	1.01	1.73	23.42	25.00	20.83	54.17	0.00
18	2	1.07	1.51	36.25	8.33	37.50	54.17	0.00
19	2	0.79	1.13	32.67	14.17	35.83	45.83	4.17
20	1	1.27	2.54	44.75	6.67	21.67	71.67	0.00
21	2	0.74	1.35	35.67	9.17	46.67	43.33	0.83
22	1	1.17	3.07	46.00	0.00	8.33	91.67	0.00
23	1	2.48	3.03	24.58	0.00	0.00	100.00	0.00
24	1	0.94	1.40	34.25	0.00	29.17	70.83	0.00
25	1	1.10	1.77	18.58	0.00	0.00	100.00	0.00
26	1	0.93	1.38	18.00	0.00	4.17	95.83	0.00
27	2	1.04	1.83	16.38	0.00	8.33	91.67	0.00
28	1	0.87	1.63	23.79	0.00	35.00	63.33	1.67
29	1	0.87	1.23	18.25	0.00	37.50	62.50	0.00
30	2	0.73	1.09	12.33	8.33	79.17	12.50	0.00
31	2	0.68	1.03	16.42	0.00	54.17	45.83	0.00
32	2	0.54	0.83	12.67	6.67	70.00	23.33	0.00
33	2	0.79	1.21	23.29	0.00	71.67	28.33	0.00
34	1	0.60	0.82	19.17	0.83	45.00	54.17	0.00
35	2	0.65	1.11	16.42	1.67	65.00	33.33	0.00
36	2	0.81	1.33	15.00	0.83	82.50	16.67	0.00
37	2	0.57	0.93	14.75	16.67	75.00	8.33	0.00
38	2	0.67	1.01	15.63	20.00	51.67	26.67	1.67
39	1	0.90	1.37	19.21	0.00	8.33	91.67	0.00
40	2	0.78	1.07	14.08	0.00	54.17	45.83	0.00
41	2	0.73	1.14	15.42	29.17	53.33	17.50	0.00
42	1	0.85	1.49	22.92	5.83	27.50	66.67	0.00
43	3	0.52	0.70	20.00	75.83	11.67	12.50	0.00

Appendix 5. Summary of mean substrate characteristics.

Mean substrate characteristics within sites. All values are expressed as a mean percentage.

Site No.	Clay %	Silt %	Sand %	Gravel %	Pebble %	Cobble %	Rock %	Bedrock %
1	0.00	7.92	5.00	7.08	7.08	10.00	62.92	0.00
2	0.00	3.75	10.00	10.00	17.50	17.50	28.75	12.50
3	0.00	45.42	23.33	7.50	3.75	4.17	8.33	6.67
4	0.00	54.17	32.92	7.92	1.67	1.67	1.67	0.00
5	0.00	54.17	38.75	2.50	1.25	1.67	1.67	0.00
6	0.00	35.00	25.00	15.00	6.67	6.67	11.67	0.00
7	0.00	43.33	16.67	11.67	9.58	2.50	7.08	9.17
8	0.00	45.83	29.17	10.83	4.17	2.50	4.17	3.33
9	0.00	26.67	30.83	15.00	10.00	10.83	2.50	2.50
10	10.00	25.00	27.50	3.75	0.42	4.17	23.33	5.83
11	18.33	33.33	16.67	13.33	5.00	1.67	4.17	7.50
12	0.00	28.33	27.50	9.17	3.33	3.33	6.67	20.83
13	0.00	36.67	35.42	4.58	4.17	4.17	5.83	9.17
14	0.00	39.17	37.50	5.00	2.92	1.25	8.33	5.83
15	0.00	18.33	7.50	5.83	5.42	7.92	19.17	33.33
16	0.00	50.00	22.50	4.17	1.67	0.42	2.92	18.33
17	0.00	40.00	15.00	1.67	2.50	1.67	14.17	25.00
18	0.00	17.50	15.83	12.08	7.92	8.75	14.17	24.58
19	0.00	20.83	14.17	13.33	19.58	16.67	10.42	10.00
20	0.00	41.67	13.33	5.83	5.83	4.17	5.83	24.17
21	0.00	13.33	20.83	0.00	2.08	4.17	8.33	49.58
22	0.00	55.83	14.17	0.83	0.83	0.00	10.83	15.83
23	0.00	74.17	23.33	0.00	0.00	0.00	0.00	2.50
24	0.00	15.83	50.00	0.83	1.67	0.00	7.92	23.75
25	0.00	90.00	10.00	0.00	0.00	0.00	0.00	0.00
26	0.00	69.17	23.33	0.00	0.00	0.00	0.83	6.67
27	4.17	59.17	36.67	0.00	0.00	0.00	0.00	0.00
28	0.00	11.67	88.33	0.00	0.00	0.00	0.00	0.00
29	0.00	28.33	52.50	16.67	6.67	0.00	0.00	0.00
30	10.00	24.17	45.00	11.67	0.00	0.00	8.33	0.00
31	0.00	32.50	52.50	9.17	5.83	0.00	0.00	0.00
32	5.83	11.67	61.67	14.17	1.67	0.83	1.67	0.00
33	8.33	7.08	72.92	0.00	5.83	1.67	4.17	0.00
34	0.00	29.17	45.83	13.33	4.58	4.58	2.50	0.00
35	0.00	34.17	49.17	14.17	4.17	0.00	0.00	0.00
36	6.67	13.33	53.33	10.42	8.75	8.33	0.00	0.00
37	0.00	4.58	33.33	25.00	25.42	10.00	1.67	0.00
38	0.00	23.33	15.42	19.17	22.50	16.67	2.92	0.00
39	0.00	68.33	31.67	0.00	0.00	0.00	0.00	0.00
40	0.00	40.00	45.00	7.50	1.67	6.67	0.00	0.00
41	0.00	3.33	11.67	18.75	30.00	30.00	6.25	0.00
42	0.00	38.33	12.08	6.67	18.33	15.83	8.75	1.67
43	0.00	2.50	11.67	11.67	24.58	24.58	26.67	4.17

Appendix 6. Water quality.

Site No.	EC (uS/cm) (at 25 oC)	Temp. (°C)	DO (mg/L)	DO (%)	pH	Turbidity (NTU)
1	273	21.6	7.54	85.4	7.43	5.7
2	201	20.4	8.2	90.7	7.3	6.6
3	197.3	21.9	6.19	66.5	6.54	4.1
4	142.2	22.5	7.55	90.7	6.56	9.6
5	142.2	22.5	7.55	90.7	6.56	9.6
6	183.5	22.3	8.22	88.2	6.73	13.9
7	178	21.2	7.35	86	6.9	14.6
8	175.2	22.6	8.81	106	6.1	20.8
9	165	23.8	10.84	86.5	6.25	12.3
10	160	24.1	6	75	6.6	10.5
11	162	24.1	6.05	77.6	6.61	10.5
12	178.2	21.6	8.22	99.1	6.37	7.6
13	166	23.2	7.17	89.5	7.3	8.1
14	140	24.2	8.95	89	6.07	7.6
15	165.20	25.60	6.86	89.50	6.20	5.70
16	171.00	23.70	6.85	89.50	6.26	6.20
17	173.00	23.90	7.71	88.30	6.72	6.50
18	155.00	19.80	10.17	100.40	6.53	11.70
19	153.40	26.50	8.47	125.00	6.88	15.80
20	167.00	26.10	6.67	69.50	7.12	5.00
21	136.00	25.90	7.16	74.10	8.43	17.90
22	127.00	25.60	5.23	62.20	7.32	18.00
23	129.00	23.20	13.17	112.90	6.53	4.70
24	187.00	21.20	6.21	73.20	7.00	9.46
25	111.90	26.80	6.26	79.50	6.69	11.90
26	114.00	26.80	6.36	60.00	7.00	12.00
27	81.50	20.90	11.00	83.50	8.50	8.00
28	94.60	23.40	6.20	67.10	8.36	14.00
29	71.20	18.30	10.16	111.90	6.64	2.40
30	67.50	20.60	9.88	102.50	6.59	3.10
31	69.30	16.70	8.81	93.10	6.74	6.90
32	61.00	17.30	10.27	99.00	6.53	2.50
33	92.80	22.30	6.03	74.30	6.96	14.20
34	60.10	19.30	91.60	93.60	6.55	6.00
35	64.70	19.20	9.45	102.10	6.72	7.50
36	57.50	20.00	9.43	104.20	6.73	3.80
37	56.30	19.00	8.23	91.80	6.70	5.40
38	56.00	18.80	9.04	97.40	6.76	2.50
39	55.90	20.30	8.89	100.00	6.86	2.10
40	51.50	18.90	9.51	103.50	6.84	2.70
41	48.30	21.20	9.41	107.90	7.27	2.20
42	48.40	21.00	9.14	104.80	7.20	2.30
43	52.00	19.90	11.34	113.50	7.77	2.60

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