A summary of three years survey data (1998-2000) of fish populations in the Barwon River

A report to the Corangamite Catchment Management Authority

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State Government Victoria
Department of Natural Resources and Environment

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Cover photographs (top to bottom): Barwon River upstream of Birregurra Creek (B. Zampatti)
Barwon River at McMillans Lane (T. Raadik)
Barwon River 4km west of Murghebolac (B. Zampatti)

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SUMMARY

The Lough Calvert Drainage Scheme (LCDS), located in western Victoria, was constructed in the 1950's and utilises a series of artificial channels and gates to prevent saline water in numerous lakes from flooding surrounding agricultural land. Saline water diverted by the LCDS is ultimately discharged into the Barwon River via Birregurra Creek.

The effects of increased salt on fish communities are poorly understood. Unnaturally high levels of salt may have lethal physiological effects or sub-lethal effects such as reduced growth rates, reduced reproductive success and reduced health and vigour. Unnaturally high salt concentrations will favour salinity tolerant taxa, and may result in altered species diversity, abundance and distribution (Mitchell *et al.* 1996). Salinisation may also affect organisms indirectly through creating changes to habitat attributes (ie. a direct effect on macrophytes which are important as cover for some fish species) or trophic relationships between species (Mitchell *et al*. 1996).

The LCDS usually operates for about three months in most years but at the time of this study had not operated since the spring of 1996 due to low rainfall. This presented an opportunity to collect baseline information on the fish community in the absence of saline water disposal. **Freshwater Ecology** (Arthur Rylah Institute for Environmental Research, Department of Natural Resources and Environment) was commissioned by the **Corangamite Catchment Management Authority** to undertake surveys of Barwon River fish communities. The assessment of fish communities is part of a long term, catchment-scale examination of the Barwon River catchment conducted in conjunction with other projects examining aquatic macroinvertebrates (Canale *et al*. 2001), platypus populations, riparian vegetation condition, instream macrophytes, terrestrial fauna and birds.

It is important to note that any impacts resulting from the previous operation of the LCDS may still be affecting fish communities. The data collected in this study therefore may not necessarily reflect the condition of fish assemblages in a state unaffected by inputs from saline water disposal. The data collected in this study does however, provide valuable baseline information on the distribution, diversity and abundance of fish species in the Barwon River, and may be used in the comparison of future surveys to provide information on changes in assemblage structure.

The principal objectives of this project were to:

- Collect baseline information of fish distribution, diversity and abundance in the Barwon River.

- Describe spatial and temporal variations in fish assemblage structure in the Barwon River.

- Identify the primary factors impacting on the condition of fish assemblages in the Barwon River.

Surveys of the fish fauna of the Barwon River were conducted in 1998, 1999 and 2000, using bank-mounted electrofishing and netting techniques. Sites were located from Pollocksford Bridge approximately 17 km upstream of Geelong to just below the junction of the east and west branches of the Barwon River, a distance of approximately 90 km.

A total of 15 species of freshwater fish (nine native and six exotic) and two species of decapod crustacea were collected from sites on the Barwon River (1998-2000). One of the native freshwater fish species collected, Yarra pygmy perch (*Nannoperca obscura*), is classified as threatened in southeastern Australia.

Native fish species comprised the majority of the catch in all three years. Short-finned eel (*Anguilla australis*), Australian smelt (*Retropinna semoni*) and flat-headed gudgeon (*Philypnodon grandiceps*) were the most abundant species collected and were also widespread. River blackfish (*Gadopsis marmoratus*), southern pygmy perch (Nannoperca australis) and Yarra pygmy perch were also widespread. Nevertheless, southern pygmy perch were most common in the mid reaches and Yarra pygmy perch were most common in the lower reaches. Mountain galaxias (*Galaxias olidus*) were primarily restricted to the upstream sites. Common galaxias (*Galaxias maculatus*) and tupong (*Pseudaphritis urvillii*) were primarily restricted to sites in the lower reaches of the study area.

Exotic species generally comprised a relatively small proportion of the catch. The exotic brown trout (*Salmo trutta*), eastern gambusia (*Gambusia holbrooki*) and redfin (*Perca fluviatilis*) were distributed throughout much of the study area. Tench (*Tinca tinca*) were collected from sites in the mid-lower reaches. Carp (*Cyprinus carpio*) were only collected in the mid-upper reaches. Goldfish (*Carassius auratus*) were primarily restricted to the lower reaches.

There was considerable spatial and/or temporal variation in the abundance of some species. Species diversity and abundance generally increased in a downstream direction. This may reflect either a progressive downstream increase in the size and diversity of available habitat supporting increased species diversity and abundance, and/or the presence of barriers to fish movement in the mid to lower Barwon River.

In the lower reaches of the study area total fish abundance decreased considerably from 1998 to 1999, due largely to a decline in the numbers of Australian smelt collected. At most sites throughout the study area total fish abundance increased substantially from 1999 to 2000.

The diversity of native fish species recorded was moderate; approximately 60% of the native species expected to occur under natural conditions were collected. Seven native species previously recorded in the Barwon River catchment were not collected in this study.

Numerous factors impacting on environmental condition within the study area and more specifically on fish assemblages were identified. These include:

- Barriers to fish migration,
- Habitat degradation,
- Introduction of exotic species and,
- Changes to water quality.

Recommendations concerning the major issues relevant to the Barwon River fish community are provided below.

Instream barriers

- Continue to investigate fish passage options for instream structures that restrict fish passage.

- Develop and implement an ongoing program to monitor the effectiveness of fishway structures in providing unimpeded passage.

Habitat degradation

- Continue stream bank protection works, revegetation and stock fencing projects along waterways throughout the catchment.

- Investigate relationships between key fish species and habitat heterogeneity to assist in understanding and interpreting any changes in fish assemblage structure in relation to environmental conditions.

Water quality

- Develop and implement a program of investigation with specific hypotheses to assess the effect of operation of the LCDS on fish species and communities.

- Continue to address through research the effects of increased salt loads on fish species and communities.

1 INTRODUCTION

Rising saline water tables are a serious and widespread environmental threat confronting rural Victoria. Although waters in some areas of Australia have naturally high salt concentrations, the increase in salt levels as well as the expansion in geographical extent of salinisation is thought to be a direct result of European settlement. Landscape changes including broad-scale irrigation schemes and extensive clearing and replacement of native vegetation with shallow-rooted crops and pasture have increased delivery of surface water to ground water tables and reduced evapo-transpiration. This has led to an increase in water table levels and transportation of saline groundwater to the surface, leading to salinisation of soils and waterways. Management attempts to control the spread of salt affected land have included pumping and disposal of saline lake and ground water direct to riverine environments. This has adversely impacted these systems (reviews can be found in: Hart *et al*. 1991, Metzeling *et al.* 1995, Ryan and Davies 1996, Mitchell *et a*l. 1996), however quantifying these effects is a complex task.

An example of this is the Lough Calvert Drainage Scheme (LCDS), located to the north-east of Colac in western Victoria. The drainage scheme was constructed in the 1950's and utilises a series of artificial channels and gates to prevent saline water from Lake Colac and Lough Calvert[1] flooding surrounding agricultural land. Lake Colac is a large, slightly saline, permanent lake while the lakes in the Lough Calvert are ephemeral saline lakes (Canale *et al*. 2001).

Water diverted by the LCDS is ultimately discharged into the Barwon River via Birregurra Creek. The LCDS usually operates for about three months in most years (Canale *et al*. 2001) but at the time of this study had not operated since the spring of 1996 due to low rainfall. There is evidence that operation of the LCDS impacts upon the water quality and invertebrate fauna of Birregurra Creek and the Barwon River (Kefford and Robley 1996, Kefford 1998a, b, Kefford 2000a, b). Nevertheless, water quality analysis and data from toxicity studies indicate that physico-chemical parameters other than salinity may confound the biological and ecological effects of unnaturally high salinity (Kefford and Robley 1996, Kefford 2000a, b).

Little is known about the potential impacts of the LCDS on other fauna and flora in the Barwon River. The Freshwater Ecology Section of the Department of Natural Resources and Environment was commissioned to undertake surveys of the fish fauna of the Barwon River in 1998, 1999 and 2000, to provide baseline data on species diversity, distribution and abundance, in the absence of saline water inputs from the scheme. The results of the 1998 and 1999 surveys have previously been discussed by Saddlier (1998) and Zampatti and Grgat (2000) respectively. In this report the results from the third year of survey (2000) are presented together with some comparison to the 1998 and 1999 survey results. The assessment of fish

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[1] Lough Calvert includes three lakes – Lower Lough South, Lower Lough North and Sanctuary Lake.

communities presented here is one component of a long term, catchment-scale examination of the Barwon River system conducted in conjunction with other projects examining aquatic macroinvertebrates (Canale *et al*. 2001), platypus populations, riparian vegetation condition, instream macrophytes, terrestrial fauna and birds.

It is important to note that any impacts resulting from the previous operation of the LCDS may still be affecting fish communities. The data collected in this study therefore may not necessarily reflect the condition of fish assemblages in a state unaffected by inputs from saline water disposal. The data collected in this study does however, provide valuable baseline information on the distribution, diversity and abundance of fish species in the Barwon River, and may be used in the comparison of future surveys to provide information on changes in assemblage structure.

The principal objectives of this project were to:

- Collect baseline information of fish distribution, diversity and abundance in the Barwon River.

- Describe spatial and temporal variations in fish assemblage structure in the Barwon River in the absence of saline water disposal.

- Identify the primary factors impacting on the condition of fish assemblages in the Barwon River.

This report is structured in four main sections. The preceding introduction provides background information and study objectives. Section two provides details of survey design and sampling methodology used in the three years of fish surveys. Section three describes and compares the three years of survey results that provide valuable baseline information on fish assemblages in the Barwon River. Section 4 discusses threatening processes that may impact on fish communities in the Barwon River, including barriers to fish migration, habitat degradation, introduction of exotic species and changes to water quality. Recommendations that provide a basis for managing key issues affecting the condition of fish assemblages are also provided.

2 METHODS

2.1 STUDY AREA

Catchment characteristics and study sites have been previously described in Saddlier (1998), Zampatti and Grgat (2000) and Canale *et al.* (2001). The Barwon River catchment is located approximately 150 km south west of Melbourne. Rising at approximately 600 m on the northern slopes of the Otway Ranges, the river flows east, primarily through agricultural land, and enters the ocean at Barwon Heads just south of Geelong (Figure 2-1). The current study focuses on the catchment from Pollocksford Bridge approximately 17 km upstream of Geelong to just below the junction of the east and west branches of the Barwon River, a distance of approximately 90 km.

2.2 STUDY SITES

A total of 12 sites were surveyed in 2000 on the Barwon River between November 27th and December 19th (Table 2-1). All of the sites surveyed in 1999 (Zampatti and Grgat 2000) were resampled in 2000, except for the site immediately downstream of Birregurra Creek (site 4). The majority of sites surveyed in 1999 and 2000 were the same as those surveyed by Saddlier (1998) with the exception of two new sites located immediately upstream (site 3) and downstream (site 4) of Birregurra Creek. These two new sites replaced sites 1 and 2 surveyed by Saddlier (1998) on the west branch of the Barwon River. Sites 1 and 2 surveyed by Saddlier (1998) are not referred to in this report. In addition, in 1999 and 2000 sites 8 and 9 were separated into upstream and downstream of instream structures (a and b respectively). In 1998 only the downstream reaches of these sites were surveyed. Due to the addition of these new sites, site numbering in 1999-2000 differs from that used by Saddlier (1998).

2.3 QUANTIFICATION OF HABITAT ATTRIBUTES

2.3.1 Hydrology

For each survey reach, the mean width (m) was calculated from at least five measurements. Mean depth (m) within each survey reach was calculated from measurements that were recorded across at least five transects strategically positioned to incorporate a representative sample of depths. Spot measurements of water quality parameters were recorded within each survey reach. Water temperature (°C) and electrical conductivity ($\mu S.cm^{-1}$) were measured with a WTW LF 320 meter, dissolved oxygen ($mg.l^{-1}$) with a WTW OXI 320 meter, turbidity (NTU) with a HACH 2100P Turbidimeter and pH with a WTW pH 320 meter.

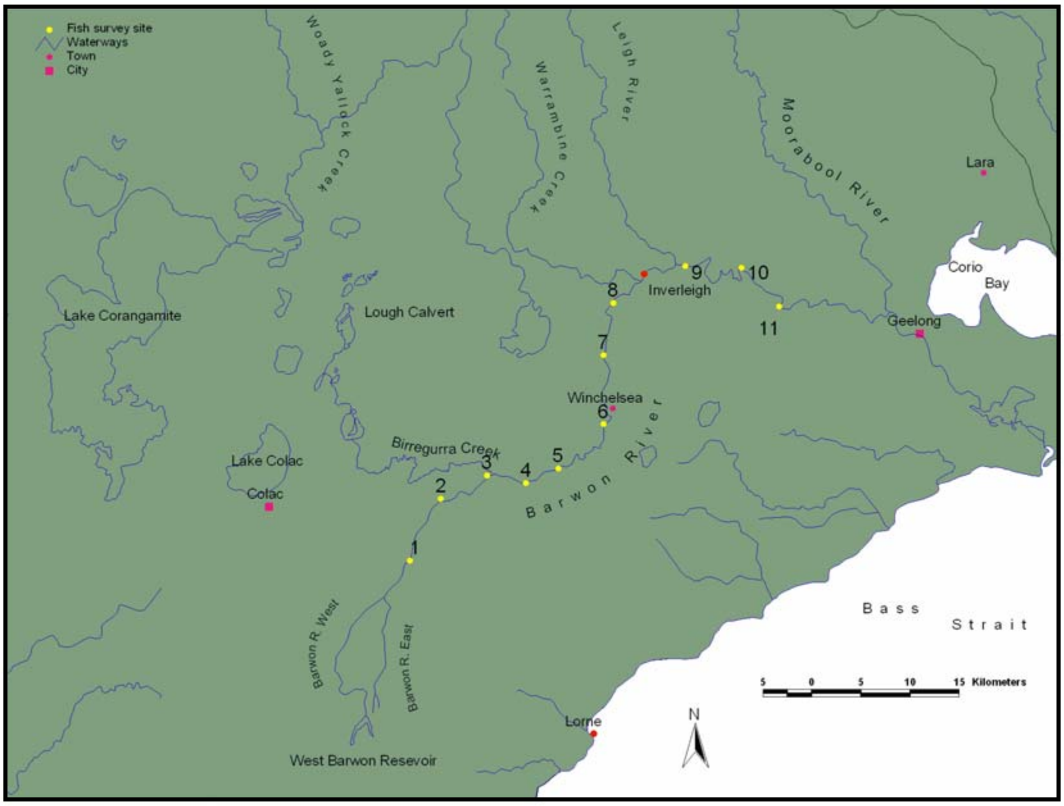

Figure 2-1. Location of fish survey sites on the Barwon River, Victoria.

Table 2-1. Location of fish survey sites on the Barwon River.

Site No.	Location	Map sheet & AMG reference (easting-northing)	Altitude (m)	Year surveyed 1998	1999	2000
1	Ds Deepdene Road	7621 741700-5747300	120	✔	✔	✔
2	End McDonalds Lane	7621 744800-5753600	120	✔	✔	✔
3	Us Birregurra Creek	7621 749500-5756000	100		✔	✔
4	Ds Birregurra Creek	7621 753400-5755200	100		✔	
5	Us & Ds Kildean Road	7621 756700-5756700	100	✔	✔	✔
6	End Karngun Road	7621 761300-5761200	100	✔	✔	✔
7	Glencoe property	7621 761300-5768200	80	✔	✔	✔
8a	Us McMillans Lane	7621 762300-5773500	80		✔	✔
8b	Ds McMillans Lane	7621 762300-5773500	80	✔	✔	✔
9a	Us Inverleigh weir	7721 243600-5777700	60		✔	✔
9b	Ds Inverleigh weir	7721 243600-5777700	60	✔	✔	✔
10	West of Murghebolac	7721 249300-5777900	60	✔	✔	✔
11	Us Pollocksford Bridge	7721 253400-5774200	40	✔	✔	✔

✔ - Site surveyed

Ds – downstream, Us – Upstream

2.3.2 Cover Elements

The relative abundance (% wetted area) of hydraulic biotypes, habitat attributes and cover elements was estimated for each survey reach. Hydraulic units at each site were defined using the categories; cascade, rapid, riffle, glide, run, pool or backwater (after Anderson & Morrison 1989; Anderson *et al.* 1989). Streambed geology was described in terms of percentage composition of various substrata, namely boulder (particle size > 256 mm), cobble (64-255 mm particle size), pebble (16-63 mm particle size), gravel (2-15 mm particle size), sand (0.1-2 mm particle size) and silt/clay (particle size < 0.1 mm). The relative abundance of dominant cover elements including coarse substratum, woody debris (logs, branches), organic debris (leaves, bark), overhanging bank, overhanging vegetation and aquatic vegetation was recorded.

2.3.3 Fish surveys

All sites, with the exception of site 3, 8a and 9a, were electrofished using a Smith-Root® 7.5GPP bank-mounted electrofisher as per Saddlier (1998). At each site, a length of stream 50 to 100 m long that incorporated all available habitat types, was sampled using a single electrofishing pass. A standard technique was used whereby an operator fished upstream from the downstream end of the section, fishing all habitat types along the edges and middle of the stream. An assistant followed the operator, collecting any missed individuals with a fine mesh dip net. All electrofishing was conducted during daylight hours. In order to standardise sampling effort current was kept constant between sites (3.5 to 4.5 A), total electrofishing time (seconds) was recorded and the area surveyed at each site (m^2) was measured. Stop nets were not utilised so the results of the electrofishing should be considered qualitative.

At site 3, 8a and 9a, where water depth reduced the efficiency of electrofishing, a standard suite of netting techniques was used, comprising six fyke nets, six bait traps and two larval nets[2]. Nets were set overnight for an average period of 14 hours. At site 2, 5, and 6, both electrofishing and netting techniques were used as described above.

All fish and freshwater crayfish were identified, counted, measured (mm) and weighed (g). Counts were also made of fish and crayfish observed, and confidently identified, but not caught. Where length measurements were recorded, fish were measured to the nearest 1 mm, length caudal fork (LCF) or total length (TL), and occipital carapace length (OCL) was measured for crayfish. Nomenclature for fish species follows Allen (1989) and Paxton *et al.* (1990), Riek (1969) and Horwitz (1990) for decapod crustacea, and Williams and Smith (1979) for freshwater shrimps.

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[2] Netting was conducted at only one site in 1998.

3 RESULTS

3.1 SUMMARY OF SPECIES DIVERSITY AND DISTRIBUTION

A total of 15 species of fish and two species of decapod crustacea were collected from sites on the Barwon River (1998-2000) (Table 3-1). Nine of the fish species were native and six were exotic. Three of the native species collected were diadromous[3], namely short-finned eel (*Anguilla australis*), common galaxias (*Galaxias maculatus*) and tupong (*Pseudaphritis urvillii*). All remaining native fish species spend their entire lifecycle in freshwater, with the exception of flat-headed gudgeon (*Philypnodon grandiceps*), which may also occur in estuaries.

One of the native freshwater fish species, Yarra pygmy perch (*Nannoperca obscura*) is classified as threatened in southeastern Australia. This species is classified as 'Lower risk - near threatened' in Victoria and is listed on the *Flora and Fauna Guarantee Act* 1988. Furthermore, the species is listed as 'Vulnerable' nationally (ANZECC 2000) and is listed as a protected species under the *Environment Protection and Biodiversity Conservation Act* 1999.

Short-finned eel and Australian smelt were the most widespread species, being collected from all sites, with the exception of site 9a for Australian smelt (Table 3-1). Flat-headed gudgeon were also widespread being collected from all sites with the exception of site 1 (Deepdene Road), site 4 (downstream of Birregurra Creek) and site 5 (Kildean Road). Mountain galaxias were restricted to the upper-most sites, ie. sites 1 and 2 (McDonalds Lane), although one individual was collected from site 6 (Karngun Road) in the mid reaches of the study area (Table 3-1). Southern pygmy perch and Yarra pygmy perch were collected throughout the study area (Table 3-1).

Two diadromous species, common galaxias and tupong, were primarily restricted to sites downstream of McMillans Lane (site 8), although one common galaxias was collected at site 6 upstream of Winchelsea (Table 3-1). River blackfish were widespread being collected from site 2 through to site 10 with the exception of site 3 (immediately upstream of Birregurra Creek), site 4 (immediately downstream of Birregurra Creek) and site 9a (below weir, downstream of Inverleigh) (Table 3-1).

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[3] Diadromous species migrate between fresh and saltwater during their lifecycle.

Table 3-1. Native and exotic freshwater fish and decapod crustacea collected at sites on the Barwon River (1998-2000).

Common Name	**Species**	**Site Number**												
		1	2	3	4	5	6	7	8a	8b	9a	9b	10	11
Native Fish														
Short-finned eel	*Anguilla australis*	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Common galaxias	*Galaxias maculatus*						✓		✓	✓	✓	✓	✓	✓
River blackfish	*Gadopsis marmoratus*		✓			✓	✓	✓	✓	✓		✓	✓	
Mountain galaxias	*Galaxias olidus*	✓	✓				✓							
Southern pygmy perch	*Nannoperca australis*	✓	✓			✓	✓	✓			✓	✓	✓	
Yarra pygmy perch	*Nannoperca obscura*	✓	✓			✓					✓		✓	✓
Flat-headed gudgeon	*Philypnodon grandiceps*		✓	✓			✓	✓	✓	✓	✓	✓	✓	✓
Tupong	*Pseudaphritis urvillii*									✓		✓	✓	✓
Australian smelt	*Retropinna semoni*	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓
Exotic Fish														
Carp	*Cyprinus carpio*				✓	✓	✓							
Goldfish	*Carassius auratus*			✓					✓	✓		✓		
Eastern gambusia	*Gambusia holbrooki*	✓										✓		
Redfin	*Perca fluviatilis*	✓		✓		✓	✓			✓	✓	✓	✓	
Brown trout	*Salmo trutta*	✓	✓			✓	✓	✓	✓	✓		✓	✓	✓
Tench	*Tinca tinca*					✓	✓		✓		✓	✓		
Yarra spiny cray	*Euastacus yarraensis*	✓	✓		✓	✓	✓	✓		✓		✓	✓	
Freshwater shrimp	*Paratya australiensis*	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

✓ - Species collected

The exotic brown trout, eastern gambusia and redfin were distributed throughout much of the study area (Table 3-1). Tench were collected from sites in the mid-lower reaches (Table 3-1). Carp were only collected from sites 3, 4, 5 and 6 in the mid-upper reaches (Table 3-1). Goldfish were primarily restricted to the lower reaches of the study area, although one individual was collected from site 3 (immediately upstream of Birregurra Creek) in the upper reaches of the study area (Table 3-1).

3.2 OVERALL COMPOSITION OF THE COMBINED CATCH[4]

The overall composition of the combined catch from all sites was similar in 1999 and 2000 (Figure 3-1). Native species comprised 92.9% and 94.5% of the catch in 1999 and 2000 respectively, whilst exotic species comprised 7.1% and 5.5% respectively.

Australian smelt, short-finned eel and flat-headed gudgeon were the most abundant species, comprising the greatest proportion of the total catch in both years (Appendix A). In 2000, however, the abundance of smelt decreased from 36% (1999) to 17% of the total catch (Appendix A). In the same period the abundance of common galaxias increased from 5% to 17% of the total catch (Appendix A). River blackfish, mountain galaxias, tupong, southern pygmy perch and Yarra pygmy perch occurred in relatively low abundances in both years (Appendix A).

Brown trout were the most abundant exotic species in 1999, representing 3% of the total catch (Figure 3-1, Appendix A). In 2000, however, the relative abundances of all exotic species were approximately equal (1% of the total catch per species) (Appendix A).

3.3 ABUNDANCE OF FISHES COLLECTED BY ELECTROFISHING

Species diversity and abundance generally increased in a downstream direction (Figure 3-2, Appendix A). Total fish abundance (CPUE – fish/hour) at sites in the upper reaches varied from 1998 to 1999 with no apparent trend (Figure 3-2, Appendix A). At sites in the mid reaches total fish abundance was similar in 1998 and 1999 (Figure 3-2, Appendix A). In contrast, in the lower reaches of the study area total fish abundance decreased considerably from 1998 to 1999, due largely to a decline in the numbers of Australian smelt collected in the latter year (Figure 3-2, Appendix A). Total fish abundance increased substantially from 1999 to 2000 at most sites throughout the study area (Figure 3-2, Appendix A).

[4] Data from the 1998 survey is not included here due to the differences in sampling techniques (eg. the use of netting techniques in addition to electrofishing in 1999 and 2000 at six sites).

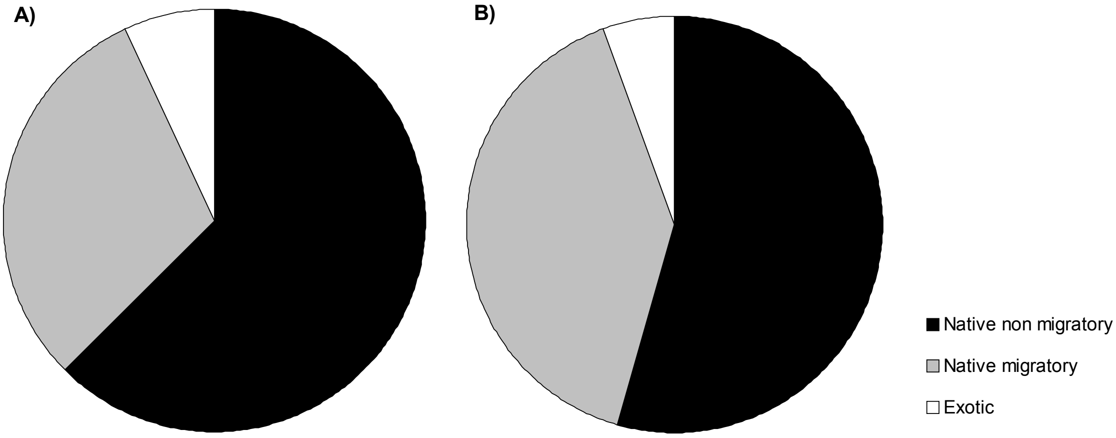

Figure 3-1. Percent compositions of native and exotic fish as a proportion of the total catch in (A) 1999 and (B) 2000.

In 1998, Australian smelt dominated the catch at sites in the lower reaches (sites 9b-11) of the study area (Appendix A). Flat-headed gudgeon were also relatively abundant at sites 8b-11 (Appendix A). In the mid reaches of the study area (site 5-7) short-finned eel comprised a considerable proportion (36-61%) of the catch, and to a lesser extent river blackfish and/or southern pygmy perch (Appendix A). In the upper reaches of the study area the predominant species were mountain galaxias and southern pygmy perch at site 1 and Australian smelt at site 2 (Appendix A).

In 1999, Australian smelt and short-finned eel dominated the catch at many sites. In the mid reaches of the study area (sites 5-7), however, southern pygmy perch comprised a considerable proportion (20-38%) of the catch (Appendix A). Likewise, mountain galaxias comprised a large proportion (30%) of the catch at site 1 and common galaxias comprised a considerable proportion of the catch at sites 10 and 11 (15% and 24% respectively) (Appendix A). Flat-headed gudgeon were also relatively abundant at sites 8b-11 (Appendix A). The remainder of the native species comprised a relatively small proportion (eg. < 10%) of the catch at each site (Appendix A).

In 2000, there were substantial increases in the relative abundance of mountain galaxias at sites 1 and 2 in the upper reaches of the study area, flat-headed gudgeon at site 2 and southern pygmy perch at site 3 (Appendix A). Furthermore, there was an increase in the relative abundance of river blackfish at sites 6, 7, 8b and 9b and a substantial increase in the proportion of the catch comprised of common galaxias at sites 8b, 9b, 10 and 11 (Appendix A). There was a corresponding decrease in the percent of the catch comprised by Australian smelt at these latter sites (Appendix A).

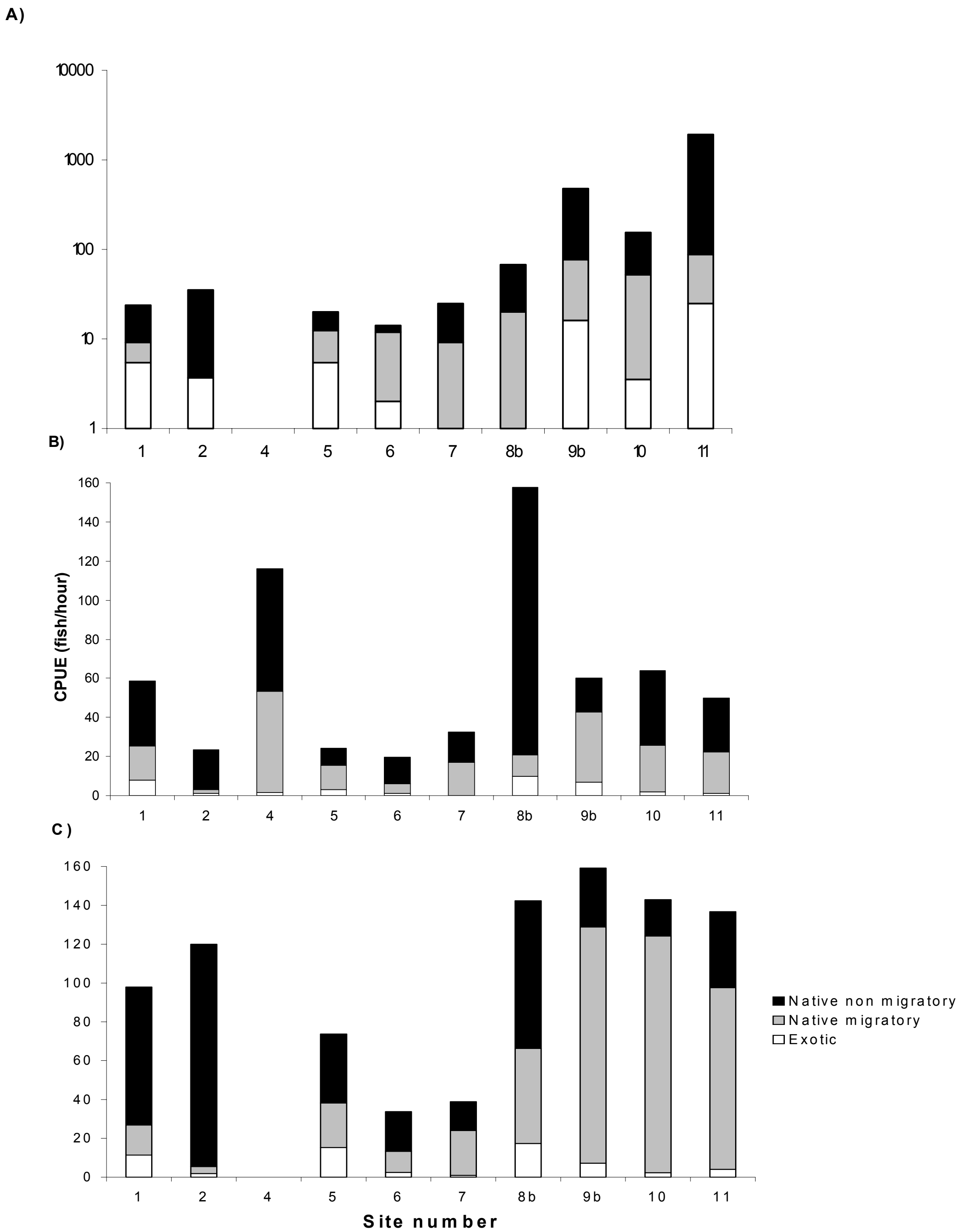

Figure 3-2. Relative abundance and composition of fish populations at sites surveyed by electrofishing in the Barwon River, (A) 1998, (B) 1999 and (C) 2000. (Note different scales)

Yarra pygmy perch were also collected in greater relative abundances in 2000 (Appendix A). This species was only collected in low numbers (< 1% of total catch) in 1999 at one site (site 10) (Appendix A). In 2000, however, Yarra pygmy perch were collected from five sites ranging in relative abundance from < 1% of the catch at site 2 to 3% of the catch at site 10 (Appendix A). Tupong represented only a small proportion of the catch in all three years. In 1998 tupong were collected from sites 9b, 10 and 11 (< 1% of total catch) (Appendix A). In 1999 tupong were collected from sites 8b and 10 (< 1% of total catch) and in 2000 tupong were only collected from site 11 (2% of total catch) (Appendix A).

Exotic species generally comprised a relatively small proportion of the catch (Appendix A). The distribution and abundance of exotic species were generally similar in 1998 and 1999 (Appendix A). An exception was carp that were not collected in 1998. In 2000 the abundances of all exotic species were generally higher (Appendix A). Brown trout were collected in highest abundances at sites 8b and 9b (both downstream of instream barriers) in the lower reaches (Appendix A). Eastern gambusia was most abundant at site 1 (Appendix A). Redfin, tench and goldfish were most abundant at the sites downstream of and including site 8b (Appendix A).

3.4 ABUNDANCE OF FISHES COLLECTED BY NETTING[5]

In 1999, flat-headed gudgeon dominated the catch at sites in the lower reaches (8a and 9a) of the study area (Appendix A). In the mid reaches of the study area (site 6) southern pygmy perch comprised a considerable proportion (48%) of the catch (Appendix A). Australian smelt and short-finned eel were also relatively abundant in the mid-upper reaches of the study area (Appendix A). In 2000, flat-headed gudgeon and short-finned eel dominated the catch at many sites (Appendix A). Australian smelt were also relatively abundant at site 8a (Appendix A). Exotic species generally comprised a relatively small proportion of the catch at each site in both years (Figure 3-3, Appendix A).

[5] Data from the 1998 survey is not included here because only one site was sampled using netting techniques in 1998.

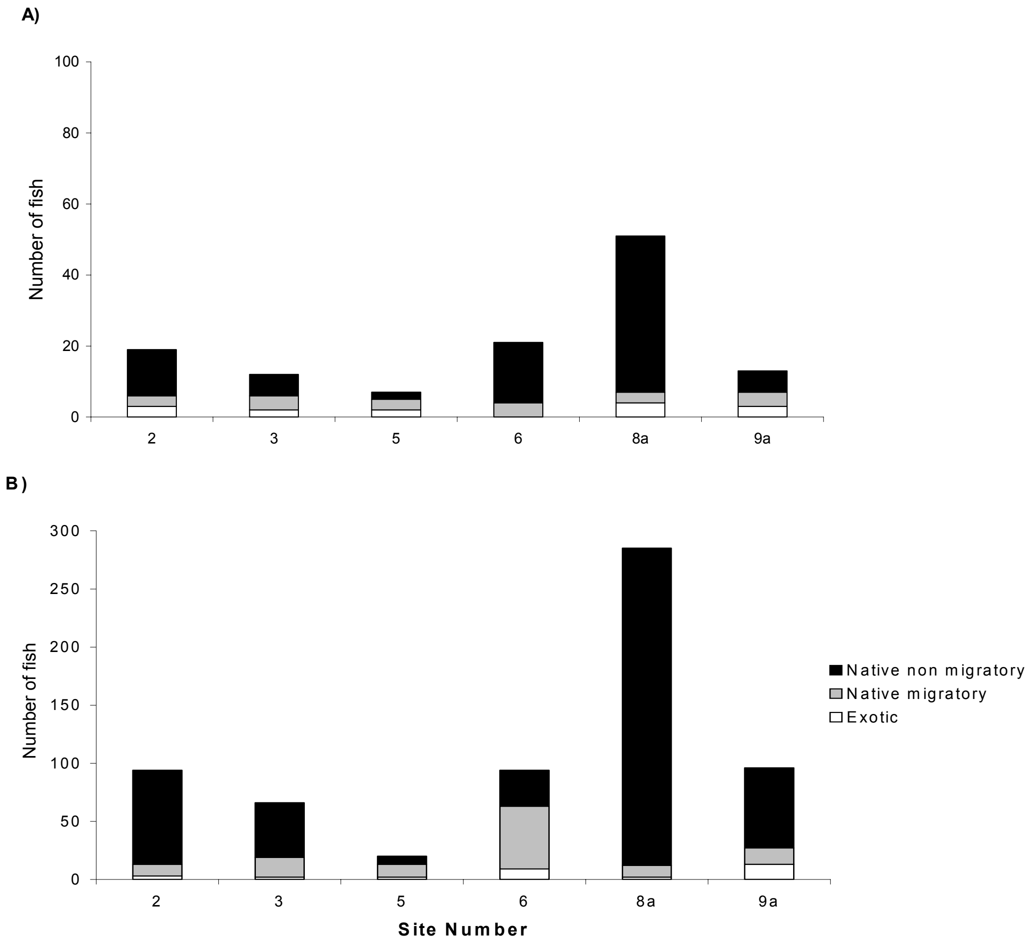

Figure 3-3. Relative abundance[6] and composition of fish populations at sites surveyed by netting in the Barwon River, (A) 1999 and (B) 2000. (Note different scales)

3.5 HABITAT AND WATER QUALITY

Habitat availability varied throughout the study area but was generally low (ie. 20-30% wetted area) at most sites (ie. sites 1, 2, 3, 4, 8a, 9a, 10). The lowest levels of instream habitat were observed at sites 3 and 4 immediately upstream and downstream of Birregurra Creek (Figure 3-4). At site 3, instream and riparian habitat was limited to exotic willows and willow debris, whilst at site 4, riparian habitat was minimal and instream habitat was predominantly rock substrate and a small proportion of aquatic vegetation. The mid reaches of the Barwon River (site 5 to 8b) were characterised by abundant instream vegetation (predominantly *Triglochin*

[6] Netting effort (time and gear) was kept constant at each site.

procera) and relatively high proportions of woody debris, particularly at sites 6 and 7 (Figure 3-4). Sites lower in the system, with the exception of site 10, were characterised by high proportions rock substrate (Figure 3-4). Site 10 had the highest habitat diversity, with native vegetation overhang and instream woody debris comprising the majority of instream habitat (Figure 3-4).

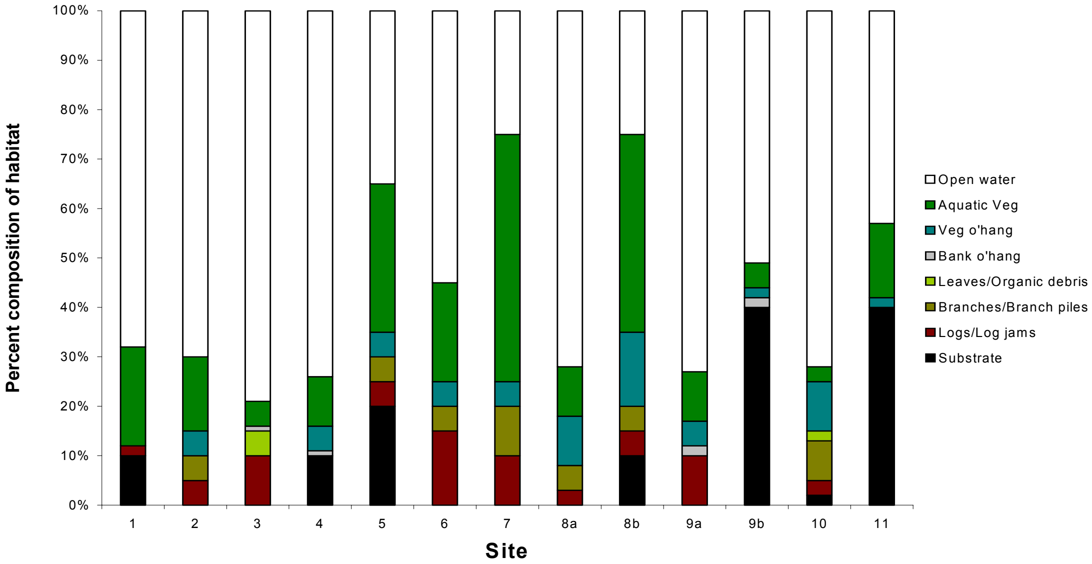

Figure 3-4. Percent composition of instream fish habitat attributes at survey sites on the Barwon River.

Measured *in situ* water quality for all sites are presented in Appendix B. In general, pH increased from 1998 (6.1-7.2) to 1999 (6.8-8). In 1999 and 2000 the pH was slightly alkaline (7-8) at all sites with the exception of site 1 (6.8) (Appendix B). Electrical conductivities and turbidities increased and decreased respectively from 1998 to 1999. Electrical conductivities and turbidities were similar in 1999 and 2000, although a spike in salinity (approximately 3100 µS/cm) was apparent at site 8 in 2000 (Appendix B). Electrical conductivity increased in a downstream direction, ranging from approximately 500 µS/cm at site 1 to 1000-2000 µS/cm at sites 10 and 11 (Appendix B). Turbidities at all sites were low (< 11 NTU) in both 1999 and 2000 and no spatial patterns are evident (Appendix B). Dissolved oxygen concentrations varied considerably both spatially (in 2000) and temporally (Appendix B). Dissolved oxygen concentrations in 1998 and 1999 were approximately 7-10 $mg.l^{-1}$ at all sites. In contrast, dissolved oxygen concentrations in 2000 ranged from 2.5 to 6.5 $mg.l^{-1}$. The lower dissolved oxygen concentrations in 2000 were associated with increased water temperatures (Appendix B).

4 DISCUSSION

4.1 SPECIES DIVERSITY, DISTRIBUTION AND ABUNDANCE

The diversity of native fish species recorded in this study was moderate, with a total of nine native species recorded, which represents approximately 60% of the native species expected to occur under natural conditions. Seven native species previously recorded in the Barwon River system (DNRE 2002) were not collected in this study, namely:

- Broad-finned galaxias (*Galaxias brevipinnis*),
- Dwarf galaxias (*Galaxiella pusilla*),
- Spotted galaxias (*Galaxias truttaceus*),
- Pouched lamprey (*Geotria australis*),
- Short-headed lamprey (*Mordacia mordax*),
- Australian mudfish (*Neochanna cleaveri*) and,
- Australian grayling (*Prototroctes maraena*).

There are few historical records for the majority of these species in the Barwon River system (DNRE 2002). An exception is Australian grayling although most records of this species in the Barwon River occur in its lower reaches downstream of the area sampled in the current study (DNRE 2002). Instream barriers on the lower reaches of the Barwon River have been identified as a likely factor limiting the distribution of Australian grayling in this system (Hall and Tunbridge 1988). All of the other native species listed above, with the exception of dwarf galaxias, require unimpeded passage between freshwater and estuarine/marine habitats and may also be affected by instream barriers on the Barwon River. The effect of instream barriers on the distribution and abundance of native species is discussed in section 4.2.

The diversity and abundance of fish species observed in this study tended to increase with distance downstream from source. Similarly, Hall and Tunbridge (1998) recorded a larger number of fish species in the lower reaches of the Barwon River compared with its upper reaches, and suggested this reflected a progressive downstream increase in the size and diversity of available habitat. Other factors, such as instream barriers to fish movement may also impact on species distribution, diversity and abundance. Instream barriers reduce connectivity in riverine environments and restrict movements critical for recolonisation, spawning, recruitment and habitat selection. This is especially true for the Barwon River that has several artificial instream barriers in its lower reaches (Raadik and Koster 2000) and contains a high proportion of diadromous species as well as obligate freshwater species with specific habitat requirements.

Several native diadromous (eg. short-finned eel, common galaxias) and non-diadromous (eg. Australian smelt, flat-headed gudgeon) species were typically predominant in the lower reaches of the study area (ie. downstream of Warrambine Creek). A range of other native and exotic species were usually present in small proportions in these reaches. In the mid reaches of the study area (ie. Barwon Park Road to Kildean Road) the proportion of native diadromous species in the catch decreased, due largely to a decline in the number of common galaxias recorded. Short-finned eel were predominant in this region, and to a lesser extent southern pygmy perch. Several other native and exotic species typically comprised a small proportion of the catch.

In the upper reaches of the study area (ie. Ingleby property to Deepdene Road) the total number of native fish species collected immediately upstream and downstream of Birregurra Creek was lower than at all other sites in the study region. Native species diversity increased further upstream (ie. McDonalds Lane and Deepdene Road). In this region one or more of the following native species were typically predominant; short-finned eel, mountain galaxias, Australian smelt and flat-headed gudgeon. Several other native and exotic species usually comprised a small proportion of the catch in these reaches.

Of the 15 fish species recorded in the current study the majority were widely distributed, although there was considerable spatial and/or temporal variation in the abundance of some species. This variation was most obvious in the lower reaches of the study area where the abundance of common galaxias increased and Australian smelt abundance decreased substantially over the duration of the study. In the upper reaches of the study area abundances of several native non-diadromous species (ie. mountain galaxias, flat-headed gudgeon and southern pygmy perch) also increased noticeably over the duration of the study.

The abundance of two diadromous species, namely common galaxias and tupong, was greatest in the lower reaches of the study area. Although species abundance may decline as distance inland increases, owing to factors such as availability of suitable habitats (McDowall 1998), in the Barwon River stream accessibility has been artificially reduced by human disturbance (eg. instream barriers). The effect of artificial instream structures on the distribution and abundance of diadromous species such as common galaxias and tupong in the Barwon River has previously been documented (Hall and Tunbridge 1988, Raadik and Koster 2000).

Mountain galaxias were primarily restricted to the upper reaches of the study area. Similarly, Hall and Tunbridge (1988) collected mountain galaxias mostly from the upper reaches of the catchment. The predominance of mountain galaxias in these reaches likely reflects its preference for smaller streams at higher elevations where water temperatures remain cool in summer (McDowall 1996). Southern pygmy perch were collected in greatest numbers in the mid reaches of the study area. The mid reaches were characterised by abundant instream vegetation and relatively high proportions of woody debris. Southern pygmy perch typically inhabit small slow flowing streams and wetlands with abundant instream cover such as aquatic vegetation (Kuiter *et al.* 1996). In the Barwon River we collected the highest abundances of southern pygmy perch in association with aquatic macrophytes.

The collection of Yarra pygmy perch in this study is the first documented record of the species in the Barwon River (DNRE 2002). Yarra pygmy perch were collected throughout the study area but were most abundant in the lower reaches between Murgheboluc and Pollocksford Bridge. Yarra pygmy perch is classified as 'lower risk – near threatened' in Victoria (DNRE 2000) and is listed on the *Flora and Fauna Guarantee Act* 1988. Furthermore, the species is listed as 'Vulnerable' nationally (ANZECC 2000) and is listed as a protected species under the *Environment Protection and Biodiversity Conservation Act* 1999. Yarra pygmy perch typically inhabit flowing water and well-vegetated streams (Kuiter *et al.* 1996) and are considered prone to threats including habitat modification, in particular the removal of riparian and instream vegetation (SAC 1991). A number of factors that may have a negative impact on Yarra pygmy perch and other native fish in the catchment are discussed in section 4.2.

Of the six exotic fish species recorded in this study, the majority were collected in greatest numbers in the lower reaches of the study area. Hall and Tunbridge (1988) also found exotic species in greatest abundance in the lower regions of the Barwon River.

4.2 IMPACTS ON AQUATIC FAUNA

Numerous factors impacting on environmental condition, and more specifically aquatic fauna assemblages, were identified within the study area. These include:

- Barriers to fish migration,
- Habitat degradation,
- Introduction of exotic species and,
- Changes to water quality.

Barriers to fish migration

The provision of fish passage throughout stream systems is an essential component of maintaining healthy stream fish assemblages, enabling spawning migrations, general movement and habitat selection, and recolonisations (Koehn and O'Connor 1990). Over half of the native fish species historically recorded in the Barwon River (DNRE 2002) migrate between freshwater and estuarine/marine habitats at some stage in their life cycle (Koehn and O'Connor 1990). Unimpeded fish passage is therefore crucial to sustaining native fish species diversity in the catchment.

The effect of instream barriers on the distribution and abundance of fish species in the Barwon River was not specifically investigated in the current study. A number of artificial barriers to fish migration present on the mid to lower Barwon River, extending from just upstream of Lake Connewarre near Geelong, to Rickett Marsh, were investigated by Raadik and Koster (2000) in December 1999. This included an assessment of several recently constructed fishways from the lower barrage, downstream of Geelong, upstream to Pollocksford, and several other potential barriers further upstream between Inverleigh and Winchelsea.

Surveys conducted during the assessment recorded common galaxias as far upstream as a weir at Inverleigh and tupong up to a ford at McMillans Lane upstream of Inverleigh (Raadik and Koster 2000). Common galaxias were the most abundant fish species collected in the surveys, although approximately 90% of common galaxias were recorded downstream of Baums Weir in the lower reaches of the catchment. Only three tupong were collected; two downstream of Baums Weir and one downstream of McMillans Lane, and only two spotted galaxias were collected; one within and one above the fishway at Baums Weir. Raadik and Koster (2000) concluded that fish passage is being provided by the fishways, although problems with the fishway structures and the presence of instream structures at Inverleigh and McMillans Lane, would impede fish passage in the Barwon River at times.

Comment: has this changed?

Similarly, in the current study tupong were recorded in low numbers (1998 – 12 individuals, 1999 – 3 individuals, 2000 – 2 individuals) and were restricted to downstream of the ford at McMillans Lane. Only one common galaxias was recorded upstream of the ford at McMillans Lane and abundances tended to be higher downstream. The absence of these species further upstream and/or higher abundances in the lower reaches of the Barwon River, support the findings of Raadik and Koster (2000) that fish passage problems do exist in the Barwon River.

Habitat degradation

An intact riparian zone is an essential component of maintaining a healthy aquatic ecosystem, acting as a buffer from surrounding land use, supplying a source of nutrients for the aquatic food chain, preventing bank erosion, and providing instream habitat and stream shading (Koehn and O'Connor 1990). The riparian zone throughout parts of the study area is largely cleared of native vegetation and comprises mostly exotic grasses. Some reaches have also experienced some level of de-snagging, straightening or channelisation in the past. This results in reduced macroinvertebrate and fish habitat as natural pool/riffle or pool/run sequences are disrupted (Canale *et al.* 2001). In general, species diversity tended to be highest at sites with an intact riparian zone and an abundant and diverse range of instream habitat available as cover to aquatic fauna. For example, at the site located immediately upstream of Birregurra Creek in the upper reaches of the study area, the riparian vegetation comprised mostly exotic grasses and willows, and instream habitat was scare comprising only small amounts of aquatic vegetation, bank overhang, logs and branches. A total of five fish species were collected at this site including two exotic species. In contrast, at the site located west of Murgheboluc in the lower reaches of the study area, the native riparian vegetation was relatively undisturbed and instream habitat was more abundant and diverse comprising aquatic vegetation, vegetation overhang, logs, branches, leaves and organic debris. A total of eight fish species were collected at this site including only one exotic species.

Introduction of exotic species

The effects of exotic species on native fish populations may include direct predation, competition for food and habitat, the spread of disease, and habitat modification. All of the exotic species recorded in the current study have been known to occur in the Barwon River for over a decade (DNRE 2002), although the distribution and abundance of some species may have increased in recent times. For example, in 1988 Hall and Tunbridge reported that carp were concentrated in the lower reaches of the river. In the current study, however, carp were recorded in the mid-upper reaches and were most abundant near Wurdiboluc in the mid catchment. Although carp have only been collected in relatively low numbers, it is possible that the distribution and abundance of this species will continue to expand in the Barwon River as it has done in other freshwater systems in Victoria and Australia in recent times (Koehn *et al.* 2000).

Changes to water quality

As identified by Canale *et al.* (2001), the primary water quality issues in the Barwon River catchment are high levels of salinity and nutrients. The effects of increased salt and nutrient loads on fish communities are virtually unknown. High levels of salt may have lethal physiological effects or sub-lethal effects such as reduced growth rates, reduce reproductive success and reduced health and vigour. High levels of salt may favour salinity tolerant taxa, resulting in altered species diversity, abundance and distribution of aquatic biota (Mitchell *et al.* 1996). Salinisation may also affect organisms indirectly through creating changes to habitat attributes (ie. a direct effect on macrophytes which are important as cover for some fish species) or trophic relationships between species (Mitchell *et al*. 1996). High nutrient levels may contribute to excessive growth of submerged aquatic macrophytes that degrades physical habitat quality by decreasing instream habitat diversity. Dense stands of macrophytes may also contribute to sediment deposition by decreasing water velocities (SKM 2001).

4.3 SUMMARY OF FINDINGS AND MANAGEMENT IMPLICATIONS

The results presented in this document provide valuable baseline information on the distribution, diversity and abundance of fish species in the Barwon River. Data from the three years of fish surveys in the Barwon River indicate that native non-migratory fish comprise a large proportion of total fish species diversity and abundance in the study area. Native migratory fish nonetheless are generally predominant in the lower reaches whilst exotic fish are generally restricted in either distribution and/or abundance throughout the study area.

Of particular significance was the collection of the threatened Yarra pygmy perch. This species was distributed throughout much of the study area although it was collected only in low numbers (1-12 fish). Alteration of habitat through agricultural and grazing practices, and predation and competition from exotic fish species are two of the key threatening processes to Yarra pygmy perch in southeastern Australia (Saddlier 1993). Both of these processes are evident in the Barwon River catchment. The preservation of aquatic habitat is essential for the maintenance of Yarra pygmy perch and other native fish populations in the Barwon River. The prevention of stock access and the provision of off-stream watering points would assist in the maintenance of aquatic habitat and water quality.

Several other key threatening process to native fish populations are evident in the Barwon River catchment. The results from this and past studies suggest that instream barriers (ie. weir at Inverleigh, ford at McMillans Lane) may restrict the distribution of native fish throughout the Barwon River. The provision of unimpeded fish passage passed these structures would potentially provide unimpeded access for native migratory species to approximately 90% of the catchment (Raadik and Koster 2000).

We have also discussed the impact of stream channelisation, water quality, clearing of riparian vegetation and exotic species on fish assemblages in the Barwon River. Potentially complex interactions between these processes make it difficult to interpret any relationships between human disturbances and fish assemblage structure. Nevertheless, the data presented here represent important baseline information critical for the development of management objectives and prioritisation of restoration activities.

4.4 RECOMMENDATIONS

Specific recommendations concerning the major issues affecting the condition of waterways in the Barwon River catchment have previously been made by Canale *et al.* (2001). The recommendations made be Canale *et al.* (2001) address some of the issues relevant to the Barwon River fish community. We provide additional recommendations below.

Instream barriers

- Continue to investigate fish passage options for instream structures that restrict fish passage.
- Develop and implement an ongoing program to monitor the effectiveness of fishway structures in providing unimpeded passage.

Habitat degradation

- Continue stream bank protection works, revegetation and stock fencing projects along waterways throughout the catchment.
- Investigate relationships between key fish species and habitat heterogeneity to assist in understanding and interpreting any changes in fish assemblage structure in relation to environmental conditions.

Water quality

- Develop and implement a program of investigation with specific hypotheses to assess the effect of operation of the LCDS on fish species and communities.
- Continue to address through research the effects of increased salt loads on fish species and communities.

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7 APPENDICES

APPENDIX A ***Summary data for fish and decapod crustacea collected at sites on the Barwon River***

Table A-1. Total numbers and length and weight data for fish and decapod crustacea collected at sites on the Barwon River in 2000 (electrofishing and netting combined).

	SITE									
SPECIES	1	2	3	5	6	7	8a & b	9a & b	10	11
Short-finned eel										
mean length (range) (mm)	511(235-750)	569(222-800)	619(45-770	494(181-720)	403(47-830)	512(340-820)	430(132-710)	462(150-875)	493(140-690)	369(130-700)
mean weight (range) (g)	366(35-860)	566(14-1265)	585(64-1087)	296(7-730)	200(3.9-805)	348(63-1300)	203(3-679)	335(4-1524)	281(3.4-635)	186(2.9-726)
n	15	11	26	38	42	25	42	81	86	17
Mountain galaxias										
mean length (range) (mm)	38(31-66)	41(32-66)			71					
mean weight (range) (g)	0.4(0.1-2.0)	0.3(0.2-0.6)			2.5					
n	40	9			1					
Common galaxias										
mean length (range) (mm)					45		116(95-132)	72(42-143)	85(45-145)	66(42-129)
mean weight (range) (g)					0.5		10(6-15)	4.1(0.3-18.8)	6.0(0.4-21.6)	2.7(0.3-14.5)
n					1		12	87	70	98
Australian smelt										
mean length (range) (mm)	54(46-64)	49(32-66)	52(43-59)	59(57-62)	64(59-67)	60	55(46-69)	55(51-60)		60(53-68)
mean weight (range) (g)	1.1(0.6-1.6)	0.8(0.2-1.7)	0.9(0.5-1.6)	1.5(1.1-1.8)	1.8(1.6-2.1)	1.7	1.3(0.8-2.3)	1.2(1-1.5)		1.6(0.9-2.5)
n	16	38	7	4	6	3	188	12		6
Southern pygmy perch										
mean length (range) (mm)	52(35-63)	55(50-60)		45(28-60)	57(49-72)	56(51-61)		54(52-55)		
mean weight (range) (g)	2.0(0.5-3.2)	2.8(2.4-3.5)		1.4(0.4-3.2)	2.9(1.6-5.4)	2.7(2-3.7)		2		
n	12	3		40	10	3		2		
Yarra pygmy perch										
mean length (range) (mm)	31			27				54	51(46-57)	52(46-58)
mean weight (range) (g)	0.4			3				2.3(2.1-2.4)	2.1(1.6-3)	2(1.4-3)
n	1			1				2	5	12
River blackfish										
mean length (range) (mm)		405		280(203-400)	229(167-332)	263(135-345)	271(112-585)	245	259(178-337)	
mean weight (range) (g)		443		208(78-449)	113(35-291)	188(23.8-300)	140(16-432)	126	157(57-288)	
n		1		4	6	3	4	1	7	

Table A-1. cont.

	SITE									
SPECIES	1	2	3	5	6	7	8a & b	9a & b	10	11
Tupong										
mean length (range) (mm)										188
mean weight (range) (g)										60.6
n										2
Flat-headed gudgeon										
mean length (range) (mm)		61(37-87)	50(34-102)		70(45-99)	60(38-74)	64(31-91)	64(29-94)	71(50-86)	68(45-92)
mean weight (range) (g)		2.4(0.4-6.8	1.4(0.1-10.1)		3.9(0.7-9.3)	2.3(0.3-3.9)	2.5(0.3-6.3)	2.5(0.1-7.2)	3.5(0.9-6.8)	3.2(0.8-6.8)
n		90	40		11	7	152	89	12	31
Yarra spiny cray										
mean length (range) (mm)		60(51-73)		19		13	21	17(14-23)	23(10-32)	36.5(34-39)
mean weight (range) (g)		120(78-193)		3.7		8.9	22.5	16(9-31)	11.6(0.1-27.9)	23(18.4-26.5)
n		3		1		1	1	7	5	2
Brown trout										
mean length (range) (mm)		166			220	417	178(146-233)	293(190-414)	300	271
mean weight (range) (g)		56			141	784	84(52-155)	388(90-919)	342	247
n		1			1	1	6	6	1	1
Carp										
mean length (range) (mm)				256(207-304)	220(199-235)					
mean weight (range) (g)				493(273-823)	311(237-354)					
n				15	4					
Goldfish										
mean length (range) (mm)							157	139(129-149)		207(178-235)
mean weight (range) (g)							98	68(50-86)		216(137-295)
n							1	2		2
Tench										
mean length (range) (mm)				270(197-375)	145		80	229(76-476)		
mean weight (range) (g)				454(150-965)	57		9.9	620(4.9-2085)		
n				2	1		1	11		
Eastern gambusia										
mean length (range) (mm)	39(28-44)									48(35-61)
mean weight (range) (g)	0.7(0.2-1.0)									2.0(0.4-3.5)
n	10									2
Redfin										
mean length (range) (mm)	325	300	160	202(190-213)	234		188(156-212)	247(183-310)	194(183-204)	
mean weight (range) (g)	630	481	56.8	154(126-181)	222		111(57-167)	307(93-520)	113(93-133)	
n	1	1	1	2	1		10	2	2	

Table A-2. Total numbers of fish and decapod crustacea collected at sites on the Barwon River in 2000 using electrofishing techniques.

	SITE								
SPECIES	1	2	5	6	7	8b	9b	10	11
Short-finned eel									
n	15	1	27	38	25	32	67	86	17
Mountain galaxias									
n	40	9		1					
Common galaxias									
n				1		12	87	70	98
Australian smelt									
n	16	28	4	1	3	46	12		6
Southern pygmy perch									
n	12	1	37		3		1		
Yarra pygmy perch									
n	1		1					5	12
River blackfish									
n				6	3	4	1	7	
Tupong									
n									2
n		22		9	7	21	25	12	31
Yarra spiny cray									
n		1	1		1	1	7	5	2
Brown trout									
n				1	1	5	6	1	1
Carp									
n			15	4					
Goldfish									
n						1	2		2
Tench									
n				1					
n	10								2
Redfin									
n	1		2	1		10		2	

Table A-3. Total numbers of fish and decapod crustacea collected at sites on the Barwon River in 2000 using netting techniques.

	SITE					
SPECIES	2	3	5	6	8a	9a
Short-finned eel						
n	10	26	11	4	10	14
Australian smelt						
n	10	7		5	142	
Southern pygmy perch						
n	2		3	10		1
Yarra pygmy perch						
n						2
River blackfish						
n	1		4			
Flat-headed gudgeon						
n	68	40		2	131	64
Yarra spiny cray						
n	2					
Brown trout						
n	1				1	
Tench						
n			2		1	11
Redfin						
n	1	1				2

Table A-4. Total numbers of fish and decapod crustacea collected at sites on the Barwon River in 1999 using electrofishing techniques.

	SITE									
SPECIES	1	2	4	5	6	7	8	9b	10b	11
Short-finned eel										
n	15	3	32	13	4	18	7	47	16	8
Mountain galaxias										
n	15	2								
Common galaxias										
n							1	5	11	11
Australian smelt										
n	12	24	39	1	1	3	113	9	29	16
Southern pygmy perch										
n	2			8	6	7		1		
Yarra pygmy perch										
n									3	
River blackfish										
n					1	1			7	
Tupong										
n							2		1	
n		6			3	5	13	15	6	9
Yarra spiny cray										
n	10		1	1	1		1	3	1	
Brown trout										
n	1	2		2			4	3	2	1
Carp										
n			1	1	1					
Eastern gambusia										
n	6							6		
Redfin										
n							5	1		

Table A-5. Total numbers of fish and decapod crustacea collected at sites on the Barwon River in 1999 using netting techniques.

	SITE					
SPECIES	2	3	5	6	8a	9a
Short-finned eel						
n	3	4	3	4	2	2
Common galaxias						
n					1	2
Australian smelt						
n	7	3		5		
Southern pygmy perch						
n				10		
River blackfish						
n	5		2		1	
Flat-headed gudgeon						
n	1	3		2	43	6
Yarra spiny cray						
n			1			
Brown trout						
n	3					
Tench						
n						1
Redfin						
n		1				2
Carp						
n		1				

Table A-6. Total numbers of fish and decapod crustacea collected at sites on the Barwon River in 1998.

	SITE								
SPECIES	1	2	5	6	7	8b	9b	10	11
Short-finned eel									
n	2		4	3 (5)	5	11	30	20	30
Mountain galaxias									
n	4								
Common galaxias									
n							4	7	4
Australian smelt									
n	1	11	1		1	8	200+	34	1000+
Southern pygmy perch									
n	3	1	3		5			6	
River blackfish									
n		2		1 (2)	2			4	
Tupong									
n							1	1	10
Flat-headed gudgeon									
n		4			1	19	22	11	21
Yarra spiny cray									
n			4	3 (1)		1	6		
Brown trout									
n	2	2	3	1			6	1	3
Goldfish									
n							1		
Tench									
n				(1)			1		
Eastern gambusia									
n	1								3
Redfin									
n									1

( ) – Refers to numbers collected using netting techniques.

APPENDIX B ***Water quality***

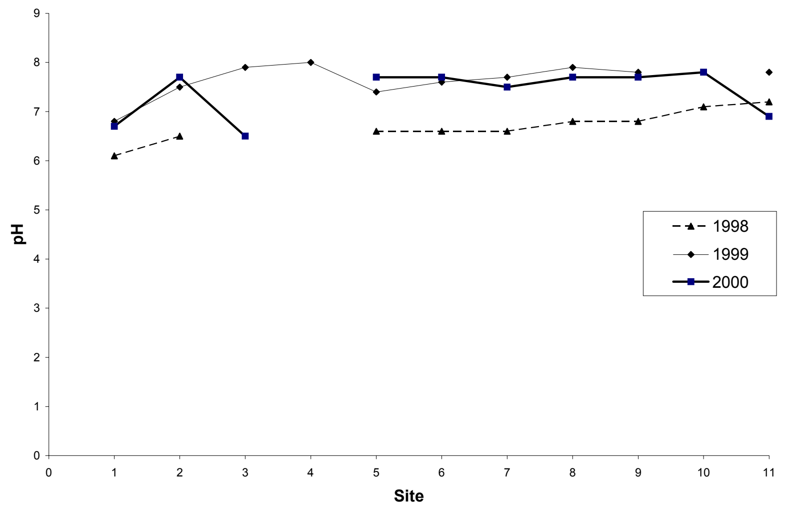

Figure B-1. Levels of pH recorded at sites in the Barwon River (1998-2000).

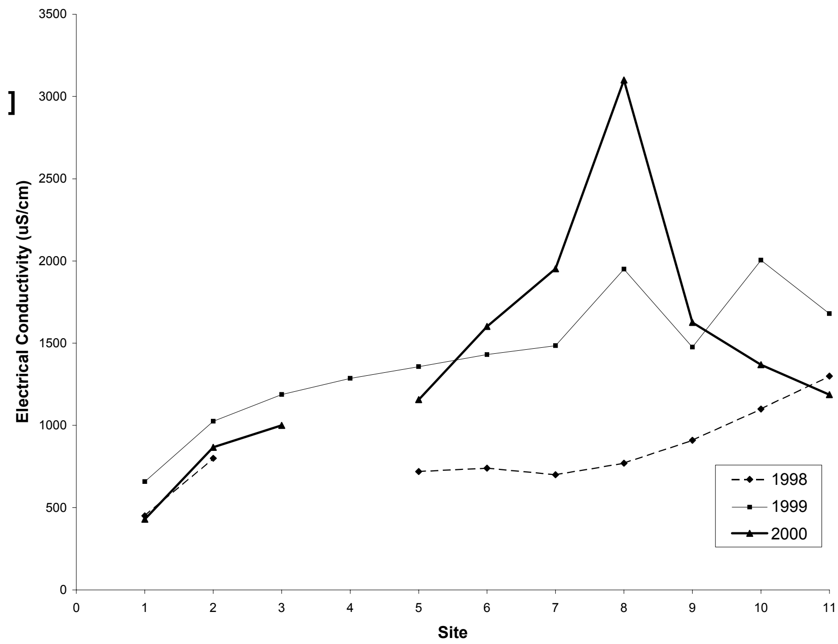

Figure B-2. Electrical conductivity concentrations recorded at sites in the Barwon River (1998-2000).

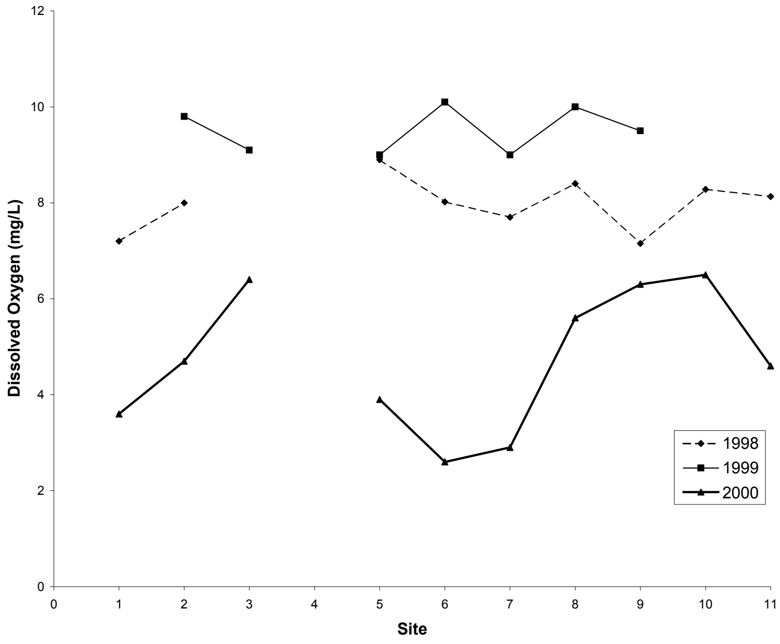

Figure B-3. Dissolved oxygen concentrations recorded at sites in the Barwon River (1998-2000).

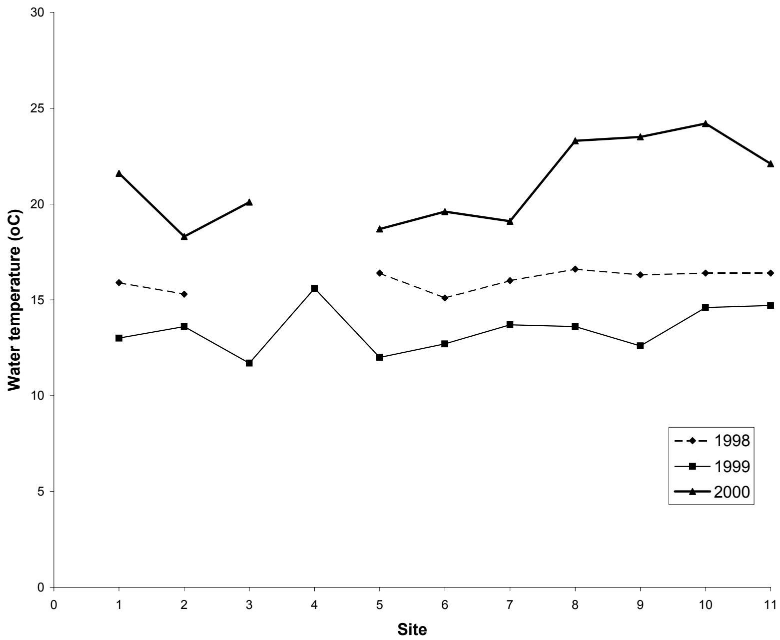

Figure B-4. Water temperature recorded at sites in the Barwon River (1998-2000).

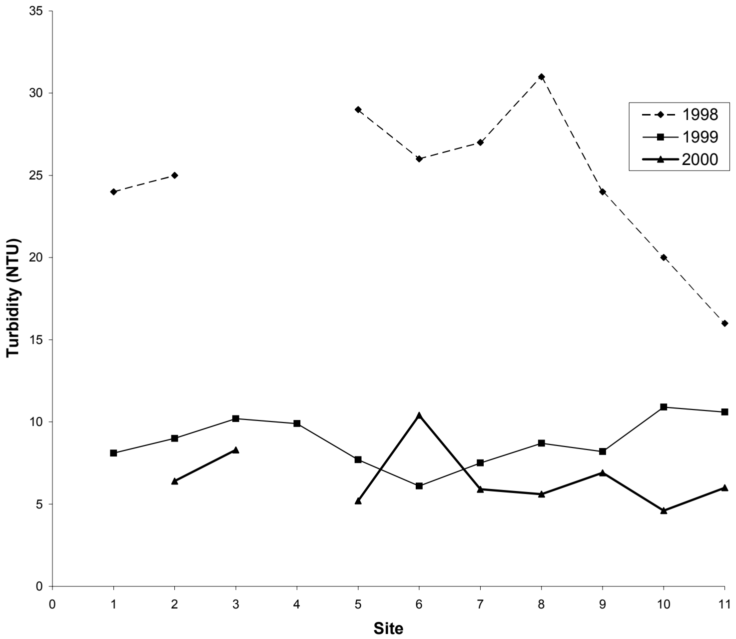

Figure B-5. Turbidity concentrations recorded at sites in the Barwon River (1998-2000).