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## Freshwater fish resources in the Snowy River, Victoria.

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# Freshwater fish resources in the Snowy River, Victoria.

Wayne Fulton and Kylie Hall (Editors)

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# Chapter 1 General Introduction

**Wayne Fulton**
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## 1.1 Introduction

As part of the overall process for the restoration of the aquatic habitat in the Snowy River following the decision to supplement present river flows, a workshop was held in Canberra in March 2002 to discuss recovery options for fish populations in the river. A report was prepared following that meeting to form the basis for a fish recovery strategy for the Snowy River (Stewardson *et al.* 2002). In that report the Snowy River Recovery Project, a joint approach by New South Wales and Victoria, was described as a process to identify and develop community and economic opportunities associated with ecological rehabilitation of the river. It was further stated that there are high expectations that repairing the health of the Snowy River will have tangible benefits for river communities and townships, for regional communities, and for regional economies. Such opportunities would include river recreation including angling, canoeing, rafting and guided river-walks. Recreational angling has been strongly supported by river communities as a positive driver for tourism on the 'recovered' Snowy River.

Fisheries Victoria, as the agency responsible for freshwater fisheries in this State, finds that it does not have detailed knowledge of the status of fish populations in the Snowy River or its tributary streams. There is also limited direct information on what key habitat issues are likely to be effecting these populations and what impact the restoration of flows may have on this fauna. The extent and nature of the recreational fisheries in the catchment and the economic and social benefits of these fisheries to the community are unknown. The restoration of Snowy River flows provides an ideal opportunity to obtain quantitative data on these key fisheries management and sociological issues.

Within this context, Australian bass (*Macquaria novemaculeata*) is an important element of the fish fauna of the Snowy River and could well be considered the icon species in this system as well as in other parts of far south eastern Victoria. The Snowy River was a highly regarded and productive recreational fishery for this species but in recent years the fishery has declined from former levels. Whilst in angling terms, good-sized Australian bass are still taken in the river, both in the middle reaches and around Orbost, it is considered by recreational anglers that the number of fish caught has declined considerably. Anglers have also perceived an increase in the occurrence of hybrid Australian bass/estuary perch (*Macquaria colonorum*) in the Snowy River.

## 1.2 Background

There have been some fish population surveys undertaken throughout the Snowy River catchment but these are essentially qualitative only, with no assessment of associated habitat. Only limited information is available on the major Snowy River tributary streams within Victoria.

In relation to Australian bass in particular, spawning is known to be highly variable with populations having strong inter-annual variations in year class strength. The adult fish live in freshwater often a considerable distance upstream from estuaries. They migrate down to the estuary to spawn roughly from July to November. Spawning takes place in the estuary and the larvae spend some time in this habitat before moving upstream into freshwater. The adult fish also move back upstream after spawning.

There are known to be certain environmental cues (especially flow related) associated with the various migrations and with spawning, and there are also likely to be barriers to upstream migration especially of juvenile fish.

The biological basis of this part of the study will be an examination of the population structure of Australian bass in the Snowy River, in the closely linked Brodribb River, and in a nearby reference catchment, the Bemm River. The objectives are to identify and interpret any differences between the populations of Australian bass in the Snowy River and nearby rivers. A number of questions are relevant in this context:

- Are there differences in juvenile Australian bass numbers in these catchments?

- If so, what are the reasons for these differences?
- Is upstream recruitment of juvenile Australian bass constrained in any of these systems?
- What is the level of hybridisation (Australian bass/estuary perch) in the system.

Wherever possible or feasible, surveys will be undertaken with a view to establishing a quantitative benchmark value that can be used at a later date.

## 1.3 Objectives

Whilst the general rationale for the project is outlined above, there are a number of individual elements to the overall project all designed to provide more specific knowledge on the freshwater fish fauna of the Snowy River system.

### 1.3.1 Fish community surveys

The objectives of this component of the project were to establish detailed qualitative and where possible quantitative benchmark assessments of fish populations in the Victorian sections of the Snowy River and its major tributary streams with a view to later assess the changes associated with Snowy River flow rehabilitation. The study would also establish habitat benchmark profiles in association with the study reaches and document the work visually.

Further surveys would examine the composition and timing of juvenile fish migrations in the lower reaches of the Snowy River with particular reference to Australian bass if possible.

Two reports address elements of these issues:

- Juvenile fish migrations in the Snowy River (including brief larval fish surveys).
- Fish distribution in the Snowy River tributaries.

### 1.3.2 Australian bass

It is generally agreed that the numbers of Australian bass in this system have declined considerably. It has been proposed that a solution to the fishery decline is to undertake population enhancement of Australian bass in the middle reaches of the river simply by stocking juvenile fish. Whilst this might overcome any recruitment problem, and may indicate whether the upstream habitat is suitable, it is a solution requiring an ongoing commitment, and does not address any underlying environmental issues or the possibility of mistakenly using hybrid or estuary perch as brood-stock.

Consequently, studies to determine the age/growth relationships for Australian bass in the Snowy River and nearby streams to assess whether there are any variations in recruitment patterns in these streams were proposed at the March 2002 workshop. Correlations between these data and environmental variables were to be examined to determine spawning cues/controls.

It was also decided to examine, where feasible, the instream and riparian habitat associated with adult Australian bass populations in the Snowy River as well as to examine movement patterns of adult Australian bass in the system.

The Australian bass work is reported as follows;

- Australian bass movement, migration and habitat suitability in the Snowy River, chapter 2.
- Literature review on Australian bass, chapter 4.
- Growth of Australian bass in the Snowy River, chapter 5.
- Taxonomic assessment of Australian bass in the Snowy River, chapter 6.

## 1.4 References

M Stewardson, P Cottingham, G Howell, P Bennett, J Boehm, J Doolan, G Hannan, J Harris, B Hart, M Thomas, M Shirley, G Quinn, L Metzeling, J Koehn (2002) Perspectives on the Scientific Panel approach to determining environmental flows for southeastern Australian Rivers (Workshop Proceedings) University of Canberra(Canberra) 5pp

# Chapter 2 Juvenile fish abundance and upstream movement within the Snowy River Catchment

**Joel Tyndall (Fisheries Research Branch, Fisheries Victoria)**

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## 2.1 Introduction

More than 95% of Australian freshwater fishes are considered diadromous, or derived from predominantly marine families (Allen 1989). Almost all are considered to be migratory, with many relying on access between estuarine/coastal waters and freshwater for population maintenance (see Harris *et al.* 1998). Many Australian native freshwater fishes exhibit catadromous spawning behaviour. The adults of these species make large-scale migrations from the upper freshwater reaches of rivers and lakes, downstream into estuaries and the ocean in which to spawn. A number of catadromous fish species can be found within the Snowy and Brodribb Rivers in south-eastern Victoria

The Australian bass could well be considered the icon species in the Snowy River. It is a percichthyid fish, native to south-eastern Australia. This species spends most of its life in the freshwater reaches of coastal rivers, before migrating downstream to estuarine regions to spawn. The juvenile Australian bass feed and grow in the estuary, before migrating upstream to the freshwater reaches of the rivers, where they mature, and reach adult size (Stewardson *et al.* 1997).

Australian bass are known to exhibit a highly variable recruitment success from year to year. The reasons for these variations are unknown, but it is thought that conditions in the river may not always be favourable for either adult or juvenile Australian bass migration and/or spawning.

In the past the Snowy River has been considered a highly regarded and productive recreational fishery for Australian bass. However, in recent years the fishery has declined from its former high levels. Although catches of good sized Australian bass from the river have not become a rare occurrence, there is feeling amongst recreational anglers that the numbers of Australian bass caught are in decline. Australian bass are now considered by some as a rare species in the Snowy River system (Stewardson *et al.* 1997), and are potentially threatened throughout Victoria (Koehn and Morison 1990).

In addition to Australian bass, a number of other native Australian migratory fish require both salt and fresh water during their life cycle.

There is limited knowledge on the spawning and migration patterns of the tupong, *Pseudaphritis urvillii*. In Victoria, adult tupong are thought to migrate from freshwater down to the estuarine reaches of coastal rivers to spawn during autumn and winter (McDowall 1996). The juveniles are then thought to exhibit a sequential movement upstream with age until they reach adulthood.

'Whitebait' is the name most commonly associated with juveniles of the family Galaxiidae. At least eight species of galaxiids have been described as being clearly amphidromous or catadromous (McDowall and Frankenberg 1981). Common galaxias, *Galaxias maculatus*, is the most widespread of these species and the best known of the galaxiids within south-eastern Australia. It is usually found in gently flowing streams or rivers. Adults migrate downstream to the margins of river estuaries, mostly during autumn on the new or full moon. Once there they spawn amongst terrestrial vegetation when inundated by high spring tides. Eggs remain out of water for 2 weeks or more until the next spring tides, when they hatch and move out to sea. The larvae spend the winter at sea growing to lengths of about 45-50 mm, before migrating back up the rivers after about 5-6 months (McDowall 1996). These upstream migrations can involve huge shoals of slender, transparent juveniles, which move into freshwater to feed and grow.

Long-finned and short-finned eels also exhibit catadromous behaviour. Between January and May, adult long-finned eels, *Anguilla reinhardtii*, and short-finned eels, *Anguilla australis,* migrate from the freshwater reaches of rivers and from lakes, out to sea to spawn. It is thought that spawning occurs in or near the Coral Sea, at depths of more than 300 metres. The larval eels, known as 'leptocephali', are then thought to be carried by oceanic currents back to the continental shelf, where they undergo metamorphosis into the next developmental phase, known as 'glass' eels (Gooley *et al.* 1999). The glass eels move into the estuarine reaches of coastal rivers where they develop pigmentation. At this stage they are known as 'elvers'. During spring and summer, the 'elvers' undertake mass migrations upstream into freshwater, where they grow and develop into sexually mature adults (McDowall 1996).

## 2.2 Objectives

The primary objectives of this study were to examine the upstream movement of Australian bass within the closely linked Snowy and Brodribb Rivers, in comparison to a nearby reference catchment, the Bemm River. The main reason for this was to identify the timing of juvenile Australian bass migrations and to assess the presence of any instream 'barriers' to upstream migration, imposed by physical habitat within the lower reaches of the Snowy River. The timing and migration of other populations of catadromous fish species within these rivers, including information on their presence and abundance, was also investigated. This was to provide a benchmark for further study of catadromous fish reproduction within the Snowy River catchment.

An additional objective was to attempt to establish the presence of larval Australian bass in the estuary of the Snowy River using plankton sampling equipment. This was a secondary objective undertaken primarily because some time was available to collect samples, albeit with limited resources for processing the samples.

## 2.3 Methods

### 2.3.1 Juvenile fish sampling survey sites

Three sites were chosen in the Snowy River as survey locations to assess the upstream movement of juvenile fish. A further site in the Brodribb River upstream of Lake Curlip, was added as a comparison and control site.

In the Snowy River, glass eel nets were set at three locations. The upper site (site one) was located just upstream of the Princes Highway Bridge at Orbost. At this location a glass eel net was placed on both sides of the river (Figure 2.1).

A further site was chosen downstream of the bridge; however, at this location only one net was used, due to limitations in access to the river.

### 2.3.2 Juvenile fish sample collection

Surveys of both rivers were conducted each fortnight between October 2002 and February 2003. All sites were sampled using glass eels nets. Glass eel nets were 10 m in length, had two 3.5 m wings with 1.4 m drop, and were constructed of 2 mm stretched nylon mesh. A detachable cod-end constructed of <0.5 mm mesh, was fitted to the end of each net.

Nets were set at the same time and in the same order each sample trip. Nets were set from 1600 hours beginning with the upstream Snowy River site, followed by the downstream site and the Brodribb River site approximately one hour later. The nets were then cleared beginning at approximately 0800 hours, in the same order as they were set. This gave a soak time of approximately 16 hours per net. The contents of each net was preserved and taken back to the laboratory. All nets were then reset and left to fish for approximately 24 hours, and were again cleared in the same order they were set starting at 0800 hours the following day. Samples were field sorted for the presence of Australian bass juveniles and the sample released. This process was repeated for a further 24 hour period, after which time the net was again checked for the presence of Australian bass. The nets were then removed from the water.

In the laboratory, all samples were sorted, with each fish identified to species level. Fork lengths were measured for a sub-sample of 30 individuals of each species. Shrimp and gastropods were counted.

### 2.3.3 Larval fish sampling survey sites

Three sites in the lower Snowy River were surveyed. Site 1 was located at Lochend (up and downstream of the boat ramp), Site 2 was from the junction of the Snowy and Little Snowy Rivers downstream to the top of Second Island, and Site 3 was downstream of the Marlo jetty to the entrance.

### 2.3.4 Larval fish sample collection

A larval fish sled (1500 x 500 mm) was operated fortnightly from November to December 2003 to sample for the presence of Australian bass larvae and juveniles. Three sled runs (each 500 m) were undertaken at each site. The speed of the towboat was maintained at 1100 rpm for all tows. The towboat zigzagged along the stream approaching each bank as close as possible so the sled sampled both near shore and middle of the river habitats. Larval fish samples from each tow run at each site were pooled and preserved in 90% ethanol. In the laboratory the samples were sorted under a dissecting microscope and the presence of Australian bass larvae or juveniles was noted.

## 2.4 Results

### 2.4.1 Juvenile fish

Eight species of fish from seven families were caught in the Snowy River (Table 2.1). Of these, six were predominantly freshwater species, while two others were estuarine species. The two estuarine fish, *Gymnapistes marmoratus* and an unidentified mullet, were both juveniles, and only one individual from each species was encountered. Of the freshwater species, five were native species, while the mosquito fish, *Gambusia holbrooki* is introduced and considered a noxious pest. The bulk of the catch in 2002-03 was made up of 'whitebait', which in this case, consisted entirely of juvenile common galaxias. Tupong, short-finned eel and flat-headed gudgeon, *Philypnodon grandiceps,* were also found in high numbers. In 2003-04, short-finned eels were the most numerous species sampled from the Snowy River.

In the Brodribb River, six species from five families were caught (Table 2.1). All six were freshwater species, and again, all were native species except for *Gambusia holbrooki.* In the Brodribb River, flat-headed gudgeon was the most abundant species, while tupong and common galaxias were also very common. Catch rates (catch per unit effort-CPUE (CPUE) in the Brodribb River peaked in early summer (December).

The highest catch rates in the Snowy River were made in the spring (October and November) with another peak in early summer. The Brodribb catches peaked only once in summer in 2002-03 and were higher in spring in 2003-04. The catch in 2002-03 from both streams (Figure 2.3 and Figure 2.4) was relatively larger than the catch in 2003-04 (Figure 2.4 and Figure 2.5). Catches were generally lower in 2003-04 compared to 2002-03. This was observed in both streams.

No juvenile Australian bass were encountered in either the Snowy or the Brodribb Rivers throughout the survey.

### 2.4.2 Larval fish

No Australian bass were recovered from the plankton tows. No further processing of the larval fish samples was undertaken, although the samples have been retained for future reference if required.

## 2.5 Discussion

There are 4 species of catadromous fish recorded from the Snowy River including 2 species of eel, the common galaxias and Australian bass (Rose and Bevitt 2003). The migration classification of tupong is somewhat confused. Rose and Bevitt (2003) list the species as amphidromous. However, Koehn and O'Connor (1990) and Raadik *et al.* (2001) discuss a migration phase. Cadwallader and Backhouse (1983) suggest the adults migrate from freshwater to the estuaries to spawn. As the young would have to make their way back upstream, tupong should probably be classified as catadromous. For the purposes of this report tupong are considered as catadromous.

A study of fish recruitment in the lower Snowy River was undertaken by Raadik in 2000 (Raadik *et al.* 2001). This study undertook glass eel netting from October 2000 to January 2001 at two sites in the river at Sandy Point and Lochend. The downstream site at Lochend is comparable to the present study in terms of species collected. As per the present study, Raadik *et al.* (2001) did not find any Australian bass but did record three of the 4 catadromous species known in the Snowy River. Raadik *et al.* (2001) recorded broad finned galaxias (*Galaxias brevipinnis*), spotted galaxias (*Galaxias truttaceus*) and southern pygmy perch (*Nannoperca australis*) from the Snowy River. The present study did not capture these species.

The present study observed differences in the timing of the migrating runs between the Snowy River and the Brodribb River. In general the peak catches in the Snowy River were earlier than the Brodribb River. The Snowy River had two main peaks while the Brodribb River only had one main run. Raadik *et al.* (2001) also recorded two peaks of migration in 2000. There were also seasonal differences in the runs from the same river for each year.

The migration of juveniles can be influenced by stream flows. For example, juvenile eel migrations can slow when flows increase and temperatures drop (Sloane 1984) and whitebait runs can cease when stream currents are low (McDowall and Eldon 1980). Other factors such as site selection and river morphology can also influence catches of migrating fish (Fulton and Pavuk 1988). Raadik *et al.* (2001) reported higher catches of migrating fish after high flow events in the Snowy River. It is likely that the differences observed in the migration patterns of juvenile fish in the Brodribb River could differ from movement patterns in the Snowy River due to the overall flow patterns of each stream both within and between years. The movement of young fish into the freshwater may have been restricted by low flows associated with the drought in 2002-03 and 2003-04. Snowy River flows varied in the two years of the study and there were few 'high flow' events in spring in 2003 compared to 2002. The lack of significant flow elevations (Figure 2.6) in spring 2003 may have depressed migration and resulted in the lower relative abundance of fish caught in the 2003-04 sampling season (Table 2.1).

No Australian bass were sampled from the investigation in either year and it was concluded that Australian bass recruitment in the years of the study either did not occur or, if recruitment did occur, it was at low levels. Australian bass do not spawn every year and involution of oocytes is known to occur in female Australian bass when stream flows are low (Harris 1986). Victoria was under the influence of a drought in the years of the study and Harris (1986) noted that Australian bass did not spawn in drought years. It is therefore possible that breeding of Australian bass did not occur at all in the years of the study.

Common galaxias were the most abundant of the migratory species from the present study. The run of common galaxias has been reported from September to December (Koehn and O'Connor 1990). The present study confirms this timing; however, some fish were seen in February and the findings also support Raadik *et al.* (2001) who suggested that upstream migration of this species can continue into the summer in the Snowy River.

Both long and short-finned eels were recorded from the present study. Short-finned eels migrate in winter and spring and long-finned eels migrate in summer (Koehn and O'Connor 1990). The present study found long-finned eels as early as October which is considerably earlier than that reported by Koehn and O'Connor (1990) and Raadik *et al.* (2001) who recorded long-finned eels in November. Short-finned eels were more common in the early parts of the present survey in the Snowy River. Raadik *et al.* (2001) reported the same observation and suggested that the timing of the surveys in September may have been on the end of the short-finned eel migration period. In contrast, the Brodribb River samples contained short-finned eels in December. The presence of Lake Curlip may slow the progress of eels in the Brodribb River.

Raadik *et al.* (2001) suggested the migration period of tupong was from October to February. In the Snowy River, the present study recorded annual variability in the timing of higher tupong catch rates. Higher catch rates were from October to December in 2002 and September to November in 2003. In the Brodribb River higher tupong catch rates were recorded later and were from December to January in 2002-03 with few tupong recorded in 2003-04.

Not all fish captured in the sampling were juveniles and not all were migratory fish. Adult big head gudgeon, pygmy perch, Australian smelt, short-finned eel, long-finned eel, and tupong were also sampled. Apart from the eels, any migration of these species is restricted to freshwater (Rose and Bevitt 2003). Eels migrate from the sea as juveniles and to the seas as mature adults. The adult eels caught in the samples are likely to be resident eels captured whilst undertaking localised movement rather than a migration.

Several adult short-headed lampreys were sampled in the glass eel nets. This species is catadromous and was probably moving into the freshwater to spawn.

No Australian bass were recorded from the larval trawls and reasons are uncertain. The reasons referred to above in relation to water flows are also relevant to larval presence (see Harris 1986)

It is also possible that the sampling technique may not have been adequate and the Australian bass may have been able to avoid the net. However, as other species of fish and larvae were captured in the trawls, including prawns and an adult mullet, avoidance was not considered to have been a problem.

Harris (1986) sampled Australian bass larvae from the Hawksbury River in New South Wales and noted that the Australian bass were always associated with aquatic macrophytes. Not all of the sites sampled in the present study had aquatic vegetation present. Sites 2 and 3 had banks of sea grass (*Zostera sp.*) in places along the stream edges and these areas were included in the trawl runs. Site 1 had no aquatic macrophytes and consisted primarily of shallow sand. There may have been a lack of sampling effort in the weed beds. The weed beds were only partially sampled as part of the overall sampling. Trials of towing the net through large areas of sea grass were unsuccessful as the net snagged or filled with weed and could not be effectively towed by the boat. Some weed beds were included in sampling runs where it was present.

Juvenile Australian bass have been sampled from a range of salinities between 0.5 and 13.5 ppt (Harris 1986). This is brackish water at less than one-third seawater. These salinities are more likely to be found in the upper reaches of the Snowy River estuaries such as around Lochend (Site 1). In the Lochend area there are very few areas of aquatic vegetation or other instream cover. If Australian bass do prefer areas of vegetation with low salinity levels then there may be a lack of Australian bass nursery areas in the Snowy River estuary. Aquatic vegetation is present in the Snowy River above the estuary but in isolated patches and is not widespread. In the estuary the aquatic vegetation is generally found in the higher salinity areas closer to the stream mouth.

In summary, surveys of the migrating juvenile fish community of the lower Snowy River indicate that this fauna remains relatively natural with only one introduced fish species recorded.

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**Figure 2.1 Glass eel nets set at site one in the Snowy River.**

**Table 2.1 Species list and relative abundance of fish sampled in the Snowy River and Brodribb River for each year of the study.**

| | | | **Snowy River** | | **Brodribb River** | | |
|---|---|---|---|---|---|---|---|
| **Species** | **Code** | | **2002/03** | **2003/04** | **2002/03** | **2003/04** | **Total** |
| Long finned eel | LFE | *Anguilla reinhardtii* | 23 | 1 | 2 | - | 26 |
| Short finned eel | SFE | *Anguilla australis* | 171 | 169 | 12 | 32 | 384 |
| Common galaxias | CG | *Galaxias maculatus* | 1990 | 73 | 78 | 90 | 2231 |
| Tupong | TP | *Pseudaphritis urvillii* | 287 | 128 | 93 | 19 | 527 |
| Short-headed lamprey | SHL | *Mordacia mordax* | - | 2 | - | 2 | 4 |
| Australian smelt | AS | *Retropinna semoni* | - | 37 | - | 24 | 61 |
| Gambusia | GH | *Gambusia holbrooki* | 12 | - | 3 | 2 | 17 |
| Flathead gudgeon | FHG | *Philypnodon grandiceps* | 171 | 21 | 112 | 84 | 388 |
| Dwarf flathead gudgeon | DFHG | *Philypnodon sp.* | - | - | - | 2 | 2 |
| Southern pygmy perch | SSP | *Nannoperca australis* | - | - | - | 1 | 1 |
| Cobbler | | *Gymnapistes marmoratus* | - | 1 | - | - | 1 |
| Tailor | PS | *Pomatomus saltatrix* | 1 | 2 | - | - | 3 |
| Australian bass | AB | *Macquaria novemaculeata* | - | - | - | - | 0 |
| | | Total Fish | 2655 | 434 | 300 | 256 | 3645 |
| Crustaceans | | | | | | | |
| Freshwater shrimp | | *Paratya australiensis* | 832 | 107 | 300 | 25 | 1264 |

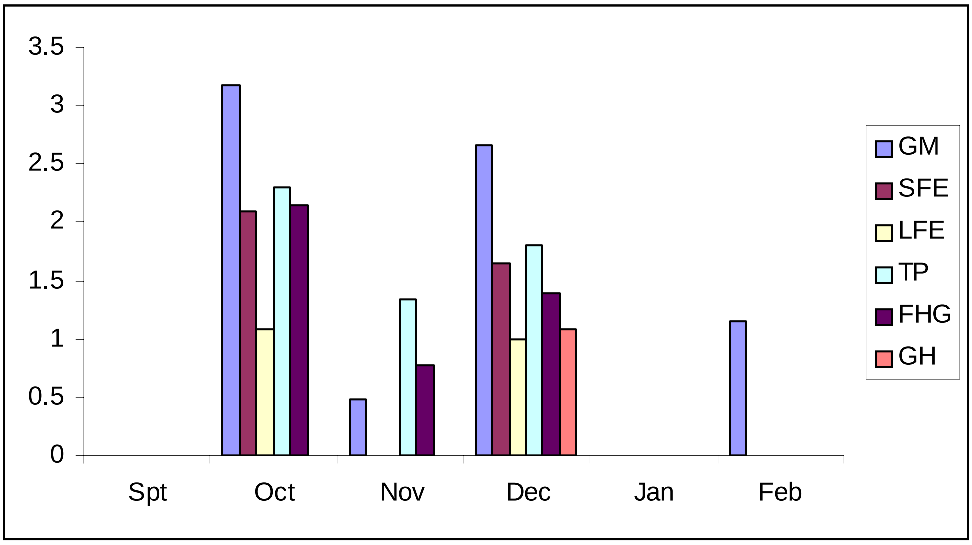


**Figure 2.2 Relative abundance of fish species sampled per month in glass eel nets in the Snowy River, 2002-03. Data pooled from three nets and log transformed.**

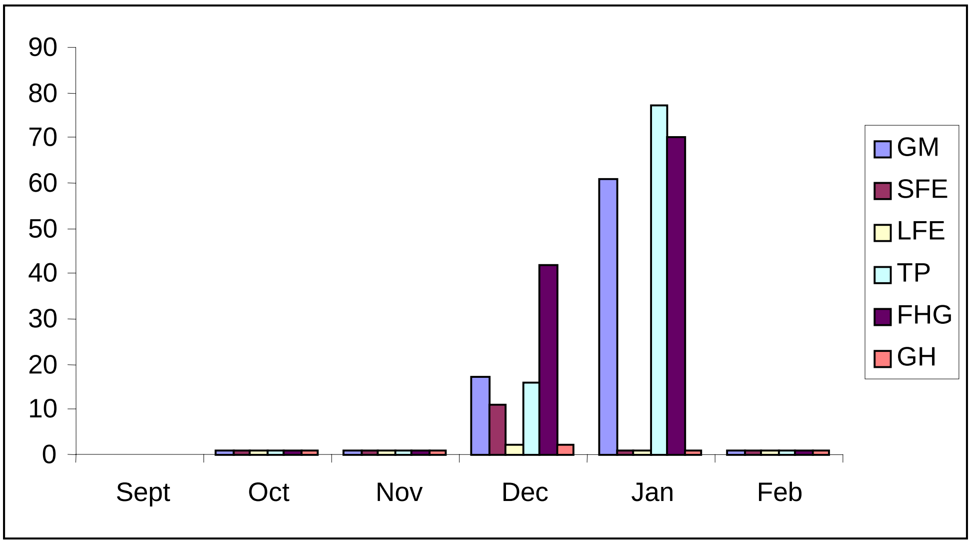


**Figure 2.3 Relative abundance of fish species sampled per month in glass eel nets in the Brodribb River, 2002-03.**

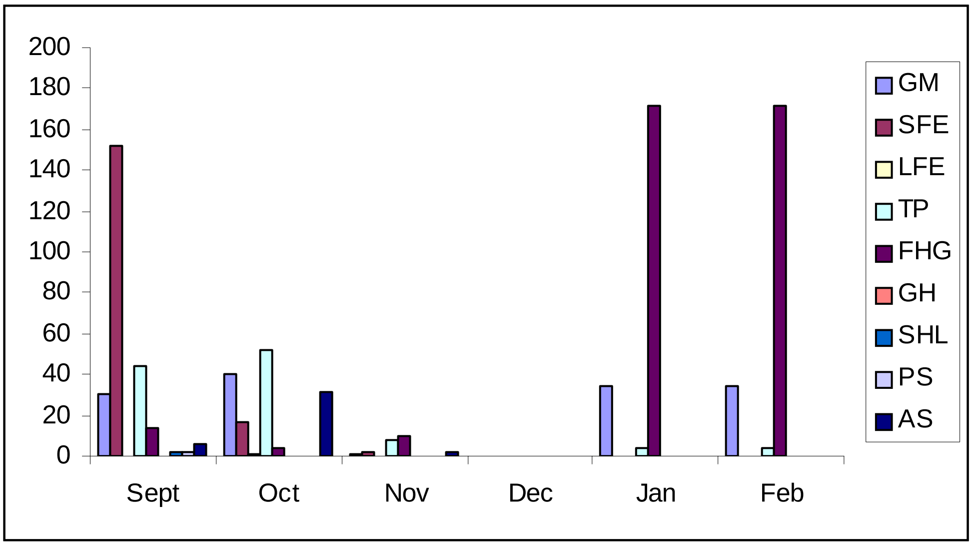


**Figure 2.4 Relative abundance of fish species sampled per month in glass eel nets in the Snowy River, 2003-04. Data pooled from three nets.**

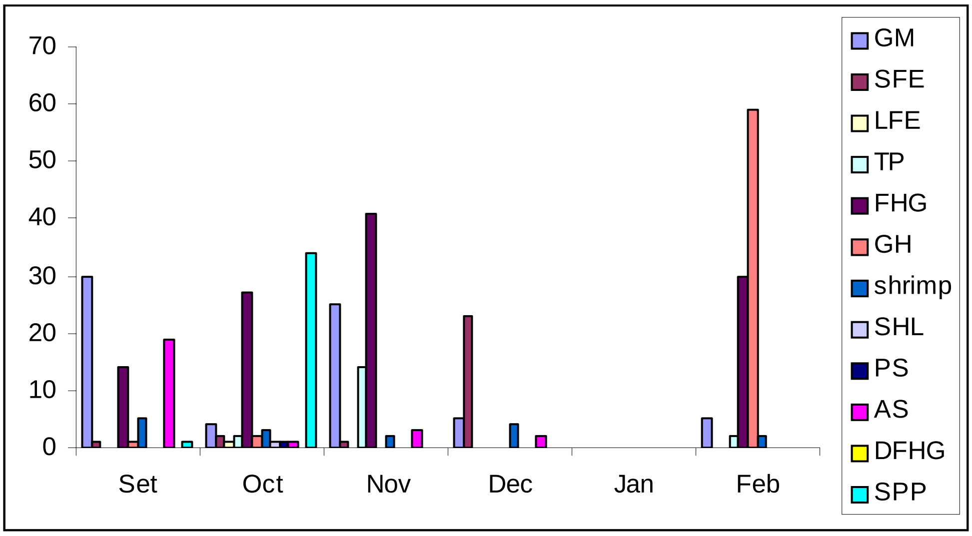


**Figure 2.5 Relative abundance of fish species sampled per month in glass eel nets in the Brodribb River, 2003-04.**

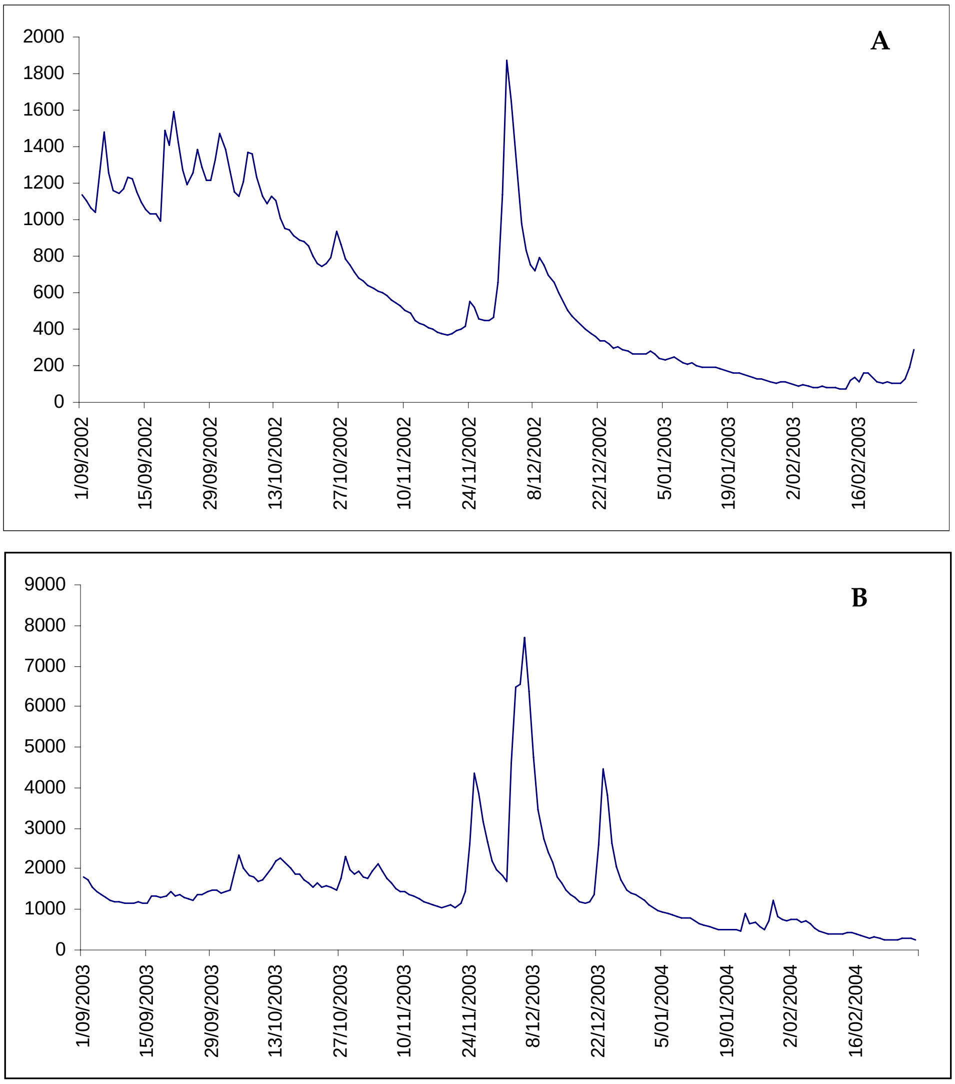


**Figure 2.6 Daily flows for Snowy River at Jarrahmond from September 2002 to February 2003 (A) and September 2003 to February 2004 (B).**

# Chapter 3 Freshwater fish in the tributaries of the Snowy River

**Daniel Stoessel (Fisheries Research Branch, Fisheries Victoria)**

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## 3.1 Introduction

An extensive literature review was compiled by Raadik (1992a, 1992b) on the distribution of freshwater fishes in East Gippsland (including the Snowy River system) pre 1991. Records over a 24-year period were combined due to "non-standardised survey methodology, different species targeted and intermittent surveys". In that study it was noted that the natural resources of this area are increasingly exploited, yet the fish assemblages of many streams remain unsurveyed, with no attempt made to elucidate the distribution or habitat preference of fish species at various stages in their life cycles, or over time. In addition to this, Raadik (1992a) noted that most sites have been surveyed at easily accessible points where the riparian and instream habitat have been disturbed, and results therefore on diversity and abundance may be flawed.

The only significant survey undertaken since the review was again by Raadik (1995) in which 117 sites within east Gippsland were surveyed; 64 of these were from the upper Snowy River system. Sampling at each of the sites was undertaken only once, and "therefore did not take into consideration how the species diversity of a given site may change over different seasons" (Raadik 1995), or apply ample effort required to locate those species considered rare. Much of the data were also pooled, and little specific information can be drawn regarding the Snowy River itself. The study reported a total of 14 fish species within the system and 3 species of crustacea, and a known, or suspected occurrence of a further 4 fish species and 2 species of crustacea.

In addition to these studies is the work by Rose and Bevitt (2003), which covers much of the main stem of the Snowy River. This research is based on return visits to chosen sites thereby ensuring effective monitoring of much of the system. The study to date has found distinct spatial variations in the fish communities of the Snowy River, and low recruitment success of migratory species. As such, Rose and Bevitt (2003) suggest continued monitoring of physical and biological components of the system to provide adaptive management to improve the physical and biological integrity of the system.

The only species specific study undertaken was completed by Jerry *et al.* (1999), who studied possible hybridisation between Australian bass and estuary perch in the Snowy, Mitchell/Tambo and Albert Rivers.

In regard to the Snowy River itself, Stewardson *et al.* (1997) found that the limited fish survey information available indicated a population composed largely of native species. Within Victoria, one of these species is considered endangered (Cox's gudgeon - *Gobiomorphus coxii*), one is vulnerable (Australian grayling - *Prototroctes maraena*) and one is near threatened (Striped gudgeon - *Gobiomorphus australis*) on the Victorian Department of Sustainability's advisory list (2007). Of these, *Prototroctes maraena* and *Gobiomorphus coxii* are on the Victorian *Flora and Fauna Guarantee Act 1988* Threatened List and *Prototroctes maraena* is listed as vulnerable on the *Commonwealth Environment Protection and Biodiversity Conservation Act 1999* List of Threatened Species.

There is some concern that the current abundance of these species is declining due to regulation of the Snowy River under the Snowy Mountain Scheme (since 1955-completed 1967) and a major de-snagging effort around 1887 (Stewardson *et al.* 1997). It is considered that these events have detrimentally impacted the river, and as a result significantly reduced the availability of deep water and cover within the main Snowy River channel.

In addition to this, increased sediment input from land management activities, dramatic changes to channel morphology, the loss of native riparian vegetation, increased salinity (Anon. 1996), and recent large intensive bushfires may all have added to the problem. These changes have resulted in temperatures that are critically high for trout and native colder water species, have decreased dissolved oxygen, and increased filamentous algae and macrophytes. The result is a lack of suitable habitat for differing life-stages of several aquatic species, and a possible reduction in the abundance of Australian bass and other species.

## 3.2 Objectives.

The three main objectives of this project were to:

- Establish detailed qualitative and, where possible, quantitative benchmark assessments of fish populations in the Victorian sections of the major tributary streams of the Snowy River with a view to later assessment of changes associated with Snowy River flow rehabilitation.

- Establish benchmark habitat profiles in association with the study reaches.
- Document the work visually.

## 3.3 Methods

### 3.3.1 Fish surveys

Sampling was undertaken in the winter of 2003 (i.e. June/July 2003), summer of 2003/2004 (Jan/Feb 2004), and the subsequent winter of 2004 (June 2004). Due to time constraints and the large number of sites to be electrofished as well as to allow comparisons with previous data, single electrofishing passes were made at each site. The results are therefore qualitative to, at best, semi-quantitative.

Sampling followed those methods described by Raadik (1995), except that a backpack electrofisher was used at all sites, rather than a bank-mounted electrofisher.

Site numbers, locations and distances electrofished were the same as those used by Raadik (1995) (Appendix 3.8A). Several sites from the original survey by Raadik (1995) were inaccessible (as a result of seasonal, fire, and total closure of roads) or dry. As a result, 35 sites were sampled. Supplementary data were used from an additional survey undertaken at Buchan (on the Buchan River - site 77) on a single day on the 19 February 2004 to aid in the determination of species distribution (Figure 3.1).

All fish caught were identified, weighed (to the nearest gram), and measured to the nearest millimetre (i.e. occipital carapace length for crayfish, and fork length for fish), and subsequently returned to the water. Several individuals unable be identified in the field were euthanased and stored in 70% ethanol solution and later identified.

All data were entered into a SAS database for further analysis. Data were subsequently pooled to allow assessment of species distribution over the catchment, and results were then mapped using Arcview. Previous distribution data gathered by Raadik (1995) were added to Arcview maps to allow comparisons of distribution.

A Cluster analysis was completed (using PRIMER) on all capture data and inferences drawn from this in regard to site habitat preferences. Grouping of sites according to species occurrence was then mapped using Arcview to allow observations in regard to habitat preferences of species.

### 3.3.2 Habitat benchmarking

Habitat benchmarking was undertaken using the methods described by Raadik (1995), using a slightly modified data sheet (Appendix 3.8B).

Variables recorded were conductivity, temperature, maximum width and depth, and average depth in metres. On each sampling occasion land use, predominant substrate and instream habitat, flow type and disturbance rating were additionally recorded.

All habitat data were entered in an Excel spreadsheet, and subsequently tested for patterns related to habitat distribution using a cluster analysis in PRIMER. Subsequent site groupings (according to the cluster analysis) were plotted using Arcview.

### 3.3.3 Visual assessment

During subsequent surveys, photographs were taken at each of the sites to allow visual comparisons over the assessment period.

## 3.4 Results

### 3.4.1 Fish surveys

Eleven species of fish from seven families were caught in the Snowy River tributaries (Table 3.1, Appendix 3.8C, Appendix 3.8D).

### 3.4.2 Species distribution

Three sites which were originally planned to be surveyed were found to be dry (i.e. sites 40, 48, and 49), and no fish were found at a further 9 sites over the survey period (i.e. sites 24, 25, 27, 28, 29, 30, 31, 34, and 35). Sites with either no fish captured or which were found to be dry were all located on tributaries on the western side of the Snowy River.

#### 3.4.2.1 Australian smelt distribution

From those sites surveyed, Australian smelt were only found in the Deddick River (i.e. sites 50, 51, 53, 55, 56) with the exception of site 26 which exists just upstream of the junction of the Little River and the Snowy River (Figure 3.2). Overall capture numbers were low, with single individuals caught at sites 51 and 53, two at site 56, and four at site 55. No individuals of the species were caught in the western tributaries, and of the 8 sites in which the species was found previously by Raadik (1995) only 5 sites produced individuals of the species.

#### 3.4.2.2 River blackfish distribution

Blackfish were found at three sites (Figure 3.3) during the study (i.e. site 56, 61 and 19) compared to 7 sites previously (Raadik 1995).

These sites are all located in the upper reaches of tributary streams (i.e. 3rd and 4th order streams) of the eastern side of the Snowy River. Numbers caught were low, and in all cases less than 3 individuals were captured.

**3.4.2.3 Climbing galaxias (*Galaxias brevipinnis)* distribution**
Climbing galaxids were found solely in the eastern tributaries (Figure 3.4), and most abundantly in the Rodger River (site 16), and its major tributary stream the Yalmy River (i.e. site 19). Unlike the previous trends however, this species was found at a greater number of surveyed sites (i.e. 7 sites in this study compared with 4 in the previous study by Radiik (1995).

**3.4.2.4 Brown trout (*Salmo trutta*) distribution**
Brown trout were the most numerous species sampled, and were found throughout the tributary system (Figure 3.5). The upper reaches of the Deddick River (i.e. the Dellicknora, Jingalalla, and the Bonang Rivers) produced the greater proportion of those individuals captured of the species, with 230 individuals (or 85.8%) captured from this region. Brown trout was only found at one additional site to the study by Raadik (1995), and was not located at another 4 sites at which it had been previously found.

**3.4.2.5 Common galaxias distribution**
Common galaxias (i.e. 17 individuals) were found at a single site (i.e. site 10) - the lowest altitudinal site surveyed (Figure 3.6). This agrees with distribution data of the previous study by Raadik (1995).

**3.4.2.6 Cox's gudgeon distribution**
This species has not previously been found within the system. A total of 3 individuals of this species were caught at two sites (Figure 3.7) during the study (i.e. sites 51 and 77). The two individuals caught at site 77, were however, sampled during a single sampling event, rather than the repeated surveys associated with site 51.

**3.4.2.7 East Gippland Spiny Crayfish (*Euastacus kershawi*) distribution**
The East Gippsland Spiny Crayfish were found at 3 sites during the survey (i.e. sites 16, 32 and 62), two of which the species had previously been unreported (i.e. sites 32 and 62). Sites in which the species were located are in the head-waters of the catchment (Figure 3.8). The previously reported existence of the species at site 60 (Raadik 1995) was not reconfirmed.

**3.4.2.8 Goldfish (*Carassius auratus*) distribution**
Although not previously found by Raadik (1995), two individuals of this species were caught just upstream of the junction of the Deddick and Snowy Rivers (i.e. site 50) over the study period (Figure 3.9).

**3.4.2.9 Long-finned eel distribution**
Long-finned eels were distributed widely across the system (Figure 3.10) and were found at all sites previously recorded by Raadik (1995), except site 38. A total of 121 individuals were caught over the 13 sites in which they were captured, with site 77 (i.e. the Buchan River) producing 27 (i.e. 22.3%) of the total caught in a single sampling event.

**3.4.2.10 Mountain galaxias (*Galaxias olidus*) distribution**
Of this species, a total of 28 individuals were caught from two sites (sites 16 and 18) over the survey period (Figure 3.11). Site 16 (located in the Rodger River) produced the greater proportion of individuals with 25 (89.2%) of the total being captured at this site. Unlike the previous study by Raadik (1995) the species was not found in the Suggan Buggan River (i.e. site 38).

**3.4.2.11 Rainbow trout (*Oncorhynchus mykiss)* distribution**
Rainbow trout were caught at a single site (i.e. site 62) on the Bonang River (Figure 3.12). The previous reported occurrence of the species by Raadik (1995) at site 22 was not reconfirmed.

**3.4.2.12 Riffle shrimp (*Australatya striolata*) distribution**
Otherwise known as eastern freshwater shrimp, a single individual of this species was captured on a single sampling event on the Buchan River (Figure 3.13). Previous recorded presence of the species by Raadik (1995) at site 50 was not reconfirmed.

**3.4.2.13 Short-finned eel distribution**
Short-finned eels were the third most numerous species surveyed with 98 individuals sampled (Figure 3.14). In addition, they were the most widely distributed with the species being present at 18 of the 36 sites sampled (i.e. 50%). Of those sites similarly surveyed to those of Raadik (1995), site 58 was the only site where the species was not located.

**3.4.2.14 Tupong distribution**
Tupong (Figure 3.15) were found within the Deddick River (sites 50, 51, 52 and 53), Little River (site 26), Buchan River (site 77), and Loongelaat Creek (site 10). Loongelaat Creek had the greatest numbers recorded at any site during the survey of this species (i.e. 13 individuals). Unlike the previous study by

Raadik (1995) however, the species was not found within the Suggan Buggan River (i.e. site 38).

### 3.4.3 Site similarity relative to species and numbers caught

A cluster analysis of the similarity of sites relative to species numbers captured at each site indicates four main groupings at 20% similarity (Figure 3.16). The resultant cluster groupings were entered into Arcview so patterns related to species distribution could be obtained. A diagrammatic representation of site similarities according to species and numbers captured over the catchment (Figure 3.17, with colours relative to grouping representation in Figure 3.16) indicates a grouping of sites on the western side of the Snowy River that were either dry (red) or had a nil catch (red). Another group (blue) was distributed in the lower reaches of tributaries, and contained sites with at least 2 individuals of long-finned eels. This group as a whole contained all records of this species. Another group (green) was generally located in the upper reaches of tributaries, and was dominated in 81.2% of cases by brown trout. The last grouping of a single site (purple) was different from all other sites in species composition, being the only site containing individuals of the common jollytail.

### 3.4.4 Site similarity relative to habitat

Habitat data is summarised in Appendix 3.8E. Temperature and conductivity records were not complete over all sites, and as a result they could not be used in subsequent analysis. Sites with all other physical habitat data complete over the study were entered into Primer. A cluster analysis indicated eight main groupings at 88% similarity (Figure 3.18). The resultant cluster groupings were entered into Arcview so as any patterns related to species distribution could be obtained. A diagrammatic representation of site similarities according to habitat (Figure 3.19, with colours relative to grouping representation in Figure 3.18) indicates a distinct pattern relative to physical habitat attributes measured during the study. Most apparent is the habitat differences found in the majority of western tributary sites relative to the eastern sites. In addition to this it was found that within individual tributaries, sites tended to be markedly different lower in the tributary, compared with sites higher in the same tributary.

## 3.5 Discussion

A total of 637 fish and crustaceans was caught representing 14 species, 11 of which are native, and 3 introduced. Of the native species recorded, Cox's gudgeon and riffle shrimp are on the Victorian *Flora and Fauna Guarantee Act 1988* Threatened List.

Species numbers are comparable to those found in a study completed by Raadik (1995) who found a total of 14 fish species and 5 species of crustacea over a greater number and spread of site locations (i.e. 64 sites in the previous survey completed by Raadik compared with 36 in the current project).

Species distribution within the tributaries is closely related to physical habitat characteristics. Whilst the habitat relationships could not be explored in detail in this study, major factors especially for catadromous species appear to be distance to the sea, altitude, and level of site disturbance. Western tributary sites tended to have either no, or low numbers of individuals; however, the greater proportion of these western sites were burnt during recent fires, and many as a result have a high to very high disturbance rating. In addition, much of this area has been cleared and, as a consequence, streams appeared to be degraded in general when compared with sites on the eastern tributaries. These findings agree with data collected by Raadik (1995), indicating low diversity within this area and a numerical dominance of introduced species.

Exotic species in general made up 47.7% of the total individuals captured during the study (this figure excludes site 77 due to it not being surveyed by Raadik). When this is compared with the figure of 32.1% calculated from Raadik's (1995) data, it appears that exotic species may be increasing in numbers in the system. An alternative may be that native species are declining in numbers.

Brown trout appeared to be dominant in upper reaches of the Deddick River particularly in the Bonang and the Jingalalla Rivers above 480 m altitude.

A total of three individuals of Cox's gudgeon were located in the Buchan River and the Deddick River during the survey. This is thought to be the first confirmation of the presence of this species within the system and subsequent samples were lodged with the Australian Museum. This species appears to be rare within the Snowy River system.

In general, fewer fish were caught at almost all sites during the current survey (i.e. excluding sites 12, 15, 22, 32, and 61), compared with Raadiks' (1995) catch data. This difference may, however, be related to sampling bias due to differing capture techniques used in each study (backpack electrofishing in the current study, and bank-mounted in the previous), or due to the impacts of several years of drought, and a recent severe bush-fire (particularly on the western side of the Snowy River) on the current survey.

Reports of goldfish within the system (Rose and Bevitt 2003) were confirmed during the current study. Individuals of the species being found on two separate sampling occasions at the junction of the Deddick and Snowy Rivers (i.e. site 50).

Previous findings of redfin (*Perca fluviatilis*) (Raadik 1992b) within the Bonang River were not confirmed; however sampling was undertaken at a single site on a single day within this river, and the absence of the species within this survey may therefore not be indicative of actual absence of the species within the system. This would appear to be the case, with Rose and Bevitt (2003) reconfirming the species presence in the Snowy and Delegate Rivers stretches within New South Wales.

As previously found by Raadik (1992b, 1995) short-finned eels were the most widely spread species throughout the system, being found at 50% of those sites surveyed. Equal second in regard to distribution were long-finned eels and brown trout (found at 33% of all sites).

Riffle shrimp are considered rare within the system, and previous reports of the species presence within the Deddick River (Raadik 1995) were not reconfirmed. Within this study, a single individual of the species was found at a single site (i.e. site 77) within the Buchan River.

As with Raadik's (1995) findings, the majority of those species limited in distribution were also limited in number. Exceptions to this rule did, however, occur with the common galaxias and the climbing galaxias which were relatively abundant at single sites.

The short-headed lamprey (*Mordacia mordax*) was not captured during the recent survey. It must be noted, however, that of those sites similarly surveyed by Raadik (1995) only three individuals were caught from a single site (i.e. site 10).

Results of a previous study by Raadik (1995) indicate freshwater species per site ranged from 0 to 6 (i.e. excluding the species *Paratya australiensis*, the presence of which was not recorded in this study). From the data in that study, a calculated average of 2.5 species per site was found using those sites sampled in both surveys. The current study found between 0 to 4 species per site with an average of 2, indicating a possible decline in species numbers at individual sites.

## 3.6 Conclusions

It appears from the current study that both diversity and numbers of fish within the system have declined since previous monitoring work was undertaken by Raadik (1995).

It is suspected that this result may be largely due to low rainfall within the tributaries. Recent extensive bushfires in the catchment may also have had an impact through increased sedimentation.

Comparison of the eastern and western tributaries show systems which are currently quite different. The majority of western tributaries were highly affected by fire and farming practices, and as a result are either sparsely populated or dominated by exotic species.

The eastern tributaries in comparison appear generally less disturbed (although the Deddick River was to some extent effected by fire), and they contain a greater number of individuals and native species. However, the upper tributaries of the Deddick River (i.e. the Dellicknora, Jingalalla, and the Bonang Rivers) were notably dominated by brown trout and rainbow trout.

Further investigation of the Buchan River and its tributaries would be of benefit due to the tributary not being surveyed to any extent since Raadik (1995). The tributary also contains two species on the *Flora and Fauna Act 1988* Threatened List (i.e. Cox's Gudgeon and riffle shrimp).

## 3.7 References

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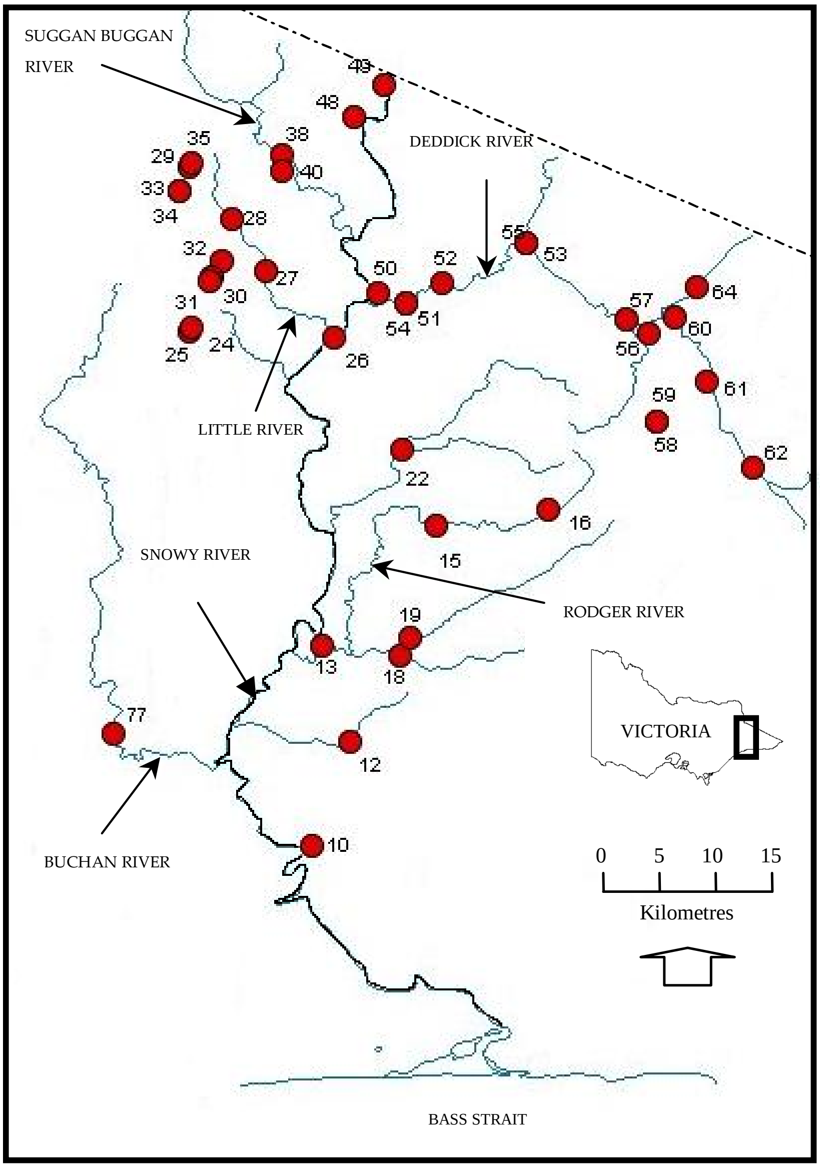


**Figure 3.1 Survey site locations for fish in the tributaries of the Snowy River.**

**Table 3.1 Species list and relative abundance of fish sampled in the tributaries of the Snowy River (pooled over all dates and sampling sites).**

| Species | Code | | Total |
|---|---|---|---|
| Long finned eel | LFE | *Anguilla reinhardtii* | 121 |
| Short finned eel | SFE | *Anguilla australis* | 98 |
| Climbing galaxias | ClG | *Galaxias brevipinnis* | 30 |
| Mountain galaxias | MG | *Galaxias olidus* | 28 |
| Common galaxias | CG | *Galaxias maculatus* | 17 |
| Australian smelt | AS | *Retropinna semoni* | 12 |
| River blackfish | RBF | *Gadopsis marmoratus* | 5 |
| Cox's gudgeon | CG | *Gobiomorphus coxii* | 3 |
| Brown trout | BT | *Salmo trutta* | 268 |
| Rainbow trout | RT | *Oncorynchus mykiss* | 14 |
| Goldfish | GF | *Carassius auratus* | 2 |
| East Gippsland spiny cray | EGSC | *Euastacus bidawalus* | 5 |
| Riffle shrimp | RS | *Australatya striolata* | 1 |

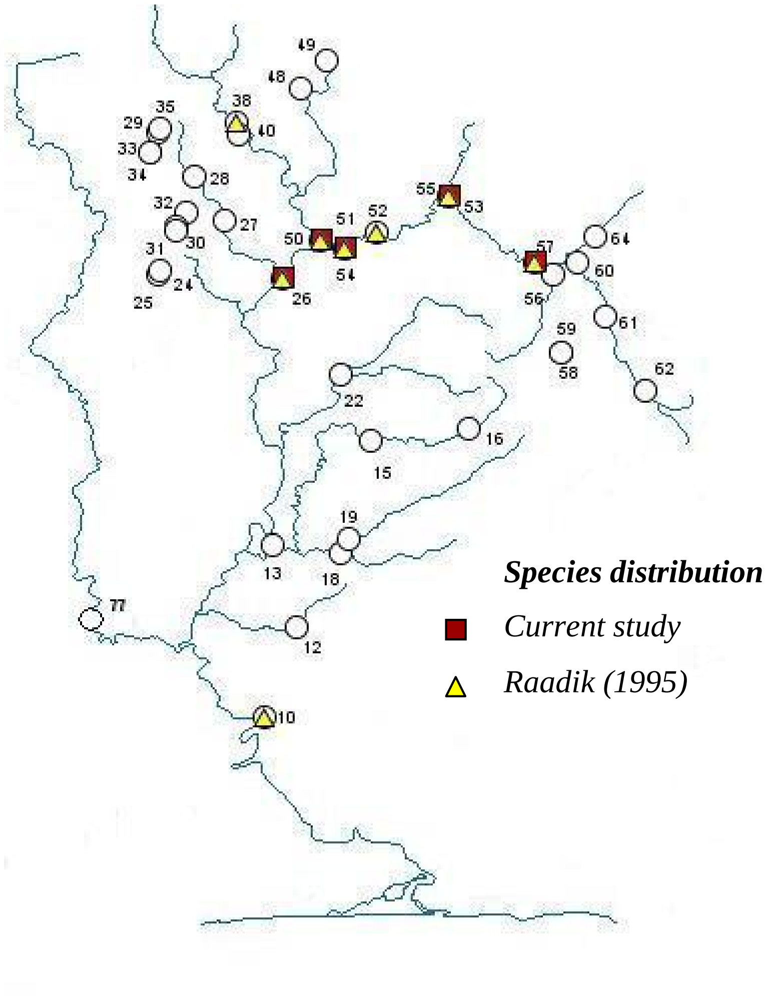


**Figure 3.2 Distribution of Australian smelt in Snowy River tributaries.**

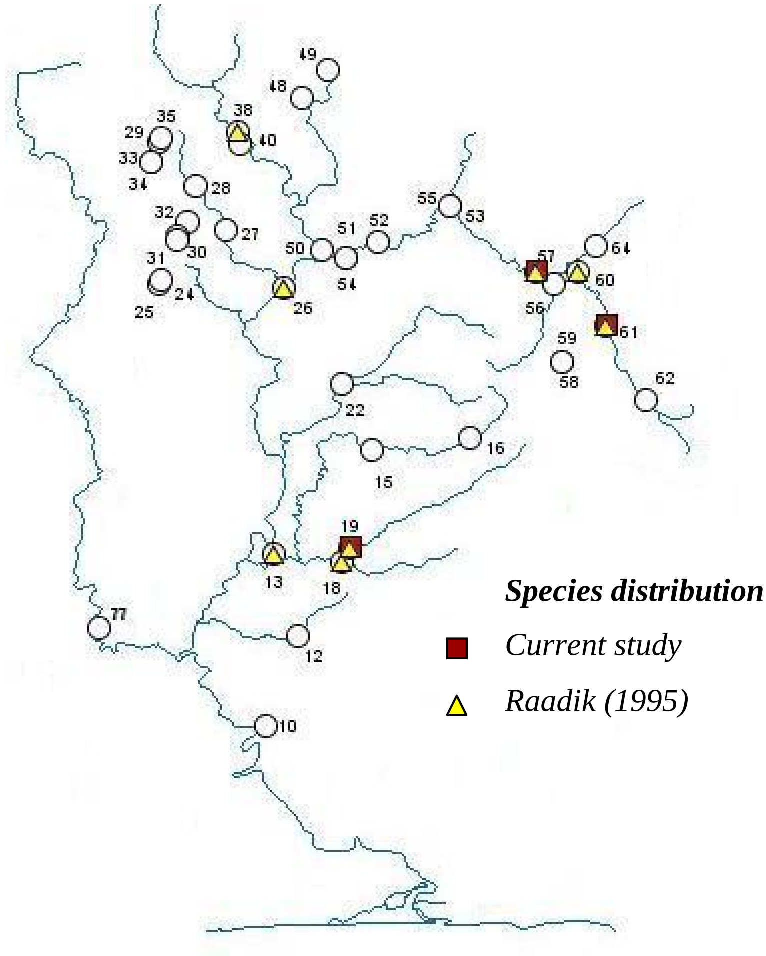


**Figure 3.3 Distribution of River blackfish in Snowy River tributaries.**

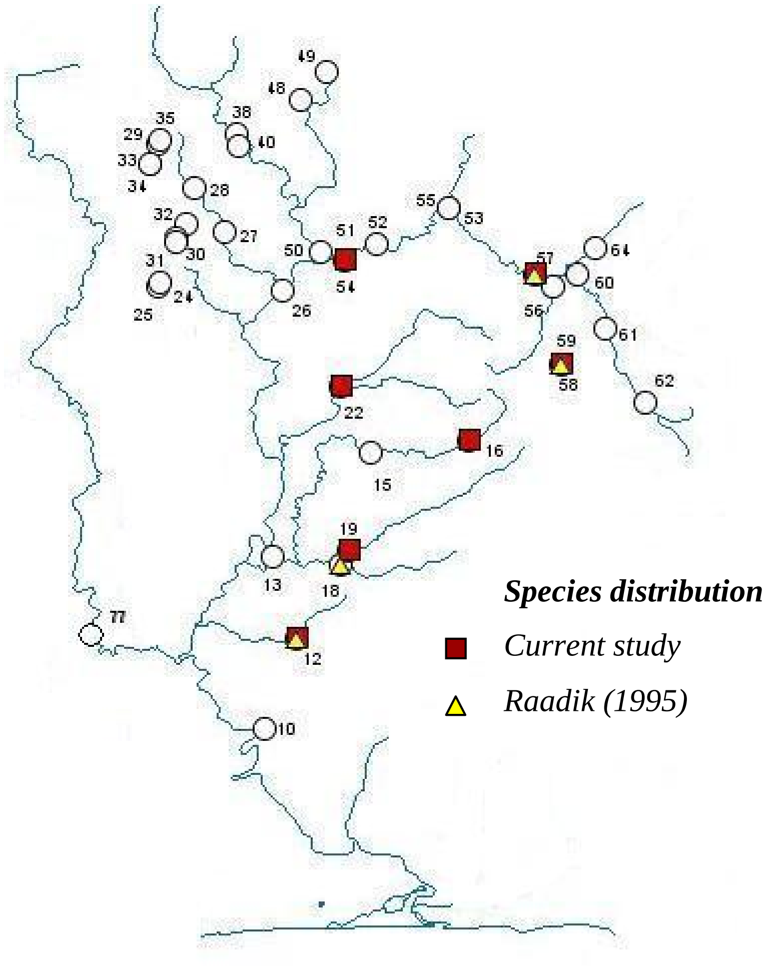


**Figure 3.4 Distribution of climbing galaxias in Snowy River tributaries.**

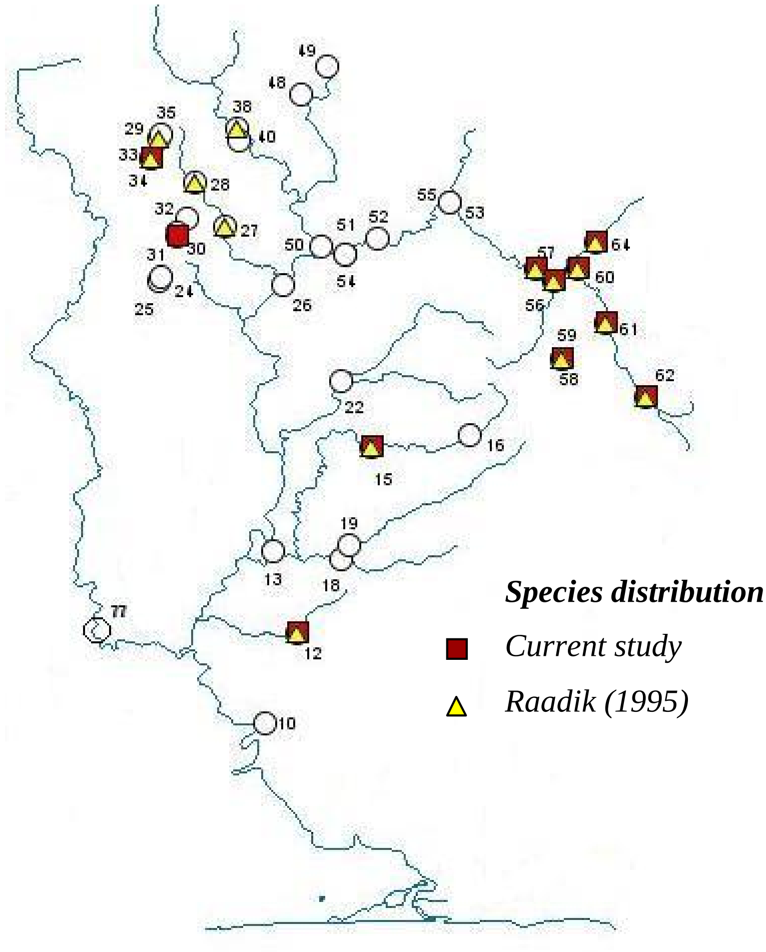


**Figure 3.5 Distribution of brown trout in Snowy River tributaries.**

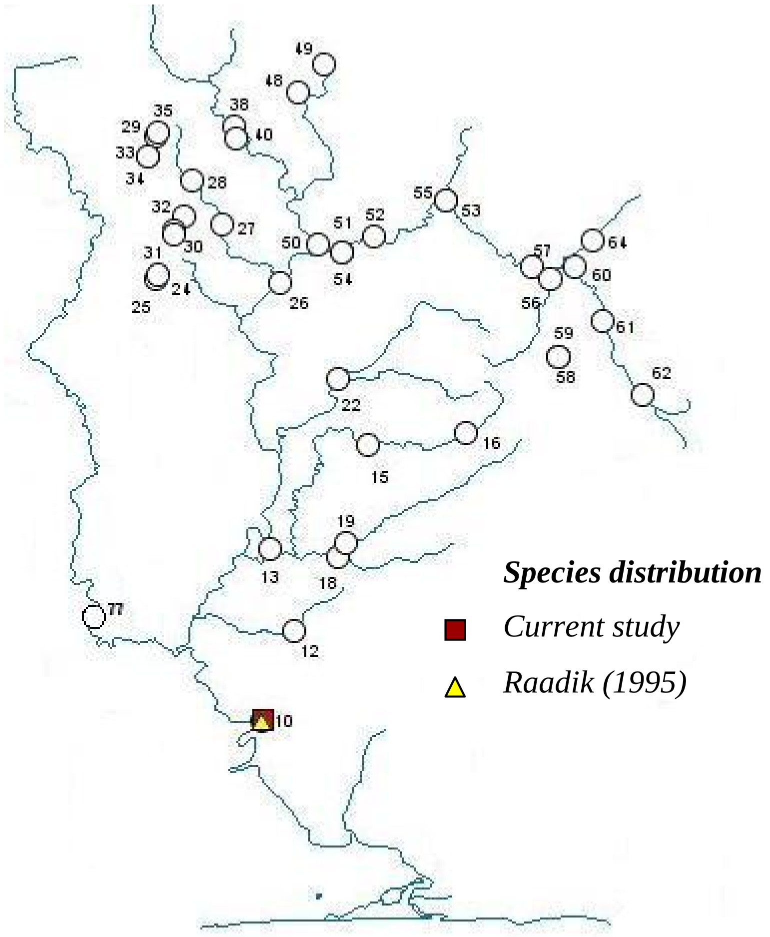


**Figure 3.6 Distribution of common galaxias in Snowy River tributaries.**

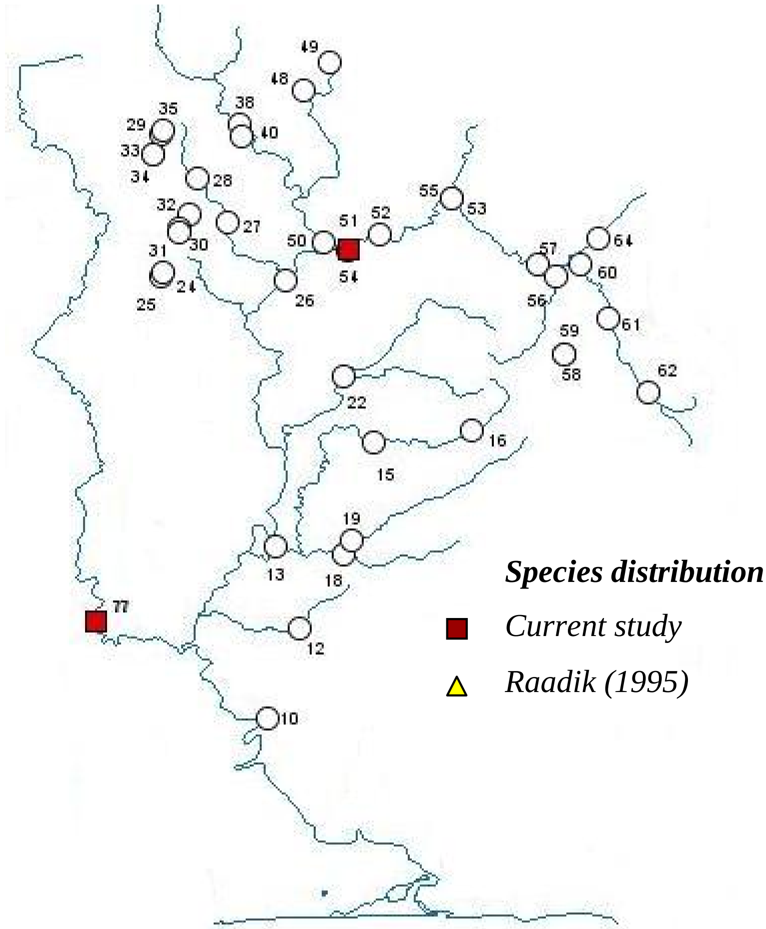


**Figure 3.7 Distribution of Cox's gudgeon in Snowy River tributaries.**

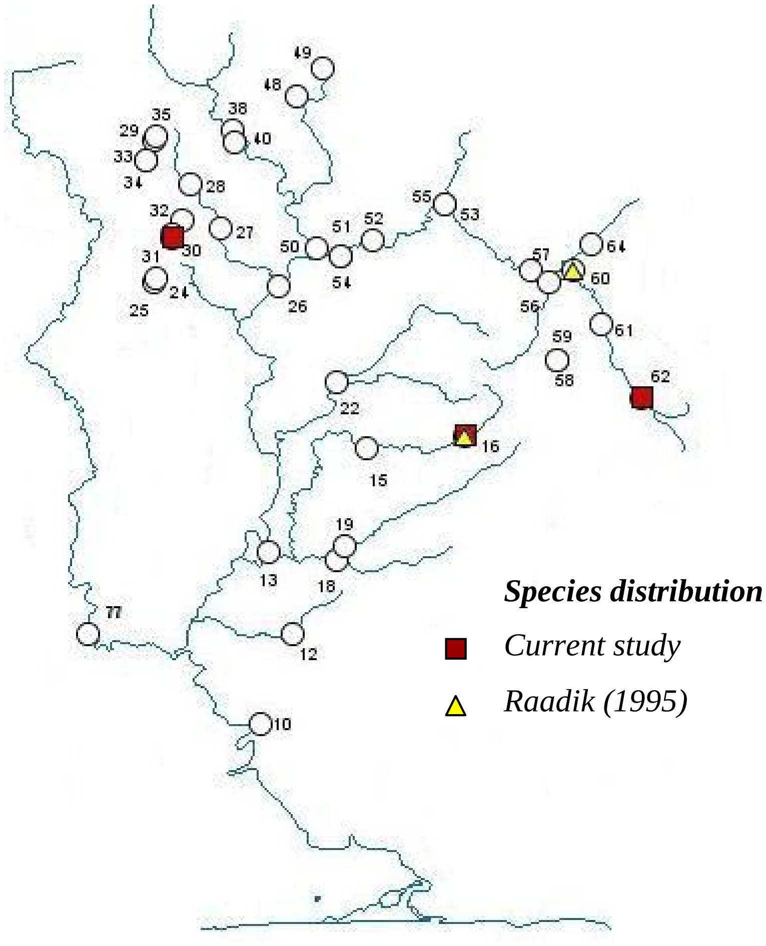


**Figure 3.8 Distribution of East Gippsland Spiny Crayfish in Snowy River tributaries.**

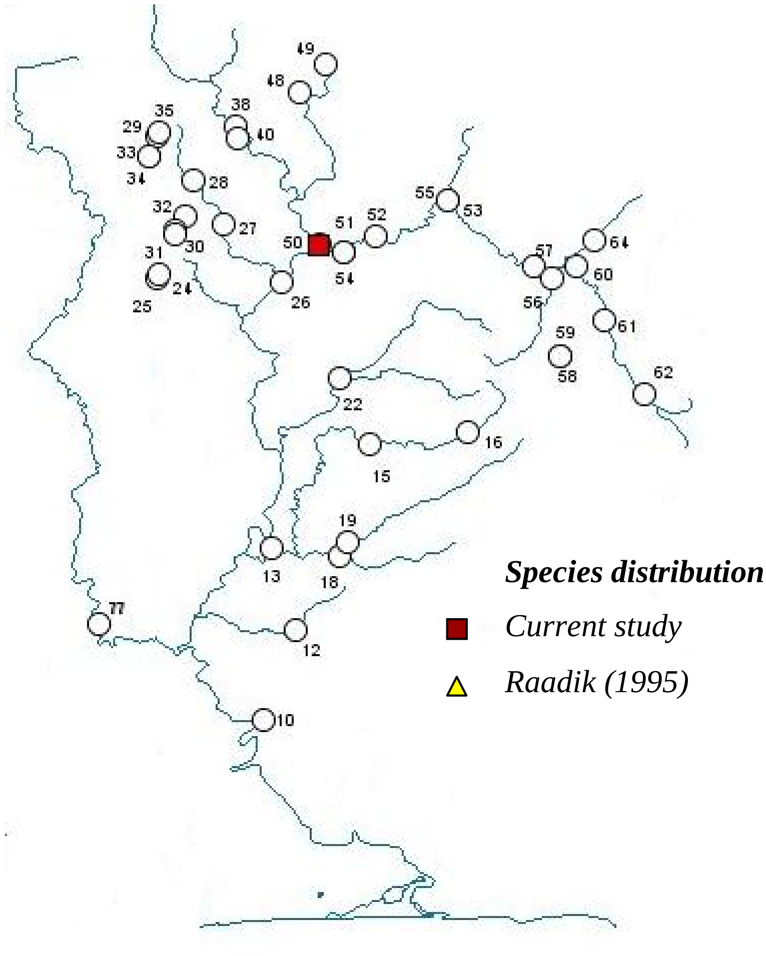


**Figure 3.9 Distribution of goldfish in Snowy River tributaries.**

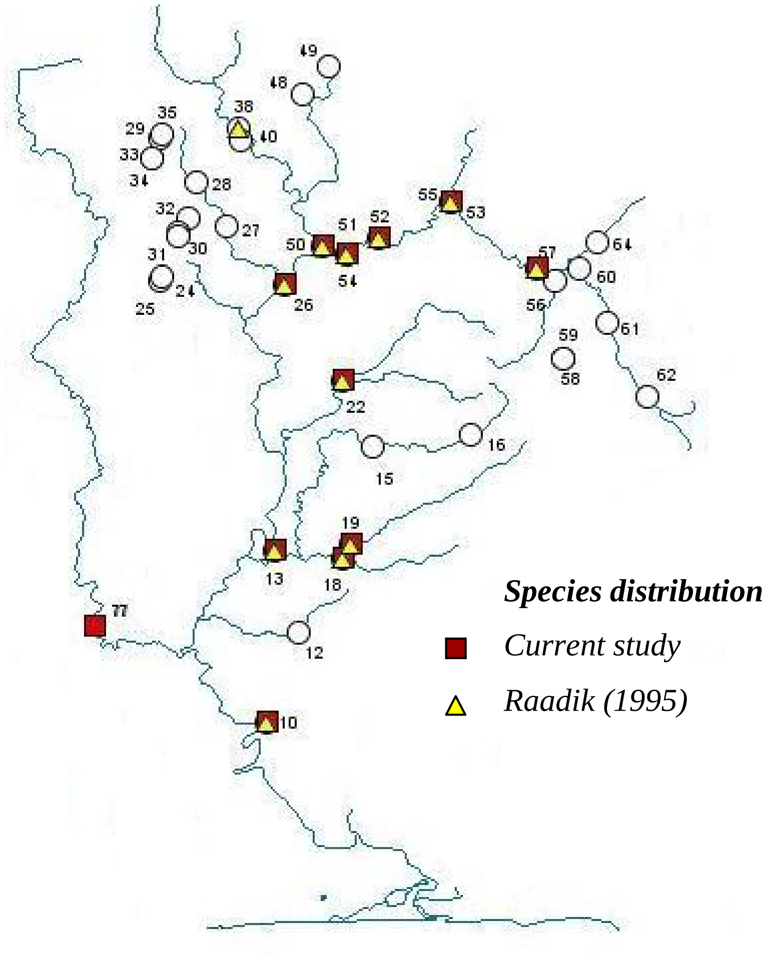


**Figure 3.10 Distribution of long-finned eel in Snowy River tributaries.**

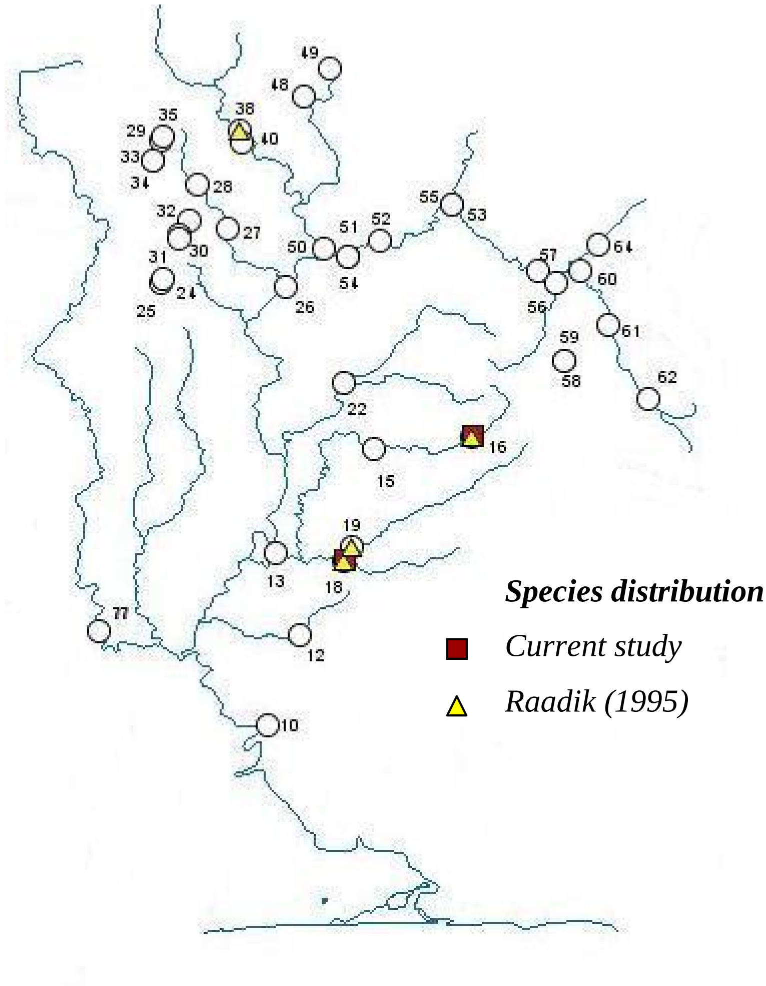


**Figure 3.11 Distribution of mountain galaxias in Snowy River tributaries.**

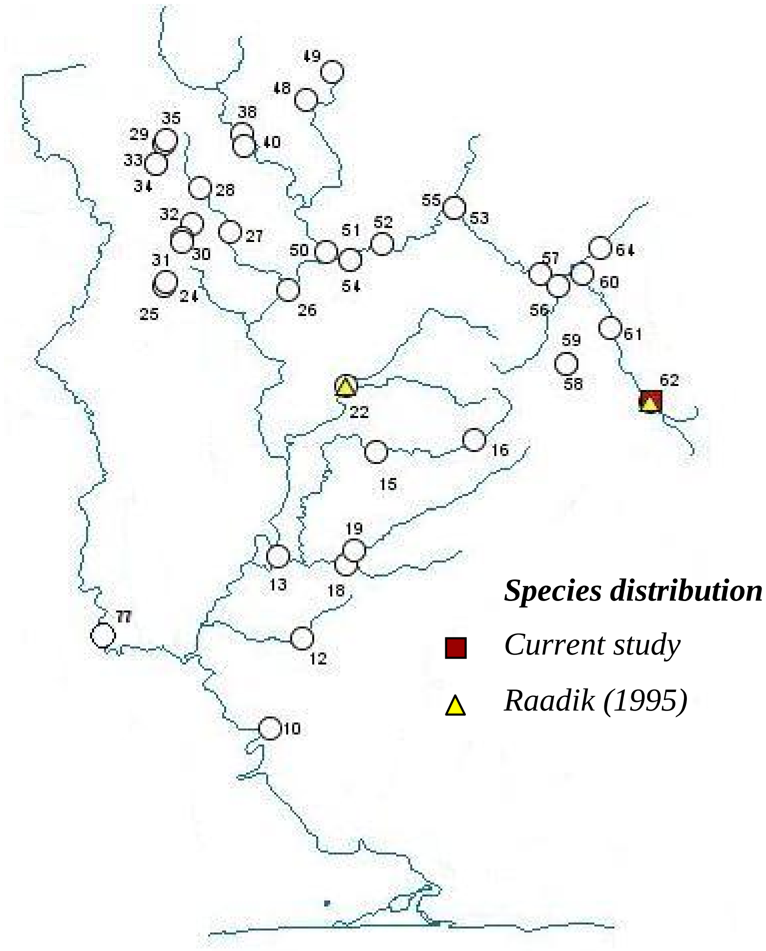


**Figure 3.12 Distribution of rainbow trout in Snowy River tributaries.**

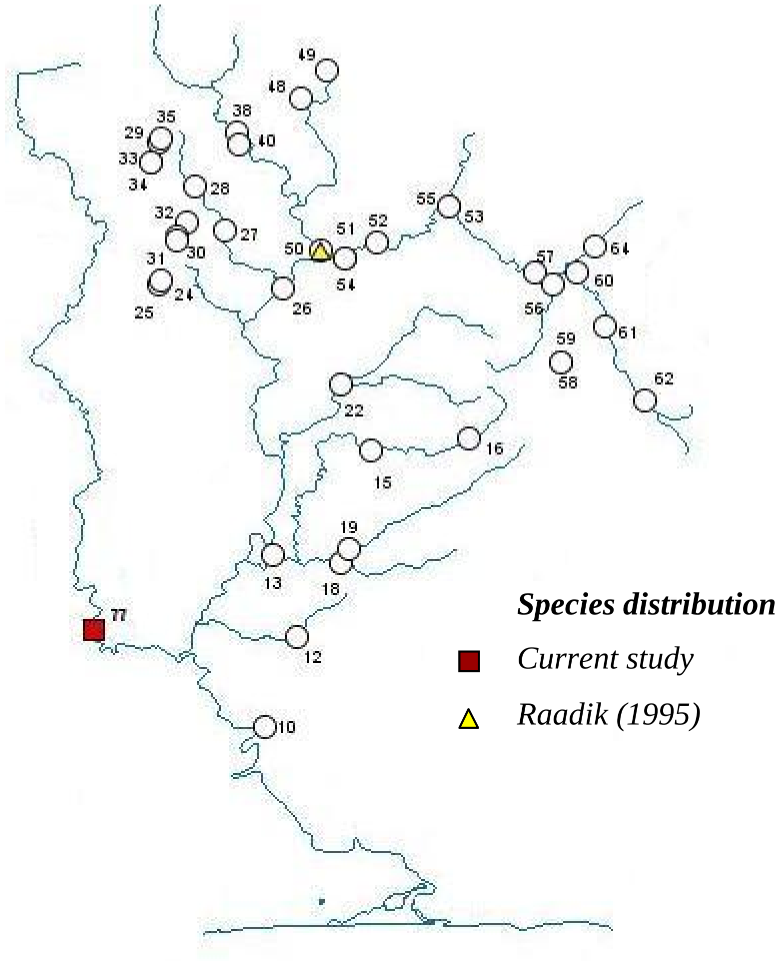


**Figure 3.13 Distribution of riffle shrimp in Snowy River tributaries.**

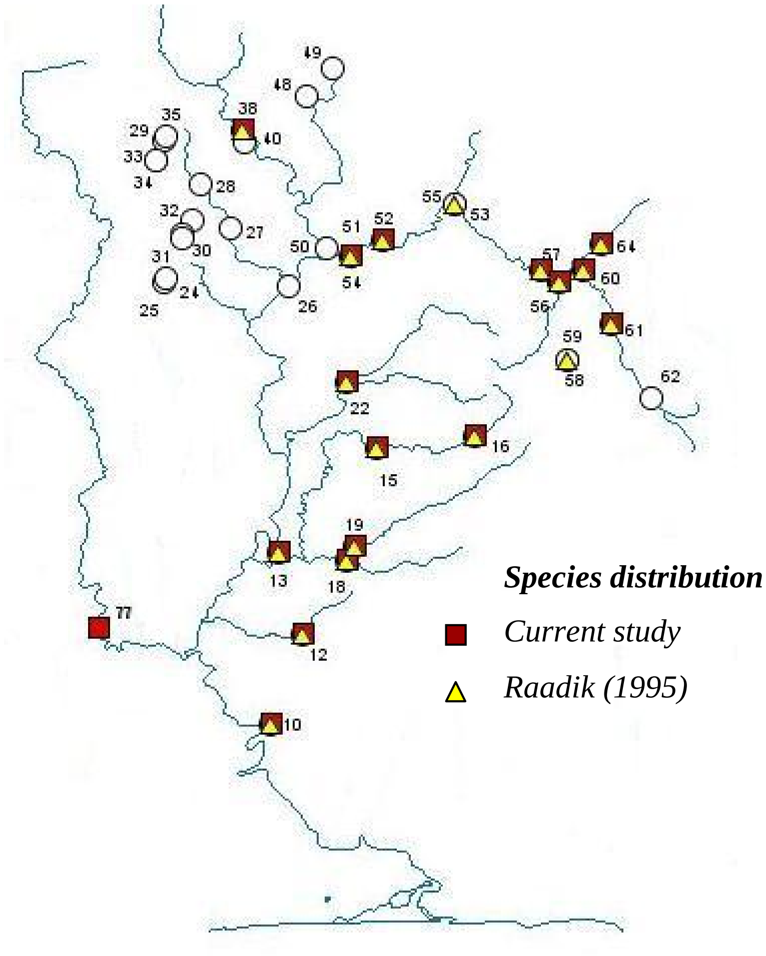


**Figure 3.14 Distribution of short finned eel in Snowy River tributaries.**

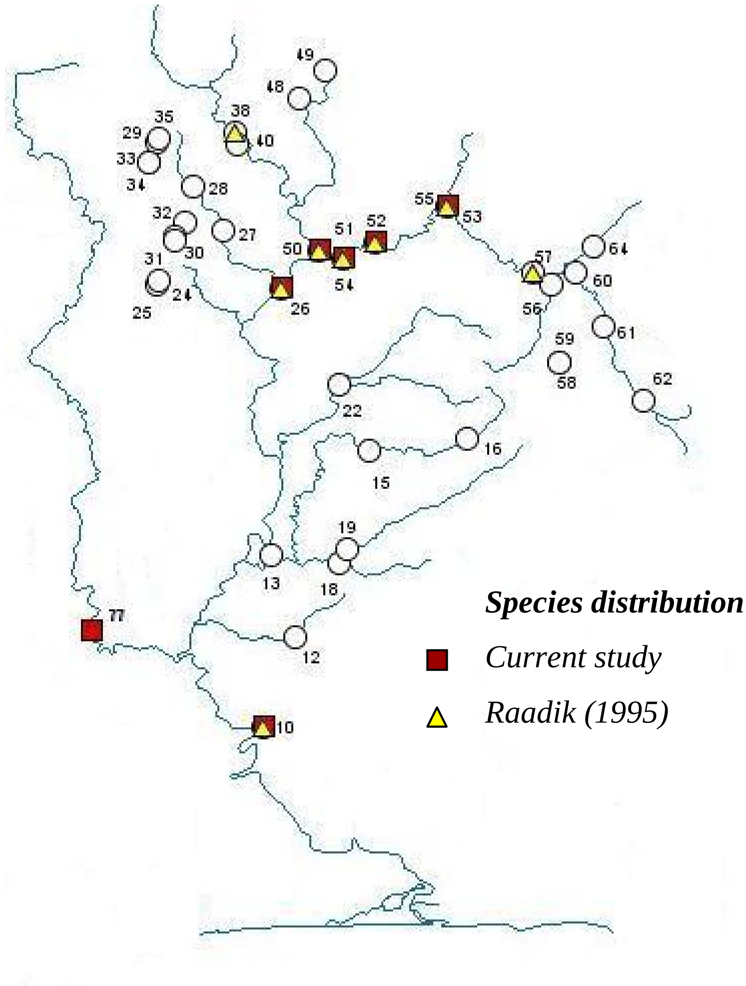


Figure 3.15 Distribution of tupong in Snowy River tributaries.

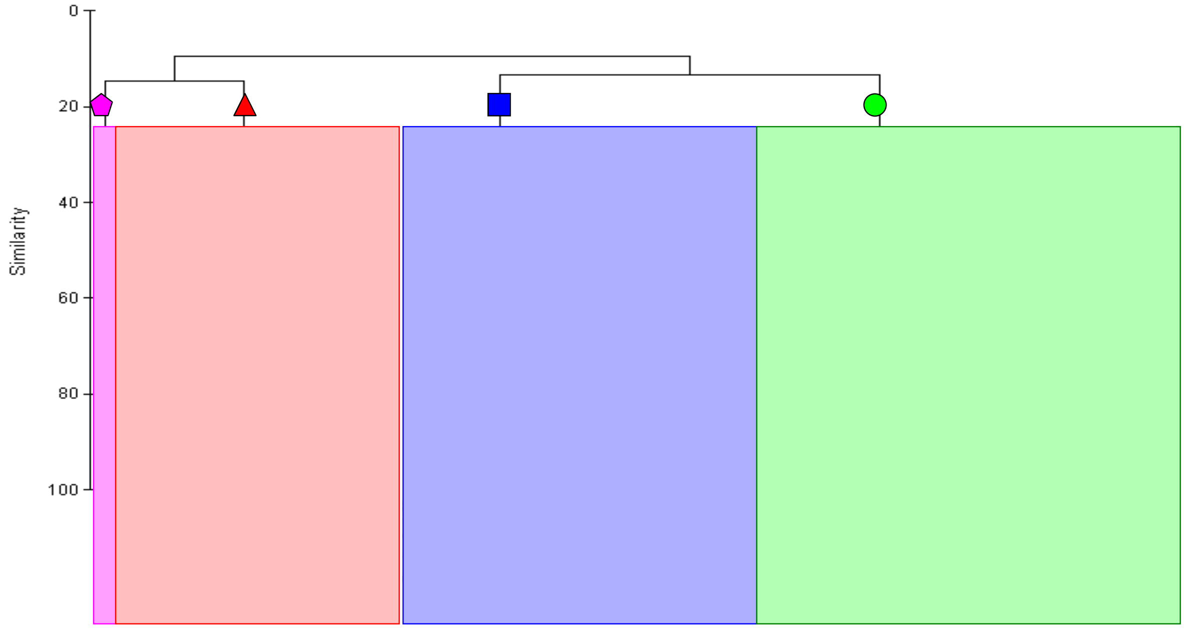


**Figure 3.16 Fish species abundance cluster analysis.**

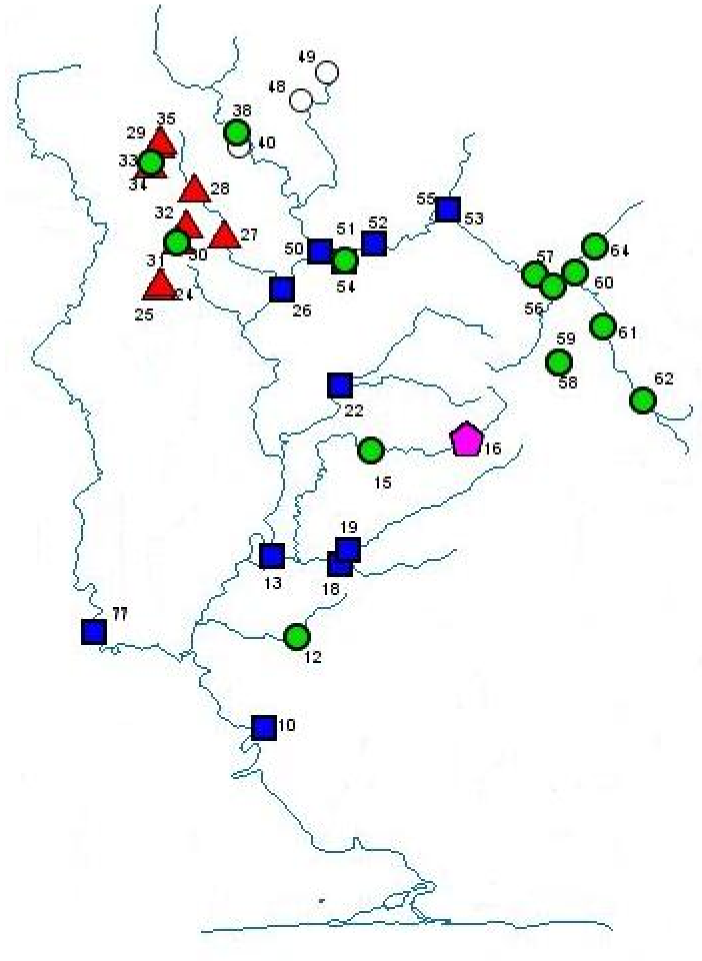


**Figure 3.17 Site groupings according to catch (coloured shapes relative to groupings in Figure 3.16).**

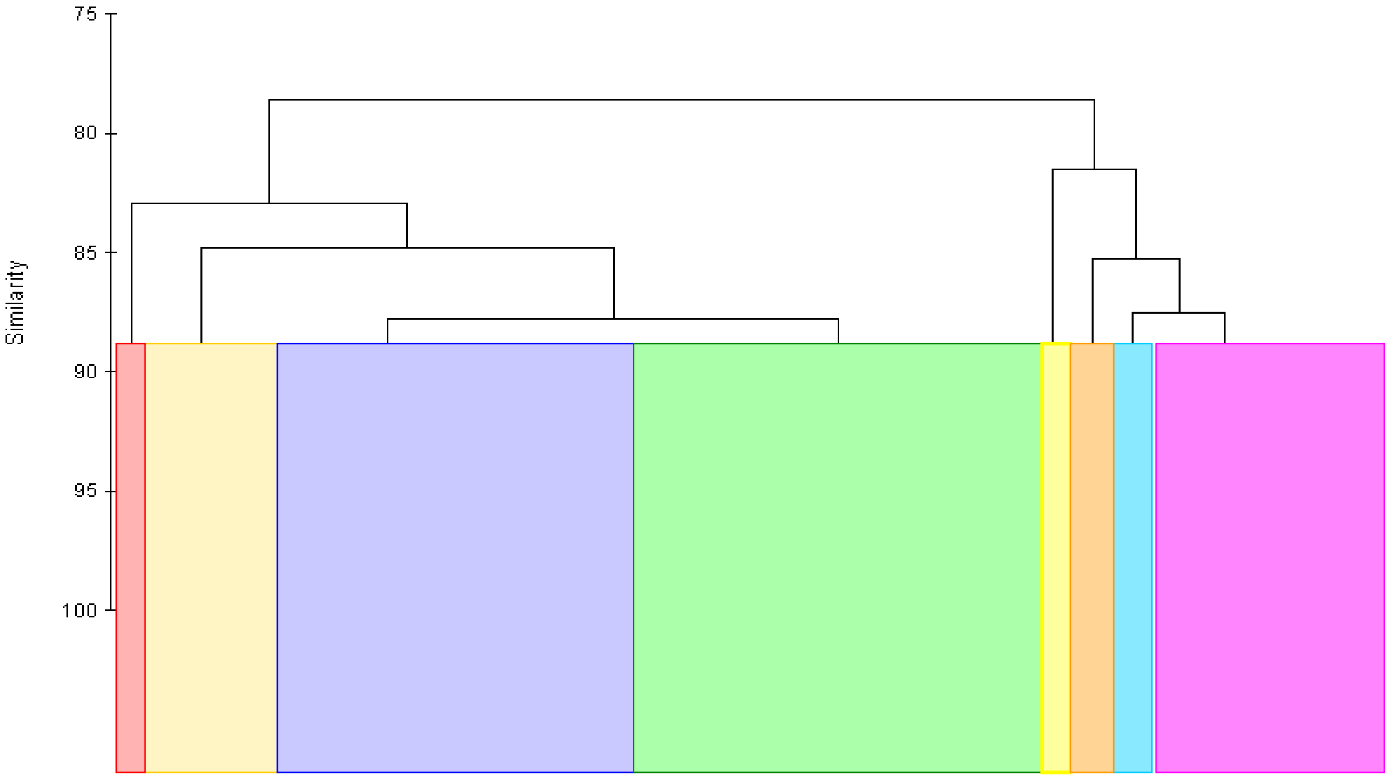


**Figure 3.18 Physical habitat cluster analysis.**

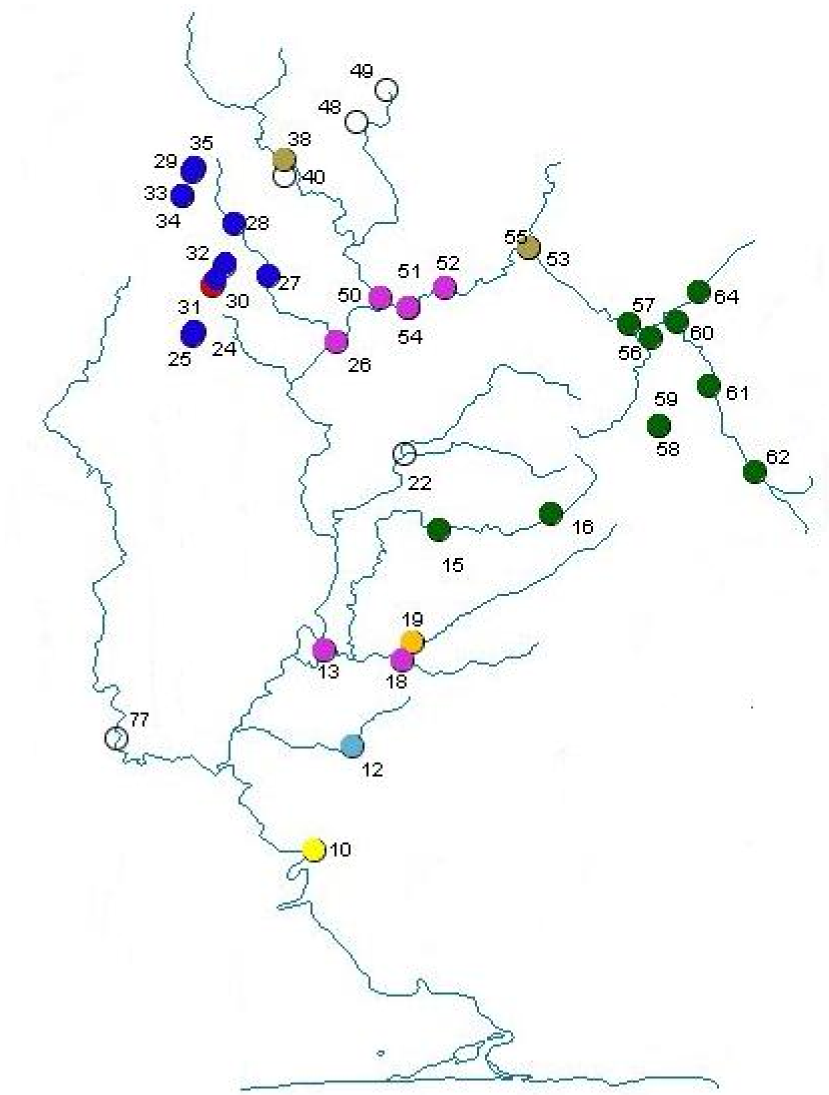


**Figure 3.19 Site groupings according to physical habitat (colours indicate groupings relative to Figure 3.18, non-coloured dots indicate sites with incomplete physical habitat data).**

# 3.8 Appendices

## Appendix 3.8A Site details.

| Site No. | WATER | LOCATION | MAP SHEET No. | GRID REFERENCE | ALTITUDE |
|---|---|---|---|---|---|
| 10 | LOONGELAAT CREEK | FORD ON GARNETT TRACK | 8522 | 619300 5838400 | 20 |
| 12 | RAYMOND CREEK | BRIDGE ON YALMY ROAD | 8523 | 622500 584900 | 190 |
| 13 | RODGER RIVER | FORD ON VARNEYS TRACK | 8523 | 620400 5858800 | 120 |
| 15 | RODGER RIVER | FORD ON DEDDICK TRACK | 8523 | 629900 587100 | 560 |
| 16 | RODGER RIVER | BRIDGE ON WARATAH FLAT ROAD | 8623 | 639200 5872400 | 680 |
| 18 | SERPENTINE CREEK | BRIDGE ON YALMY ROAD | 8523 | 626800 5857700 | 170 |
| 19 | YALMY RIVER | BRIDGE ON YALMY ROAD | 8523 | 627600 5859500 | 170 |
| 22 | MOUNTAIN CREEK | FORD ON DEDDICK TRAIL | 8523 | 627200 5878900 | 260 |
| 24 | BOUNDAY CREEK | BRIDGE ON SUGGAN BUGGAN/GELANTIPY ROAD | 8523 | 610100 5891100 | 860 |
| 25 | SELDOM SEEN CREEK | BRIDGE ON SUGGAN BUGGAN/GELANTIPY ROAD | 8523 | 610300 5891600 | 840 |
| 26 | LITTLE RIVER | JUNCTION WITH SNOWY RIVER | 8523 | 621900 5890500 | 145 |
| 27 | LITTLE RIVER | BRIDGE ON BONANG/GELANTIPY ROAD | 8523 | 616400 5897300 | 790 |
| 28 | LITTLE RIVER | BRIDGE ON SNOWY RIVER ROAD | 8523 | 613700 5902700 | 870 |
| 29 | LITTLE RIVER | CULVERT ON BLACK MOUNTAIN ROAD | 8524 | 610200 5908000 | 990 |
| 30 | GOODWIN CREEK | BRIDGE ON SNOWY RIVER ROAD | 8523 | 613000 5898500 | 860 |
| 31 | WULGULMERANG CREEK | BRIDGE ON SNOWY RIVER ROAD | 8523 | 612100 5896800 | 830 |
| 32 | RED SOIL CREEK | CULVERT ON SNOWY RIVER ROAD | 8523 | 612000 5896400 | 820 |
| 33 | WOMBARGO CREEK | BRIDGE ON BLACK MOUNTAIN ROAD | 8524 | 609400 5905600 | 950 |
| 34 | SPLITTERS CREEK | JUNCTION WITH WOMBARGO CREEK | 8524 | 609400 5905600 | 950 |
| 35 | OMEO CREEK | JUNCTION WITH LITTLE RIVER | 8524 | 610400 5908500 | 990 |
| 38 | SUGGAN BUGGAN RIVER | BRIDGE ON SNOWY RIVER ROAD | 8524 | 617800 5909500 | 370 |
| 50 | DEDDICK RIVER | JUNCTION WITH SNOWY RIVER | 8523 | 625500 5894900 | 175 |
| 51 | DEDDICK RIVER | FORD ON ARMSTRONG TRACK | 8523 | 627800 589380 | 200 |
| 52 | DEDDICK RIVER | BRIDGE AMBOYNE SETTLEMENT ROAD | 8523 | 630800 589580 | 240 |
| 53 | DEDDICK RIVER | JUNCTION WITH TINGARINGY CREEK | 8623 | 637800 5899900 | 390 |
| 54 | MINCHIN CREEK (OLD JOE CREEK) | JUNCTION WITH DEDDICK RIVER | 8523 | 627800 5893800 | 200 |
| 55 | TINGARINGY CREEK | JUNCTION WITH DIDDICK RIVER | 8623 | 637800 5899900 | 390 |
| 56 | JINGALALLA RIVER | 1ST FORD ON TINGARINGY TRACK | 8623 | 645900 5891900 | 480 |
| 57 | JINGALALLA RIVER | BRIDGE ON DELLICKNORA ROAD | 8623 | 647600 589040 | 520 |
| 58 | JINGALALLA RIVER | FORD ON MINCHIN TRACK | 8623 | 648100 5881300 | 695 |
| 59 | HOME CREEK | JUNCTION WITH JINGALALLA RIVER | 8623 | 648100 5881300 | 695 |
| 60 | BONANG RIVER | BRIDGE ON DELLICKNORA ROAD | 8623 | 649800 589200 | 570 |
| 61 | BONANG RIVER | BRIDGE ON BONANG HIGHWAY | 8623 | 652400 588540 | 640 |
| 62 | BONANG RIVER | BRIDGE ON RESULT CREEK ROAD | 8623 | 656000 587660 | 820 |
| 64 | DELLICKNORA CREEK | CULVERT ON CAMMERON TRACK | 8623 | 651800 589510 | 600 |
| 77 | BUCHAN RIVER | DOWNSTREAM BRIDGE IN PARK AT BUCHAN | 8523 | 603300 5849950 | |

**Appendix 3.8B Habitat data sheet.**

| | | |
|---|---|---|
| **Water** | **Site number** | **Date** |
| ***Conductivity*** | **Temp.** | |
| ***Max. width*** | ***Max depth*** | ***Ave. depth.*** |

***Predominant substrate (circle one)***

| Boulder | Cobble | Pebble | Gravel | Sand | Silt/Clay |
|---|---|---|---|---|---|
| >256mm | >64mm | >16mm | >2mm | >0.0125mm | <0.0125mm |

***Land Use (circle one or two)***

**Forest** **Partly cleared** **Cleared** **Burnt** **Other (name)**

***Flow type (circle one or two)***

**Rapid** **Cascade** **Run** **Riffle** **Glide** **Pool** **Backwater**

| | |
|---|---|
| Rapid | - flowing faster than a normal walking pace/greater than 20cm in depth/some white water apparent |
| Cascade | - several rapid declines in water height over water stretch |
| Run | - flowing faster than a normal walking pace/greater than 20cm in depth/no white water apparent |
| Riffle | - slow to rapid flow/less than 20cm in depth/some water disturbance by substrate |
| Glide | - flowing slower than a normal walking pace/less than 20cm in depth/little or no water disturbance by substrate |
| Pool | - water flowing slower than a normal walking pace(or not at all)/greater than 20cm in depth |
| Backwater | - water not flowing laterally within river, or not flowing at all/often circular motion apparent |

***Predominant instream habitat (circle one)***

**Rock** **Woody debris** **Organic debris** **Bank overhang** **Vegetation overhang** **Aquatic vegetation**

***Disturbance rating (circle one)***

**Very Low** **Low** **Moderate** **High** **Very high** **Extreme**

***Disturbance categories***

| | |
|---|---|
| Very Low - | riparian vegetation is virtually undisturbed |
| Low - | any disturbance is minor |
| Moderate - | agricultural land and/or cleared on one side of the stream only and vegetation on the other is virtually undisturbed |
| High - | agricultural land and/or cleared on one side of the stream only and vegetation on the other is clearly disturbed |
| Very High - | Agriculture and/or cleared on both sides of the stream |
| Extreme - | Agriculture and/or cleared on both sides of the stream, with virtually all vegetation consisting of exotic species |

**Comments**

**Appendix 3.8C Catch summary by site.**

| Site | Species | Count | Mean length | Min length | Max length | Mean weight | Min weight | Max weight |
|---|---|---|---|---|---|---|---|---|
| 51 | *Retropinna semoni* | 1 | 57 | 57 | 57 | 2 | 1.5 | 1.5 |
| | *Gobiomorphus coxii* | 1 | 80 | 80 | 80 | 6 | 5.5 | 5.5 |
| | *Anguilla reinhardtii* | 14 | 363 | 115 | 640 | 169 | 1.5 | 695 |
| | *Anguilla australis* | 4 | 339 | 125 | 900 | 490 | 4 | 1943 |
| | *Pseudaphritis urvillii* | 1 | 210 | 210 | 210 | 90 | 90 | 90 |
| 52 | *Anguilla reinhardtii* | 9 | 360 | 190 | 530 | 186 | 16 | 432 |
| | *Anguilla australis* | 2 | 265 | 130 | 400 | 63 | 5 | 120 |
| | *Pseudaphritis urvillii* | 3 | 129 | 112 | 148 | 21 | 10 | 33 |
| 53 | *Retropinna semoni* | 1 | | | | | | |
| | *Anguilla reinhardtii* | 11 | 392 | 110 | 590 | 266 | 5 | 760 |
| | *Pseudaphritis urvillii* | 5 | 160 | 129 | 190 | 37 | 21 | 56 |
| 54 | *Galaxias brevipinnis* | 3 | 117 | 110 | 125 | 14 | 13 | 17 |
| | *Anguilla australis* | 1 | 440 | 440 | 440 | 153 | 153 | 153 |
| 55 | *Retropinna semoni* | 4 | 47 | 42 | 55 | 1 | 1 | 1 |
| | *Anguilla reinhardtii* | 2 | 375 | 300 | 450 | 183 | 90 | 275 |
| 56 | *Retropinna semoni* | 2 | 54 | 47 | 60 | 2 | 2 | 2 |
| | *Galaxias brevipinnis* | 1 | 95 | 95 | 95 | 9 | 9 | 9 |
| | *Salmo trutta* | 19 | 166 | 100 | 307 | 77 | 11 | 290 |
| | *Anguilla reinhardtii* | 4 | 513 | 360 | 750 | 523 | 113 | 1150 |
| | *Gadopsis marmoratus* | 2 | 331 | 315 | 346 | 317 | 273 | 360 |
| | *Anguilla australis* | 5 | 345 | 180 | 520 | 92 | 8.5 | 288 |
| 57 | *Salmo trutta* | 78 | 139 | 74 | 260 | 46 | 4 | 189 |
| | *Anguilla australis* | 6 | 347 | 105 | 810 | 315 | 3 | 1332 |
| 58 | *Galaxias brevipinnis* | 1 | 96 | 96 | 96 | 8 | 8 | 8 |
| | *Salmo trutta* | 7 | 109 | 86 | 138 | 17 | 9 | 30 |
| 59 | *Salmo trutta* | 2 | 155 | 80 | 229 | 67 | 7 | 127 |
| 60 | *Salmo trutta* | 18 | 185 | 114 | 315 | 88 | 20 | 299 |
| | *Anguilla australis* | 3 | 483 | 290 | 650 | 319 | 40 | 612 |
| 61 | *Salmo trutta* | 14 | 187 | 120 | 268 | 92 | 16 | 183 |
| | *Gadopsis marmoratus* | 1 | 293 | 293 | 293 | 197 | 197 | 197 |
| | *Anguilla australis* | 2 | 460 | 460 | 460 | 209 | 195 | 222 |
| 62 | *Salmo trutta* | 75 | 182 | 66 | 342 | 82 | 4 | 353 |
| | *Eustacus bidawalus* | 1 | 10 | 10 | 10 | 3 | 3 | 3 |
| | *Oncorhynchus mykiss* | 14 | 163 | 118 | 226 | 61 | 22 | 142 |
| 64 | *Salmo trutta* | 17 | 235 | 105 | 300 | 179 | 14 | 318 |
| | *Anguilla australis* | 16 | 539 | 220 | 850 | 533 | 24 | 1649 |
| 77 | *Gobiomorphus coxii* | 2 | 97 | 95 | 98 | 8 | 7.5 | 7.5 |
| | *Anguilla reinhardtii* | 27 | 357 | 210 | 580 | 152 | 14 | 576 |
| | *Australatya striolata* | 1 | | | | | | |
| | *Anguilla australis* | 3 | 302 | 265 | 370 | 55 | 33 | 95 |
| | *Pseudaphritis urvillii* | 8 | 119 | 90 | 140 | 15 | 8 | 28 |

## Appendix 3.8D Summary of species captured by site.

| | Site number | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 10 | 12 | 13 | 15 | 16 | 18 | 19 | 22 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 38 | 50 | 51 | 52 | 53 | 54 | 55 | 56 | 57 | 58 | 59 | 60 | 61 | 62 | 64 | 77 | Total |
| AUSTRALIAN SMELT | | | | | | | | | | | 1 | | | | | | | | | | | 3 | 1 | | 1 | | 4 | 2 | | | | | | | | | **12** |
| BROADFIN GALAXIAS | | 1 | | | 11 | | 8 | 5 | | | | | | | | | | | | | | | | | | 3 | | 1 | | 1 | | | | | | | **30** |
| BROWN TROUT | | 2 | | 24 | | | | | | | | | | | | | 4 | 8 | | | | | | | | | | 19 | 78 | 7 | 2 | 18 | 14 | 75 | 17 | | **268** |
| COMMON GALAXIAS | 17 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | **17** |
| COXS GUDGEON | | | | | | | | | | | | | | | | | | | | | | | 1 | | | | | | | | | | | | | 2 | **3** |
| EAST GIPPS SPINY CRA | | | | | 3 | | | | | | | | | | | | 1 | | | | | | | | | | | | | | | | | 1 | | | **5** |
| GOLDFISH | | | | | | | | | | | | | | | | | | | | | | 2 | | | | | | | | | | | | | | | **2** |
| LONGFIN EEL | 6 | | 13 | | | 4 | 13 | 11 | | | 4 | | | | | | | | | | | 3 | 14 | 9 | 11 | | 2 | 4 | | | | | | | | 27 | **121** |
| MOUNTAIN GALAXIAS | | | | | 25 | 3 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | **28** |
| RAINBOW TROUT | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 14 | | | **14** |
| RIFFLE SHRIMP | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 | **1** |
| RIVER BLACKFISH | | | | | | | 2 | | | | | | | | | | | | | | | | | | | | | 2 | | | | | 1 | | | | **5** |
| SHORTFIN EEL | 5 | 11 | 5 | 6 | 1 | 5 | 7 | 10 | | | | | | | | | | | | | 6 | | 4 | 2 | | 1 | | 5 | 6 | | | 3 | 2 | | 16 | 3 | **98** |
| TUPONG | 13 | | | | | | | | | | 1 | | | | | | | | | | | 2 | 1 | 3 | 5 | | | | | | | | | | | 8 | **33** |
| Total | **41** | **14** | **18** | **30** | **40** | **12** | **30** | **26** | **0** | **0** | **6** | **0** | **0** | **0** | **0** | **0** | **5** | **8** | **0** | **0** | **6** | **10** | **21** | **14** | **17** | **4** | **6** | **33** | **84** | **8** | **2** | **21** | **17** | **90** | **33** | **41** | **637** |

## Appendix 3.8E Habitat data.

| Site | Water | Distance electrofished (m) | Season | Year | Predominant substrate | Land use category | Stream flow type | Max. width (m) | Max. depth (m) | Ave. depth (m) | Predominant instream habitat | Disturbance rating | Conduct. | Temp. (C) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **10** | *Loongelaat Creek* | *140* | winter | 2003 | boulder | forest | pool | 5 | 1.5 | 0.5 | rock | low | | |
| | | | summer | 2004 | boulder | forest | pool | 6 | 1.5 | 0.4 | rock | very low | 48 | 19.2 |
| | | | winter | 2004 | boulder | forest | pool | 5 | 1.5 | 0.5 | rock | very low | | |
| **12** | *Raymond Creek* | *120* | winter | 2003 | gravel | forest | pool | 5 | 1.5 | 1 | woody debris | low | | |
| | | | summer | 2004 | sand | forest | pool | 7 | 1.5 | 0.5 | woody debris | very low | 288 | 18.4 |
| | | | winter | 2004 | pebble | forest | pool | 7 | 1.5 | 0.5 | woody debris | very low | | |
| **13** | *Rodger River* | *150* | winter | 2003 | boulder | forest | riffle | 25 | 1.75 | 0.75 | rock | low | | |
| | | | summer | 2004 | pebble | forest | riffle | 15 | 1.5 | 1 | rock | very low | 86 | 24.3 |
| | | | winter | 2004 | cobble | forest | cascade | 20 | 1.5 | 0.5 | woody debris | very low | | |
| **15** | *Rodger River* | *140* | winter | 2003 | boulder | forest | riffle | 6 | 1 | 0.4 | rock | low | | |
| | | | summer | 2004 | cobble | forest | riffle | 7 | 0.7 | 0.4 | woody debris | very low | 69 | 21.4 |
| | | | winter | 2004 | boulder | forest | cascade | 8 | 1.2 | 0.4 | woody debris | very low | | |
| **16** | *Rodger River* | *70* | winter | 2003 | cobble | forest | riffle | 4 | 0.6 | 0.2 | woody debris | low | | |
| | | | summer | 2004 | silt/clay | forest | riffle | 5 | 0.5 | 0.3 | woody debris | very low | 47 | 15.5 |
| | | | winter | 2004 | gravel | forest | glide | 5 | 0.9 | 0.4 | woody debris | very low | | |
| **18** | *Serpentine Creek* | *150* | winter | 2003 | cobble | forest | riffle | 5 | 1.2 | 0.75 | rock | low | | |
| | | | summer | 2004 | boulder | forest | riffle | 7 | 0.8 | 0.4 | rock | very low | 118 | 18.8 |
| | | | winter | 2004 | cobble | forest | glide | 6 | 1 | 0.5 | rock | very low | | |
| **19** | *Yalmy River* | *160* | winter | 2003 | cobble | forest | riffle | 5 | 0.4 | 0.2 | rock | low | | |
| | | | summer | 2004 | cobble | forest | riffle | 10 | 0.6 | 0.25 | rock | very low | 9 | 21.4 |
| | | | winter | 2004 | cobble | forest | glide | 8 | 1 | 0.4 | rock | very low | | |
| **22** | *Mountain Creek* | *150* | winter | 2003 | boulder | burnt | riffle | 5 | 0.75 | 0.3 | rock | moderate | | |
| | | | summer | 2004 | cobble | burnt | riffle | 8 | 0.8 | 0.3 | woody debris | low | 96 | 24.3 |
| **24** | *Boundary Creek* | *160* | winter | 2003 | boulder | burnt | cascade | 3 | 0.4 | 0.1 | rock | very high | 100 | 8.1 |
| | | | summer | 2004 | boulder | burnt | cascade | 2 | 0.3 | 0.1 | rock | very high | 4 | 19.2 |
| | | | winter | 2004 | sand | burnt | cascade | 2 | 0.2 | 0.1 | rock | extreme | | |
| **25** | *Seldom Seen Creek* | *130* | winter | 2003 | cobble | burnt | cascade | 1 | 0.3 | 0.1 | rock | very high | 90 | 6.7 |
| | | | summer | 2004 | cobble | burnt | cascade | 2 | 0.4 | 0.15 | rock | very high | 35 | 19.9 |
| | | | winter | 2004 | sand | burnt | cascade | 3 | 0.5 | 0.1 | aquatic vegetation | very high | 28 | 5.7 |
| **26** | *Little River* | *120* | winter | 2003 | boulder | forest | cascade | 6 | 1.5 | 0.7 | rock | low | 80 | 8.5 |
| | | | summer | 2004 | boulder | forest | glide | 6 | 1.5 | 0.4 | rock | low | 94 | 20.9 |
| | | | winter | 2004 | boulder | forest | glide | 8 | 1 | 0.4 | woody debris | very low | 63 | 6.9 |
| **27** | *Little River* | *160* | winter | 2003 | boulder | forest | cascade | 10 | 1.5 | 0.7 | rock | high | 50 | 6.2 |
| | | | summer | 2004 | boulder | burnt | cascade | 5 | 0.5 | 0.3 | rock | very high | 69 | 19.2 |
| | | | winter | 2004 | boulder | burnt | run | 8 | 1 | 0.3 | rock | low | 44 | 7.1 |
| **28** | *Little River* | *160* | winter | 2003 | sand | cleared | run | 12 | 1 | 0.3 | aquatic vegetation | high | 50 | 8.2 |
| | | | summer | 2004 | cobble | forest | riffle | 8 | 0.5 | 0.3 | aquatic vegetation | high | 67 | 24.9 |
| | | | winter | 2004 | pebble | cleared | riffle | 9 | 0.4 | 0.2 | aquatic vegetation | extreme | 34 | 7.9 |
| **29** | *Little River* | *150* | winter | 2003 | sand | forest | run | 3 | 1 | 0.4 | woody debris | very low | 40 | 6.2 |
| | | | summer | 2004 | boulder | burnt | cascade | 3 | 1 | 0.3 | woody debris | high | 47 | 18.6 |
| | | | winter | 2004 | cobble | forest | cascade | 4 | 0.3 | 0.15 | vegetation overhang | very low | 41 | 6.5 |
| **30** | *Goodwin Creek* | *30* | winter | 2003 | cobble | burnt | glide | 5 | 1 | 0.4 | woody debris | high | 120 | 8.4 |
| | | | summer | 2004 | boulder | burnt | pool | 3 | 0.3 | 0.1 | rock | high | 175 | 16.8 |
| | | | winter | 2004 | boulder | partly cleared | pool | 4 | 0.2 | 0.1 | rock | moderate | 96 | 10.4 |
| **31** | *Wulgulmerang Creek* | *140* | winter | 2003 | sand | burnt | glide | 5 | 1 | 0.4 | woody debris | high | 140 | 7.4 |
| | | | summer | 2004 | sand | burnt | pool | 3 | 1 | 0.4 | aquatic vegetation | very high | 146 | 19.7 |
| | | | winter | 2004 | gravel | partly cleared | pool | 4 | 1 | 0.3 | aquatic vegetation | moderate | 89 | 7.4 |
| **32** | *Red Soil Creek* | *150* | winter | 2003 | sand | burnt | glide | 2 | 0.4 | 0.2 | aquatic vegetation | high | 690 | 9.6 |
| | | | summer | 2004 | boulder | burnt | pool | 1 | 0.3 | 0.1 | vegetation overhang | high | 513 | 23.6 |
| | | | winter | 2004 | sand | burnt | pool | 2 | 0.3 | 0.1 | aquatic vegetation | extreme | 363 | 10.1 |

# Chapter 4 Australian bass literature review


### Daniel Stoessel (Fisheries Research Branch, Fisheries Victoria)


## 4.1 Introduction

Australian bass and estuary perch are closely related percichthyids that are similar in appearance and have overlapping ranges in distribution (Williams 1970, Llewellyn and MacDonald 1980, Jerry *et al.* 1999). The similarity in morphology between the two species caused confusion in identification on a national scale for many years before taxonomic discreteness was confirmed in the 1970s (Jerry *et al.* 1999). Williams (1970) reported discriminating features that could distinguish 99.6% of individuals and since then it has been generally accepted that the two species can be readily identified by assessing key factors in their appearance. However, in the Snowy River some Australian bass have proven difficult to identify based on how they look. Hybridisation between Australian bass and estuary perch can occur and has been confirmed in some Victorian waters including the Snowy River (Jerry *et al.* 1999). The presence of hybrids only adds to the identification confusion and the identification of Australian bass should not be solely based on morphological attributes as this could lead to incorrect classification (Jerry *et al.* 1999).

For Australian bass in particular, spawning is known to be highly variable with typical populations having strong interannual variations in year class strength (Harris 1986). The adult fish live in freshwater often a considerable distance upstream from estuaries. They migrate down to the estuary to spawn roughly from July to November. Spawning takes place in the estuary and the larvae spend some time in this habitat before moving upstream into freshwater. The adult fish also move back upstream after spawning.

There are known to be certain environmental cues (especially flow related) associated with the various migrations and with spawning, and there are also likely to be barriers to upstream migration especially of juvenile fish.

## 4.2 Distribution

The Australian bass is a catadromous percichthyid, native to south-eastern Australia. It is considered potentially threatened in Victoria (Koehn and Morison 1990) and rare in the Snowy River system (Stewardson *et al*. 1997). The species inhabits coastal waters from Fraser Island in Queensland's south, to tributaries of Gippsland Lakes in Victoria. The species is known to travel extensive distances upstream to altitudes of about 600 m (McDowall 1996); its upstream distribution is, however, limited by the existence of waterfalls of any considerable size (Williams 1970).

The Australian bass is catadromous and is thought to prefer deeper waters with some hydraulic cover. The species is often found in association with submerged objects such as trees, and rocks (Sanders 1973). The species is highly prized by anglers and spends most of its life in the freshwater reaches of the rivers in its range, before migrating to estuarine regions to spawn. The young in turn use the estuary as a nursery habitat until migrating upstream before the onset of winter the following year (Stewardson *et al.* 1997).

## 4.3 Species decline

It is suspected that illegal fishing activities (Marshall 1979) and the construction of artificial barriers, river regulation and mitigation works, removal of snags and shoreline vegetation, water pollution and acidification of streams and rivers have had dire consequences for many Australian bass populations. Such activities create not only physical obstructions but also subtle barriers in the form of lowered and stratified temperature regimes, oxygen levels and liberated hydrogen sulphide (Harris 1984).

Of additional concern is that basic control over construction of artificial barriers in Australian streams is fragmented and only limited records are kept. As a result, there is a lack of information on their occurrence and features (Harris 1984). Earlier efforts aimed at rectifying these problems through the instillation of fishways were often counter-productive. These constructions have generally imitated overseas structures which are designed exclusively to aid upstream adult salmonid migration (Mallen-Cooper 1992), and therefore make no allowance for the migration of juveniles of a species such as Australian bass.

Preliminary investigations on habitat availability for migratory species in south-eastern Australia has suggested that 32 to 49% of the habitat that is potentially useable has been degraded or nullified by stream impoundments (Harris 1984, Harris and Rowland 1996).

## 4.4 Population structure

### 4.4.1 Genetic variation

Jerry (1997) found that there existed subtle genetic differences in the nine wild riverine populations of Australian bass he studied (i.e. from the Noosa River in Queensland to the Mitchell River in Victoria). His results indicated that Australian bass do not belong to a large homogeneous population, but rather conform to an isolation by distance pattern of population structure, with genetic heterogeneity increasing with distance between localities (Jerry 1997).

The genetic mixing that does occur between systems is thought to be a consequence of the migration of mature adult fish after flood events, and not of larval or juvenile Australian bass migration (Williams 1970, Harris 1986). Sanders (1973) supported this by stating that records existed of adults of the species being taken by trawlers in marine waters adjacent to estuaries.

### 4.4.2 Morphological variation

Jerry and Cairns (1998) found considerable morphometric variation between Australian bass females and males for many characteristics both within and between geographically distinct river drainages. Females were on average larger than males within a population and a comparison of males or females from any two different sampling localities revealed significant heterogeneity in a clinal pattern. As with those studies undertaken on the genetics of the species, these specific morphological traits are thought to indicate restrictive inter-populational movement, and that each sample locale constitutes a separate stock.

### 4.4.3 Reproduction

The presence of small Australian bass in apparently isolated habitats has led to the supposition that the species breeds in freshwater lagoons streams and ponds (Sanders 1973, Hooker 1969). However, the species is now known to be catadromous, spawning exclusively in a saline environment in the wild.

Commercially, Australian bass are produced by a combination of intensive and extensive culture methods in both fresh and brackish water through a process of hormone injection (generally human chorionic gonadotropin) at the base of the pelvic fin (Battaglene and Talbot 1993, Battaglene *et al.* 1989a).

Transfer of larvae to ponds usually involves a drop in salinity from 30 to 15 ppt or lower, and occurs when the larvae are between 10 and 21 days old (Battaglene and Talbot 1993).

Several abnormalities have appeared in the larvae of artificially breed individuals, including fainting or shock response, lack of functional swim bladders and deformations of the spine (scoliosis and lordosis), jaw or eyes. The exact cause of these malformations in the past has proven to be illusive, although van der Wal (1983) theorised that it may be temperature related, while Battaglene *et al.* (1989a) proposed that malformations may be related and/or exacerbated by an inadequate supply of high quality sea and fresh water or dietary deficiencies.

Problems associated with inflation of the swimbladder (which are now thought to be a direct factor causing malformations of individuals) have been reduced primarily through the use of very low light intensities (i.e.<1 lux), and additionally by controlling environmental factors such as salinty (range of 15-35 pp), aeration (i.e.<50 mL/min), withholding feed (Battaglene and Talbot 1993), and by the control of temperature ranges between 18 to 20 °C (Batteglene and Talbot 1990) in the early rearing phase, i.e. 1-12 days (Battaglene *et al.* 1989b).

### 4.4.4 Reproduction research of wild stocks

Details of the reproduction of Australian bass in the wild is extremely limited, and has been hindered in the past due to the confusion related to the identification of Australian bass and estuary perch as separate species.

Sexual segregation is the norm in populations of Australian bass in the non-breeding season, with most males remaining in tidal waters, while females travel further upstream (McDowall 1996).

Recruitment and year-class strength is theorised to be positively correlated to the level of flooding in the spawning months (Harris 1985, Stewardson *et al.* 1997). Preferred spawning habitats of the species are similar to estuary perch, i.e. reefs, sandbars and submerged aquatic plant beds (McCarraher 1986, McCarraher and McKenzie 1986). Individual mean fecundity has been found to range between 49,000 eggs in a fish of 270 mm LCF, to 1,429,000 in a fish of 446 mm (Harris 1986).

In general, Australian bass males mature at approximately 180 mm and 2-4 years of age (McDowall 1996), and females between 200 mm and 280 mm and 5-6 years of age (Llewellyn and MacDonald 1980, McDowall 1996). Spawning may occur repeatedly in a season, usually after flood events (McDowall 1996) between June and early December (Harris 1986, McCarraher 1986) at temperatures of 11 to 16 °C (Harris 1986, van der Wal 1983) and salinities of 8 to 22 g/kg (Harris 1986, McCarraher 1986).

The annual timing of maturation and migration of adults tends to differ over the range of the species. Generally, however, gonadal maturation commences in autumn, i.e. February to May (Harris 1986) and the onset of migration from mid June (van der Wal 1983).

The return of the adults to freshwater (i.e. subsequent to spawning) extends over several months from mid-August to mid-October, while the young may be found in freshwater from the end of October when they are 12 to 15 mm long (van der Wal 1983).

### 4.4.5 Hybridisation

A possible hybrid of the species was first reported by Williams (1970) at the northern geographical limit of estuary perch in the Richmond River, on the far north coast of New South Wales. The supposition that the species can hybridise was confirmed by Jerry *et al.* (1999) who found that Australian bass can interspecifically hybridise with estuary perch and that the maternal parent of these hybrids is always found to be Australian bass. Williams (1970) suggested that the maternal dominance of Australian bass is a consequence of estuary perch males interbreeding with Australian bass females before the males of the Australian bass have matured (i.e. annually).

Within Victoria, spawning aggregation overlap is also possibly occurring as a consequence of the states' rivers being comparatively short, and having lower total flow levels than similar rivers in New South Wales or Queensland, thereby concentrating salinity gradients over a shorter distance and increasing the likelihood of spawning aggregation overlap (Williams 1970).

### 4.4.6 Feeding and diet

Australian bass complete yolksac absorption at 19 to 21 °C and start feeding 3-7 days after hatching (Battaglene and Talbot 1990). Larvae of the species feed on zooplankton and chironomid larvae, while older fish are generalised carnivores, eating a wide range of fish, crustaceans (i.e. shrimp and prawns) and other invertebrates (McDowall 1996, McCarraher 1986). Due to the species being a euryphagic carnivore its diet often overlaps with several other carnivorous freshwater vertebrates, the composition of which is significantly effected by season and habitat type (Harris 1985).

### 4.4.7 Growth

Preliminary growth data for Australian bass in Victorian riverine water, approximates to 1 year olds being slightly over 200 mm, 4 year olds ~300 mm, 6 year olds ~350 mm, 8 year olds ~400 mm, up to the oldest fish of 14 years being slightly over 500 mm in length (McCarraher 1986). In general, however, growth of Australian bass tends to be variable, and is mainly dependant on both the habitat type utilised (McDowall 1996) and the sex of the individual, with females usually being larger than males of a similar age in any population (Harris 1987, Jerry and Cairns 1998). Historically, the species has been recorded to 600 mm in length and 3.8 kg in weight, and 22+ years of age (Harris and Rowland 1996, McDowall 1996).

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# Chapter 5 Growth of Australian bass in the Snowy River.

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## 5.1 Introduction

The Snowy River was a highly regarded and productive recreational fishery for Australian bass, but in recent years the fishery has declined from former levels. Whilst in angling terms, good-sized Australian bass are still taken in the river both in the middle reaches and around Orbost, it is considered by recreational anglers that the number of fish caught has declined considerably.

To try to determine the reasons for this decline, studies of the age/growth relationships for Australian bass in the Snowy River and nearby streams to assess whether there are any variations in recruitment patterns in these streams, were proposed.

It was determined very early in the study that the lack of a clear distinction between Australian bass and estuary perch was a complicating factor. In addition, the very low Australian bass numbers and difficulty in collecting significant numbers of fish, resulted in early redirection of priorities.

## 5.2 Aims and Objectives

The aim of the study was to compare the population structure of Australian bass in the Snowy River with the closely linked Brodribb River, and in a nearby reference catchment, the Bemm River. Due to the presence of Australian bass/estuary perch hybrids, it was imperative that some sort of test be performed to be confident that any analysis was undertaken on confirmed Australian bass. However, tests were not readily available and had to be developed for this project.

The aims of the project were to:

- Develop a test for identifying between Australian bass, estuary perch and their hybrids.
- Report on the hybridisation levels between Australian bass and estuary perch in the Snowy River.
- Determine the age/growth relationships for Australian bass in the Snowy River and nearby streams to assess whether there are any variations in recruitment patterns in these streams.
- Assess the need for supplementary stocking of Australian bass in the Snowy River.

The objectives were to collect Australian bass from the Snowy, Brodribb and Bemm Rivers to:

- Establish benchmark population profiles in each river if possible.
- Construct a reliable age/length key for the Snowy River.
- Identify differences between the populations.
- Identify any dominant or missing year classes.
- Examine existing flow and other environmental data to determine whether there are any correlations with year class strength in any of these systems.

## 5.3 Project Design and Methods

### 5.3.1 Population structure

Samples of putative Australian bass were collected by boat electrofishing, mesh netting and angling between October 2002 and December 2003. Recreational anglers also assisted in the collection of samples. Electrofishing was used in the Snowy and Brodribb Rivers only as the boat could not be launched in the Bemm River. This method involved electrofishing along the stream margins targeting areas of cover such as over-hanging willows and sunken tree snags. Mesh nets (from 32 mm to 112 mm stretched mesh) were used primarily in the Brodribb and Bemm Rivers. Nets were set in the late afternoon and monitored and regularly checked until after dark. Angling was undertaken in all rivers. The angling sessions usually began in the evening just prior to sunset and continued into the night. Lures were the primary angling method used. Sampling trips were usually undertaken on a monthly basis.

Sampling was undertaken from the lower reaches of the freshwater section of the Snowy River around Orbost and as far upstream as Jacksons Crossing. In the Brodribb River sampling was restricted to the water supply pumping station and downstream of the Princes Highway to Lake Curlip. In the Bemm River access was restricted and was only available at three sites in the lower freshwater sections of the stream.

The intention was to sample otoliths from the entire size range of fish present in the population to construct an age length key. Due to the low numbers of fish collected, otolith collection was restricted and targeted to cover the size range of fish encountered. Sagittal otoliths from the samples were sent to the Central Aging Facility (Victorian Department of Primary Industries) for ageing.

The issue of hybridisation was addressed by taking fin clips from a range of fish from the Snowy, Brodribb and Bemm Rivers. Fin clips (about 1 $cm^2$) were taken from the tail of captured putative Australian bass and stored in ethanol (90%). The putative Australian bass samples were compared to reference samples of Australian bass from the Logan River (Queensland) and estuary perch samples from the Hopkins River (Victoria) (Chapter 6). The DNA analysis was also capable of identifying hybrids between the two species.

Growth of Australian bass and hybrids was analysed by constructing growth curves from positively identified samples and comparing them using Kimura's likelihood test.

### 5.3.2 Recruitment and flows

Flow data for the Snowy River from 1974 to 2002 was obtained from Theiss Environmental. The years where there is evidence of Australian bass only, hybrids only and both Australian bass and hybrids being recruited were compared to the average daily flows for each month. The years were designated as high or low flow years depending on whether the average daily flows for each month passed 5000 Ml. This was a nominal value only and was used as it roughly split the data in half. Any year where the daily average flow was over 5000 Ml (in any month) was assessed as a high flow year. Harris (1986) reported Australian bass involution of eggs if water flows didn't rise before September, so a comparison of the flows for just the four months prior to September with Australian bass and or hybrid recruitment years was also made. The analysis involved the construction of a Bray-Curtiss similarity matrix and subsequent cluster analysis and multi-dimensional scaling ordination to investigate any commonalities of the flow events and spawning years.

## 5.4 Results

### 5.4.1 Australian bass

Australian bass are distributed widely in the Snowy River but are not locally abundant. Catches were generally low and consisted of only a few individuals per sampling trip.

Overall, a total of 109 putatively identified Australian bass from the Snowy, Brodribb and Bemm Rivers were submitted for DNA analysis. Of these fish, 49 were confirmed as Australian bass, 15 as estuary perch and 45 (41%) were identified as hybrids. Not all the hybrids were first cross and there was evidence that backcrossing had occurred to at least the 2$^{nd}$ generation level.

The majority of the hybrids detected (n=31) were 1$^{st}$ generation, but 10 of the hybrids were 2$^{nd}$ generation back crosses (three could not be distinguished between 1$^{st}$ and 2$^{nd}$ generation hybrids). Of these back crossed fish, 10 were 2$^{nd}$ generation Australian bass, one was 2$^{nd}$ generation estuary perch, two were either 1$^{st}$ or 2$^{nd}$ generation estuary perch and one was either 1$^{st}$ or 2$^{nd}$ generation Australian bass (Table 5.1).

The incidence of hybridisation and introgression was confirmed for each river. Of the 80 fin clip samples submitted for DNA analysis from the Snowy River, 45% were found to be hybrids. In the Brodribb and Bemm Rivers, the rate of hybrids was 36% and 28%, respectively. These levels of hybridisation were much higher than anticipated. Because there was some delay between sample collection and completion of the genetic work, the consequence was severely depleted samples from which to conduct further analyses. The sample of positively confirmed Australian bass was restricted to 44 from the Snowy River, 3 from the Bemm River and only 2 from the Brodribb River.

Thirteen of the positively identified Snowy River Australian bass were aged by analysis of sagittal otoliths. The oldest Australian bass was estimated at 17 years and the youngest Australian bass was estimated at 3 years of age. Age frequencies of the positively identified Australian bass are presented in Figure 5.1.

This limited data shows that Australian bass recruitment in the Snowy River has occurred almost annually, although there are periods when no recruitment was detected. It appears that hybridisation may only occur periodically.

The age-length relationship for Australian bass and hybrids is presented in Figure 5.2. Hybrids between various species are known to sometimes exhibit accelerated growth. The growth of Australian bass and hybrids was tested with Kimura's likelihood test. There was no statistical difference between the Australian bass and hybrid growth curves (Pr=.9005). The Von Bertalannfy growth curve estimates for all Australian bass (i.e. not discriminated by sex) were $L\infty$ =379.9, K = 0.5021 and t0 = 0.6346).

### 5.4.2 Comparison of Australian bass populations between rivers

Australian bass were collected from all study streams, but in generally low numbers from the

Bemm and Brodribb Rivers. Only three of the 18 Bemm River samples and two of the 11 fish submitted from the Brodribb River were confirmed as Australian bass. The low sample numbers prevented meaningful comparisons of population attributes between the rivers. Hybridisation was confirmed in each of these rivers as was back crossing in the second generation.

### 5.4.3 River flow

Australian bass recruitment was detected for years 2000, 1998, 1997, 1996, 1995, 1994, 1991, 1990, 1989 and 1986 (Figure 5.1). Hybridisation was detected from years 2002, 2000, 1998, 1997, 1990, 1986, 1980 and 1978 (Figure 5.2). Multi-variate analyses of the incidence of Australian bass and hybrid breeding found no discernible patterns that indicated Australian bass breeding was associated with high flow years (Figure 5.3).

Similar, analysis of the flows of the preceding four months did not indicate any relationship between high flows prior to September and Australian bass recruitment.

## 5.5 Discussion

### 5.5.1 Australian bass age, growth and recruitment

The age and growth of Australian bass in the Snowy River differed to that observed by Harris (1987) from New South Wales streams. The length at age of Australian bass in the Snowy River was larger than the stream samples reported by Harris (1987). However, as Australian bass growth is dependent on habitat type (Harris 1987), some variation is to be expected between rivers. It may be that the lower numbers of Australian bass in the Snowy River have resulted in higher growth rates.

The maximum age recorded from the Snowy River was 25 years. That was similar to the maximum of other aged Australian bass from different populations (Harris 1987). The ageing confirms that Australian bass are a long-lived fish. There was no significant difference in the growth of Australian bass and their hybrids in the Snowy River so the increased growth rates seen in many hybrids is not evident in hybrids of Australian bass and estuary perch.

In the Snowy River, Australian bass (or Australian bass/estuary perch hybrids) were generally found to be uncommon within the river reaches upstream of Orbost. However, as some fish were captured from most of the sites where sampling was attempted, it was concluded that the population of Australian bass in the Snowy River is relatively low in numbers but widespread throughout the river. There are adult fish in the system but recruitment levels in the last few years are low. If recruitment had occurred to any degree, more smaller and younger fish would have been expected.

Harris (1986) noted that females of the species required a flood to complete ovarian maturation and to move downstream to the spawning areas and that Australian bass recruitment was high after floods. The present study found no indication from the Snowy River that the high flow years had resulted in better recruitment. Victoria was in drought during the present study and the environmental conditions may not be conducive to Australian bass breeding and/or recruitment. Harris (1986) reported no Australian bass breeding during droughts so drought conditions may have been inhibiting spawning and recruitment in the Snowy River over the last few years. If the cues initiating spawning do not occur with frequency, then recruitment could be limited.

It is possible that the cues required to send the fish downstream to spawn are not occurring regularly in the Snowy River. However, there have been some relatively high floods in the Snowy River but recruitment still hasn't occurred. Some other factors limiting Australian bass recruitment may also be operating. For example, the sand slug in the Snowy River upstream of Orbost has been suggested as a possible barrier to fish movement as it may impact on migration of adult and juvenile Australian bass as they move between the estuary and freshwater. The verification of spawning in some years indicates that the sand is not an impediment to movement of all adults and juvenile Australian bass in all years.

### 5.5.2 Hybridisation and its impacts

Stocking with hatchery produced Australian bass has been suggested as an option to increase Australian bass stocks in the Snowy River. Such an undertaking requires detailed consideration given the presence of hybrids and the identification issues. The DNA markers developed for this study can be used to identify future broodstock and ensure introgression is not compounded.

The detection of introgression in the Snowy River and Bemm River catchments is an important finding and has several implications:

- For the long-term genetic integrity and conservation of the Australian bass stocks in the Snowy River (and more widely).
- For aquaculture and stocking programs using Snowy River Australian bass broodstock.
- For recreational anglers and fisheries regulations.

Hybridisation is a naturally occurring process in many fish populations and it is generally considered that the presence of F1 hybrids should not affect the genetic integrity of either parent stock, as long as the hybrids are sterile (O'Brien and Mayr 1991, Jerry *et al.* 1999). The presence of back crossing in the Snowy and Bemm River Australian bass implies that at least some of the F1 hybrids are not sterile. It is not known if there has always been a naturally occurring level of back crossing in the Gippsland streams or if there has been some more recent process that has occurred that has triggered an increase in the incidence of back-crossing. Jerry *et al.* (1999) considered back crossing may be rare between Australian bass and estuary perch as they found no evidence of introgression using allozymes and mitochondrial DNA from over 400 specimens from across their range but they could not entirely refute its existence.

Hybridisation can be a powerful process impacting on populations and has even been implicated in fish extinctions (Miller *et al.* 1989, Jerry *et al.* 1999). Whilst Jerry *et al.* (1999) considered that hybridisation was a rare event, the present study results would indicate that it is quite common in the Snowy, Brodribb and Bemm Rivers. Based on the limited samples available from the present study, it appears that hybridisation may occur periodically in the Snowy River.

Hybridisation in fish populations is relatively common world wide (Hubbs 1955) and the incidence increases where there are two closely related sympatric species. The incidence of hybridisation is favoured by a number of factors (see Hubbs 1955) but Jerry *et al.* (1999) suggested crowded spawning aggregations, unequal numbers of parent fish and a restricted spawning area were likely to contribute to Australian bass/estuary perch hybridisation in Victorian streams. Gippsland is at the end of the geographical range of Australian bass and there are significant estuary perch populations in the estuaries (McCarraher 1986). The low levels of Australian bass may be a factor in the levels of hybridisation. It appears that some years are more conducive to hybridisation between these two species than others. The oldest hybrid aged was twenty-five years (from 1979) so the process has been occurring for some time. Although it is a naturally occurring function, the presence of interspecific breeding indicates an apparent breakdown of the isolating mechanisms that separate the two species.

It is possible that introgression is a naturally occurring process between Australian bass and estuary perch and has always occurred at some level. The present study detected the incidence of introgression in two separate catchments and it is possible that introgression is present in at least the rivers where hybridisation has been detected. The Snowy River is a highly disturbed river in regards to flows and catchment landuse. An increase in hybridisation and backcrossing may be expected in such a disturbed system (Hubbs 1955). However, the Bemm River is a relatively pristine river with no dams, natural flow regimes and little agriculture in the catchment, yet back crossing is still present. It is possible that the Bemm River hybrids have moved from the Snowy River but inter-populational movement of Australian bass between catchments is thought to be restricted (Jerry and Cairns 1998). If such movement is not occurring between the Snowy and Bemm Rivers, then the findings suggest that introgression in populations of Australian bass and estuary perch may be natural and not exacerbated by environmental degradation.

Australian bass/estuary perch hybrids were reported by Jerry *et al.* (1999) from several Victorian streams in Gippsland, so it is possible that the incidence of introgression is more widespread in rivers other than the Snowy and Bemm Rivers. The methods used in the present study indicate genomic DNA analysis should be used to reassess the genetic status of Australian bass and estuary perch populations over a wider geographical scale. Such work would give context to the incidence of introgression in the Snowy and Bemm Rivers by elucidating the extent of hybridisation in other Australian bass populations in Victoria.

Australian bass are currently not listed as threatened in Victoria. The incidence of hybridisation and backcrossing requires further investigation to determine how widespread the incidence of hybridisation is in Victoria and to identify the abundance and distribution of 'pure' Australian bass stocks. The importance of populations of pure Australian bass may increase if hybridisation is found to be widespread.

Australian bass from the Snowy River have previously been used as broodstock for aquaculture ventures and offspring have been restocked into the river. Broodstock from the Snowy River have also been collected for possible future stocking programs within Victoria. There is a possibility that some of these fish have been wrongly identified and may have been hybrids. Subsequent artificial propagation and release of the offspring may further complicate the genetic structure of the Snowy River Australian bass population. Jerry (1997) raised the need for caution when undertaking supplemental stockings to reduce implications on the genetic structure of populations. Broodstock sourced from Victorian rivers should be identified using DNA analysis methods before use in restocking programs or commercial operations where the offspring can be introduced into the wild.

Recreational angling regulations currently apply to each individual species. From a recreational aspect, anglers cannot be sure of which species they are catching and thus there are ramifications for the current angling regulations as they currently pertain to Australian bass and estuary perch, separately. Similarly, Fisheries Officers cannot identify angler's catches adequately to enforce the regulations. A review of Australian bass and estuary perch regulations is required to address this issue and for the sake of ease, the two species may have to be considered as one, particularly in areas of sympatric distribution.

## 5.6 Conclusions

- Australian bass are a long-lived and slow growing species.
- Recruitment of Australian bass in the Snowy River has been poor over a long number of years and the numbers of juvenile fish in the populations are lower than would normally be expected.
- Insufficient numbers of Australian bass were available to link recruitment or recruitment failure with flow data.
- Hybridisation and introgression between Australian bass and estuary perch has occurred in the Snowy and Bemm Rivers.
- The identification of Australian bass from the Snowy River and other Gippsland rivers is difficult and requires a genetic test. Morphological identification is not sufficient.
- Snowy River Australian bass collected as broodstock for aquaculture operations should be identified before being used for breeding. All Victorian Australian bass should be identified prior to using in aquaculture.
- The extent of the introgression between Australian bass and estuary perch on a state basis requires determination.

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**Table 5.1 Species assignment of fish samples submitted for DNA analysis from the Snowy, Brodribb and Bemm rivers.**

| | Snowy River | Brodribb River | Bemm River |
|---|---|---|---|
| Australian bass | 44 | 2 | 3 |
| estuary perch | | 5 | 10 |
| 1st generation hybrid | 24 | 3 | 4 |
| 1st or 2nd generation Australian bass | 1 | | |
| 1st or 2nd generation estuary perch | 1 | | 1 |
| 2nd generation Australian bass | 2 | | |
| ≥ 2nd generation Australian bass | 4 | 1 | |
| ≥ 2nd generation Australian bass | 3 | | |
| ≥ 2nd generation estuary perch | 1 | | |
| | | | |
| Percentage of sample hybrids | 45% | 36% | 28% |
| Total | 80 | 11 | 18 |

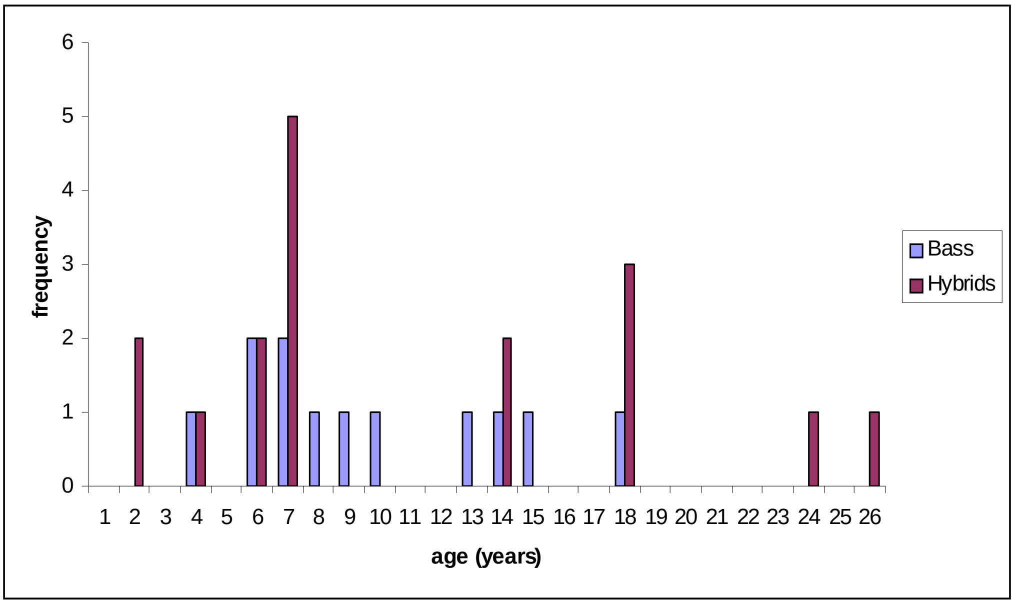


**Figure 5.1 Age frequency of Snowy River Australian bass (n=8) and hybrids (n= 17).**

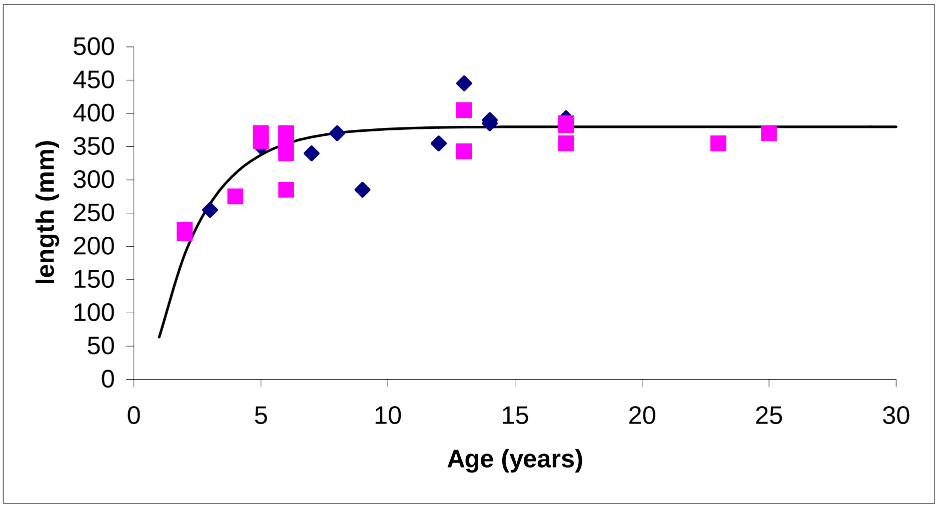


**Figure 5.2 Age length relationship for Australian bass and Australian bass/estuary perch hybrids in the Snowy River. Diamonds are Australian bass, squares are hybrids, line is Von Bertalannfy estimated age and growth curve for Australian bass.**

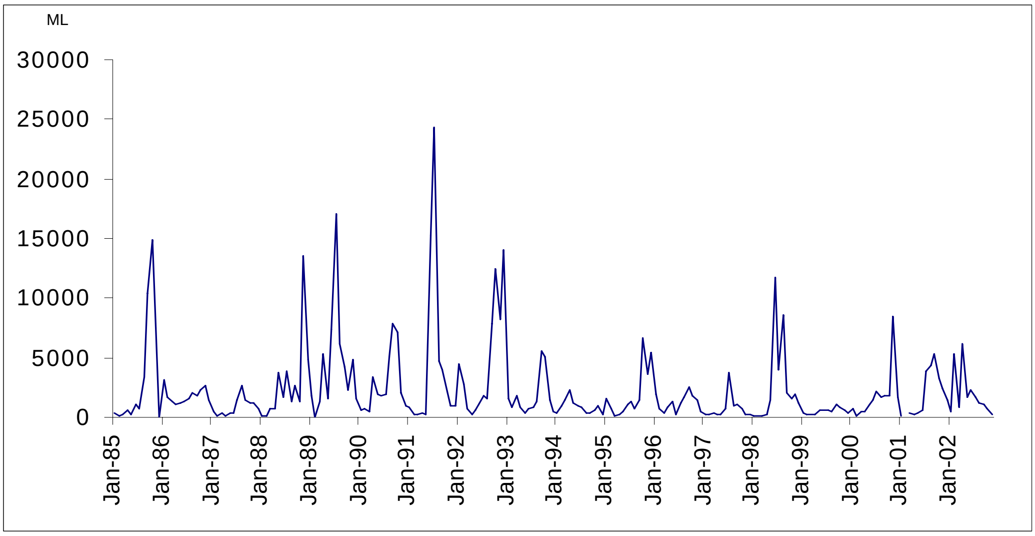


**Figure 5.3 Mean daily average flows by month for the Snowy River at Jarrahmond from 1985 to 2002.**

# Chapter 6 Taxonomic assessment of Australian bass and estuary perch

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## 6.1 Executive Summary

This report describes a taxonomic assessment of Australian bass (*Macquaria novemaculeata)* and estuary perch *(Macquaria colonorum)* samples provided to the Molecular Ecology Laboratory at Macquarie University by the Victorian Department of Primary Industries. A modern DNA approach was implemented based on analysis of microsatellite markers to identify individual samples as Australian bass, estuary perch or hybrid.

## 6.2 Summary

Microsatellites represent perhaps the most powerful class of markers in modern population genetics. They have almost unparalleled power and precision in elucidating population genetic structure, population admixture, hybridization, and identifying individual migrants and hybrids.

Given that no microsatellite markers were available for Australian bass or estuary perch a protocol to isolate, clone and characterize a set of specific microsatellite DNA markers was established. Six microsatellite loci for Australian bass were developed that also work successfully for estuary perch. These markers were used to genotype 109 unknown individuals (including ten putative Australian bass and ten putative estuary perch samples), plus six Australian bass and four estuary perch samples from 'hybrid-free' areas.

Microsatellites detected moderate genetic variability in the samples and showed enough power to discriminate between the two species and identify interspecific hybrid individuals. In addition, the markers also have the power to distinguish between 1st and later generation hybrids, which suggests that hybrids are fertile and able to backcross with the parental species.

The statistical analysis was conducted using a powerful model-based assignment test that assigns (probabilistically) individuals in a sample to a species, or jointly to two species if their genotypes indicate that they are admixed. From the sample of 109 individuals, analysis identified 45% of individuals as Australian bass, 14% as estuary perch, and 41% as hybrids (including 1st, 2nd and ≥ 2nd generation backcrosses). The results confirmed that Australian bass and estuary perch from the 'hybrid-free' areas are genetically distinct, but, interestingly, they also showed that two out of ten putative Australian bass samples and all putative estuary perch samples from the Snowy River are actually classified as hybrids.

Future taxonomic assessments of Australian bass and estuary perch based on microsatellite markers developed here would greatly benefit by the inclusion of a larger number of reference samples from the parental species.

## 6.3 Introduction

Taxonomic discrimination of Australian bass from estuary perch was identified as a significant impediment to the study of population dynamics of Australian bass in the Snowy River (Chapter 5). Consequently, a specific study using the latest genetic techniques was commissioned to examine the relationships between these species and determine the identity of samples collected.

The Victorian Department of Primary Industries (DPI) commissioned Dr Luciano Beheregary at the School of Biological Sciences, Macquarie University to undertake this work.

The schedule of work for this project was as follows:

**Project: *"Taxonomic assessment of Australian bass and estuary perch"***

*The University, through a research team headed by Dr L Beheregaray will undertake assessment of fish samples collected by DPI from the Snowy River. Included in these samples are fish which DPI will identify as either Australian bass or estuary perch (at least ten of each).*

*DPI will provide the University with a total of 116 samples, stored in glass vials in 70% ethanol, in good condition.*

*The task of the University will be to analyse the samples so as to identify all of the fish with confidence, and to determine if any hybridisation is evident.*

*The University will provide DPI with a written final report which describes the results of these tests.*

## 6.4 Materials and Methods

### 6.4.1 DNA extraction, microsatellite isolation and characterization

Genomic DNA was extracted from ethanol preserved tissue samples using a salting-out method (Sunnucks and Hales 1996) modified as in Beheregaray and Sunnucks (2001). Microsatellites were isolated using a modification of an enrichment technique

(Fischer and Bachmann 1998) described in Saltonstall (2003). Genomic DNA of Australian bass was digested with *Rsa*I and *Hae*III and fragments ligated to two oligo adaptors. Biotinylated oligo probes ($dGA_{10}$ and $dGT_{10}$) were hybridized to the digested DNA and selectively retained using streptavidin magnetic particles (Promega). Polymerase chain reactions (PCRs) were performed on the microsatellite-enriched eluate using one of the oligo adaptors as a primer. The product from the first PCR was used as template to repeat the enrichment process. The enriched library was purified using a gene clean kit (Qbiogene), ligated into pcR 2.1-TOPO vector (Invitrogen) and transformed into TOP10 cells. Plasmid DNA was purified and sequenced on an ABI 377 automated DNA sequencer (PE Applied Biosystems) using dye terminator chemistry. Thirty putative positive clones were sequenced and oligonucleotide primers flanking nine microsatellite loci were developed using PRIMER 3 (Rozen and Skaletsky 1997). Primer sequences for the loci will be published as part of a technical primer note (Schwartz *et al.*, in preparation).

## 6.4.2 Microsatellite amplification and visualization

Microsatellite loci were amplified by PCR using a 10 µl radiolabelled reaction containing ~ 50-100 ng of DNA, 12 pmol of each primer, 0.5 units of *Taq* DNA polymerase, 200 µM of dCTP, dGTP, and dTTP, 20 µM of dATP, 2-2.5 mM $MgCl_2$, 10 mM Tris-HCl (pH 8.3), 50 mM KCl, 0.1% Triton X-100 and 0.05 µl [$\alpha$-$^{33}$P] dATPat 1000 Ci/mmol overlaid with mineral oil. PCRs were performed in a MJ Research thermocycler and consisted of 94 °C for three minutes, followed by a "touchdown" (32 cycles at 94 °C/20s, annealing/45s and 72 °C/60 s), and a final step of 72 °C for four minutes. The annealing temperature of the touchdown PCRs decreased two degrees per cycle until stabilizing at the fifth cycle (from 63°C to 55°C). PCR products were separated by 6% polyacrylamide gel electrophoresis and visualized by autoradiography.

## 6.4.3 Data analysis

### 6.4.3.1 Genetic variability

The software GENEPOP 3.3 (Raymond and Rousset 1995) was used to estimate expected ($H_E$) and observed ($H_O$) heterozygosities, test for linkage disequilibrium, and calculate allele frequencies.

### 6.4.3.2 Individual assignment to species

The analysis of individual assignment as Australian bass, estuary perch or hybrid was conducted based on multi-locus genotype data using a method implemented in STRUCTURE (Pritchard *et al*. 2000). STRUCTURE is a powerful model-based assignment test that assigns (probabilistically) individuals in a sample to populations (species in this case), or jointly to two or more populations if their genotypes indicate that they are admixed. STRUCTURE develops a genetic identity for each species based on the allelic frequencies from genotypes of known individuals. Using Bayesian method, unknown individuals can then be assigned with a particular probability to each species identity (Pritchard *et al*. 2000).

Individuals were assigned as either Australian bass or estuary perch if their probability of identity was ≥ 93% to one species, 1st generation hybrid if 40-60% to both species, 1st or 2nd generation backcross if 61-70% identity to one species, 2nd generation backcross if 71-80% identity to one species, and ≥ 2nd generation backcross if 81-90% identity to one species.

With the objective of verifying the general pattern of assignment as either Australian bass or estuary perch (as revealed by STRUCTURE), assignment tests were conducted with the program GENECLASS (Cornuet *et al.* 1999). GENECLASS uses a likelihood-based technique which calculates population allele frequencies, computes the likelihood of an individual multi-locus genotype belonging to a candidate set of populations, and assigns that individual to the population where the likelihood of its genotype is the highest.

# 6.5 Results

Six microsatellite DNA loci were isolated and characterized for the Australian bass that also PCR amplify successfully for estuary perch. These markers were used to genotype 109 unknown individuals (including ten putative Australian bass and ten putative estuary perch samples), plus six Australian bass and four estuary perch samples from areas assumed to be 'hybrid-free'.

Exact tests for linkage disequilibrium revealed no significant locus-pairwise comparisons. This indicates that the six loci are independent molecular markers. The six loci showed an average allelic diversity of 4.2 and average heterozygosity of 0.55 (Tables 6.1-6.3). These values are considered as moderate compared to those of a review of microsatellite variation in 32 teleost species (DeWoody and Avise 2000). As expected, most loci showed a significant deficiency of heterozygotes / excess of homozygotes when all individual samples are pooled, an expected result when combining samples from different species.

**The analysis of individual assignment based on STRUCTURE revealed that the microsatellite markers have enough power to discriminate between the two species and identify interspecific hybrid individuals (**

Figure 6.1). In addition, the markers also have the power to distinguish between 1st and later generation hybrids, which suggests that hybrids are fertile and able to backcross with the parental species. Although the distinction between 1st and later generation hybrids was possible, larger reference samples than those available for this study would enable more discriminative power.

From the sample of 109 individuals (not including the ten samples from 'hybrid-free' areas), analysis identified:

- 49 as Australian bass.
- 15 as estuary perch.
- 31 as 1st generation hybrids.
- 2 as 2nd generation Australian bass.
- 2 as either 1st or 2nd generation estuary perch.
- 1 as either 1st or 2nd generation Australian bass.
- 8 as ≥ 2nd generation Australian bass.
- 1 as ≥ 2nd generation estuary perch.

These results confirmed that Australian bass and estuary perch from the 'hybrid-free' areas are genetically distinct, but, interestingly, they also showed that two out of ten putative Australian bass samples from Snowy River (individuals 1-10) are 1st generation hybrids and that all putative estuary perch samples from that same locality (individuals 11-20) are actually classified as hybrids.

Results from the GENECLASS analysis were useful to confirm the general pattern of individual assignment as either Australian bass or estuary perch revealed by STRUCTURE, except for six cases. GENECLASS is expected to show less power than STRUCTURE for individual assignment when reference samples are small. Therefore, it is possible that the few discrepancies observed in the GENECLASS analysis represent artefacts due to small sample size.

## 6.6 Conclusions

- Six polymorphic microsatellite DNA loci were developed for Australian bass. These markers also amplify successfully for estuary perch.
- Microsatellite markers showed enough power to discriminate between the two species, to identify interspecific hybrid individuals and to distinguish between 1st and later generation hybrids.
- From a sample of 109 individuals, analysis identified 45% of individuals as Australian bass, 14% as estuary perch, and 41% as hybrids.
- The results confirmed that Australian bass and estuary perch from the 'hybrid-free' areas are genetically distinct.
- The analysis showed that two out of ten putative Australian bass samples and all putative estuary perch samples from Snowy River are actually classified as hybrids.
- Future taxonomic assessments of Australian bass and estuary perch based on microsatellite markers developed here would greatly benefit by the inclusion of a larger number of reference samples from the parental species. An appropriate sampling design should include a larger number of individuals per locality (i.e. 20-30) and a more representative number of localities (especially from regions near the Snowy River).

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**Table 6.1 Results of species assignments. A DNA ID was assigned to each sample upon DNA isolation at the laboratory. Tissue ID / Sampling location was recorded from the collection vial and/or paper insert with the tissue sample.**

| DNA ID | Tissue ID | Sampling Location | Species Assignment STRUCTURE | Australian bass / estuary perch assignment validated by GENECLASS§ |
|---|---|---|---|---|
| 1 | 0217001 | Snowy River, Wall TK | Australian bass | √ |
| 2 | 040217002 | Snowy River | Australian bass | √ |
| 3 | 040311001 | Snowy River, Jacksons Crossing | 1st gen hybrid | |
| 4 | 040218001 | Snowy River, Sandy Point | Australian bass | √ |
| 5 | 040311002 | Snowy River, Jacksons Crossing | 1st gen hybrid | |
| 6 | 44030219012 | Snowy River, Wall TK | Australian bass | √ |
| 7 | 040217003 | Snowy River, Wall TK | Australian bass | √ |
| 8 | 040217004 | Snow River, Wall TK | Australian bass | √ |
| 9 | 44040124009 | Snowy River, Wall TK | Australian bass | √ |
| 10 | 44030219009 | Snowy River, Wall TK | 1st gen hybrid | |
| 11 | 44021204005 | Snowy River | ≥ 2nd gen Australian bass | |
| 12 | 44021204012 | Snowy River | 1st gen hybrid | |
| 13 | 44030204003 | Snowy River | 1st gen hybrid | |
| 14 | 44021204002 | Snowy River | 1st gen hybrid | |
| 15 | 44030204008 | Snowy River | 1st gen hybrid | |
| 16 | 44021204014 | Snowy River | 1st gen hybrid | |
| 17 | 44021204003 | Snowy River | 1st gen hybrid | |
| 18 | 44030204004 | Snowy River | ≥2nd gen estuary perch | |
| 19 | 44021204010 | Snowy River | 1st gen hybrid | |
| 20 | 44021204006 | Snowy River | 1st gen hybrid | |
| 21 | 44031127009 | Bemm River | Estuary perch | √ |
| 22 | 44031127007 | Bemm River | Estuary perch | √ |
| 23 | 44031001001 | Bemm River | 1st gen hybrid | |
| 24 | 44021209001 | Bemm River | Australian bass | √ |
| 25 | 44031127002 | Bemm River | Estuary perch | √ |
| 26 | 44031127001 | Bemm River | Estuary perch | √ |
| 27 | 44030826002 | Bemm River | 1st gen hybrid | |
| 28 | 44030826004 | Bemm River | 1st gen hybrid | |
| 29 | 44030826005 | Bemm River | Australian bass | X |
| 30 | 44031127010 | Bemm River | Estuary perch | √ |
| 31 | 44031127008 | Bemm River | Estuary perch | √ |
| 32 | 44030826003 | Bemm River | Australian bass | √ |
| 33 | 44030826001 | Bemm River | 1st gen hybrid | |
| 34 | 44031127004 | Bemm River | Estuary perch | √ |
| 35 | 44031127006 | Bemm River | Estuary perch | √ |
| 36 | 44031127003 | Bemm River | Estuary perch | √ |
| 37 | 44030827001 | Bemm River | 1st or 2nd gen estuary perch | |
| 38 | 44031127005 | Bemm River | Estuary perch | √ |
| 39 | 44031002002 | Brodribb River | Estuary perch | √ |
| 40 | _ _ 021105001 | Brodribb River, Cabbage Tree | ≥ 2nd gen Australian bass | |
| 41 | 44030929001 | Brodribb River | Estuary perch | √ |
| 42 | 44031027001 | Brodribb River | Estuary perch | √ |
| 43 | 44031124001 | Brodribb River | 1st gen hybrid | |
| 44 | 44031125001 | Brodribb River | Australian bass | √ |

| | | | | |
|---|---|---|---|---|
| 45 | _ _02103003 | Brodribb River | Estuary perch | √ |
| 46 | 44030929003 | Brodribb River | 1st gen hybrid | |
| 47 | 44030929002 | Brodribb River | Estuary perch | √ |
| 48 | 44031002001 | Brodribb River | Australian bass | √ |
| 49 | 44030219013 | Snowy River | Australian bass | √ |
| 50 | 44030204005 | Snowy River | Australian bass | √ |
| 51 | 44021118002 | Snowy River | 1st gen hybrid | |
| 52 | 44030923001 | Snowy River | 2nd gen Australian bass | |
| 53 | 44030219010 | Snowy River | Australian bass | √ |
| 54 | 44030219008 | Snowy River | Australian bass | √ |
| 55 | 44021104001 | Snowy River | Australian bass | √ |
| 56 | 44040120009 | Snowy River | Australian bass | √ |
| 57 | 44021201009 | Snowy River | Australian bass | √ |
| 58 | _ _021023001 | Snowy River* | 1st gen hybrid | |
| 59 | 44220104002 | Snowy River | Australian bass | √ |
| 60 | 44030219007 | Snowy River | Australian bass | √ |
| 61 | 44030219018 | Snowy River | Australian bass | √ |
| 62 | 44030219019 | Snowy River | 1st gen hybrid | |
| 63 | 44030923005 | Snowy River | 1st gen hybrid | |
| 64 | 44030807002 | Snowy River | Australian bass | √ |
| 65 | 44030219017 | Snowy River | Australian bass | √ |
| 66 | 44030219006 | Snowy River | Australian bass | √ |
| 67 | 44021204013 | Snowy River | Australian bass | √ |
| 68 | 44030219005 | Snowy River | Australian bass | √ |
| 69 | 44220104003 | Snowy River | Australian bass | √ |
| 70 | 44021106001 | Snowy River | Australian bass | √ |
| 71 | 44040122003 | Snowy River | 1st gen hybrid | |
| 72 | 44030807004 | Snowy River | Australian bass | √ |
| 73 | 44021204011 | Snowy River | Australian bass | √ |
| 74 | 44030204007 | Snowy River | 1st gen hybrid | |
| 75 | 44030204006 | Snowy River | 1st gen hybrid | |
| 76 | 44030219004 | Snowy River | 1st gen hybrid | |
| 77 | 44040123002 | Snowy River | 1st gen hybrid | |
| 78 | 44030204002 | Snowy River | ≥2nd gen Australian bass | |
| 79 | 44021218003 | Snowy River | Australian bass | √ |
| 80 | 44040123001 | Snowy River | 1st gen hybrid | |
| 81 | 44030923004 | Snowy River | Australian bass | X |
| 82 | 44030219011 | Snowy River | Australian bass | X |
| 83 | 44021218005 | Snowy River | Australian bass | √ |
| 84 | _ _ 021023004 | Snowy River | Australian bass | X |
| 85 | 44030219015 | Snowy River | 1st or 2nd gen estuary perch | |
| 86 | 44030219003 | Snowy River | Australian bass | X |
| 87 | 44021218004 | Snowy River | 1st gen hybrid | |
| 88 | 44021204001 | Snowy River | Australian bass | √ |
| 89 | 44030219001 | Snowy River | ≥2nd gen Australian bass | |
| 90 | 44021218002 | Snowy River | ≥2nd gen Australian bass | |
| 91 | 44030807003 | Snowy River | 1st gen hybrid | |
| 92 | 44021204008 | Snowy River | Australian bass | √ |
| 93 | 44030219014 | Snowy River | Australian bass | X |

| | | | | |
|---|---|---|---|---|
| 94 | 44021118003 | Snowy River | 1st or 2nd gen Australian bass | |
| 95 | 441118001 | Snowy River | 1st gen hybrid | |
| 96 | 44030204001 | Snowy River | Australian bass | √ |
| 97 | 44021204007 | Snowy River | 2nd gen Australian bass | |
| 98 | 44021204004 | Snowy River | ≥ 2nd gen Australian bass | |
| 99 | 44030923002 | Snowy River | Australian bass | √ |
| 100 | 44040121008 | Snowy River, Wall TK | Australian bass | √ |
| 101 | 44030807001 | Snowy River | Australian bass | √ |
| 102 | 44040122001 | Snowy River, Wall TK | Australian bass | √ |
| 103 | 44040121009 | Snowy River, Wall TK | Australian bass | √ |
| 104 | 44040218002 | Snowy River, Sandy Point | Australian bass | √ |
| 105 | 44030219016 | Snowy River | ≥ 2nd gen Australian bass | |
| 106 | 44030923003 | Snowy River | Australian bass | √ |
| 107 | 44021218001 | Snowy River | ≥ 2nd gen Australian bass | |
| 108 | 44030219002 | Snowy River | Australian bass | √ |
| 109 | _ _ 021023002 | Snowy River, Brodribb River | 1st gen hybrid | |
| 110 | Australian bass 1** | | Reference sample | Reference sample |
| 111 | Australian bass 2** | | Reference sample | Reference sample |
| 112 | Australian bass 3** | | Reference sample | Reference sample |
| 113 | Australian bass 4** | | Reference sample | Reference sample |
| 114 | Australian bass 5** | | Reference sample | Reference sample |
| 115 | Australian bass 6** | | Reference sample | Reference sample |
| 116 | Estuary perch 1** | | Reference sample | Reference sample |
| 117 | Estuary perch 2** | | Reference sample | Reference sample |
| 118 | Estuary perch 3** | | Reference sample | Reference sample |
| 119 | Estuary perch 4** | | Reference sample | Reference sample |

§ √: assigned to same species as STRUCTURE, X: not assigned to a particular species

* paper insert = Brodribb

** samples from non-hybrid zones

**Table 6.2 Genetic variability. $H_O$ and $H_E$ are observed and expected heterozygosity, respectively (based on 119 individuals). * indicates significant deficiency of heterozygotes as expected when combining samples from two genetically different species.**

| Locus | No. Alleles | $H_O$ | $H_E$ |
|---|---|---|---|
| AB001 | 6 | 0.57* | 0.68 |
| AB009 | 4 | 0.61* | 0.62 |
| AB006 | 4 | 0.57* | 0.61 |
| AB097 | 2 | 0.24 | 0.24 |
| AB107 | 2 | 0.73 | 0.71 |
| AB114 | 7 | 0.32* | 0.46 |

**Table 6.3 Allele frequencies.**

| Locus | Alleles (in base pairs) | Frequency |
|---|---|---|
| AB001 | 224 | 0.306 |
| | 228 | 0.004 |
| | 232 | 0.043 |
| | 234 | 0.440 |
| | 236 | 0.013 |
| | 238 | 0.194 |
| AB006 | 180 | 0.332 |
| | 188 | 0.177 |
| | 190 | 0.368 |
| | 192 | 0.123 |
| AB009 | 271 | 0.004 |
| | 273 | 0.282 |
| | 275 | 0.532 |
| | 285 | 0.182 |
| AB097 | 104 | 0.864 |
| | 112 | 0.136 |
| AB107 | 290 | 0.652 |
| | 300 | 0.348 |
| AB114 | 115 | 0.004 |
| | 117 | 0.175 |
| | 119 | 0.004 |
| | 131 | 0.527 |
| | 133 | 0.023 |
| | 141 | 0.267 |

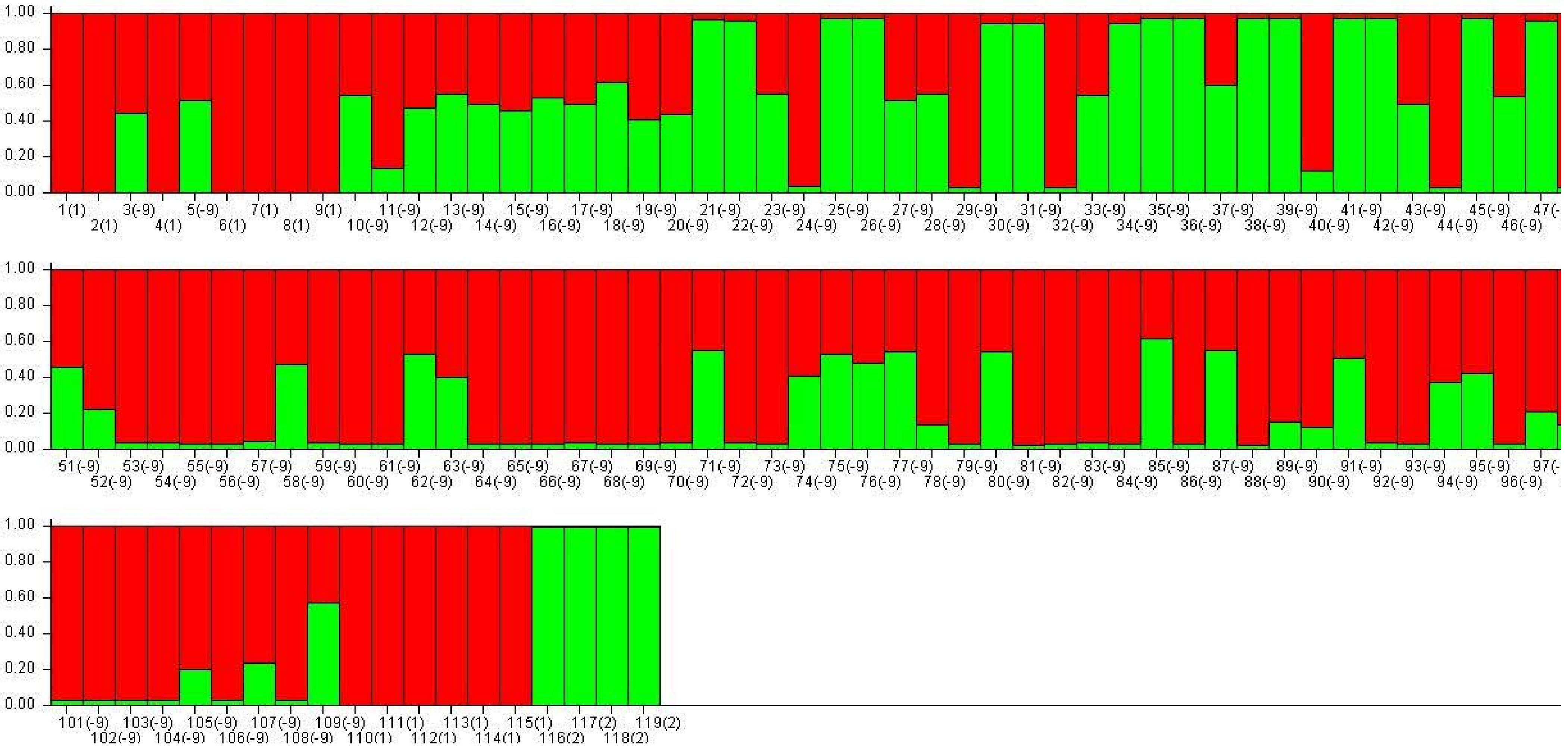


**Figure 6.1 Results of analysis of STRUCTURE. Assignment probability of each individual estimated by STRUCTURE to the Australian bass (red / dark grey in black and white print) or estuary perch (green / pale grey) genetic identity. Each vertical bar represents one individual identified by DNA ID on the X axis (number in parenthesis is of no importance).**

# Chapter 7 Australian bass movement, migration and habitat suitability in the Snowy River

**Paul Brown (Fisheries Research Branch, Fisheries Victoria)**

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## 7.1 Introduction

Australian bass are known to be catadromous migrants that travel extensively within larger catchments of rivers on the south-eastern coast of Australia. The life history of Australian bass starts with larvae hatching in estuarine waters, where they develop until settlement occurs in beds of macrophytes at about 25-30 mm TL (Harris and Rowland 1996). As juveniles during spring–summer they migrate upstream into the catchment where they mature after 2-4 years, for males; or 5-6 years, for females (van der Wal 1983). Males may remain in (or near) tidal waters while females travel further upstream. The population is thus sexually-segregated outside the breeding season (Harris and Rowland 1996).

On maturity, the adults return downstream to spawn. Although decreasing day-lengths and temperatures are thought to synchronise gonadal development, high river flows are thought to be important triggers for downstream migration and spawning (Harris 1986). Strong recruitment and subsequent year-class-strength were also correlated to flooding during spawning months in New South Wales (Harris 1985). The timing of downstream spawning migration is variable depending on location, but in central New South Wales, after fish mature in February-May, spawning usually occurs from June-September at temperatures ranging from 11-16 °C (Harris 1986, van der Wal 1983). In Victorian waters, observations indicate either greater uncertainty, or more temporal variability, and downstream spawning migrations are said to occur June–December (McCarraher 1986). The adults return movements into freshwater after spawning may take several months in New South Wales, during August-October (van der Wal 1983).

The high degree of uncertainty about the scale, timing, and trigger mechanisms of Australian bass movements in Victoria hinders the overall understanding of the species life-history requirements. This study aims to increase this understanding and thus aid efforts to rehabilitate coastal rivers through catchment and flow-management.

Much of what is known about Australian bass habitat comes from anecdotal knowledge of anglers and other observers. There is little formally known from scientific research and assessment. Sanders (1973) summarised this thus, *"Australian bass prefer deeper waters with some hydraulic cover. The species is often associated with submerged objects such as trees and rocks."* Anglers certainly traditionally target Australian bass in-and-around complex habitat including large woody debris, aquatic macrophyte beds and under overhanging riparian vegetation.

While some research and assessment activity has reinforced this general knowledge of which freshwater habitats are important, there has been little directly addressing Australian bass habitat requirements. The health of riparian vegetation was correlated to increased Australian bass abundance at sites in the Hawkesbury River (Growns *et al.* 1996).

Further research activities, aside from the present study, that may shed more light on this question are under way in New South Wales (NSWDPI 2004a, NSWDPI 2004b).

Practical instream methods are typical of the habitat-restoration approach currently popular for rehabilitation of Australian native-fish communities, including species such as Australian bass. However, in direct contrast to many other recreationally valued species around the world (eg. percids, salmonids, centrarchids), there is no formal and detailed description of *high-quality* physical habitat for Australian bass. Without such definitions, it is difficult to assess whether physical-habitat degradation is in fact a significant cause of a depressed population of Australian bass. Therefore, habitat rehabilitation activities are currently aiming for an (at best) ill-defined or unknown target.

It is acknowledged that one reason there has been poor focus on such habitat description and definition is the technical and physical difficulties associated with such work. Radio-telemetry of Australian bass in the Shoalhaven River downstream of Tallowa Dam did not observe any catchment scale movements of tagged fish during the six-month study. Nor did it provide the detailed habitat-knowledge expected, due to technical difficulties (Gehrke *et al.* 2001).

Acoustic telemetry is increasingly being used in marine, and estuarine environments to monitor fish movement behaviours (Lucas and Baras 2000). Arrays of remote listening and data-logging devices are deployed to record data from individually coded acoustic 'pinger' tags that can be implanted in fish. Acoustic listening stations are smaller, more self-contained, easier to use and cheaper than similar radio-receiving technology.

Underwater observation is routinely used in North America, Europe and New Zealand for a range of riverine, fish survey activities (Dolloff *et al.* 1996). Anecdotal reports suggest that swimmers in the Snowy River have observed Australian bass underwater using snorkel and/or scuba gear (Mr. Jim Nixon, pers. comm. 1996, Mr Craig Ingram, pers. comm. 2003).

In this present study, innovative methods such as acoustic telemetry and underwater-observation by snorkel swimmers are used in an attempt to meet the technical challenges issued by the need to investigate Australian bass movement and habitat-use.

Alongside this, a habitat-suitability model will also be built with a less traditional method of elucidating and formalising the body of anecdotal knowledge used by anglers in their daily qualitative-assessment of "Australian bass habitat."

## 7.2 Methods

### 7.2.1 Adult Australian bass movement

From January to March 2004 a total of 13 putative Australian bass were caught, fitted with individually coded acoustic tags and released at their capture location. Fin clips were taken from all but 4 fish, as tissue samples to confirm their species identity using genetic testing. Four out of six fish from Jackson's Crossing were unable to be genetically tested due to a failure in preservative-supplies. Australian bass that were tagged represent a range in size, gender and location from Orbost up to Jackson's Crossing. Upstream and downstream movement was recorded as the tagged Australian bass passed within range of the listening stations between January and the final data-download in October 2004.

#### 7.2.1.1 Acoustic listening stations and acoustic transmitting tags

In December 2003 and January 2004 a total of 14 acoustic listening stations (VEMCO, VR2 units) were deployed in the Snowy River and estuary, from Marlo upstream to Jackson's Crossing (Figure 7.1, Figure 7.2 and Table 7.1).

Each VR2 was capable of receiving an acoustic signal from a transmitter passing within a distance up to (and often exceeding) the width of the river: therefore any transmitters passing a VR2 were detectable. VR2s were deployed by suspending them in the river and chaining them to an immoveable object. On detecting a coded-transmission, the on-board processor decoded the signal and recorded the time and date of the transmission along with the identifying code for that tag (fish). Data are stored in memory and field-staff downloaded the stored data to a laptop computer periodically.

The transmitters used, VEMCO model V8SC, are 'coded pingers' that send acoustic pulse trains containing an ID number which permits identification of the specific tag (Figure 7.3). The coded pingers transmit at 60.0 kHz with a random delay between a 60 and 180 seconds. This randomisation allows multiple pingers to be received and decoded clearly by a single VR2, without code-collisions masking each other. V8SC pingers are 9 x 28 mm in size and weigh 4.7 g in air. Battery life is anticipated to be 580 days (~1.6 years). Software (VR2PC, VEMCO) scans all the data files for any given coded-pinger and builds a list-file of the times and dates here that coded pinger was encountered by any VR2. This file is the basis for subsequent analyses of movement rates etc.

#### 7.2.1.2 Capture of Australian bass and implanting of acoustic tags

Based on the weight of the tags and applying the "rule-of-thumb" that tags should represent ~2% of the fish body-weight Australian bass were required to be >235 g (Winter 1983) to undergo a tag implant. Australian bass were captured with the method that was least stressful and caused the least physical damage to the fish. Angling (with lures) was preferred and was tried first at each location. Electrofishing was also a preferred method and although effective, it was limited to the few locations where electrofishing boat access was possible. If Australian bass could not be obtained using angling or electrofishing then mesh-nets were used. Mesh nets were set for 1 hour either side of dusk and constantly attended to ensure that Australian bass (and any by-catch) were removed from the nets as soon as possible after capture.

On capture, fish were anaesthetised using benzocaine until gill-movements became slow and irregular. Each fish was weighed and measured (fork-length). Sex was sometimes determined via inspection during the surgical procedure, but this was not always possible. The acoustic pingers were implanted surgically via a 2.5 cm incision on the ventral side of the fish just above the mid-line. The transmitters were inserted into the abdominal cavity. The incision was closed by sutures and sealed with a cyanoacrylate based adhesive. Total surgery time averaged two to three minutes. Fish were kept moist during surgery with water sprayed via an atomiser over the gills and body. Most surgery was done immediately, or within one to two hours of capture. Occasionally fish were held in the river in a cage overnight before surgery.

After surgery, anaesthetised fish were also tagged with a numbered plastic dart-tag into the dorsal musculature to enable external identification in case of capture by an angler. When possible, a tissue sample (fin-clip) was also taken to confirm species identification by DNA testing. Tagged Australian bass were allowed to recover (<10 minutes) in a cage in the river before release at the capture-site.

**7.2.1.3 Acoustic coded-pinger tagged Australian bass**

Twelve Australian bass were implanted with acoustic coded-pingers and released in 4 locations from Orbost up to Jackson's Crossing (Table 7.2). Fish ranged in weight from 377 g to 2.2 kg. The group contained at least 3 confirmed males and females.

**7.2.1.4 Passage across sand reach**

The 'sand slug' is a ~16 km reach of relatively featureless, sand-filled channel, where summer flow levels result in a shallow (<50 cm), braided, open channel. Although the boundaries of this feature are hard to determine precisely, it predominantly lies upstream from Orbost, through Bete Belong and Jarrahmond to where the Snowy River flows out of the hills at the northern boundary of the coastal floodplain. The acoustic listening stations at Wood Point and the butter factory were situated close to the upstream and downstream boundaries of the sand slug, respectively.

The sand slug reach is viewed by many to be a potential bottleneck for migrating fish. This is possibly more an issue for small species or young/small individuals but nevertheless remains a possible hindrance for adult Australian bass returning to estuarine waters to spawn and also re-accessing the upper catchment after spawning is completed. Observation of any movements of coded-pinger tagged Australian bass across this sand slug will therefore be of relevance to Snowy River restoration objectives.

### 7.2.2 Australian bass habitat assessment

To describe the habitat associations of Australian bass in the Snowy River, a plan was developed involving a multi-disciplinary comparison of data collected in three ways:

- A conceptual habitat model developed from the views of recreational fishers
- A physical habitat model built using visual fish-census
- Radio-tagging combined with physical measurement.

**7.2.2.1 Eliciting Australian bass habitat suitability information from the views of recreational fishers**

A standardised survey form was designed containing 27 questions centred on identification of habitat characteristics such as water depth, water velocity, substrate and instream and overhead cover descriptions (Appendix 7.7A).

The survey form also contained preliminary questions to determine the respondent's level of recent Australian bass fishing experience. This included questions on the degree to which they target the species, the seasons of the year to which their habitat-information may relate most to, their confidence in diagnosing the identity of their Australian bass catch from a related and very similar species (estuary perch), and the degree to which distance-from-the-sea influences this diagnosis.

Each quantitative question regarding a habitat characteristic (eg. depth) was paired with a question, designed as a weighting factor (wf), on how important the respondent regarded that particular characteristic. Respondents were asked if they regarded each criteria as: unimportant (wf=0), slightly important (wf=1), important (wf=2), very important (wf=3), or vitally important (wf=4). If, for instance, a respondent regarded a depth as *unimportant*, their judgement about depth-suitability was weighted zero in the overall model; conversely judgements about depth-suitability from a respondent regarding depth as *vitally important* were weighted to have four-times the significance of those who regarded depth as slightly important.

Respondents were also asked to rank seven major types of cover as preferred fishing spots for Australian bass. Average ranks were calculated for each cover-type, again weighted by the degree of importance with which each respondent regarded cover.

Responses were treated anonymously and data was pooled for each question to produce a distribution of the views of anglers regarding each of the habitat characteristics and a mean weighting factor for each characteristic.

Interviews were conducted mainly over a single weekend-gathering of anglers at the Snowy River. The anglers were mainly members of *Native Fish Australia*, the *Orbost Angling Club*, or interested local fishers. Interviews were largely done "face-to-face", in a standard manner by a single interviewer (i.e. Paul Brown), although some were also conducted over the telephone after the initial collection.

**7.2.2.2 Visual fish census**
Underwater visual identification of Australian bass habitat was attempted on several dates in March 2004. Snorkel-swimming surveys were conducted within river-reaches where Australian bass had previously been caught using other methods (eg. electrofishing, angling, netting). Sites surveyed included the 'butter factory bend' at Orbost (250 m pool length); Wall Creek (200 m pool and run); Sandy Point (600 m of pools and runs); Jonkers (300 m part of pool, both banks); and at Jackson's Crossing (300 m of pool and run) on the Snowy River. The lower section of the Roger River was also surveyed (200 m).

Despite the Snowy River appearing superficially to be 'clear', the horizontal underwater visibility was only mediocre. Objects could be seen between 1 and 1.5 metres away from a diver (Figure 7.4).

Two methods of visual fish census were tried; an adaptation of 'crawl-diving' with careful searching through 'cover' in an upstream direction; and a 'drift-diving' method where a line of swimmers searched downstream through more open water. Neither method produced many observations of Australian bass however the 'crawl-diving' enabled some observations to be made. Swimmers mainly worked in pairs and moved through the areas to be searched with a combination of crawling, surface snorkelling and snorkel-diving. As Australian bass were observed, their initial position was marked with a weighted-streamer. Each mark was revisited after the search was complete. Snorkelers made measurements of water and fish depth (m); distance from bank and distance to cover (m); and water velocity (average water column velocity) (m/sec) and fish 'nose' velocity, or the water velocity measured at the depth at which the fish was observed. The substrate and cover used by the fish were also described.

**7.2.2.3 Habitat suitability model**
The variables described in section 7.2.2.2 can be combined into a model that will rate a chosen habitat for its overall suitability for adult Australian bass, in terms of the physical habitat attributes of the site. There is virtually no quantitative literature and/or data on the relationship between abundance or standing-stock of Australian bass and the quality of habitat. In the absence of information that would guide the relative importance of each variable, a simple method of equal weighting is proposed. (NB: angler's opinions about relative importance of the different variables have already been accounted for). However, the model uses a modified limiting-factor procedure (Raleigh *et al.* 1986). The assumption being that variables with a habitat suitability index (HSI) in the average to good range can be compensated for by higher suitability in the other variables. However, variables with low suitability cannot be compensated for and thus become limiting factors for the habitat suitability.

Initial habitat suitability model:

$$HSI_1 = \left(V_D \times V_S \times V_B \times V_C\right)^{1/N}$$

where $N$ = the number of variables included in the equation. Or if any single variable $\leq$ *limiting threshold*, then HSI = the lowest component value

To estimate HSI for the physical habitat at a given location, the above equation is solved for the number of variables available. This provides an overall rating for a given site with values that can range from 0 (unsuitable) to 1 (completely suitable).

In principal, Australian bass should be observed in habitat that is highly-*suitable*, by definition. Australian bass would only occupy unsuitable habitat if:

- There was no highly-suitable habitat available at all; or
- There was an oversupply of Australian bass relative to the amount of highly-suitable habitat.

Both seem unlikely to apply to the Snowy River. Therefore, to improve the initial HSI, the observations of Australian bass in habitat (made in section 7.2.2.2) were used to calibrate the model. Combination of variables and the limiting factor threshold were tried, until relatively high index values were achieved for the observations, while retaining as many habitat variables as possible.

**7.2.2.4 Radio-tagging**
An original objective of this project was to use the known locations of radio-tagged fish to derive habitat suitability information. Only a single Australian bass was implanted with a radio-transmitter at Wall Creek on the 17 February 2004.

## 7.3 Results

### 7.3.1 Australian bass movement

From the seven Australian bass, four putative Australian bass and 2 Australian bass x estuary perch hybrids that were implanted with coded-pingers, a total of 58,483 interactions (hits) with the acoustic listening-stations (VR2s), were recorded to 5 October 2004.

Some fish spent long periods of time within range of VR2s and recorded thousands of hits; others (#223 and 218) recorded only 1 or 2 hits, nevertheless providing useful information as to the fish's movement since tagging. Two fish have, to date, not been detected on any VR2 (#216 and 224). The distribution of data recorded across all the tagged fish is shown in Figure 7.5.

Data shows a range of behaviours including home-range behaviour and movements from some individuals moving several kilometres. Some fish moved past, or were recorded on several VR2s in succession, indicating their progression up and downstream. It is also evident that some individuals were able to pass-by a VR2 undetected, as there are instances of fish 'skipping' several listening-stations and then appearing again elsewhere. This is unfortunate, but does not preclude the usefulness of the data set.

**7.3.1.1 Diurnal patterns**
When downloading data, field staff noticed that Australian bass often seemed to be detected by a VR2 at night but the same fish was absent during the day for several days at a time. The frequency of detections (pings) of tagged Australian bass, by most of the VR2s, increased during the hours of darkness. If the number of pings is cumulated for each hour and plotted as a frequency for each fish at a given VR2, diurnal patterns can be observed as in Figure 7.6.

Although occasional individuals were detected during the daylight period, a diurnal rhythm was generally observable at most VR2s. The combined data pooling the frequency of all Australian bass detected at all VR2s reinforces this diurnal rhythm (Figure 7.7). The frequency of detection is minimal during 09:00–17:00 hrs and increases from 18:00 hrs to a peak at 02:00 hrs before declining to 'daytime levels' by ~09:00 hrs.

It is uncertain what behaviour is illustrated by increased frequency of detection, such as occurs during the 'night' period in Figure 7.7. Computer simulations of a tag (ie. a fish) moving randomly at a range of speeds in a river reach containing a single VR2 showed that increased average detection frequency can be achieved in two ways:

- By a slow-speed fish, if the tag is occasionally within detection range for long periods; or
- By a high-speed fish, where the tag is often within detection range for short periods.

Therefore, the diel pattern of detection frequency observed in Figure 7.7 could be achieved by either increased, or decreased, activity at night.

**7.3.1.2 Rate of movement and distance**
**7.3.1.2.1 Speed travelled**
The river-distance of each VR2 from the ocean was measured using ARC/View geographic information software. Individual maximum movement-rates between VR2s were estimated from the distances divided by the period, calculated as arrival time (at second VR2) minus departure time from the first VR2. Eight tagged fish moving between VR2s were observed. Their average downstream speed was 4.5 km/h, although speed varied from 1.2 to 12.3 km/h. Upstream speeds varied from 0.4 to 15.8 km/h with an average of 3.6 km/h. One of these fish was an F1-hybrid, one of unknown origin and the remaining six were Australian bass.

**7.3.1.2.2 Distances moved**
Figures 9-17 illustrate the distance and direction moved by all fish that were caught and tagged in freshwater, and where some re-encounter data were recorded by VR2 listening stations. Genetic testing (Chapter 6) has shown that they were six Australian bass, one F1-hybrid, and two were un-tested and classed as putative Australian bass.

The greatest downstream movements recorded were of ~83 km by fish #223, a 2.2-kg putative Australian bass, from Jackson's Crossing down to Marlo Jetty (Figure 7.12); and fish #218 (1.5kg, F1-hybrid) again from Jackson's Crossing down to the Little Snowy River near Marlo (Figure 7.10).

Large upstream movements were also observed; such as those of fish #228, a 1.6 kg female Australian bass tagged at Sandy Point some 50 km from the ocean (Figure 7.14). This individual made repeated visits to the lower catchment in the Brodribb River at the mouth of Cabbage Tree Creek and the Marlo area in the Snowy River, returning at least four times to the Sandy Point vicinity. Australian bass #217, and #220 tagged at Orbost in January both moved upstream ~30 km to the Wall Creek/Sandy Point area in May 2004 (Figure 7.9 and Figure 7.12).

Several fish also showed long periods of residence in a single location. Australian bass #219, #220 and putative Australian bass #230 remained in almost daily contact with a single VR2 for months at a time close to the location where each fish was originally captured and tagged (Figure 7.11, Figure 7.12 and Figure 7.16). While #219 and #220 also eventually made catchment-scale movements, #230 was resident near the Jackson's Crossing VR2 during the entire study.

**7.3.1.3 Environmental cues**

Daily flow data are available from the Jarrahmond gauge for the entire period for which fish-movement data have been collected (22 January–5 October 2004). There were three significant flow events during this period, peaking on 13 May, 19 July and 11 September. Two out of nine fish with data-records undertook significant catchment-scale movements seemingly in response to the first flow event on 13 May. The flow increase in May (~2000 ML/d) of around 1 week duration coincided with fish #217 moving 30 km upstream and then 40 km downstream (Figure 7.9). Fish #220 also moved 30 km upstream on this flow, and may have remained upstream between Sandy Point and Jackson's Crossing (Figure 7.12). The peak of the same flow event prompted the reappearance of fish #219 that moved back downstream to the Wall Creek area after over a month's absence (Figure 7.11). Fish #218 must have moved down to the estuary from Jackson's Crossing before the influence of this flood peak was felt (Figure 7.10). Fish #230 did not seem to move from Jackson's Crossing in response to this, or any subsequent flow-peak (Figure 7.16). However, a substantial proportion of this first flow-event entered the Snowy River from the Buchan River. The Buchan River is downstream of Jackson's Crossing. Whether the second and third flow events also had their origins in the Buchan River is unknown.

A second larger and more sustained flow event peaked on the 19 July. Fish #223 and #225 both were re-detected again, coincident with this second (July) flow peak, after a period of absence (Figure 7.12 and Figure 7.13). However, this is the only evidence of any movement-response from any of the tagged fish coincident with this flow-event.

The third substantial flow peak, in September, again produced little obvious movement behaviour in the tagged fish. Although it may have prompted fish #228 to return to the estuary 'yet-again' (Figure 7.14).

Only two Australian bass (# 219 and #229) were observed making a 'classic' downstream migration in the late winter/spring. Australian bass #219, made a single brief visit to Marlo Jetty in late August before returning to the Wall Creek area (Figure 7.11). Putative Australian bass #223, originally tagged at Jackson's Crossing remained unobserved until it was detected at Marlo in late July and early August. Australian bass #229 was tagged and spent most of the project near Sandy Point (Figure 7.15). In mid-August it swam downstream and was observed at several VR2s in the estuary, (eg. Little Snowy River, Second Island, Brodribb boat ramp, Brodribb at Cabbage Creek and Marlo Jetty), until mid-September.

Similar, but less definitive observations, can also be made about several other fish. Fish #230, was not seen for several months after tagging at Jackson's Crossing in February, until it turned up briefly at Marlo Jetty at the end of July and again in early August (Figure 7.16). Australian bass #228 made several visits to the lower estuary from the Sandy Point area between the end of July and early October (Figure 7.14). Such movements may be associated with spawning behaviour, but the pattern is unclear.

Individuals may make multiple visits to estuarine waters from freshwater residence, as well as individual fish taking-up residence in the estuary over the late Winter–Spring period (Figure 7.17). Five fish with this behaviour were logged by VR2s in the Snowy River at: Marlo Jetty, Second Island, Little Snowy confluence and Lochend; and in the Brodribb River at the confluence of Cabbage Tree Creek and at the boat ramp.

#### 7.3.1.4 Passage across sand reach

In this section, 'downstream' and 'upstream' refer to position in the catchment relative to the sand-slug. Seven tagged individual Australian bass were observed crossing the sand-slug reach at least once during the period January-October 2004. Some individual fish crossed the sand-slug several times. Five of these fish were later confirmed by genetic analysis as Australian bass, one individual was an F1-hybrid and one putative Australian bass tagged at Jackson's Crossing was not genetically tested (no fin-clip).

Australian bass #217, crossed once upstream and once moving downstream. This fish was tagged at Orbost on 22 January, was last noted downstream on 24March, then next observed upstream on 14 May. This fish departed the upstream area on 17 May and returned downstream by 20 May.

Australian bass #219, crossed once upstream and once moving downstream. This fish was tagged at Wall Creek on 17 February and was last noted upstream on 23 August. It was next observed on the same day downstream and again on 30 August before it appeared again upstream on 2 September.

Australian bass #220, crossed once moving upstream. This fish was also tagged at Orbost on the 22nd of January and remained downstream until the 12th of May. Then it was observed on the 14th and 15th of May after moving upstream.

Australian bass #228, crossed three times moving upstream and four times moving downstream. This very mobile fish was tagged upstream at Sandy Point on 19 February and was next observed downstream on 8 April. By 18 April, this fish was back upstream where it remained until at least 10 May. On the 2 June, and again on 11 August this fish was observed downstream. However on 11 August it swam upstream and was observed there until at least 25 August. On 27 August it was noted downstream. By 8 September this fish was back upstream where it remained until around 29September. It was last observed downstream after its seventh passage across the sand slug during the study period!

Australian bass #229, crossed once moving downstream. This fish was also tagged upstream at Sandy Point on 19 February where it was observed periodically until 8 August when it moved rapidly downstream.

Putative Australian bass #223, crossed once moving downstream. This fish was tagged upstream at Jackson's Crossing on 25 February and was next observed downstream in the estuary on 27 July and 6 August.

F1-hybrid #218 , crossed once moving downstream. This hybrid was also tagged upstream at Jackson's Crossing on the 11th of March and was not seen again until it was observed downstream on 9 May.

Four of the six fish tagged that did not cross the sand slug were initially released at Jackson's Crossing and they potentially remain in the upper catchment.

### 7.3.2 Australian bass habitat

#### 7.3.2.1 Anglers perception model

In total, 14 anglers were identified as 'Australian bass anglers' and interviewed to ascertain their perceptions of what makes good habitat for adult Australian bass. The level of experience of respondents, as measured by the number of days spent fishing for Australian bass, varied from less than once-per-month to greater than five-times per month. Most had fished at a similar frequency for the last five-years. However, no respondents were excluded due to a lack of previous experience.

While 71% of respondents said they target 'Australian bass only', most anglers (64%) said they at least occasionally encounter estuary perch and 36% said they never do. Less than half the respondents (43%) were confident in their ability to diagnose between the species; and 50% said they were only sometimes confident. However, no respondents were excluded due to an inability to diagnose Australian bass from estuary perch.

All respondents used habitat-cues to target their fishing activity, rather than fishing where it was easiest, or fishing all the available water. Therefore no respondents were excluded because they didn't use habitat-cues to choose a location to fish.

The responses of all the interviewees (n=14) provided the data set used subsequently to define anglers perceptions of Australian bass habitat.

#### 7.3.2.2 Habitat suitability curves

Suitability is reported as habitat suitability indices (HSI) on a scale of 0–1, with 1 being most suitable, and 0 being unsuitable. This is a standard method used as input to a number of methods for evaluating, comparing and modelling fish habitat.

**Depth ($V_D$)**
Most anglers regarded depth during the day as 'important' while at night most regarded depth as only 'slightly-important.' During the day, shallow water was deemed unsuitable while depths of over 0.9 m were classed as highly suitable; whereas at night, slightly shallower habitats were deemed more suitable than they were during the day (Figure 7.18).

**Water Velocity ($V_S$)**
Most anglers regarded water velocity as 'important', both by day and night. Slower water velocities were generally deemed more suitable by day or night. Very fast water was deemed unsuitable during the day. However, at night some anglers reported also finding Australian bass using fast runs and riffles (Figure 7.19).

**Substrate ($V_B$)**
Most anglers regarded substrate as an 'important' habitat consideration during the day, whereas this reduced to 'slightly-important' at night. Nevertheless, 21% of anglers (n=6) regarded substrate as of 'no importance'. Hard substrates of cobble, boulder, and bedrock were seen as most suitable as daytime habitat. At night, the range of suitable substrates broadened to include the finer particles (Figure 7.20).

**Cover ($V_C$)**
Most anglers regarded proximity to, or presence of, physical cover in some form as 'vitally important' (64%) or 'very important' (36%) during the day, and most still rated it as 'important' at night although there was a broader range of views.

The scale at which proximity to cover was most suitable (ie. most important) during the day was less than 1.0 m. At night, while anglers chose mid-range distances to cover as moderately suitable, they regarded proximity to cover at much larger scales (ie. >10 m) as most suitable (Figure 7.21). Interestingly, anglers also regarded close proximity (<0.5 m) to cover at night, as unimportant.

The seven specified cover types were ranked from most to least suitable as Australian bass habitat. After being weighted according to the degree of importance that each respondent regarded proximity to cover, the top three during the day were; large submerged logs; shade from overhanging trees or shrubs; and boulders and rock-ledges. The top ranked three at night were; large submerged logs again; with submerged weed-beds making an appearance ahead of boulders and rock ledges (Figure 7.22).

There were other significant cover features, that interviewees felt were not included in the above categorisation, but were important habitat attributes for adult Australian bass. These included: depth as cover; bridge pylons and other artificial structures; foam/white water/bubbles eg. found in plunge-pools at bases of waterfalls etc.

**7.3.2.3 Visual census model**
Despite extensive searching, only five underwater observations of Australian bass were made with four suitable for physical measurement (Table 7.3). Three fish appeared unalarmed, the fourth may have been fleeing (but took up a position within the cover similar to unalarmed fish), the fifth was observed fleeing the swimmer in open water (habitat not measured).

Lack of observations prohibits development of a formal model describing habitat use. However, the following is a summary description of habitat that Australian bass were observed using during the day: gently flowing, or static water, over 70 cm in depth, and within 6 m of the river bank. Australian bass were suspended in the lower 2/3 of the water column, over substrates ranging from silt to gravel, surrounded by and underneath dense cover providing shade. This cover was usually a willow thicket but occasionally had large-woody debris embedded.

Habitat suitability index (HSI) developed previously, from the expert knowledge of anglers, was calibrated to the attributes of each site where Australian bass were observed. For the initial $HSI_1$ no limitation level is proposed. $HSI_1$ values are very low and range 0.02-0.07. An alternative HSI model ($HSI_2$) is proposed such that the threshold for an individual factor becoming limiting is set at 0.4, all observations become limited by, and restricted to, the substrate component ($V_B$). $HSI_2$ values are still low and range from 0.2-0.3 for observed Australian bass habitats in Table 7.3.

Taking into account the opinion of 21% of anglers, which said that substrate was unimportant, we propose a third, simpler HSI model ($HSI_3$) that does not contain the substrate variable ($V_B$), but retains variables for depth, velocity and proximity-to-cover. $HSI_3$ values are higher, but still low for observations No.1 and 4. (Table 7.4) ($HSI_3$: 0.35-0.98).

To further calibrate the HSI to better fit observations No.1 and No. 4 (Table 7.4) the limiting value could be relaxed to 0.3 ($HSI_4$). This removes the depth limitation for these observations and provides HSI values of 0.69-0.98 for the four habitats where Australian bass were observed.

**7.3.2.4 Habitat data collection through radio-tagging**
Only a single Australian bass was implanted with a radio-transmitter at Wall Creek on 17 February 2004. This Australian bass was absent from the release site on the next and subsequent visits, and could not be located from other vehicle/boat access points in the area. Preliminary data from acoustic and radio-tagged Australian bass shows that movement away from the release site seems to be normal even under stable and low river flows.

# 7.4 Discussion

## 7.4.1 Movement

Individual Australian bass show movement behaviours far more complex than simple models of mass catadromous spawning migration might suggest (Harris and Rowland 1996). Behaviour of some Australian bass in the first 80 km of freshwater can be described as "reach resident" or having a temporary home-range. They were repeatedly observed, for a number of weeks or months, at a given location. A minority of individuals were 'nomadic', making repeated transitions from estuarine to riverine habitats during April-September over at least 50 km of river.

**7.4.1.1 Movement scale and behaviour**
Australian bass make catchment scale movements (ie. 10s of km) at all times of the year, in both upstream and downstream directions, sometimes within a few days. These movements may sometimes coincide with increased flows, but not always. Such movements may be important behaviour, related to many other factors in addition to spawning (eg. habitat choice, water-quality, feeding etc). Of the three significant flow peaks during this study, most movement was noted to coincide with the first flow-peaks of autumn. This prompted upstream movement followed by a net downstream movement for some fish; or disappearance after a long period of residence; or appearance after a long period of absence, for others. This increase in movement may simply be fish seeking new resources at the first significant opportunity after a sustained summer low level. The poor water-quality associated with the autumn flow-peak (P. Brown observed high turbidity and sediment-load originating in flows from the Buchan River) may also have caused fish downstream of the Buchan River to move to find better water quality. The subsequent winter flow peak was also coincident with re-appearance of absent tagged fish indicating further catchment scale movements. However, most fish showed no response to a spring flow-peak in September.

**7.4.1.2 Movement and reproduction**
Geographic segregation of the sexes outside the spawning season now seems unlikely in the Snowy River catchment, despite such observations for Australian bass generally (Harris and Rowland 1996). Sex was ascertainable in a number of fish during the tag implantation. Acoustic tagged females #217, #220, and #228 were mainly observed within 50 km of the ocean throughout the study. Males #230, #227 and #224 remained >80 kms from the ocean all of the time. However, no males were confirmed as Australian bass. Two were putative Australian bass and one was determined to be an F1 hybrid. It is possible that not all F1 hybrids develop and display what is reported as normal Australian bass sexual behaviour (ie. geographic segregation).

During the late winter (28 July) until the end of study (4 October) some estuarine visits, and periods of estuarine-residence from a number of Australian bass may indicate a phase of reproductive behaviour. Although these movements did not always coincide with flow-peaks, the base flows had increased to >1000 ML/d during this period. To support the assertion about the timing of reproduction, seventeen Australian bass were collected from the freshwater reaches of the Snowy River and Cabbage Tree Creek shortly after this study had finished (29–31 October). Based on external examination three males were running with milt and at least one female had recently spawned (ie. abdomen flaccid, vent red and swollen). Therefore, migration and the subsequent spawning season may extend from the end of July through to at least the end of October.

Five acoustic-tagged Australian bass that were observed downstream of the sand-slug after 28 July were logged near Marlo Jetty, Second Island, Little Snowy confluence and Lochend and in the Brodribb River at the confluence of Cabbage Tree Creek and at the boat ramp. This may indicate that the spawning area is within the reach defined approximately by Lochend downstream to Marlo and up the Brodribb River to the Cabbage Tree Creek.

**7.4.1.3 Daily behaviour**
The acoustic telemetry data also provided clear evidence of diel activity patterns in Australian bass and their hybrids in the Snowy River. However, care must be taken in how these data are interpreted. The primary purpose of the VR2s was to monitor large-scale movements, and they were not randomly situated. Most were deployed in pool habitat and associated with overhanging trees or other structures (by necessity of the installation method). From telemetric studies of related species such as estuary perch, and observations of Australian bass made by anglers, it seems likely that the cycle of increased detection rate observed during the hours of darkness may indicate increased activity at a habitat-unit scale. Most detections of an individual Australian bass were on a single VR2 for a given 24 hr period. Activity cycles may therefore indicate a nocturnal increase in the proportion of time spent near VR2s, in pool habitats with overhanging riparian-structure, however, only at a scale relevant to a single VR2 (ie. ~200 m).

**7.4.1.4 Speed**
Average speeds recorded by Australian bass are very fast compared to acoustic-tagged estuary perch in the Snowy River, and radio-tagged golden perch in Lake Eildon (0.02–2 km/h) (John Douglas unpublished observation). Burst speed swimming ability of juvenile Australian bass (~93mm TL) was determined as 0.12 km/h in an experimental fishway (Mallen-Cooper 1992). However, speeds measured in the present study are of adult Australian bass (>300 mm TL) travelling between VR2s, and give an indication of the speed of 'travelling' fish, as opposed to small scale feeding movements etc. Some of these downstream movements were also coincident with high flows, which may have assisted downstream passage for individual fish.

Despite tagged fish occasionally being able to skip past some VR2s, the present array of VR2s was a success. They identified catchment-scale movements of 30-80 km, reach scale movements of 1–30 km and habitat scale movements via patterns of presence and absence around individual VR2s. In testing, the successful decoding of tags by individual VR2s occurred at ranges of at least 100 m. To avoid code-collisions from nearby tags, the pings occur at random intervals every 90-180 seconds apart. For fish to slip past undetected (ie. skip) they would have to pass through the whole field of detection (2 x 100m = 200m) within the period between pings (90-180 seconds). The average travelling speeds for Australian bass moving between VR2s was 4.5 km/h and 3.6 km/h, downstream and upstream respectively. A speed of 4 km/h is equivalent to a fish travelling 133–200 m within the period between pings. Therefore it seems likely that speed alone could easily account for avoidance of detection. For a better detection rate, tags with a shorter delay between pings could be used. However, the compromise is that such tags would have greater power requirements and therefore tags of equivalent size would have a shorter lifespan. One advantage of the present study is that tags will enable replicate behavioural observations on the same fish over two spawning seasons. An alternative may be to site the VR2s at points where fish are likely to hesitate during migration such as immediately below rapids. A trade-off here may be the reduction in decoding efficiency caused by acoustic background noise from the rapids.

**7.4.1.5 Barriers to movement in the lower river**
The 'sand slug' can be variously defined but at its worst it lies between Orbost and Wood Point. The sand slug doesn't seem to be a barrier preventing migration and movement of adult Australian bass. The exact timing and therefore flow conditions prevalent, when fish crossed, is usually unknown. However, many adults crossed upstream when flows were between 284-2062 ML/d. Some crossed multiple times upstream and downstream sometimes very rapidly. Fish #219 swam from Wall Creek to Marlo Jetty (a distance of 45 km) in 11 hours with a flow of ~1100 ML/day on the Jarrahmond gauge. The same fish then returned upstream over three days when flows were between 1000 and 1500 ML/d at Jarrahmond. While it has been hypothesised that the sand slug reach may be a barrier to adult Australian bass, as it lacks the large-scale cover and depth preferred by large fish, such fish can potentially traverse the ~16 km quicker than small individuals. This strategy may therefore limit their exposure to unsuitable habitat. Juvenile Australian bass may have lesser needs for depth, but greater need for refuge cover in the sand slug reach, as their poorer swimming abilities would increase

the time they must spend to ascend, and therefore their exposure to predators.

## 7.4.2 Habitat

### 7.4.2.1 Radio tagging

The single radio-tagged fish rapidly disappeared from all accessible sites. Given the rate of movement of this fish it was not practical, within the resources of this project, to develop detailed habitat maps of areas frequented by individual Australian bass. The radio-tagging was abandoned as a method of collecting habitat-use observations. The method may still have merit for future research, however, such a project would need to use alternative long-range searching strategies for fish (eg. use of light aircraft followed by canoe downstream through otherwise inaccessible areas) and a substantial number of tags to increase observations.

### 7.4.2.2 Visual Observation

When compared with overall catch-rates from other fisheries and other species, catch rates of Australian bass in the lower Snowy River catchment from a range of methods (eg. netting, electrofishing, angling) suggest that abundances of Australian bass range from low to moderate at best. Low abundance of adult Australian bass may partially explain the low numbers of underwater-observations achieved by snorkel swimmers. Similar methods have been successfully employed for surveying the habitat requirements and relative abundance of many riverine fish species (Dolloff *et al.* 1996, Teirney and Jowett 1990, Young and Hayes 2001).

Other factors, such as observer-disturbance, may also be important in the low observation rate of Australian bass by swimmers. Avoidance of swimmers by Australian bass was noted, by wading-observers during some preliminary swims in the summer of 2002–03, and steps were taken to minimise disturbance by:

- using an upstream crawling method rather than the downstream drift, and
- minimising the number of swimmers to one or two.

Despite this, some Australian bass were seen to flee divers and these could not be used in subsequent habitat analysis. On at least one occasion, a careful swim through some large woody debris produced no observations; whereas a deftly cast fishing lure, 30 minutes later, showed the presence of Australian bass at the same site. Poor visibility was probably the most limiting factor in the success of underwater observation as an approach. Perhaps the preliminary swims and training that took place prior to the major bushfires in summer 2003 raised a false confidence in the potential of this method. In the Tambo River training session, underwater visibility approached 6 m. The following summer when snorkel surveys were attempted in the Snowy River, water-turbidity from bushfire-related sediment, was prohibitive on most occasions. Horizontal, underwater visibility was rarely >1.5 m.

### 7.4.2.3 Anglers perceptions of Australian bass habitat

Using experts' knowledge of fish habitat has many precedents. Expert opinion is often used in natural resource management in model construction (Yamada *et al.* 2003). Such input is routinely used as input to habitat evaluation procedures. Bovee (1986) described three categories of suitability criteria, based on the data types behind the criteria. Bovee's, type 1 curves are based on professional judgement/expert opinion, with little or no empirical data. Habitat suitability index curves for many species of fish in North America (eg. American shad, striped bass, shortnose sturgeon and paddlefish) were developed using the *Delphi technique* (Crance 1987). The concept of the *Delphi technique* is based on the premise that "opinions of experts are justified as inputs to decision-making where absolute answers are unknown". Expert panels, have been used recently on the Snowy River and elsewhere in Australia to formalise, accumulate and describe experts' assessments' of environmental flow requirements (Anon 1996, Swales and Harris 1995). The experience level that anglers have with their fishery is often correlated to their fishing success (Douglas 2004, Douglas and Hall 2004). One assumption made in the present study is that anglers with more experience, and hence more success, are probably better assessors of Australian bass habitat than inexperienced anglers. This only applies if the anglers use habitat cues to choose their fishing location and all respondents did.

Anglers clearly had an appreciation of the diel behavioural differences of Australian bass. The day-habitat suitability curves describe refuge habitat, whereas the night-habitat suitability curves describe habitat used by more active Australian bass. This activity is likely to include mainly feeding behaviour.

At night, the high suitability of habitats where cover-proximity at scales of >10 m may reflect many anglers' views that fish move away from cover into the open water of pools and riffles at night. Some anglers' views may also be biased by the fact that they avoid areas of cover at night to lessen tackle-losses, and that unless they know the river very well, they are unaware of the proximity to cover in the dark.

These suitability curves can be used singly to assess qualitative changes in Australian bass habitat due to changes in individual habitat attributes (eg. in a rehabilitation exercise). Alternatively, and perhaps more usefully, they can be combined in an overall Habitat Suitability Index, or Model. The combination can be achieved by using the individual curves as input into habitat simulation software, such as PHABSIM (Shuler and Nehring 1993), or RHYHABSIM (Brown 2003), or by using the HSI to calculate an overall suitability index for a given habitat.

Some of the assumptions used in calibration of HSI using the Australian bass observations by snorkelers are:

- Australian bass that were observed by snorkelers were in highly-suitable day-time habitat, and
- the suitability of habitat relates to physical habitat only, no other limiting factors are relevant (barriers to migration, water quality and quantity, etc).

Since only daytime observations and measurements associated with Australian bass-in-habitat were made, a model for night-time habitat could not be calibrated. The assumption remains that the anglers' perceptions of habitat quality at night are valid. Aspects of it are supported by capture of Australian bass in nets around dusk in open water pools, several metres away from cover. More day-time and nocturnal observations of Australian bass locations should be obtained to better calibrate the preliminary HSI model proposed.

## 7.5 Conclusions

- While they may occupy temporary home-ranges for durations of weeks-months, Australian bass move frequently and rapidly around the Snowy River catchment, sometimes, but not always, in response to increased flows.
- Downstream movement and spawning in the Snowy River may occur from the end of July until at least end of September; in 2004 this corresponded to a period when base flows were elevated above 1000 ML/d at Jarrahmond.
- Adult Australian bass successfully negotiated the sand-slug both downstream and upstream under a wide range of flow conditions.
- Acoustic-tagging and remote listening stations/data loggers are a useful and valid way of collecting life-history information about Australian bass populations in the Snowy River.
- Acoustic-tagged Australian bass show strong circadian patterns of behavior that may reflect their increased nocturnal activity.
- Habitat suitability curves are presented for use in habitat simulation modelling and assessment systems (eg. PHABSIM, RHYHABSIM etc).
- Habitat suitability for adult Australian bass in the streams of south-eastern Australia is high during the day for sites >0.9 m deep; with water velocities of <0.5 m/s; over cobble, boulder and bedrock substrates; within 1 m proximity of physical cover such as large submerged logs, shade from overhanging trees or boulders and rock-ledges.
- Habitat suitability for adult Australian bass in the streams of south-eastern Australia is high during the night for sites >0.6 m deep; with water velocities of <0.3 m/s; over gravel and bedrock substrates; within 10 m proximity of physical cover such as large submerged logs, boulders and rock-ledges or submerged macrophyte beds.
- More diurnal and nocturnal observations of Australian bass locations should be obtained to better calibrate the preliminary HSI model proposed.

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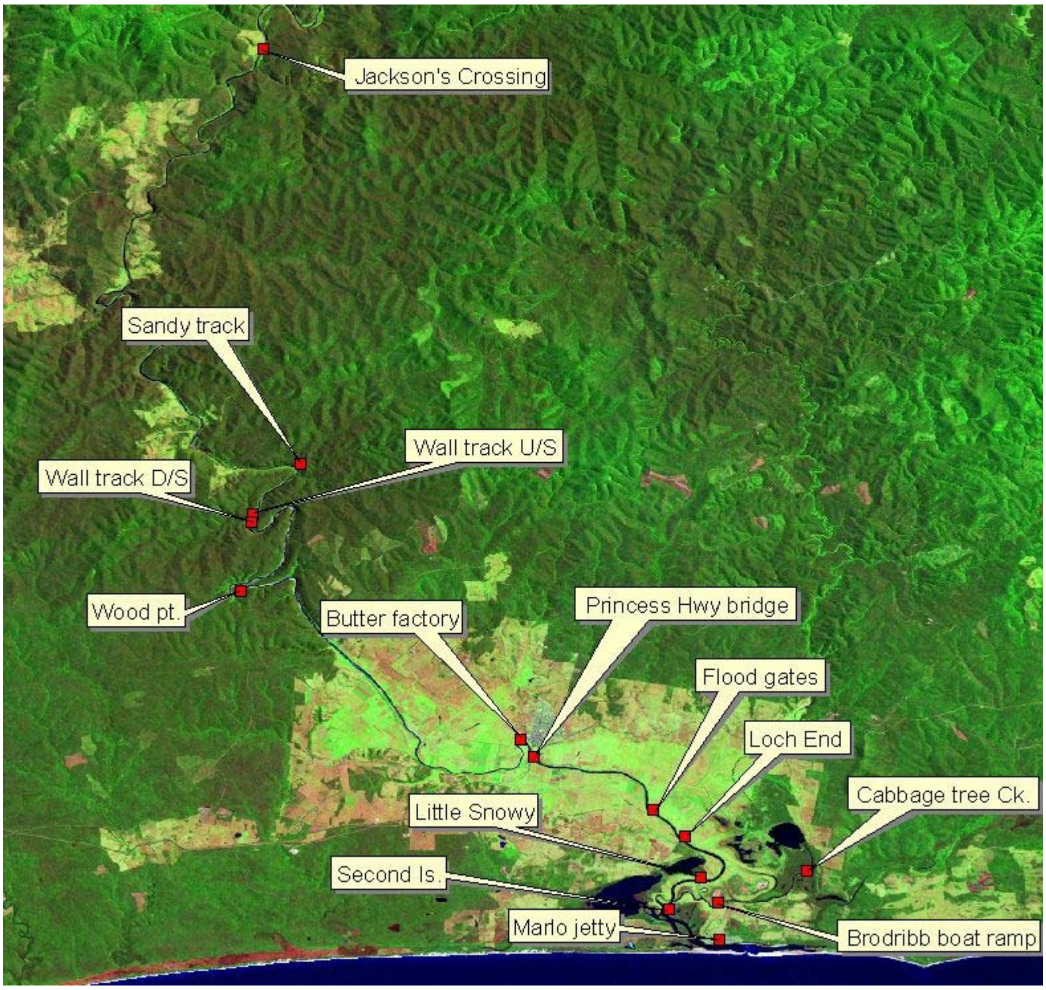



**Figure 7.1 Locations of an array of acoustic listening-stations (Vemco, VR2) deployed along the Snowy River.**


**Figure 7.2 A VR2 acoustic listening station.**

**Table 7.1 Identification code, and geographic position of each acoustic listening-station.**

| VR2 | Location | River-distance from ocean (km) | Latitude | Longitude |
|---|---|---|---|---|
| 3287 | Snowy River, Marlo Jetty | 1.3 | -37.798100 | 148.534745 |
| 3288 | Snowy River u/s Second Island | 4.1 | -37.784517 | 148.512539 |
| 3293 | Snowy River u/s Little Snowy | 6.6 | -37.770321 | 148.526322 |
| 3289 | Brodribb River, boat ramp | 8.5 | -37.781250 | 148.534167 |
| 3292 | Snowy River, Lochend | 10.1 | -37.752417 | 148.519283 |
| 3291 | Snowy River, floodgates | 12.0 | -37.740300 | 148.505367 |
| 3290 | Brodribb River below Cabbage Tree Ck | 12.8 | -37.767327 | 148.573450 |
| 3294 | Snowy River, Orbost bridge | 18.1 | -37.716940 | 148.452585 |
| 3285 | Snowy River u/s butter factory | 19.6 | -37.709717 | 148.446750 |
| 3283 | Snowy River, Wood Point | 37.8 | -37.643833 | 148.323333 |
| 3282 | Snowy River d/s Wall Creek | 46.5 | -37.613784 | 148.328069 |
| 3295 | Snowy River u/s Wall Creek | 47.0 | -37.610139 | 148.328542 |
| 3286 | Snowy River, Sandy Point | 50.1 | -37.588017 | 148.350017 |
| 3284 | Snowy River d/s Jackson's Crossing | 84.0 | -37.404408 | 148.333596 |


**Figure 7.3 The acoustic transmitter (V8SC) used to detect Australian bass in proximity to a VR2 listening station.**

**Table 7.2 Details of Australian bass captured and fitted with acoustic-pinger tags during 2004. Genetic results are from diagnostic DNA tests (Chapter 6).**

| Day | Capture/release location | Length (mm) | Weight (g) | Sex | Vemco code | Dart tag No. | Genetic results |
|---|---|---|---|---|---|---|---|
| 22 Jan | Wall Creek | 470 | 1870 | ? | 219 | 3438 | Australian bass |
| 22 Jan | Orbost butter factory | 460 | 1695 | F | 217 | 3440 | Australian bass |
| 22 Jan | Orbost butter factory | 430 | 1380 | F | 220 | 3439 | Australian bass |
| 17 Feb | Wall Creek | 418 | 1296 | ? | 221 | 3402 | Australian bass |
| 18 Feb | Sandy point | 408 | 1157 | ? | 225 | 3410 | Australian bass |
| 19 Feb | Sandy point | 275 | 377 | ? | 229 | 10964 | Australian bass |
| 19 Feb | Sandy point | 442 | 1626 | F | 228 | 3409 | Australian bass |
| 25 Feb | Jackson's Crossing | 367 | 812 | ? | 216 | 10962 | N/a |
| 25 Feb | Jackson's Crossing | 300 | 494 | M | 224 | 10992 | N/a |
| 25 Feb | Jackson's Crossing | 485 | 2193 | ? | 223 | 3408 | N/a |
| 26 Feb | Jackson's Crossing | 310 | 574 | M | 230 | 10999 | N/a |
| 11 Mar | Jackson's Crossing | 360 | 834 | M | 227 | 3401 | F1 Australian bass/estuary perch hybrid |
| 11 Mar | Jackson's Crossing | 403 | 1480 | ? | 218 | 3405 | F1 Australian bass/estuary perch hybrid |

**Figure 7.4 Large woody debris in the Snowy River, with school of Australian smelt (*Retropinna semoni*) in the foreground.**

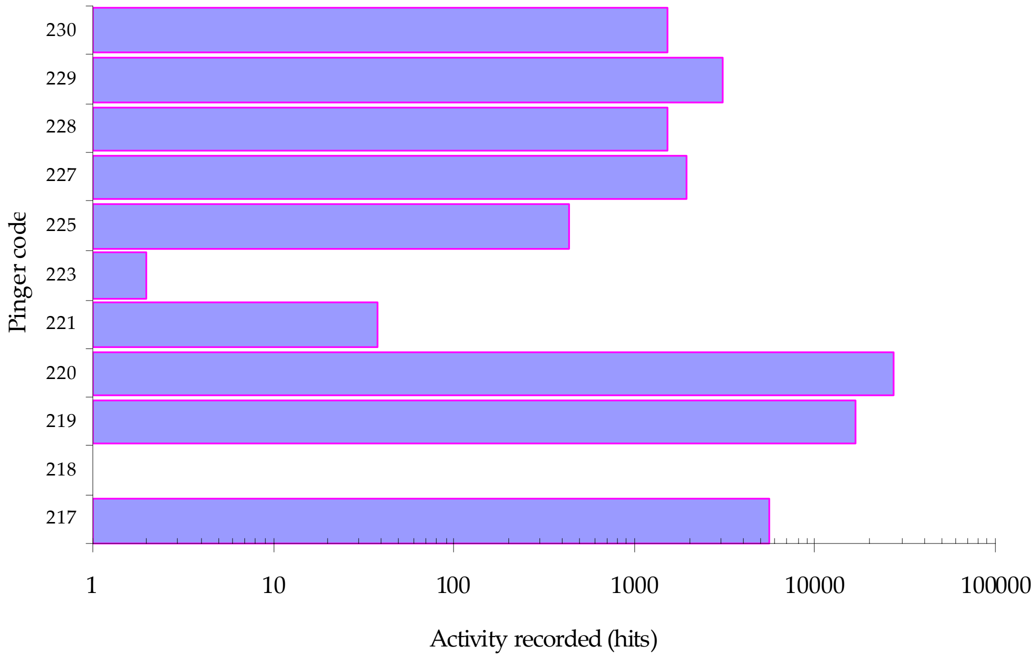



**Figure 7.5 Distribution of data 'hits' recorded to 5 October 2004 on the array of VR2s, by 11 of the 13 originally tagged Australian bass.**

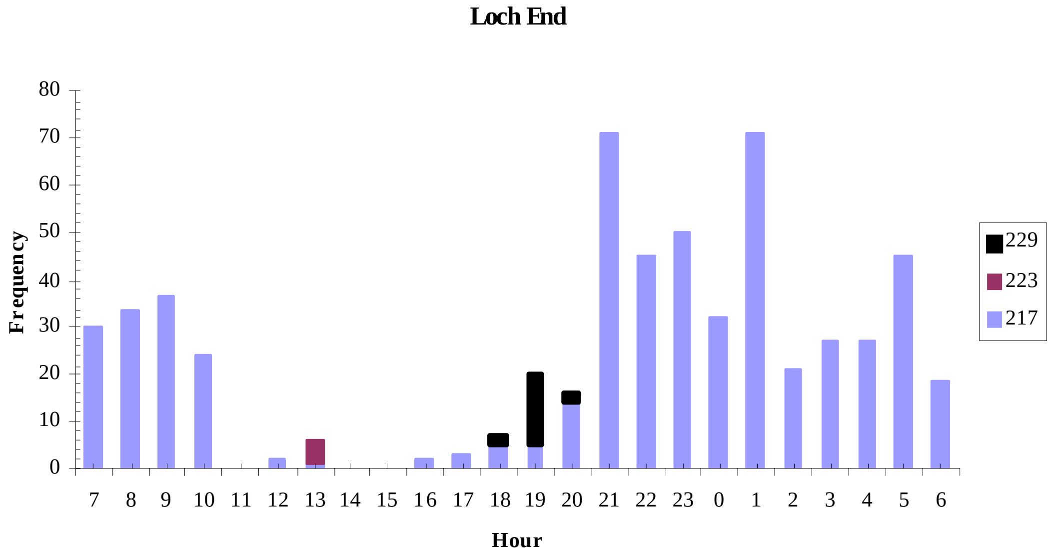



**Figure 7.6 The listening station at Loch End detected three Australian bass (#229, 223 and 217) during the study. The diel distribution of these 'pings' is shown as a frequency distribution. Hour 12=noon, 0=midnight.**

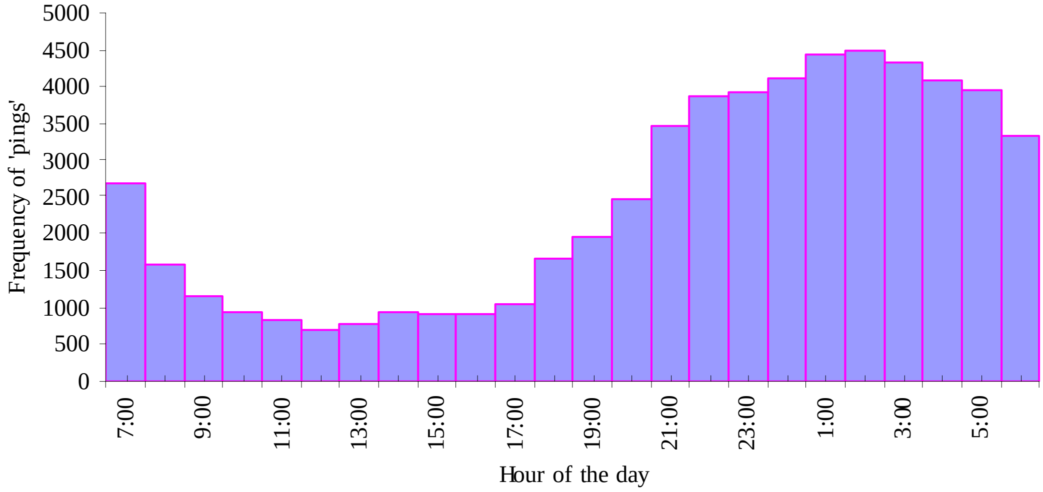



**Figure 7.7 Diel distribution of all detections for all Australian bass by all VR2 listening stations.**

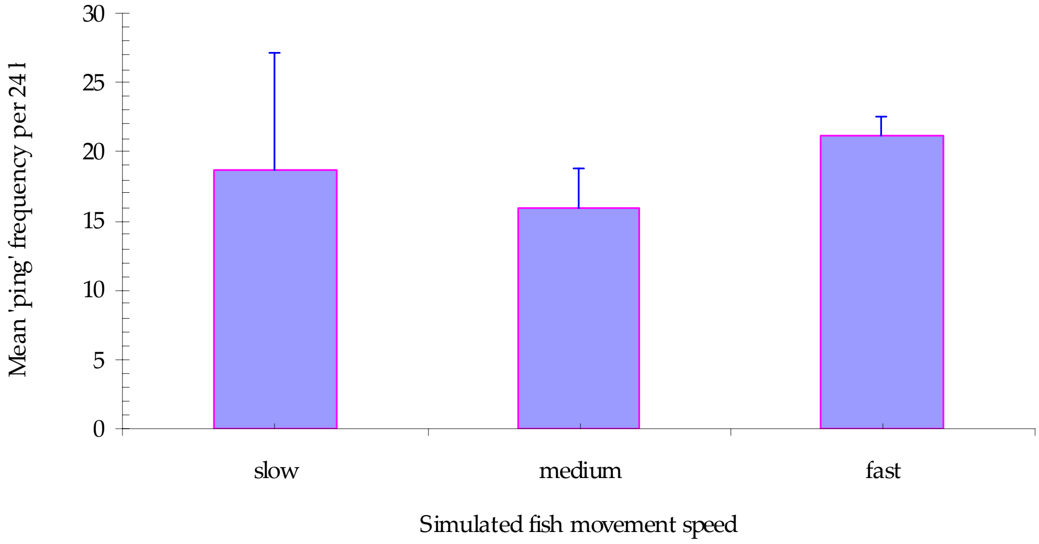



**Figure 7.8 Results of computer simulations of an acoustically tagged fish moving randomly at three different speeds within a river reach containing a single VR2. Simulations ran for 100 days in a reach 10 km x 0.1 km with a VR2 situated centrally with a detection range of 200m. Over each 3-minute timestep, 'slow' fish moved 20m; 'medium' fish moved 100m and 'fast' fish moved 500 m. Bars indicate mean detection frequency per 24 h period (+se).**

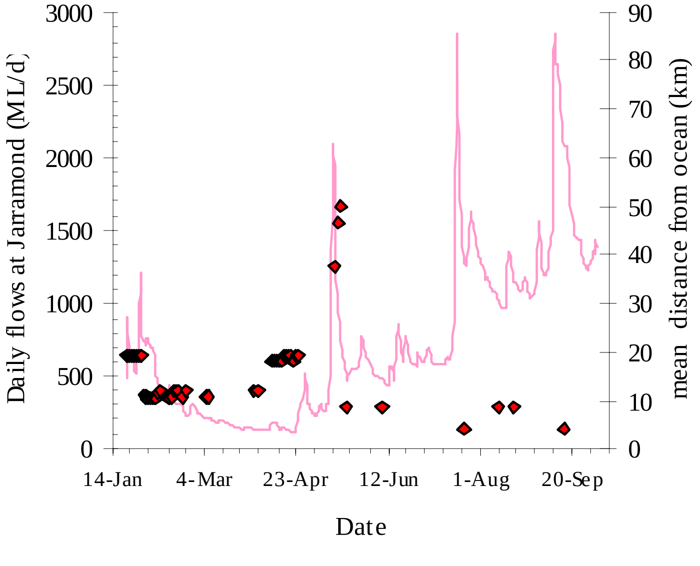



**Figure 7.9 Movement behaviour of Australian bass (#217). Data points represent river-distance from the ocean on a day when a pinger-code was detected within the range of a VR2. Curve is mean daily flow estimated from the Jarrahmond gauge (Theiss Hydrographic Services).**

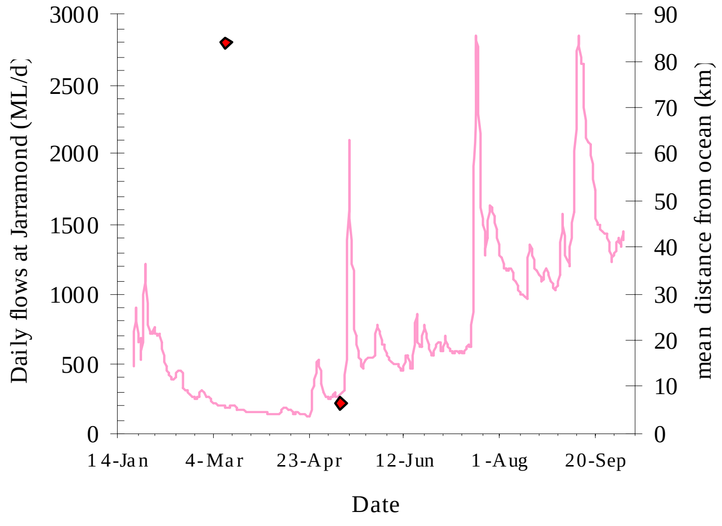



**Figure 7.10 Movement behaviour of F1 hybrid (#218). Legend as for Figure 7.9.**

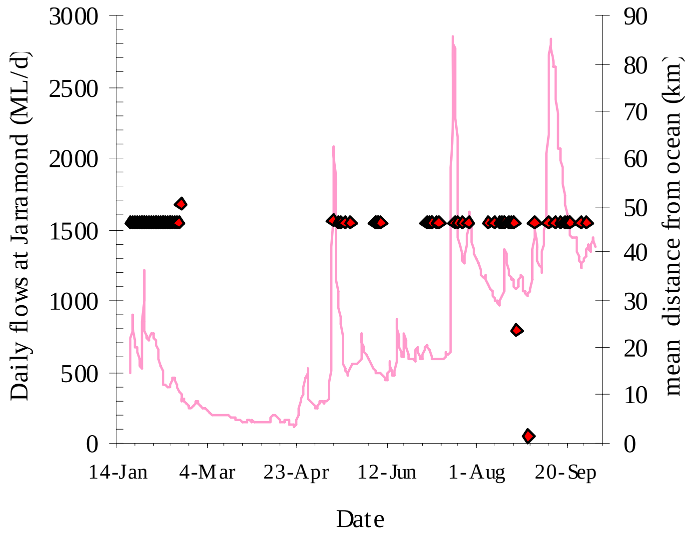



**Figure 7.11 Movement behaviour of Australian bass (#219). Legend as for Figure 7.9.**

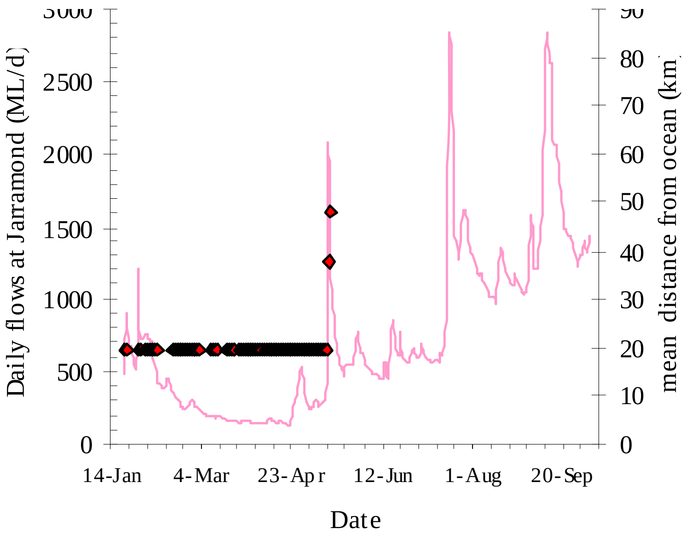



**Figure 7.14 Movement behaviour of Australian bass (#220). Legend as for Figure 7.9.**

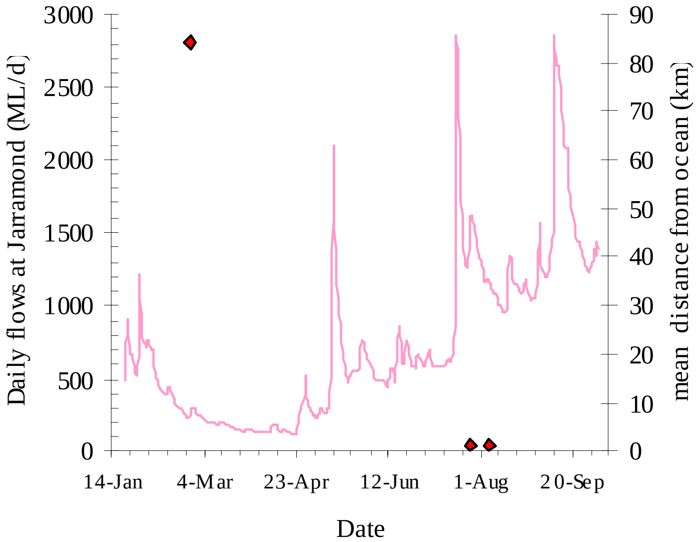



**Figure 7.12 Movement behaviour of putative Australian bass (#223). Legend as for Figure 7.9.**

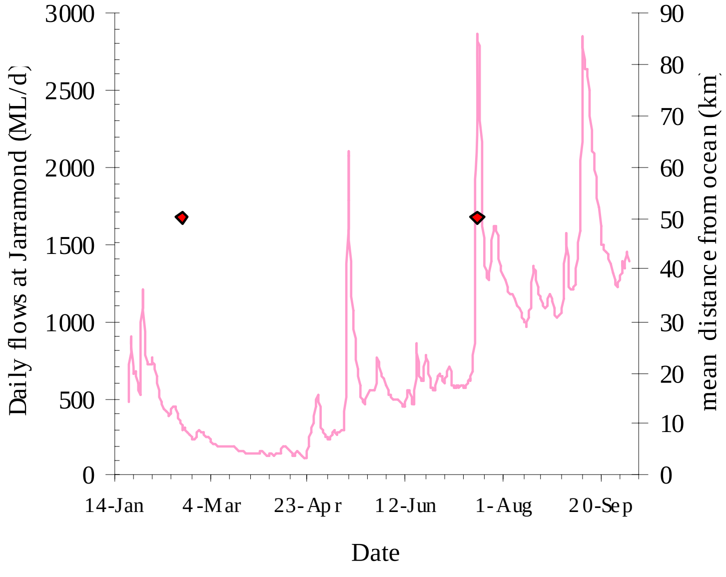



**Figure 7.13 Movement behaviour of Australian bass (#225). Legend as for Figure 7.9.**

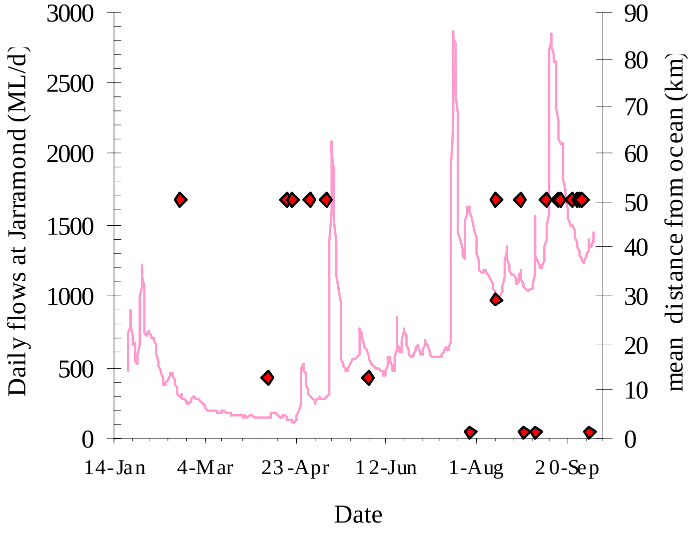



**Figure 7.14 Movement behaviour of Australian bass (#228). Legend as for Figure 7.9.**

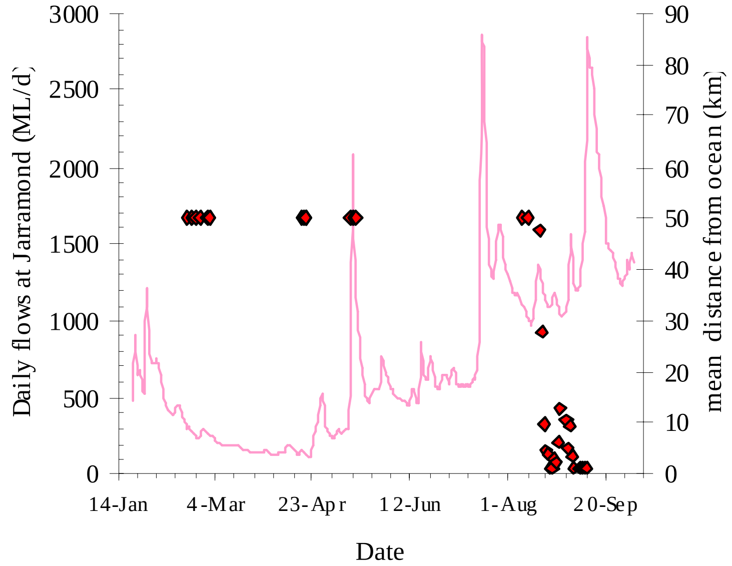



**Figure 7.15 Movement behaviour of Australian bass (#229). Legend as for Figure 7.9.**

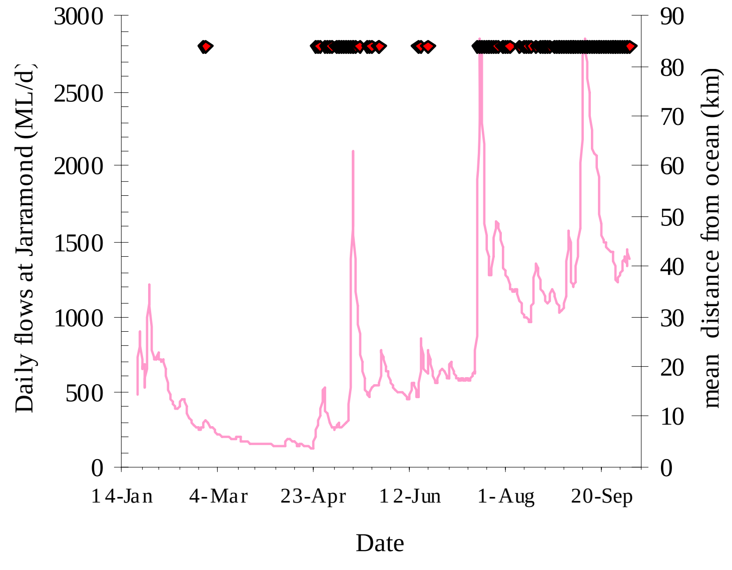



**Figure 7.16 Movement behaviour of putative Australian bass (#230). Legend as for Figure 7.9.**

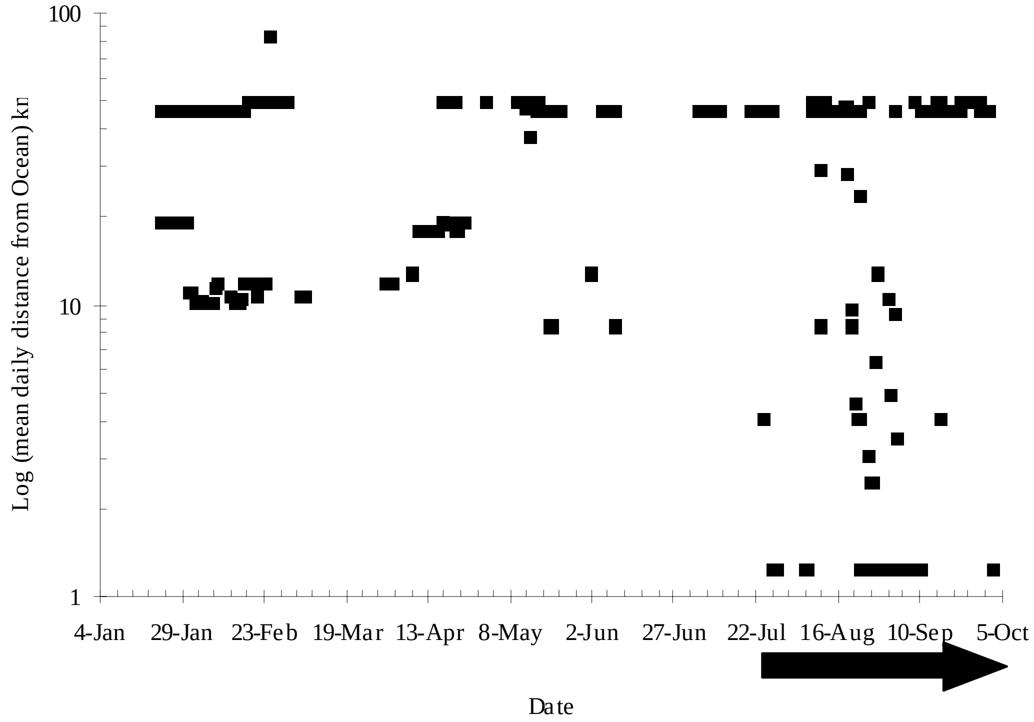
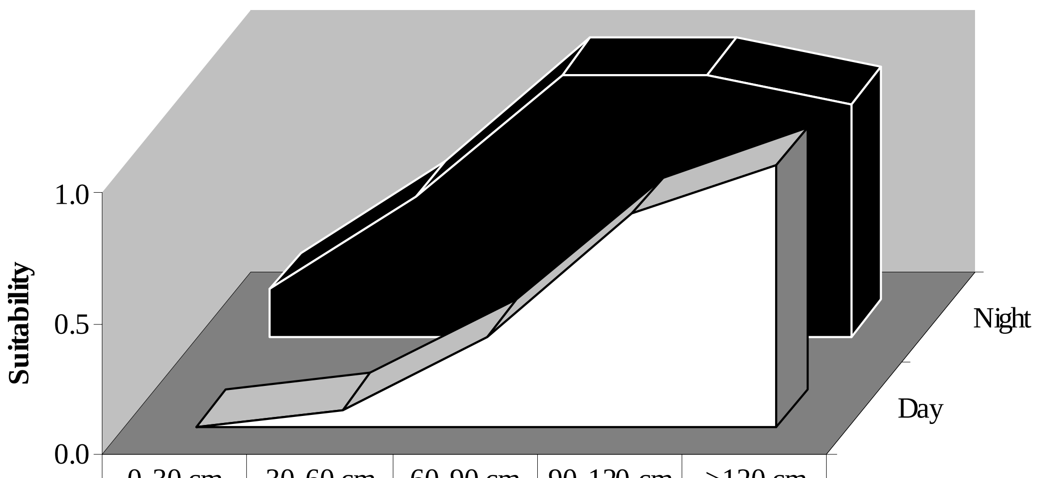
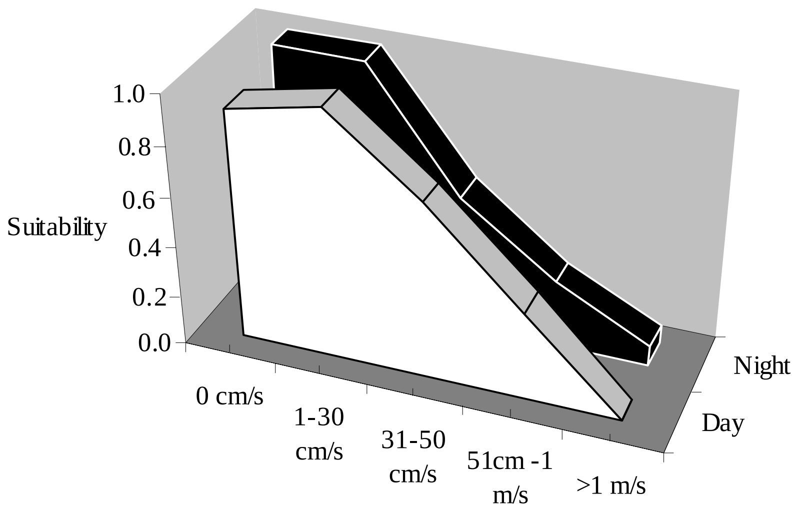



**Figure 7.17 The period when four Australian bass (#217, #219, #228 and #229), and one putative Australian bass (#223) that were tagged in freshwater, visited the estuarine waters of the Snowy River can be broadly defined as from end of July to at least the start of October (arrow). This may be connected with reproductive behaviour.**



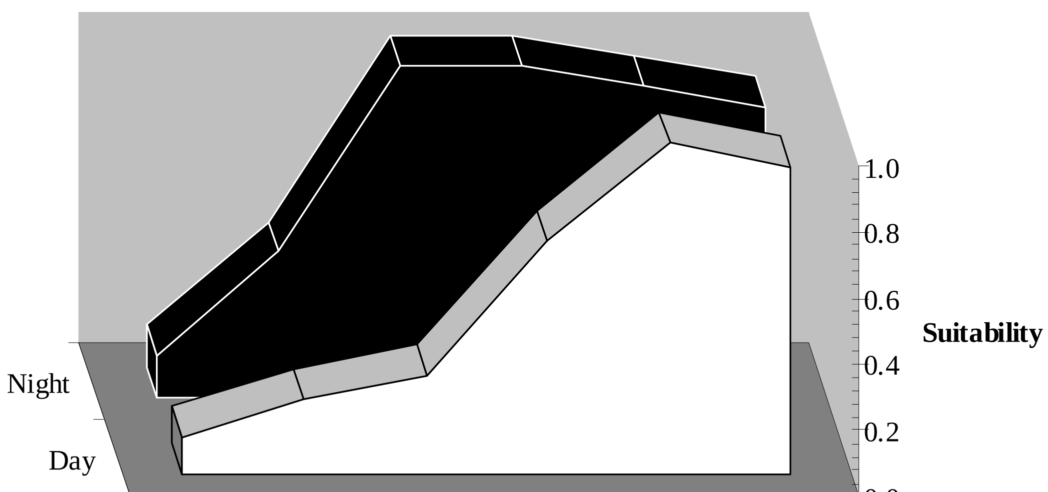

| | 0-30 cm | 30-60 cm | 60-90 cm | 90-120 cm | >120 cm |
|---|---|---|---|---|---|
| □ Day | 0.00 | 0.07 | 0.35 | 0.81 | 1.00 |
| ■ Night | 0.18 | 0.53 | 1.00 | 1.00 | 0.88 |

**Figure 7.18 Minimum water-depth, habitat suitability ($V_D$) curves for adult Australian bass during the day (white) and at night (black). Indices for the depth classes are indicated in the data-table.**



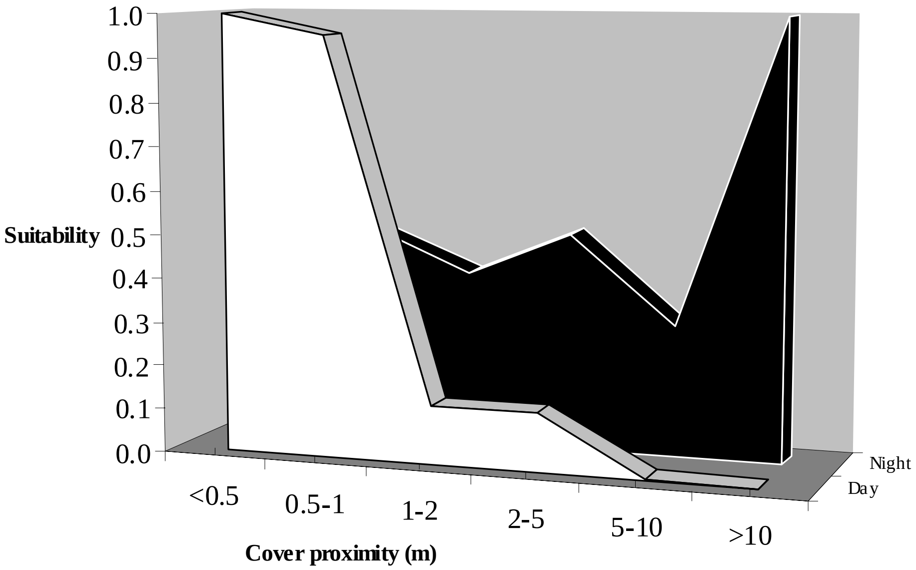

| | 0 cm/s | 1-30 cm/s | 31-50 cm/s | 51cm -1 m/s | >1 m/s |
|---|---|---|---|---|---|
| □ Day | 0.93 | 1.00 | 0.71 | 0.36 | 0.00 |
| ■ Night | 1.00 | 1.00 | 0.54 | 0.27 | 0.08 |

**Figure 7.19 Water-velocity suitability ($V_S$) curves for adult Australian bass during the day (white) and at night (black). Indices for the velocity classes are indicated in the data-table.**




| | mud/clay | sand | gravel | cobble | boulder | bedrock |
|---|---|---|---|---|---|---|
| □ Day | 0.11 | 0.22 | 0.30 | 0.70 | 1.00 | 0.93 |
| ■ Nigh | 0.13 | 0.44 | 1.00 | 1.00 | 0.94 | 0.88 |

**Figure 7.20 Substrate suitability ($V_B$) curves for adult Australian bass during the day (white) and at night (black). Indices for the velocity classes are indicated in the data-table.**




| | <0.5 | 0.5-1 | 1-2 | 2-5 | 5-10 | >10 |
|---|---|---|---|---|---|---|
| □ Day | 1.0 | 1.0 | 0.1 | 0.1 | 0.0 | 0.0 |
| ■ Night | 0.00 | 0.50 | 0.40 | 0.50 | 0.30 | 1.00 |

**Figure 7.21 Cover-proximity suitability ($V_C$) curves for adult Australian bass during the day (white) and at night (black). Indices for the proximity-classes are indicated in the data-table.**

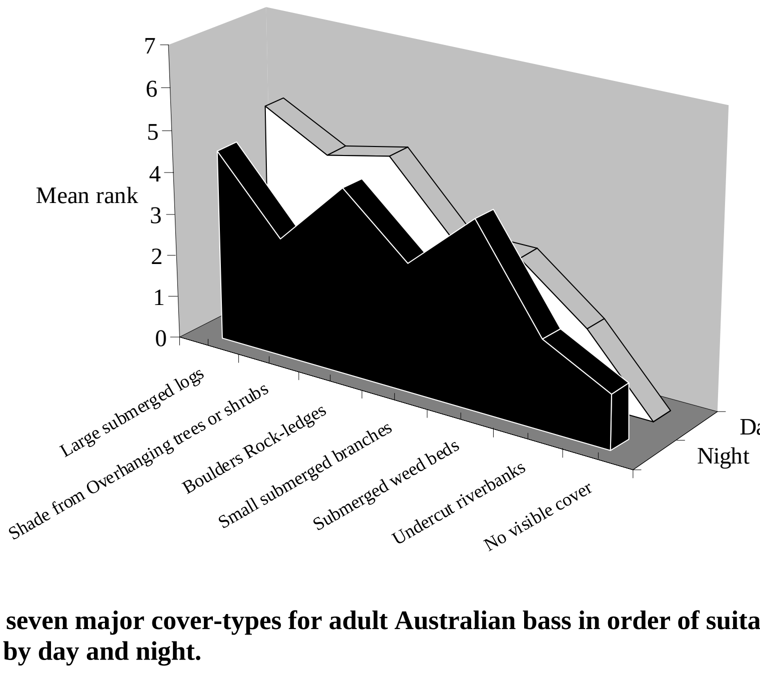



**Figure 7.22 Ranking seven major cover-types for adult Australian bass in order of suitability (Most suitable =7, least suitable =1) by day and night.**

**Table 7.3 Habitat description of Australian bass in the Snowy River observed by snorkel swimmers. First 3 observations were made at Wall Creek, the last at Jackson's Crossing.**

| Est. fish length (cm) | Water depth (m) | Fish depth (from surface) (m) | Water column velocity ['nose' velocity] (m/s) | Distance to bank (m) | Distance to cover (m) | Substrate | Cover description |
|---|---|---|---|---|---|---|---|
| 40 | 0.7 | 0.55 | 0 [0] | 1.5 | 0 (in cover) | Fine silt and leaf litter | Intersection of 3 logs (diam. 0.2–0.8 m). 2 hardwood and 1 willow log. Overhead cover sparse willow-canopy, providing partial shade |
| 35 | 1.0 | 0.85 | 0 [0] | 4.4 | 0 (in cover) | Sand and fine gravel | Scour hole under willow root-mat in centre of dense canopy of overhanging branches. In complete shade. |
| 40 | 1.4 | 0.5 | <0.05 [<0.05] | 5.4 | 0 (in cover) | gravel | In willow sticks and branches with fibrous roots within 1.2 m of canopy edge, in partial shade |
| 20 | 0.8 | 0.65 | 0 [0] | 2.5 | 0 (in cover) | gravel | Underneath root-mat near centre of a bushy clump of willow branches |

**Table 7.4 HSI models and their component variables used to assess the underwater observations of adult Australian bass in daytime habitat from Table 7.3.**

| Model component | Obs.1 | Obs.2 | Obs.3 | Obs.4 |
|---|---|---|---|---|
| $V_D$ | 0.35 | 0.81 | 1 | 0.35 |
| $V_S$ | 0.93 | 0.93 | 0.93 | 0.93 |
| $V_C$ | 1 | 1 | 1 | 1 |
| $V_B$ | 0.2 | 0.25 | 0.3 | 0.3 |
| $HSI_1 = (V_D \times V_S \times V_C \times V_B)^{1/4}$. **Unless (min<0.4) then = min** | ***0.20*** | ***0.25*** | ***0.30*** | ***0.30*** |
| $HSI_2 = (V_D \times V_S \times V_C \times V_B)^{1/4}$ | ***0.51*** | ***0.66*** | ***0.73*** | ***0.56*** |
| $HSI_3 = (V_D \times V_S \times V_C)^{1/3}$ **Unless (min<0.4) then = min** | ***0.35*** | ***0.91*** | ***0.98*** | ***0.35*** |
| $HSI_4 = (V_D \times V_S \times V_C)^{1/3}$ **Unless (min<0.3) then = min** | ***0.69*** | ***0.91*** | ***0.98*** | ***0.69*** |

## 7.7 Appendix

**Appendix 7.7A Australian bass habitat questionnaire.**

This survey will collect information on what you think makes good habitat for bass. We'd like you to be honest with us because we are not after your secret-spot! We are trying to learn about how to protect and rehabilitate stream habitat for bass. We will not ask you to name particular locations but we will ask you about the characteristics of sites that you know hold bass, because you have caught them there. In framing your answers, please consider the context as *Australian bass fishing in the streams and rivers of eastern Victoria and/or southern NSW*.

Please answer by circling the most relevant option (s) given.

**Your Fishing**

1. How many days (over the last 12 months) would you have spent fishing for Australian bass as a recreational angler? (circle one)

| | | | | |
|---|---|---|---|---|
| Up to 12 | 12–36 | 36–60 | >60 | 0 |

2. Over the last 5-years, how many days (on average) would you have spent fishing for Australian bass as a recreational angler? (circle one)

| | | | | |
|---|---|---|---|---|
| Up to 12 | 12–36 | 36–60 | >60 | 0 |
| (<=once a month) | (one to three times a month) | (3–5 times a month) | (>5 times a month) | |

On a given day some anglers may fish without targeting a particular species; some may fish to target a small range of species (eg. bream, estuary perch or bass); or some will target a particular species. When anglers are fishing for a species they often look for a particular 'type' of water that they believe may hold fish. This may be due to past-experience (ie. catching that species of fish in that location before), or because they judge the place to offer certain features that would make it attractive or 'habitable' by their target species.

3. When "*bass fishing*" do you target …(circle one)

| | | |
|---|---|---|
| Australian bass only | Australian bass and other sportfish (eg. Bream/Estuary perch) | ..or anything that comes along |

4. When Australian bass fishing do you *also* catch estuary perch? (circle one)

| | | | |
|---|---|---|---|
| never | occasionally | often | mostly |

5. If you catch one. How confident are you in identifying/diagnosing a Australian bass from an estuary perch? (circle one)

Very confident  Only sometimes confident  Often uncertain  Not very confident

6. Was your answer to the previous question based on where (how far upstream) the fish is caught? (circle one)

Mainly  Partly  Not at all

7. Seasonally speaking, what are the main times you fish for bass? (circle more than one if necessary)

Spring  Summer  Autumn  Winter

**Habitat Questions**

In answering this questionnaire we would like you to focus on physical features on a within-river scale. Don't try frame your answers thinking about "the whole river" but focus on the part of the rivers that you fish. Think about the characteristics of the bit of water you swim your lure or bait in rather than the whole reach you walk or boat through. Try and remember, or visualise, some of the spots where you have caught fish recently and use these to base your answers on. The questions refer to 'bass worth fishing for'; we'll call them adult bass.

On a river that you know holds bass, at a <u>new</u> Australian bass fishing location, where no one has told you where the Australian bass are, how do you pick where to fish? (circle one)

Try to fish every inch of water  Fish only where it's easy  Make decisions of where to fish based on what habitat I think Australian bass prefer

**Now try this scenario:**

I have just brought you to a new location. You've never fished it before and you have to try and work out what water is worth fishing to catch a bass. You can use whatever legal tackle you want to. We'll try and analyse categories of habitat separately (ie. depth, water velocity, substrate, cover, bankside and aquatic vegetation etc).

**Depth.**

With what importance do you regard water depth in choosing to fish a location for bass? (circle one)

| | | | | | |
|---|---|---|---|---|---|
| **Daytime** | not important | slightly important | important | very important | vitally important |
| **Night time** | not important | slightly important | important | very important | vitally important |

We have assumed that maximum depth is not a limiting factor for bass, even though it may effect your decision, due to lure running-depth etc. However, there may be a minimum depth below which you wouldn't consider fishing.

What depth (s) of water you would consider may hold Australian bass (circle more than one if necessary)?

| | | | | | |
|---|---|---|---|---|---|
| **Daytime** | 0–30 cm (0–1′) | 30–60 cm (1–2′) | 60-90 cm (2–3′) | 90–120 cm (3–4′) | >120 cm (>4′) |
| **Night time** | 0–30 cm (0–1′) | 30–60 cm (1–2′) | 60-90 cm (2–3′) | 90–120 cm (3–4′) | >120 cm (>4′) |

**Velocity.**

With what importance do you regard water velocity in choosing to fish a location for bass? (circle one)

| | | | | | |
|---|---|---|---|---|---|
| **Daytime** | not important | slightly important | important | very important | vitally important |
| **Night time** | not important | slightly important | important | very important | vitally important |

Water speed or velocity can be difficult to estimate, let alone 'imagine', without the proper equipment. To make it more realistic consider it in terms of how confident you would be to fish the different categories. In other words, which ones would be worth fishing for Australian bass (eg. still water, gently flowing, swiftly flowing..etc)

Which water speed(s) would you fish for Australian bass with reasonable confidence (circle more than one answer if necessary)? (circle more than one if necessary)

| *Category description* | *Dead still* | Gently flowing | *Flowing (eg swirly surface, current lines)* | *Swiftly flowing (eg. wavy broken surface, run)* | *Very fast (eg. torrential, boils and standing waves, white water)* |
|---|---|---|---|---|---|
| **Daytime** | 0 cm/s | 1–30 cm/s | 31–50 cm/s | 51cm –1 m/s | >1 m/s |
| **Night time** | 0 cm/s | 1–30 cm/s | 31–50 cm/s | 51cm –1 m/s | >1 m/s |

**Substrate (i.e. composition of stream bed –eg. sand, gravel, rock etc)**

With what importance do you regard the composition of the stream bed when choosing a location to fish for bass? (circle one)

| | | | | | |
|---|---|---|---|---|---|
| **Daytime** | not important | slightly important | important | very important | vitally important |
| **Night time** | not important | slightly important | important | very important | vitally important |

Over what types of streambed substrate would you confidently fish forAustralian bass(circle more than one answer if necessary)?

| Category definitions (particle diameters, mm) | <0.06 mm | 0.06–2mm | 2–64 mm | 65–264mm | >264mm | |
|---|---|---|---|---|---|---|
| **Daytime** | Mud, silt or clay | sand | gravel | cobbles | boulders | bedrock |
| **Night time** | Mud, silt or clay | sand | gravel | cobbles | boulders | bedrock |

**Cover (Refuge structure)**

With what importance do you regard the proximity to, and presence of, cover structure when choosing a location to fish for bass? (circle one)

| | | | | | |
|---|---|---|---|---|---|
| **Daytime** | not important | slightly important | important | very important | vitally important |
| **Night time** | not important | slightly important | important | very important | vitally important |

Please rank (1=most preferred to 7=least preferred) the types of physical cover to which you would confidently fish for bass? (NB: Equal ranks are allowed)

| Cover type | Boulders Rock-ledges | Small submerged branches | Undercut riverbanks | No visible cover | Large submerged logs | Submerged weed beds | Shade from Overhanging trees or shrubs |
|---|---|---|---|---|---|---|---|
| **Daytime** | | | | | | | |
| **Night time** | | | | | | | |

List here any other ‘favourite’ types of cover …………………………………………………
……………………………………………………………………………………………………………………………………………………………
……………………………………………………………………………………………………………………………………………………………
………………………………………………………………………………………………………………………………………………………

When fishing for bass, what is the furthest distance from cover that you would confidently fish a bait or lure? (circle one)

| | | | | | | |
|---|---|---|---|---|---|---|
| **Daytime** | <0.5 m | 0.5 m–1 m | 1–2 m | 2–5 m | 5–10 m | >10 m |
| **Night time** | <0.5 m | 0.5 m–1 m | 1–2 m | 2–5 m | 5–10 m | >10 m |

**Thanks very much for your help, and your time**.

Lastly, is there **anyone else** that you feel could valuably contribute to this survey (Name and contact telephone No.)?
……………………………………………………………………………………………………………..

While the above data will always be treated anonymously, if you wish to receive a copy of the report please supply your name and address: ………. ………
……….. ………. ………… …….