A guide to the management of native fish:
Victorian Coastal Rivers and Wetlands

2007

A Guide to the Management of Native Fish: Victorian Coastal Rivers, Estuaries and Wetlands

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EXECUTIVE SUMMARY

The rivers, estuaries and wetlands that occur south of the Great Dividing Range (GDR) in coastal Victoria, play a vital role in the social, economic and environmental health of the State. However, the health of these systems is declining due to a number of threatening processes. Threatening processes such as water extraction, clearing of native vegetation, landuses which increase nutrient loads and the introduction of alien flora and fauna, have all reduced the quality of these ecosystems. This in turn has led to a decline in the health and diversity of flora and fauna reliant on these aquatic habitats. There are over 500 plants and animals currently listed as threatened under the State's *Flora and Fauna Guarantee Act 1988*, with over 20% of the plants and 35% of the animals thought to be dependent on aquatic or riparian ecosystems.

The rivers, estuaries and wetlands of the coastal catchments of Glenelg Hopkins, Corangamite, Port Phillip, Westernport, West Gippsland and East Gippsland currently support 27 native freshwater finfish, 40 large native freshwater decapods, seven freshwater bivalve molluscs and over 150 estuarine fish species. These species represent substantial social, economic and environmental value providing fisheries resources to the Victorian community and industry, as well as contributing to the biodiversity of aquatic ecosystems in these catchments. However many of these species are experiencing population declines. The exact causes of these declines are not well understood, however it is likely that the decreasing health of aquatic ecosystems in coastal catchments is reducing their ability to persist long-term. Addressing the problem of poor river, estuarine and wetland health in coastal catchments is therefore important to ensure the retention of the State's aquatic biodiversity and to ensure the social and economic values of these systems are maintained.

This guide is designed as a manual to assist local natural resource managers in the management of native freshwater and estuarine fish populations in their coastal catchments. The document contains valuable information on the distribution, biology and habitat requirements of native freshwater and estuarine finfish, large decapod crustaceans and large bivalve molluscs. Information is also provided on the impact of various threats on river health in general and on particular species. It is envisaged that this information can then be linked into the existing Victorian regional river health process, enhancing the effectiveness of the River Health Strategy (RHS) in providing integrated river health management. It provides a valuable information tool for all catchments south of the Great Dividing Range in Victoria and is supported by the Fish Assessment Support Tool (FAST), a web-based decision support tool which helps managers identify management activities aimed at protecting and enhancing populations of native freshwater and estuarine fish species using one of two approaches. The first approach will assist managers in planning standard on-ground works (e.g. bank stabilisation works) with the aim to minimise detrimental impacts to native fish species. The second

approach will assist in the prioritisation of on-ground works aimed specifically at protecting and enhancing native fish populations.

The guide is split into 5 main parts (A, B, C, D and E). Part A provides context to this guide explaining the scope, geographic boundaries and species which are considered. Part B outlines the existing policy and legislative framework for the conservation and sustainable use of native fish and examines in detail the current high priority threats to native fish. Part C outlines a suite of recommendations on the management of fish in coastal catchments of Victoria. Part D gives summary information on the distribution, biology and habitat requirements of some of the key native freshwater and estuarine finfish, large decapods and large bivalve molluscs. Part D provides guidance on how current knowledge gaps can be addressed through various targeted research programs. The final section, Part E, provides a synopsis of the best approach to monitoring fish as part of various river management programs, and is intended to assist natural resource managers in the development of well designed and appropriately targeted monitoring programs.

The guide in combination with the web-based tool, FAST, will help provide the tools for regional resource managers to more effectively value their fish assets, set priorities and make informed and targeted decisions about native fish management. It is hoped that these two tools will become a valuable resource for those involved in the management of native fish and their habitats.

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1 Introduction

1.1 Fish habitat - the current condition of Victoria's coastal rivers, estuaries and wetlands

Healthy rivers, estuaries and wetlands are essential for maintaining native fish populations, and in a broader context play an important role in the social, economic and environmental wellbeing of Victoria. They provide valuable drinking and irrigation water, areas for recreation such as boating, swimming and fishing, and in many cases are important cultural areas for Indigenous communities. These waterbodies also support a large variety of plants and animals other than fish and provide vital ecosystem services such as water purification and nutrient cycling. Yet despite their value, all available evidence suggests that the health of Victoria's rivers and estuaries is declining. Based on the 2004 Index of Stream Condition (ISC), 32% of Victoria's rivers are considered to be in poor or very poor condition, while only 21% are considered to be in good or excellent condition (Figure 1.1: Department of Sustainability and Environment 2005a). In the coastal catchments south of the Great Dividing Range (including the catchments of Corangamite, Glenelg Hopkins, Port Phillip, Westernport and East and West Gippsland), 30.6% of Victoria's rivers are rated as very poor to poor, while only 26% are considered in good condition (Victorian Government 2006).

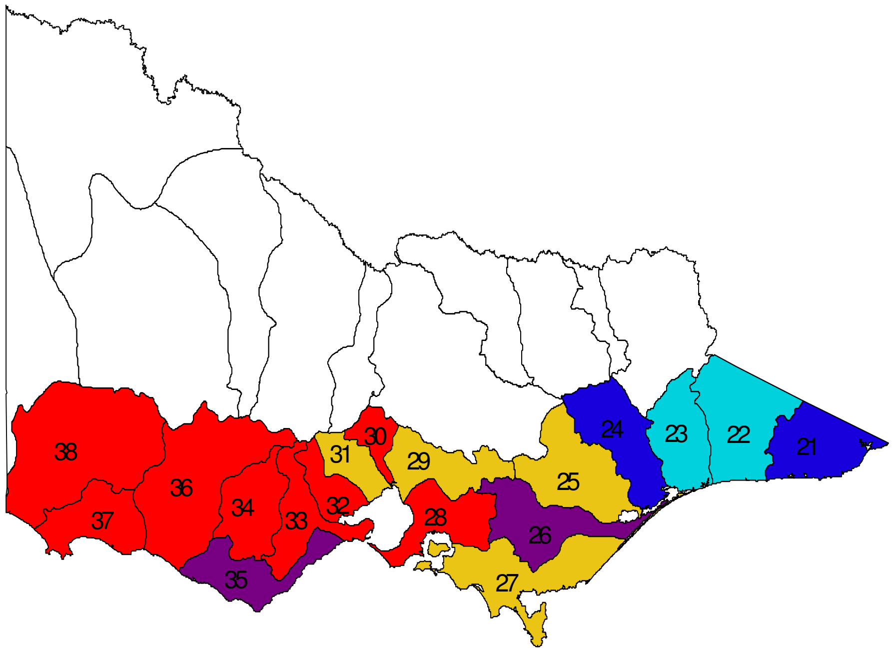
Victorian estuaries are similarly affected, with a strong correlation between the extent and utilisation of catchment land and estuarine condition. Approximately 45% of Victoria's estuaries are considered modified or highly modified (Figure 1.2: National Land and Water Resources Audit 2002a). Highly modified estuaries are generally associated with large, extensively developed catchments, often with intensive development on and around their floodplains. The most extensively modified estuaries are located in West and Central Victoria (National Land and Water Resources Audit 2002a). These estuaries typically receive excessive sediment and nutrients from agricultural and urbanised areas. With the exception of the Gippsland Lakes which is considered extensively degraded, most estuaries located in the Gippsland region of the State are considered largely unmodified or near-pristine.

Wetlands in coastal Victoria are considered to be in a poor condition. Estimates suggest that in some areas of Victoria up to 73% of natural wetlands greater than one hectare have been removed or substantially modified (Norman and Corrick 1988). Very little information is available on the number of smaller wetlands that have been lost or degraded but it is likely that this figure is as high if not higher than that for larger wetlands. Wetland drainage is one of the primary processes involved in the loss and degradation of wetlands. Drainage schemes have typically been undertaken to promote agricultural expansion but they have been and continue to be undertaken for everything from flood mitigation through to urban development (Norman and Corrick 1988). Of the wetlands that remain in Victoria today, many continue to be subjected to a number of damaging processes, including; draining, clearing, grazing, high nutrient loads, pollutants, recreational pressures (boating, fishing, etc) and increasing human-induced salinisation. Since the work conducted by Norman and Corrick (1988) 20 years ago, no further comprehensive wetland surveys have been undertaken. Declines in wetland condition and number since then are likely to have been significant.

The declining health of our rivers, estuaries and wetlands is the result of the cumulative impacts of a number of human activities such as removal of instream habitat, clearing of native vegetation, water extraction, water flow control, infilling and draining of wetlands, the introduction of alien flora and fauna and land uses which increase nutrient loads to waterbodies. These activities have ultimately led to waterways that are characterised by changed flow regimes, poor water quality, degraded riparian zones, loss of channel form, poor instream habitat and low biodiversity.

The deteriorating quality of aquatic environments has contributed significantly to the declining abundance and diversity and the reduced distribution of a range of fish, birds and other plants and animals reliant on these habitats. To date over 200 plants and fauna native to Victoria are listed under the National *Environmental Protection and Biodiversity Conservation Act* 1999 (EPBC Act) and over 500 plant and animal taxa are listed as threatened under the Victorian *Flora and Fauna Guarantee Act* 1988 (FFG Act: Department of Sustainability and Environment 2007b). To date, there are 24 freshwater and estuarine fish species, and 18 freshwater aquatic crustaceans listed under the FFG Act. Of all items listed under this Act, approximately 20% of the plant taxa and 35% of the animal taxa depend on aquatic or riparian ecosystems. Of the 36 potentially threatening processes currently listed under the FFG Act (see Appendix A), over 40% relate either directly or indirectly to the health of rivers, estuaries and wetlands, yet many of these processes continue today (Department of Sustainability and Environment 2007c).

Addressing the problem of poor river, estuary and wetland health requires an integrated approach that deals with the major causes of river and wetland stress and examines how best to restore the health of Victoria’s coastal inland aquatic ecosystems. Static and selective management of individual components of aquatic ecosystems is unlikely to provide long-term solutions to river health issues. Management needs to be integrated and able to adapt to changing knowledge, techniques, development pressures and evolve with Victoria’s changing climate.



- >70% of major rivers and tributaries in good or excellent condition
- 51-70% of major rivers and tributaries in good or excellent condition
- 31-50% of major rivers and tributaries in good or excellent condition
- 11-30% of major rivers and tributaries in good or excellent condition
- <10% of major rivers and tributaries in good or excellent condition

21	East Gippsland	27	South Gippsland	33	Barwon
22	Snowy	28	Bunyip	34	Lake Corangamite
23	Tambo	29	Yarra	35	Otway
24	Mitchell	30	Maribyrnong	36	Hopkins
25	Thomson	31	Werribee	37	Portland
26	LaTrobe	32	Moorabool	38	Glenelg

Figure 1.1: Percentage of major rivers and tributaries in each river basin in coastal Victorian catchments in good or excellent condition based on 2004 Index of Stream Condition (Score > 37 = good to excellent rating: Department of Sustainability and Environment 2005a)

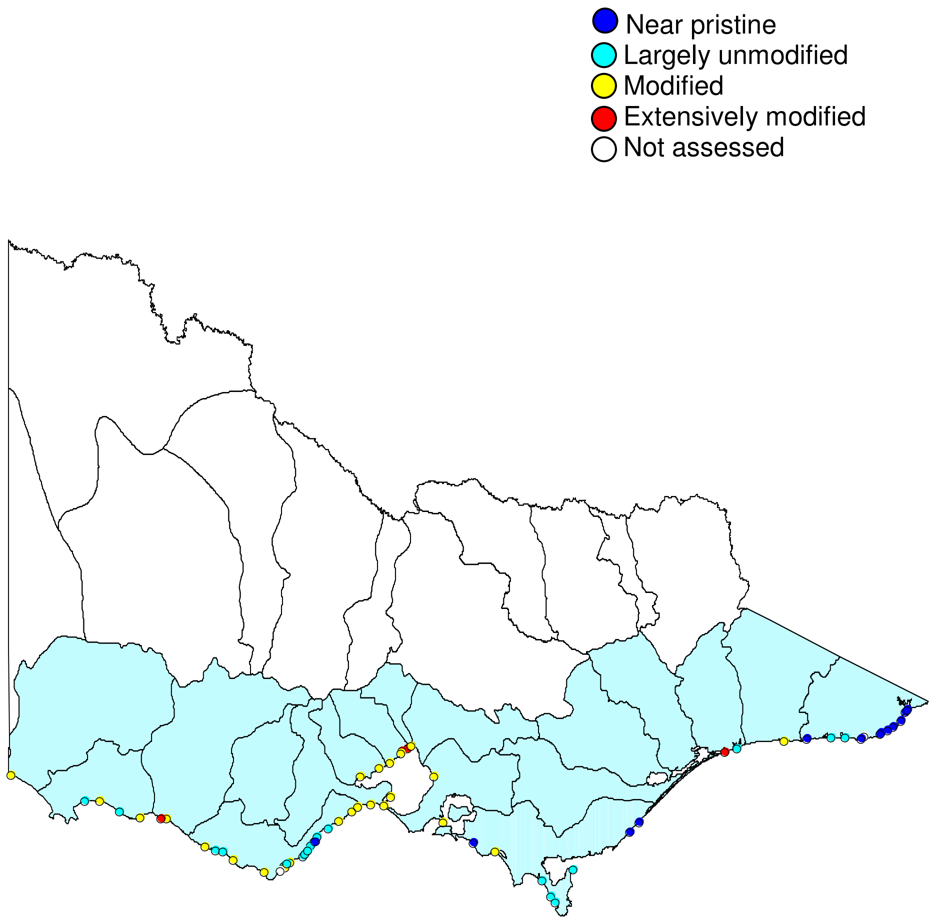


Figure 1.2: Current condition of coastal Victorian estuaries assessed (59 estuaries assessed in Victoria) in the 2002 Australian Catchment, River and Estuary Assessment. (Basins in blue represent the coastal catchments covered by this plan)

1.2 Native fish of Victoria's coastal catchments

Victoria's coastal aquatic ecosystems, include all rivers, estuaries and wetlands south of the Great Dividing Range (GDR), in the catchment districts of Glenelg Hopkins, Corangamite, Port Phillip and Westernport, West and East Gippsland. These ecosystems are home to 27 native freshwater fish species, 47 large native freshwater decapods[1] and bivalve molluscs and play a role in the life of over 150 native estuarine and marine fish species. These species are important components of Victoria's biodiversity and a vital part of the State's river and wetland health. They play a key role in aquatic and terrestrial food chains and are valuable indicators of the overall health of aquatic ecosystems. A decline in fish communities can be a warning that the natural functioning of aquatic ecosystems is at risk.

The economic, social and cultural value of some native coastal freshwater and estuarine fish species cannot be under estimated. For example Victorian's were estimated to have spent approximately $400 million on recreational fishing-related goods and services, with an estimated 550 000 Victorians (c. 13% of Victoria's population: Henry and Lyle 2003) participating in recreational fishing activity in the year May 2000 to April 2001. Approximately 85% of all recreational fishing activity in Victoria in 2000/01 occurred in rivers, estuaries, coastal embayments, lakes and dams (Henry and Lyle 2003).

There are currently 37 fishing licences that permit commercial fishing of finfish or bait species in Victoria's estuaries and small inlets and a total of 18 commercial eel fishing licences (Department of Primary Industries 2006a). Commercial fishing target species in the Gippsland Lakes include Black bream (*Acanthopagrus butcheri*), mullet (*Mugil* spp.), trevally (*Pseudocaranx* spp.), Tailor (*Pomatomus saltatrix*), Australian salmon (*Arripis* spp.), King George whiting (*Sillaginodes punctata*), garfish (*Hyporhamphus* spp), Dusky flathead (*Platycephalus fuscus*), prawns (various species) and the alien Carp (*Cyprinus carpio*). A variety of bait species, including sand worms, shrimp, crabs and shellfish (bivalve molluscs) are also collected commercially from a number of inlets/estuaries (e.g. the Gippsland Lakes, Lake Tyers, the Snowy River estuary, Sydenham Inlet and Mallacoota Inlet) and sold as recreational fishing bait. Commercial fishing for finfish had ceased in all Victoria estuaries other than Gippsland Lakes by 2003. Commercial finfish and prawn catches from the Gippsland Lakes in 2004/2005 had an estimated wholesale market value of $1.3million. The commercial eel industry across Victoria produces eel products with an estimated market value of $1.46 million/annum (Department of Primary Industries 2006a).

The iconic value of fish as recreational resources or indicators of environmental health cannot be underestimated. Yet, despite their social, economic and environmental value, around 37% of the freshwater species

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[1] Decapod: a crustacean of the order Decapoda (e.g. crab, lobster or shrimp) characteristically having ten legs each joined to a segment of the thorax

that occur in the coastal catchments of Victoria have significantly declined in abundance and distribution. Estuarine species appear to be less affected by declines, with the exception of two species, Black bream and the Pale mangrove goby (*Mugilogobius platynotus*). The Gippsland Lakes population of the economically valuable species, Black bream, has shown persistent recent reductions in abundance, while, the Pale mangrove goby is listed under the FFG Act. However, the limited knowledge of the biology and population status of many estuarine species and their generally long lifespan, means that it is possible declines of many estuarine species may have gone unnoticed.

Although the exact reasons for declines in Victorian native fish populations is poorly understood, it is likely that deteriorating habitat and environmental conditions in coastal waterbodies are decreasing the resilience of native fish populations. For example, in waterways of the Port Phillip and Westernport Catchment Management Authority (PPWCMA) area alone, over 800 instream barriers (Heron et al. 2003) had been recorded, with only 27 having been successfully modified to allow some fish passage (R. Coleman, Melbourne Water, pers. comm. 2007). While of the 104 reaches assessed in the Port Phillip and Westernport catchments in the 2004 Index of Stream Condition report less than 9% scored eight or more out of ten for the streamside zone sub-index (Victorian Government 2006) – a score considered to indicate good riparian vegetation in a reach, while over 70% scored 5 or less.

To date, thirteen alien fish species have been recorded in Victoria with most now widespread throughout the State. There is potential for some of these alien fish to place enormous predation and competition pressure on native fish species in some areas, contributing to declines of some species and the loss of valuable habitat areas. In some areas in the Murray-Darling Basin, alien Carp make up over 90% of the biomass of fish species (Carp Control Coordinating Group 2000). Catch records indicate that Carp has been a major component of total commercial catches from the Gippsland Lakes and tributaries for the last 25 years (Department of Primary Industries 2006a), but to date they have not been as high in other coastal systems of Victoria.

1.3 Purpose of this guide and the Fish Assessment Support Tool (FAST)

This project aims to provide resources to natural resource managers to facilitate an improved management of native freshwater and estuarine fish populations in coastal Victoria. The project has two primary components. The first is this State-wide Guide to the Management of Native Fish (GMNF), which contains valuable information about native freshwater and estuarine fish, their distribution, habitats and the ecological processes essential for their health, and the policy and legislative framework for their conservation and sustainable use. It provides guidelines for consistent and integrated coastal catchment management activities that will positively affect native freshwater and estuarine fish populations and communities. The guide will link closely with the existing implementation of regional River Health Strategies (RHS) providing additional guidance regarding how to set priorities and make informed and targeted decisions about native fish management in coastal rivers, wetlands and estuaries (Figure 1.3). The GMNF will also provide a valuable resource document to natural resource managers that will identify and address knowledge gaps that exist in relation to the ecological requirements and/or management of native fish, their habitats and essential ecosystem processes.

The second component of the project is the web-based centrally managed Fish Assessment Support Tool (FAST). This tool will assist river and wetland managers in two ways. The first will assist in determining the likely impact of intended works on specific aquatic fauna at and immediately downstream of the works, as well as providing guidance on the steps necessary to minimise these impacts on coastal fish communities. FAST will also assist in the prioritisation of on-ground works aimed specifically at protecting and enhancing native fish populations.

FAST is intended to assist river practitioners with their works activities without the need for specialist biological advice and will provide the following outputs:

- comprehensive list of native coastal fish predicted to be present within the works area,
- an assessment (in the form of a score) of the likely affect of a specified works action on each species present,
- an overall score or threat rating for the works,
- a comprehensive list of alternative works activities with associated likely impacts on fish populations,
- guidelines on impact minimisation through modification of works timing and alternative works options,
- advise on appropriate fish enhancement works, and
- a guide to undertaking fish habitat enhancement works.

This guide and the associated web-based decision support tool (FAST) aim to facilitate the conservation and protection of coastal native fish, their habitat and ecological processes that support these populations. The benefits of achieving these goals will not only improve conservation prospects for fish species but will also improve recreational fishing opportunities.

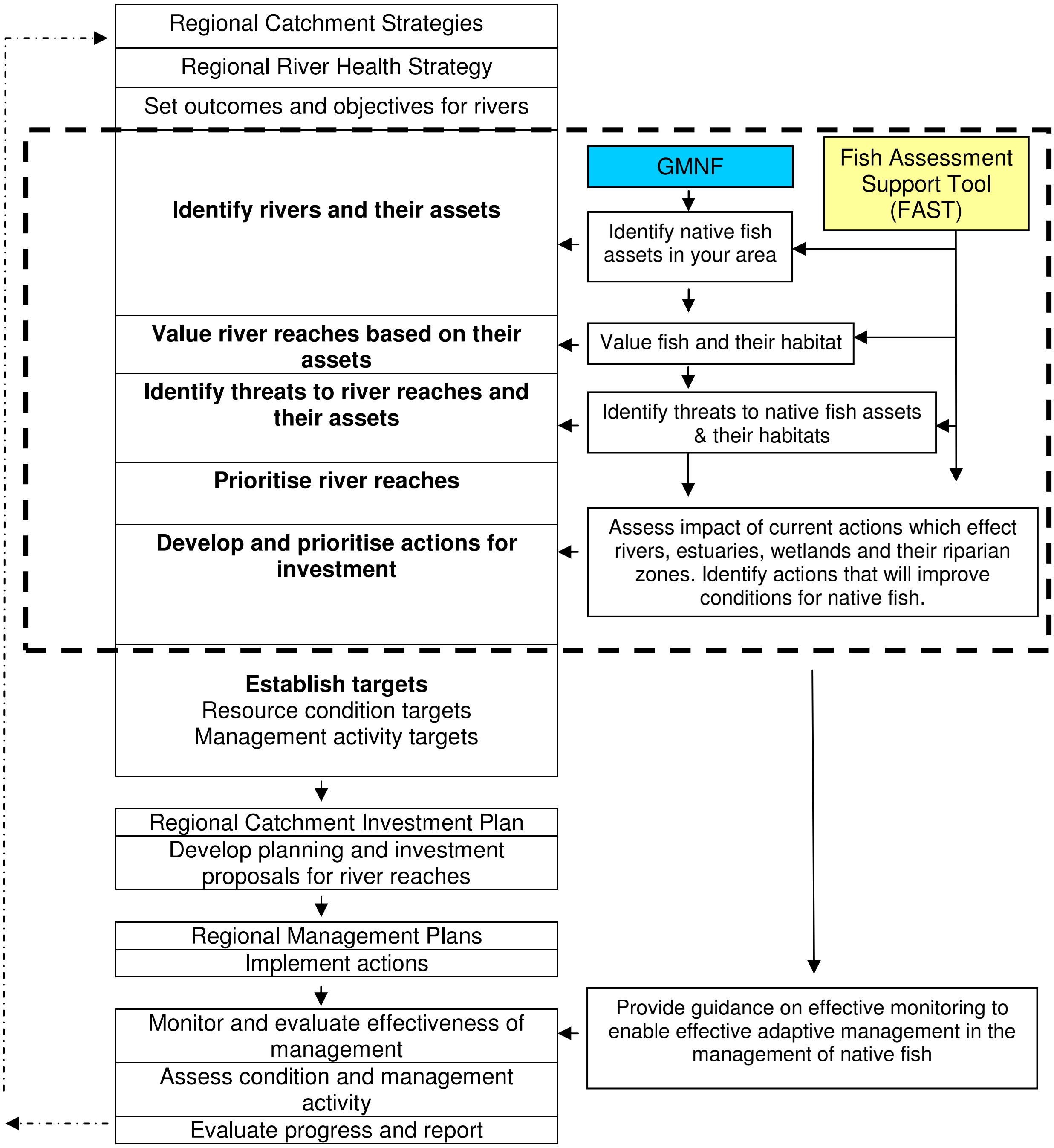

Figure 1.3: The asset-based approach to prioritisation of investment within the RHS, illustrating the role the GMNF can play in augmenting the existing process.

1.4 Scope of the guide

1.4.1. Geographic boundaries of the guide

This guide focuses on all native fish and 'fish-inhabited' wetlands and waterways south of the Great Dividing Range (GDR). For the purposes of this project a "river" follows the definition provided in the Victorian River Health Strategy (VRHS) and is defined as:

- *The channel*
- *The riparian zone, which includes adjoining land that regularly influences or is influenced by a river, including regularly wetted floodplain and any associated floodplain wetlands*
- *Any associated estuary or terminal lake*

(Department of Natural Resources and Environment 2002)

This guide encompasses all components of coastal waterways from the source to the mouth and will include associated estuarine waters such as: the Gippsland Lakes, Sydenham Inlet, Lake Connewarre (Barwon River estuary), Lake Tyers, Mallacoota Inlet, and Anderson Inlet. The guide does not encompass the larger marine embayments such as Port Phillip Bay, Westernport Bay and Corner Inlet. These areas are considered primarily marine-driven systems, containing a large number of marine species and are therefore considered beyond the scope of this project. However, it is acknowledge that for some diadromous[2] migratory species (e.g. eels), marine environments play a vital role in their life cycle and should also as be recognised as essential habitats, vital for their ongoing health.

'Fish-inhabited' wetland for the purposes of this guide has been derived from the Ramsar definition of wetlands and are defined as:

Areas of natural lake, billabong, swamp, marsh, fen, or peatland, whether permanent or temporary, that is mostly static [3], with water that is fresh, brackish or salt which supports native freshwater or estuarine fish or large decapod crustaceans or large freshwater bivalve mussels or has the potential to provide suitable habitat for them, should natural processes (e.g. floodplain connection, natural flood regimes, etc) be restored.

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[2] Diadromous: migratory between fresh and salt waters

[3] Some estuarine wetlands may be influenced by occasional tidal flows, while inland wetlands may be generally considered static but can be considered to flow during larger flood events

1.5 Focus of the guide

During this project's inception it was envisaged that the guide would cover only native freshwater finfish species in Victoria, south of the GDR. However, after preliminary discussions with regional stakeholders, it was identified that there was a major lack of ecological, distributional and management knowledge for both native freshwater and estuarine fish species in regional areas. The Catchment Management Authorities (CMAs) and Melbourne Water indicated that the guide would be most valuable if it encompassed all native fish that occurred in **wetlands**, **rivers and estuaries** south of the GDR including some of the large threatened decapod crustaceans and bivalves. This effectively increased the number of native "fish" encompassed by the project from 27 native freshwater fish species to over 200 native freshwater and estuarine finfish, large freshwater decapod crustaceans and large freshwater bivalve mollusc species.

The major increase in the number of native organisms to be included in the project required some form of prioritisation of the 200 species. The use of functional groups or guilds is one way of managing species with similar traits or habitat requirements as units in an ecosystem, as functionally similar species are likely to respond in a similar fashion to specific disturbances or modifications (Growns 2004). A group of freshwater and estuarine fish experts (Scientific Advisory Group) was therefore consulted to define a number of native fish categories, from which a prioritisation process could be applied. Categories were then developed around existing published definitions (e.g. Potter and Hyndes 1999).

1.5.1. Prioritisation of native fish species

The current knowledge of native freshwater fish species and their habitats is relatively good, and in most instances this information can be quickly collated without extensive research, either from published documents or through discussions with the relevant experts. In contrast, knowledge of the biology and habitat requirements of many of the estuarine species is generally poorly understood. Information on these species is often limited to where they are commonly caught by recreational anglers. This lack of information, in combination with the large number of species encompassed under the "estuarine" categories, limits the capacity of the guide to describe the habitat and ecological requirements of all individual species in detail. Species have therefore been prioritised and the level of detail contained within this document scaled accordingly. Priority has been given to:

- Freshwater and estuarine species recognised as threatened (listed under EPBC Act, FFG Act, or recognised under the DSE 2007 Threatened Vertebrate or 2008 Threatened Invertebrate Advisory Lists (Victorian Department of Sustainability and Environment 2007, 2008)
- Freshwater and estuarine species that are recreationally targeted (information derived from DPI resources and the Scientific Advisory

Panel[4]) or are of cultural significance (see section 7.2.2 for details), and

- Remaining freshwater species for which we have good knowledge.

The remainder of the estuarine species have been prioritised according to their level of dependence on estuary environments (see section 7.3) with greater emphasis placed on species heavily reliant on estuarine environments to complete life cycles. Species for which we have limited knowledge are indicated as such, and will be described according to existing information on biology.

The focus of this guide will be to provide a quick reference to information on the habitat requirements, ecology and threats to each of the focus species. While not feasible to provide all detailed biological information, references are provided where more detail biological and life cycle information can be sourced.

As mentioned previously, large freshwater decapod crustaceans (belonging to the families Atyidae, Parastacidae and Hymenosomatidae) and large freshwater bivalve molluscs (belonging to the families Hyriidae and Corbiculidae) have been included in the guide. It was considered beyond the scope of this project to cover smaller macroinvertebrates and marine macroinvertebrates.

1.5.2. Native fish categories

Based on the geographic boundaries of the project, the following categories have been included in this document:

Freshwater species*:* Native finfish, large decapods[5] and bivalve molluscs that require freshwater environments to complete all or part of their life cycle.

Estuarine species: Native finfish species that utilise estuarine environments for essential life cycle stages or may enter estuaries regularly in large numbers to promote a particular life stage (e.g. juvenile development). This group is further defined by a number of categories dependent upon the level of reliance the species has on the estuarine environment and according to the definitions provided by Potter and Hyndes (1999).

> Estuarine residents (ER): Species that must complete their entire life cycle in the estuarine environment. The estuary is critical to their entire life cycle (Figure 1.4). These are solely estuarine species.
>
> Estuarine dependents (ED): Species that must use estuaries for completion of their life cycle and spend a large proportion of their life in

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[4] The scientific advisory panel included Dr John Koehn (DSE ARI), Tarmo Raadik (DSE ARI), Dr Jeremy Hindell (DPI), Tom Ryan (Independent consultant) and Stephen Saddlier (DSE ARI)

[5] Decapod: a crustacean of the order Decapoda (e.g. a crab, lobster or shrimp) characteristically having 10 legs each joined to a segment of the thorax.

estuary habitats. Estuaries are a critical habitat for part of their life cycle (Figure 1.4).

Estuarine opportunists (EO): species that can complete their life cycle at sea, but may enter estuarine environments in large numbers (usually as juveniles) to exploit the available habitats. Estuaries are NOT a critical habitat (Figure 1.4) for these species.

Marine stragglers: primarily native marine finfish species that may enter an estuary irregularly, usually in small numbers and are generally found near the estuary mouth or in regions where the salinities remain high (Figure 1.4: Potter and Hyndes 1999).

Under these definitions there are 27 native freshwater fish species, seven estuarine residents, 19 estuarine dependent, 57 estuarine opportunists, 82 marine stragglers, 39 large freshwater decapod crustaceans and eight large freshwater bivalve molluscs in Victoria's coastal catchments (Tables 1.1-1.3[6], Section 7 and Appendix B). There are also a number of freshwater native fish species which do not naturally occur in coastal catchments but have been introduced to these regions since European settlement. Many of these fish species are listed as threatened under State or Commonwealth legislation and therefore must be recognised within this guide (Table 1.4). The value of these populations outside their range varies according to the severity of declines across their overall range, ongoing threatening processes within their natural range and social value. For example, the Maquarie Perch, *Macquaria australascia,* population in the Yarra River is outside its natural range but is considered important in the overall context of the management and protection of that species throughout Victoria (see section 7.3 for further details).

There are 11 alien freshwater fish species (i.e. fish species that are not native to Australia), one alien estuarine dependent fish (Yellowfin goby, *Acanthogobius flavimanus*) and one alien marine straggler (Japanese Goby, *Tridentiger trigonocephalus*) that are recognised as persisting in Victoria's coastal catchments (Table 1.5). These species represent a potential threat to the health of native fish populations and therefore must be managed accordingly.

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[6] Table 1.1 - 1.3 provides a sub list of all native fish species covered by the plan. This sub list was developed using the prioritisation process described in section 1.5.1.

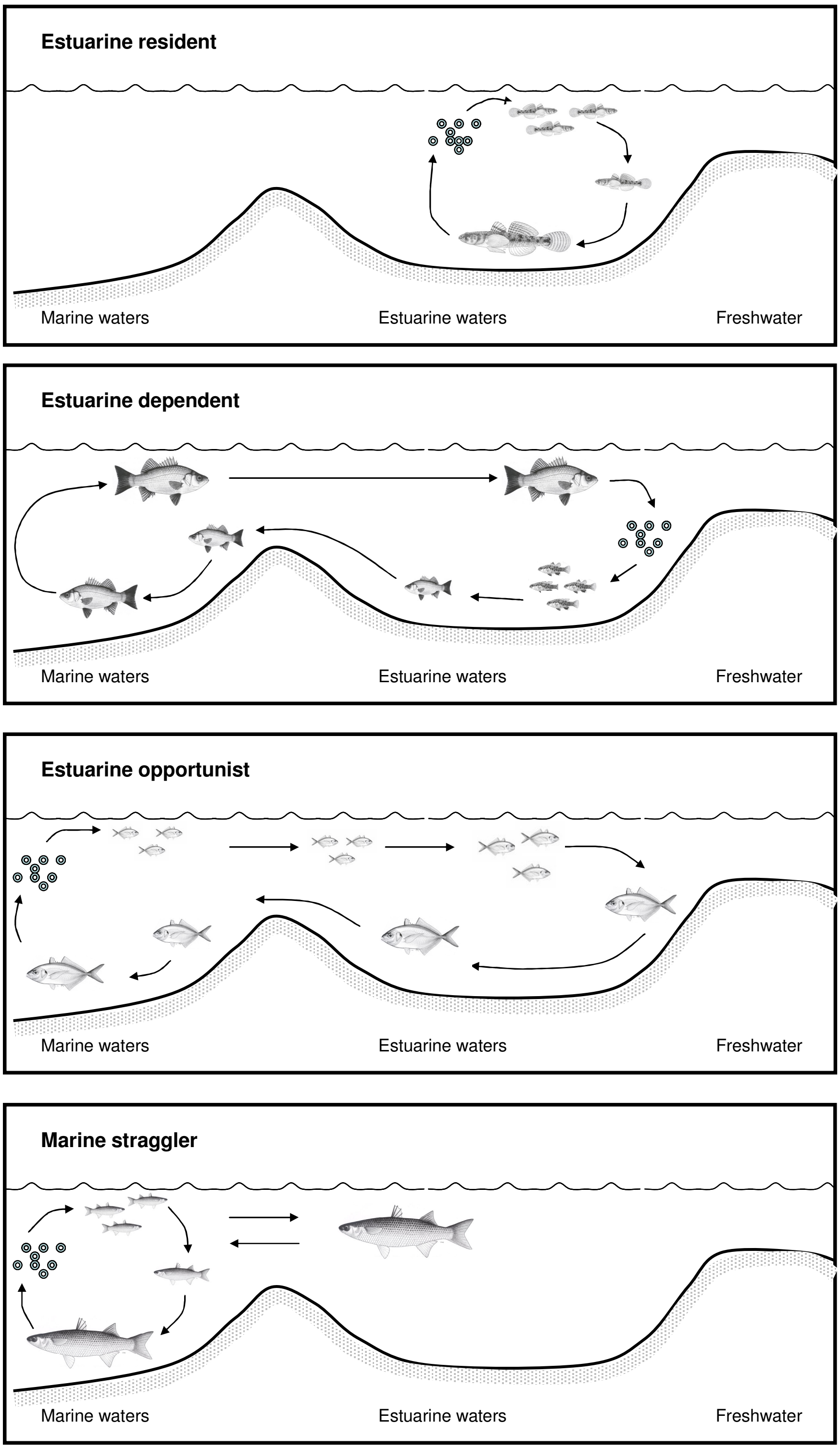

Figure 1.4 Diagrammatic representation of the various definitions of estuarine and marine species (adapted from Potter and Hyndes 1999).

Table 1.1: A list of priority freshwater finfish species, with notes on their conservation status⸸.

Common name	Species name	FFG listed[#]	DSE 2007 (advisory list*)	EPBC listed[‡]	Recreationally targeted for consumption (c) or for bait (b)	Culturally significant species
Australian bass	*Macquaria novemaculeata*				C	✓
Australian grayling	*Prototroctes maraena*	✓	Vulnerable	Vulnerable		
Australian mudfish	*Neochanna cleaveri*	✓	Critically endangered			
Australian smelt	*Retropinna sp (SEC + MTV)*[†]					
Australian whitebait	*Lovettia sealii*	✓	Critically endangered			
Broad-finned galaxias	*Galaxias brevipinnis*				B	
Common galaxias	*Galaxias maculatus*				B	
Cox's gudgeon	*Gobiomorphus coxii*	✓	Endangered			
Dwarf flat-headed gudgeon	*Philypnodon macrostomus*					
Dwarf galaxias	*Galaxiella pusilla*	✓	Vulnerable	Vulnerable		
Empire gudgeon	*Hypseleotris compressa*	✓	Vulnerable			
Flat-headed gudgeon	*Philypnodon grandiceps*				B	
Flinders pygmy perch	*Nannoperca sp1*					
Freshwater herring	*Potamalosa richmondia*	✓	Regionally extinct			
Long-finned eel	*Anguilla reinhardtii*				C	✓
Mountain galaxias	*Galaxias olidus*					
Obscure galaxias	*Galaxias sp.1*					
River blackfish (all forms)	*Gadopsis marmoratus*		Critically endangered (upper Wannon River form only)		C	✓
Pouched lamprey	*Geotria australis*					
Short-finned eel	*Anguilla australis*				C	✓
Short-headed lamprey	*Mordacia mordax*					
Southern pygmy perch	*Nannoperca australis*					

Common name	Species name	FFG listed#	DSE 2007 (advisory list*)	EPBC listed‡	Recreationally targeted for consumption (c) or for bait (b)	Culturally significant species
Spotted galaxias	*Galaxias truttaceus*					
Striped gudgeon	*Gobiomorphus australis*		Near threatened			
Tupong	*Pseudaphritis urvillii*				C	
Variegated pygmy perch	*Nannoperca variegata*	✓	Endangered	Vulnerable	B	
Yarra pygmy perch	*Nannoperca obscura*	✓	Near threatened	Vulnerable		

† recently published information indicates that in coastal Victoria there are likely to be two genetically distinct species of smelt with the potential for a number of sub-species within individual river basins. Conservation of these species is therefore under review, and it is suggested that individual river basins are the appropriate scale for management as the overall basis for protecting biodiversity and evolutionary potential (Hammer et al. 2007).

⸕ Details on the conservation status of species can be found in section 7.2.1 of the guide, culturally significant species section 7.2.2, and recreationally targeted species in section 7.2.3. Information on the biology of all freshwater finfish of coastal Victoria is in section 7.3.

(‡Department of Environment Water Heritage and the Arts 2007a, #Department of Sustainability and Environment 2007b, *Victorian Department of Sustainability and Environment 2007)

Table 1.2: A list of freshwater priority decapods and bivalve mollusc species, including threatened, recreationally targeted and culturally significant species[†].

Common name	Species name	FFG listed	DSE (2008- draft advisory list[‡])	EPBC listed	Recreationally targeted for consumption (c) or for bait (b)	Culturally significant species
Alpine spiny cray	*Euastacus crassus*	✓	Endangered			✓
Common freshwater shrimp	*Paratya australiensis*				B	
Common yabby	*Cherax destructor*				B & C	✓
Curve tail burrowing cray	*Engaeus curvisuturus*	✓	Endangered			
Dandenong burrowing cray	*Engaeus urostrictus*	✓	Vulnerable			
Eastern freshwater prawn	*Australatya striolata*	✓	Data Deficient			
Gippsland spiny cray	*Euastacus kershawi*				C	✓
Glenelg freshwater mussel	*Hyridella glenelgensis*	✓	Critically Endangered			
Glenelg spiny cray	*Euastacus bispinosus*	✓	Vulnerable			✓
Lilly Pilly burrowing cray	*Engaeus australis*	✓	Endangered			
Mallacoota burrowing cray	*Engaeus mallacoota*	✓	Endangered			
Orbost spiny cray	*Euastacus diversus*	✓	Endangered		C	✓
Narracan burrowing cray	*Engaeus phyllocercus*	✓	Vulnerable			
South Gippsland spiny cray	*Euastacus neodiversus*	✓	Vulnerable			✓
Strezelecki burrowing cray	*Engaeus rostrogaleatus*	✓	Endangered			
Warragul burrowing cray	*Engaeus sternalis*	✓	Endangered			
Western swamp cray	*Gramastacus insolitus*	✓	Vulnerable			

† Details on the conservation status of species can be found in section 7.2.1 of the guide, species that are recreationally targeted in section 7.2.3. Information on the biology of large, freshwater decapod crustaceans and large freshwater bivalve mussels in section 7.4.

(‡Victorian Department of Sustainability and Environment 2008)

Table 1.3: A list of priority estuarine species, including threatened, recreationally targeted, culturally significant species and estuarine residents.

Common name	Species name	Species Classification	FFG listed[#]	DSE (2007 advisory list*)	EPBC listed[‡]	Recreationally targeted for consumption (c) or for bait (b)	Culturally significant species
Australian anchovy	*Engraulis australis*	ER				C & B	
Black bream	*Acanthopagrus butcheri*	ER				C	✓
Dusky flathead	*Platycephalus fuscus*	EO				C	✓
Eastern Australian salmon	*Arripis trutta*	EO				C	✓
Eastern blue-spot goby	*Pseudogobius sp. 9*	ER					
Estuary perch	*Macquaria colonorum*	ER				C	✓
Gummy shark	*Mustelus antarticus*	MO				C	
King George whiting	*Sillaginodes punctata*	EO				C	
Lagoon goby	*Tasmanogobius lasti*	ER					
Mulloway	*Argyrosomus japonicus*	ED				C	
River garfish	*Hyporhamphus regularis*	ER					
Pale mangrove goby	*Mugilogobius platynotus*	EO	✓	Vulnerable			
Poddy mullet (sea mullet)	*Mugil cephalus*	MS				C	
Sand flathead	*Platycephalus bassensis*	MS				C	
Sand trevally	*Pseudocaranx wrighti*	EO				C	✓
Sandy Sprat	*Hyperlophus vittatus*	ED				C & B	
School shark	*Galeorhinus galeus*	MS				C	
Silver trevally	*Pseudocaranx dentex*	EO				C	✓
Snapper	*Chrysophrys auratus*	ED				C	
Southern sea garfish	*Hyporhamphus melanochir*	EO				C	
Smallmouthed hardyhead	*Atherinosoma microstoma*	ED				B	

Common name	Species name	Species Classification	FFG listed#	DSE (2007 advisory list*)	EPBC listed‡	Recreationally targeted for consumption (c) or for bait (b)	Culturally significant species
Tailor	*Pomatomus saltatrix*	ED				C	
Yellow-eye mullet	*Aldrichetta forsteri*	EO				C	
Yellow-fin bream	*Acanthopagrus australis*	ER				C	✓
Western Australian salmon	*Arripis truttaceus*	EO				C	✓
Western blue-spot goby	*Pseudogobius olorum*	ER					

ER= estuarine resident, ED= estuarine dependent, EO= Marine-estuarine opportunist, MS= marine straggler (see section 1.5.2 for definitions of each category)

⊺ Details on the biology of species with conservation status and that are recreationally targeted can be found in section 7 of the guide, *estuarine residents* in section 7.6.2, and estuarine dependent in section 7.6.4. A summary of the distribution and biology of all *estuarine opportunists* covered by the guide can be found in Appendix B.

(‡Department of Environment and Heritage 2007, #Department of Sustainability and Environment 2007b, *Victorian Department of Sustainability and Environment 2007)

Table 1.4: A list of Australian freshwater finfish and invertebrates, introduced outside of their natural range, currently in Victorian coastal waters and consequently regarded as alien species

Common name	Species name	FFG listed#	DSE (2007 advisory list*)	EPBC listed‡	Recreationally targeted for consumption (c) or for bait (b)	Culturally significant species
Golden perch	*Macquaria ambigua*	✓	Vulnerable		C	
Macquarie perch	*Macquaria australasica*	✓	Endangered	Endangered	C	
Marron	*Cherax tenuimanus*				C	
Murray cod	*Maccullochella peelii peelii*	✓	Vulnerable		C	
Silver perch	*Bidyanus bidyanus*	✓	Critically endangered		C	
Trout cod	*Maccullochella macquariensis*	✓	Critically endangered	Endangered		

(‡Department of Environment and Heritage 2007, #Department of Sustainability and Environment 2007b, *Victorian Department of Sustainability and Environment 2007)

Table 1.5: Alien fish species that persist in Victoria coastal waters

Common name	Species name	Species Classification	Native distribution
Atlantic salmon	*Salmo salar*	FW -alien	North-eat coast USA and Canada, north-west coast Europe
Brown trout	*Salmo trutta*	FW -alien	Western Asia and Europe
Carp	*Cyprinus carpio*	FW -alien	Central Asia, Japan and China
Chinook salmon	*Oncorhynchus tsawytscha*	FW - alien	
Goldfish	*Carassius auratus*	FW -alien	China
Japanese Goby	*Tridentiger trigonocephalus*	MS -alien	
Eastern gambusia	*Gambusia holbrooki*	FW -alien	Southeastern USA, northern Mexico
Oriental weatherloach	*Misgurnus anguillicaudatus*	FW -alien	Northeast Asia to central china, Siberia, Korea, Hainan
Rainbow trout	*Oncorhynchus mykiss*	FW -alien	West coast USA, Canada, Northern Mexico and Pacific coast of Siberia
Redfin	*Perca fluviatilis*	FW -alien	Parts of Europe
Roach	*Rutilus rutilus*	FW -alien	Parts of Europe
Tench	*Tinca tinca*	FW -alien	Western Asia, Europe except northern Scandanavia
Yellow-finned goby	*Acanthogobius flavimanus*	ED -alien	Asia: Japan Korea and Siberia

FW= freshwater, ED= estuarine dependent, MS= marine straggler (see section 1.5.2 for definitions of each category)

(Allen et al. 2003)

1.6 Guiding principles for the management of fish

- A precautionary approach is to be applied where knowledge or understanding is limited

- A holistic approach is necessary for river management and rehabilitation

- It is important to manage communities and ecological processes not just species or areas

- Protection of existing natural assets is a priority:
    - *it is more cost effective to conserve existing wild fish populations and aquatic communities now, than to attempt to rehabilitate them later*
    - *protect the most valuable areas (e.g. those with threatened species, with a high fish diversity, habitats that support species of economic value, etc.* SEE PART B)
    - *protect habitats in good condition*
    - *prevent deterioration of good habitats and populations by removing threats*
    - *improve the condition of habitats impacted by degradation processes from best to worst or by expanding and linking good reaches*
    - *make sure rehabilitation or restoration goals are realistic and achievable in the face of uncontrolled impacts*

- Conservation is generally best undertaken within a species' natural habitat, rather than conserving them in areas outside its natural range

- Biodiversity conservation is central to ecologically sustainable development

- Effective conservation is limited by the knowledge and understanding of the species, populations and the ecosystem.

PART A: CURRENT MANAGEMENT AND THREATS TO NATIVE FISH

2 Current management of waterways and fish in coastal Victoria

2.1 Current management of rivers, estuaries and wetlands

There is now a recognised need for coordinated river rehabilitation between a number of organisations around the State that play important roles in the management and conservation of aquatic ecosystems. Organisations responsible for the management and control of activities in and around waterbodies include: Department of Sustainability and Environment (DSE), regional Catchment Management Authorities (CMAs), Melbourne Water (MW) Parks Victoria (PV), Department of Primary Industries (DPI), urban and rural water authorities, local government authorities, port authorities and coastal boards.

Regional Catchment Strategies

At present, the strategic directions for the management of catchments and waterways are specified through Regional Catchment Strategies (RCS). The major focus of the RCS is on regional catchment planning and management, with the overall policy direction and investment provided at the State level. The RCSs set broad regional priorities across issues and catchments for the management of land and water resources and under these documents detailed action plans for priority land and water resource management are developed. Within this framework, river health and waterway management has been identified as one of the priority management issues.

Victorian River Health Strategy

The Victorian River Health Strategy (VRHS) was developed to coordinate river health management across the State (Department of Natural Resources and Environment 2002), with the primary objective of creating "Healthy rivers, streams and floodplains which meet the environmental, economic, recreational and cultural needs of current and future generations". The VRHS provides a State-wide policy framework for managing the health of Victoria's rivers, floodplains and estuaries. It aims to restore stressed rivers and protect healthy waterways through an integrated approach of improving environmental flows, declining water quality and degraded riparian habitats.

Regional River Health Strategies

At a regional scale, each CMA and Melbourne Water (river managers of Port Phillip and Westernport catchment) is responsible for developing and operating its RCS, which provides the framework for the development and implementation of the regional River Health Strategy (RHS: Figure 2.1). The regional RHSs provide a clear process for identifying and prioritising key management activities based on economic, social and environmental implications. Using this framework, each CMA is responsible for the development of management actions and targets for river health within their jurisdictions. The regional RHSs have a timeframe of five years.

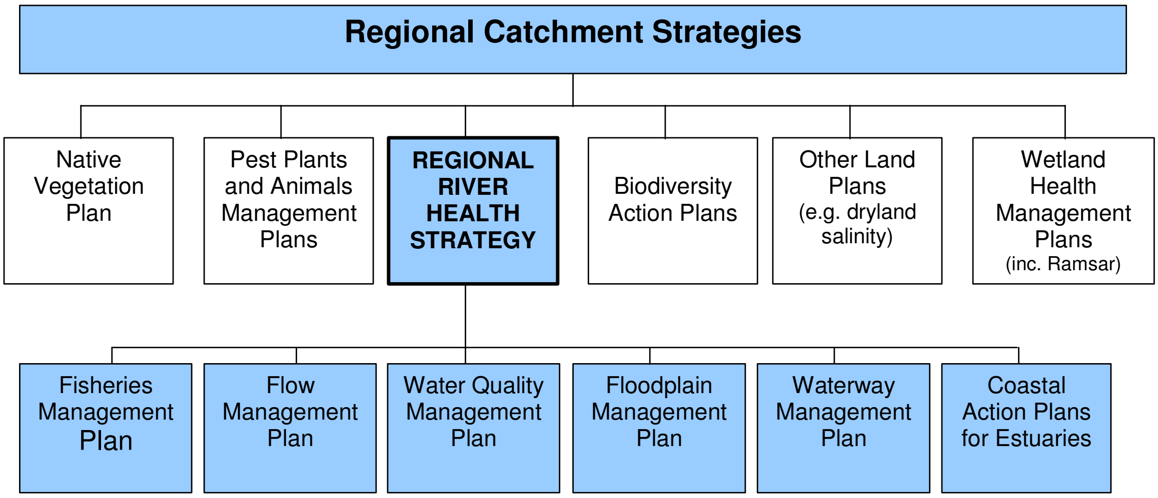

Figure 2.1: Regional management framework

Estuaries Coastal Action Plans

The Victoria Coastal Strategy (VCS) provides the broad policy framework for the planning and management of Victoria's coast including marine waters from the State territorial waters limit to upstream limit of tidal influence in estuaries (Victorian Coastal Council 2002). Coastal Action Plans (CAPs) which were developed in accordance with the *Coastal Management Act* 1995, provide a key mechanism for the implementation of that strategy. The CAPs provide strategic direction for the future management of an area of coast by identifying necessary priorities, actions and outcomes.

The Estuaries CAPs sit alongside the Regional CAPs and provide focussed strategic direction to protect and improve the management of estuaries (Western Coastal Board 2005) - a key action required under the VCS (Victorian Coastal Council 2002). Within the Estuaries CAPs, estuaries are identified as of *high, medium* or *other* priority. Those afforded a high or medium priority ranking are to have specific management plans developed for them. The remaining estuaries are to be managed through the extension of existing plans or other management programs. Under the Estuaries CAP the local regional CMA and the relevant coastal board are to coordinate and provide guidance for estuary planning and review estuary management plans. The South West Estuaries CAP (Harty 2002b) provides a five year role out for the development of estuary management plans in the south west region. The Central West Estuary CAP, is currently under revision (Western Coastal Board 2005), while the Gippsland Estuary CAP received ministerial approval late 2006 (Gippsland Coastal Board 2006). The VCS is currently being reviewed.

Wetlands

In 1971, Australia became a signatory to the Ramsar Convention on Wetlands. The Convention on Wetlands provides guidance on preparing Commonwealth policies, legislation and tools for managing wetlands. Eleven of Victoria's wetlands are listed as Ramsar sites under the Convention on Wetlands. Five of these occur within the management area of this guide: Port Phillip Bay (Western Shoreline), Bellarine Peninsula, Gippsland Lakes, Western District Lakes, and the Edithvale-Seaford Wetlands, in southeast metropolitan Melbourne. Substantial areas of Victoria's Ramsar sites are situated in protected areas on public land and are managed either directly or indirectly by Parks Victoria. Management plans have been developed for each of the wetlands listed under the Ramsar convention and reviews are currently being prepared for the Ecological Character Descriptions of each listed wetland. DSE is responsible for implementing the Convention on Wetlands in Victoria.

All Victorian wetlands are recognised under Victoria's Biodiversity Strategy (VBS). The principal outcomes sought under VBS are:

- maximum retention and restoration of existing wetlands, as far as practicable
- viable wild populations of native wetland-dependent flora, fauna and ecological communities
- a representative selection of Victoria's wetland environments afforded protection in the State's protected area network of parks and reserves
- a strong partnership between owners of wetlands on private land, catchment and coastal authorities and local and State government agencies that encourages wetland owners to use wetlands wisely and sustainably, restore degraded wetlands and protect wetland biodiversity, and
- an increased awareness and appreciation of wetlands by the community leading to a higher level of active participation in wetland conservation and monitoring.

(Department of Natural Resources and Environment 1997)

DSE is currently in the process of developing the Land and Biodiversity at a time of Climate Change White Paper on behalf of the Victorian Government. At the time of writing, the Green Paper had just been released with the white paper to be released April 2009. Under the new restructured white paper wetlands will now be covered under a revised Victorian River Health Strategy planned for revision in 2009 (S. Loo, DSE, pers. Com.)

DSE takes a lead role in developing and implementing policy and legislation, and generally promoting conservation and wise use of wetlands throughout Victoria. In addition, CMAs are addressing poor management of wetlands on private land by implementing salinity plans, wetland management plans, and water allocation strategies.

Estuary Entrance Management Support System

Estuary entrance management, particularly artificial river mouth openings, have the potential to have a negative impact on a range of native fish species if conducted under the wrong conditions. In the 2002 Victorian Coastal Strategy, it was identified that a lack of clear and transparent guidelines for the management of river mouth openings was hindering estuary management (Victorian Coastal Council 2002). In 2004 an Estuary Entrance Management Support System (EEMSS) was developed by Deakin University through a project funded by the Australian Government's Natural Heritage Trust (Western Coastal Board 2005). EEMSS is a Microsoft Access database which assists managers across coastal Victoria to integrate the myriad of issues, risks and effects in the decision-making process for the artificial opening of estuary entrances. The support system examines the impacts of intermittently closed estuaries on the environmental, social and economic values of those estuaries and assesses the need for opening accordingly (Arundel 2006, EEMSS 2006). Further information of the system can be found on the Glenelg Hopkins CMA website.

2.2 Current management of coastal native freshwater and estuarine fish

2.2.3 Planning and strategic programs

Regional River Health Strategies

Victoria has adopted an assets-based approach to natural resource management (NRM), which is implemented through the RCSs and the RHSs. Natural assets are defined as the tangible physical elements of the environment which are valued by the community. The conceptual framework for this asset-based approach combines information about assets, their services and values, and the threats to those assets (Figure 2.2). The process enables the prioritisation of regions within a catchment to enable the most effective investment. Within the regional RHS environmental, social, cultural and economic assets are all identified and valued within each major river reach.

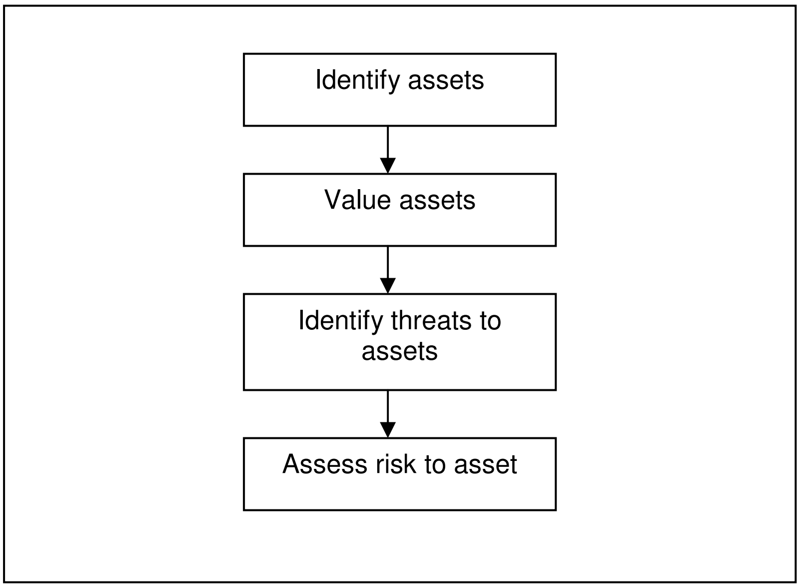

Figure 2.2: The asset-based approach to NRM in Victoria

Under the current regional RHS, native fish populations are recognised as an asset and therefore must be identified and valued accordingly. As part of this process NRM managers need to understand the distribution and value of each of the species occurring in their region to enable the appropriate allocation of investment in their region. In the existing RHS framework, native fish are incorporated into the process through a number of values and threats identified in the River Values and Environmental Risk System (RiVERS) database:

Assets and their values

- **Native fish** - the observed number of species compared with the number of species expected at the site based on best available historical knowledge.
- **Native fish migration** – rivers containing species with high conservation values and/or migratory requirements receive higher ranking than those with no migratory species or species with no formal conservation values.
- **Significant fauna** – the presence of fish fauna recognised under Victoria threatened species advisory lists or State and/or Commonwealth legislation.
- **Fishing** – rivers are ranked according to the level of recreational/commercial fishing known to occur in each river – an indicator of social and economic value.

Threats to assets and their values

- **Barriers to fish migration** – based on ISC each river/reach is scored according to the number of barriers to fish movement and the temporal scale (proportion of each year) over which each barrier prevents fish movement.
- **Introduced fish** – the number of introduced fish species at a site as a proportion of the total number of species at the site (native and introduced).

In many instances use of the regional RHS threat assessment process has been highly successful in identifying and valuing important threatened populations and in addressing some of the major threats to these and other native fish in freshwater sections of coastal waterways. For example, in relation to the threat "barriers to fish movement", some of these barriers have now been modified to enable the passage of a variety of fish species within rivers and enable migratory movement of fish to and from marine environments. This will undoubtedly have positive outcomes for many fish species. However, many NRM managers have recognised that they are restricted in their effectiveness to adequately address fish-related issues. This is primarily due to a number of factors including:

- limited regional knowledge of fish-related issues, (including understanding how particular threats may impact on fish populations) particularly in estuarine waters,
- the patchy availability of up-to-date information about the distribution, status, habitat and ecological requirements of coastal native fish,
- limitations with some of the metrics (i.e. asset and threat assessment tools) currently used in the regional RHS, which only have limited value in helping to understand the status of, or impacts on native fish populations; and
- the lack of guidance or co-ordination between management agencies in developing actions and targets for the management of native fish and their habitats.

The RiVERS database is currently being revised and the data within it updated. The fish asset and threat measures are being reviewed with the aim of making them more robust in the next version of RiVERS.

Asset framework for assessment of risks to estuaries

A State-wide asset-based approach to the identification of estuarine assets is currently been developed by DSE in partnership with Deakin University. As part of this process it has been identified that the existing database (RiVERS) used to prioritise river reaches within the regional RHS requires refinement to be applicable for estuarine reaches of rivers (Arundel 2007). As such, the DSE and Deakin University are:

- assessing the applicability of environmental, social and economic values in RiVERS for estuary priority setting, and
- identifying appropriate replacements if particular environmental, social and economic values are not applicable.

The asset-based approach is still to be refined but preliminary investigations identified that a modified version of the RiVERS asset, 'Native Fish: observed to expected' is likely to be applicable to the estuary model (Arundel 2007).

However, Arundel (2007) notes there is a lack of comprehensive and systematic surveys of Victorian estuaries and further investigation will be required before this asset can be effectively used to evaluate estuary condition. Similarly the use of a modified version of the 'Native fish migration' asset component of the regional RHS is also being investigated and several other assets (e.g. rare and threatened fauna, fishing, etc) relating to fish are being considered (Arundel 2007).

Fisheries Management Plans

There are currently a number of Fisheries Management Plans (FMPs) that have been, or are being, developed for various freshwater and/or estuarine waterways in the coastal catchments of Victoria. FMPs have been completed for freshwater and estuarine waters in coastal catchments of southwest Victoria bounded by the Glenelg and Hopkins River catchments, and for the estuarine waters of Mallacoota Inlet, Anderson Inlet and Lake Tyers in Gippsland. Additional plans are currently being developed for each of the remaining coastal catchments of Victoria (K. Weaver, DPI, pers. comm. 2007). A management plan for commercial eel fishing in freshwaters and estuaries along the Victorian coast has been in place since the mid 1990s.

These plans specify the objectives, strategies and performance measures for managing fishing activities in the waters specified in each of the plans and identify processes for participating in management of issues relevant to the prevention of negative impacts on fish habitats that supports production of key fisheries resources. With the exception of the eel fishery FMP, these plans deal primarily with the management of recreational fishing activities that target fish, mollusc, crustacean and other invertebrate species for food, sport or use as fishing bait.

Currently only five of the 27 native freshwater fish species that occur in Victorian coastal catchments are actively targeted by recreational anglers, and less than 8% of the 150 finfish which actively use estuarine environments are targeted by recreational anglers. Of the 47 large freshwater decapod crustaceans and large freshwater bivalve molluscs that inhabit our coastal catchments, approximately seven species are currently targeted for consumption or bait. Management of fishing impacts is therefore only likely to directly affect a relatively small percentage of the total fish and large macroinvertebrate species that exist in Victoria's coastal waterways. However, minimising the indirect impacts of fishing on physical habitat, biotic community structure and ecological process will provide broader benefits in maintaining the health of aquatic ecosystems.

Action statements and threatened species recovery plans

There are currently several pieces of State and Commonwealth legislation which provide for the listing of flora and fauna (including fish) and their environments as threatened and the management of threatening processes. The Australian Government mechanism for Commonwealth environment protection and biodiversity conservation is the *Environment Protection and Biodiversity Conservation Act* 1999 (EPBC Act). The EPBC Act provides for:

- identification and listing of species and ecological communities as threatened
- development of Recovery Plans for listed species and ecological communities
- development of a register of critical habitat
- recognition of Key Threatening Processes; and where appropriate
- reducing the impacts of these processes through Threat Abatement Plans.

The Federal Minister for the Environment, Heritage and the Arts may make or adopt and implement recovery plans for threatened fauna, threatened flora (other than conservation dependent species[7]) and threatened ecological communities listed under the EPBC Act.

Recovery Plans set out the research and management actions necessary to stop the decline of, and support the recovery of, listed threatened species or threatened ecological communities. The aim of a Recovery Plan is to maximise the long-term survival in the wild of a threatened species or ecological community. Recovery Plans state what must be done to protect and restore important populations of threatened species and habitat, as well as how to manage and reduce threatening processes. Recovery Plans achieve this aim by providing a planned and logical framework for key interest groups and responsible government agencies to coordinate their work to improve the plight of threatened species and/or ecological communities.

To date, no EPBC Act recognised Recovery Plans have been finalised for the five native species of fish listed under the EPBC Act which naturally occur in coastal Victorian waters (see Table 1.1 & 1.3). Draft recovery plans have recently been developed for Yarra pygmy perch (*Nannoperca obscura*), Variegated pygmy perch (*Nannoperca variegata*) and the Dwarf galaxias (*Galaxiella pusilla*). A draft plan is in preparation for Australian grayling although no plan has yet been developed for the Pale mangrove goby.

In Victoria, the *Flora and Fauna Guarantee* Act 1988 (FFG Act) provides for the listing of threatened taxa and communities and potentially threatening processes, and the development of management documents (known as Action Statements) to protect these items and ameliorate threats. Taxa and communities may be listed as threatened under the FFG Act if they are rare, in a demonstrated state of decline or prone to future threats. A potentially threatening process can be listed if in the absence of management, it poses or has the potential to pose, a significant threat to the survival or evolutionary development of a range of flora and fauna. Once a species, community or threatening process is listed, an Action Statement must be prepared for each

[7] A native species is eligible to be included in the ***conservation dependent*** category at a particular time if, at that time, the species is the focus of a specific conservation program, the cessation of which would result in the species becoming vulnerable, endangered or critically endangered within a period of 5 years.

item as soon as possible after the listing, outlining what has and/or should be done to conserve and/or manage the item.

Currently there are 24 native fish taxa and 13 potentially threatening processes listed under the Act which are relevant to Victoria's coastal rivers, estuaries and wetlands. However, to date there have only been 12 Action Statements published for native fish and only seven developed for the relevant potentially threatening processes. DSE, relevant CMAs and a range of other organisations are involved in the implementation of Action Statements. DSE has developed a web-based information system to store, update and retrieve information about actions to recover threatened species and communities: the Actions for Biodiversity Conservation system (ABC). The purpose of ABC is to:

- identify priority locations for threatened species and communities and priority management actions at those locations
- communicate actions and priorities to land managers
- monitor progress towards implementation by recording and reporting on results
- prepare and review Action Statements and Recovery Plans, and
- record and report on the status and trends for threatened species and communities.

2.2.2 Current monitoring and assessment programs for coastal rivers, estuaries and wetlands

Index of Stream Condition

Existing monitoring programs such as the State-wide Index of Stream Condition (ISC), have been designed to assist broad scale management of freshwater waterways by providing an integrated measure of their environmental condition (Ladson et al. 1999). This program currently scores five components of stream condition: hydrology, the condition of the channel and riparian zone, water quality and aquatic life based on the number of families of macroinvertebrates recorded at a designated site (Ladson et al. 1999). At present the ISC does not incorporate measures of native fish community health, a key component of river health. Review of the decision-making process indicates that although native fish were considered a potentially good indicator of river health and one which the community could easily relate to and identify with, the cost of developing methodology and sampling for native fish was considered prohibitive compared to other potentially suitable measures (Department of Natural Resources and Environment 1999). However, cost-effective methods for monitoring native fish populations have since been developed for the Sustainable Rivers Audit (Murray-Darling Basin Commission 2004b) and a slightly modified version of these are currently being applied to rivers in the coastal catchments through the Southern Rivers Audit – Southern Basins Program (see below).

Sustainable Rivers Audit – Southern Rivers Program

In 2004, the Sustainable Rivers Audit (SRA) – Southern Basins Program commenced in coastal Victoria to overcome the lack of consistent and detailed information on the health of coastal Victorian rivers. The audit is a modified version of the Sustainable Rivers Audit originally developed for rivers in the Murray-Darling Basin and has been designed as a comprehensive assessment of the condition of fish health at the river basin scale. It is envisaged that the program will assist in the setting and monitoring of targets for catchment and river health, provide a trigger to review threats to the rivers of the basin and, where appropriate, review management actions required to address these threats (Environmental Protection Authority Victoria 2007). Key tasks for the audit are to assess the existing health of the basin's rivers, to detect trends in health through time and predict the long-term ecological consequences of these changes. The indicators that are currently being used in the assessment are:

- fish diversity and relative abundance (native and alien)
- hydrology, and
- macroinvertebrates (small animals such as insects, snails, worms and shrimps).

A further three indicators are currently under development:

- physical form
- riparian vegetation, and
- floodplain condition.

Under the fish component of this program all 18 river basins south of the Great Dividing Range are to be sampled. In each basin, 18 randomly chosen freshwater sites, stratified according to altitude, will be sampled once during the five year program providing a snapshot of the fish species present, their relative numbers, lengths, and the health and condition of individuals of each species (J. Lieschke, DSE, ARI, pers. comm. 2007). This program is due to be finished during the 2008/09 sampling season. In addition to this, each river basin's estuary will also be sampled providing a snapshot of fish biodiversity values. This information will provide a reference point for future surveys from which changes in the fish communities can provide an indication of changes in river health. Ideally this program should be repeated over a number of years to provide a more comprehensive picture of changes in fish communities over time. Additional funding is being sought to continue the program.

It is important to recognise that the Audit is not designed to assess the ecological impacts of any specific management activity or policy in isolation and will not replace existing investigative or compliance monitoring for specific activities or operations (Murray-Darling Basin Commission 2004b). The audit is not designed to provide specific information for a given river. It was designed as a long-term monitoring tool for overall river health. Investigative and compliance monitoring will require programs that have been designed specifically to report on the management objectives.

Index of Wetland Condition

The recently developed Index of Wetland Condition (IWC) also excludes native fish from its method (Department of Sustainability and Environment

2005b). In order for a key ecological component to be included in the method it had to meet a series of requirements (e.g. consistency of use between wetlands, repeatability through to the level of knowledge of the relationship between the measure and human-induced changes in condition: Department of Sustainability and Environment 2005b). Based on this evaluation process it was determined that measures of species abundance, richness and diversity for fish:

- were unlikely to be suitable for use at all wetland types, as although native fish are likely to be common in some wetland types it is unlikely that they will be present or obvious in all wetlands types, and
- are unlikely to be repeatable unless conditions are similar at the wetland when the assessment is repeated.

Interpretation of data also relies on knowing or establishing relationships between wetland condition and a fish species/community. There is a lack of current knowledge linking fish communities or individual species with measures of wetland condition (Department of Sustainability and Environment 2005b).

3 Threats to native fish populations

In 1992, CSIRO published a report that listed eight direct causes of change to the rivers of rural Australia: modification of stream channels, damming watercourses, manipulation of stream flow, draining wetlands, transferring water to urban and industrial consumers, disposing of waste, extracting groundwater and irrigating agricultural land (CSIRO 1992). Siltation was identified as one of the most widespread processes degrading Australian rivers (CSIRO 1992).

More recent reviews of river health in Victoria under the Victorian River Health Strategy highlighted five primary modifications and eight processes that were substantially impacting on Victorian rivers.

Threatening modifications:

- barriers
- channel modifications
- flow deviation
- alien flora
- alien fauna, and
- stock access.

Threatening processes:

- bank erosion
- bed instability
- water quality
- temperature

- algal blooms
- degraded riparian vegetation
- loss of instream habitat, and
- modification of wetland connectivity.

3.1 Key threats to native species identified under current legislation and policy

A number of potentially threatening processes have been listed under the FFG Act which can directly or indirectly impact on the health of native fish populations.

- alteration to the natural flow regimes of rivers and streams[8]
- alteration to the natural temperature regime of rivers and streams
- degradation of native riparian vegetation along rivers and streams
- increased sediment input into rivers and streams due to human activities
- input of organotins to marine and estuarine waters
- input of petroleum and related products into marine and estuarine environments
- input of toxic substances into rivers and streams
- introduction and spread of *Spartina* to estuarine environments
- deliberate or accidental introduction of live fish into public and private waters within a Victorian river catchment in which the taxon to which the fish belongs cannot be reliably be inferred to have been present prior to 1770AD[9]
- invasion of native vegetation by "environmental weeds"
- prevention of passage of aquatic biota as a result of the presence of instream structures
- removal of wood debris from streams
- the discharge of human-generated marine debris into marine or estuarine waters, and
- wetland loss and degradation as a result of change in water regime, dredging, draining, filling and grazing.

Only one relevant threat is listed under the EPBC Act, "Land Clearance". Under the Act the definition of land clearance is:

Land clearing consists of the destruction of the above ground biomass of native vegetation and its substantial replacement by non-local species or by human artifacts. Native vegetation is defined as vegetation in which native

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[8] FFG Action statement No. 177 "Alteration of the natural flow regimes of rivers and streams", extraction of water is recognised as a contributing factor under this threatening process.
[9] FFG Action statement No. 190 "Introduction of live fish into waters within Victorian river catchments", according to the action statement the threat encompasses all fish belonging to the class chordata and therefore includes predatory fish such as salmonids and *Gambusia* as well as habitat modifiers such as Carp.

species constitute more than 70% of the plant cover, or other vegetation containing populations of species listed under the EPBC Act. Substantial replacement by non-local species or human artifacts is defined as the achievement of more than 70% of the total cover by species or human artifacts that did not occur previously on the site.

Land clearing includes clearance of native vegetation for crops, improved, pasture, plantations, gardens, houses, mines, buildings and roads. It also includes infilling of wetlands or dumping material on dry land native vegetation, and the drowning of vegetation through the construction of impoundments. It does not include silvicultural operations in native forests and manipulation of native vegetation composition and structure by grazing, burning or other means.

3.2 Threat prioritisation for the development of the guide

The development of this guide required the identification and prioritisation of all threats that impact native fish. Prioritisation will better enable the development of effective and consistent recommendations that targeted key areas of native fish management. In order to facilitate this process a preliminary workshop was conducted with a group of native fish experts[10] from across Victoria. In this workshop eight broad threats to native fish were identified:

- Barriers to native fish passage
- Degradation and loss of riparian habitat
- Degradation and loss of aquatic habitat
- Modified flows
- Inappropriate artificial opening of river mouths (mouth opening)
- Alien species
- Declining water quality and
- Exploitation/harvesting

These categories were then further divided into a number of more specific threats classified under each of the broader descriptors, providing a total of 41 specific threats identified as likely to impact on the health of native fish populations across the coastal catchments in Victoria (Appendix C). Using the scoring system outlined in Table 3.1, each of the key native fish species was then assessed to determine the level of risk it faced if exposed to each of the 41 threats. Risk scores for each native fish species with a conservation status have been detailed in Table 3.2a-c, risk scores for other species can be found on the FAST database.

Once the major threats to each fish species were identified a series of workshops were held in each of the coastal catchments. The aim of the workshops were to identify the extent and intensity of threats to native fish

[10] The native fish expert group included Dr John Koehn (DSE ARI), Tarmo Raadik (DSE ARI), Dr Jeremy Hindell (DPI), Tom Ryan (Independent consultant) and Steve Saddlier (DSEARI)

populations throughout coastal Victoria and to prioritise the threats according to the geographic and temporal scale of the threat and the level of impact of that threat or the interaction between the threat and the asset (native fish).

Participation in workshops was sought from local and regional natural resource managers and associated agencies and groups (e.g. conservation groups, water supply managers, etc), since they hold the most extensive and detailed knowledge of the geographic extent and the temporal scale of threats in their regions. Suitable participants were identified by each relevant CMA and other regional based NRM agencies. The workshops assumed that each participant would provide an unbiased assessment of the geographic and temporal scale of each of the threats in their region.

In these workshops, participants were asked to score each of the 41 threats for each basin in their region based on the geographic and temporal scale of the threat, using Tables 3.3 (geographic scale) and 3.4 (temporal scale). This provided a total score for each threat for each of the basins across coastal Victoria. At the completion of workshops, participants were asked to assess the scores across the basin in the region for each threat. This helped ensure consistency between basin groups. In addition, as certain issues were not comprehensively understood by all workshop members (e.g. water quality, wetland loss), appropriate CMA members were asked to verify scoring in each of the relevant basins to ensure consistency amongst basins.

An overall score for ***each*** threat was then derived by adding the total score for each basin to the fish risk scores, examples of which are provided in Table 3.2a-c. The full scores for each basin can be found on the FAST database (e.g. see example formula 3.1). The top 15 threats based on those that received the highest score, have been discussed in detail below. In addition to the 15 highest threats to fish across coastal Victoria, we have also discussed in detail the threat, *Inappropriate artificial river mouth opening – sudden low dissolved oxygen*. It was deemed a large enough threat in estuary environments to be discussed in detail. The score for this threat was lower than other threats (see Appendix C) because estuaries are small in terms of geographic scope and openings happen relatively infrequently on an annual basis. However, the impacts to fish are substantial and as large numbers of migratory species and recreationally important species utilise estuary environments, it was included in the detail description.

Table 3.1: Threat severity - the level of damage to a species that can be reasonably expected within 10 years under the current circumstances.

Score	Description
4	The threat is likely to cause the loss of this species in this area
3	The threat is likely to cause the loss of populations of this species in this area
2	The threat is likely to impair or degrade populations in this area over time
1	The threat will cause the loss of some individuals in this area but will not impact most populations negatively
0	The threat is unlikely to impact this species/group of species in this area

Table 3.2a: Key threats to native coastal Victorian freshwater fin-fish with a State or Commonwealth conservation classification (see Table 3.1 for scoring details)

Please note that threat scores for freshwater and estuarine species that do not have a conservation status can be found on the FAST database

Species	Barriers					Loss of instream habitat						Loss of riparian habitat			Modified flows							Exotic species				Declining water quality										Exploitation				mouth opening
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
Common name	Instream barriers	Loss of floodplain connectivity	Habitat fragmentation	Low flows prevent river mouth opening	Channelisation	Loss of Structural Woody Habitat (SWH)	Channelisation	Sedimentation	Loss of aquatic vegetation	Loss of wetlands	Bed Erosion	Exotic plants	Loss riparian vegetation	Bank Erosion	Loss seasonal flow	Loss within seasonal flow variability	Reduced flooding	Habitat change due to low flow	Reduction of flow volumes	Changes to water table level	Drought conditions	Exotic predators	Habitat modifiers	Competitors	Native spp outside their range	Low DO	High nutrients/faecal contamination	Increasing salinity	Changes in water temperature	High turbidity	Herbicides/ pesticides	pH/ Acid Sulphate Soils (ASS)	Algal bloomns	Metals	Litter	Recreational fishing	Commercial fishing	Capture for aquarium trade	Capture for bait	Artifical River mouth opening: sudden loss DO
Australian grayling	4	1	2	4	0	1	1	3.5	1.5	0.5	2	1	3	2.5	4	2	2	2	4	2	1	2.5	1	2	1	3	1.5	1	1	3	2	2	2	1	1	0	0	0	0	2
Australian mudfish**	3.5	3	2	4	1	1	3	1	4	4	2	1	3	2	3	1	3	3	3	2	2	2	2	1	1	0	1	1	1	2	2	2	1	1	1	0	0	1	0	2
Australian whitebait*	4	1	1	4	1	2	2	2.5	3	1	2	1	2	2	2	1	2	1.5	1	2	1	2.5	2	1	1	2	2	0	1	2.5	2	2	2	1	1	0	0	0	1	3
Cox's gudgeon**	3	1	2	2	1	2	2	3	2	1	2	1	2	3	2	1	1.5	2	2	2	1	2	1	1	1	2	2	1	1	2	2	2	2	1	1	0	0	1	1	2
Dwarf galaxias	0	2	2	0	2	1	3	2	4	4	2	1	3	2	3	2	3	3	3	2	3	4	2	3	1	1	2	2	1	2	2	2	2	1	1	0	0	2	0	0
Empire gudgeon*	3	2.5	2	1	1	2.5	2.5	2	3	3	2	2	3	2.5	2	1	2.5	2	2	2	1	1.5	1	1	1	1	2	0	1	1	2	1	2	1	1	0	0	2	0	1
Freshwater herring*†	4	1	1	3	1	1	2	2	2.5	1	2	1	2	2	2	1	2	2	2	2	1	1.5	1	1	1	2	2	0	1	2	2	2	2	1	1	1	0	0	0	3
River blackfish (upr Wannon R. form)	1	1.5	2	0	1	3.5	3.5	3	2.5	0.5	2	2.5	3.5	3	2	1	1.5	2	1.5	2	2.5	2	1	2	1	1.5	2	1.5	3	2	2	2	2	1	0.5	2	0	0	0	0
Striped gudgeon**	3	2.5	1.5	2	1	2	2.5	2	2.5	2.5	2	1	2.5	2.5	2	1	2	2.5	1.5	2	1	2	1.5	1	0.5	0.5	2	1	1	1.5	2	1	2	1	1	0	0	1	0	2
Variegated pygmy perch	1	1.5	2	0	1	2	3	3	4	2	2	1	3	2.5	2.5	1.5	2	3	2.5	2	2.5	3.5	2	1.5	2.5	2.5	2	1	1	2	2	1.5	1	1	1	0	0	1	0	0
Yarra pygmy perch	1	3	2.5	0	2	2	3.5	3	4	4	2	1	3	2.5	3.5	1.5	3	3.5	3	2	3.5	3.5	2	1.5	2	1.5	2	0.5	1	2	2	2	1	1	1	0	0	1	0	0

* known only from a single stream in coastal Victoria
** known only from a few locations
† species presumed extinct in coastal Victoria
Note: the numbers at the top of the threats list (1-41) relate to FAST

Table 3.2b: Key threats to native coastal Victorian freshwater decapods and bivalve molluscs with a State or Commonwealth conservation classification (see Table 3.1 for scoring details)

Please note that threat scores for freshwater and estuarine species that do not have a conservation status can be found on the FAST database

Species	Barriers					Loss of instream habitat						Loss of riparian habitat			Modified flows							Exotic species				Declining water quality										Exploitation				mouth opening	Climate change
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41
Common name	Instream barriers	Loss of floodplain connectivity	Habitat fragmentation	Low flows prevent river mouth opening	Channelisation	Loss of SWH	Channelisation	Sedimentation	Loss of aquatic vegetation	Loss of wetlands	Bed Erosion	Exotic plants	Loss riparian vegetation	Bank Erosion	Loss seasonal flow	Loss within seasonal flow variability	Reduced flooding	Habitat change due to low flow	Reduction of flow volumes	Changes to water table level	Drought conditions	Exotic predators	Habitat modifiers	Competitors	Native spp outside their range	Low DO	High nutrients/faecal contamination	Increasing salinity	Changes in water temperature	High turbidity	Herbicides/ pesticides	pH/ ASS	Algal bloomns	Metals	Litter	Recreational fishing	Commercial fishing	Capture for aquarium trade	Capture for bait	Artifical River mouth opening: sudden loss DO	Long-term changes to weather/temp. patterns
Alpine spiny cray	0	1	1	0	2	2	2	2	2	1	2	1	3	3	2	1	2	3	2	2	2	3	2	1	2	2	2	3	2	2	3	2	2	1	1	4	0	0	1	0	1.7
Curve-tail burrowing cray	0	1	1	0	2	2	2	2	2	3	2	1	3	4	2	1	2	3	2	3.5	1	1	1	1	1	1	2	3	2	1	3	2	1	1	1	0	0	0	0	0	1.8
Dandenong burrowing cray	0	1	1	0	2	2	2	2	2	3	2	1	3	4	2	1	2	3	2	3.5	1	1	1	1	1	1	2	3	2	1	3	2	1	1	1	0	0	0	0	0	1.8
Glenelg spiny cray	0	1	1	0	2	2	2	2	2	1	2	1	3	3	2	1	2	3	2	2	2	3	2	1	2	2	2	3	2	2	3	2	2	1	1	4	0	0	1	0	1.7
Lilly pilly burrowing cray	0	1	1	0	2	2	2	2	2	3	2	1	3	4	2	1	2	3	2	3.5	1	1	1	1	1	1	2	3	2	1	3	2	1	1	1	0	0	0	0	0	1.8
Mallacoota burrowing cray	0	1	1	0	2	2	2	2	2	3	2	1	3	4	2	1	2	3	2	3.5	1	1	1	1	1	1	2	3	2	1	3	2	1	1	1	0	0	0	0	0	1.8
Narracan burrowing cray	0	1	1	0	2	2	2	2	2	3	2	1	3	4	2	1	2	3	2	3.5	1	1	1	1	1	1	2	3	2	1	3	2	1	1	1	0	0	0	0	0	1.8
Orbost spiny cray	0	1	1	0	2	2	2	2	2	1	2	1	3	3	2	1	2	3	2	2	2	3	2	1	2	2	2	3	2	2	3	2	2	1	1	4	0	0	1	0	1.7
South Gippsland spiny cray	0	1	1	0	2	2	2	2	2	1	2	1	3	3	2	1	2	3	2	2	2	3	2	1	2	2	2	3	2	2	3	2	2	1	1	4	0	0	1	0	1.7
Strezelecki burrowing cray	0	1	1	0	2	2	2	2	2	3	2	1	3	4	2	1	2	3	2	3.5	1	1	1	1	1	1	2	3	2	1	3	2	1	1	1	0	0	0	0	0	1.8
Warragul burrowing cray	0	1	1	0	2	2	2	2	2	3	2	1	3	4	2	1	2	3	2	3.5	1	1	1	1	1	1	2	3	2	1	3	2	1	1	1	0	0	0	0	0	1.8
Western swamp cray	0	3	1	0	2	2	2	2	2	3	2	1	3	3	2	1	2	3	2	3.5	2	2	2	1	2	2	2	3	2	2	3	2	2	1	1	0	0	0	0	0	2.3
Eastern freshwater shrimp	0	1	1	0	2	2	2	2	2	2	2	1	3	3	1	1	2	2	2	2	3	3	2	1	2	3	2	3	2	2	3	2	2	1	1	4	0	0	1	0	1.9
Glenelg freshwater mussel	0	1	1	0	0	1	3	3	2	2	3	1	2	2	1	1	3	3	3	2	3	1	3.5	0	1	2	2	3	3	4	3	1	1	3	1	0	0	3	0	0	2.1

Note: the numbers at the top of the threats list (1-41) relate to FAST

Table 3.2c: Key threats to native coastal Victorian estuarine fish with a State or Commonwealth conservation classification

(see Table 3.1 for scoring details) Please note that threat scores for freshwater and estuarine species that do not have a conservation status can be found on the FAST database

Species	Barriers					Loss of instream habitat						Loss of riparian habitat			Modified flows							Exotic species				Declining water quality										Exploitation				mouth opening	Climate change
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41
Common name	Instream barriers	Loss of floodplain connectivity	Habitat fragmentation	Low flows prevent river mouth opening	Channelisation	Loss of SWH	Channelisation	Sedimentation	Loss of aquatic vegetation	Loss of wetlands	Bed Erosion	Exotic plants	Loss riparian vegetation	Bank Erosion	Loss seasonal flow	Loss within seasonal flow variability	Reduced flooding	Habitat change due to low flow	Reduction of flow volumes	Changes to water table level	Drought conditions	Exotic predators	Habitat modifiers	Competitors	Native spp outside their range	Low DO	High nutrients/faecal contamination	Increasing salinity	Changes in water temperature	High turbidity	Herbicides/ pesticides	pH/ ASS	Algal bloomns	Metals	Litter	Recreational fishing	Commercial fishing	Capture for aquarium trade	Capture for bait	Artifical River mouth opening: sudden loss DO	Long-term changes to weather/temp. patterns
Pale mangrove goby	1	1	2	1	2	0	0	1	3	2	2	0	2	1	1	1	1	1	1	0.5	1	1	1	1	1	3	2	1	1	1	2	1	1	1	1	0	0	1	0	3	1.5

Note: the numbers at the top of the threats list (1-41) relate to FAST

Table 3.3: The scale of the impact/threat - the geographic scope of the impact in each basin that has happened since settlement.

Score	Description
4	The threat is widespread across the basin/catchment **and/or** will affect > 80% of native fish populations/communities
3	The threat is widespread and will affect native fish at many locations (50-80% of native fish populations/communities)
2	The threat is localised in its scope and will only affect native fish at some locations (20-49% of fish populations/communities)
1	The threat is very localised and will only affect a portion of individuals at some locations (<20% of fish populations/communities)
0	The threat is unlikely to impact this species/group of species at any geographic scale

Table 3.4: The temporal scale of the impact/threat - The frequency of the impact and the rate of asset deterioration.

Score	Description
4	The threat is imminent (likely to occur at any moment)
3	The threat is constant **and/or** spreads rapidly
2	The threat occurs frequently **and/or** spreads at a medium rate
1	The threat occurs infrequently **and/or** spreads slowly
0	The threat occurs at a rate that does not reduce the asset condition or ability to recover over time.

Threats that produce chronic and frequent impacts to the condition of an asset would get a high score.

Formula 3.1

Overall score for threat 'Instream barriers' = Basin 21 (GS + TS) + Basin 22 (GS + TS) + Basin 23 (GS + TS) + Basin 24 (…) + …… + Basin 38 (GS + TS) + Risk score Australian grayling + Risk score Australian mudfish + …+ Risk score Western swamp cray

Where GS is the Geographic Scale and TS is the Temporal Scale of the threat as defined by tables 3.3 and 3.4 respectively.

3.3 Threats to native fish in coastal Victoria

The top 15 threats, ranked as High Priority, in the workshops across coastal Victoria are listed in Table 3.5.

Table 3.5: High priority threats to native fish identified in the regional workshops undertaken in the development of this guide

***High priority* threats**	Listed as potentially threatening process under FFG Act	Listed as key threatening process under EPBC Act
Loss instream habitat		
Loss of aquatic vegetation		
Sedimentation	✓	
Channelisation		
Loss of wetlands	✓	✓
Loss of structural woody habitat	✓	
Degradation of riparian habitat		
Loss of native riparian vegetation	✓	✓
Bank erosion		
Modified flows		
Reduced flow volume	✓	
Loss of seasonal flow regimes	✓	
Declining water quality		
Herbicides and pesticides	✓	
High turbidity/suspended solids		
High nutrients (including faecal contamination from cattle)		
Alien species		
Alien predatory fish	✓	
Barriers to fish movement		
Instream barriers	✓	
Change of habitat due to low flows/Habitat fragmentation	✓	

These processes are relatively widespread through coastal catchments in Victoria and are likely to substantially affect a large number of native fish species in these catchments. As such, the above processes are perceived as those with the highest likelihood of impacting on the future persistence of native fish populations in coastal Victorian catchments.

It is important to note that Table 3.5 is an assessment of the level of impact or risk these threats have across coastal catchments from Glenelg Hopkins through to East Gippsland. It is therefore a very broad assessment of the risks posed within each basin. The ranking of these threats varied substantially between basins and this emphasises the need for catchment-based assessment that address specific threats for each basin. This guide will provide the framework and biological information that will help inform natural resource managers, however specific threat assessment should be undertaken in each basin using FAST to identify key threats for specific works.

3.4 High priority threats to native fish

3.4.1 Loss of instream habitat

Loss of aquatic habitat

Aquatic vegetation, including submerged (e.g. seagrasses, *Myriophyllum* spp, *Potamogeton* spp, *Triglochin* spp.) and emergent vegetation (e.g. Cumbungi, *Baumea* spp., mangroves), can play an important habitat role, providing shelter for native fish, productive food source areas, suitable sites for some species to lay their eggs and potential juvenile nursery areas. A number of Victorian native fish species are reliant on instream native vegetation (e.g. Australian mudfish - *Neochanna cleaveri*, Australian smelt - *Retropinna semoni*, Dwarf galaxias, Mountain galaxias - *Galaxias olidus*, Variegated and Yarra pygmy perches, Hairy pipefish - *Urocampus carinirostris*, Small-mouthed hardyhead - *Atherinosoma microstoma*, Western swamp cray - *Gramastacus insolitus*) and the loss or substantial modification of the instream vegetation structure is likely to impact on these species. This habitat also has important secondary benefits for other fish such as:

- supporting enhanced biomass and diversity of macroinvertebrates (an important source of food)
- preventing or reducing bank erosion, and
- Providing nursery areas (especially in estuarine environments).

Removal of instream vegetation through river channel or estuary modifications, loss through smothering by sediment or input of toxic substances to the waterbody, algal blooms, river cleaning practices, freshwater extraction, increasing salinity, urban development, drought or inappropriate revegetation can all contribute to a substantial loss of habitat for many native fish communities.

Little published information is available on the extent and nature of instream vegetation in the coastal catchments of Victoria. West Gippsland CMA (WGCMA) provides a summary of the number of reaches with good instream habitat incorporating the presence of structural woody habitat (SWH), pool, run, riffle zones, a variety of substrate types as well as aquatic vegetation. The WGCMA identified that 44 of the 110 reaches represented by the Bass, Powlett and Tarwin Rivers were in good to excellent condition in terms of instream habitat (West Gippsland CMA 2007). A detailed survey of the aquatic vegetation of the Tarwin River was conducted in 1994, but no further surveys were reported (West Gippsland CMA 2007).

A detailed study of the macrophyte community in the mid and upper reaches of the Glenelg River was undertaken in 1996 as part of an assessment of the impacts of the Rocklands Reservoir on instream communities (Mitchell et al. 1996). The report identified that submerged aquatics were completely absent from five of the nine study sites and that aquatic emergent macrophyte species such as Cumbungi (*Typha domingensis)* and Common reed (*Phragmites australis)* dominated sand depositional sites: a process promoted by the changes in flow regime caused by the Rocklands reservoir. Mitchell et al. (1996) identified that fluctuations in river flows as a result ot the Reservoir and the subsequent instability of the substratum (sand mobilisation) have inhibited colonisation of sites by submerged aquatics and favoured emergent species which often prefer sand depositional sites. Water quality analysis also indicated that increasing salinity due to reduced water releases from Rocklands may be inhibiting the growth of submerge macrophytes at many of the sites studied in the Glenelg River (Mitchell et al. 1996). Few other studies have provided details on instream vegetation in Victorian streams and wetlands.

Very little information is available on the potential loss and/or degradation of aquatic vegetation in estuarine environments in coastal Victoria. However, documentation of the loss of seagrasses in larger Victoria embayments has been more comprehensive. In the period between 1970 and 1984 there was a major (70%) decline in *Heterozostera* spp. seagrass beds in Western Port (Jenkins et al. 1997) and these losses paralleled a 40% decline in the total commercial catch of finfish in the bay (Jenkins et al. 1993). Causes for the seagrass loss in Western Port have not been clearly identified but are likely to be attributed to a number of factors including increased sedimentation and nutrients from catchment activities: activities that are also likely to have affected instream vegetation in estuaries entering the bay.

Modifications to the physical components of rivers and wetlands can not only cause the loss of instream flora but may also alter the biodiversity balance within the stream and increase the available habitat for some plant species, as was noted in the Glenelg River below the Rocklands Resevoir (see Mitchell et al. 1996). For example, low flow rates and the more permanent flow associated with highly regulated rivers and wetlands (see section 3.4.3) can promote the growth of emergent macrophytes such as Common reed (*Phragmites australis*) and Cumbungi (*Typha* spp.). Modifications of the physical environment can result in decreased aquatic flora diversity compared with a natural system, with some species dominating the available habitat. But these semi-monocultures can provide valuable habitat for native fish and provide shelter and habitat for some aquatic invertebrates in systems which may otherwise lack alternative habitat.

The lack of documented information on the extent and condition of aquatic vegetation in coastal catchment of Victoria prevents any assessment of the likely magnitude of loss of instream vegetation since European settlement. However, human-induced changes to rivers, wetlands and estuaries, such as sedimentation, erosion, flood control, grazing by livestock, loss of riparian vegetation and decreasing water quality are all likely to have impacted on the type and extent of aquatic vegetation in Victorian waterways. A recent review of the extent and magnitude of the processes that can contribute to the loss of aquatic vegetation in waterbodies across coastal Victoria, indicates that modifications to instream aquatic vegetation are likely to be substantial particularly in freshwater and estuarine wetlands and the lowland estuarine reaches of waterways where human impacts are typically widespread (National Land and Water Resources Audit 2002b, a).

Sedimentation

Under natural conditions the magnitude and duration of sediment loads to waterways is largely determined by climate, topography, soil types, geology, vegetation and the timing of runoff. Some catchments may naturally have received relatively high sediment inputs on an intermittent basis as a consequence of extreme events such as extensive wildfire and flooding. However, the volumes of sediment and the duration of these events have been exacerbated by human activities such as clearing for forestry and agriculture, degradation and removal of riparian zones and wetlands, urbanisation, road construction and extractive industries.

Soil erosion data indicates that there has been a 100-fold increase in the supply of sediments to south eastern coastal catchment streams (New South Wales (NSW) to Victoria: National Land and Water Resources Audit 2002b). The greatest rate of increase has been in southern Victoria, where sediment supply is estimated to have increased by up to 1000 times natural levels in basins that have historically had very low rates (e.g. Bunyip River and Portland Coast: National Land and Water Resources Audit 2002b).

High sediment loads represent a significant threat to many native fish species, as the deposition of the sediment smothers vital instream native fish habitat such as deep pools, aquatic vegetation and woody debris. Indirect threats to native fish include the depression of invertebrate productivity through smothering and habitat modification. Sediment can also contribute to habitat fragmentation with large sediment deposits potentially creating a barrier between important native fish habitats within the river. High sediment loads received during crucial life stages can also impact on the reproductive output of some native fish species by smothering and killing demersal[11] fish eggs. Sediment loads can contribute substantially to water turbidity adversely impacting on the gills of some native fish species and reducing visibility for sight based feeders. Sediment can also carry significant nutrient loads which can contribute to the reduction in water quality.

Channelisation

The straightening and channelisation of rivers involves the removal of obstructions to flow such as bends, instream vegetation, rocky areas and may involve artificially protecting banks from erosion by concreting banks or other erosion control forms. These modifications are believed to increase the navigational accessibility of the river, improve drainage and aide flood control, however investigations of such river modifications in Australia have shown that

[11] Demersal fish eggs: eggs which sink or are deposited near the bottom of a waterbody.

the expected benefits are rarely achieved (Department of Natural Resources and Environment 2002). Channelisation also results in:

- steeper stream gradients, which increases water flow velocity, making stretches of stream inhabitable for some species
- reduced average pool depths but a deeper river overall as the stronger currents wash away bottom sediments and/or increase erosion, which leads to the loss of instream habitat variability (e.g. deep holes, low flow meanders, aquatic vegetation, structural woody habitat)
- loss of riparian vegetation
- loss of pool, riffle, run sequences
- loss of the natural bank morphology and
- increased turbidity levels

Channelisation can represent a substantial threat to many fish and invertebrate species that rely on instream habitat variability or the quality of the bank and riparian zone. For example, the Glenelg freshwater mussel (*Hyridella glenelgensis*) requires streams with significant amounts of sandy sediment and aquatic vegetation, two components that are often quickly lost as a consequence of channelisation. Cannelisation can result in the loss of slow water refuges such as meanders, aquatic vegetation and SWH, which are important for various pygmy perches (*Nannoperca* spp.), the River blackfish (*Gadopsis marmoratus)* and several galaxiid species.

Loss of wetlands

The loss of floodplain wetlands and other native fish habitat wetlands has occurred extensively throughout Victoria, with almost 4000 natural wetlands (191 000ha) lost since European settlement (Department of Sustainability and Environment 2005b). Whilst the initial impetus for the removal of wetlands appears to have been for the benefit of agricultural expansion, drainage schemes and infilling have also been associated with flood mitigation, water supply, salinity control, sewage schemes, development of ports, industry or urbanisation, particularly evident in coastal regions (Norman and Corrick 1988).

One particularly significant example, is the draining of the culturally significant Koo-wee-rup Swamp which was formed primarily by the Bunyip River, the Ararat Creek and numerous minor tributaries (Norman and Corrick 1988). The original swamp covered approximately 40 000ha and was vegetated with tea tree and rushes. Reclamation works saw the draining of the swamp and subsequent agricultural development of almost all of the wetland area, with only deep drainage channels remaining. Estimates indicate that silt and sand discharge into Western Port subsequent to the removal of the swamp and until 1983 have amounted to 6 000 000m^3 (Norman and Corrick 1988).

Wetlands are also substantially impacted by changes to their natural water regimes, which can drastically alter the wetland appearance and functioning. Changes to the water regime can be imposed by drainage, raising or lowering of water tables, construction of levee banks and the use of wetlands for water storage or wastewater disposal. Salinity, grazing by livestock, increased nutrients, wetland pest plants, Carp, sedimentation, etc, all impact substantially on the health of wetlands in Victoria. At least nine potentially threatening processes listed under the FFG affect wetlands and many species that depend on wetlands are now threatened with extinction (Department of Natural Resources and Environment 1997), including seven native fish species which utilise wetlands for all or part of their life cycle.

Loss of structural woody habitat

Structural woody habitat (SWH) refers to fallen trees and large branches lying in the river channel. This wood helps create localised microhabitats such as eddies, small isolated areas of turbulence or still water which provides suitable habitat for native fish and other organisms. The wood also provides a large surface area on which invertebrates and algae can attach. This habitat component is vital for many native fish to provide:

- spawning sites (e.g. River blackfish)
- protection from strong currents and sunlight
- orientation points to identify habitat and territory
- shelter from predators
- vantage points to help capture prey
- the provision of food
- instream habitat diversity, and
- encourages variability in stream depth and width.

In many streams and estuaries of Victoria, SWH was systematically removed to improve stream flow, improve passage for boats, reduce the severity of flooding and assist with substrate removal (e.g. sand, gravel and gold extraction). There is no evidence to suggest that this practice reduces flooding, but the removal of SWH can have a severe effect on the health of freshwater ecosystems and on their flora and fauna and increase erosion processes (Rutherford et al. 2002, Cottingham et al. 2003).

Although this practice has largely stopped (although not completely), the natural replacement of SWH has been hindered by the lack of riparian vegetation along many streams and rivers. With no natural vegetation remaining there is no immediate source of SWH and in many systems replacement can only be achieved by artificially placing logs into rivers and estuaries until the riparian vegetation has been replaced and had time to develop. Such replacement is now seen as a viable option for habitat rehabilitation in some areas.

3.4.2 Degradation and loss of native riparian habitat

Loss of native riparian vegetation

The riparian land is the land adjoining, directly influencing or influenced by, a river or wetland. Vegetation in this zone provides shade, supplies energy, nutrients and habitat to the stream and floodplain. This important habitat component plays some vital roles:

- overhanging cover (physical habitat)
- regulates instream primary production through shading and inputs of organic matter
- traps sediment, nutrients and other contaminants reducing the loads of these pollutants to streams and wetlands
- protects river banks from erosion, and
- provides a food source (e.g. terrestrial invertebrates/carbon inputs) and habitat (e.g. SWH, leaf litter, twigs, insects, etc).

Degradation of this zone is caused by clearing native vegetation, stock grazing, recreational use, increasing salinity, changes in flow regimes and alien pest species such as rabbits and willows. Loss of the quality and quantity of native riparian vegetation can affect a stream and its native fish communities by:

- increasing the amount of sunlight reaching the stream which facilitates the growth of algae. This can subsequently can lead to reduced oxygen levels in the water when the algae starts to break down, making these areas uninhabitable for many native fish
- increasing stream temperatures which can impact on a number of native fish species which prefer cooler waters and it can expose them to high levels of UV light
- altering the loads of organic matter (see Box 3.2) and woody debris (hardwood vs softwood) entering the stream, disrupting natural nutrient flows and instream habitat availability and reducing the numbers of macroinvertebrates, which form an important food resources for some fish species/life stages
- modifing the volumes and/or seasonality of organic inputs to a stream, reducing the number of aquatic invertebrates supported by the system; an important food source for many native fish (see Box 3.2 for details)
- increasing the sediment and nutrient loads to the stream from the catchment, and
- destabilising stream banks, leading to erosion and increased sediment loads downstream and also reducing downstream habitat for native fish.

Over 54% of the reaches assessed in the coastal catchments of Victoria as part of the 2004 ISC were described as cleared (i.e. considered largely devoid of native vegetation) or highly disturbed, while only around 18% scored 8 or more (out of 10) for the streamside zone sub-index (Victorian Government 2006) – a score considered to indicate that the riparian vegetation in these reaches was largely intact (Victorian Government 2006). The removal and modification of riparian vegetation can adversely affect all aspects of stream and wetland habitat, and has been identified as a major cause for the decline of Victoria's native freshwater fish (Koehn and O'Connor 1990b).

Box 3.2: Exotic plants

Exotic plants are an increasing problem along rivers in Victoria. Many of these plants are garden escapees that in the absence of natural predators and pathogens may slowly overtake native vegetation (Pen 1999). Replacement of natural riparian vegetation by introduced trees and grasses can have substantial effects on the instream and terrestrial biota. Exotic deciduous species such as willows and poplars can modify the timing and intensity of organic inputs into streams. Natural vegetation typically drops small amounts of leaves and twigs year round, providing a constant supply of organic matter to streams. In contrast, deciduous willows and poplars provides a massive input of quickly decaying organic matter producing one large input of nutrients to the stream, with little or no input at other times of the year. This can limit instream productivity for the remainder of the year, restricting food availability for aquatic species (Pen 1999). In addition, litter from native vegetation – particularly eucalypts – is protected by high concentrations of secondary plant products such as phenolics. This greatly reduces their rate of decomposition (in compassion with exotic species) providing a sustained source of food for aquatic detritivores, particularly in streams in which connection to riverine (floodplain) vegetation is irregular. The absence of leaves on deciduous trees or the absence of any canopy at all in the case of pasture or grassed areas in the riparian zone can also modify the light levels received by the stream and consequently the temperature regime in the stream (Pen 1999).

Bank Erosion

Bank erosion can be a natural part of Victorian stream processes. However, this process has been exacerbated by land clearance and changes to the riparian vegetation. Clearing of native vegetation in a catchment can lead to increased runoff, particularly during storm events, which ultimately increases water flow velocity in streams (Pen 1999). Further, the loss of riparian vegetation and instream vegetation can lead to unstable banks and a decreased capacity for flow velocity to be reduced. Waterways which retain native riparian vegetation can in part reduce the impact of these larger flow velocities as the riparian vegetation will effectively slow the water as it enters the stream and protect the banks from erosion processes in the stream. However, once native riparian vegetation is removed, damaged by stock or replaced with alien plant species, the potential for bank erosion is increased in rivers. The resulting incision of the banks can ultimately deepen the channel, increase the steepness of the bank and hence increase the potential of the bank to collapse. Stock add to the problem by placing further pressure on already unstable banks. Over 40% of the 569 reaches assessed in the 2004 ISC in the coastal catchment of Victoria had moderate to extreme erosion of the banks (Victorian Government 2006), while less than 3% were considered stable (Victorian Government 2006).

Bank erosion is particularly detrimental to species reliant on the riparian zone for shelter and breeding. As such many of the burrowing cray species which burrow in the riparian zones, are at risk from stock access, bank erosion and collapse.

3.4.3 Modified flows

Reduced flow volume

The extraction and the retention of water from waterways is widespread in Victoria with almost all rivers in coastal catchments of the State subject to some level of water extraction or damming (Doeg and Heron 2003). These processes can lead to reduced flow volumes in streams and wetlands, which can ultimately lead to:

- reductions in the amount of available instream habitat
- lowered water levels resulting in instream habitat fragmentation preventing native fish from moving between vital habitat areas
- loss of floodplain wetlands and hence important habitat and feeding zones
- less available instream water during drought periods, reducing habitat availability
- loss of habitat complexity, reducing the refuge habitat available for small species and some life-stages
- increase the ephemeral nature of streams, reducing the availability of permanent water
- loss of cues to migration for spawning
- reduction in water quality, and
- lack of natural river mouth opening (estuary closure) preventing natural migrations.

Natural flood patterns are important to maintain river profiles: during floods, sediment is moved and deposited. Reduced flooding causes the build up of sediments, which can fill natural pools and smother instream habitat. Without natural floods to flush the river, the channel can decrease in size, reducing its capacity to contain the increases in flow during very wet years.

Australian native fish have evolved to cope with drought conditions. In natural systems extreme drought events may cause the loss of many individuals and in some cases the local extinction of species. The migratory nature of many of native fish species enables them to recolonise areas after severe events. However, when changes to flow volumes causes drought conditions to occur regularly, there is little chance for species to recolonise and they may be permanently lost.

Loss or modification of seasonal flow regimes

Under natural flow conditions, streams in coastal Victoria typically have a high flow in winter followed by relatively low flows in summer. Dams, weirs, water extraction and other flow modifications can all alter these natural flow regimes. Irrigation releases from dams can produce sustained high flows in summer with little or no flow in winter (see Figure 3.1). This can lead to the increased erosion of riverbanks: high flows followed by a rapid reduction in water depth can cause water laden banks to collapse under their own weight, particularly if they have been ‘notched’ as a result of previous extended periods of unchanging (regulated) flow. The change in timing of flow events can also impact substantially on instream biota.

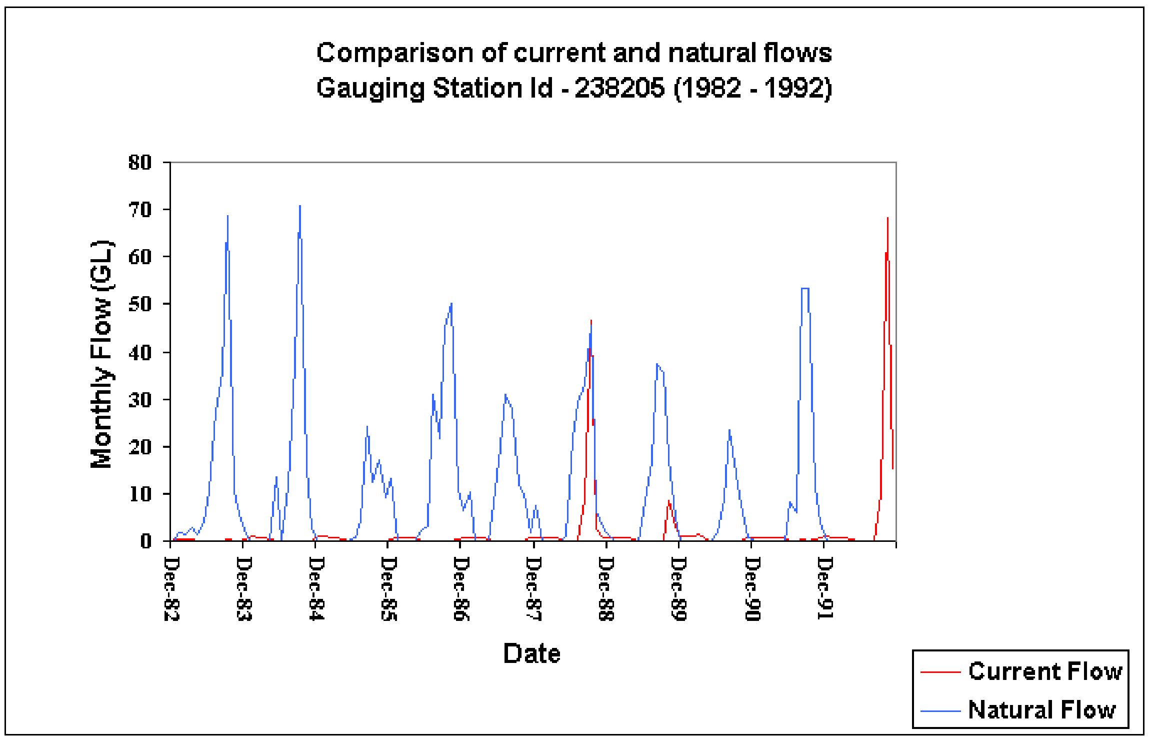

Figure 3.1: Illustration of the variation in flows from the natural regime in a coastal Victorian river basin (Glenelg River basin) as a consequence of upstream dams (Department of Environment Water Heritage and the Arts 2007b).

Many native fish rely on natural seasonal flow regimes to stimulate spawning and migration. For example, female Tupong (*Pseudaphritis urvillii*), migrate downstream to their estuarine or marine spawning grounds during high flows in late autumn and winter (Koehn and O'Connor 1990a). The Broad-finned galaxias (*Galaxias brevipinnis*) and the Spotted galaxias (*Galaxias truttaceus*) require a rise in water level to stimulate spawning. The Spotted galaxias lays its eggs on fringing vegetation, while the Broad-finned galaxias lays eggs along the edges of the streams, both of which require a second high flow to cover the exposed eggs before they can hatch. If the second rise in water is not received the eggs are likely to perish (O'Connor and Koehn 1991, O'Connor and Koehn 1998). The loss of seasonal flow regimes can therefore severely impact on the long-term survival of these and other flow dependent species.

Major storages exist in all Victorian catchments south of the GDR, except East Gippsland. Of these basins, over 50% have been classified as fully allocated[12]

[12] **Fully allocated/developed** is a termed used in surface water management areas where the sustainable yield has been nominally set at the current allocation because either: 1) no further development can occur due to the high salinity of the remaining water or 2) the determination of

in terms of their developed surface flows, four of which have over 70% of their developed - sustainable yield[13] allocated (i.e. all of the water in the river can be removed after considering instream environmental flows). However, in many instances the sustainable yield allocations have not fully addressed the environmental requirements[12]. Of the remaining basins south of the GDR, four have between 30-70% of their developed - sustainable yield allocated for extraction and only five basins south of the divide are considered to have low surface water development (i.e. 30% of the developed-sustainable yeild allocated: Department of Environment Water Heritage and the Arts 2007b, c).

Loss of seasonal flows as a consequence of high levels of water extraction from coastal aquatic systems is one of the major environmental impacts on coastal native fish. Without seasonal cues for migration and spawning many native fish populations will start to decline and in some instances can be lost completely from the system.

3.4.4 Alien predatory fish

Alien predatory fish do not naturally occur in Australia and are known to prey on native fish, their eggs, or larvae. Many alien predatory fish have been introduced to Victoria for recreational purposes, namely Redfin (*Perca fluviatilis)*, Brown trout (*Salmo trutta)*, Rainbow trout (*Oncorhynchus mykiss)*, Chinook salmon (*Oncorhynchus tshawytscha*) and Atlantic salmon (*Salmo salar*). Eastern gambusia (*Gambusia holbrooki*) were introduced for the control of mosquitos. Many of the above mentioned species are widespread throughout coastal Victoria and represent a substantial predatory pressure on a number of native fish species.

Redfin (*Perca fluviatilis*)

Redfin are native to Europe and Asia, with the exception of Spain, southern Italy and Greece (Clarke et al. 2000). They were introduced to Tasmania in 1862 for recreational fishing purposes and were subsequently introduced to Victoria in 1868. The species is now found in Victoria, NSW, South Australia (SA), Western Australia (WA) and Tasmania (Clarke et al. 2000).

Redfin are a popular game fish that inhabit a variety of waterbodies including billabongs, dams, lakes, rivers and streams. They show a preference for areas

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the sustainable yield is awaiting outcomes of detailed environmental flow studies (Department of Environment Water Heritage and the Arts 2002).

[13] The **developed yield** refers to the annual volume of water that is available for diversion at a defined level of reliability, taking account of environmental water requirements. **Sustainable yield** is the estimated maximum volume of water than can be diverted after taking account of in-stream environmental water requirements. However where sustainable yields have been limited in accordance with the current allocations within the SWMA, it is assumed that the current environmental water provisions represent the maximum volume of water that can currently be made available to the environment after consideration is given to the rights of existing users, and related social and economic impacts. In some situations these provisions may not fully meet the environment's requirements (Department of Environment Water Heritage and the Arts 2007c).

with aquatic vegetation, rocky outcrops and SWH and are unable to swim up steep gradients or sections of rivers with high water velocities (Cadwallader and Backhouse 1983). They are tolerant of high salinities (up to 50% seawater), however they are rarely found in brackish water. Redfin are prolific breeders with females carrying up to 100 000 eggs/kg of fish (Clarke et al. 2000).

The species' predatory nature, prolific breeding ability and tendency to form large shoals means it is likely compete with larger native fish for food and predate on small native fish species. Cadwallader and Backhouse (1983) suggests that the species has the potential to significantly reduce the abundance of smaller native fish species such as pygmy perch and Carp gudgeon in enclosed systems, while Wager and Jackson (1993) indicate that Dwarf galaxias, Yarra pygmy perch and Variegated pygmy perch are all likely to be impacted by Redfin.

<u>Brown Trout (*Salmo trutta*)</u>

Brown trout are native to Europe. They were introduced to Tasmania in 1860 and later to Victoria, NSW, SA and Queensland to enhance recreational fishing (Cadwallader 1996). The species is currently found from southern Queensland through the eastern parts of NSW, most rivers of Victoria, south-eastern SA, southwestern Australia and Tasmania (Clarke et al. 2000).

Brown trout are a popular game fish, whose self sustaining populations are generally restricted to cooler (4-19^{o}C) streams above altitudes of 600m (Arthington and Bludhorn 1995). Adults of the species can tolerate warmer streams but breeding is restricted in these waterbodies. They tend to prefer shallow, well oxygenated waters with stream beds of gravel, cobbles and pebbles, areas with large amounts of overhanging riparian vegetation and instream SWH. Brown trout may also inhabit lakes, resevoirs, deeper river holes, and some estuaries (Allen et al. 2003).

Brown trout have had a major impact on the distribution and abundances of some native freshwater fish and invertebrate communities and have been implicated in the decline of species on the IUCN redlist, including the Yarra pygmy perch, Variegated pygmy perch, Australian grayling (*Prototroctes maraena*) and Dwarf galaxias. The species has also been shown to reduce populations of Mountain galaxias (Fletcher 1979), Broad-finned galaxias (Jackson and Williams 1980), Spotted galaxias (McDowall 2006) and River blackfish through competition and predation (Jackson 1978). The principal impacts of Brown trout are direct predation and/or food and habitat competition and introduction of disease (Cadwallader 1996, Clarke et al. 2000).

<u>Rainbow trout (*Oncorhynchus mykiss*)</u>

Rainbow trout are native to the western coast of the USA, Canada and northern Mexico (Clarke et al. 2000). They were first introduced to Australia in NSW in 1894 and were subsequently introduced to Tasmania, Victoria, SA, Queensland and WA (Clarke et al. 2000). The species has persisted in all of these states and self sustaining populations generally persist in cooler high altitude areas of NSW, Victoria, Australian Capital Territory (ACT) and Tasmania. Stocked populations are maintained in warmer areas of all states except Northern Territory (NT) and SA (Clarke et al. 2000). Sea-run trout have been reported to occur in Victorian and Tasmanian streams (Arthington and Bludhorn 1995).

Rainbow trout are a cold water species (4-22^{o}C) preferring fast flowing water with high oxygen content (Cadwallader and Backhouse 1983). They prefer streams with large amounts of overhanging riparian vegetation and SWH for cover, however they will also live in deep river holes, lakes and estuaries (Cadwallader and Backhouse 1983). They require gravel based sediment in well oxygenated waters for successful spawning.

Rainbow trout have a significant impact on native fish and invertebrates through direct predation and food and habitat competition (Arthington and Bludhorn 1995, Clarke et al. 2000). The Mountain galaxias has been widely reported as having either dramatically reduced abundance or severely fragmented distributions in the presence of trout (Jones et al. 1990, Koehn and O'Connor 1990c, Lintermans 1991). Linterman (2000) reported the recolonisation of a trout-inhabited stream by the Mountain galaxias once Rainbow trout had been eradicated. Research in New Zealand has identified that Rainbow trout also actively prey on Australian smelt and Broad-finned galaxias and has been implicated in the local decline of these species in New Zealand (Rowe et al. 2003, Ward et al. 2005).

Eastern gambusia (*Gambusia holbrooki)*

Eastern gambusia are native to southern USA and northern Mexico and were first introduced into Australia in 1925 to control mosquitoes. This species has been largely ineffective as a mosquito control agent (Lloyd et al. 1986) but has subsequently become a widespread and persistent pest. They now occur in NSW, South Australia (SA), Western Australia (WA), Queensland, Northern Territory (NT) and Victoria. The species can persist in almost every aquatic habitat in south-eastern Australia except in tableland streams where winter temperatures affect their reproductive cycle (Clarke et al. 2000).

Eastern gambusia typically favour warm, slow flowing water amongst aquatic vegetation at the edge of waterbodies. However, they are exceptionally tolerant to a wide range of environmental conditions (Pen and Potter 1991) and will inhabit, marshes, lakes, dams, slow flowing streams billabongs and aqueducts. They are able to tolerate a wide range of temperatures from just above freezing to 38^{o}C (Lloyd et al. 1986). The species can persist in waters with low dissolved oxygen and in salinities ranging from fresh through to fully marine (McDowall 1996). They are an omnivorous, viviparous breeder (McDowall 1996), with an aggressive nature, and are therefore likely to impact on a range of native fish and amphibian species (McKay et al. 2001, Clunie et al. 2002). Impacts include competition for resources such as food and space, harassment such as fin nipping and chasing and predation of eggs, larvae and juveniles of native fish and amphibians. In Australia, no local native fish extinctions have been attributed to the Eastern gambusia but the fish is likely to impact small native fish species such as Variegated pygmy perch, Dwarf galaxias, and Yarra pygmy perch and it is considered likely to prey on the eggs, larvae and juveniles of larger species (Wager and Jackson 1993).

Other predatory species

Two other alien predatory fish species are present in Victorian coastal catchments, namely the Atlantic salmon (*Salmo salar*) and the Chinook or Quinnat Salmon (*Oncorhynchus tshawytscha*). The Chinook salmon is native to western-north America and northeast Asian coastlines, including Japan. While the Atlantic salmon is naturally found on the northeast coast of USA and Canada and the northwest coast of Europe. Both species have a very limited distribution in Victorian coastal catchments and as yet have not formed self-sustaining populations. The Department of Primary Industries periodically stocks Chinook salmon in Lake Purrumbete and Lake Bullen Merri (Department of Primary Industries 2006b) and has previously stocked Atlantic salmon in the LaTrobe River (Allen et al. 2003) but has not scheduled stocking of Atlantic salmon for the 2007/2008 period (Department of Primary Industries 2006b). Both species are likely to have similar impacts on native fish species as other Salmonid species including the Brown and Rainbow trout.

3.4.5 Declining water quality

High nutrients (including faecal contamination or pathogens)

Decreasing water quality is a common issue across Victoria's coastal catchments. Of particular concern in many catchments is the high nutrient load of many waterways, estuaries and wetlands. While nutrients are essential for river function, excess nutrients can disrupt normal processes, increasing the risk of algal blooms and increase epiphytic growth on submerged aquatics, such as seagrasses, affecting their growth. This in turn can lead to other water quality issues such as low dissolved oxygen.

Increased nutrient loads to Victorian waterways since European settlement are a consequence of extensive clearing in combination with use of artificial fertilisers, increasing urbanisation and associated waste management (e.g. unmanaged sewage disposal), industry, loss of floodplain wetlands and high intensity grazing in riparian zones. Point source discharges are a significant source of nutrient loads in river basins and estuaries close to major population centres. Similarly, rivers located near smaller non-sewered towns, can receive high loads of point source nutrients from poorly functioning septic systems. A significant proportion of the total nutrients are also contributed to streams from sediments. The problem is therefore often exacerbated in areas which have significant erosion issues.

The direct impacts of high nutrient loads on many native fish species is not well documented, however indirect impacts associated with the toxic effects of algal blooms, decreasing dissolved oxygen levels and loss of aquatic vegetation are better documented. Fish and associated aquatic fauna (shellfish) can also be contaminated with toxins from algal blooms and some pathogens commonly associated with human and animal faecal waste. These contaminants can represent substantial human health risks if contaminated fish and shellfish are consumed by humans.

Herbicides and pesticides

Pesticides and herbicides are used widely in agricultural and forestry systems in Australia. Many of these chemicals have hazardous or unknown effects on non-target organisms. With current application techniques (e.g. spraying) it is inevitable that fractions of the applied herbicides and pesticides will enter aquatic ecosystems via spray drift, runoff and leaching (Wijngaarden et al. 2005). Non-target species living in water catchments of agricultural or forestry areas are potentially at risk of harm, especially if they have similar toxicant receptors as the target organisms. In a recent review of freshwater ecosystems studies of neurotoxic insecticides it was identified that the most sensitive taxa to the organophosphate and synthetic pyrethroid insecticides tested were representatives of crustaceans, insects and fish (Wijngaarden et al. 2005).

A clear example of the potential effects of spray drift on aquatic biota was recorded in northern Tasmania by Davies and Cook (1993). Aerial spraying of the pyrethroid, cypermethrin, on a Shining gum (*Eucalyptus nitens)* plantation resulted in a spray drift of around 0.05mg/L to nearby small streams. This contamination resulted in a 200 fold increase in the macroinvertebrate drift (i.e. the large scale movement of aquatic invertebrates, either dead or alive, downstream with the current). The macroinvertebrate drift remained elevated over background levels for eight days after the spray event and macroinvertebrate populations only recovered after winter floods. Brown trout noted to have fed heavily on the drifting organisms were observed to be lethargic, lost self-righting ability and startle response, had an anaemic appearance of the gills and a strong variation of colour patterning accompanied by hardening and haemolysis of muscular tissue (Davies and Cook 1993). The event resulted in both direct (i.e. loss of aquatic invertebrates) and indirect effects (i.e. impacts to fish and food sources) of the aquatic biota (Davies and Cook 1993).

The quantities of pesticides and herbicides used in Australia are difficult to gauge, however sales of crop protection pesticides have increase some 836% in the period 1974 to 1991; an annual increase of 36% (Radcliffe 2002). Taking into account pricing increases and chemical use trends over this period there appears to have been a substantial increase in the volume of compounds potentially hazardous to non-target organisms applied to agricultural districts and their surrounding ecosystems.

The toxicity of chemicals varies greatly with their intrinsic properties, but generally different classes often show general patterns of toxicity (Radcliffe 2002). For example the synthetic pyrethroids generally have a low toxicity to mammals and birds but are highly toxic to fish and invertebrates. Today the most widely used group of pesticides, the organophosphates, are highly toxic to invertebrates (including crustaceans such as spiny and burrowing crays) and are generally considered less toxic to fish but this is highly dependent on the fish species (WHO 1986). Around 5 000 tonnes of the active ingredients found in organophosphates pesticides and herbicides are in use annually on crops such as fruits, nuts, viticulture, grain, vegetables, pasture seed and cotton crops (Radcliffe 2002).

High suspended solids

The amount of suspended material (e.g. silt and clay) in the water can alter the amount of light that can penetrate the water column. High levels can therefore restrict instream primary production and may in some cases kill submerged aquatic plants (including seagrasses), through lack of light. This can then reduce native fish habitat availability. High levels of fine particles in the water column can also irritate and clog fish gills reducing their capacity to breathe and impede feeding capacity in visually cued organisms. The suspended solids in the water column of a river, estuary or wetlands can be affected by catchment clearing, flow regulation, water extraction, nutrient loads, sediment entering the river from the catchment, changes in water chemistry and the removal of riparian vegetation.

High turbidity levels (a measure of suspended solids) are a widespread water quality issue in Australia. The affected areas included most inland and lower rainfall basins of the North-East Drainage Division, the majority of the Murray-Darling Drainage Division and the more intensively developed basins of the southern South-East Coast Drainage Division (National Land and Water Resources Audit 2000). According to the National Land and Water Resources Audit (2000) over half of the basins in the coastal catchments of Victoria exceeded the recommended turbidity guidelines. Only the LaTrobe, Thomson, Snowy, and Mitchell catchments recorded good levels (< 5NTU: based on the criteria outlined in Victoria's SEPP surface water quality guidelines) for turbidity in the 2000 report.

Inappropriate Artificial River Mouth Opening - Low dissolved oxygen

Fish require certain levels of dissolved oxygen (DO) within the water column to survive. The absence of oxygen or low levels (c. < 5ppt can cause stress) of oxygen in the water column can cause the death of native fish and other instream fauna and may impact on the health on aquatic flora (Koehn and O'Connor 1990a). Stagnation of the water, increasing water temperatures, decomposition of organic material and high nutrient loads can all lead to a reduction in the amount of dissolved oxygen present within the water column. The conditions which can lead to low dissolved oxygen conditions can be directly and indirectly caused by:

- water extraction: low summer flows can cause the build-up of nutrients, chemicals or saline water and the stratification of stagnant pools leading to anoxia (the absence of dissolved oxygen).
- loss of riparian habitat: reduced shading of the water body can increase water temperatures leading to increasing fish demand for

oxygen, excessive algal growth both of which can lead to low oxygen conditions
- bank erosion (loss riparian vegetation): can reduce stream or wetland depth resulting in higher water temperatures
- high nutrient loads due to agricultural practices, urbanisation and loss of riparian vegetation and floodplain wetlands: can increase the risk of algal blooms which can significantly reduce oxygen levels during the decomposition of the algae and at night when algae stop photosynthesising, and
- limited water mixing.

Estuary management can involve the periodic opening of sand barriers at the river mouth to release water out to sea. The impetuous is often to mitigate flooding problems for properties in the immediate vicinity of the estuary however this sudden opening can have a severe impact on the fauna of the estuary if the opening is not timed appropriately (Barton and Sherwood 2004).

In low flow conditions estuaries often become highly stratified (Barton and Sherwood 2004). The upper layers of the waterbody tend to be highly oxygenated and provide an ideal habitat for fish and other aquatic biota. However, with limited mixing, the bottom salt wedge layer (see section 9.3.1 for further details) in the estuary can quickly become anoxic (zero dissolved oxygen) and no longer suitable for aquatic biota. Low flows in combination with the development of a sand wedge across the mouth of the river can exacerbate these conditions, leaving only a very shallow layer of oxygenated water above the anoxic water. Artificially opening the river mouth when these conditions are present can result in a sudden drop in the dissolved oxygen levels in the entire estuary as the top oxygenated layer will rush out to sea leaving only the anoxic bottom layers behind. This can cause mass fish deaths such as those reported in the Surrey River, western Victoria in July 2005 (Barton and Sherwood 2004).

3.4.6 Barriers to fish movement

Instream barriers

Instream barriers refer to any man-made barrier that limits the free passage of native fish between habitats. Barriers can include large structures such as weirs and dams but also includes smaller less obvious obstacles such as culverts, road crossings and stream modifications that greatly increase flow velocity (e.g. channelisation). Large barriers such as weirs or dams are readily identified as barriers to native fish. Smaller, less obvious barriers such as culverts, road crossing and channelised waterways are generally not as well recognised, though they may be impassable for some native fish species.

Over 70% of Victoria's coastal native freshwater fish species are migratory (Harris 1984, Koehn and O'Connor 1990a) and therefore barriers to movement can seriously impact on their access to vital habitat for spawning or feeding. In some catchments it has been estimated that there are over 800 barriers to native fish movement (R. Coleman, Melbourne Water, pers. comm. 2007). Data gathered as part of the 2004 ISC showed that, over 71% of the assessed streams and rivers in the coastal catchment of Victoria had some form of native fish passage barrier. This is likely to substantially impact on the long-term persistence of many native fish species, particularly those which migrate to spawn and is likely to contribute to localised extinctions.

Barriers can also contribute to a number of other deleterious impacts, including:

- reduction in the diversity and abundance of accessible habitats
- increased angling pressure below barriers
- increased predation by birds or other fish
- reduction in genetic diversity due to limited or no input from outside sources, and
- accumulation of sediment upstream of the barrier.

Fragmentation/change of habitat

Instream habitat fragmentation refers to the loss of longitudinal connectivity between habitats types within a stream (e.g. no connection between pools, or between pools, runs and other habitat segments of streams). Physical barriers such as weirs, channelisation or sand banks can reduce instream connectivity, and this may be exacerbated by low flows induced by extraction and/or drought. Low volumes of water can result in limited connection between pools, floodplains or other suitable habitats. Similarly, sedimentation processes which smother riffle zones with sediment may create sand banks that divide a stream during low flow periods or remove important habitat area during high flows. Stream "improvement" programs also exacerbate the extent of this threat. Activities such as dredging sand bar areas, removal of SWH and removal of instream vegetation, while intended to facilitate flows can all lead to sedimentation further downstream. The disconnection of pools can increase the susceptibility of some species to predation, including angling, and can exacerbate the problems associated with poor water quality.

Low flows and river modifications such as channelisation can also reduce access to floodplain waterbodies such as billabongs, lakes, salt marshes, flood runners and distributory channels. These waterbodies are naturally connected to rivers during high flows and are critical parts of the river ecosystem. They are typically highly productive when filled, providing an extensive and complex variety of habitats and food sources for many aquatic organisms including native fish. These habitats can provide important nursery areas for a number of juvenile native fish (e.g. Dwarf galaxias, Australian smelt, Australian mudfish, various pygmy perch, Pale mangrove goby) as they provide suitable shelter areas from large predators with an ample supply of food. Wetlands are also temporarily inhabited by native fish species such as the Short-finned eel, *Anguilla australis* and Long-finned eel, *A. reinhardtii* that are able to move across land looking for water after a wetland or river section has dried, and the Australian mudfish and Dwarf galaxias that are known to aestivate[14] and survive periods of drying (Humphries 1986, Romanowski 2004, McDowall 2006).

[14] Aestivate: the adults are able to survive out of free water in moist conditions

Access to floodplain waterbodies can be affected by changes to the flow regime (e.g. volumes, seasonality and frequency) as well as modifications of the channel. These modifications can result in the long term loss of these floodplain habitats through lack of flooding and in the short term, limit or exclude native fish access to these valuable habitat areas. For some species of native fish this may result in reduced recruitment and the decline of the species.

3.5 Current management responses to high priority threats in coastal Victoria

3.5.1 Loss of instream habitat

The importance of replacing SWH in Victorian streams and estuaries has been acknowledged in many of the regional RHSs. As such, there are programs in place which aim to actively replace SWH and which will provide long-term indirect natural replacement of SWH through the rehabilitation of riparian zones. Direct replacement of SWH should be aimed to maximise habitat for the available native fish fauna, reduce instream erosion processes and encourage the natural re-establishment of aquatic vegetation. Positioning and formation of SWH will differ according to the site and the species of aquatic fauna native to that reach and therefore it is important to seek expert advice in the placement of wood in rivers and estuaries. Land and Water Australia have produced a number of documents outlining the geomorphic or engineering role of SWH (Rutherford et al. 2002, Cottingham et al. 2003, Brooks et al. 2006, Treadwell et al. 2007). There has also been some recent research on the placement and formations most suitable for a diversity of native fish species in the Murray-Darling Basin (Nicol et al. 2002, 2005).

Management of aquatic vegetation is less defined, and few of the regional RHSs deal with this component of river health directly. The East Gippsland CMA has identified the use of the native emergent macrophyte, Common reed, *Phragmites australis*, to control bank erosion in the Mitchell River and others are currently addressing bank erosion issues through re-establishing vegetation on banks. Melbourne Water has also undertaken some aquatic revegetation works in the Bunyip River (D. Cook, Australian Ecosystems, pers. comm. 2007).

The current scale of Ecological Vegetation Classes (EVCs) have only limited application in the management of instream aquatic vegetation, as the scale is generally too coarse to fully encompass the suite of species found in a typical stream. Recently revised wetland typology has seen improvements in this area with a recent EVC group (962: Riparian Wetland) produced which describes the floristic communities of the instream wetlands, extending to lower flood-prone banks on relatively quiet stretches of stream verge. This description deals with the riparian margin, and semi-aquatic and aquatic herbs. This EVC has yet to be mapped (A. Oats, DSE, pers. comm. 2007), but it is described as widespread across the State within major watercourses. However the floristic group is typically restricted to very small patches within these watercourses. Lentic wetland EVCs are often more comprehensive.

The ISC does not currently have a sub-index that considers instream floristic habitat components. The current scoring only deals with SWH and the condition of the riparian zone which is measured from the high water mark on the bank to a distance 30m perpendicular to the river. Aquatic vegetation is therefore often overlooked in assessment of river habitat components and few surveys of instream floristics are available.

Replacing instream habitat

In some cases, instream vegetation is likely to re-establish itself once the threatening processes have been removed (D. Cook, Australian Ecosystems, pers. comm., 2007, K. Hardcastle, Syrinx Environmental PL, pers. comm. 2007). However, natural reestablishment will be dependent on the availability of instream propagules, competition with introduced aquatic weeds, the condition of the stream and the persistence of substrate should the stream have been subject to large erosion processes (D. Cook, Australian Ecosystems, pers. comm. 2007). Reestablishment of instream vegetation in flowing environments requires appropriate guarding to ensure roots can quickly establish without plants being flushed away during high flow periods. Revegetation techniques are often restricted to mature individuals, as seeds will invariably be washed away. The presence of SWH or other structural components creating areas of slack water will be important in this regard. Management plans for streams which are impacted by erosion and with low habitat availability within the aquatic-zone should consider aquatic vegetation reestablishment.

Control of sediment movement, erosion and the replacement of SWH will all assist in the re-establishment of instream vegetation. Comprehensive surveys of the type, extent and condition of instream vegetation and other associated habitat would be useful in identifying streams and wetland with high aquatic fauna values and provide baseline data to assess the impact of erosion control measures.

Aquatic weeds

There are several aquatic weeds that are recognised as threat to river, wetland and estuarine health (e.g. S*partina*, Salvinia, Parrots feather *Myriophyllum aquaticum*, Cabomba *Cabomba caroliniana*, Canadian pond weed *Elodia* spp., Reed sweet grass *Glyceria maxima,* See Box 3.3 for a case study). Control of these species will be a vital part of ensuring the health of aquatic ecosystems. Phase 1 and 2 of the Victorian Noxious Weed Review (See Box 3.4 for further details) were recently completed (Weiss 2006). As part of the review process:

- the status of currently listed noxious weeds was reviewed
- the potential of spread and further invasion of regional priority weeds not already declared in Victoria, but noted in Regional Weed Action Plans (nine species in total) were assessed

- assessed the potential spread and invasiveness of other weed species identified as important for the State. This includes species on the Weeds of National Significance (WONS) list, the National Environmental Alert List and other species nominated by the community through the CMAs (Weiss 2006).

Research by Bunn et al.(1998) indicates that the restoration of native riparian vegetation is an effective long-term means of controlling invasive macrophytes. The shading created by the riparian vegetation reduces the density of these species without disrupting the river substrate, minimising erosion potential and impacts to other more desirable aquatic vegetation.

Box 3.3: Case Study: Reed sweet grass
Reed sweet grass (*G. maxima)* which was introduced to Australia as a palatable pasture grass has now become an invasive weed throughout much of southern Australia (Clarke et al. 2004). Its spread and prolific growth is facilitated by poor agricultural practices which can increase nutrient loads to aquatic ecosystems and the removal of native riparian vegetation which can alter light and hydrological regimes in rivers and wetlands. The species competes aggressively with native species and may cause major changes in ecosystem processes. The grass has now been confirmed as a source of cattle poisoning (Barton et al. in Clarke et al. 2004). Reed sweet grass is recognised as an autogenic ecosystem engineer, with the ability to convert sections of fast flowing aerobic streams into partially anaerobic swamps and significantly alter macroinvertebrate communities, which in turn can impact on the fauna communities which rely on these aquatic organisms for food (Clarke et al. 2004). The impacts of revegetation and shading on *G. maxima* have yet to be determined (Clarke et al. 2004).

Box 3.4 Victorian Noxious Weed Review
Under the Victorian Pest Management Framework - Weed Management Framework (2002) it was identified that a review was required that assessed the economic, environmental and social impacts of noxious weeds. The Victorian Noxious Weed Review (VNWR) commenced in 2002 and aims to review all potential and currently listed noxious weeds and to develop a decision-support framework. The review followed the principles contained in the Proposed National Technical Specification for Post Border Weed Risk Management (CRC for Australian Weed Management). The VNWR has been rolled out in three phases:

- Phase 1: completed in 2004 - a review of the existing list of 101 declared noxious weed species
- Phase 2: recently completed - assessed the potential of regional priority weeds not already declared in Victoria, but noted in Regional Weed Action Plans

Phase 3: to be completed – assess the potential of other weed species identified as important for the State.

Management of the river channel - channelisation

Under the VRHS it has been recognised that the channelisation of rivers in Victoria has reduced instream habitat and that many of the activities associated with this management practice exacerbated other threatening processes such as bed and bank erosion (Department of Natural Resources and Environment 2002). As such the VRHS outlines the need for regional RHS to assess the current condition and management of the channel and determine if there are opportunities to restore habitat. The regional RHS's have established management objectives for major river reaches and set prioritise for:

- protection of public infrastructure assets
- protection of other environmental and social assets, and
- restoration of instream habitat and connectivity.

(Department of Natural Resources and Environment 2002)

The protection of assets under the VRHS is based on a risk assessment which examines the value of the asset, consequences of its damage or loss, likelihood of the threat and the cost of protection works. The strategy does not directly address the reestablishment of meanders or reconnection of disassociated rivers with their floodplain ecosystems. However, these issues should be addressed in high priority areas where possible.

Loss of wetlands

To date, wetland management in many regions has primarily focussed on Ramsar sites, with little or minimal management of wetlands that have not been recognised under the convention. Only five sites within the management boundaries of this guide have been recognised as requiring conservation status under the Ramsar Convention (Department of Sustainability and Environment 2008), yet there are over 9000 wetlands, >1ha in the coastal catchments of Victoria (Norman and Corrick 1988). The Corangamite CMA has developed a Wetland Strategy for its region, the vision of which is to "maintain the extent and enhance the quality of wetlands...". Most of the remaining coastal CMAs are currently in the process of developing similar strategies. One of the key priorities from these strategies will be to develop wetland action plans. Ensuring these plans incorporate the management of native fish will be important in creating ecologically integrated plans. DSE has planned to incorporate wetlands within their revision of the VRHS planned for 2009.

3.5.2 Degradation and loss of native riparian habitat

The importance of riparian habitat has been acknowledged in all of the regional RHSs. Each regional RHS has identified priority areas where remnant vegetation must be protected and zones where weed control and/or replanting is required. Each responsible agency has a required riparian protection/ revegetation target that has been set under the relevant regional RHS. Revegetation programs are based around the relevant EVC benchmark for that reach of the river. These benchmarks provide guidelines on the density of planting and the proportion of the plants that should be planted from each life form. But the EVCs are typically coarse in scale and often do not provide the fine scale zones of plants which would be seen in a cross section of the plant communities running from the bank through to the periphery of the riparian zone (i.e. a reflection of the water regime experienced in the cross section). CMAs and other NRM agencies must therefore assess the habitat requirements of each of the species on the EVC list and determine planting zones accordingly.

In the past revegetation programs did not necessarily address this issue and efforts were mainly focussed on the upper sections of the riparian zone with little emphasis on revegetating the bank. However many of the CMAs are now ensuring that revegetation programs include the bank and are establishing planting protocols to ensure species' selection is appropriate for that water regime (G. Peters, CCMA, pers. comm. 2007).

A number of assessment tools are available for evaluating the condition of riparian zones:

ISC
The ISC provides a useful rapid assessment tool to determine the condition of the riparian zone, assessing nine different indicators of health including the connectivity of the zone, understorey, canopy, weeds, etc. The streamside assessment is based on a comparison between the current condition of the site compared with its EVC benchmark (Department of Sustainability and Environment 2004). This score then provides sub-indices for the overall ISC and can be used to set priorities, measure the effectiveness of integrated management and provide information with which to set benchmarks for stream condition throughout the State (Ladson et al. 1999).

ISC also considers the physical form of the bank to assess the current level of erosion of the bank and the banks potential for further erosion. The score considered the toe of the bank and assesses the bank profile, slope, density of vegetation, presence of exposed roots, and any evidence of previous or current erosion (Department of Sustainability and Environment 2004).

Rapid Appraisal of Riparian Condition
Land and Water Australia has developed a Rapid Appraisal of Riparian Condition (RARC) based around a similar approach as that used to develop the ISC (Ladson et al. 1999, Jansen et al. 2005). The system has been designed to use at a large number of sites and is responsive to changes in grazing management. As such it is useful in determining the relationships between riparian condition and management practices. Jansen et al. (2005) have noted however that the system is designed for rivers with relatively permanent water, with at least 60% canopy cover and the assessment is only intended to be used to assess the current condition and will not indicate the potential for recovery of ecosystem function in rehabilitated areas.

Riparian Revegetation Assessment Technique
Sutter and Newell (2002) recently developed an assessment tool that evaluated the success of riparian revegetation programs. The tool involves contrasting the revegetation site with the condition of the site prior to planting and therefore attempts to identify the degree of improvement of the ecological values of the site. This system requires further refinement (G. Newell, DSE, ARI, pers. comm. 2007).

Habitat Hectares
Habitat Hectares native vegetation assessment was developed in Victoria to assess the quality of remnant native vegetation (Parkes et al. 2003). This

system is applicable to remnant vegetation in both terrestrial systems and the riparian zone. The method attempts to assess how 'natural' a site is by comparing it to the same vegetation type in the absence of major ecosystem changes that have occurred since European settlement of Australia (Parkes et al. 2003). The method is useful in providing comparison between systems, however it is not useful in structurally simple systems, such as grasslands, wetlands, or other treeless communities (Parkes et al. 2003).

3.5.3 Modified flows

Victoria currently has a water allocation framework aimed at protecting river health, social and cultural values and providing all users with appropriate and tradeable entitlements. Bulk entitlements are currently managed by DSE and apply to regulated rivers such as those with large dams or weirs. The bulk entitlements define the amount of water a rural or urban water authority may take from a river storage, but can also require the manager to release a particular environmental flow regime from a storage (Department of Natural Resources and Environment 2002). It is also possible that a bulk entitlement can be provided for the environment.

Bulk entitlements may also apply to unregulated rivers, where water authorities and private diverters are authorised to extract water directly from the river. Historically the majority of the water was taken in summer, often risking ecological stress, however for approximately 18 years, new summer diversion licences have not been issued (Department of Natural Resources and Environment 2002). Under the water allocation framework, a risk-based management approach has been applied to prioritise streams in Victoria into management categories according to a number of criteria. Streams classified with a high environmental value and a high level of risk from extractive processes, have been given the highest level of management and it is the responsibility of the CMAs to develop and implement Streamflow Management Plans (SFMP) for these rivers. Under these plans there are provisions to improve the environmental flow regime over time. The emphasis of these plans has been to maintain or protect environmental or ecological values by ensuring sufficient water is available for plant and animal communities and/or ecosystem functions.

The Victorian Environmental Flow Monitoring and Assessment Program (VEFMAP) has been established to coordinate the monitoring of ecosystem responses to environmental flows (Chee et al. 2006). High priority rivers in the coastal catchments that have been included in the initial Statewide program include the Thomson, Macalister and the Glenelg Rivers (Chee et al. 2006).

The Victorian Floodplain Management Strategy (VFMS) provides a Statewide framework for managing floods and provides the context for the development of regional Floodplain Management Strategies by the CMAs and Melbourne Water (Department of Natural Resources and Environment 2002). One of the primary principles under the regional Floodplain Strategies is that wherever possible, rivers should be allowed to flood naturally and that statutory planning processes should not permit any buildings or development on the floodplain.

Under Part 10 (sections 201 to 212) of the Water Act, each CMA or responsible authority (Melbourne Water) has floodplain management responsibilities for its declared region.

Their key functions include:

- determine out how far floodwaters are likely to extend and how high they are likely to rise
- declare flood levels and flood fringe areas
- declare building lines
- control developments that have occurred or that may be proposed for land adjoining waterways
- develop and implement plans and to take any action necessary to minimise flooding and flood damage, and
- provide advice about flooding and controls on development to local councils, the Secretary for Planning and Environment and the Community.

As with the regional RHS, decisions made under the VFMS must take into account the social, economic and environmental values of the floodplain. In many instances, the floodplain area can provide very rich and fertile land which can provide substantial economic returns or desirable water front living. Historically, this has meant that housing, infrastructure and other physical assets have been placed within the floodplain zone. In such areas, re-establishing links to the river are unlikely to be feasible especially if there are potentially high losses of assets. Re-establishing links in floodplain zones through re-establishing natural river banks and profiles where little or no development has occurred and preventing further development in these zones should be a priority for all local government councils, CMAs and Melbourne Water.

3.5.4 Alien predatory fish

Alien predatory fish such as salmonids (trout and salmon) and Redfin are currently managed as a fisheries resource through the Department of Primary Industries (DPI), Fisheries. These fish species have significant social and economic benefits as they provide sport fisheries and are a choice table fish. In many areas, Redfin maintain self-sustaining populations. Brown trout also have become self-sustaining in many highland streams, but many other Victorian streams do not maintain suitable habitat for trout populations to persist at high levels over the long-term. In order to maintain recreational opportunities, trout are regularly stocked in recreationally targeted streams in which there are no self sustaining populations. Similarly, salmon are stocked in a number of lakes in southern Victoria. Trout and salmon have been stocked in Victorian waters since the 1860s and the DPI currently releases between 300 000 and 400 000 salmonids each year (Department of Primary Industries 2005) to support recreational fisheries. The DPI currently has a stocking policy, which requires that in order for a waterway to be stocked, there must be no reasonable evidence that the released fish may constitute an unacceptable risk to a threatened species or community (e.g. Listed under Victoria's FFG Act or the Commonwealth EPBC Act: Department of Primary Industries 2005). As such, no stocking should occur in ecologically sensitive areas.

However, limited knowledge of the current distribution of some threatened species or communities may mean inadvertent stocking in sensitive areas. Further, trout may escape into sensitive areas from trout farms, some members of the general public may also illegally stock areas without consideration of the potential impacts on native fish communities and stocked fish may migrate to sensitive native fish habitats. Greater community awareness of these issues and improved understanding of threatened species distributions will help alleviate these problems.

A recent review commissioned by the NSW National Parks and Wildlife Service on the potential for control of Eastern gambusia populations in NSW, highlighted that there were currently limited methods available for the control of this alien species (McKay et al. 2001). It was noted that very few of the available methods have been trialled in a range of water body types and all methods require the sacrifice of non-target species. The report noted that given the species' small size and large potential population sizes, the eradication of entire populations is unlikely (McKay et al. 2001). McKay et al. (2001) noted that the greatest potential for success was in small-sized standing waterbodies such as dams and ponds. However, all the methods examined have clear disadvantages and the potential to impact on non-target native species including those that are threatened, restricts these options.

3.5.5 Declining water quality

Widespread land degradation, such as land clearing and erosion, has led to increased sediment inputs into Australian rivers and streams. The Environmental Protection Authority (EPA) is currently running a program formally known as Ecosystem Guidelines for Sedimentation and Suspended Particulate Matter in Rivers and Streams (SPM). The aim of this project is to develop a set of indicators that water resource managers can use to assess sedimentation risks to ecosystem health.

Erosion, nutrients and other associated water quality issues (e.g. dissolved oxygen, aquatic toxicants, etc) are currently being addressed under the regional RHS. A range of strategies such as nutrient management/water quality strategies, have identified priority riparian zones that require fencing to prevent stock access and areas that require rehabilitation to minimise bank erosion and to reduce sediment and nutrients loads to the river and/or wetland from the surrounding environment. Other programs under the regional RHS include the application of better waste management practices on dairy farms, undertaking audits to ensure compliance with the Codes of Forest Practice for timber production on public land, stormwater drain stenciling and stormwater education in schools and ongoing monitoring. All are aimed at achieving outcomes such as reduced nutrient and sediment loads to the State's rivers, estuaries and wetlands.

The Victorian State Government recently acknowledged the impacts that more than 400 unsewered country towns in Victoria were having on the water quality of the State's rivers and wetlands. As such, the *Country Towns Water Supply and Sewerage Program* was established to attempt to sewer as many country Victorian towns as possible. The program, which commenced in 2006, is aiming to provide sewage services to 23 priority towns throughout the State, including 13 in coastal Victoria.

As identified in section 2.1 an Estuary Entrance Management Support System (EEMSS) was recently developed to provide clear and transparent guidelines for the management of river mouth openings. This Microsoft Access-based database assists managers across coastal Victoria to integrate the myriad of issues, risks and effects in the decision-making process for the artificial opening of estuary entrances. The support system examines the impacts of intermittently closed estuaries on the environmental, social and economic values of those estuaries and assesses the need for opening accordingly (Arundel 2006, EEMSS 2006).

Victoria has developed a set of environmental quality objectives for the protection of aquatic ecosystems in rivers and streams for the State Environment Protection Policy (Waters of Victoria). The objectives of SEPP acknowledge there is a wide range of aquatic ecosystems that function in a variety of ways and respond to many different threats.

The environmental quality objectives under SEPP describe the level of environmental quality needed, in most surface waters, to avoid risks to beneficial uses and to protect the ecosystems. If an objective is not attained, the beneficial uses are likely to be at risk. The non-attainment of an objective in a waterbody will trigger further investigation using a risk-based approach, to refine the assessment of risks to beneficial uses. From this assessment, actions will be implemented or regionally appropriate objectives will be developed. Unfortunately, there is very little within existing policies to ensure that managing agencies act appropriately when water quality does not meet these objectives. However, this process is currently recognised under the regional RHS and is now used as a water quality threat indicator under these programs. As such, the water quality objectives set under SEPP are used to help set targets for river health, placing greater responsibility on managing agencies to act if water quality objectives are not met.

3.5.6 Barriers to fish movement

In the initial round of RHS in 2004, each CMA identified barriers to native fish movement, and through a prioritisation method, listed barriers that could be modified or removed to provide the best outcomes for native fish movement. Some barriers which could be removed or modified without adversely affecting water supplies and which were considered priority under the State Fishways Program are currently being altered to allow fish passage.

The number of barriers identified in this process and their location were based on the Statewide Index of Stream Condition (ISC 1999), the RiVERS dataset and the State Fishway Program (McGuckin and Bennett 1999). This data was the most comprehensive at the time and enabled the identification of almost 1300 barriers to fish passage in the south-east coast division (McGuckin and Bennett 1999, O'Brien and Blackburn 2003). Unfortunately, much of the data for the State Fishway Program was based on topographical maps produced in the 1980s and some dated back to 1971 (McGuckin and Bennett 1999). This meant that barriers installed since the development of the map may have been overlooked, along with small historical barriers on tributaries and private property. Areas of channelised stream, culverts and road crossings were generally not recorded. As noted by a number of natural resource managers, there are substantial numbers of historical infrastructure on the rivers in many districts which may act as native fish barriers. Many of these structures are no longer needed, however, their existence is not widely known. A more comprehensive assessment of native fish barriers throughout the coastal catchments is therefore required.

Many of the CMAs are currently in the process of undertaking more extensive surveys of their rivers under their jurisdiction to determine the number, type and potential impact of river structures to native fish passage. Amongst other things, this will provide a valuable check on potential barriers immediately up or downstream from current or proposed fishways.

3.5.7 Habitat rehabilitation sites (Demonstration reaches)

Many habitats for native fish species are degraded and require a suite of rehabilitation activities, including provision of environmental flows and native fish passage, alien species management, replacement of SWH and the rehabilitation and protection of riparian margins and floodplain wetlands. To be most effective, it is recognised that such actions should be undertaken in an integrated and cohesive way.

The creation of demonstration reaches is an important component of the implementation of the *Native Fish Strategy for the Murray-Darling Basin 2003-2013* (Murray-Darling Basin Commission 2004a). Demonstration reaches aim to integrate all land and water programs to form a comprehensive rehabilitation exercise on important and visible river reaches that illustrate the habitat management activities for the wider community. Reaches suitable as demonstration sites should be degraded but fixable, incorporate measurement and monitoring programs, and support the testing of scientific hypotheses. Rehabilitation activities should address a number of threats and ecological issues, and incorporate multiple management interventions. Being located along prominent, visible and large (i.e. 20 -100 km) stretches of river, can maximise their value and potential for wider-scale application and ensure broad public exposure.

The key purpose of these sites is to show the community the cumulative benefits of using a number of actions for rehabilitating native fish populations and communities as well as to support managers and scientists in testing and refining their understanding of the systems involved. Demonstration reaches can assist in engaging the community and gaining their support, ownership and involvement in rehabilitation works as they witness the benefits to the environment. To achieve their purpose, it is important that the community plays an integral part in the creation of the reaches. During the establishment of demonstration reaches, site-specific information needs to be gathered regarding historic, current and potential threats, and biological and ecological information. Scientific, Indigenous and anecdotal information can assist in understanding the dynamics of native fish populations, 'natural' conditions and human impacts.

A range of demonstration reaches are currently being established across the Murray-Darling Basin. In northern Victoria, there are three demonstration reaches in various stages of establishment, situated along the Campaspe River, the Ovens River, and Hollands Creek. The rehabilitation of these river reaches is occurring through the existing regional River Health Strategies framework. Through the demonstration reach concept, there is great potential to include native fish as a key component to demonstrate improvements to river health from onground actions.

3.6 Future management responses and climate change

From 1910-2000, Australia's average temperature increased by 0.76˚C (0.08˚C/decade). This rate of increase has been more rapid in the period since 1950 with an increase of 0.13˚C/decade for maximum temperatures and 0.21˚C/decade for minimum temperatures (Whetton et al. 2002). Compared to National trends, Victoria's maximum temperatures are rising at a faster rate (Whetton et al. 2002). Detailed analysis of impacts on rainfall and runoff in Victoria have revealed varying trends, with potential long-term changes dependent strongly on various global warming scenarios. However, climate models applied to three scenarios of global warming generally show a reduction in the mean annual runoff for Victoria (Jones and Durack 2005). Generally, the decreases in runoff tend to be smaller in the north-east and south-east and somewhat higher in the north-west and southwest of the State. Minimum changes are between -5% and -10% across the State while the largest potential changes could reduce runoff by over 50% in all Surface Water Management Areas (Jones and Durack 2005). Models also suggest that extreme daily rainfall events may become more extreme, even where average rainfall declines (Whetton et al. 2002).

The long-term implication of these changes is that there is a high probability that there will be less water entering Victorian rivers, streams and wetlands annually, but a higher likelihood of large flow events associated with extreme daily rainfall events and an increase in stream and wetland temperatures. This is likely to compound the already high levels of water extraction experienced in Victorian streams, leading to increased habitat fragmentation, fewer annual flood events and reduced spring flushes but larger and more destructive extreme flood events. Increased temperatures will also impact substantially on temperature restricted native fish species such as Mountain galaxias, with distribution ranges of these species likely to contract to higher altitudes where water temperatures remain lower. Lower annual flows will reduce freshwater flushing and modify the position of salt wedges at the marine-freshwater interface in estuarine environments and lower river reaches. This will increase the area of effective estuarine habitat and allow more marine species to utilise these habitats and allow estuarine species to move further upstream.

Management decisions must take into account these potential changes and accommodate adaptive management. For example, care should be taken in managing upper reaches of all rivers to protect the remaining habitat for species likely to suffer range contraction. Environmental water allocations may need to accommodate long-term reductions in runoff to ensure rivers receive sufficient flows to accommodate the persistence of diverse native fish communities, protection of refugia habitats may become increasingly important during longer and unpredictable dry periods, while management plans for estuarine environments will need to consider the impacts that higher salt loads will have on existing estuarine habitats and upstream habitats which may change from predominately fresh to brackish or salty habitats.

3.7 Unmanageable threats and setting benchmarks

3.7.1 Unmanageable threats

Many natural resource managers will be faced with the decision of how to effectively manage a resource in the face of threats over which they have no control or capacity to deal with. This may be a large scale threat such as climate change, which no one person or organisation can predict or control, or smaller scale threats such as environmental flow allocation which is the domain of a government policy and may have a range of competing interests for the one limited resource. In both instances the question to ask is: how can the resilience of a system be improved to ensure the long-term persistence of the ecosystem in the face of these unmanageable threats?

Ecosystem resilience

A critical habitat requirement for population persistence and resilience is the availability of refugia habitat (Sedell et al. 1990, Lake et al. 2007). Refugia habitats are sites which provide a temporal refuge from biophysical disturbances. The recovery rates of ecosystems is highly dependent upon the persistence of species in refugia habitats to repopulate areas once the disturbance or threat has been removed. Hence, they provide an ecosystem with resilience in the face of threats.

In some instances, surviving disturbances may depend on life history adaptations (e.g. adaptations to desiccation, ability to move away from disturbance events, etc), but in many instances particular habitats serve as the refugia (Lancaster and Belyea 1997). However, in many degraded situations not only have residential habitats been reduced or lost, but so have any refugia habitats. Therefore, for a particular species or community, residential habitats must be restored along with suitable refugia capable of providing resilience to the system for both natural and anthropogenic disturbances (Lake et al. 2007).

One of the most damaging processes to refugia habitat is the isolation of the river or wetland from its surrounding environment. This can primarily occur when there is a disconnection of the biotic and hydraulic components of the waterbody and riparian zone (Sedell et al. 1990). For example, where riparian habitats have been removed, the waterbody is disconnected from the regulatory mechanisms of light energy, organic sources (e.g. leaves and wood) and physical structures (e.g. SWH) and thus becomes more hydraulically unstable. Similarly, channelisation, flow regulation, degradation or disconnection from the floodplain can also isolate a stream or river, resulting is the loss or degradation of refugia habitats (Sedell et al. 1990). Restoring the links with surface and ground water flow, as well as with the riparian and landscape habitats will enhance the potential for rivers to provide refugia habitat (Jansson et al. 2007).

Refugia habitat and threats

For aquatic environments suffering the impacts of reduced flows the provision of refugia might mean ensuring that there is sufficient groundwater fed pools within a river to accommodate species during interrupted flows and drought. On a site or patch scale, these habitats need to contain areas for small native fish to hide from larger predatory fish or birds and ideally should be shaded by riparian vegetation to minimise high temperatures and low dissolved oxygen conditions. The provision of SWH and other structural diversity such as rocks in these pools will assist in providing predator avoidance habitat during drought, will improve the potential for food sources and may also create a refuge habitat for a variety of species. The maintenance of backwaters and connection to tributaries are all likely to provide refugia during flood events and may improve drought refuge access.

Providing refugia for other threats such as increasing temperatures due to climate change may require preservation of upstream habitats to enable temperature sensitive species to retreat to higher altitudes. Streams that have good longitudinal connectivity (i.e. no restrictions to native fish passage) and continue to provide native fish access to unimpacted segments of the stream may provide refugia for species able to move away from point source pollutants or other human-related disturbance. Although no single habitat or site is likely to be a refuge for all organisms from all disturbances, the more dynamic, connected and self regulatory the site is, the more biotically resistant and resilient it will be (Sedell et al. 1990).

Refugia should be maintained to ensure there are a sufficient number and diversity of refuges to accommodate a variety of species (not all refugia will be suitable for all species). There is a need to maintain a sufficiently large pool of individuals of each species to provide for repopulation of the waterbody once flows or water volumes are returned. Refugia should also be provided at a variety of scales (i.e. from water shed to patches). However, understanding the spacing of refugia within basins is both a theoretical and practical problem. In many instances, we simply do not know how many refugia are required to 'threat-proof' a system against these unmanageable threats (Sedell et al. 1990).

Drought

Large parts of southern and eastern Australia have experienced exceptionally dry conditions since October 1996 (Australian Bureau of Meteorology 2007). For Victoria, the period from October 1996 to October 2007 is the driest 11 year period since 1900, eclipsing the previous record set in 1935-1946 (Australian Bureau of Meteorology 2007). This has undoubtedly impacted on the availability of water in rivers and wetlands. In response to this ongoing climate period each of the regional management authorities (CMAs and Melbourne Water) have been developing drought response plans. The plans identify priority areas for protection and consider the impacts of a range of flow scenarios. The plans will identify management actions which will protect areas that are either:

- important for long term achievement of RHS objectives
- refuge areas that need protection/management in order to give the river/wetland the best chance of recovery post-drought, and
- sites where threatened aquatic species or communities occur.

3.7.2 Adapting benchmarks

As identified by Rutherford et al. (2000), it is important to identify threats that can and cannot be managed effectively in an area, and the current condition and trajectory of the region's assets before setting targets or benchmarks. It would be undesirable/unfeasible to set a benchmark for restoration (i.e. returning a system back to its pre-European condition) for a river or reach if, for example, social demands for the water far outweighed the environmental concerns for flows in the river. In this instance, understanding the value of the river from social, environmental and economic perspectives are important in setting the benchmark. If a river has high social and economic values it is perhaps better to set a benchmark that is more in line with these values. In such a case, the target may need to acknowledge that only 50% or even 30% of the natural fish species in the area is going to recover because the river is going to be effectively managed as a social asset rather than as a conservation asset. Costly habitat replacement works may therefore not be worthwhile, but lower cost, quick habitat replacement steps may help enhance the persisting populations and provide refuge habitat in the face of disturbances.

It is also important to think about benchmarks within the context of a critical ecological threshold. This refers to a condition beyond which, processes within and external to, the ecosystem, prevent the re-establishment of historic ecosystem functioning (i.e. it has shifted to an alternative state). The system has become so modified that it is no longer feasible (fiscally and/or physically) for rehabilitation works to return the system to pre-European condition. Setting a benchmark to return the system back to its original condition may not be achievable at all, let alone within a limited budget.

PART B: RECOMMENDATIONS FOR THE MANAGEMENT OF FISH

4 Fish Assessment Support Tool (FAST)

As outlined in section 3, many of the high priority threats to native fish are already being addressed through existing programs. However, it is important to recognise that many of these programs may have been developed with limited knowledge of the impacts that these management actions will have on the persistence of fish species. The web-based support tool, FAST, has been developed to assist natural resource managers to more effectively include fish within existing and future river protection and enhancement programs.

The database was developed using the information derived from a number of workshops involving fish scientists and local resource managers from coastal Victoria, details of which are described in section 3.2. This information was then combined with the best available knowledge of species biology and ecology including, distribution, spawning and migration calendars, and biotic and abiotic requirements (Part C) to provide a tool which can deliver the following outputs:

- a comprehensive list of the native coastal fish predicted to be present within the CMA/works area, including information on their conservation status, recreational significance and cultural values
- a list of the current threats and an assessment (in the form of a score) of the level of impact each of the threats pose to that species within each basin
- an assessment (in the form of a score) of the likely affect of a specified works action on each species present at an intended works site
- an overall score/threat rating for the intended works
- guidelines on impact minimisation through modifications of works timing and alternative works options
- advise on appropriate and adaptive fish enhancement works, and
- guidance on undertaking fish habitat enhancement works.

This information can be used in the asset based approach to the prioritisation of investment within the RHS (Figure 1.3 and 4.1) and can assist river practitioners with their specific works activities on coastal waterways without the need for specialist biological advice. The tool can be used can be used both retrospectively (to assess the impacts of any proposed works activities on native fish) and as a tool to guide managers on appropriate works aimed explicitly to enhance fish habitats. FAST has been specifically developed for the Victorian coastal Catchment Management Authorities and Melbourne Water, however it may also be used by other groups (e.g. conservation groups) undertaking works on aquatic waterways in coastal Victoria.

4.1 Prioritisation and decision making processes within FAST and the guide

Figure 4.1 and the following text outlines how FAST can assist in the prioritisation of investment within the RHS (Steps 1 to 3) and how the tool can be utilised to identify and modify existing actions which may adversely impact on fish under the existing RHS (Step 1 to 6). Further instructions on how to use the tool can be found on the FAST website (xxxx).

FAST should be used in conjunction with the recommendations listed in section 5. All the recommendations in section 5 have been developed to both link with, and enhance existing programs, to ensure that existing actions and future decision-making maximise the value of such actions for the conservation and rehabilitation of native fish.

Additional, complementary recommendations fall under community and stakeholder engagement (section 6), knowledge gaps (section 7) and monitoring (section 8). These are designed to enhance our understanding of fish ecology and enable effective adaptive management.

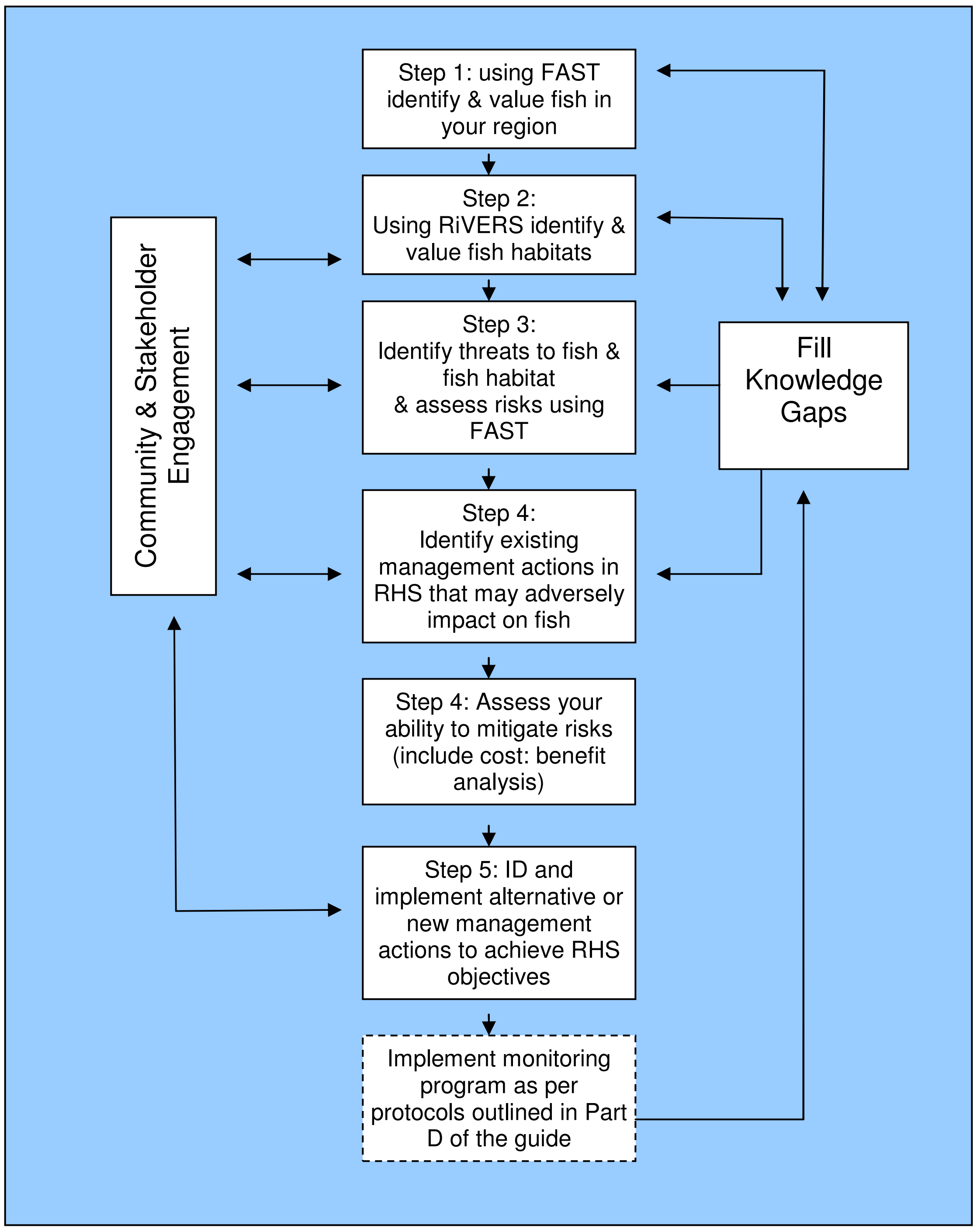


Figure 4.1: Prioritisation and decision making process.
Tasks to be undertaken in each step are described below.

Step 1. Identify and value your fish assets

1A. Using FAST, identify what fish species potentially occur in your region, their distribution and conservation status.

1B. Using FAST and the triple bottom line principles of environmental, social and economic values, assess the value of each asset. This will help identify high priority assets and assist you in determining what management actions will be valuable to those assets.

- Go to step 2

Step 2. Identify and value/prioritise your habitat assets

2A. Using RiVERS and other relevant databases (e.g. estuaries and wetland databases) identify all the priority fish habitat areas[15] in your catchment (including rivers, floodplain wetlands, other wetlands and estuaries) that meet the below criteria:

i. *Sites where National, State or regionally recognised threatened fish occur.*
ii. *Sites which support economically important species.*
iii. *Sites with a high diversity of native fish.*
iv. *Sites which support culturally or socially valuable species*
v. *Drought refugia which may become increasingly important with the predicted impacts of climate change.*
vi. *Sites which support populations with a high genetic diversity.*
vii. *Sites that remain in good condition and continue to provide valuable ecosystem services (e.g. erosion protection, nutrient filter, etc) and native fish habitat.*
viii. *Sites with potential as future habitat for threatened species within their former range.*
ix. *Floodplain habitats that remain connected to the river.*
x. *Sites that support other species identified as valuable in step 1.*
xi. *Sites that provide access to good upstream habitat.*

2B. Overlay the economic, social and/or environmental values which have been identified for these zones in your regional RHS and other regional plans and strategies, to determine any potentially conflicting management zones (i.e. conservation management vs social management). This will enable re-evaluation to determine which asset protection is considered the highest priority.

[15] Where data is limited you may need to consider undertaking research to fill knowledge gaps before you can effectively manage for fish

It is important to understand that the information provided in step 2A only provides the suite of factors that would accord a priority status to a particular waterbody or section of a waterbody for native fish. Prioritisation of these areas will need to be done according to your objectives and the value of your assets determined in step 1. For example, if you are managing a waterbody primarily for social and economic reasons, habitats which support economically important species are likely to have a higher priority than a site which supports a population of non-threatened, non-economic species with a high genetic diversity. Use your economic, social and environmental overlays to provide a prioritisation process specifically for your reach or region.

- Go to **step 3**

Step 3. Identify the threats to fish and fish habitat and assess the risks

3A. Using FAST identify the specific threats to your priority habitat areas and your fish assets

i Use FAST and other available resources to identify what threats are currently and likely to impact on these valuable habitat areas and your assets

ii Using the threat and risk assessment undertaken in the RHS and FAST determine the risks to your assets based on the risk assessments conducted as part of your regional RHS (e.g. likelihood x consequence)

- Go to **step 4**

Step 4. Assess your ability to mitigate these risks

4A. Using FAST identify threats and potentially threatening management actions that can be easily or effectively mitigated, against those which will require extensive long term modifications, and those that are unmanageable

i Undertake a cost: benefit analysis for all threats and impacts that could potentially be managed

ii Identify your ability to modify existing actions/management interventions minimise the impacts on fish or value add by modifying the action to enhance fish populations- refer to FAST for options

Step 5. Identify and implement alternative or new management actions which will protect, enhance and rehabilitate your priority habitats whilst achieving RHS objectives

5A. Use FAST to consider the impacts of management intervention on native fish populations and communities.

- *i Seek to establish current recommended practice from this process.*
- *ii Enhance all current delivery programs to incorporate fish*

5B. Protect your priority habitat areas

- *i Identify what targeted management is required to protect and enhance these habitats for fish based on the threats identified in step 4 and the recommendations provided in section 5*
- *ii Undertake a detailed cost:benefit analysis to determine the programs which are likely to give you the highest benefit relative to cost*
- *iii Develop and clearly state your intended management objectives to ensure monitoring can be effectively targeted*
- *iv Incorporate fish related management actions within your existing delivery programs to enhance the management of native fish in your region*

5 Recommendations for the management of high priority threats to native fish

The below recommendations are structured to reflect the high priority threats identified in section 3.3 and the management responses currently operating in Victoria (section 3.5). They have been developed to both link with and enhance existing programs. As such, some of the recommendations provide very broad guidance on how to approach fish management for a particular threat, reflecting the lack of fish related information within existing programs (e.g. components of "Loss of instream habitat"), while others provide very specific guidance that aims to provided additional detail to management programs which already address native fish extensively in their objectives (e.g. "Barriers to fish movement"). The recommendations should be used to help guide managers in their approach to include fish within their RHS and should be used in conjunction with FAST when designing works specifically for fish within river reaches.

5.1 Loss of instream habitat

I. Manage and restore instream aquatic vegetation diversity

a. *Encourage the re-establishment of submerged aquatic macrophytes by reinstating natural flow regimes, managing salinity and excluding stock from river and wetland habitats.*
b. *Protect existing instream macrophytes.*
c. *Revegetate riparian zones to reduce instream sediment and nutrient loads.*
d. *Re-establish floodplain wetlands to reduce nutrient and sediment loads to waterways.*
e. *Control alien species.*

II. Continue to replace SWH in priority habitat areas which support fish species reliant on this habitat component

III. Where practical reinstate meanders and connection with floodplain habitats in channelised streams and estuaries. If not practical:

a. *Use SWH to improve the availability of instream habitat*
b. *Reinstate riffle zones, and*
c. *Encourage the development of aquatic vegetation by creating areas of low flow and backeddies.*

IV. Investigate the value of existing instream habitat data collected under the ISC to provide information on potential and current fish habitat

a. *Is the information valuable in its current form?*
b. *What other habitat components should be measured in future surveys?*

V. Protect and enhance the suitability of drought refuge habitats (i.e. enhance habitat resilience, e.g. ground water fed pools)

a. *Identify key refuge habitats in each system.*
b. *Develop drought strategies for each refuge habitat.*

c. *Ensure riparian revegetation programs provide sufficient shading to these habitats, to reduce evaporation and pool temperatures.*
d. *Restrict stock access to key habitats.*
e. *Implement pest management control in these habitats,*
f. *Replace SWH in these habitats to provide suitable refugia for a range of species.*

VI. Improve knowledge of other wetlands

a. *Map other wetlands which are known to be or suspected to be significant to native fish.*
b. *Develop complementary GIS layers associated with wetland mapping.*
c. *Determine the condition of wetlands which are known to be or suspected to be significant to native fish.*
d. *Identify fish-related threats in existing and future wetland management plans (e.g. restricted access to waterways, loss of aquatic vegetation, presence of carp/gambusia, etc) and determine actions to mitigate these threats.*
e. *Manage the threats to native fish in all wetlands recognised as important to native fish.*

VII. Protect remaining floodplain wetlands from degradation, and rehabilitate degraded systems where possible

a. *Protect those that remain in good condition (i.e. those that continue to provide ecosystem services/ remain connected to the river).*
b. *Re-establish the linkages between floodplain wetlands and rivers.*
c. *Continue to consider native fish requirements as part of the determinants for environmental flows in these systems.*
d. *Implement habitat enhancement programs such as rehabilitation, fencing , etc, in floodplain zones.*

VIII. Investigate the need for artificial habitat (such as LUNKERS) and other alternative erosion/sediment transportation control techniques (e.g. sedimentation basins, pylon fields, etc) where required to enhance fish habitat access

5.2 Degradation and loss of native riparian habitat

I. Ensure existing native riparian vegetation management programs.

a. *Consider the risks of management interventions (i.e. onground works) to native fish populations and communities.*
b. *Maximise the potential for riparian revegetation to contribute to fish habitat enhancement (e.g. minimise bank erosion, filter incoming nutrients, provide long-term SWH input, provide necessary shade levels to the river/wetland, etc).*
c. *Ensure revegetation programs target the entire riparian zone from the bank to the periphery of the zone influenced by the river.*

II. Undertake risk assessments for all potential and current aquatic weed species as part of the Noxious Weed Review and associated processes.

5.3 Modified flows

I. Give high priority to modifying flow regulation practices so that they facilitate the restoration of native fish populations.

a. *Protect the flow regimes of streams with pristine or close to pristine flow regimes.*
b. *Continue to consider native fish conservation as part of the Environmental Flow determinants.*
c. *Maintain and reinstate a flow regime that mimics hydrographic characteristics of the natural flow regime, both within and between years.*
d. *Maintain and reinstate a flow regime that will increase the timely watering of targeted wetlands and river zones.*
e. *Maintain and enhance refuge habitats in rivers with high levels of extraction to help buffer against drought conditions that may be exacerbated by extraction.*
f. *Accommodate the potential long-term reductions in flows due to climate change.*
g. *Acknowledge the importance of freshwater flows to estuarine environments.*
h. *Ensure rivers with existing fishways receive adequate flows and fishways are appropriately maintained to enable ongoing fish passage throughout the year.*
i. *Undertake a risk assessment to determine the impact of current barriers on the delivery of environmental flows to the entire river including the estuary.*

5.4 Exotic predatory fish

I. Clearly define, within the state-based biosecurity framework, the roles and responsibility of all stakeholders in the prevention of introduction, the management and control of exotic flora and fauna

a. *Undertake risk assessments for all potential and current exotic fauna species which may impact on the health of native fish populations and high priority fish habitat sites.*
b. *Forecast and develop contingency strategies to prevent the introduction of new exotic species, including rapid response programs.*
c. *Implement strategies for containment and/or eradication of existing undesirable exotic species.*
d. *Implement appropriate management actions to mitigate impacts of alien species.*
e. *Test appropriateness of existing Williams' Carp Separation Cage design and other pest species control techniques for use in southern Victoria.*

5.5 Water quality and bank erosion

I. Manage the impacts of erosion, sedimentation and increasing nutrients (including low dissolved oxygen) on the health of native fish populations

a. *Encourage the installation of sediment traps on all road crossings.*
b. *Ensure nutrient management plans consider the management of native fish particularly in priority habitat areas.*
c. *Ensure instream erosion control works enhance fish habitat and mitigate any potential threats.*
d. *Minimise sediment buildup in instream pools, especially those supporting valuable communities and those that may act as refuge habitats during drought or low flows.*
e. *Remove non-native deciduous flora from riparian zones.*
f. *Ensure riparian revegetation programs are minimising the impacts of these threats on priority fish habitats.*
g. *Implement continuous dissolved oxygen monitoring in key refuge sites.*
h. *Implement other water quality (e.g. pH, nutrients,) monitoring at key refuge sites.*

II. Encourage primary producers and other industry (e.g. forestry) to minimise the impacts of pesticides and herbicides on waterbodies

a. *Encourage the establishment and maintenance of buffer zones such as thick vegetation between spray zones and aquatic habitat.*
b. *Encourage the use of low toxicity alternative pesticides and herbicides by providing up to date information on low impact alternatives.*
c. *Encourage the establishment and use of forestry best practice protocols for herbicide and pesticide use that minimise the impacts of chemical use on aquatic ecosystems and non-target organisms.*
d. *Follow CRS best practice guidelines for herbicide use near aquatic environments.*

III. Utilise the EEMSS to determine the most suitable time to artificially open river mouths

a. *Encourage the reestablishment of riparian vegetation surrounding estuary and upstream to provide nutrient filtering services.*
b. *Encourage primary producers to minimise artificial fertiliser use near waterbodies to minimise nutrient inputs to aquatic ecosystems.*
c. *Fence riparian zones to prevent livestock access to waterbodies and their riparian zones.*

5.6 Barriers to fish movement

I. Ensure the effective operation of existing fishways.

a. *Provide adequate training on the maintenance of fishways to all maintenance personnel.*

b. *Develop maintenance plan/schedule for fishways in your region.*
c. *Evaluate the effectiveness of existing fishways to provide passage to native fish*

II. Identify and prioritise the value of barrier removal or the installation of fishways on all remaining barriers using the selection criteria established in State Fishway Program.

a. *Priority should be given to those:*
    i. *Barriers at the lower end of the catchment (i.e. closest to the sea or final waterbody).*
    ii. *Barriers which may restrict the movements of species with National state or regional conservation significance.*
    iii. *Barriers in rivers with good overall condition.*
    iv. *Barriers that would provide the greatest increase in the width and length of river habitat available to native fish.*
    v. *Barriers that once removed will enhance other conservation programs being undertaken in the region.*
b. *Assess, describe and map barrier types:*
    i. *Identify information gaps in the existing barriers database and undertake further surveys where necessary to locate and map infrastructure (including smaller culverts, road crossings, etc) that may not have been recognised previously and may occur in reaches that meet the above criteria.*
    ii. *Include channelised reaches, reaches with limited or very little instream habitat and reaches impacted by thermal inputs or high velocity release flows.*
    iii. *Update barriers database for each region including GPS location of each barrier to enable mapping.*
c. *Identify and assess modification/removal options and undertake cost: benefit analysis.*

III. Remove or modify all priority barriers as identified in recommendation 5.6 (II) to maximise benefits for fish communities.

a. *Removal is the best option where practical.*
b. *Replace culverts with a bridge or lower culvert entrance to ensure access during all flows, widen culvert to increase light penetration and reduce flow velocity, install shelter zones within culvert to provide rest zones for fish passage, etc.*
c. *Modify channels to replace removed meanders or increase shelter zones and instream habitat to facilitate fish passage.*

IV. Evaluate the effectiveness of fishways to provide passage to fish, especially target species.

a. *Monitoring should be undertaking during the migration periods of key species and during varying flow scenarios.*

6 Community and stakeholder engagement

I. Promote integrated management of aquatic habitats.

a. *Establish Habitat Rehabilitation Sites (HRS) that involve a number of stakeholders and incorporate a range of aquatic habitat management activities that maximise environmental outcomes for fish and illustrate the habitat management activities that can have positive environmental outcomes for native fish.*
b. *Ensure that all interest groups (including agricultural and indigenous groups) are considered during the development and establishment of HRS.*

II. Increase community and stakeholder awareness.

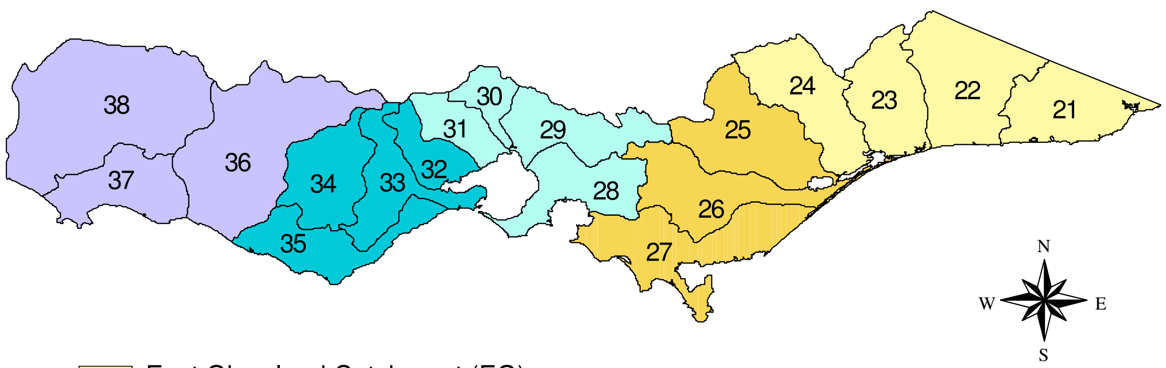
a. *Seek to improve interagency liaison and stakeholder inclusion in fish management decisions (especially at the regional level: DPI, DSE, CMA, anglers, conservation groups, and indigenous groups).*
b. *Improve the availability and accessibility of relevant fish distribution and ecological information for management agencies (central quality assured database, complementary GIS layers and associated information).*
c. *Highlight the potential areas of synergy between native fish conservation and angling.*
d. *Develop and implement a fish species education program to foster recognition and understanding in the wider community. For example you could:*
    i. *Raise community awareness about the role and importance of wetlands (floodplains, swamps, billabongs, etc) and their ecological significance for native fish.*
    ii. *Increase community and stakeholder awareness of the importance of migration and fish passage to Victoria's native fish species by providing appropriate signage at fishway sites, links to the State Fishway Program, fish passage literature and other pertinent information on CMA, local councils, road maintenance agencies and water board websites.*
    iii. *Develop an identification guide to increase awareness and recognition of estuarine species.*

PART C: BIOLOGY OF NATIVE FISH AND LARGE DECAPODS AND BIVALVE MOLLUSCS

7 Current knowledge and condition of native fish populations in coastal Victoria

A brief summary of some of the basic biology and habitat requirements of each of the priority species is provided below. Information has been sourced through relevant freshwater and estuarine fish experts from across Victoria and where possible from published information. Providing all biological information was beyond the scope of this document, however where further information is available, additional resources are listed in Appendix D. A summary of the distribution and biology of all estuarine opportunistic species found in coastal Victoria can found in Appendix B.

Details on the distribution of each species in the following sections refer to the basins and catchments in which each species has been recorded. Figure 7.1 provides the reference map for this data.



East Gippsland Catchment (EG)
West Gippsland Catchment (WG)
Port Phillip and Western Port Catchment (PP)
Corangamite Catchment (C)
Glenelg Hopkins Catchment (GH)

21	East Gippsland	27	South Gippsland	33	Barwon
22	Snowy	28	Bunyip	34	Corangamite
23	Tambo	29	Yarra	35	Otway
24	Mitchell	30	Maribyrnong	36	Hopkins
25	Thomson	31	Werribee	37	Portland
26	LaTrobe	32	Moorabool	38	Glenelg

Figure 7.1: Map of river basins in each of the catchments in coastal Victoria.

7.1 Knowledge gaps

7.1.1 Distribution

Across most of Victoria there have been few comprehensive and systematic surveys of fish communities in either freshwater (T. Raadik, DSE, ARI, pers. comm. 2007) or estuarine environments (Arundel 2007). This has meant that much of the distribution data for many freshwater and estuarine species is patchy or outdated (e.g. Jackson and Davies 1983, Turnbridge 1983, 1988, Koehn and O'Connor 1990c, Koehn et al. 1991, Raadik 1992). Survey data in many instances has been limited to specific research projects, with targeted outcomes focussing on a specific fish within a catchment, or community composition data for a particular region or catchment (e.g. Raadik and O'Connor 1997a, Zampatti 2001, Raadik 2005). Species with a specific interest (i.e. those with a threatened status) are likely to have had more detailed studies conducted, but in many cases these distribution studies may not have been comprehensive enough to cover their entire potential ranges (e.g. Zampatti 2001) or are now outdated. Although, recent surveys such as the Sustainable Rivers Audit and surveys conducted by Barbee et al. (2006) and Raadik et al. (2001) are starting to redress this issue for some species, much of this information in not widely available. Understanding the current distribution of species will be vital in understanding and documenting distribution changes as a consequence of climate change.

Species requiring up-to-date distribution data include the Australian grayling, Australian mudfish, Yarra pygmy perch, Variegated pygmy perch (Saddlier and Hammer 2007 draft-a), Dwarf galaxias (Saddlier et al. 2006 draft), Mountain galaxias, River blackfish (upper Wannon River form), Cox's gudgeon (*Gobiomorphus coxii*), Striped gudgeon (*Gobiomorphus australis*), Australian whitebait (*Lovettia sealii*), Estuary perch (*Macquaria colonorum*), Glass goby (*Gobiopterus semivestitus*), Pale mangrove goby, spiny crays (*Euastacus* spp.), other freshwater invertebrates, and many more common species across Victoria. Care should therefore be taken in utilising the data contained within this document, as although it is currently comprehensive it is limited by what survey data was available at the time of writing. It is advisable that a precautionary approach should always be taken when making management decisions. Planning should use the principle of what species could potentially be at a site, with what is currently known about species, rather than assuming a species is not there.

Detailed distribution data, gathered as part of systematic distribution surveys across Victoria, will provide valuable information of the value of various habitats and regions to the preservation of these aquatic species. If properly designed, the surveys will also provide baseline data to determine long-term population distribution changes.

A key component of improving the distribution dataset will be to ensure that NRM across Victoria have access to this data when required. Ensuring that distribution and other relevant data is regularly maintained and made available to NRM agencies will be a key tool in ensuring that native fish are considered in catchment enhancement programs.

7.1.2 Biology and ecological requirements

In most cases there is relatively good information available on the adult stages of native freshwater fish species. Unfortunately, information on the ecological and biological requirements of larval and juvenile stages and on the migratory and spawning requirements of many freshwater and estuarine species, is very limited (J. Hindell, DSE, ARI, pers. comm. 2007, Koehn and O'Connor 1990a). Further, studies on many estuarine species are often limited to southwest of Western Australia (e.g. Prince et al. 1982, Gill and Potter 1993, Valesini et al. 1997, Young et al. 1997, Potter and Hyndes 1999, Sarre et al. 2000, Young and Potter 2002, Hoeksema and Potter 2006, and others) or the east coast of Australia (e.g. Gray et al. 1996, West and King 1996, Gray et al. 1998, Hannan and Williams 1998, Griffiths 2001, Mazumder 2005, Silberschneider and Gray 2005, Stewart et al. 2005, Mazumder et al. 2006), although this situation is slowly changing (e.g. Hindell 1994, Walsh and Mitchell 1995, Crinall and Hindell 2004, Hindell and Jenkins 2004, 2005). As such there are still substantial knowledge gaps of the ecological requirements of many native fish in Victoria including those of economic importance.

7.1.3 Management requirements

The lack of ecological knowledge limits our ability to manage effectively for many of these species, as although we may understand some or all of the ecological requirements of adults, our lack of knowledge on early life history phases may mean that management may overlook critical habitat components, or threats to these stages. Further, early life stages (e.g. larvae, eggs, etc) may have lower tolerances to particular environmental variables (e.g. water quality, etc) than that of their adults (T. Ryan, pers. comm. 2007). Using the knowledge derived from tolerances of adult stages may not be sufficient to protect early life stages and this may potentially limit or result in no recruitment from systems, with the eventual loss of that species in that waterbody and/or catchment.

Information on the ability of species to recolonise areas is also limited for many non-diadromous species (T. Raadik, DSE, ARI, pers. comm. 2007). This restricts our ability to identify expected response times of species after management intervention or an environmental perturbation. Understanding the connectivity between both local and broad scale populations will be important in managing effectively for native fish species.

For individual fish species to persist through any disturbance event that contributes to the loss of suitable habitat, key recruitment waterbodies, or refugia are required. Refugia may offer either spatial or temporal respite or resilience in the face of that disturbance, such as drought or fire. An understanding is needed of how refuge habitats influence fish community structure and dynamics. Refuge size, the intensity of the perturbation and the mobility of the fish species will all contribute to the predicted persistence of a fish species following a disturbance event and an understanding of the dynamics of this interaction will also assist in management for native fish species.

7.1.4 Response

Understanding the basic life-history of many species will be an important step in being able to effectively manage our native fish species. Without knowledge of the basic life-cycle and the biotic and abiotic requirements of each stage of development for all finfish and large macroinvertebrates, management can never be proactive. Comprehensive surveys which monitor the spawning behaviour, juvenile and larval stages and which assess the migratory patterns of adults will help alleviate some of these problems. In addition, information on species' response to management intervention and tolerances to a range of parameters will enable more responsive management. A number of suitable areas of research have been detailed below. This list is not comprehensive but outlines some of the key priority areas that require immediate funding.

I. ***Determine the life-cycle history of all freshwater and estuarine species***
    a. *Improve our understanding of the life-cycle history of all species.*
    b. *Determine the physical and ecological requirements of each species at all stages of their lifecycle (i.e. egg, newly hatched, larvae, juvenile and adult).*
    c. *Improve our understanding of the importance of wetlands for native fish.*
    d. *Improve our understanding of valuable fish habitats for different fish lifestages.*
    e. *Improve our understanding of environmental processes that are important to freshwater and estuarine fish species (e.g. flow requirements).*
    f. *Understand the water quality requirements of each life-cycle stage.*

II. ***Undertake distribution surveys for all valuable species to assist in identifying priority habitats.***
    a. *Undertake systematic sampling of Victorian estuaries to establish a list of expected estuarine fish species.*

III. ***Determine the connectivity among fish populations (especially non-diadromous species) to determine recolonisation rates following management intervention or an environmental perturbation.***
    a. *This should identify key recruitment waterbodies for all native fish including refugia habitats which provide the genetic basis for recolonisation after catastrophic events.*
    b. *This should encompass both broad scale and fine scale connectivity.*

c. *This will help target monitoring more effectively by providing expected response rates to disturbance events for various fish species.*

IV. Conserve and investigate genetic variation within species

a. *Populations with high genetic diversity are valuable for providing species resilience to change; these populations should be identified and conserved.*
b. *Isolated populations which have the potential for speciation (limited genetic input from external populations) or may be at risk of localised extinction should be identified and conserved (e.g. Wannon River, River blackfish).*

7.2 Species values

7.2.1 Conservation values

There are currently nine freshwater finfish (Table 1.1), 14 large freshwater decapod crustaceans/bivalve molluscs (Table 1.2) and one estuarine finfish (Table 1.3) native to coastal Victoria listed under State and/or Commonwealth conservation legislation. These species have been recognised as threatened and as such are protected by law. Species that are listed under the FFG Act can only be harvested by anglers if a Governor in Council Order has been declared. A further two finfish species/forms have been recognised on Victorian State advisory lists, the River blackfish (upper Wannon River form) and the Striped gudgeon. Species on the DSE advisory lists are not protected by threatened species law (see below for details). An outline of the habitat, biological requirements and threats identified under their respective Action Statements, Scientific Advisory Committee final recommendation reports and other available literature has been provided for all these species in sections 7.3 (freshwater finfish), 7.4 (freshwater invertebrates) and 7.6 (estuarine finfish).

Updates to the *Flora and Fauna Guarantee Act 1988* threatened species list can be found at:

http://www.dse.vic.gov.au/dse/nrenpa.nsf/LinkView/0488335CD48EC1424A2567C10006BF6DB4F254CBD292B50F4A256817002AFF40

While updates to the *EPBC Act* can be found at:

http://www.deh.gov.au/biodiversity/threatened/species/index.html

Conservation categories

IUCN: International Union for the Conservation of Nature and Natural Resources or more commonly referred to as the World Conservation Union.

The IUCN Red Lists are widely recognised as the most comprehensive, apolitical global approach for evaluating the conservation status of plant and animal species (IUCN 2008). Information included on the list is principally provided by the Species Survival Commission (SSC) and from Birdlife International Network with other information provided by members of the Red List Consortium and partner organisations. The SSC comprises nearly 8000 specialists with representatives in almost all countries of the world. The listing of a species is based on scientific information and is peer reviewed and is thus recognised as the most authoritative guide to the status of biological diversity. However, there are some important limitations to the current dataset. The species groups covered so far are biased towards terrestrial, and in particular forest, ecosystems. The IUCN recognises that there are substantial knowledge gaps for taxa in both freshwater and marine ecosystems and information gaps are substantial for the taxonomic groups in these ecosystems including fish, molluscs, crabs and crayfish (IUCN 2008).

DSE 2007- Advisory List of Threatened Vertebrate Fauna in Victoria, and
DSE 2008 *(draft)* - Advisory List of Threatened Invertebrate Fauna in Victoria (DRAFT)

These are advisory lists only, and provide guidance as to a species' conservation status. Inclusion on this list does not have the same statutory implications as being listed under legislation, such as the FFG Act or EPBC Act (Department of Sustainability and Environment 2007a). As such, there are no legal requirements or consequences that flow from inclusion of a species in this advisory list unless they also carry statutory listing under either State or Commonwealth legislation. Assessment for inclusion on the DSE 2007 and DSE 2008 (draft) advisory lists are based on the criteria recommended by the IUCN Species Survival Commission 2001 (Department of Sustainability and Environment 2007a).

7.2.2 Cultural values

Indigenous Australians have occupied Australia for around 50 000 years (Bowler et al. 2003). During this time there is strong evidence that waterways, wetland and estuarine environments were exploited for their ample supply of flora and fauna. Physical evidence of the importance of rivers, wetlands and estuaries to indigenous Australians include middens, fossils, and the remains of sophisticated rock traps, funnels and other physical modifications, such as those seen at Lake Condah (see below for details). There are also numerous written accounts from early English colonists of fishing practices (Eyre 1845), fishing for crayfish and collecting mussels for food (Humphries 2007) and information provided by Indigenous Australian elders on fishing techniques in various regions (Campbell 1994). However, the physical evidence of early aquaculture in areas such as Lake Condah illustrate that Indigenous Australians were not only exploiters of these valuable resources but were also environmental modifiers, altering the physical environment to enhance the survival and growth of fish, eels and other valuable resources. These early aquaculture systems would not only have enhanced fish productivity but would also have altered local water currents, changing the hydraulic environment for riverine biota (Humphries 2007, McKinnon 2007). The effectiveness of this kind of modification would have relied on an intimate knowledge of the biology of the targeted fauna and this vast knowledge has the potential to revolutionise natural resource management in Victoria. The Indigenous Partnership Framework acknowledges this importance and aims to facilitate the full, effective and equitable participation of Indigenous people in all aspects of land and natural resource management (Department of Sustainability and Environment 2007d). As such it is important to recognise the value and importance of native fish in the every day lives of Indigenous Australians across coastal Victoria.

Aboriginal peoples and the utilisation of the waterways resources of coastal Victoria

There are between 9-12 language groups which occupy the land now defined by the CMA boundaries of Glenelg Hopkins, Corangamite, Port Phillip and Westernport, West Gippsland and East Gippsland (Australian Institute of Aboriginal and Torres Strait Islander Studies and Sinclair Knight & Merz 2002). Evidence suggests that many of these groups relied heavily on the flora and fauna of waterways to provide food and other physical resources such as fibres to create bags and nets and materials to make hooks and other implements and for decoration (Humphries 2007).

As a food resource, native fish formed a very important part of aboriginal diet during the summer months (Campbell 1994). Indigenous people employed a variety of hunting techniques to harvest native fish, molluscs and crustaceans from the diverse aquatic habitats of the region including rivers, estuaries, and wetlands (Coutts 1981, McNiven 2006). Bone hooks, spears, traps and nets were used to catch eels, snapper, gurnard, bream, flounder, garfish, mullet, trevally and flathead in the Gippsland region (Campbell 1994). Mussels and other crustaceans were collected for food from coastal estuaries and freshwater systems of the State, while the shells of various mussels and oysters were used for cutting, scraping skins and plant fibres and creating jewellery (Coutts 1977). In some regions of the State certain fish species were actively managed by Aboriginal clans, in an early form of aquaculture, evidence of which is still present in western Victoria near Mt William, Toolondo and within the Budj Bim Landscape, including Lake Condah (McKinnon 2007).

Southwestern Victoria

The Kirrae Wirrung, Gunditj Mara and Gadabanud, collectively known as the *Maar* (the people) occupied the country from the south Australian border eastward to Lorne. Short-finned eels (*Anguilla australis*) or *Kooyang* in the Aboriginal languages of southwest Victoria were a particularly important resource for the *Maar*, particularly in the Lake Condah region and in the wetlands around Mt William (Smyth and Bahrdt Consultants 2004, McNiven 2006). Research by Builth (2002) indicates that the Lake Condah region was actively farmed for eels, with extensive trapping facilities and smoking trees found in the vicinity. The culture and society of the *Maar* grew around the *Kooyang* with permanent villages built in regions where the *Kooyang* were harvested. Permanent traps, channels, weirs and holding areas were also built which enabled them to actively manage and harvest *Kooyang* through an aquaculture system (Smyth and Bahrdt Consultants 2004). Builth (2002) also suspects that the Gunditj Mara people of the region traded the smoked eels across Victoria and South Australia and *Kooyang* would have represented an important economic and dietary resource for many of the people in this region. *Kooyang* were also an important symbol for the *Maar*, connecting current day people with past generations, their country and their culture (Smyth and Bahrdt Consultants 2004). Aboriginal communities in the region maintain a strong cultural connection with *Kooyang* today and continue to harvest them for food in the Hopkins River, Mount Emu Creek and the waters of the Hopkins Basin (Smyth and Bahrdt Consultants 2004).

In 2004 Lake Condah gained National Heritage Listing and the area is currently under consideration for World Heritage listing (Indigenous Land Corporation 2005). The Gunditj Mara in partnership with Commonwealth, State and Local Government bodies and authorities and private enterprise are planning to re-flood the Lake and surrounding wetlands as part of the Lake Condah Sustainable Development Project (Perry et al. 2006). The aim is to re-establish the original biodiversity of the lake and to redevelop the indigenous *Kooyang* aquaculture business of the region.

South-eastern Victoria

Information published by Keen (2004) indicates fish also composed an important part of the diet of the people of the Gippsland region (the Kŭnai/Kurnai tribe/nation). George Augustus Robinson (the first Chief Protector of Aborigines: Smyth and Bahrdt Consultants 2004) remarked in 1844 that the people of the Gippsland region appeared to be Ichthyophagist (subsisting on fish), with shellfish, fish and eels dominating their diet (Keen 2004). Records of seasonal movements of the people of the Gippsland region indicate that camp locations were timed to exploit the movements of eels and migratory fish. Summer and autumn periods were often spent at the beach, river mouths and/or entrances to lakes, while in spring, the Kŭnai people were often found living near swamps and lakes to fish for eels as they moved downstream (Keen 2004). Keen (2004) identified one country group in the region, the *Bunjil Tumbun* named after the Estuary perch (*Tumbun*) and it is probable that this fish had special significance to this group of people.

A recent small survey conducted in the Lake Tyers (*Bung Yarnda*) district of eastern Victoria, by DPI Fisheries, identified that fishing is still an important food source for many individuals retaining strong links with cultural traditions (J. Simpson, DPI Fisheries pers. comm. 2007). The survey revealed that aboriginal communities in the Lake Tyers district actively fished for Dusky flathead, Black bream, Australian salmon and a variety of other commonly captured fish and invertebrates.

Central Victorian coast

The peoples of central Victoria, collectively called the Kulin nation were made up of five tribes, three of which occupied the lands south of the Great Dividing Range. Like other tribes in the coastal Victorian catchments, the Woiwurrung, Boon wurrung and Wathaurung tribes were closely associated with the rivers, wetlands and estuaries in their region. Eels or *Yuk* in the Kulin languages were an important food for the Kulin along with mussels, fish (*Duat* :Woiwurrung) and yabbies (*Duyang*: Woiwurrung & Boonwurrung). Eels were often caught in weirs made of stone and also in woven funnels (A*rrabine*).

Spiritual connection

Few published dreamtime stories talk of freshwater or estuarine fish of the coastal catchments of Victoria, however Keen (2004) alluded to a story of the Kŭnai nation which talks of a great flood. The story refers to a frog which drank all the water which was then released when an eel made him laugh by dancing on his tail. Eels therefore appear to hold special significance to both the peoples of south-eastern and southwestern Victoria, as a food source, economic resource and as part of their stories and connection to the land.

Species of cultural significance

As outlined above fish and shellfish of the waterways of coastal Victoria, played a vital part of Indigenous Australians lives. Fish were important for food, their economy and provided a spiritual link to their land. The multitude of species that were important to indigenous Australians are too many to detail in this document, however two species, the Estuary perch and Short-finned eel, which appear to have had strong social (food resource), economic and spiritual value have been described in section 7.3 (Short-finned eel) and section 7.6 (Estuary perch).

7.2.3 Recreational and commercial fishing values

A number of native fish species are either currently or have previously been targeted by recreational and commercial anglers. These species are considered iconic for their social and/or economic value, in addition to their intrinsic value in contributing to biodiversity and ecosystem health. Species considered in this category are listed in Table 1.1, 1.2 and 1.3. Details of the biology of these species can be found in relevant Fisheries Management Plans. A summary has been provided in section 7.3 (finfish), 7.4 (decapod crustaceans and bivalve molluscs) and 7.6 (estuarine finfish).

The DPI Fisheries currently regulates the number, size and season when recreationally and commercially targeted species can be taken. Readers should refer to the latest fishing regulations found on the DPI website for all regulations and restrictions.

http://www.dpi.vic.gov.au/dpi/index.htm

7.2.4 Other coastal Victorian freshwater finfish species

The level of knowledge of the ecological and habitat requirements of many of the native freshwater finfish species is relatively high compared to the knowledge of estuarine species and invertebrate species. As such, the biology and ecology of native freshwater finfish species not covered in the categories: conservation, cultural, recreationally targeted are summarised in section 7.3 (Tables 7.1 - 7.4).

Further details of their biology and habitat requirements can be found on the DSE website under VicFishInfo or follow the links “Native Plants and Animals” then “Freshwater Ecosystems”. The information provided on this website is derived from “Biological Information for Management of Native Freshwater Fish in Victoria” (Koehn and O'Connor 1990a) and subsequently updated.

7.3 Distribution, biology and ecology of freshwater finfish species

As mentioned in section 1.5.1, information provided within the guide on individual species has been prioritised according to a species value (i.e. conservation status, recreational importance, cultural significance) or the level of knowledge of their biology. A summary table of all freshwater finfish species native to coastal Victoria catchments, their distribution, spawning period, migration calendar and basic habitat requirements have been provided in Tables 7.1 - 7.4. For those species with high value, detailed biological information has been provided in the relevant section below.

Table 7.1: Summary of the distribution and habitat preferences of all freshwater finfish native to coastal Victorian catchments

Common Name	Species Name	CMA district	Basins	Altitudinal position	Migratory	Found in estuaries	Found in wetlands	References
Australian bass	*Macquaria novemaculata*	EG,WG	20-27	L,F,U	yes	yes	no	Raadick pers. com. 2008, Allen et al. 2003, Koehn & O'Connor 1990
Australian grayling‡	*Prototroctes maraena*	all	all except 34	L,F,U	yes	yes	no	Raadick pers. com. 2008, Koehn & O'Connor 1990
Australian mudfish‡**	*Neochanna cleaveri*	WG,PP,C	27,29,33,35	L	yes	yes	yes	Raadick pers. com. 2008, Allen et al. 2003, Koehn & O'Connor 1990
Australian smelt†	*Retropinna (SEC +MTV)*	WG,PP,C, GH, EG, WG	21-38	L,F	partly*	yes	yes	Raadick pers. com. 2008, Allen et al. 2003, Koehn & O'Connor 1990, Hammer et al. 2007
Australian whitebait‡*	*Lovettia sealii*	WG	27	L	yes	yes	no	Raadick pers. com. 2008, Allen et al. 2003,
Broad-finned galaxias	*Galaxias brevipinnis*	all	all except 34	L,F,U	yes	yes		Raadick pers. com. 2008, Allen et al. 2003, Koehn & O'Connor 1990
Common galaxias	*Galaxias maculatus*	all	all except 34	L,F	yes	yes	yes	Raadick pers. com. 2008, Allen et al. 2003, Koehn & O'Connor 1990
Cox's gudgeon‡**	*Gobiomorphus coxii*	EG,WG	20-23, 27	L,F,U	yes	yes	no	Raadick pers. com. 2008, Allen et al. 2003,
Dwarf flat-headed gudgeon	*Philypnodon macrostomus*	EG, WG, PP	21-28	L	no	yes	yes	Raadick pers. com. 2008, Allen et al. 2003, Koehn & O'Connor 1990
Dwarf galaxias‡	*Galaxiella pusilla*	all	24-39	L	no	no	yes	Raadick pers. com. 2008, Allen et al. 2003, Koehn & O'Connor 1990
Empire gudgeon‡*	*Hypseleotris compressa*	EG	21	L	yes	yes	yes	Raadick pers. com. 2008, Allen et al. 2003,
Flat-headed gudgeon	*Philypnodon grandiceps*	all	21-38	L,F	no	yes	yes	Raadick pers. com. 2008, Allen et al. 2003, Koehn & O'Connor 1990
Flinders pygmy perch	*Nannoperca sp.* 1.	EG, WG	21-27	L,F	no	no	yes	Raadick pers. com. 2008
Freshwater herring‡***	*Potamalosa richmondia*	EG	21	L	yes	yes		Raadick pers. com. 2008
Long-finned eel	*Anguilla reinhardtii*	EG,WG	20-28	L,F	yes	yes	yes	Raadick pers. com. 2008, Allen et al. 2003, Koehn & O'Connor 1990
Mountain galaxias	*Galaxias olidus*	EG,WG,PP,C	22-35	F,U	unlikely	no	no	Raadick pers. com. 2008, Allen et al. 2003, Koehn & O'Connor 1990
Obscure galaxias	*Galaxias* sp.1	GH, C	34,36,37,38, 39	L,F,U	unlikely	no	yes	Raadick pers. com. 2008
Pouched lamprey	*Geotria australis*	all	all except 34	L,F	yes	yes	no	Raadick pers. com. 2008, Allen et al. 2003, Koehn & O'Connor 1990
River blackfish	*Gadopsis marmoratus*	all	all except 20 and 39	L,F	no	no	no	Raadick pers. com. 2008, Allen et al. 2003, Koehn & O'Connor 1990
Short-finned eel	*Anguilla australis*	all	all except 34, 39	L,F,U	yes	yes	yes	Raadick pers. com. 2008, Allen et al. 2003, Koehn & O'Connor 1990
Short-headed lamprey	*Mordacia mordax*	all	all excluding 34	L,F	yes	yes	no	Raadick pers. com. 2008, Allen et al. 2003, Koehn & O'Connor 1990
Southern pygmy perch	*Nannoperca australis*	WG,PP, C, GH	27-39	L,F	no	no	yes	Raadick pers. com. 2008, Allen et al. 2003, Koehn & O'Connor 1990
Spotted galaxias	*Galaxias truttaceus*	all	all except 34	L,F	yes	yes	yes	Raadick pers. com. 2008, Allen et al. 2003, Koehn & O'Connor 1990
Striped gudgeon‡**	*Gobiomorphus australis*	EG,WG	20-24, 27	L,F	yes	yes	yes	Raadick pers. com. 2008, Allen et al. 2003, Koehn & O'Connor 1990
Tupong	*Pseudaphritis urvillii*	all	all except 34, 39	L,F,U	yes	yes	yes	Raadick pers. com. 2008, Allen et al. 2003, Koehn & O'Connor 1990
Variegated pygmy perch‡	*Nannoperca variegata*	GH	38	L,F	no	no	yes	Raadick pers. com. 2008, Allen et al. 2003, Koehn & O'Connor 1990
Yarra pygmy perch‡	*Nannoperca obscura*	PP,C,GH	28,29,30,33, 34-39	L,F	no	no	yes	Raadick pers. com. 2008, Allen et al. 2003, Koehn & O'Connor 1990

‡indicates species with a conservation status, see section 7.2.1 for details *known from only a single stream; ** known from only a few locations; ***species presumed extinct in Victoria; †recently published information indicates that in coastal Victoria there are likely to be two genetically distinct species of smelt with the potential for a number of sub-species within individual river basins. Conservation of these species is therefore under review, and it is suggested that individual river basins are the appropriate scale for management as the overall basis for protecting biodiversity and evolutionary potential (Hammer et al. 2007).

L= lowland river reaches, F= foothill river reaches, U= upland river reaches. See Figure 7.1 for location and name of catchments and basins

Table 7.2: General biology of all native freshwater finfish in coastal Victoria catchments

Common name	Spawning calendar	Spawning habitat	Early Larval Life	Adult Main Habitat
Australian bass	mid Jun- mid Dec	EST	EST/MAR?	FW
Australian grayling‡	May-Jun	Anadromus, FW benthic eggs	EST/MAR?	FW
Australian mudfish‡**	Jul- Aug	FW	EST/MAR?	FW
Australian smelt	Sept-Nov	FW/EST	FW/EST	FW
Australian whitebait‡*	Aug-Sept	FW, adhesive eggs attach to under water debris	FW/EST	EST/MAR
Broad-finned galaxias	May-Jun	FW	MAR	FW
Common galaxias	Mar-May (coastal pop) Jul- Oct (landlocked pop)	EST	MAR	FW
Cox's gudgeon‡**	Mar - April	FW, lays egg on solid surfaces e.g. rock or log	FW/EST	FW
Dwarf flat-headed gudgeon	Oct-Mar	?	?	FW/EST
Dwarf galaxias‡	spring (Aug-Sept)	FW, lays eggs on submerged plants, stones or leaves	FW	FW
Empire gudgeon‡*	summer?	FW/EST?	EST	FW
Flat-headed gudgeon	Oct-Mar	FW	?	FW/EST
Flinder's pygmy perch	unknown	FW	FW	FW
Freshwater herring‡***	July-Aug	FW/EST?, Diadromous	EST/MAR?	FW
Long-finned eel	Jun-Sept	MAR	MAR/EST	EST/FW
Mountain galaxias	July-Nov	FW lotic waters, beneath leaf litter/ boulders	FW	FW
Obscure galaxias	June-Aug	FW	FW	FW
Pouched lamprey	Oct-Dec	FW	FW/MAR	FW/MAR
River blackfish	Nov-Jan	FW	FW	FW
River blackfish (upper Wannon River form)‡	Nov-Jan	FW	FW	FW
Short-finned eel	Jan -Mar	MAR	MAR/EST	FW/EST
Short-headed lamprey	Oct-Dec	FW	FW/MAR	FW/MAR
Southern pygmy perch	Jul - Oct	FW	FW	FW
Spotted galaxias	May-Jun	FW, on stream margins above H_2O level	MAR/FW	FW
Striped gudgeon‡**	Jan- April	FW?, lays egg on solid surfaces e.g. rock or log	EST	FW
Tupong	Sept- Dec	EST/MAR?	EST/MAR?	EST/FW
Variegated pygmy perch‡	Oct- Nov	FW	FW	FW
Yarra pygmy perch‡	Sept - Nov	FW	FW	FW

‡indicates species with a conservation status, see section 7.2.1 for details; *known from only a single stream; ** known from only a few locations; ***species presumed extinct in Victoria, FW = freshwater; EST = estuary; BUR= burrowing/riparian zone; ? = indicates incomplete knowledge.

Table 7.3: Migration calendar for all native freshwater migratory fish in coastal Victoria catchments

Common name	Priority Category	Life Stage	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Australian bass	Recreational	Larvae/juveniles	↑	↑	↑	↑						↑	↑	↑
		Adults				↓	↓	↓	↓	↑	↑			
Australian grayling	Conservation	Larvae					↓	↓	↓					
		Juvenile	↑									↑	↑	↑
		Adults						Unknown						
Australian mudfish**	Conservation	Larvae						Unknown						
		Juvenile									↑	↑	↑	
		Adults						Unknown						
Australian smelt	other	Larvae						unknown						
		Juvenile	↑	↑	↑									↑
		Adults						unknown						
Australian whitebait*	Conservation	Larvae						Unknown						
		Juvenile						Unknown						
		Adults							↑	↑	↑			
Broad-finned galaxias	other	Larvae						↓	↓	↓				
		Juvenile									↑	↑	↑	↑
		Adults						unknown						
Common galaxias	other	Larvae						↓	↓	↓				
		Juvenile									↑	↑	↑	↑
		Adults				↓	↓	↓	↓					
Cox's gudgeon**	Conservation	Larvae						Unknown						
		Juvenile									↑	↑	↑	↑
		Adults						Unknown						
Empire gudgeon*	Conservation	all life stages						Unknown						
Freshwater herring***	Conservation	Larvae						Unknown						
		Juvenile									↑	↑	↑	
		Adults						↓	↓	↓				
Long-finned eel	Recreational	Larvae						unknown						
		Glass eels			↑	↑	↑	↑	↑	↑				
		Brown elvers						unknown						
		Immature eels						unknown						
		Silver eels						unknown						
Pouched lamprey	other	Larvae						unknown						
		Juvenile								↓	↓	↓		
		Adults							↑	↑	↑	↑	↑	
Short-finned eel	Recreational	Larvae						unknown						
		Glass eels					↑	↑	↑	↑	↑			
		Brown elvers						unknown						
		Immature eels						unknown						
		Silver eels						unknown						
Short-headed lamprey	other	Larvae						unknown						
		Juvenile							↓	→				
		Adults						↑	↑	↑	↑	↑	↑	
Spotted galaxias	other	Larvae						↓	↓	↓				
		Juvenile									↑	↑	↑	↑
		Adults						unknown						
Striped gudgeon**	Conservation	Larvae						Unknown						
		Juvenile									↑	↑	↑	
		Adults						Unknown						
Tupong	Recreational	Larvae						unknown						
		Juvenile	↑	↑								↑	↑	↑
		Adults				↓	↓	↓	↓					

↑ Upstream migration
↓ Downstream migration

*known from only a single stream; ** known from only a few locations; ***species presumed extinct in Victoria.

Table 7.4: The habitat preferences of all adult native freshwater finfish in coastal Victoria catchments

Asset	Habitat preferences														
Common name	estuary position‡	muddy or sandy substrate	rocky substrate	Slow flow	fast flow	turbid water	clear water	rffle zones	deep holes/pools	undercut banks	SWH or other submerged objects	submerged aquatic vegetation	emergent aquatic vegetation	overhanging riparian veg	wetland/ swamps
Australian bass	M, U	✓	✓	✓					✓	✓	✓	✓	✓		✓
Australian grayling‡	all		✓	✓	✓		✓	✓	✓						
Australian mudfish‡**	NA	✓		✓		✓	✓			✓	✓	✓	✓	✓	✓
Australian smelt	all	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓		✓
Australian whitebait‡*	all	✓	✓	✓		✓	✓				✓	✓			
Broad-finned galaxias	NA	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓
Common galaxias	M, U	✓		<0.2m/ sec	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Cox's gudgeon‡**	M, U		✓	✓	✓		✓	✓			✓	✓	✓	✓	
Dwarf flat-headed gudgeon	M, U	✓	✓		✓	✓	✓		✓	✓	✓	✓	✓		
Dwarf galaxias‡	NA	✓		✓		✓	✓		✓			✓	✓	✓	✓
Empire gudgeon‡*	M, U	✓	✓	✓		✓	✓		✓	✓	✓	✓	✓	✓	
Flat-headed gudgeon	M, U	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	
Flinder's pygmy perch	NA	✓		✓		✓	✓		✓		✓	✓	✓	✓	✓
Freshwater herring‡***	all		✓	✓	✓		✓	✓	✓		✓	✓			
Long-finned eel	all		✓		✓				✓	✓	✓	✓	✓		✓
Mountain galaxias	NA	✓	✓		✓		✓	✓			✓	✓		✓	
Obscure galaxias	NA	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓		✓
Pouched lamprey	all	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	
River blackfish	NA	✓	✓	✓			✓		✓	✓	✓	✓	✓	✓	
Short-finned eel	all	✓	✓	✓	✓				✓	✓	✓	✓	✓		✓
Short-headed lamprey	all	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓			
Southern pygmy perch	NA	✓		✓		✓	✓		✓		✓	✓	✓	✓	✓
Spotted galaxias	U	✓		✓		✓	✓		✓	✓	✓	✓		✓	✓
Striped gudgeon‡**	M,U	✓	✓	✓		✓	✓		✓	✓	✓	✓	✓	✓	✓
Tupong	all	✓	✓	✓	✓				✓	✓	✓	✓		✓	✓
Variegated pygmy perch‡	NA	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Yarra pygmy perch‡	NA	✓	✓	✓		✓	✓		✓			✓	✓	✓	✓

‡indicates species with a conservation status, see section 7.2.1 for details; *known from only a single stream; ** known from only a few locations; ***species presumed extinct in Victoria; U=saline reaches of the river, M = middle of the estuary, L = estuary cloest to the river mouth, NA= not applicable

Australian grayling *(Prototroctes maraena)*

IUCN Red List	Vulnerable (A1c[16])
EPBC Act	Vulnerable
FFG Act	Threatened
DSE (2007)	Vulnerable

The Australian grayling has been found in coastal drainages of NSW, Victoria and Tasmania and has been recorded on King Island in the Bass Strait (McDowall 2006), geographically the species is widespread, but within regions the species has only a sparse distribution. This is an amphidromous[17] species, the well grown juveniles migrating into lowland rivers from the sea during spring. Not much is known about its reproduction, but the species is known to spawn in freshwater, perhaps over gravely or sandy shoals, and the eggs are thought to develop in estuarine or marine environments. The juveniles are thought to spend most of their early years in the ocean and recent otolith chemistry[18] indicates that they move into freshwater environments later in life (Crook et al. 2006).

Managed river flows may be significantly contributing to the decline of this species. O'Connor and Mahoney (2004) found no reproductive development of the species in the Barwon River but found evidence of resorption of ovaries in the females where there were no flood flows during the spawning season. They hypothesised that spawning may be inhibited by river regulation (i.e. the lack of flood flows), thus suggesting this may be a significant threat to the persistence of this species. Recent otolith chemistry studies identified that the species appears to have a lack of life-history flexibility and this may render the species vulnerable to river impoundments that fragment migration pathways and access to the sea (Crook et al. 2006).

Impoundments restricting migrations, substantial habitat loss and modification, predation by Brown trout and possibly Redfin perch and exploitation (McDowall 2006) have all been implicated in the decline of this species. This species has received conservation status at State and Commonwealth levels and is one of the few Australian native freshwater fish species recognised under the International Union for Conservation of Nature and Natural Resources Red List (IUCN Red List: Wager 1996b).

Australian mudfish *(Neochanna cleaveri)*

FFG Act	Threatened

[16] Under the IUCN Red list a taxon is Vulnerable when it is not Critically Endangered or Endangered but is facing a high risk of extinction in the wild in the medium-term future. A1c refers to a taxon that has experienced an observed, estimated, inferred or suspected population reduction of at least 20% over the last 10 years or three generations, whichever is the longer, due to a decline in area of occupancy, extent of occurrence and/or quality of habitat.

[17] Amphidromous: Refers to fishes that regularly migrate between freshwater and the sea (in both directions), but not for the purpose of breeding.

[18] Otolith chemistry- an otolith is a component of the inner ear of fish. These structures grow continuously throughout life and accumulate trace elements from the surrounding water. Chemical analysis of an otolith can therefore reveal information about the primary habitat of a fish during varying stages of its development.

DSE (2007) Critically Endangered

The Australian mudfish inhabits well vegetated, low elevation wetlands and swamps in Tasmania and coastal Victoria (Table 7.1: Koehn and Raadik 1991). The species is largely cryptic during the day but emerges at night to forage in dense aquatic vegetation (McDowall 2006). The Australian mudfish spawns in winter in freshwater habitats, but the juveniles then move to the sea for about three months. The species must have access to and from the sea to complete its life cycle. The Australian mudfish is known to be capable of withstanding habitat dehydration and hence can inhabit ephemeral streams and wetlands. Fish also have the capacity to withstand low dissolved oxygen levels in water through surface gulping (McDowall 2006).

Studies of wetlands across Victoria in the 1980s revealed that large proportions of the two wetland types (shallow and deep freshwater marshes) favoured by Australian mudfish have been lost since European settlement (Norman and Corrick 1988). In the Snowy River and Gippsland Lakes catchments, 25% of shallow and 34% of deep freshwater marshes have been lost, while in South Gippsland more than 23 000ha of the wetlands preferred by the Australian mudfish had been destroyed by the 1980s (Corrick and Norman 1980). More recent surveys indicate that this loss now amounts to an overall loss of 99% of potential mudfish habitat in the region (Koehn and Raadik 1991). According to Koehn and Raadik (1991), the loss of such large areas of habitat must be the greatest threat to this species in Victoria.

The species appears to be declining because of unrestricted stock access, habitat loss and modification and possibly due to instream barriers (McDowall 2006) or other stream modification that have isolated wetland habitats from the main river channel.

Australian whitebait *(Lovettia sealii*)

FFG Act Threatened
DSE (2007) Critically Endangered

The Australian whitebait occurs in Tasmania and has only recently been recorded in a Victorian coastal stream (Raadik, T., DSE, ARI, unpubl. data). The Australian whitebait is anadromous, with no known landlocked populations (McDowall 2006). The adults spawn in lower reaches/upper tidal estuaries of rivers during spring and then die. The eggs are deposited on woody debris and substrate boulders, where they develop and hatch after about three weeks. Larvae are then flushed to sea (Blackburn 1950).

Information on Victorian populations is very limited. In Tasmania the species once supported a valued whitebait fishing industry with catches up to 480 000kg/annum in the 1940s, however the industry quickly declined and closed by 1949. The industry has only been periodically opened since that date but without the return to catches of the 1940s. The decline in the fishery in Tasmania seems to have resulted initially from exploitation, however the species' failure to recover after 18 years without harvesting suggests that other forces may have been implicated in its collapse and/or contributing to sustained low production (McDowall 2006). Fulton (1984) suggested that exploitation in combination with environmental perturbations such as the pollution of estuarine environments and high predation levels imposed by alien trout may have seriously depressed the populations to such a level, that has prevented recovery. Despite the rapid declines, the species has not been formally recognised as requiring conservation protection in Tasmania (McDowall 2006).

In Victoria, the species persistence is likely to be threatened by habitat loss and degradation, trout predation and barriers to movement (McDowall 2006).

Cox's gudgeon *(Gobiomorphus coxii)* and Striped gudgeon *(Gobiomorphus australis)*

FFG Act	Cox's gudgeon- Threatened
DSE (2007)	Cox's gudgeon - Endangered
DSE (2007)	Striped gudgeon - Near Threatened

These species occur from southern Queensland through to Wilson's Promontory in the Southeast Coast Drainage Divisions (Raadik 1992, Allen et al. 2003).
Little is known of migratory habits of the Cox's gudgeon although it is thought that young are washed downstream and later migrate up river. Juveniles of the Striped gudgeon have been noted migrating upstream in spring after winter floodwaters subside. Both species have been recorded climbing wet vertical surfaces such as dams and weirs (Bishop and Bell 1978, Koehn and O'Connor 1990a, Allen et al. 2003). Cox's gudgeon breeds between March and April and the Striped between late summer and autumn. Both species lay their eggs on hard surfaces such as rocks and logs, with the males guarding the eggs until they are hatched (Koehn and O'Connor 1990a).

The Striped gudgeon is common at lower altitudes in coastal streams and tends to favour habitats with submerged rocks, logs and vegetation and slow flows, although it has been recorded in turbulent rapid-flowing headwaters (Koehn and O'Connor 1990a). The juveniles are commonly found in estuaries. Adults of Cox's gudgeon are more likely to be found away from the coast up to altitudes of 700m, while the juveniles are more common lower in the river (Allen et al. 2003). They favour river sections with fringing vegetation and generally occur in clear flowing water, occasionally in rapids or standing water (Allen et al. 2003).

Cox's gudgeon is considered rare in terms of distribution and abundance, having only been collected from a total of 10 sites in Victoria (Scientific Advisory Committee 1994). The species is threatened by a number of processes including: increase in sedimentation in Victoria rivers and streams due to human activities, introduction of live fish outside their range and prevention of passage due to instream barriers (Scientific Advisory Committee 1994). Although there is no evidence of trout predation on Cox's gudgeon in Australia, trout in New Zealand have been found to feed on *Gobiomorphus* spp. in lakes and estuaries (McDowall 1990).

The Striped gudgeon has not yet been listed under the FFG Act, although it is recognised as "Near Threatened" in Victoria (Department of Sustainability and Environment 2003). The species has been recognised as under threat due to a large contraction of its known range within Victoria (T. Raadik, DSE, ARI, pers. comm. 2007). Threats are likely to be similar to those facing the Cox's gudgeon.

Dwarf galaxias *(Galaxiella pusilla)*

IUCN Red List	Vulnerable (B1 +2bcd[19])
EPBC Act	Vulnerable
FFG Act	Threatened
DSE (2007)	Vulnerable

Dwarf galaxias are patchily distributed in the coastal drainages of south-eastern Australia (Table 7.1), Bass Strait and north-eastern corner of Tasmania (Allen et al. 2003). The Dwarf galaxias is a mid-water, free-swimming native freshwater fish that is generally found in wetlands, swampy creeks and streams that are sensitive to lowered water tables (McDowall 2006). The species is able to survive habitat dewatering through aestivation or dormancy in one life stage (Humphries 1986, Romananowski 2004). The exact mechanism is unknown, but several authors have suggested the adults may utilise crayfish burrows or shelter in moist depressions (Humphries 1986, Romananowski 2004). Damage to these burrows and depressions through stock trampling may threatened the species' refuge habitat (Saddlier et al. 2006 draft). The Dwarf galaxias breeds in late winter-spring with the female laying between 65-120 adhesive eggs on the underside of aquatic vegetation or on a hard surface such as a stone (Saddlier et al. 2006 draft). The species is thought to have a mostly annual life cycle and consequently, populations experience substantial fluctuations in abundance both within and between years. As its name suggests, this is a very small species with males recorded to a length of 3.4cm and females 4cm (Saddlier et al. 2006 draft).

The species is vulnerable to a variety of activities including: loss of habitat due to lowered water tables, wetland drainage and alteration of flow regimes, removal of aquatic vegetation, forestry, water abstraction, urbanisation, and agricultural practices including trampling of habitat by stock (McDowall 2006) and predation by alien fish species (Saddlier et al. 2006 draft). The vulnerability of this species is in part due to its preference of shallow wetland areas that are easily impacted by nearby activities or are easily drained (McDowall 2006). Reductions in flow may also reduce the amount of shallow-edge habitat available to this species.

Empire gudgeon *(Hypseleotris compressa)*

FFG Act	Threatened
DSE (2007)	Vulnerable

The Empire gudgeon is only found in one small population in Victoria, inEast Gippsland (Raadik, T., DSE, ARI. unpubl. data), however the species is quite

[19] The category B1 + 2bcd refers to taxa with an extent of occurrence estimated to be less than 20,000 km^2 or area of occupancy estimated to be less than 2000 km^2, and estimates indicating that populations are severely fragmented or known to exist at no more than ten locations and are continuing to decline, inferred, observed or projected by area of occupancy area and extent and/or quality of habitat and number of locations or subpopulations (IUCN 2006).

widespread throughout the remainder of Australia with populations found in NSW, Queensland, NT, and Western Australia. It therefore only affords a conservation status in Victoria (Allen et al. 2003). The species is found in the lower reaches of rivers in flowing or still water around aquatic plants and fallen tree branches. Juveniles are typically found in fast flowing water or in estuaries (Allen et al. 2003). Breeding is known to occur from early spring through to autumn. Adhesive eggs are laid in rows on rocks, aquatic plants or sand, where they are guarded by the male until they hatch 10-14 days later (Auty 1978). It is a midwater, carnivorous species that has been described as an effective destroyer of mosquito larvae (Auty 1978).

The species has been found to be sensitive to nutrient enrichment of rivers and estuaries caused by the input of treated sewage effluent and urban runoff (Growns et al. 1998). However, it is not apparent if it is the enrichment or the decline in habitat quality that reduces the abundance of this species. The demersal nature of the species' eggs makes the Empire gudgeon susceptible to abrasion and blanketing of the eggs from high sediment loads (Lucas 2005). The species has shown sensitivity to riparian degradation with population abundances significantly reduced in areas with degraded riparian vegetation (Growns et al. 1998). The Empire gudgeon is also highly attractive, making it a potentially sought after species by aquarists, posing a risk to persistence in the absence of conservation protection.

Freshwater herring (*Potamalosa richmondia)*

FFG Act	Threatened
DSE (2007)	Regionally Extinct

Freshwater herring have only been found in one isolated population in Victoria in the Genoa River in far-east Gippsland (Raadik 1992). The species is know presumed to be regionally extinct. It is believed that this population was the southern edge of their distribution with the majority of populations found in NSW. It is considered relatively abundant in rivers north of the Hawkesbury River in NSW, but it is less common in the southern half of its range (Briggs 1980 in Pidgeon 1989). Typically the adults inhabit freshwater environments, migrating downstream to the estuary/ocean to spawn in July and August. It is believed that the larvae and juveniles inhabit estuary areas or the ocean (Koehn and O'Connor 1990a). The species shows a preference for clear moderately flowing streams, but has also been found in standing waters and slightly turbid slow-flowing streams. Information on the biology of the species is very limited, but it is described as carnivorous, feeding mainly on insects and crustaceans (Pidgeon 1989).

While listed under the Victoria FFG Act, the species has no formal conservation status in NSW. Populations are threatened by the construction of weirs and impoundments that may impede their migration both by imposing a physical barrier and by changing the discharge conditions necessary for their migration (Pidgeon 1989). Limited knowledge of the biology and habitat requirements of this species makes it difficult to ascertain the effects of other potential threats.

River Blackfish (Upper Wannon River form: *Gadopsis marmoratus*)

DSE (2007)   Critically Endangered

River blackfish are widespread in Victoria, however a population in western Victoria appears to have been isolated from the rest of the mainland stock for some time and its members have developed some structural modifications such as a reduction in the number of spines in the dorsal fin (T. Raadik, DSE, ARI, pers. comm. 2007). This form of the species has therefore been recognised as distinct morphological form (*G. marmoratus* upper Wannon River form, 2001). Specific information on the biology of the Wannon form is limited but they are presumed to have similar requirements to other blackfish found south of the GDR. As such it is assumed that they are bottom dwelling, nocturnally active and feed on a variety of insects, crustaceans, worms, small fishes and fish eggs. They prefer clear, gently flowing streams with abundant log snags and are tolerant of increases in salinity (slightly brackish, 10ppt) and a temperature range of 5°-25°C (Allen et al. 2003). Adult blackfish spend most of their time in a single pool adjacent to a snag pile (Jackson 1978) and their home ranges are typically 25-30m (Koehn and O'Connor 1990a).

River blackfish have a low fecundity, habit of home-ranging and its popularity as an angling species, makes it susceptible to overfishing. Blackfish deposit their eggs inside submerged logs and the dependency of the species on SWH can result in the loss of populations when these habitat components are removed (Scientific Advisory Committee 1991). The species is also susceptible to increasing sediment loads (Doeg and Koehn 1994) which smother available habitat and eggs, increasing salinity which affects the survival of the juvenile stages (Ryan and Davies 1996, Clunie 2002) and competition from alien species such as trout (Jackson 1978). The following processes have been identified as threatening the upper Wannon River form of the River blackfish: loss of shading riparian habitat, loss of instream habitat, contaminants entering waterways, deterioration in water quality due to catchment changes, increased sediment loads, reduction in water temperatures during spawning (thermal pollution), overfishing, prolonged drought, competition with Brown trout and predation of young by salmonids.

Short-finned eel

The Short-finned eel is a catadromous fish that is commonly found in freshwater lakes and wetlands from Mt Gambier in South Australia to the Richmond River in NSW (Allen et al. 2003). At sexual maturity (approximately 14 years of age for males and 18-24 years in females) the eels cease feeding and migrate downstream to deep oceanic breeding sites in the Coral Sea near New Caledonia (Allen et al. 2003). Breeding migration typically occurs from summer to autumn and it is thought that the adults die at the spawning site shortly after breeding. Newly hatched larvae drift on oceanic currents back to coastal areas over a period of about six months before metamorphosing into glass eels in coastal waters and subsequently migrating into the estuaries of southern Australia between May and October (Koehn and O'Connor 1990a, Allen et al. 2003). The glass eels then transform into brown elvers as they migrate upstream into freshwater environments between October and January. Evidence suggests that the immature eels remain within freshwater environments feeding until they reach sexual maturity, when they begin the downstream migration for breeding (Koehn and O'Connor 1990a, Allen et al. 2003).

The Short-finned eel is a bottom-dwelling fish, which moves and feeds mainly at night. In freshwater environments eels tend to favour habitats with structure during the day such as areas with dense macrophytes, SWH, undercut banks, rocks and cobbles (Jellyman and Chisnall 1999). Little is known of the habitats they use in estuarine and marine environments. Eels are opportunistic carnivores, feeding on invertebrates and fish (McKinnon 2007).

Variegated pygmy perch *(Nannoperca variegata)*

IUCN Red List	Vulnerable (D2[20])
EPBC Act	Vulnerable
FFG Act	Threatened
DSE (2007)	Endangered

The Variegated pygmy perch or Ewen's pygmy perch is restricted to several small populations in southwestern Victoria and adjacent south eastern South Australia. Little is known about the habitat requirements of the Variegated pygmy perch, but it is noted to prefer clear flowing well vegetated streams (Koehn and O'Connor 1990a) over gravel or cobbles (Allen et al. 2003). The species is believed to be carnivorous, feeding on benthic insect larvae and crustaceans (Allen et al. 2003). The species breeds from spring to early summer.

The historical distribution of the species is unclear as it was only recently described, however like other members of this family, it is likely the species has suffered significant declines in abundance (Saddlier and Hammer 2007 draft-a). The species is vulnerable to extinction due to its small and disjunct distribution, habitat disturbance (e.g. erosion, loss of native riparian vegetation through grazing, clearing, etc) and lack of habitat which can be considered secure from disturbance (Fisher 2003). Major threats include wetland drainage and groundwater extraction, loss of aquatic vegetation, climate change, drought, salinisation of freshwater habitats, habitat damage through grazing and lack of regeneration and loss of riparian vegetation (Saddlier and Hammer 2007 draft-a). Alien fish competitors and predators, the alteration of temperature regimes and sediment input have also been recognised as potentially threatening processes (Fisher 2003).

Yarra pygmy perch *(Nannoperca obscura)*

IUCN Red List	Vulnerable (B1 +2bc[21])

[20] D2 refers to populations that are very small or restricted in the form and is characterised by an acute restriction in its area of occupancy (typically less than 100 km^2) or in the number of locations (typically less than five). Such a taxon would thus be prone to the effects of human activities (or stochastic events whose impact is increased by human activities) within a very short period of time in an unforeseeable future, and is thus capable of becoming Critically Endangered or even Extinct in a very short period (IUCN 2006).
[21] A taxon is Vulnerable when it is not Critically Endangered or Endangered but is facing a high risk of extinction in the wild in the medium-term future. The category B1 + 2bc refers to a taxon whose extent of occurrence estimated to be less than 20,000 km^2 or area of occupancy estimated to be less than 2000 km^2, and estimates indicate the populations are severely fragmented or known to exist at no

EPBC Act	Vulnerable
FFG Act	Threatened
DSE (2007)	Near Threatened

The Yarra pygmy perch is found in the Maribyrnong basin in southern Victoria, west to the Millicent Coast drainage basin in the southeast of South Australia. The species typically occurs in slow-flowing or still waters amongst dense aquatic, mostly emergent vegetation. Little is known of the biology of this species, although it is assumed that breeding behaviour is similar to closely related species such as the Southern pygmy perch which lay demersal, non-adhesive eggs over the submerged aquatic vegetation and the substrate (Saddlier and Hammer 2007 draft-b). Spawning in the Yarra pygmy perch occurs during September and October (Allen et al. 2003) at temperatures between 16-24°C, when males and females are 3.5 and 4 cm in length, respectively. This carnivorous fish feeds on insects, insect larvae and planktonic crustaceans (Allen et al. 2003) and adults are known to attain a total length of 7.5cm (Saddlier and Hammer 2007 draft-b).

The Yarra pygmy perch has declined since its description in 1872 and is now thought to be extinct in the Yarra and Bunyip drainage systems (Saddlier 2003). The fragmented nature of the remaining populations render them vulnerable to population declines from threats including habitat destruction from grazing and agriculture, draining of wetlands/and swamps and the removal of instream and riparian vegetation. Introduced or alien predatory fish such as Brown trout, Rainbow trout, Redfin and Golden perch are believed to predate on this species placing it under additional pressure (Saddlier 2003). The similar habitat and feeding requirements of this species and the alien Eastern gambusia suggests that Eastern gambusia may competitively exclude the Yarra pygmy perch. The Eastern gambusia may also consume their eggs and young fish. This species is one of the few Australian freshwater fish species recognised under the International Union for Conservation of Nature and Natural Resources Red List (IUCN Red List: Wager 1996a)

Translocated natives with a conservation status

There are currently six alien native species (i.e. species native to Australia but not native to coastal Victoria catchments) that are known to be present in coastal Victoria catchments (Table 7.5). Many of these species are currently recognised as requiring protection under State and/or Commonwealth conservation legislation (see Table 1.4). As such, while populations in their natural range continue to decline the introduced populations may be important populations in the context of the long-term conservation of these species. For example, populations of Macquarie perch (*Macquaria ambigua*) in their natural range are severely depleted and struggling to persist, however, translocated populations present in the Yarra River, are currently in good self-sustaining condition. It is important to maintain this population as a genetic resource to enable reintroductions to its natural range. The importance of the degree of the threat posed will vary with each species and their location.

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more than ten locations and there is continuing decline, inferred, observed or projected, in the occupancy and area and extent and/or quality of habitat (IUCN 2006).

As stated in section 1.6 of this document, one of the guiding principles in the management of native fish in coastal Victoria will be *Conservation is best undertaken within a species' natural habitat*. This can only be achieved by minimising the threats to local natives in their natural local habitat. This project recognises that some alien native fish species are a potential threat to local native fish populations through predation and/or competition. Therefore while the importance of these species is acknowledged, the project does not support further introductions of non-local natives into coastal catchments.

Further information about the biology and habitat requirements of these species which have been translocated to Victoria's coastal catchments can be found on the Murray-Darling Basin Commission's Native Fish Strategy website:

http://www.mdbc.gov.au/NFS/native_fish_information

Native Fish Australia's website:

http://www.nativefish.asn.au/

or DSE website and follow the links to Plants +Animals > Native Plants + Animals > Freshwater ecosystems (google: VicFishInfo)

http://www.dse.vic.gov.au/dse/index.htm

Table 7.5: Distribution of translocated freshwater fin-fish species with Commonwealth or State conservation status currently found in coastal Victoria

Asset		Distribution	
Common name	**Scientific name**	**CMA Area**	**River basins**
Golden perch	*Macquaria ambigua*	PP	28,29,30
Macquaire perch	*Macquaria australasica*	GH,PP	??, 29,30
Murray cod	*Maccullochella peelii peelii*	PP	29
Silver perch	*Bidyanus bidyanus*	PP	29,30
Trout cod	*Maccullochella macquariensis*	PP	29

See Figure 7.1 for location and name of catchments and basins.

7.4 Distribution, biology and ecology of large freshwater decapod crustaceans and bivalve mussels

As identified in the development of this guide there is a dearth of information available on the distribution, ecology, and management requirements of many large freshwater invertebrates. Providing information on all freshwater invertebrate species was beyond the scope of this project as there are over 300 families represented by many thousands of species in Victoria. Therefore, a limited subset of the large macro-invertebrates was chosen in consultation with key stakeholders and relevant scientific experts. These include:

- large freshwater decapod crustaceans - freshwater decapod crustaceans greater than 30mm in length and found to inhabitat primarily freshwater habitats or surrounding habitats directly influenced by freshwater environments (i.e. burrowing crayfish). This includes species belonging to the families of Atyidae (freshwater shrimps), Parastacidae (yabbies, freshwater crays and burrowing crays) and Hymenosomatidae (freshwater crabs), and
- large freshwater bivalve molluscs – truly freshwater bivalve molluscs (i.e. belonging to the families of Hyriidae, Sphaeriidae and Corbiculidae - the predominately marine families Geloinidae and Mytilidae may occasionally occur in the fresh to brackish waters of estuaries and coastal lakes, but are not considered truly freshwater) greater than 30mm in length

A summary of the distribution of each species considered by the guide is provided in Table 7.6. Further details on species biology can be found in relevant tables (Table 7.7 to 7.9) and in the summary descriptions below.

Table 7.6: Summary of the distribution of large decapod crustaceans and bivalve molluscs native to coastal Victorian catchments

Common name	Scientific name	CMA Area	River basins	Lowland, Foothill, Upland
Alpine spiny cray	*Euastacus crassus*	EG	22,23	U
Central Highlands burrowing cray	*Engaeus affinis*	WG,PP	25,26,28,29	F,U
Central Victorian spiny cray	*Euastacus woiwuru*	EG,PP	26,28,29	F,U
Clayton's spiny cray	*Euastacus claytoni*	EG	22	F,U
Coastal freshwater mussel	*Hyridella australis*	EG, WG, PP, C	24, 29, 33, probably more	F
Coastal freshwater mussel	*Hyridella depressa*	EG, WG, PP, C	24, 26, 35, possibly more	F
Coastal freshwater mussel	*Hyridella drapeta*	EG, WG, PP, C	21-29,33,35, possibly more	F
Common freshwater shrimp	*Paratya australiensis*	all	all	L,F,U
Common yabby	*Cherax destructor*	all	all except 20, 21 and 22	L,F
Curve-tail burrowing cray	*Engaeus curvisuturus*	WG	25,26	F,U
Dandenong burrowing cray	*Engaeus urostrictus*	PP	28,29	F,U
East Gippsland burrowing cray	*Engaeus orientalis*	EG	20,21,22	F,U
East Gippsland spiny cray	*Euastacus bidawalus*	EG	20,21,22	L,F,
Eastern freshwater shrimp	*Australatya striolata*	EG	21,22	L,F,U
Foothill burrowing cray	*Engaeus victoriensis*	PP	28,29	L,F,U
Freshwater crab	*Amarinus lacustris*	WG,PP,C, GH	27-38, excluding 34	L
Gippsland burrowing cray	*Engaeus hemicirratulus*	WG,PP	25,26,27,28,29	F,U
Gippsland spiny cray	*Euastacus kershawi*	EG,WG,PP	21-29	L,F
Glenelg freshwater mussel	*Hyridella glenelgensis*	GH	38	L
Glenelg spiny cray	*Euastacus bispinosus*	GH	38	L,F,U
Granular burrowing cray	*Engaeus cunicularius*	WG,PP,C	26-29,33,35	L,F,U
Hairy burrowing cray	*Engaeus sericatus*	C,GH	35,36,37	L,F,U
Lilly pilly burrowing cray	*Engaeus australis*	WG	27	L, F
Lowland burrowing cray	*Engaeus quadrimanus*	EG,WG,PP	20-30	L,F
Mallacoota burrowing cray	*Engaeus mallacoota*	EG	21	L
Murray River mussel	*Alathyria jacksoni*	EG, WG, PP	22-29	L,F
Narracan burrowing cray	*Engaeus phyllocerus*	WG, PP?	27,28	F,U
North-eastern burrowing cray	*Engaeus cymus*	EG,WG	23,24,25	F,U
Orbost spiny cray	*Euastacus diversus*	EG	22	F
Otway burrowing cray	*Engaeus fultoni*	C	35	L,F,U
Otway cray	*Geocharax gracilis*	C,GH?	33,35,36?	L,F
Pea mussel	*Corbicula australis*	all	all	L,F
Portland burrowing cray	*Engaeus strictifrons*	GH	36,37,38	L
Richards burrowing cray	*Engaeus laevis*	EG,WG,PP	21,22,26,27,28	L,F
South Gippsland burrowing cray	*Engaeus karnanga*	WG	27	L,F
South Gippsland spiny cray	*Euastacus neodiversus*	WG	27	L,F,U
South-eastern river mussel	*Velesunio ambiguus*	all	24-38, excluding 34	L,F
Southern river mussel	*Hyridella narracanensis*	EG, WG, PP, C	24, 26, 29, 35, possibly more	L,F
Southern Victorian spiny cray	*Euastacus yarraensis*	PP,C	29,30,31,33,35	L,F
Strezelecki burrowing cray	*Engaeus rostrogaleatus*	WG	26,27	F,U
Tubercle burrowing cray	*Engaeus tuberculatus*	WG,PP	25,26,28,29	U
Upland burrowing cray	*Engaeus lyelli*	PP,C,GH	31,34,36,38	U
Variable spiny cray	*Euastacus yanga*	EG	20,21	L,F
Warragul burrowing cray	*Engaeus sternalis*	WG?PP?	28	F
Western burrowing cray	*Engaeus merosetosus*	C,GH	33,34,35,36	L,F,U
Western cray	*Geocharax falcata*	GH	26,37,38,39	L,F
Western swamp cray	*Gramastacus insolitus*	GH	36,38	L

Table 7.7: General biology of locally native large decapod crustaceans and bivalve molluscs with conservation classification or are recreationally targetted

Asset	General biology						
Common name	Migratory	Found in Estuaries	Commonly Found in Wetlands	Spawning calendar	Spawning habitat	Early Larval Life	Adult Main Habitat
Alpine spiny cray‡				May -October	eggs + juveniles held beneath tail	FW	FW
Common freshwater shrimp	✓	✓	✓	July-April	FW/EST	EST	FW
Common yabby			✓		FW	FW	FW
Curve-tail burrowing cray‡					eggs + juveniles held beneath tail	BUR	BUR
Dandenong burrowing cray‡						BUR	BUR
Eastern freshwater prawn‡	✓	✓		summer?	eggs + early larvae held under tail, then released	EST/FW	FW
Glenelg freshwater mussel‡				?	larvae released into water column + attach to gills of fish, later settling into substrate	FW	FW
Glenelg spiny cray‡				May-October	eggs + juveniles held beneath tail	FW	FW
Lilly pilly burrowing cray‡				?	eggs + juveniles held beneath tail	BUR	BUR
Mallacoota burrowing cray‡				spring-summer	spawn in burrows, eggs + juveniles held beneath tail	BUR	BUR
Narracan burrowing cray‡				mid-late spring	spawn in burrows, eggs + juveniles held beneath tail	BUR	BUR
Orbost spiny cray‡				?	eggs + juveniles held beneath tail	FW	FW
South Gippsland spiny cray‡				May - October	eggs + juveniles held beneath tail	FW	FW
Strezelecki burrowing cray‡				?	eggs + juveniles held beneath tail	BUR	BUR
Warragul burrowing cray‡				?	eggs + juveniles held beneath tail	BUR	BUR
Western swamp cray‡			✓	Oct-Dec	eggs + juveniles held beneath tail	FW	FW

FW = freshwater; EST = estuary; BUR= burrowing/riparian zone;
? = indicates incomplete knowledge.

Table 7.8: Adult habitat preferences of large decapod crustaceans and bivalve molluscs with conservation status or are recreationally targeted

Asset	Adult habitat preferences														
Common name	estuary position[ŧ]	muddy or sandy substrate	rocky substrate	Slow flow	fast flow	turbid water	clear water	rffle zones	deep holes/pools	undercut banks	SWH or other submerged objects	submerged aquatic vegetation	emergent aquatic vegetation	overhanging riparian veg	wetland/ swamps
Alpine spiny cray	NA		✓	✓	✓		✓	✓	✓		✓	✓			
Common freshwater shrimp**	M,U								✓			✓			✓
Common yabby	NA	✓		✓					✓	✓	✓	✓			✓
Eastern freshwater prawn	M, U		✓		✓		✓	✓			✓	✓			
Glenelg freshwater mussel	NA	✓		✓			✓								
Glenelg spiny cray	NA	✓	✓	✓		✓	✓		✓	✓	✓	✓		✓	
Orbost spiny cray	NA		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	
South Gippsland spiny cray	NA	✓	✓	✓		✓	✓		✓	✓	✓	✓	✓	✓	
Western swamp cray	NA	✓		✓		✓	✓		✓		✓	✓	✓		✓

Note: all burrowing crays are strictly terrestrial and reliant on healthy native vegetation in the riparian zone.

Table 7.9: Habitat preferences of large native freshwater decapods and bivalve molluscs without conservation status and not recreationally targeted found in coastal Victoria

Common name	Scientific Name	Found in Estuaries	Also Found in Wetlands	Migratory
Central Highlands burrowing cray	*Engaeus affinis*	N	**Y**	N
Central Victorian spiny cray	*Euastacus woiwuru*	N	N	N
Clayton's spiny cray	*Euastacus claytoni*	N	N	N
Coastal freshwater mussel	*Hyridella australis*	N	N	N
Coastal freshwater mussel	*Hyridella depressa*	N	N	N
Coastal freshwater mussel	*Hyridella drapeta*	N	N	N
Common freshwater shrimp	*Paratya australiensis*	**Y**	**Y**	N
Common yabby	*Cherax destructor*	N	**Y**	N
East Gippsland burrowing cray	*Engaeus orientalis*	N	N	N
East Gippsland spiny cray	*Euastacus bidawalus*	N	N	N
Foothill burrowing cray	*Engaeus victoriensis*	N	N	N
Freshwater crab	*Amarinus lacustris*	N	**Y**	N
Gippsland burrowing cray	*Engaeus hemicirratulus*	N	N	N
Gippsland spiny cray	*Euastacus kershawi*	N	N	N
Granular burrowing cray	*Engaeus cunicularius*	N	N	N
Hairy burrowing cray	*Engaeus sericatus*	N	**Y**	N
Lowland burrowing cray	*Engaeus quadrimanus*	N	**Y**	N
Murray River mussel	*Alathyria jacksoni*	N	N	N
North-eastern burrowing cray	*Engaeus cymus*	N	N	N
Otway burrowing cray	*Engaeus fultoni*	N	**Y**	N
Otway cray	*Geocharax gracilis*	N	**Y**	N
Pea mussel	*Corbicula australis*	N	N	N
Portland burrowing cray	*Engaeus strictifrons*	N	**Y**	N
Richards burrowing cray	*Engaeus laevis*	N	N	N
South Gippsland burrowing cray	*Engaeus karnanga*	N	N	N
South-eastern river mussel	*Velesunio ambiguus*	N	N	N
Southern river mussel	*Hyridella narracanensis*	N	N	N
Southern Victorian spiny cray	*Euastacus yarraensis*	N	N	N
Tubercle burrowing cray	*Engaeus tuberculatus*	N	N	N
Upland burrowing cray	*Engaeus lyelli*	N	N	N
Variable spiny cray	*Euastacus yanga*	N	N	N
Western burrowing cray	*Engaeus merosetosus*	N	N	N
Western cray	*Geocharax falcata*	N	**Y**	N

Burrowing crayfish *(Engaeus spp*)

FFG Act	Threatened
DSE (2008 draft)	Warragul and Dandenong burrowing crayfish - Critically Endangered
DSE (2008 draft)	Curve-tail, Gippsland, Narracan, South Gippsland, Western burrowing crayfish - Endangered
DSE (2008 draft)	Lilly Pilly, Otway, Mallacoota and Hairy burrowing crayfish- Vulnerable

There are currently seven species, belonging to this genus, that are recognised as threatened under the FFG Act, including: Lilly Pilly burrowing cray (*Engaeus australis*), Curve-tail burrowing cray (*E. curvisuturus*), Mallacoota burrowing cray (*E. mallacoota*), Narracan burrowing cray (*E. phyllocerus*), Strezelecki burrowing cray (*E. rostrogaleatus*), Warragul burrowing cray (*E. sternalis*) and the Dandenong burrowing cray (*E. urostrictus*). The genus *Engaeus* is restricted to south-eastern Australia (Horwitz 1990). Most burrowing crayfish are small, cryptic and predominately burrowers, spending most of their life underground (Horwitz 1990). Burrows are typically found in the riparian habitats of rivers, swamps and wetlands, where they interact with either groundwater or surface water runoff. Burrowing crayfish generally feed on plant material such as roots and decomposing leaves, rotting logs and small invertebrates (Suter and Richardson 1977, Growns and Richardson 1988). These crayfish breed in burrows and larvae develop under the abdomen of the female (van Praagh 2003e, f, d, Morey 2004). There is only very limited knowledge of the biology of all these threatened species.

All seven species naturally have severely restricted distribution making them vulnerable to localised threats (van Praagh 2003e, f, d, Morey 2004). Action statements have only been prepared for four of the seven species (Mallacoota, Narracan, Strezelecki and the Warragul burrowing crays) however their similar biology would suggest that they are likely to be impacted by similar threats. Landuse change such as clearing, grazing and cropping are likely to contribute to the decline of populations of these species. Grazing in riparian habitats is of particular threat as compaction and pugging by stock can interfere with burrows and cause the loss of streamside vegetation. Modifications to watertable levels and drainage patterns are also likely to influence all of these species. Herbicide and pesticide use is likely to impact on these species with decapod crustaceans shown to be highly sensitive to some chemicals, particularly to organophosphates and carbamates (Davies et al. 1994, Radcliffe 2002).

Common freshwater shrimp (*Paratya australiensis*)
[rec]

Paratya australiensis is the most common freshwater atyid shrimp in south-eastern Australia. It is found from the Torrens River in South Australia to southern Queensland and eastern Tasmania (Walsh and Mitchell 1995). It commonly inhabits lowland rivers but may also be found in wetlands and some upland streams. The species can also be commonly found in seagrass meadows in estuary environments in Victoria. Adults favour submerged leafy macrophytes in low salinity environments, while larvae develop in the deep saline layer of the salt wedge (see section 7.5.1 for details on salt wedge) where they provide an important food source for a number of estuarine fish species (Howell et al. 2004). Once the salt wedge becomes stagnant the larvae of the shrimp move into deeper pools upstream of the estuary. The species breeds from July to April but breeding has been noted to peak for 6-10 weeks after peak discharge from the river when the salt wedge has intruded (Walsh and Mitchell 1995).

Common yabby (*Cherax destructor*) [rec]

The common freshwater yabby is an omnivorous, semi-aquatic, freshwater crayfish found in a wide range of habitats east of the Tambo River in Victoria (naturally absent in western Victoria: T. Raadik, DSE, ARI, pers. com.), NSW, southern Queensland, SA and parts of the NT (Withnall 2000). The species inhabits low lying swamps, streams, rivers and dams. The species rarely occurs in big-river environments with high flows, except in the vicinity of dams and weirs (Sheldon and Walker 1989). Yabbies are able to tolerate a wide range of temperatures (i.e. 1°C to 35°C) although optimum growth occurs between 20°C and 25°C. The species is also tolerant of a wide range of dissolved oxygen levels and will tolerate salinities up to 8ppt after which growth will cease and mortality may occur (Withnall 2000).

Yabbies prefer muddy or silted bottoms, are capable of burrowing into the soil up to 2m and will survive in burrows during periods of desiccation. Their reproduction is primarily related to water temperature and day length, with mating occurring in spring to early summer when water temperatures reach above 15°C (Withnall 2000). Reproduction peaks between October and January. The female provides care for eggs and the early larval stages by retaining eggs and larvae in a brood pouch under her tail (Withnall 2000).

Eastern freshwater prawn (*Australatya striolata*)

FFG Act	Threatened
DSE (2008 draft)	Vulnerable

The Eastern freshwater prawn or Riffle shrimp range extends from Claudie River Cape York Peninsula, Queensland through to Victoria where it reaches its most southern limit of its range in the Far East Gippsland and Snowy River basins (Smith 1994, Raadik 1995, Raadik and O'Connor 1997b). The species tends to occupy flowing streams in the riffle zone or rock localities, where they used the stones for shelter. Very little published information is available on this species biology and/or ecology (CNR 1995). Unpublished literature suggests that shortly after hatching larvae of the species drift down to the estuary where they grow (Smith 1987) before returning to freshwater habitats later in development. The species grows to between 2-5cm and is found throughout river systems from headwaters through to the estuary (T. Raadik, DSE, ARI, pers. comm. 2007).

Freshwater crab (*Amarinus lacustris*)

Amarinus lacustris is a false spider crab commonly found in temperate and Mediterranean regions of southern-eastern Australia (not found east of Wilsons Promontory) and New Zealand. Riverine crabs such as *A. lacustris* have direct development of larvae inside eggs, which are carried by the female in a brood pouch until after they hatch as juvenile crabs (Johnston and Robson 2005). Johnston and Robson (2005) found a strong association between crab sex, habitat and time of year of *A. lacustris* in two southwest Victorian rivers with females preferring pool habitats during March and April (the non-gravid period of the year), but returning to riffle zones once they are gravid. Males in contrast occur most often in riffles between July and November but equally common in pools and riffles in January to May (Johnston and Robson 2005).

Johnson and Robson (2005) suggested that habitat selection maybe associated with the preference for slow flow water during moulting and copulation. *Amarinus lacustris* exhibits soft shelled mating during Mach, April and May. Young are believed to be released into the riffle zones during high flows in early spring through to mid summer (Nov-Jan). This behaviour enables eggs and young to be brooded in highly oxygenated water from which wide dispersal can be achieved on release. There is no precise data on longevity, however field data suggests that individuals of the species are likely to live longer than one year (Johnston and Robson 2005).

Larger members of the species are known to exploit sheltered slower flowing edge regions or sheltered on the underside of rocks within fast flowing habitats. Johnston and Robson (2005) have hypothesised that small interstitial spaces in finer grained habitats may limit the size of crabs able to effectively inhabit them.

Freshwater crayfish *(Geocharax* spp.)

This genus is represented by two species in the coastal catchments of Victoria namely *Geocharax falcata* (Western crayfish) and *G. gracilis* (Otway crayfish). Both have a limited range in the west of the State (see Table 9.14) and are thus regarded as short-range endemics. These species are commonly found in the riparian zone, where they forage, mate and burrow to take refuge from predators (March and Robson 2006). As such they are vulnerable to riparian disturbance. Their poor dispersal ability, long life cycles and slow maturation makes them vulnerable to habitat loss, although neither species is currently considered of conservation significance. *Geocharax gracilis* has shown a preference for riparian habitat in forest blocks with a low soil compaction, high levels of overhanging stream vegetation and intact riparian vegetation (March and Robson 2006). Habitats supporting other landuse activities such as grazing have been shown to support far fewer burrows regardless of the presence or absence of native vegetation or the active presence of grazing cattle compared to remnant riparian vegetation (March and Robson 2006). This suggests that simply excluding cattle from riparian zones will not lead to an increase of crayfish burrows. March and Robson (2006) suggest that compacted soils, reduced shading and loss of organic matter inputs to the stream and riparian zone as a result of landuse may be responsible for this observation.

Glenelg freshwater mussel *(Hyridella glenelgensis)*

FFG Act Threatened
DSE (2008 draft) Critically Endangered

Five species of *Hyridella* inhabit the coastal catchments of Victoria including the threatened *Hyridella glenelgensis* (Glenelg freshwater mussel). The Glenelg freshwater mussel is the smallest of the freshwater mussels of Australia, reaching a maximum recorded size of 52mm (Playford, 2005). The species prefers areas of stream with strong flow, significant amounts of riparian vegetation and sandy sediment. The species is a filter feeder that lives off plankton from the water column. This is the rarest of Australian freshwater mussels, but was once known throughout the Glenelg River system (Playford 2005). Its range has now contracted and it is only found in one small tributary of the Glenelg –Wannon River in southwestern Victoria (Walker et al. 2001).

All available literature suggests that fish, native to the particular area in which mussels of this genus are found, are the hosts of the viable mussel larvae (glochidial). The glochidial attach themselves to the fish (often the gills or the operculum of the gill), where they feed and develop, before detaching themselves and settling into the substrate. The closely related species, *Hyridella drapeta,* has shown an affinity with River blackfish and a variety of galaxiids (Atkins 1979). Atkins (1979) identified that larvae of *H. drapeta* peak in numbers with the annual rise in stream temperature, but suggested that salinity and stream discharge are unlikely to be important environmental stimuli for reproduction in freshwater mussels. Detailed biology of *H. glenelgensis* is not currently available.

Murray River mussel *(Alathyria jacksoni*)

Alathyria jacksoni typically occurs in the main channels of rivers in relatively fast flowing water (Sheldon and Walker 1989). The species is a powerful burrower able to anchor itself against a strong current, but it is unable to withstand low oxygen environments associated with slow flows or impoundments. The species requires a stable environmental supply of oxygen and therefore its distribution is likely to be affected by the availability of suitable oxygen rich habitats (Sheldon and Walker 1989). Evidence from the Murray River suggests the species may be declining in response to the highly regulated flow the river now receives (Walker 1981). The species is only partially tolerant of desiccation and will only survive a few days out of water (Walker 1985). Consequently this species is likely to be substantially impacted by reduced flows caused by extraction, impoundments and long-term drought.

Pea mussel *(Corbicula australis)*

The freshwater clam *Corbicula australis* is a hermaphroditic mollusc which commonly inhabits disturbance prone sandy lotic habitats (Byrne et al. 2000). These clams commonly occur in large numbers and can therefore form an important component of benthic production, nutrient cycling and water purification in southeast Australian streams. Their capacity to self fertilise and their habit of brooding young until the juveniles are sufficiently developed to crawl away, enables the clams to have a high reproductive output and a rapid colonisation potential. Research in NSW has indicated that spawning is initiated with an increase in river temperatures above 18^{o}C while the end of spawning and the cessation of brooding coincide with a decrease in temperature below 20^{o}C (Byrne et al. 2000). Consequently, thermal pollution associated with flow releases from upstream impoundments may affect the timing of reproduction in downstream populations of *C. australis* (Byrne et al. 2000). This clam is a short-lived species with a maximum lifespan of approximately two years reported for NSW (Byrne et al. 2000). Populations of this species are prone to dramatic declines due to post-breeding mortality and physical removal, followed by recovery to high levels of abundance (Byrne et al. 2000).

Spiny crayfish *(Euastacus* spp.)

FFG Act	Threatened
DSE (2008 draft)	Alpine, Glenelg River, Orbost and South Gippsland spiny cray - Endangered
DSE (2008 draft)	East Gippsland spiny cray - Vulnerable

There are currently four species, belonging to this genus, that are recognised as threatened under the FFG Act: the Glenelg spiny cray (*Euastacus bispinosus*), Alpine spiny cray (*E. crassus*), Orbost spiny cray (*E. diversus*) and the South Gippsland spiny cray (*E. neodiversus*: Table 1.1). These species generally inhabit flowing, aerated, cooler streams and all have restricted distributions (Murray 2001, van Praagh 2002, 2003b, a). Most species of this genus are moderate burrowers, which seek refuge under rock ledges and amongst submerged, instream tree roots and woody debris (Zeidler 1982). Freshwater crayfish are bottom-dwelling opportunistic scavengers. Their diet consists mainly of aquatic and semi-aquatic plant debris and the fungi and bacteria associated with this (Murray 2001, van Praagh 2002, 2003b, a). Other authors have also indicated that some species consume benthic invertebrates (Goddard 1988). All species care for their eggs and young during early growth. The Glenelg spiny cray is still targeted by recreational fishermen despite their threatened status (O'Brien 2007).

Habitat destruction and modification resulting in reduced water quality and habitat fragmentation, increased sediment and siltation loads to streams as a result of land clearing, timber harvesting, grazing and other alterations to catchments, are believed to impact substantially on the survival of these species (Murray 2001, van Praagh 2002, 2003b, a). Introduced alien biota, such as Brown trout, is also believed to have an impact on these species and in many instances (particularly for the Glenelg spiny cray and Orbost spiny cray) over collection for food or bait is believed to have contributed to declines (Murray 2001, van Praagh 2002, 2003b, a). Herbicide and pesticide use is likely to impact on these species with decapod crustaceans shown to be highly sensitive to some chemicals, particularly to organophosphates and carbamates (Davies et al. 1994, Radcliffe 2002)

South-eastern River Mussel *(Velesunio ambiguous)*

The freshwater mussel *Velesunio ambiguous* is common in south-eastern Australia and is found in NSW, Victoria and Queensland. This mussel is generally associated with impoundments, lakes, billabongs and minor streams, but it is not found in larger rivers except in regions influenced by dams, weirs or sheltered pockets along the margins (Sheldon and Walker 1989). Walker (1983) suggested that the lack of occurrence of these species in larger fast flowing rivers may reflect a weak anchorage which prevents it from resisting strong currents. The species is able to actively regulate oxygen uptake enabling it to persist in low oxygen environments. It is also well adapted to periods of drought with laboratory experiments showing that it can survive for 280 days out of water (Walker 1981).

Western swamp cray (*Gramastacus insolitus*)

FFG Act	Threatened
DSE (2008 draft)	Critically endangered

The Western swamp cray is confined to permanent swamps or creeks and drains connected to swamps in the Grampians in Victoria and in south-eastern South Australia (van Praagh 2003c). This crayfish prefers freshwater swamp habitats almost completely covered in vegetation. Unlike other freshwater crayfish species, the Western swamp crayfish does not appear to burrow. Breeding is known to occur between October and December (Zeidler and Adams 1990) but very little other ecological or biological information is available (van Praagh 2003c).

The species suffers from a very restricted distribution with only nine locality records for Victoria (Zeidler and Adams 1990). Zeidler and Adams (1990) identified that the species was most likely more widespread before swamps were drained for agriculture and pastoral purposes. The species is therefore vulnerable to future habitat loss and localised environmental perturbations or catastrophic events such as extended drought or fire (van Praagh 2003c). Some decapod crustaceans are known to exhibit high sensitivity to certain pesticides (Davies et al. 1994) and the species may be vulnerable to this threat. Grazing by cattle in riparian habitat may also trample individuals.

7.5 Victorian Estuaries

The Australian Catchment, River and Estuary Assessment 2002 (National Land and Water Resources Audit 2002a) identified six subclasses of estuaries in Australia based on the influence of waves, tides and river energy. Victorian estuaries are mainly wave dominated (47 of the 59 estuaries in Victoria), with an accumulation of sediment around the entrance that often creates a barrier at the mouth (National Land and Water Resources Audit 2002a). The barrier formation in these estuaries means that many Victorian estuaries are intermittently closed, particularly during periods of low freshwater inflow. These types of estuaries are very efficient at trapping sediment and therefore at high risk of sedimentation and nutrient accumulation (National Land and Water Resources Audit 2002a). This, in combination with their seasonally stratified water column, increases their susceptibility to algal blooms. The remaining 11 estuaries are classified as either large tide-dominated embayments, such as Corner Inlet and Port Phillip Bay (which are not considered estuaries under this guide, see section 1.4), or smaller tide and river-dominated rivers that discharge into these larger embayments. The majority of the smaller tide and river-dominated estuaries occur in highly urbanised catchments and are at threat from water quality issues, as well as pressure from recreational and commercial fishing pursuits (National Land and Water Resources Audit 2002a).

7.5.1 Valuable habitats in estuaries

Estuaries support diverse and abundant native fish, and are important nursery areas for many species, including those of commercial and recreational importance (Lenanton and Potter 1987, Potter et al. 1990, Gray et al. 1996). The shallow fringes of estuaries, including seagrass, mangrove and sand habitats are important for juvenile fishes (Potter et al. 1990, Gray et al. 1996). However, different species and assemblages of fishes may utilise different habitats within an estuary at different times in their life history, including seasonally and daily. For example, the fish fauna of shallow margins often differs from those of deeper mainstream waters and again along estuarine salinity gradients and these patterns may vary according to the time of day (Gray et al. 1998). Such patterns are likely to vary both within and among estuaries and over time, and judgements on the values of different habitats to fish are often difficult (Gray et al. 1996).

Salt wedge

Many Victorian estuaries are typified by the occurrence of a salt wedge. The wedge naturally forms in many estuaries because of limited mixing of freshwater and saltwater layers. During low flow periods sea water will move into the estuary via tidal influence. As the salt water is much heavier than freshwater, it tends to move upstream below the lighter freshwater. The varying densities of the water in combination with limited mixing processes in the estuary environment results in two distinct layers and the creation of a wedge of salt water underneath the freshwater (see Figure 7.2). The salt wedge can move up and down the river and dissipate according to the tides and freshwater flow volumes. Typically salt wedges start to form in late spring when freshwater flows decrease. The wedge will remain through summer and autumn and will only begin to reduce during high flow periods in winter and early spring (Newton 1994).

The wedge is a unique habitat area for a number of species. For example, recruitment to estuaries of the Common freshwater shrimp (*P. australiensis)* is dependent on the presence of a stable salt wedge, which enables the retention of planktonic larvae (Walsh 1994). This shrimp has shown to be an important part of the diet of Estuary perch (Howell et al. 2004). Similarly the wedge has been shown to play an important role in the retention of the eggs and larvae of species that spawn in late spring (e.g. Black bream, Estuary perch) as the wedge acts as a barrier inhibiting the semi-buoyant eggs (density dependent) and larvae from entering the upper sea-ward flowing surface water layer and being lost from the system (Newton 1996). The large change in salinities between the two waterbodies can also restrict the movement of stenohaline[22] species and the deeper salt layer can become extremely depleted in oxygen (anoxic), making the lower layers of the estuary below the wedge uninhabitable for many species and even toxic to species at certain times of the year (i.e. early to late autumn).

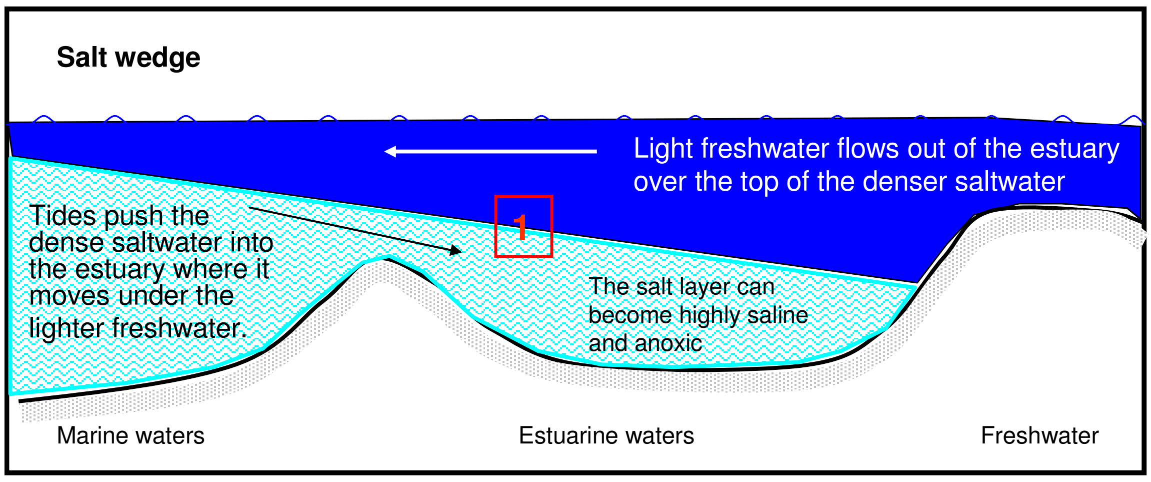

Figure 7.2: Illustration of a typical salt wedge

1. Halocline (the interface between the saltwater and freshwater layer). This becomes more pronounced as the wedge stagnates in summer. The halocline will move according to the relative influence of the tide or freshwater flows.

Seagrass and bare sand

In eastern and southern Australia the diversity and overall abundances of native fish are often higher over seagrass and associated nearby sand habitat than over sand habitat isolated from seagrasses by >100m (Ferrell and Bell 1991, Gray et al. 1996). Gray et al. (1996) postulated that this is most likely due to the structural complexity of the seagrass habitat providing greater shelter and protection from predators, as well as increased food resources, compared with bare sand (Connolly 1994, Hindell 2006). Both Gray et al (1996) and Ferrell and Bell (1991), identified that seagrass habitats were important for small fish of economic importance as well as small, inconspicuous resident species (e.g. gobiids) in NSW. In particular it was found that Yellow-fin bream *(Acanthopagrus australis)*,Tarwhine *(Rhabdosargus sarba)* and

[22] Stenohaline- species that can only survive in a narrow range of salinities

Luderick *(Girella tricuspidata)* primarily occurred over seagrass in estuaries and bays of northern NSW, where as Sand whiting *(Sillago ciliate)* more commonly occurred over sand (Gray et al. 1996). Hindell (1994) identified that these habitats are valuable areas for larger piscivorous fish in Victoria, with large carnivorous fish using seagrass areas to forage for prey and for shelter. Hindell (1994) noted that six of the species (including Black bream) recorded using seagrass environments contribute to commercial and recreational fisheries in the region.

Research on the temporal changes in the native fish assemblages in different habitats has shown that there can be significant changes in native fish assemblages over sand on a daily basis. For example larger individuals of some species (e.g. Southern silverbiddy, *Gerres subfasciatus* and Dusky flathead*)* that typically reside over deeper habitats during the day and species more commonly associated with seagrass (e.g. Port Jackson chanda perch *Ambassis jacksoniensis*), have been captured over shallow sand at night (Gray et al. 1998). The research highlights the importance of bare sand habitats to both small and large fish and also emphasises the importance of sampling fish communities at varying temporal scales.

Mangrove and saltmarshes

Mangroves and saltmarshes are highly specialised wetland communities that persist in the intertidal zone of estuaries, bays and inlets (Harty 2002a). These zones are strongly influenced by oceanic tides and by freshwater runoff from the landward side. This unique hydrological cycle makes these zones highly complex systems, subjected to a range of impacts from both aquatic and terrestrial threats.

Saltmarshes are environments that are comprised of a small number of specialised emergent terrestrial plants, marsh ponds, unvegetated pools and tidal creeks (Minello et al. 2003). In Victoria, saltmarshes occur high in the intertidal zones of estuaries and bays and are usually dominated by succulent shrubs. Mangrove forests, in contrast, are dominated by semi-aquatic salt tolerant trees. Only one species of mangrove is found in Victoria, the White Mangrove (*Avicennia marina).* Mangroves occur mainly in the upper part of the intertidal zone, growing amongst saltmarsh and other coastal wetland communities and there is often no clear demarcation between each community. Saltmarshes typically occur on the landward side of mangrove forests and higher in the intertidal zone, and consequently have shorter and less frequent periods of inundation than mangrove dominated zones (Connolly et al. 1997, Thomas and Connolly 2001). These areas are often inundated during spring tides and bad weather.

Mangroves and saltmarshes provide vital habitat for a variety of flora and fauna, contribute organic matter to the estuary, assist in stabilising shorelines against erosion from storms, act as filtering systems for sediments and other substances (Harty 2002a) and contribute SWH to estuary environments. Human-induced modifications to sediment and nutrient loads received by these environments and sea-level rises are gradually changing these habitats.

Increased silt loads, nutrient levels and rising sea levels in many southeastern Australian estuaries is promoting the proliferation of mangroves at the expense of saltmarsh habitats (Saintilan and Williams 1999, Harty 2002a). In a review of 29 photogrammetric surveys covering 20 estuaries in NSW, Victoria and Queensland, Saintilan and Williams (1999) described an increase in the area of mangroves, and a corresponding decrease in saltmarshes. In 70% of the estuaries surveyed, mangrove incursion on saltmarshes exceeded 30%, and in some instances losses of saltmarsh within an individual estuary approached 100% (Saintilan and Williams 1999, Saintilan and Rogers 2002).

Hindell and Jenkins (2005) identified the importance of mangrove habitats to a number of small (< 30mm) gobiid species (e.g. Pale mangrove goby, Western blue spotted goby*, Pseudogobius olorum*) in a Victorian embayment. It was noted that the greatest species' richness, biomass and abundances of fish occurred along the edges of the mangroves compared to within the mangrove forest itself and nearby mudflats (Hindell and Jenkins 2004, 2005). Individuals in the mangrove zones were typically larger and represented a more diverse group of species. It is likely that the tidal nature of these zones preclude the exclusive use of these habitats by most species, except by those species with special adaptations. For example species with special physiological adaptations which enable them to cope with periods of dehydration or are able to seek refuge in burrows, buried in the mud or hidden in epiphytes (Hindell and Jenkins 2005). Hindell and Jenkins (2005) suggest that some species are likely to exploit mangrove habitats during high tides and follow the receding tide back during low tide periods, rather than remain in these habitats at low tide and attempt to cope with potential desiccation (e.g. toadfish).

Little is known about the native fish associated with Australian saltmarsh habitats, particularly in south-eastern Australia (Connolly et al. 1997, Mazumder 2005). Of the limited research that has been conducted, most studies have identified that saltmarsh habitats play an important role as native fish habitat (Mazumder 2005) and are particularly important as foraging habitats for small native fish (Crinall and Hindell 2004). Crinall and Hindell (2004) identified ten native fish species on the saltmarsh flats. Most of these were juveniles and small fish including Yellow-eye mullet (*Aldrichetta forsteri)*, Silver fish *(Leptatherina presbyteroides)* and the economically important, King George whiting. Species richness of fish in saltmarshes is typically lower than that in nearby mangroves, seagrass and unvegetated habitat, however the opposite pattern has been found for fish abundances (Crinall and Hindell 2004). Both Mazumber et al. (2005) and Crinall and Hindell (2004) suggest that despite infrequent inundation by tides, saltmarsh does play an important role as native fish habitat.

Reefs and other structural components

Biogenic[23] reefs containing aggregations of mussels, oysters, tube worms (*Galeolaria* spp.) sponges, tunicates, tubeworms and other suspension feeders are vital components of estuarine ecosystems. The suspension feeders associated with these reef systems suppress the accumulation of organic matter in shallow estuaries by consuming phytoplankton and can facilitate the establishment of seagrass beds (Pufahl and James 2006). These emergent structures also provide heterogeneity and structural complexity, which may represent an important habitat for a variety of native fish and other aquatic species. Structural components such as reefs, rocks and other debris (including man-made structures) provide refuge from predators and

[23] Biogenic: is a substance produced by life processes. It may be either constituents (e.g. coal or oil), or secretions, of plants or animal (e.g. chalk, limestone, pearls, etc).

competitors or may represent important food resources and critical nursery or spawning habitat for some species (Turner et al. 1999).

7.6 Distribution, biology and ecology of estuarine species

Estuarine fish can be divided into four categories depending on their dependence on or affinity with estuaries (see section 1.5.2). This dependence also relates to the level of risk a species has to a threat. Species with a close affinity for particular habitats (e.g. the estuary itself or seagrass, mangroves, etc, within the estuary) at all life stages (e.g. Western blue spotted goby) are at a higher risk from threats that impact on that habitat than species with limited affinity with habitat (e.g. Black bream).

Mobility within an estuary can also influence the level of risk a species may face due to a particular threat. Sedentary species may not be as able to escape the impacts of a variety of threats (e.g. changes in salinity, water quality, sedimentation, etc) as easily as mobile species. The relatively sedentary, benthic species, Bridled goby (*Arenigobus bifrenatus)* and benthic invertebrates for example, are more likely to be impacted by sedimentation or sudden localised changes in water quality than the highly mobile and demersal Mulloway (*Argryosomus japonicus)*, which can quickly move away from sites when conditions become unsuitable. Eggs in particular maybe substantially impacted if they adhere to a surface. For example, eggs of the River garfish (*Hyporhamphus regularis*) are laid on seagrass and are far more likely to be impacted by the loss of seagrass or sedimentation on seagrass beds within the estuary than a species which maybe restricted to an estuary but which has pelagic eggs (e.g. Black bream).

It is also important to understand the risk to transitory/migratory species in estuaries. Many of these species are diadromous species that will only utilise the estuary environment for very short periods and thus may be able to avoid estuary threats. If however, they are unable to move through these habitats because of particular impacts, they may not be able to complete vital life stages and these species will slowly decline in that region or river.

7.6.1 Prioritisation of estuary species in this guide

Estuary species have been prioritised based on their level of dependence on estuary environments and their economic or conservation value. *Estuary residents* (see section 1.5.2 for definitions) have been given the highest priority, as these species are most likely to be impacted by environmental perturbations in the estuary environment. Information provided for these species is more detailed than that given for species less reliant on estuaries. Species which have conservation values or are recreationally or commercially important are considered the second highest priority as the value of these species in estuarine environments is increased due to their economic or conservation importance. Species that have estuary dependent (ED) life stages are considered the third highest priority. Table 7.21 details what life stage is reliant on the estuary and what period in the year is most important. *Estuarine opportunists* and *marine stragglers* are of lower priority as these species utilise estuary environments, but can complete their life cycles outside of estuaries. A summary of available information for *estuarine opportunists* is provided in Appendix B.

Some of the information provided on estuary species in this document is based on information and research that has been gathered in estuaries other than those found in Victoria. Although this information is valuable, biological requirements, spawning and migration timing etc, is likely to vary among estuaries. For example, data collected from studies in southern NSW or western SA are more likely to provide data relevant to nearby Victoria estuaries (e.g. southern NSW species' data is likely to be similar to eastern Victorian estuaries, but is less likely to be reliable for western Victorian estuaries); data from WA should be viewed as general information only. Users of this document must therefore exercised caution in making specific management decisions that are critically reliant on the accuracy of information for species with no or only limited knowledge from local estuaries.

Table 7.10: Summary of the distribution of all estuarine residents, estuarine dependent and recreationally targeted finfish species in the coastal catchments of Victoria

Common Name	Species Name	Category/ Section of Guide	Angling species	CMA district	Basins	Estuary position
Australian anchovy*	*Engraulis australis*	ED* - 7.6.3	Yes	all	all except 34	all
Black bream	*Acanthopagrus butcheri*	ER - 7.6.3	Yes	all	all except 34	all
Blue rock whiting	*Haletta semifasciata*	ED - 7.6.4		all	all except 34	L
Blue sprat	*Spratelloides robustus*	ED** - 7.6.4		all	all except 34	L
Dusky flathead	*Platycephalus fuscus*	EO - 7.6.3	Yes	PP,WG,EG	21,22,23,24,25	L, M
Eastern Australian salmon	*Arripis trutta*	EO - 7.6.3	Yes	all	all except 34	L, M
Eastern blue-spot goby	*Pseudogobius* sp. 9	ER - 7.6.2		all	all except 34	L
Elongate hardyhead	*Atherinosoma elongata*	ED - 7.6.4		GH	38	L, M
Estuary perch	*Macquaria colonorum*	ER - 7.6.2	Yes	all	all except 34	M, U
Glass goby	*Gobiopterus semivestitus*	ER - 7.6.2		all	all except 34	all
Gummy shark	*Mustelus antarcticus*	MS - 7.6.3	Yes	all	all except 34	L
Hairy pipefish	*Urocampus carinirostris*	ED* - 7.6.4		all	all except 34	all
Half-banded pipefish	*Mitotichthys semistriatus*	ED - 7.6.4		PP, WG	27,28,29, 30, 31	L
King George whiting	*Sillaginoides punctata*	EO - 7.6.3	Yes	all	all except 34	L, M
Lagoon goby	*Tasmanogobius lasti*	ER - 7.6.2		all	all except 34	L, M
Little rock whiting	*Neoodax balteatus*	ED - 7.6.4		WG, PP, C	all except 34	L, M
Mulloway	*Argyrosomus japonicus*	ED - 7.6.3	Yes	all	all except 34	
Old wife	*Enoplosus armatus*	ED - 7.6.4		WG, PP, C	26,27,28,29, 30,31,32,33	L, M
Pale mangrove goby	*Mugilogobius platynotus*	ER - 7.6.2		PP, C	28,29,30,31, 32	M, U
Pike-head hardyhead	*Kestratherina esox*	ED - 7.6.4		WG?,PP, C, GH	27-38, except 34	L, M
Pilchard	*Sardinops neopilchardus*	ED - 7.6.4		all	all except 34	L
Poddy mullet	*Mugil cephalus*	MS - 7.6.3	Yes	all	all except 34	all
Port Jackson chanda perch	*Ambassis jacksoniensis*	ED - 7.6.4		EG	21-24	all
River garfish	*Hyporhamphus regularis*	ER - 7.6.3	Yes	WG, EG	21-24	all
Sand flathead	*Platycephalus bassensis*	MS - 7.6.3	Yes	all	all except 34	L
Sand trevally	*Pseudocaranx wrighti*	EO - 7.6.3	Yes	all	all except 34	L,M
Sand whiting	*Sillago ciliata*	ED - 7.6.4		WG?, EG	21-24	all
Sandy sprat	*Hyperlophus vittatus*	ED* - 7.6.4		all	all except 34	L, M
School shark	*Galeorhinus galeus*	EO - 7.6.3	Yes	all	all except 34	L
Short-snout hardyhead	*Kestratherina brevirostris*	ED - 7.6.4		WG?,PP, C, GH	27-38, except 34	all
Silver fish	*Leptatherina presbyteroides*	ED* - 7.6.4		all	all except 34	all
Silver trevally	*Pseudocaranx dentex*	EO - 7.6.3	Yes	all	all except 34	L,M
Slender weed whiting	*Siphonognathus attenuatus*	ED - 7.6.4		all	all except 34	L
Small-mouthed hardyhead	*Atherinosoma microstoma*	ED - 7.6.4		all	all except 34	all
Snapper	*Chrysophrys auratus*	ED - 7.6.3	Yes	all	all except 34	all
Southern sea garfish	*Hyporhamphus melanochir*	EO - 7.6.3	Yes	all	all except 34	L,M
Southern silverbiddy	*Gerres subfasciatus*	ED* - 7.6.4		EG	21-22	L
Tailor	*Pomatomus saltatrix*	ED* - 7.6.3	Yes	all	all except 34	L, M
Tarwhine	*Rhabdosargus sarba*	ED* - 7.6.4		WG?, EG	21-24	L, M
Western Australian salmon	*Arripis truttaceus*	EO - 7.6.3	Yes	GH,C,PP, WG	27,28,29,30,31,32,33 ,35,36,37,38	L,M
Western blue-spotted goby	*Pseudogobius olorum*	ER - 7.6.2		GH	38, 37?	U
Yellow-eye mullet	*Aldrichetta forsteri*	EO - 7.6.3	Yes	all	all except 34	all
Yellow-fin bream	*Acanthopagrus australis*	ED* - 7.6.3	Yes	EG, WG	21,22,23,24,25,26	all

See Figure 7.1 for location and name of catchments and basins; L= lower estuary near river mouth, M= middle estuary, U = upper estuary, near the fresh water interface
* studies in Western Australia indicate that these species can persist in purely marine environments but will enter estuaries in large numbers, usually as juveniles and as such these species are classed as *estuarine opportunists* in WA. As systems are likely to vary considerably between WA and Victoria and evidence suggests that these species are dependent on estuarine environments in Victoria the project has classed them as *estuarine dependent* until local research indicates otherwise. ** studies in Western Australia indicate these species are purely marine species that only occasionally enter estuarine environments in Western Australia. As systems are likely to vary considerably between WA and Victoria and evidence suggests that these species are dependent on estuarine environments in Victoria the project has classed them as ED until local research indicates otherwise.

7.6.2 Estuarine residents

Estuarine residents as defined by Potter and Hyndes (1999) are those species that must complete their entire life cycle in the estuarine environment. Only eight *estuarine residents* are native to Victorian estuaries, five of which belong to the gobiid family (Table 7.10). All of the remaining species are considered of recreational or commercial fishing importance (i.e. Black bream, Estuary perch, and River garfish). A detailed description of the known biology of the Estuary perch and Pale mangrove goby have been provided below.

Table 7.11: General biology and habitat preferences of estuarine resident fish species

Common Name	Preferred water column position	Adult preferred habitat	Spawning period/ location	Eggs	Juvenile habitat	Diet
Black bream	demersal-transient	structured -reef, rock, SWH, vegetation	Sept-Feb/ estuary	pelagic, floats at halocline, laid on substrate	estuary, seagrass	carnivore, mainly invertebrates
Eastern blue-spot goby	benthic	unvegetated	?	benthic	?	small crustaceans
Estuary perch	demersal-transient	structured -reef, rock, SWH, vegetation in both freshwater and estuarine habitats	Jul-Dec (when water temp 14-19^{o}C), lower estuary	pelagic	estuary/ marine, seagrass	opportunistic carnivore, mainly invertebrates and small fish
Glass goby	pelagic-limited mobility	in and around structure	estuaries	probably pelagic	estuaries	plankton
Lagoon goby	benthic	sand	?	benthic	?	small crustaceans
Pale mangrove Goby	benthic	sand around mangroves and between seagrass patches	estuaries	?	estuaries	small crustaceans and polychaetes
River garfish	demersal-transient	vegetation/ mudflats	Oct - Mar/ vegetated areas	eggs stick to seagrass	seagrass	herbivorous - may consume invertebrates
Western blue-spotted goby	benthic	shallow silty substrate /sheltered sites away from wave action (boats or wind) or sheltered by the presence of macrophytes	spring & autumn[WA]/ upper reaches of estuary/ marine	guards eggs	as adults, macrophytes presence is important[WA]	omnivorous - algae, mats of bacteria and fungi, invertebrates in winter

[WA] Refers to information sourced from research conducted in Western Australia

Estuary Perch (*Macquaria colonorum*)

The Estuary perch is common in coastal drainages of southern Victoria. The species favours estuarine environments and the lower tidal reaches of rivers (Allen et al. 2003). It is typically found in deep channels in highly brackish environments of estuaries but can also be found in shallow mud-bottom areas in slightly brackish water and in freshwater reaches of rivers above the tidal influence (McCarraher and McKenzie 1986). The species has also been noted to occasionally move into the marine environment (McCarraher and McKenzie 1986).

Migratory movement of the species is restricted to seasonal movement to spawning grounds, where between Aug and December reproductively active individuals seek estuarine environments with a water salinity of between 10-24ppt (McCarraher and McKenzie 1986). Females tend to lay eggs on underwater structures such as reefs or aquatic vegetation. McCarraher and McKenzie (1986) identified that spawning could be greatly reduced or delayed in estuaries where these condition could not be met. They noted that low salinity in estuaries due to flooding or a lack of tidal influence could delay spawning until optimal conditions were reached in that estuary.

Estuary perch are opportunistic carnivores that commonly feed on smaller fish, crabs, prawns, shrimp and other aquatic invertebrates (McCarraher and McKenzie 1986). Howell et al. (2004) noted that Estuary perch are primarily mid-water to surface feeders in summer, but had not investigated the impact of seasonal changes on feeding patterns. A summary of their habitat requirements and biology can be found in section 7.3.3.

Pale mangrove goby *(Mugilogobius platynotus)*

FFG Act Threatened
DSE (2007) Vulnerable

The Pale mangrove goby is found in south-eastern Australia, from southern Queensland to SA, excluding Tasmania. The species is generally found in mangroves or holes in sea grass areas and will sometimes enter freshwater (Barnham 1998). The fish are typically found in the middle to upper estuary over a sand/mud substratum where they may seek shelter in flooded burrows in the sediment at low tide. They are a benthic carnivorous species which feed on small insect larvae, crustaceans and juvenile fish (Raadik and Hindell in prep.). This species is known to tolerate high water temperatures and a wide range of salinities (Barnham 1998) and has the capacity to persist in low oxygen environments (Gee and Gee 1995).

The SAC final recommendation report notes that the species has been identified as rare in terms of distribution (Scientific Advisory Committee 2005). This species has only been identified in Western Port despite sampling in other suitable locations (Scientific Advisory Committee 2005). The limited distribution of this species in Victoria places it under threat from habitat loss and modification, including processes such as sedimentation, development and modified flow regimes. Species, such as this, with a limited distribution and limited capacity to move, are also vulnerable to localised environmental problems.

7.6.3 Key recreationally and commercially targeted estuary species

Species considered in this category are listed in Table 7.10 (angling species). Details of the biology of these species can be found in relevant Fisheries Management Plans. A summary has been provided in Tables 7.12 to 7.13.

In addition to the vertebrate species and the large threatened decapod crustaceans and bivalve mussels that are targeted recreationally, there are a number of estuarine invertebrate species which are commonly found in estuarine habitats that are actively sought for bait or human consumption (e.g. sand worms, non-threatened prawns and other shell fish). These groups are represented by a multitude of species and it is beyond the scope of this guide to discuss their biology in detail. However, it is important to note that estuarine environments are valuable for these species and therefore that estuarine invertebrates should not be overlooked in planning for estuarine ecosystems. Potential population declines of sand worms are discussed briefly below.

Table 7.12: General biology of recreationally targeted estuarine finfish species in coastal Victoria

Common name	Found in freshwater	Found in wetlands	Spawning calender	Spawning habitat	Early larval life	Adult main habitat
Australian anchovy			summer	MAR/EST	MAR/EST	MAR/EST
Black bream	occ		Sep-Feb	EST	EST	EST/MAR
Dusky flathead	occ		winter	?	MAR/EST	MAR/EST
Eastern Australian salmon			summer	MAR	MAR/EST	MAR/EST
Estuary perch	✓	✓	Aug-Sept	EST	EST/MAR?	EST/FW
Gummy shark			Nov-Feb (live bearer)	MAR	MAR	MAR/EST
King George whiting			Apr-Jun	MAR	MAR/EST	MAR
Mulloway			spring-summer?	MAR	MAR/EST	MAR/EST
Poddy mullet	✓		Mar-Jul	MAR	MAR	MAR/EST
Sand flathead			Aug-Oct	MAR	MAR	MAR/EST
Sand trevally			summer	MAR/EST	MAR	MAR
School shark			Dec-Jan (live bearer)	MAR/EST	MAR	MAR
Silver trevally			summer	MAR/EST	MAR	MAR
Snapper			Oct-Mar (temp 18°C)	waters <50m deep	MAR/EST	MAR/EST
Southern sea garfish			oct-summer	MAR	MAR	MAR/EST
Tailor			Apr-Nov	MAR	EST	MAR/EST
Yellow eye mullet	occ		late summer-winter	EST/MAR?	EST/MAR	EST/MAR
Yellow finned bream			Winter	EST/MAR	EST/MAR	EST/MAR
Western Australian salmon			Feb- Jun	MAR	MAR/EST	MAR/EST

MAR= marine habitats, EST= estuarine habitats, occ= occasionally will enter these habitats

Table 7.13: Habitat preferences of recreationally targeted estuarine finfish

	Habitat preferences within estuaries of recreationally targeted estuarine species									
Common name	**estuary position[ǂ]**	**muddy or sandy substrate**	**rocky substrate**	**shallows**	**deep water/holes**	**undercut banks**	**SWH or other submerged objects (e.g rocks)**	**submerged aquatic vegetation**	**emergent aquatic vegetation**	**overhanging riparian veg**
Australian anchovy	all					pelagic - utilises all habitats				
Black bream	U	✓	✓				✓	✓		
Dusky flathead	L, M	✓								
Eastern Australian salmon	L, M	✓								
Gummy shark	L	✓	✓	✓	✓				✓	
King George whiting	L,M	✓	✓					✓	✓	
Mulloway	all	✓	✓					✓		
Poddy mullet	all	✓		✓						
Sand flathead	L	✓		✓	✓					
Sand trevally	L, M	✓								
School shark	L	✓	✓	✓	✓				✓	
Silver trevally	L, M	✓								
Snapper	all		✓		✓		✓	juv		
Southern sea garfish	all	✓		✓				✓		
Tailor	L,M									
Yellow eye mullet	all	✓		✓			✓			
Yellow finned bream	all			juv			✓	✓		
Western Australian salmon	L,M	✓								

L= lower estuary near river mouth, M= middle estuary, U = upper estuary, near the fresh water interface

Decline of recreationally and commercially targeted estuarine fish species

Garfish

The three garfish species represented in Victorian waters are the Southern sea garfish (*Hyporhamphus melanochir,* EO), the River garfish (*H. regularis,* ED), and the Eastern sea garfish (*Hyporhamphus australis,* EO). The latter two are restricted to waters in the east of Victoria and therefore have only limited commercial viability in the State, although all species are likely to be targeted recreationally. Information on the status of these fish in Victorian waters is limited. Research in NSW has indicated that the Eastern sea and River garfish fisheries are in decline (Stewart et al. 2005). Commercial landings of River garfish from NSW estuaries peaked at around 140 tonnes in 1974/75, while in the past decade, catches have averaged less than 30 tonnes per year; catches of Eastern sea garfish have gone from 280 tonnes in 1992/93 to only 44 tonnes in 1999/2000 (Stewart et al. 2005).

Australian garfish species have key habitat requirements that make them vulnerable to impacts in the inshore and estuarine environment (Stewart et al. 2005). For example:

- many of the garfish species feed in seagrass areas and some directly on seagrass leaves
- Southern sea garfish lay eggs on seagrass leaves (and possibly on macroalgae fronds) in sheltered estuarine and inshore areas
- River garfish are restricted to estuaries and rely on seagrass areas as spawning and feeding areas, and
- several garfish species are found in the seagrass beds as juveniles.

(Stewart et al. 2005)

Research in Victoria on the biology and the sustainability of Southern sea garfish has been limited. A recent resource valuation study indicated that the commercial catches of the Southern sea garfish in one of the primary catch areas (Corner Inlet[24]) did not appear to have declined substantially from 2000/01 to 2003/04 (Hundloe et al. 2006). However, there has been a substantial decrease in the commercial catch in Port Phillip Bay with catches peaking in 1980/81 at 106 tonne to less than 30 tonnes in 2003/04, while Western Port Bay has seen an almost complete loss of commercial catch from a peak of 39 tonne in 1979/80 to 1 tonne in 2003/04 (Hundloe et al. 2006). The report did not speculate on the potential reasons for this decline.

Mulloway

Silberschneider and Gray (2005) identified a dearth of information relating to wild Mulloway populations in Australia. Little is known of their spawning requirements or cues, their early larval history or migratory requirements. It is hypothesised that Mulloway spawn in the surf zone near river mouths and that spawning may be cued by freshwater discharge from nearby estuaries. However, knowledge of this part of their biology is not clear. The lack of knowledge of the spawning requirements of this species, its commercial and recreational value, in combination with its long-life span make this species potentially vulnerable to a variety of threats including reduced

[24] Data for sea garfish catches in Corner Inlet only covered commercial catches from 2000. No data was provided for years preceeding this and declines in catches may have occurred over the long-term.

flows. As noted by Silberschneider and Gray (2005) commercial catches of Mulloway in recent years have seen significant declines in capture volumes in both NSW and SA. Research has identified that in NSW the fish are growth overfished[25] and it is suggested that with the existing fishing protocols, the species is likely to see major population crashes in NSW (Silberschneider and Gray 2005).   Similar outcomes are also predicted to occur in SA (G. Ferguson, PIRSA, pers. comm. 2007). As there is currently no commercial catch of Mulloway in Victoria, major population crashes caused by overfishing are unlikely to occur provided appropriate controls on recreational fishing are maintained, however the species may face threats associated with habitat modifications in Victoria (e.g. extraction of water and modifications to seasonal flows).

Sand worms

Polychaetes are an ecologically important component of estuarine habitats providing ecosystems services through nutrient cycling and prey items for fish and birds. However very little is known of their physiological tolerances or biology (Arundel 2003). A number of species of polychaete are colloquially termed “sand worm” or “bait worm”. A common example is the nereidid, *Australonereis ehlersi* (Pod worm or Estuarine bait worm) (Arundel 2003). This and other similar species are collected for bait in estuaries throughout coastal Victoria. They are generally found in the intertidal zone amongst seagrass beds and sand and silty substrates. Trampling and disturbance of the substrate associated with the bait harvesting process is likely to be detrimental to estuarine habitats and there is also anecdotal evidence that sand worms in some estuaries are suffering population declines.   It has been suggested that reduced freshwater flows to estuarine environments may be implicated (M. MacDonald, DPI Fisheries, pers. comm. 2007), but destruction of habitat, changes in the frequency of estuary openings, etc may all play a role in declines of sand worms.

7.6.4 Estuarine dependent fish

Estuarine dependent (ED) species refer to those species that must use estuaries for completion of some part of their life cycle. Although these species are reliant on estuaries, they have the capacity at some stage in their life cycle to move out of estuaries and potentially utilise other estuary environments should the environment become undesirable. However, should the threats impact on that estuary during the part of the life cycle in which estuaries form a critical part, they are at risk.

Twenty three native Victorian species have been identified as estuarine dependent (Table 1.3 and 7.10). Of these, four are considered of recreational importance, Australian anchovy (*Engraulis australis*), Mulloway, Snapper (*Chrysophrys auratus*), Tailor and Yellow-fin bream and further details have been provided in section 7.6.3. A brief summary of biology of all of the ED species is provided in Table 7.14 and the timing of estuarine use are provided in Table 7.15.

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[25] Growth overfished: Fish are being harvested at a size smaller than the biological and economic optimum. (NSW SOE 2006). The minimal length is too small to protect spawning populations and insufficient juveniles are reaching spawning age.

Table 7.14: General biology of estuarine dependent fish in coastal Victoria

Common Name	Species Name	Category	Preferred water column position	Preferred habitat	Diet	Spawning period/ location	Eggs	Comments	References
Australian Anchovy	*Engraulis australis*	ED* rec	pelagic-transient	pelagic	pelagic invertebrates	marine shallows/ coasts/ estuaries	planktonic		Hoedt & Dimmlich 1995, Rogers et al. 2003, Valensini et al. 1997, Platell et al. 2006, Young & Potter 2002, Neira & Sporcic 2002, Potter et al. 1993, Neira & Potter 1992, Blackburn 1950, Dimmlich & Ward 2006
Blue Sprat	*Spratelloides robustus*	ED**	demersal/pelagic	open water	zooplankton	Oct-Feb	planktonic	juveniles do NOT require sheltered areas	Rogers et al. 2003, Valesini et al. 1997
Dusky Flathead	*Platycephalus fuscus*	ED	benthic	unvegetated	crustaceans and fish	summer, offshore and in estuary	pelagic		Gray et al. 1998, Muzumber et al. 2006
Elongate Hardyhead	*Atherinosoma elongata*	ED	semi-pelagic	vegetated shallows	zooplankton	spring-probably shallow, sheltered waters	benthic - attached to plants	1year life cycle, but some can live through to second year, evidence that they can complete lifecycle within estuaries (236)	Young et al. 1997, Young & Potter 2002, 2003, Humphries & Potter 1993, Valenini et al. 1997, Prince & Potter 1983, Prince et al. 1982, Potter & Hyndes 1999
Glass Goby	*Gobiopterus semivestitus*	EO	pelagic-limited mobility	in and around structure	plankton	estuaries	probably pelagic		
Hairy Pipefish	*Urocampus carinirostris*	ED*	benthic	seagrass-zostera	zooplankton	spring/ summer/ shallow seagras	live bearers	Paternal care of young	Howard & Koehn 1985, Potter & Hyndes, Valesini et al. 1997
Mulloway	*Argyrosomus japonicus*	ED rec	demersal - semi pelagic - highy transient	all	piscovore	?? - surf zones/ estuaries		recreationally targetted, long lived, juveniles enter estuary when c. 5-10cm long	Kailola et al. 1993; Fish MP
Pike-head Hardyhead	*Kestratherina esox*	ED	demersal-semi-pelagic	all	plankton		benthic - attached to plants		Gommon et al 1994
Pilchard	*Sardinops neopilchardus*	ED	pelagic	all	plankton	inshore environments - lower estuarine regions	pelagic		Rogers et al. 2003
Port Jackson Chanda Perch	*Ambassis jacksoniensis*	ED	demersal-semi pelagic	all	small invertebrates				Gommon et al 1994
Sand Whiting	*Sillago ciliata*	ED	demersal	adults prefer sand, juveniles common in mangroves, seagrass and unveg mud/sand	polychaetes and crustaceans	Sept - April/ not clear, but probably in estuaries or around entrances	scatter over substratum	not common outside of east Vic. - lower to upper	Gommon et al 1994
Sandy Sprat	*Hyperlophus vittatus*	ED*	pelagic-sand	various	zooplankton	all year	pelagic	nursery restricted to estuarine and protected inshore marine waters	Gaughan et al. 1996, Potter et al. 1983, Neira et al. 1992
Short-snout Hardyhead	*Kestratherina brevirostris*	ED	demersal-semi-pelagic	all	plankton		benthic - attached to plants		Gommon et al 1994
Silver Fish	*Leptatherina presbyteroides*	ED*	demersal-semi-pelagic	sand, shallows	plankton/meiofauna	probably sheltered waters; esturaine (49)	probably planktonic		Crinall & Hindell 2004, Young & Potter 2002, Valesini et al. 1997, Mazumber et al. 2006, Gray et al. 1998, Potter et al. 1983, Potter & Hyndes 1999
Small-mouthed Hardyhead	*Atherinosoma microstoma*	ED	semi-pelagic	vegetated	zooplankton/ microphaic carnivore	spring-probably shallow, sheltered waters	benthic - attached to plants	1 year life	Harris 1995
Southern Silverbiddy	*Gerres subfasciatus*	ED*	demersal/semi-pelagic	various - reef	zooplankton/small crustaceans				Linke et al. 2001, Hannan & Williams 1998, West & King 1996, Loneragan et al. 1987, Mazumber et al. 2006, Jelbart et al. 2006, Gray et al. 1998, Miller & Skilleter 2006, Potter & Hyndes 1999; Young et al. 1997
Snapper	*Chrysophrys auratus*	ED rec	pelagic	structure/open water	Crustaceans, marine worms, starfish, sea urchins, shellfish and fish	Oct-Mar (water temp 18°C)/ waters < 50m deep		larvae benthic	Hayes 1991, Kailola et al. 1983, May & Maxwell 1986, Paulin 1990
Tailor	*Pomatomus saltatrix*	ED* rec	pelagic	all	piscivorous - also eat macroinvertebrates	April to November/ coastal	planktonic		Potter & Hyndes 1999
Tarwhine	*Rhabdosargus sarba*	ED*	demersal	various-reef/seagrass	benthic invertebrates, mainly molluscs	spring /probably coastal	pelaigc/substratum		Potter & Hyndes 1999
Yellow-fin Bream	*Acanthopagrus australis*	ED rec	demersal	vegetated/reef	benthic invertebrates/fish (molluscs, crustaceans, worms, fish and ascidians)	winter-around river entrances (evidence of protandry)	pelagic	long-lived, juveniles probably prefer shallow vegetated habitats. Inhabit estuaries, coastal rivers, creeks, lakes & bays, usually in amrine or brackish water, but in dry season may penertrate into fresher water, migrate from their feeding to their spawning grounds	Allen et al. 2002, Chessman 2006, Gray et al. 1998, Griffiths 2001, Muzumber et al. 2006

* studies in Western Australia indicate that these species can persist in purely marine environments but will enter estuaries in large numbers, usually as juveniles and as such these species are classed as estuarine opportunists in WA. As systems are likely to vary considerably between WA and Victoria and evidence suggests that these species are dependent on estuarine environments in Victoria the project has classed them as ED until local research indicates otherwise.** studies in Western Australia indicate these species are purely marine species that only occasionally enter estuarine environments in Western Australia. As systems are likely to vary considerably between WA and Victoria and evidence suggests that these species are dependent on estuarine environments in Victoria the project has classed them as ED until local research indicates otherwise. ED rec: refers to species which are recreataionlly targeted.

Level of dependence of native estuary dependent fish species on estuary environments

Table 7.15: Life stage and timing of estuary use by native estuarine dependent species

Common name/species	Lifestage	Summer	Autumn	Winter	Spring
Australian anchovy	adult	***	***		***
Engraulis australis	juvenile	**	***	***	
	larvae	***	***		***
	eggs	***	**		**
Blue sprat	adult	**WA****		**WA****	**WA****
Spratelloides robustus	juvenile	**WA****	**WA****	**WA****	
	larvae	**WA****	**WA****		
	eggs	**WA****			**WA***
Blue rock whiting	adult	***	***	***	***
Haletta semifasciata	juvenile	***	***	***	***
	larvae	***			***
	eggs	***			***
Dusky flathead	adult	**NSW**	**NSW**	**NSW**	**NSW**
Platycephalus fuscus	juvenile	*	*	*	*
	larvae	**NSW***	**NSW***		
	eggs	**ocean spawner**			
Elongated hardyhead	adult	**WA**	**WA**	**WA**	**WA**
Atherinosoma elongata	juvenile	**WA**	**WA**		
	larvae	**WA**			**WA**
	eggs	**?**	**?**	**?**	**?**
Hairy pipefish	adult	***	***	***	***
Urocampus carinirostris	juvenile	***	***	***	***
	larvae	*			*
	eggs	**live bearer**			
Half-banded pipefish	adult	**	**	**	**
Mitotichthys semistriatus	juvenile	**	**	**	**
	larvae	*			*
	eggs	**live bearer**			
Little rock whiting	adult	**	***	***	***
Neodax balteatus	juvenile	**	***	***	***
	larvae	***			***
	eggs	***			***
Mulloway	adult				
Argyrosomus japonicus	juvenile	**NSW/SA**	**NSW/SA**	**NSW/SA**	**NSW/SA**
	larvae		**NSW**		
	eggs	**ocean spawner**			

[blue box] Species present in estuary. Information based on Victorian data unless otherwise stated

[?] Information unknown

***high confidence in data, ** medium confidence in data, *low confidence in data
Blue boxes with NSW, WA, SA, QLD refer to where information on species is collected, information relating to this species may not reflect patterns in Victorian waters. This information should therefore be treated with caution.

Table 7.14: continued …

Common name/species	Lifestage	Summer	Autumn	Winter	Spring
Old wife	adult				
Enoplosus armatus	juvenile	**	**		**
	larvae	**			?
	eggs	**			?
Pike-head hardyhead	adult	***	***	***	***
Kestratherina esox	juvenile	***	***	***	***
	larvae	*			*
	eggs	?			?
Pilchard	adult	WA**		WA**	WA**
Sardinops neopilchardus	juvenile	WA**	WA**	WA**	
	larvae	WA**	WA**		
	eggs	WA**			WA**
Port Jackson chanda perch	adult	NSW**	NSW**	NSW**	NSW**
Ambassis jacksoniensis	juvenile	NSW**			NSW**
	larvae	NSW*	NSW*		
	eggs	ocean spawner			
Sand whiting	adult	NSW	NSW	NSW	NSW
Sillago ciliata	juvenile	NSW	NSW	NSW	NSW
	larvae	NSW	NSW	NSW	NSW
	eggs	NSW	NSW		NSW
Sandy sprat	adult				
Hyperlophus vittatus[1]	juvenile	***	***	*	
	larvae	NSW***	NSW***		
	eggs				
Short-snout hardyhead	adult	NSW	NSW	NSW	NSW
Kestratherina brevirostris	juvenile	NSW	NSW	NSW	NSW
	larvae	NSW			NSW
	eggs	?			?
Silver fish	adult	***	***	***	***
Leptatherina presbyteroides	juvenile	***	***	***	***
	larvae	***	***		
	eggs	?			
Slender weed whiting	adult	*	*	*	*
Siphonognathus attenuatus	juvenile	*	*	*	*
	larvae	*			*
	eggs	*			*

Species present in estuary. Information based on Victorian data unless otherwise stated

? Information unknown

***high confidence in data, ** medium confidence in data, *low confidence in data
NSW, WA, SA, QLD refer to where information on species is collected, information relating to this species may not reflect patterns in Victorian waters. This information should therefore be treated with caution.

1. The sandy sprat is classified as a marine-estuarine opportunist in W.A. Neira et al 1992
2. Spawning previously thought to be exclusively around Fraser Island. Recent data disputes this, but further information is not published/available.

Table 7.14: continued …

Common name/species	Lifestage	Summer	Autumn	Winter	Spring
Small-mouthed hardyhead	adult				
Atherinosoma microstoma	juvenile				
	larvae	?			?
	eggs	?			?
Snapper	adult	***			***
Chrysophrys auratus	juvenile	***	***	***	***
	larvae	***			***
	eggs	***			***
Southern Silverbiddy	adult	NSW**	?	?	NSW**
Gerres subfasciatus	juvenile	NSW*	NSW**	NSW**	NSW*
	larvae	NSW**	NSW**	NSW*	NSW**
	eggs	NSW			NSW
Tailor[2]	adult	*	*	?	?
Pomatomus saltatrix	juvenile	*	*	?	?
	larvae	?	?	?	?
	eggs	ocean spawner			
Tarwhine	adult	WA	WA	WA	WA
Rhabdosargus sarba	juvenile	WA	WA	WA	WA
	larvae	?			?
	eggs	?			?

[blue box] Species present in estuary. Information based on Victorian data unless otherwise stated

? Information unknown

***high confidence in data, ** medium confidence in data, *low confidence in data
NSW, WA, SA, QLD refer to where information on species is collected, information relating to this species may not reflect patterns in Victorian waters. This information should therefore be treated with caution.

PART D: ADAPTIVE MANAGEMENT

8 The role of ecosystem monitoring in natural resource management

In December 2002, Victoria signed a bilateral agreement with the Australian Government for the regional component of the Natural Heritage Trust (NHT), this is currently under review. The 2002 agreement, amongst other things, sets out the roles and responsibilities of the Australian Government and the Victorian State Government for delivering the objectives of the Trust, provides accreditation of the natural resource management plans developed by regional bodies and establishes monitoring and evaluation arrangements, including standards and targets (National Heritage Trust 2005). The framework of the agreement requires that targets be set by regional bodies as a component of the accreditation process prior to investment by governments on those plans.

Each of the regional NRM agencies (CMAs and Melbourne Water) were required to develop Resource Condition Targets (RCT[26]) and Management Action Targets (MAT[27]) for each of their RCSs. These targets provide a benchmark against which performance of each of the agencies can be gauged and continued investment will be linked to the achievement of these targets. As such there has been increasing pressure on CMAs and other NRM agencies to report on success of all natural resource management projects to ensure ongoing funding.

Monitoring has therefore become a vital part of each CMA and Melbourne Water investment strategy for two primary reasons:

I. it can assess if you have achieved a specified MAT or RCT, and hence provide a clear performance measure for future investment; and
II. it can provide a tool in adaptive management to ensure that long-term RCTs can be met within the set timeframe.

The first is a simple process of assessing performance against the stated target. However, the second component is a valuable tool that can be used to identify if a specified action is appropriate to achieving the longer term goal. For example a RCT might be:

*Increase passage for **all** native fish by 70km in 'X' River.*

This target will be achieved by the MAT:

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[26] RCT must be specific, time-bound and measurable targets, relating largely to resource condition, for example "80km stream with improved physical form as measured by sub-index of ISC"
[27] MAT: targets set to contribute to the progress of the longer-term RCT, for example "80km of riparian vegetation fenced"

Remove or modify 9 barriers to fish passage barriers in 'X' River.

However, if post works monitoring has revealed that only 10% of the migratory native fish species persisting in that river can move through the modified barriers, further actions will need to be undertaken to enable the full suite of native migratory fish to move through these systems. Management actions can therefore be set or modified based on the information provided by the monitoring to improve ecosystem management and increase the likelihood of achieving RCT.

8.1 Biological indicators and ecosystem monitoring

Monitoring biological components of an aquatic system is a valuable way to assess the level of impact of human activities. This is because biological monitoring directly measures the condition of the resource at risk, detects problems that other methods such as chemical or physical assessments may miss or underestimate, and it can provide a systematic approach for measuring improvements resulting from the implementation of river and wetland health programs (Karr 1991).

Typically biological indicators are composed from a variety of biological information from a number of different flora and fauna groups that create a "picture" of biological health. The presence, condition, age structure and numbers of the types of fish, insects, algae, plants and/or other aquatic life can all provide information on the health of a specific waterbody such as a river, wetland, or estuary.

Often the term *indicator species* has been used to describe species particularly sensitive species to environmental changes, but it is rare that a single species in isolation can be used as a biological indicator. The difficulty of using a single biological component is that aquatic taxa are often complex with varied and indirect responses to different ecosystem disturbances. They may be sensitive to certain environmental disturbances yet tolerant of others (Davis 1995) and there are often confounding effects (e.g. environmental impacts rarely result from one isolated event and there are often multiple causes for a system modification or even multiple threats impacting at a system at any one time). Consequently, biological indicators are generally groups or types of biological resources that can be used to assess environmental condition.

Measuring improvements resulting from the implementation of a specific action or program through the use of a smaller group of biological components is however potentially feasible, but only with species for which there is a clear relationship between the improvement and their response. For example, measuring the success of a fish barrier to increased native migratory fish passage may simply require monitoring a subset of the native fish community (i.e. the migratory fish). If all of the species within this fish category or guild are being recorded both upstream and downstream of the modified barrier during a variety of flows and conditions, it is highly likely to assume the modification was a success. Unfortunately, in Australia the knowledge of the tolerances of native fish to most threats is limited (Harris 1995) and there are only a very few situations where the response of a particular species or group of species is likely to be clear cut.

8.2 The use of fish for ecological assessments

Many of the water quality, flow and structural quality issues in rivers occur on relatively large temporal and spatial scales (e.g. alteration of streamflow regimes, loss of habitat area, loss of habitat diversity, obstruction of free passage through streams and riparian degradation). It is therefore important that monitoring programs and indicators within these, reflect the scale of these threats and provide an effective means of assessing the condition of rivers at the scale at which the river is impacted (Harris 1995).

The longevity and mobility of fish means they can act as indicators over large temporal and spatial scales. This increases their suitability as biological indicators, particularly for the diffuse and widespread impacts of stream structural changes (Harris 1995). The position of fish at the top of the food chain means they integrate the ecological processes of the river and a trophic analysis can provide information on the communities on which they feed (Harris 1995). Further, their visibility and high profile within the community means they can easily be captured and identified by those with only limited expertise.

As such fish are valuable indicators of river health that can be readily monitored. They are also considered an accurate assessment of environmental health because:

- fish communities represent various trophic classes and use foods from aquatic and terrestrial sources providing an integrated view of the river or catchment
- comparable results can be expected from an unperturbed site at various times
- some fish range over wide areas and are less affected by natural microhabitat differences than smaller organisms (e.g. algae and macroinvertebrates). This makes fish extremely useful for assessing regional and macrohabitat differences
- most fish species have long life spans (2-10+ years) and can reflect both, long-term and current water resource quality
- fish continually inhabit the receiving water and integrate the chemical, physical, and biological histories of the waters
- fish represent a broad spectrum of community tolerances from very sensitive to highly tolerant and respond to chemical, physical, and biological degradation in characteristic response patterns
- both acute toxicity (missing fish/deaths) and stress effects (depressed growth or reproductive success, increased susceptibility to disease, behavioural responses) can be evaluated

- fish are highly visible and valuable components of the aquatic community to the public (i.e. fish are the “charismatic” megafauna of aquatic ecosystems to which the general community can easily relate) and recreational fishers can provide quick feedback on fish response
- the ecology and habitat requirements of fish (mainly freshwater species) are relatively well known (compared to invertebrates)
- the sampling frequency for trend assessment is less than for short-lived organisms such as macroinvertebrates
- fishes are easily identified, enabling identification of many specimens in the field, and
- quantitative as well as qualitative data can be readily collected without excessively increasing sampling costs.

(Harris 1995, Simon and Lyons 1995)

Potential disadvantages include:

- often difficult to compare sites due to differences in habitats and the different capture techniques used within these habitats
- high mobility means fish may flee from points of impact
- some species occur in low densities or are highly aggregated so that distribution is highly patchy
- some sampling equipment requires expertise, licensing (e.g. electrofishing) and can be expensive
- very little is known of larval stages of many species which often inhabit different environments from adults, limiting population data
- fish species may not be very diverse in some waterbodies (e.g. some wetlands), and
- some species of fish are long-lived and there may be substantial lag times between an environmental impact and population declines.

(Downes et al. 2002, Whitfield and Elliott 2002)

Fish are therefore considered a valuable indicator of waterway health. However, simply knowing whether fish live in a particular system is not enough. Karr (1994 in Harris 1995) identified that four components should be evaluated in programs to monitor effects of environmental actions to ensure sensitivity to all forms of degradation: the structure, composition, individual health and ecological processes of the biota. It is therefore important to know what kinds of fish are present (community composition), their abundance, distribution, their health, recruitment processes, movement, what species should be present and changes to the community condition over time, in order to get an accurate estimate of river health.

8.3 Monitoring fish in Victoria

Freshwater systems

Fish have been extensively used in the USA for assessing the impact of various environmental perturbations through the multimetric Index of Biotic Integrity (IBI), the most widely used analytical framework for fish assessments (Fausch et al. 1984, Karr 1991). It was previously thought that Australia's relatively low species diversity and the high proportion of alien species in our waterways precluded the successful application of an IBI approach (Murray-Darling Basin Commission 2004b). However, Harris (1995) discussed the value of utilising fish for bioassessment in Australia, proposing a modified version which has since been assessed and validated in the NSW Rivers Survey (Harris and Silveira 1999).

Harris (1995) proposed the use of guilds based around the habitat requirements or tolerances of certain fish species. It was identified that pelagic[28] species are likely to be responsive to changes in physical structure, such as SWH, or water velocity in pools, while benthic insectivorous species are likely to be sensitive to stream-bed changes such as siltation or loss of macrophyte beds. The Australian grayling, Australian smelt, Freshwater herring and various galaxiids were identified as pelagic species, while pool-dwelling insectivorous species included gudgeons, Tupong and River blackfish. However, the guilds proposed by Harris and Silveira (1999) were only tested for use in the USA's IBI where they were used as a large-scale measure of river health. The use of these groups for measuring the success of specific actions would require knowledge of the likely response time of the guilds after implementing the improvement.

The Sustainable Rivers Audit (SRA) was developed to benchmark river health across the Murray-Darling Basin and utilised a slightly modified version of the IBI system proposed by Harris (1995). The program's aim was to standardise sampling methodology across the Basin to provide consistent Basin-wide information on the health of rivers to support objective comparisons of river condition over space and time. This program has proved valuable in providing broad scale river health assessment for each river basin integrating a number of bioindicators including fish, macroinvertebrates, and hydrology. As mentioned in section 2.2.2, a modified version of this program has been applied to Victoria's southern catchments, through a Victorian Government initiative using SRA methods called the Southern Basins Program.

Estuarine systems

Fish have been used extensively as indicators of the biological health or integrity of estuarine environments in South Africa (Ramm 1990). Ramm (1990) developed the Estuarine Community Degradation Index (CDI) which was based on a comparison of the fish community present within an aquatic

[28] Pelagic: inhabit the mid and upper water column, as opposed to bottom or benthic zone

system, to the community that would exist in the absence or prior to the degradation. The index assumes that the differences between the potential community and the present assemblage are due to habitat degradation and it has been used successfully to monitor the recovery of a number of estuaries over time in South Africa (Whitfield and Elliott 2002). More recently a new series of indices have been developed by Harrison et al. (2000) which looks at both qualitative and quantitative comparisons with reference fish communities in estuarine environments. Application of these or other fish community indices in Australian estuarine environments has been limited. To date, we know of no systematic application of condition assessments to Victorian estuaries which incorporate fish as an indicator. The recent Australian Catchment, River and Estuary Assessment 2002 examined only broad components of ecological systems, relied heavily on expert opinion and was consequently highly subjective (National Land and Water Resources Audit 2002a). Under the Southern Basins Program of SRA each river basin's estuary will be sampled by the end of 2009. As outlined in section 2.2.2 this program has been designed to provide baseline information as a reference point for future surveys of fish communities.

8.4 Monitoring fish to answer specific questions: When, where, how often and how?

Monitoring and assessment is a major component of an adaptive management cycle (Salafsky et al. 2001, Salafsky et al. 2002, Cottingham et al. 2005). It requires consideration from the outset of the project to ensure the monitoring and assessment program is aligned with the ecological objectives of the project so it can be included in management planning (Cottingham et al. 2005). As such it is important to follow certain steps:

Planning

- Determine the management objectives, targets or purpose of the project
- Define/construct a model/picture of the situation at the project site and determine what questions need to be answered/state any assumptions
- Select variables to be monitored (focus on a simple set of indicators that are linked to the assumptions being made)
- Optimise the study design

Action

- Determine the current condition of the asset(s)
- Implement management actions
- Monitor to test the assumptions/answer the questions

Review

- Analyse the data
- Review management objectives to determine if they have been met
- Revise management actions and objectives to adapt and learn

8.4.1 Monitoring: PLANNING

The Planning component of the process is an important step and may require a great deal of work. But in many instances this may have already been established as part of regional RHS or under other related plans and strategies. There are a multitude of resources that explain the working processes of this component of the framework (Appendix D). The information below is therefore only a very brief summary and further information can be sought from the list of resources in Appendix D.

Determine management objectives

Clearly defining what it is that the project is trying to achieve is an important starting point for the project. This enables the development of a benchmark for measuring success. This is a critical component in the development of regional RHS and for some threats relating to native fish, the objectives may have already been set in the region through existing plans and strategies (e.g. increase passage for native fish).

Once the broad mission is set, the target condition must be determined. Again many of these may already have been set in the region, such as "180km available to native fish migration from the Glenelg River mouth".

Define or construct a model of the situation

As most conservation takes place in complex situations it is important to have some kind of conceptual model that helps simplify and organise information. A good model enables a team to visualise what is happening at the site and should incorporate all the available information. For example, Figure 8.1 illustrates a simple conceptual model which describes all the ecological processes associated with a fish barrier.

The model suggests that the barrier has blocked the passage of native fish preventing natural migratory patterns. This may have reduced or eliminated recruitment of particular species in the river and the barrier may also have caused physical damage to species attempting to move both upstream and downstream. The barrier may also have reduced downstream flows and buffered seasonal flow fluctuations limiting migratory cues to downstream individuals and potentially decreasing downstream water quality. The weir pool can trap drifting larvae reducing their capacity to survive and it may promote populations of undesirable alien species.

From this model, a set of hypotheses can be developed. For example, removal of the weir will:

- increase native migratory fish passage in this section of the stream
- increase the distribution and abundance of migratory species upstream
- increase the potential of native migratory fish species to breed naturally
- reduce stress to native migratory fish populations
- help increase seasonal flow fluctuations improving native fish migratory cues
- enable more effective downstream larval passage, potentially increasing the capacity of the population to reproduce
- reduce the capacity of the stream to favour undesirable alien fish species, through the removal of the weir pool, and
- improve flushing of sediments from the substratum.

A good model will facilitate the identification of positive and negative impacts of the activities, which can provide the foundations for learning later. Once the activities are implemented, review of the model will identify if the assumptions were correct. Review of the model in the light of this information should lead to further learning, the refinement of the model (or its replacement in extreme cases) and appropriate adaptive management. It is also important to make the assumptions within the model explicit. This ensures it is clear what the model predicts and that the appropriate data can be collect for testing.

1. The barrier reduces the upstream migration of fish and other aquatic fauna by placing a physical barrier in the stream. This reduces the biodiversity of the fish communities upstream and may reduce downstream diversity of upper river spawners due to reduced or absent reproduction. 2. The barrier may cause damage, stress, limit, or reduce survival of adults, juveniles and larvae. 3. The barrier reduces within season flow fluctuations limiting cues to movement. 4. Reduced flows can decrease water quality, reduce flushing of detritus, nutrients and fine sediment. 5. Slow flow weir pool may trap drifting larvae. 6. Provide habitat for slow water alien species such as Eastern gambusia fish and/or Carp. 7. Habitat space for macroinvertebrates and fish in the substratum is reduced because of infilling with fine sediments due to low flows.

Figure 8.1: Fish barrier conceptual model

Select variables to be monitored

The selection of appropriate variables is a very important component of monitoring and assessment program design (Cottingham et al. 2005). A number of factors need to be considered when selecting these variables:

- the specific objectives and hypotheses to be explored by the monitoring and assessment program
- the degree of confidence in the causal link between the variable change and changes induced by management actions or ecological response (note: The strength of association between cause and effect of threats to native fish populations is not always clear).
- information that may be required to assess and manage risks to the system

In the fish barriers example, if the hypothesis is: "*Installation of a fishway will permit free movement of migratory native fish upstream*", this could be measured by assessing fish densities upstream or downstream before and after the installation of the fishway. Monitoring the changes in the migratory fish community both upstream and downstream of the barrier before and after modifications will be important to determine the effectiveness of the fishway to provide passage, it will determine to what extent the management objective of "free fish movement" has been achieved. Other hypothesis associated with the "success" of the fishway may require complex sampling and consultation with expert researchers is advisable.

Monitoring of rehabilitation interventions may also need to determine whether or not additional habitat such as the replacement of SWH has increased overall native fish populations, or whether they have just caused an aggregation around these new structures. Answering such questions may need sophisticated monitoring designs and consultation with experienced researchers will be necessary.

Determine how best to measure these variables.

Freshwater fish are typically measured through a variety of sampling including electrofishing, fyke nets and bait traps, while in estuarine environments gill nets, hook, line or fyke nets are commonly used. The suitability of each type of equipment will be dependent on the size of the target organisms, the habitats to be sampled and what component of the community you wish to measure (e.g. entire community, adults only, etc). For example, fine mesh drift nets and light traps are typically used for larval sampling, while electrofishing (freshwater only) and fyke nets are more commonly used for adults. Choice of collection devices should consider the possible bias each capture technique might have and this should be offset with additional capture techniques to ensure the sampling design can provide the information you require.

Alternative sampling such as acoustic telemetry can be utilised in both freshwater and estuarine environments. This method can provide relatively continuous record of fish movements and is ideal for asking fine scale questions about habitat use and seasonal movements. However this can be a relatively expensive monitoring tool.

Determine when it is best to measure these variables

It is also important to consider at what time of the year the sampling or monitoring is going to be most effective. This will largely be determined by what you are sampling and what question you are trying to answer. For example if you are trying to determine the effectiveness of a fishway to provide passage for a particular species it would be important to be monitoring that fishway during its migration periods, including downstream larval drift and/or returning juveniles. However, if you are attempting to determine the value of a habitat improvement, which is concerned with the entire fish community (including native migratory, non-migratory and alien fish species) it would be important to sample when the fish community is expected to be the most diverse. As fish catchability is reduced in colder months, the value of winter assessments is limited (Harris and Silveira 1999). Migrating species frequently move downstream to estuarine spawning habitats in winter (catadromous) and mortality patterns show strong winter peaks for non-migratory species. Fish assessments aimed at determining the diversity of fish communities in a particular reach or river should therefore only be carried out in summer when the total abundance of fish and representation of catadromous species in the area are highest (Harris and Silveira 1999).

Optimise the study design

An important step to consider is what level of change will be required to convince stakeholders that the management action delivered the envisaged response. The size of the change you need to detect will largely dictate how intensive your monitoring program needs to be and your level of knowledge of the predicted response. The smaller the effect size the more intensive the sampling protocol will need to be to detect any changes.

The size of the effect should be closely linked to your specific targets and objectives. For example, if the barrier improvement program is to reinstate native migratory fish populations, the measurable targets might include the species of interest (60% increase in the number of native migratory fish species moving through the site), abundance (50% increase in abundance of species ‘x’), spatial extent (50km of river available to all native migratory fish species) and/or recruitment. Ensuring the involvement of a statistician in the development of the study design is an important component of maximising the value of the project, from the start. They will be able to advise on sampling frequency, number of sampling sites, replicates required, and the types of comparisons and results that would be possible.

It is also important to understand over what time frames you expect to see a response. Some species may take time to recolonise an area if they have been excluded or become locally extinct, particularly if there is limited connectively between the site and recruiting populations. Undertaking a monitoring program that only monitors changes over 12 months is unlikely to be sufficient for these native fish species, although species with closer and more accessible source populations might respond very quickly. Recovery periods are likely to be longer for low fecund species and non-diadromous species compared with diadromous species with high fecundity and good dispersal ability. Recovery times of native fish species to various environmental perturbations are currently not well understood and research and monitoring is required to improve our knowledge.

8.4.2 Monitoring: ACTION

Determine the current condition of the asset(s)/variables to be measured

Separating changes in ecological condition due to a particular management intervention from other natural or human induced variability requires an understanding of conditions of the environment both before and after the management action is implemented (Cottingham et al. 2005). Monitoring the asset before and after the intervention (temporal control, see below) can then be compared with a control or reference site (spatial control, see below) to determine if the changes observed are a consequence of the intervention or simply seasonal or other variability. Programs without spatial and/or temporal controls make it harder to determine whether the observed ecological or environmental response is caused by the implemented management action or some other environmental change.

Temporal controls: can be used to increase confidence that an observed response is due to the implemented management action and is an essential component to monitor, in order to detect changes arising from river health improvements. These controls simply mean measuring the selected variables or asset at the site prior to any management intervention (Figure 8.2). For the barrier example, this would simply involve monitoring fish populations above the barrier before and after the fish barrier removal. Monitoring results after river improvements have been implemented can then be directly compared to the results prior to the improvement and reveal if the river improvements are having the desired impact on the aquatic ecosystem. This can increase the power of inferring a causality between a management action and an ecological response (Cottingham et al. 2005). This type of before and after monitoring requires sufficient “before” monitoring to ensure seasonal and annual fluctuations in the fish community do not blur system improvements or degradation. However, monitoring for extended periods of time prior to the commencement of a putative impact is rarely achievable (Downes et al. 2002) or may not be practical. Impacts are often ongoing disturbances that began decades before any monitoring program or assessment commenced. This type of control is not a classical control as it does not account for unmeasured ‘drivers’ that follow the same temporal pattern as the ‘driver’ under investigation.

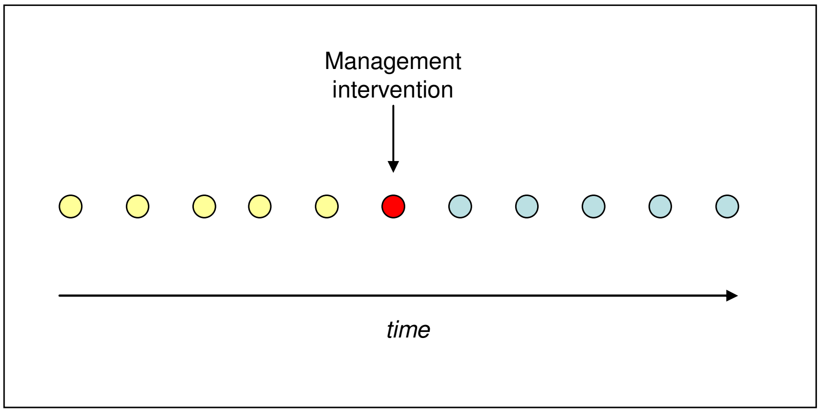

Figure 8.2: Illustration of a temporal control.
Each dot represents a sampling occasion at the same site. ◯ = sampling before management intervention. ● = management intervention (e.g. install fishway), ● = sampling after the management intervention.

Reference sites (spatial control)**:** are reaches or streams that occur in the same region as the site of interest and that are of similar size, elevation and stream gradient and are considered pristine or relatively undisturbed. These sites provide baseline data from which changes in fish communities in the site of interest can be gauged against to determine its current condition, improvements or loss of condition over time, and/or to understand natural fluctuations in communities in the region in comparison to changes imposed by some environmental improvement or perturbation.

Monitoring a reference site can assist in determining what is a seasonal or annual change in community composition or relative abundances of fish and what is actually a response induced by a stream improvement or environmental impact. The use of local reference sites can overcome this issue by simultaneously monitoring the fish population in nearby river reaches that are relatively free from human disturbances. Information from these sites in addition to any historical data that may be available can provide the basis from which to compare the site of interest to determine if the native fish community has been strongly influenced by stream modifications. Unfortunately, undisturbed reference sites may not always be available.
In this instance, monitoring fish populations in two similar streams in the same region simultaneously, for example, one in which erosion problems are being addressed and the other which continues to experience erosion issues will help provide the information needed (Figure 8.3). Similar changes in the fish community in both streams would likely indicate natural cycles, however changes in one community and not the other, maybe a result of changes to that river or section of river.

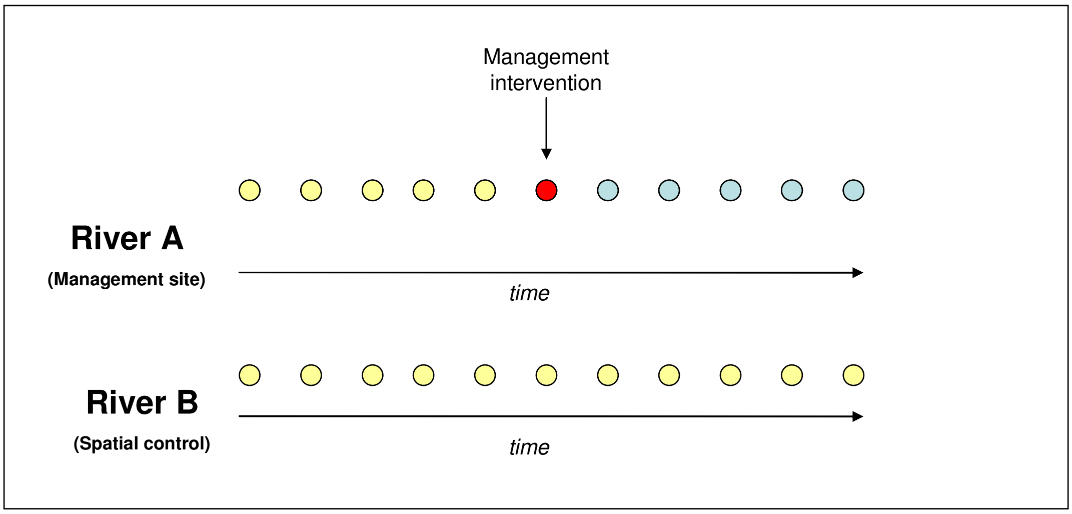

Figure 8.3: Illustration of a spatial control.
Each dot represents a sampling occasion at each site. River A represents the site in which you are undertaking management works, while River B is your control site. ○ = sampling before management intervention. ● = management intervention (e.g. install fishway), ○= sampling after the management intervention.

Implement management and monitoring plans

Once you have optimised your study design and measured the current condition of the variables at your site and spatial reference site it is time to implement the stated management actions and your "after" monitoring plan.

8.4.3 Monitoring: REVIEW

Analysing the collected data is a fundamental process of transforming raw information into a useable format. It is from this stage that informed decisions can be made about whether or not the onground actions are achieving the predefined target and/or set goals and objectives.

8.4.4 Recommended monitoring programs

I. ***Assess your management action to ensure it is providing sufficient protection against the identified threats and modify management actions as required.***

II. ***Continue to assess/monitor broad scale river health, using a modified version of ISC which incorporates fish or other accepted and standardised methodologies which include fish.***

III. Monitor revegetated riparian zones to assess the effectiveness of revegetation programs to enhance fish habitat and determine whether any additional rehabilitation measures are required.

IV. Monitor established fishways to determine their success for all migratory fish species.

i Conduct fish surveys both at the top and bottom of fishway to assess the effectiveness of the fishway

- *Can fish find the entrance?*
- *Can all species can get to the top?*
- *Is the fishway is functioning over a range of flow conditions, etc?*

ii Determine if there is an improvement in the fish community upstream (e.g. enhanced recruitment, enhanced biodiversity, etc)

V. Ensure adequate monitoring programs are implemented to determine the effectiveness of rehabilitation activities for fish.

i Establish broad scale surveys to determine the current status of all fish species.

ii Determine causal effect of management improvements on fish communities and populations.

iii Determine the recovery period of fish species after intervention or environmental perturbations.

iv Determine causal effect of management improvements on water quality.

9 Implementation

The *Guide to the Management of Native Fish* (GMNF) has been developed to provide information on the distribution, biology and management of native fish. This information has been collated to assist NRMs in the development of targets and onground actions under their regional RHS. As such, the Guide should assist managers and community groups in ensuring that native fish are considered in the development of NRM plans and management works. It aims to provide a resource that can support the development of actions relevant to sustaining native fish and to assist in providing a more holistic approach to river health throughout coastal Victoria.

The FAST system will support the GMNF and the RHS through the identification of primary threatening processes to native freshwater and estuarine fish in particular basins. FAST will provide specific management recommendations and actions to address threatening processes at a reach scale. FAST will provide guidelines on modifying onground actions to minimise the impacts to native fish, provide recommendations on alternative fish friendly actions and provide a detailed threat assessment for native freshwater and estuarine fish populations in each CMA region.

10 Glossary

Aestivate: refers to a dormancy period during drought: the species has the ability to survive out of water in moist conditions
Amphidromous: species that regularly migrate between freshwater and the sea (in both directions), but not for the purpose of breeding
Anadromous: species that migrate from the sea to freshwater to spawn
Anoxic: in reference to waterbodies, it refers to water with no oxygen
Benthic: refers to species that persist in the ecological region at the lowest level of a body of water such as an ocean or a river, including the sediment surface and some sub-surface layers.
Biogenic: is a substance produced by life processes. It may be either constituents, or secretions, of plants or animal.
Bivalve: are molluscs belonging to the class **Bivalvia**. They typically have two-part shells, with both valves being symmetrical along the hinge line. The class has 30,000 species, including scallops, clams, oysters and mussels.
Carnivore: eating a diet of only animal flesh
Catadromous: species that migrates from freshwater to the sea to spawn
Decapod: A crustacean in the order Decapoda (e.g. crab, lobster or shrimp) characteristically having ten legs each joined to a segment of the thorax.
Demersal: dwelling at or near the bottom of a waterbody
Diadromous: species that migrate between fresh and salt waters
Ecologically Sustainable Development: there is no universally accepted definition of ecologically sustainable development (ESD), Australia's National Strategy for Ecologically Sustainable Development 1992 (NSESD) defines ESD as:

'using, conserving and enhancing the community's resources so that ecological processes, on which life depends, are maintained, and the total quality of life, now and in the future, can be increased'.

(Ecologically Sustainable Development Steering Committee 1992)

The fundamental principal of this definition is that economic and social progress depends on base ecosystem services (e.g. oxygen production and carbon dioxide absorption by plants) and a healthy environment. It recognises that biodiversity conservation is pivotal to ensuring ongoing healthy and effective ecosystem services, as it is the diversity of flora and fauna in ecosystems that facilitate these services and provide ongoing resilience of these systems to environmental change (both natural and human induced). Conserving biodiversity is therefore a vital component of effective ESD.

Elvers: young eels which have developed teeth and pigmentation
Endemic: confined to a particular region
Estuary: the National Land and Water Audit 2002 defined an estuary as a semi-enclosed coastal water body where:

- salt from the open sea mixes with freshwater draining from the land; or
- marine and fluvial sediments occur together

(National Land and Water Resources Audit 2002a)
For the purposes of this guide larger embayments such as Port Phillip Bay, Westernport Bay and Corner Inlet were excluded. See section1.4.1 for further details.
Estuarine dependent: see section 1.5.2
Estuarine opportunist: see section 1.5.2

Estuarine resident: see section 1.5.2
Alien species: refers to species now occurring in Australia that are not native to Australia
Fecundity: fertility; capable of producing offspring
Freshwater fish/species: see section 1.5.2
Glass eels: the toothless unpigmented form of an eel, this is a juvenile stage from which they develop into elvers at around 12-18 months.
Gravid: carrying developing young or eggs
Herbivore: eating a diet composed only of plants
Hermaphrodite: an animal or plant, having both male female reproductive organs
Insectivore: consumes a diet only of insects
Introduced species: refers to species that are native to Australia but do not naturally occur in that basin. That is they have been introduced through human intervention (intentionally or otherwise).
Interstitial: the small or narrow space, between things or parts
Lentic: static water, such as a wetland or billabong
Lotic: flowing water, such as a river or creek
Macrophytes (aquatic): Any aquatic plant that can be seen with the unaided eye, such as reeds, sedges, etc, they are larger than most algae
Management Action Targets (MAT): targets set under the regional RHS that contribute to the longer term RCT
Macroinvertebrate:
Marine-estuarine straggler:
Omnivore: eating a diet of both plant and animal
Pelagic: inhabit the mid and upper water column, as opposed to the bottom or benthic zone
Polychaetes: a class of annelid worms some times called bristle worms
Protandry: development of male organs before female to avoid self-fertilization.

Ramsar: The Ramsar Convention is an international treaty for the conservation and sustainable utilisation of wetlands, aimed at stemming the progressive encroachment on and loss of wetlands now and in the future, recognizing the fundamental ecological functions of wetlands and their economic, cultural, scientific, and recreational value. The official title is *The Convention on Wetlands of International Importance, especially as Waterfowl Habitat.* The convention was developed and adopted by participating nations at a meeting in Ramsar, Iran on February 2, 1971 and came into force on December 21, 1975. The Convention on Wetlands provides guidance on preparing national policies, legislation and tools for managing wetlands.

Refugia: sites which provide a temporal refuge from biophysical disturbances
Resource Condition Targets (RCT): targets set under the RCS or RHS which are specific, time-bound and measurable. These targets relate to resource condition
River: refer to section 1.4.1
Stenohaline: species that can only survive in a narrow range of salinities
Structural woody habitat: any debris of woody nature (including: logs, branches, twigs, leaves) that accumulates in aquatic habitats and provides habitat for aquatic organisms. Previously referred to as Large Woody Debris.
Viviparous: bearer of live young
Wetland: refer to section 1.4.1

11 Acronyms

ABC = Actions for Biodiversity Conservation
ARI = Arthur Rylah Institute for Environmental Research
AROT = Victorian Rare or Threatened species list
BUR = Burrowing/riparian zone
CAP = Coastal Action Plan
CCCG = Carp Control Coordination Group
CCMA = Corangamite Catchment Management Authority
CMA = Catchment Management Authority
CSIRO = Commonwealth Scientific and Industrial Research Organisation
DPI = Department of Primary Industries
DSE = Department of Sustainability and Environment
ED = Estuarine Dependent
EEMSS = Estuarine Entrance Management Support System
EGCMA = East Gippsland Catchment Management Authority
EO = Estuarine Opportunist
EPA = Environment Protection Authority
EPBC Act = *Environment Protection and Biodiversity Conservation Act* 1999
ER = Estuarine Resident
ESD = Ecologically Sustainable Development
EST = Estuarine
EVC = Ecological Vegetation Class
FFG Act = *Flora and Fauna Guarantee Act* 1988
FMP = Fisheries Management Plan
FW = Freshwater
GDR = Great Dividing Range
GHCMA = Glenelg Hopkins Catchment Management Authority
GMNF = Guide to the Management of Native Fish
HP = High Priority threat
IBI = Index of Biotic Integrity
ISC = Index of Stream Condition
IUCN = International Union for Conservation of nature and Natural Resources/ World Conservation Union
IWC = Index of Wetland Condition
MAR = Marine
MAT = Management Action Target
MDB = Murray-Darling Basin
MDBC = Murray-Darling Basin Commission
MS = Marine Straggler
MW = Melbourne Water
NHT = National Heritage Trust
NRM = Natural Resource Management
NSESD = National Strategy for Ecologically Sustainable Development
PPCMA = Port Phillip and Western Port Catchment Management Authority
PV = Parks Victoria
RARC = Rapid Appraisal of Riparian Condition
RCS = Regional Catchment Strategy
RCT = Resource Condition Target
RiVERS = River Values and Environmental Risk System
RHS = River Health Strategy
SAC = Scientific Advisory Committee
SFMP = Streamflow Management Plan

SPM = Guidelines for sedimentation and suspended particular matter in rivers and streams
SRA = Sustainable Rivers Audit
SWH = Structural Woody Habitat
VBS = Victorian Biodiversity Strategy
VCS = Victorian Coastal Strategy
VEFMAP = Victorian Environmental Flow Monitoring and Assessment Program
VFMS = Victorian Floodplain Management Strategy
VHP = Very High Priority threat
VNWR = Victorian Noxious Weed Review
VRHS = Victorian River Health Strategy
VROT = Victorian Rare or Threatened species list
WGCMA = West Gippsland Catchment Management Authority
WONS = Weeds of National Significance

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Appendix A: Threatening processes as identified under the FFG Act

Table A1: Abbreviated Department of Sustainability and Environment, Flora and Fauna Guarantee Act 1988, Threatening Processes List, December 2007, identifying those processes which specifically impact on coastal fish, aquatic invertebrates and their habitats.

Threatening process identified under the FFG Act 1988	Current action statement
Alteration to the natural flow regimes of rivers and streams	Yes, 2003
Alteration to the natural temperature regimes of rivers and streams	Yes, 2003
Degradation of native riparian vegetation along Victoria rivers and streams	Yes, 2003
Increase in sediment input into Victoria rivers and streams due to human activities	Yes, 2003
Input of organotins to Victorian marine and estuarine waters	None available
Input of petroleum and related products into Victoria marine and estuarine environments	None available
Input of toxic substances into Victorian rivers and streams	None available
Deliberate or accidental introduction of live fish into public and private waters within a Victorian river catchment in which the taxon to which the fish belongs cannot reliably be inferred to have been present prior to 1770AD	Yes, 2003
Invasion of native vegetation by ‘environmental weeds’	None available
Prevention of passage of aquatic biota as a result of the presence of instream structures	Yes, 2003
Removal of wood debris from Victorian streams	Yes, 2003
The discharge of human-generated marine debris into Victorian marine or estuarine waters	None available
Wetland loss and degradation as a result of change in water regime, dredging, draining, filling and grazing	None available

Appendix B: Summary of biological requirements of estuarine opportunist finfish of coastal Victoria

Common Name	Species Name	Category	CMA district	Basins	Estuary position	Preferred water column position	Preferred habitat	Diet	Spawning period/ location	Eggs	Comments	References
Adelaide Weedfish	*Heteroclinus adelaide*	EO	PP, C, GH	28-38, except 34	L	demersal/benthic	seagrass /reef/ algae	inverts	?	live bearers		Gommon et al. 1994, Kuiter 1993
Big-bellied Seahorse	*Hippocampus abdominalis*	EO	all	all except 34	L	demersal/benthic	seagrass/ reef/ algae	plankton	?	live bearers	Paternal care of young	Gommon et al. 1994, Kuiter 1993
Bridled Goby	*Arenigobius bifrenatus*	EO	all	all except 34	U, M	benthic	burrows into soft substrate, saline reaches of river	?	middle & upper estuary	guards eggs		Gill & Potter, 1993, Barnham 1998
Bridled Leatherjacket	*Acanthaluteres spilomelanurus*	EO	all	all except 34	L	demersal	reef/ algae/ seagrass	benthic invertebrates	Spring/early summer	pelagic		Gommon et al. 1994, Kuiter 1993
Briggs Crested Pipefish	*Hippocampus breviceps*	EO	all	all except 34	L	demersal/benthic	seagrass/ reef/ algae	plankton	Spring/early summer	live bearers	Paternal care of young	Gommon et al. 1994, Kuiter 1993
Brush-tail Pipefish	*Leptoichthys fistularis*	EO	PP, C, GH	28-38, except 34	L	demersal/benthic	seagrass/ reef/ algae	?	?	live bearers	Paternal care of young	Gommon et al. 1994, Kuiter 1993
Common Toadfish	*Tetractenos hamiltoni*	EO	EG	20, 21?	all	demersal	various	wide range of inverts		pelagic		Gommon et al. 1994, Kuiter 1993
Deep-body Pipefish	*Kaupus costatus*	EO	WG, PP, C, GH	27-38, except 34	L, M	benthic	vegetation	zooplankton	spring	live bearers	Paternal care of young	Gommon et al. 1994, Kuiter 1993
Eastern Australian Salmon	*Arripis trutta*	EO	all	all except 34	L, M	pelagic-transient	all	mostly piscovorous - also squid etc	summer - offshore/coastal	pelagic-coastal	most abundant east of Wilson's Prom	Potter & Hyndes 1999; Valesini et al. 1997; Stanley 1977
Eastern Fortesque	*Centropogon australis*	EO	PP, WG, EG	20-27	L	benthic	reef/ algae/ seagrass	small invertebrates/fish	spring- probably shallow, sheltered waters			Gommon et al. 1994, Kuiter 1993
Eastern Sea Garfish	*Hyporhamphus australis*	EO	EG	20, 21	L, M	demersal-transient	vegetation/ mudflat	herbivorous - may consume inverts	October to March - vegetated areas	eggs stick to seagrass		Gommon et al. 1994, Kuiter 1993
Glass Goby	*Gobiopterus semivestitus*	EO	all	all except 34	all	pelagic-limited mobility	in and around structure	plankton	estuaries	probably pelagic		Gommon et al. 1994, Barnham 1998
Greenback Flounder	*Rhombosolea tapirina*	EO	all	all except 34	L, M	benthic	unvegetated	benthic crustaceans	winter - probably deeper sheltered waters	planktonic		Gommon et al. 1994, Kuiter 1993
Half-bridled Goby	*Arenigobius frenatus*	EO	WG, PP, EG	20-28	all	benthic	seagrass	aquatic inverts and some algae	Spring-summer/ seagrasses	benthic		Gommon et al. 1994, Barnham 1998
Javelin Pipefish	*Lissocampus runa*	EO	all	all except 34	L	benthic	algae	zooplankton-small crustaceans	probably spring/ summer	brood eggs		Gommon et al. 1994, Kuiter 1993
King George Whiting	*Sillaginodes punctata*	EO	all	all except 34	L, M	demersal	sand or open vegetation/seagrass beds	early juvenile and larvae - copepods, larger juvenile and adults - benthic inverts	autumn/ winter - western Vic/eastern SA, coastal	pelagic, planktonic		Jenkins and May 1994, Jenkins et al. 2000, Potter & Hyndes 1999
Kuiter's Weedfish	*Heteroclinus kuiteri*	EO	WG, PP	27, 28, ??	L	demersal/benthic	seagrass/reef/algae	inverts	?	live bearers		Gommon et al. 1994, Kuiter 1993
Large-eye Weedfish	*Heteroclinus macropthalmus*	EO	WG, PP, C, GH	27-38, except 34	L	demersal/benthic	seagrass/reef/algae	inverts	?	live bearers		Gommon et al. 1994, Kuiter 1993
Large-mouthed Goby	*Redigobius macrostoma*	EO	EG, WG, PP, GH	20-27, 29, 30, 38	L	benthic	sand	small inverts	?	benthic	ususally on rocky reefs or pylons in small agregations	Kuiter 1993, Barnham 1998
Little Weedfish	*Heteroclinus puellarum*	EO	GH	37,38	L	demersal/benthic	seagrass/reef/algae	inverts	?	live bearers		Gommon et al. 1994, Kuiter 1993
Long-finned Goby	*Favonigobius lateralis*	EO	all	all except 34	L	benthic	sandy /sheltered regions	carnivorous (polychaete and crustaceans)	shallow coasts	benthic - larvae with a short pelagic stage	positively correlated with salinity/ can spend entire lifecycle within an estuary, considered a marine species that spawns in high salinities near estuary mouth or inshore coastal waters, rests on the bottom and shimmies to cover itself in sand/silt - too fine a sediment can be fatal.	Gill & Potter, 1993; Young et al. 1997, Potter & Hyndes 1999
Long-snouted Flounder	*Ammotretis rostratus*	EO	all	all except 34	L, M	benthic	unvegetated-including around edges of vegetation	small invertebrates	?? - winter	pelagic		Gommon et al. 1994, Kuiter 1993
Longtail Weedfish	*Heteroclinus sp.3*	EO	EG,WG,PP	20-33	L	demersal/benthic	seagrass/ reef/ algae	inverts		live bearers		Gommon et al. 1994, Kuiter 1993
Luderick	*Girella tricuspidata*	EO	all	all except 34	L, M	demersal	vegetated/ structure	herbivorous	August to March/surf zone and estuary mouths	pelagic		Gommon et al. 1994, Kuiter 1993
Milwards Weedfish	*Heteroclinus sp.6*	EO	PP, C, GH	28-38, except 34	L	demersal/benthic	seagrass/reef/ algae	inverts	?	live bearers		Gommon et al. 1994, Kuiter 1993
Mother-of-Pearl Pipefish	*Vanacampus margaritifer*	EO	EG,WG,PP	20-33	all	benthic	seagrass-zostera	zooplankton	spring/summer/shallow seagrass	live bearers	Paternal care of young	Gommon et al. 1994, Kuiter 1993
Pale Mangrove Goby	*Mugilogobius platynotus*	EO	WG,PP	27,28	M, U	benthic	mud/sand	small crusteceans/polychaetes	?	?	FFG vulnerable	Gommon et al. 1994, Gee and Gee 1995, Barnham 1998
Port Phillip Pipefish	*Vanacampus phillipi*	EO	all	all except 34	all	benthic	seagrass-zostera	zooplankton	spring/summer/shallow seagras	live bearers	Paternal care of young	Gommon et al. 1994, Kuiter 1993
Prickly Toadfish	*Contusus brevicaudatus*	EO	all	all except 34	L, M	demersal	unvegetated/ structural edges	benthic inverts	?	pelagic		Gommon et al. 1994, Kuiter 1993

Note: all references for tables in Appendix B can be found in the Further reading section (Appendix D)

Common Name	Species Name	Category	CMA district	Basins	Estuary position	Preferred water column position	Preferred habitat	Diet	Spawning period/ location	Eggs	Comments	References
Pug-nose Pipefish	*Pugnaso curtirostris*	EO	all	all except 34	L	benthic	reef/ rubble/ algae	zooplankton	?	live bearers	Paternal care of young	Gommon et al. 1994, Kuiter 1993
Ring-backed Pipefish	*Stipecampus cristatus*	EO	all	all except 34	L	benthic	weed and sandy areas rather than seagrass	?	?	live bearers	Paternal care of young	Gommon et al. 1994, Kuiter 1993
Sand Mullet	*Myxus elongatus*	EO	all	all except 34	L	demersal	unvegetated	small crustaceans	probably winter - coastal and or mouths of estuaries	pelagic		Gommon et al. 1994, Kuiter 1993
School Whiting	*Sillago flindersi*	EO	EG,WG	20-27	L,M	demersal	sand	crustaceans, amphipods, decapods, mysids and copepods	October to March/ coastal	pelagic	not common in Vic	Gommon et al. 1994, Kuiter 1993
Sculptured Seamoth	*Pegasus lancifer*	EO	EG, WG, PP, C, GH	23 to 38, except 34	L	benthic	sand/sparse seagrass/rubble	small crustaceans	?	?		Gommon et al. 1994, Kuiter 1993
Short-snout Seahorse	*Hippocampus breviceps*	EO	all	all except 34	L	demersal/benthic	seagrass/ reef/ algae	plankton	?	live bearers	Paternal care of young	Gommon et al. 1994, Kuiter 1993
Silver Trevally	*Pseudocaranx georginanus*	EO	all	all except 34	L, M	pelagic	soft substrate	carnivorous (inverts)	summer, offshore and in estuary	pelagic	long lived	Fisheries MP, Smith-Vaniz and Jelks 2006
Six-spined Leatherjacket	*Meuschenia freycineti*	EO	all	all except 34	L	demersal	seagrass	omnivorous	probably along coasts in late spring/summer	pelagic		Hindell 2006
Sand Trevally	*Pseudocaranx wrighti*	EO	all	all except 34	L, M		soft substrate	carnivorous (inverts)	summer, offshore and in estuary	pelagic		Fisheries MP
Smooth Pipefish	*Lissocampus caudalis*	EO	all	all except 34	L	benthic	algae	zooplankton-small crustaceans	probably spring/ summer	brood eggs		Gommon et al. 1994, Kuiter 1993
Smooth Toadfish	*Tetractenos glaber*	EO	all	all except 34	all	demersal	various	wide range of inverts	?	pelagic		Gommon et al. 1994, Kuiter 1993
Soldierfish	*Gymnapistes marmoratus*	EO	all	all except 34	all	benthic	seagrass, - closely associated with seagrass	invertebrates - bigger ones eat fish	spring-probably shallow, sheltered waters	pelagic		Hindell & Jenkins 2005, Potter & Hyndes 1999
Southern Crested Weedfish	*Cristiceps australis*	EO	all	all except 34	L	demersal/benthic	seagrass/ reef/ algae	fish/inverts	summer-live bearer	live bearers		Gommon et al. 1994, Kuiter 1993
Southern Fiddler Ray	*Trygonorrhina guanerius*	EO	all	all except 34	L	benthic	sand - near seagrass	molluscs/crustaceans	?	?		Gommon et al. 1994, Kuiter 1993
Southern Pygmy Leatherjacket	*Brachaluteres jacksonianus*	EO	all	all except 34	L, M	demersal	vegetation/ reef	small inverts	spring/ summer	pelagic		Gommon et al. 1994, Kuiter 1993
Southern Sea Garfish	*Hyporhamphus melanochir*	EO	EG, WG, PP, C, GH	all except 34	L, M	demersal-transient	vegetation/ mudflat	herbivorous - may consume inverts	October to March - vegetated areas	eggs stick to seagrass		Potter & Hyndes 1999
Spiny Pipehorse	*Solegnathus spinosissimus*	EO	all	all except 34	L	benthic	vegetation	zooplankton	?	live bearers	Paternal care of young	Gommon et al. 1994, Kuiter 1993
Spot-shoulder Weedfish	*Heteroclinus perspicillatus*	EO	EG,WG,PP,C,GH	21-38, except 34	L	demersal/benthic	seagrass/reef/algae	inverts	?	live bearers		Hindell & Jenkins 2005; Kuiter 1993
Spotted Pipefish	*Stigmatopora argus*	EO	all	all except 34	L, M	demersal	seagrass	zooplankton	males brood eggs - young hatch and released from pouch/spring	live bearers	Paternal care of young, short pelagic stage	Hindell 2006, Valesini et al 1997
Tamar River Goby	*Afurcagobius tamarensis*	EO	all	all except 34	L, M	benthic	sand/ mud/ sparse vegetation	meiofauna/ benthic	?? - spring - benthic	?? - benthic	rests on silt or mud bottoms in quiet waters of brackish estuaries and coastal lakes	Allen et al. 2003, Barnham 1998
Tommy Rough	*Arripis georgianus*	EO	all	all except 34	L, M	pelagic-transient	all	pelagic inverts/small fish	April to June	pelagic		Potter & Hyndes 1999
Variegated Snakeblenny	*Ophiclinops varius*	EO	WG, PP, C, GH	27 to 38, except 34	L	benthic	sand/sparse seagrass/rubble	small crustaceans	?	?	secretive, in Amphibolus seagrass areas with detritus layer on sand	Gommon et al. 1994, Kuiter 1993
Weeping Toado	*Torquigener pleurogramma*	EO	all	all except 34	all	demersal	various	wide range of inverts	?	pelagic	sheltered ares, usually in small to large schools over sand	Gommon et al. 1994, Kuiter 1993
Western Australian Salmon	*Arripis truttaceus*	EO	WG, PP, C, GH	27-38, except 34	L, M	pelagic-transient	all	mostly piscovorous - also squid etc	feb to june - offshore/coastal	pelagic-coastal	abundant west of the prom	Gommon et al. 1994, Kuiter 1993
White's Seahorse	*Hippocampus whitei*	EO	all	all except 34	L	demersal/benthic	seagrass/reef/algae	plankton		live bearers	Paternal care of young	Gommon et al. 1994, Kuiter 1993
Wide-bodied Pipefish	*Stigmatopora nigra*	EO	all	all except 34	L, M	demersal	seagrass	zooplankton	males brood eggs - young hatch and released from pouch/spring	live bearers	Paternal care of young, short pelagic stage	Gommon et al. 1994, Kuiter 1993
Yank Flathead	*Platycephalus speculator*	EO	all	all except 34	L, M	demersal	sand	crustaceans and fish	within estuaries	planktonic	long lived, >1year	Hindell 2006, Potter & Hyndes 1999
Yellow-eye Mullet	*Aldrichetta forsteri*	EO	all	all except 34	L, M, U	demersal-transient, all depths - particularly shallow banks at high tide	sand/mud-around structure	ominvore prefers	late spring-autumn	pelagic	schools just prior to spawning, recreationally targetted common in moyne, mary and hopkin rivers - common everywhere., juveniles prefer esturay habitats (49)	Chubb et al. 1981; Jenkins et al. 1996; Crinall & Hindell 2004; Young et al. 1997; Young & Potter 2002; Fisheries MP, Potter & Hyndes 1999

Note: all references for tables in Appendix B can be found in the Further reading section (Appendix D)

Appendix C: List of threats and their scale of impact as defined by the regional workshops and threats at threatened fish workshop.

Broad threat		Detailed threat	Workshop scores: Geographic + Temporal Scale (Table 3.3 +3.4)	Impacts on threatened fish species (FAST)	Total score for coastal Victoria
Barriers to fish movement	1	Instream barriers (e.g. weirs, culverts, dams, etc)	92.5	89	181.5
	2	Loss of access to wetland/floodplains†	96.5	77	173.5
	3	Habitat fragmentation (e.g. within stream fragmentation, loss of connectivity)†	91.5	99	190.5
	4	Low flow prevent river mouth opening**	**	103	103
	5	Channelisation	75	79	154
Degradation and loss of instream habitat	6	Loss of SWH	91	104	195
	7	Channelisation	70.5	121	191.5
	8	Sedimentation	90	130	220
	9	Loss of aquatic vegetation	83.5	152	235.5
	10	Loss of floodplains and wetlands (draining, filling, reduced flooding, etc)	85.5	110	195.5
	11	Bed erosion	50.5	106	156.5
Degradation and loss of riparian habitat	12	Alien plant species which modify nutrient flows **and/or** change water temperature (e.g. pasture, willows, poplars, etc)	99	55	154
	13	Loss/degradation riparian vegetation (including stock access)	101	146	247
	14	Bank erosion	77	138	215
Modified flow regimes	15	Loss of seasonal flow regimes (i.e. high flows in winter and low flows in summer) †	84	113	197
	16	Loss of within seasons flow variability†	83.5	73	156.5
	17	Reduced flooding		105	105
	18	Habitat change due to reduced flows		138	138
	19	Reduced flow volume	88.5	108	196.5
	20	Change in water table		109	109
	21	Drought		99	99
Alien species	22	Introduced predatory fish (salmonoids, Redfin, Eastern gambusia, etc)	112	116	228
	23	Habitat modifiers (Carp)	78	90	168
	24	Competitors (Weather loach, Roach, Eastern gambusia, Tench, Goldfish, Carp)	90	78	168
	25	Native species outside their range	36.5	80	116.5
Declining water quality	26	Low dissolved oxygen**	48**	125	173
	27	High nutrients (including faecal contamination)	89.5	111	200.5
	28	Increasing salinity	74	104	178
	29	Changes in temperature (cold/hot water releases)	33	99	132
	30	High turbidity/suspended solids	73	106	179
	31	Herbicides/pesticides	66	130	196
	32	pH/acid sulphate soils	30	106	136
	33	Algal blooms	56	91	147
	34	Metals	45	72	117
	35	Litter (e.g. leaching from rubbish dumps, storm water runoff)	50.5	69	119.5
Exploitation	36	Recreational fishing	56.5	78	134.5
	37	Commercial fishing	26	51	77
	38	capture for aquarium trade/ amateur enthusiasts	24	31	55
	39	capture for bait	36	19	55
Inappropriate artificial river mouth opening	40	Sudden localised loss of water quality (low DO)**	31.5	110	141.5
Other	41	Climate change*	*	121	121

* Climate change was not consistently scored in each workshop, but it was considered a highly important threat that should be discussed within this project

**Low Dissolved Oxygen and artificial river mouth opening were scored inconsistently within workshops. As these threats are linked and have high impacts on the fauna communities in areas affected it was considered an important enough issue to be discussed in detail in the guide.

Appendix D: Further reading

Index to additional resources

Australian grayling (*Prototroctes maraena*)

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