Survey of fish populations in West Barwon Reservoir

INTRODUCTION

Historically, short-finned eels (*Anguilla australis*) have been observed by the local community and Barwon Water operational staff in West Barwon Reservoir and the Barwon River immediately downstream. This includes observations of adult short-finned eels migrating out of the reservoir and downstream when it spills (Figure 1). Recent research in Lake Condah in western Victoria has also shown that adult short-finned eels migrate out of the lake and downstream when the lake spills (Koster et al. 2020). However, during recent reservoir spilling in winter/spring 2021, no short-finned eels were observed migrating out of the reservoir (Jayden Woolley, pers. comm.). Consequently, there is increased interest from the local community on the status of short-finned eel and other migratory fish populations in the reservoir.

Information on the status of fish populations in West Barwon Reservoir is limited, although previous studies in the upper Barwon catchment have recorded the nationally threatened Australian grayling (*Prototroctes maraena*), as well as short-finned eel, river blackfish (*Gadopsis marmoratus*), southern pygmy perch (*Nannoperca australis*), Australian smelt (*Retropinna semoni*) and galaxiids (*Galaxias* spp.) (Raadik 2000; Environous 2008; Alluvium 2021). The system retains some submerged aquatic vegetation, undercut banks, overhanging vegetation and riffle-pool sequences, which provide important habitat for fish and other aquatic animals (Hayley Vinden, pers. comm.).

Figure 1. Short-finned eel

Objectives

The aim of this project is to conduct a survey to collect baseline data on short-finned eel and other fish populations in the West Barwon Reservoir. The information collected is a first step to inform the potential effect of the reservoir on migratory fish species, with a specific focus on short-finned eel populations throughout the system. More specifically:

- Is the dam likely to prevent eels from accessing the river upstream of the reservoir?
- Is the dam likely to be having any implications to eel populations below it in the Barwon River?
- Is the dam likely to prevent eels from migrating downstream out of the reservoir?

It is important to note that the surveys were conducted over only a few days and therefore provide only a snapshot of the species that may be present in the reservoir. More broadly, a lack of monitoring data to determine the status of, or trends in, eel populations throughout Victoria also precludes a comparison of eel populations to other systems in the State.

METHODS

Study area

The Barwon River rises in the Otway Ranges and flows close to the townships of Forrest, Birregurra, Winchelsea and Inverleigh, before joining the Moorabool River and flowing through Geelong and the Lower Barwon Wetlands, joining the coast at Barwon Heads. The Barwon River flows through Eastern Maar Country and Wadawurrung Country and has great cultural significance to both Traditional Owner Groups. The river is a major water supply for Geelong and smaller urban centres and is also an important farm water supply for the region. The system is significantly altered via extensive farm dam storages, on-stream reservoirs and many diversion licences.

The West Barwon Reservoir sits on the west branch of the upper Barwon River to provide urban water supply to Geelong. It was constructed between 1959 and 1965 and has a dam wall height of 43 m and a capacity when full of 21,504 ML. Water stored in West Barwon Reservoir can be released directly into the west branch, or into the east branch via a diversion tunnel. In accordance with Barwon Water's Bulk Entitlement, water is transferred into the 57km diversion channel to Wurdee Boluc Reservoir. Additionally, Barwon Water releases passing flows of around 4-5 ML per day to the west branch from the West Barwon Reservoir depending on time of year and Barwon system storage levels. The reservoir has spilled four times over the last 20 years, with a significant spill event occurring recently in winter/spring 2021. The West Barwon Reservoir was identified in the Victorian State Fishway Program as a barrier to fish movement (McGuckin & Bennett 1999).

The Upper Barwon River Environmental Entitlement 2018 is also held in the West Barwon Reservoir and is delivered by the Corangamite Catchment Management Authority (CCMA) on behalf of the Victorian Environmental Water Holder (VEWH). This water is released, when possible, down the river (via both west and east branches) in a targeted way to maximise environmental benefits. Releases typically take the form of a continuous low flow (base flow) or a fresh (pulse of water) to trigger a particular environmental response.

Fish sampling

Sampling was conducted at West Barwon Reservoir between September 11th and 13th 2021 using single-wing fyke netting and a Smith–Root model 7.5 GPP boat–mounted electrofishing unit (Figure 2). Nets were set in the late afternoon, checked the following morning (0900-1100 hours), reset and checked in the afternoon (1400-1700 hours) and again the following morning (0900-1100 hours). A total of 20 nets were set. Electrofishing was conducted during daylight hours. Fish collected were identified and counted, and up to 50 individuals per species measured for length (mm) and weight (grams) (large-bodied species only), and then released.

Figure 2. Boat electrofishing (left) and fyke netting (right)

FINDINGS

- A total of 349 individual fish comprising two native and two exotic fish species were collected in the fyke netting and electrofishing surveys in 2021 (Table 1, Appendix A).

Table 1. Numbers of individual fish species collected in fyke netting and electrofishing surveys

Species	Electrofishing	Fyke	Length (mm)	
			Min-Max	Average
Common Galaxias (*Galaxias maculatus*)	201	4	37-140	96
*Redfin Perch (*Perca fluviatilis*)	0	103	96-245	139
Flat-headed Gudgeon (*Philypnodon grandiceps*)	25	10	25-110	70
*Brown Trout (*Salmo trutta*)	3	3	215-519	397

*Introduced

- Common Galaxias was the most abundant fish collected, comprising 58% of the total abundance (Table 1, Figure 3). Common Galaxias (*Galaxias maculatus*) is a small (max. size ~200 mm) migratory species found in coastal rivers, streams and lakes in southern Australia, New Zealand, and southern South America. The species normally exhibits a diadromous life history (i.e., migrates between marine and estuarine or freshwater habitats as part of their life cycle) (McDowall 1988). Adults migrate downstream to estuaries around autumn–winter, where they spawn during high spring tides around the new or full moon on inundated vegetation (Hicks et al. 2010; Hickford & Schiel 2014). After hatching the larvae drift downstream to the sea, with juveniles migrating back into fresh water in spring–summer (McDowall & Eldon 1980). Common Galaxias is also able to establish landlocked populations which are able to reproduce entirely in freshwater (Chapman et al. 2006). The size of Common Galaxias collected in the surveys ranged from 37 to 140 mm, which represent juvenile and mature individuals. The collection of juvenile Common Galaxias in the surveys suggests that the species is reproducing within West Barwon Reservoir.

- The introduced Redfin Perch (*Perca fluviatilis*) was the second most abundant species collected, comprising 30% of the total abundance (Table 1, Figure 3). This species has become a highly successful invader of aquatic environments, with the capacity to detrimentally impact native fishes through predation and competition (Morgan et al. 2002). A broad range of sizes of Redfin Perch were collected (96 to 245 mm) comprising juvenile and mature individuals.

- Flat-headed Gudgeon (*Philypnodon grandiceps*) were collected in low numbers (Table 1, Figure 3). This species is a small (max. size ~120 mm) non-migratory species found in coastal and inland rivers, streams and lakes in south-eastern Australia. The size of Flat-headed Gudgeon collected in the surveys ranged from 25 to 110 mm, which represent juvenile and mature individuals.

- Small numbers of the introduced Brown Trout were also collected, ranging in size from 215 to 519 mm (Table 1, Figure 3).

Figure 3. Fish species collected in West Barwon Reservoir. Common Galaxias (top left), Redfin Perch (top right), Flat-headed Gudgeon (bottom left), Brown Trout (bottom right)

- No short-finned eels were collected in the current surveys. The short-finned eel is a diadromous species found in eastern Australia, New Zealand, Norfolk Island, Lord Howe Island and New Caledonia. Mature short-finned eels live for up to decades (e.g., 20-30 years) before migrating from freshwater to the sea to spawn, with juvenile eels (known as elvers and glass eels) then migrating from the sea into estuaries about 12 months later (Figure 4) (Arai et al. 1999; Koster et al. 2021). Juvenile migrations into freshwater from the sea are potentially influenced by a range of factors at different spatial scales such as offshore oceanic conditions (e.g. productivity, temperature, current strength and direction) which affect larval feeding, survival and transport (Friedland et al. 2007), and local environmental conditions near the ocean-freshwater interface (e.g. freshwater river plumes, reduced salinities) that can attract migrating fish into freshwater habitats (Jowett et al. 2005), and are not known to be philopatric (i.e., they do not seek to return to the same areas as their parents) (Shen & Tzeng 2007). Short-finned eels are harvested in commercial and recreational fisheries in Australia and New Zealand and have a particular cultural significance to First Nations people. Short-finned eels are listed as ‘Near Threatened’ on the IUCN Red List of Threatened Species (Pike et al. 2019) with barriers to riverine movement and freshwater habitat loss being key threats.

- The absence of short-finned eels in the surveys could indicate that opportunities for movement into the reservoir (and reaches upstream) are limited. Some fish may be able to migrate upstream into the reservoir during certain ‘windows of opportunity’, such as high flow events when the reservoir spills. However, the steep slope of the spillway, as well as dry periods when no water is spilling, would make the spillway impassable to many native fish and impede access to the river upstream of the reservoir (Figure 5).

- The consequences of impeded upstream access past the reservoir for short-finned eel populations are unknown. However, a potential consequence of limited eel establishment in headwater reaches could be altered population structure (i.e., population density and sex ratio). For instance, in upstream reaches, female short-finned eels tend to predominate. If movement is prohibited, demographic differences between upstream and downstream areas of a barrier can be dramatic (Newhard et al. 2021). Furthermore, population densities downstream of barriers can be artificially high, reducing growth and survival. Fish accumulating below barriers may also suffer higher rates of predation from other fish and piscivorous birds (Gehrke et al. 2002).

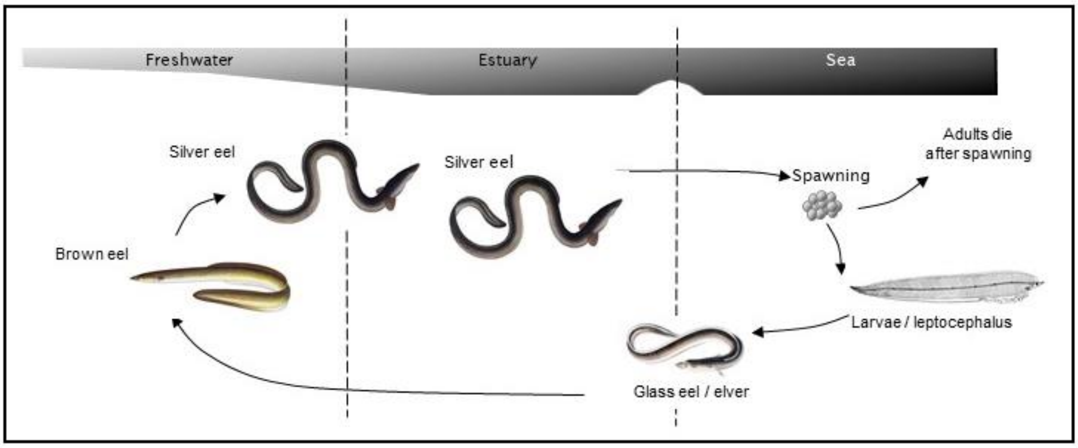

Figure 4. Life cycle of the Short-finned eel (adapted from Koehn & Crook 2013)

Figure 5. Spillway at West Barwon Reservoir

- For eels which do enter the reservoir, the success of their downstream return movement over the spillway (Figure 5) towards the sea to spawn is also unknown. However, injuries and mortality resulting from fish passage over spillways during downstream migration can be significant (Larinier 2001). In addition, searching for suitable passage routes can result in migratory delays, which may prevent fish from moving under favourable environmental conditions. Eel migrations are often synchronized with environmental cues (e.g., river flow, water temperature) which are presumed to promote successful migration, and delays at dams may cause fish to miss an optimal migratory window (Mensinger et al. 2021).

CONCLUSIONS AND RECOMMENDATIONS

- Improved fish passage past West Barwon Reservoir would increase opportunities for short-finned eel and migratory fish species to access habitats in the upper reaches of the system. Currently, upstream access to the 51 square kilometre catchment on the West Barwon River is impeded. Notwithstanding, the provision of fish passage over the reservoir is considered difficult (Alluvium 2021).

- Furthermore, other fish passage barriers in the catchment are considered higher priority for improving fish passage, particularly those in the lower reaches (e.g. Barwon Breakwater, Buckley's Falls, Barwon barrages) because they restrict access to a greater amount of habitat for migratory fishes such as short-finned eel migrating upstream from the sea (Marsden et al. 2016).

- The CCMA has recently installed fish passage infrastructure at the lower Barwon at two key sites, the Lower Barwon Tidal Barrage and at the Reedy Lake Outlet regulator. This includes a cone fishway, Vertical Slot Fishway and elver ramps at the Barrage and a Vertical Slot Fishway and Elver Ramp at the Reedy Lake Outlet. Other barriers in the Lower Barwon that require further mitigation when funding is available includes numerous regulators and infrastructure associated with the lower Barwon Wetlands and Buckley's Falls/Baum Weir (Denis Lovric, pers. comm.).

- More broadly, crucial gaps in our knowledge of the life history of eels that limit our ability to develop targeted conservation and management strategies need to be addressed (Righton et al. 2021).

    - A critical life history phase of eels is the downstream migration of adults from freshwater into the sea to spawn. Environmental flows to stimulate adult eels to migrate downstream have been recently incorporated into streamflow management plans for coastal rivers such as the Barwon-Moorabool river systems. However, the linkages between river flow, including environmental watering events, and migration of adult eels have not been comprehensively tested or validated. Establishing an acoustic tracking program in the Barwon-Mooraboolriver system to investigate migration would help to provide evidence to validate and support refinement and implementation of environmental flows to assist the management and conservation of eel populations.

    - The life history of eels is also characterised by extensive migrations into freshwater/estuaries from the sea by juveniles. The strength and success of these migrations determines the status and sustainability of adult eel stocks in freshwater into the future. Establishing a long-term monitoring program for the Barwon-Moorabool River system to determine annual recruitment trends of juvenile eels would allow for long-term analysis of trends and status of juvenile eel stocks and associated environmental drivers. This information is needed, for example, to improve our understanding of the effects of flow on juvenile migration, and to ensure environmental water entitlements are used to achieve the best environmental outcome with the water that is available.

- A long-term monitoring program of migratory fish populations in the Barwon-Moorabool river system would also help to fill knowledge gaps and develop targeted conservation and management strategies.

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Appendix A Length and weight details of fish collected

Collection method	Species	Length (mm)	Weight (g)
Electrofishing	*Galaxias maculatus*	108	
Electrofishing	*Galaxias maculatus*	103	
Electrofishing	*Galaxias maculatus*	132	
Electrofishing	*Galaxias maculatus*	98	
Electrofishing	*Galaxias maculatus*	85	
Electrofishing	*Galaxias maculatus*	120	
Electrofishing	*Galaxias maculatus*	123	
Electrofishing	*Galaxias maculatus*	79	
Electrofishing	*Galaxias maculatus*	96	
Electrofishing	*Galaxias maculatus*	88	
Electrofishing	*Galaxias maculatus*	67	
Electrofishing	*Galaxias maculatus*	128	
Electrofishing	*Galaxias maculatus*	98	
Electrofishing	*Galaxias maculatus*	111	
Electrofishing	*Galaxias maculatus*	125	
Electrofishing	*Galaxias maculatus*	70	
Electrofishing	*Galaxias maculatus*	112	
Electrofishing	*Galaxias maculatus*	103	
Electrofishing	*Galaxias maculatus*	106	
Electrofishing	*Galaxias maculatus*	100	
Electrofishing	*Galaxias maculatus*	75	
Electrofishing	*Galaxias maculatus*	83	
Electrofishing	*Galaxias maculatus*	95	
Electrofishing	*Galaxias maculatus*	83	
Electrofishing	*Galaxias maculatus*	78	
Electrofishing	*Galaxias maculatus*	82	
Electrofishing	*Galaxias maculatus*	97	
Electrofishing	*Galaxias maculatus*	82	
Electrofishing	*Galaxias maculatus*	83	
Electrofishing	*Galaxias maculatus*	81	
Electrofishing	*Galaxias maculatus*	94	
Electrofishing	*Galaxias maculatus*	107	
Electrofishing	*Galaxias maculatus*	122	
Electrofishing	*Galaxias maculatus*	108	

Electrofishing	*Galaxias maculatus*	94
Electrofishing	*Galaxias maculatus*	78
Electrofishing	*Galaxias maculatus*	104
Electrofishing	*Galaxias maculatus*	37
Electrofishing	*Galaxias maculatus*	113
Electrofishing	*Galaxias maculatus*	132
Electrofishing	*Galaxias maculatus*	90
Electrofishing	*Galaxias maculatus*	69
Electrofishing	*Galaxias maculatus*	140
Electrofishing	*Galaxias maculatus*	88
Electrofishing	*Galaxias maculatus*	86
Electrofishing	*Galaxias maculatus*	79
Electrofishing	*Galaxias maculatus*	131
Electrofishing	*Galaxias maculatus*	47
Electrofishing	*Galaxias maculatus*	102
Electrofishing	*Galaxias maculatus*	93
Electrofishing	*Philypnodon grandiceps*	25
Electrofishing	*Philypnodon grandiceps*	106
Electrofishing	*Philypnodon grandiceps*	84
Electrofishing	*Philypnodon grandiceps*	53
Electrofishing	*Philypnodon grandiceps*	93
Electrofishing	*Philypnodon grandiceps*	59
Electrofishing	*Philypnodon grandiceps*	73
Electrofishing	*Philypnodon grandiceps*	103
Electrofishing	*Philypnodon grandiceps*	53
Electrofishing	*Philypnodon grandiceps*	53
Electrofishing	*Philypnodon grandiceps*	51
Electrofishing	*Philypnodon grandiceps*	76
Electrofishing	*Philypnodon grandiceps*	48
Electrofishing	*Philypnodon grandiceps*	95
Electrofishing	*Philypnodon grandiceps*	86
Electrofishing	*Philypnodon grandiceps*	37
Electrofishing	*Philypnodon grandiceps*	90
Electrofishing	*Philypnodon grandiceps*	51
Electrofishing	*Philypnodon grandiceps*	40
Electrofishing	*Philypnodon grandiceps*	64
Electrofishing	*Philypnodon grandiceps*	39

Electrofishing	*Philypnodon grandiceps*	55	
Electrofishing	*Philypnodon grandiceps*	50	
Electrofishing	*Philypnodon grandiceps*	46	
Electrofishing	*Philypnodon grandiceps*	37	
Electrofishing	*Salmo trutta*	435	779
Electrofishing	*Salmo trutta*	372	572
Electrofishing	*Salmo trutta*	215	126
Fyke Net	*Perca fluviatilis*	239	246
Fyke Net	*Perca fluviatilis*	240	232
Fyke Net	*Perca fluviatilis*	96	9
Fyke Net	*Perca fluviatilis*	169	66
Fyke Net	*Perca fluviatilis*	100	11
Fyke Net	*Perca fluviatilis*	157	54
Fyke Net	*Perca fluviatilis*	245	228
Fyke Net	*Perca fluviatilis*	128	29
Fyke Net	*Perca fluviatilis*	152	47
Fyke Net	*Perca fluviatilis*	166	57
Fyke Net	*Perca fluviatilis*	147	45
Fyke Net	*Perca fluviatilis*	115	20
Fyke Net	*Perca fluviatilis*	136	35
Fyke Net	*Perca fluviatilis*	112	18
Fyke Net	*Perca fluviatilis*	178	75
Fyke Net	*Perca fluviatilis*	170	61
Fyke Net	*Perca fluviatilis*	232	191
Fyke Net	*Perca fluviatilis*	116	20
Fyke Net	*Perca fluviatilis*	113	19
Fyke Net	*Perca fluviatilis*	110	12
Fyke Net	*Perca fluviatilis*	125	27
Fyke Net	*Perca fluviatilis*	132	28
Fyke Net	*Perca fluviatilis*	126	22
Fyke Net	*Perca fluviatilis*	111	15
Fyke Net	*Perca fluviatilis*	138	36
Fyke Net	*Perca fluviatilis*	110	19
Fyke Net	*Perca fluviatilis*	118	21
Fyke Net	*Perca fluviatilis*	136	34
Fyke Net	*Perca fluviatilis*	122	23
Fyke Net	*Perca fluviatilis*	122	22

Fyke Net	*Perca fluviatilis*	125	23
Fyke Net	*Perca fluviatilis*	124	23
Fyke Net	*Perca fluviatilis*	137	31
Fyke Net	*Perca fluviatilis*	131	29
Fyke Net	*Perca fluviatilis*	122	24
Fyke Net	*Perca fluviatilis*	107	15
Fyke Net	*Perca fluviatilis*	132	30
Fyke Net	*Perca fluviatilis*	138	33
Fyke Net	*Perca fluviatilis*	127	27
Fyke Net	*Perca fluviatilis*	120	19
Fyke Net	*Perca fluviatilis*	126	25
Fyke Net	*Perca fluviatilis*	98	11
Fyke Net	*Perca fluviatilis*	111	18
Fyke Net	*Perca fluviatilis*	120	25
Fyke Net	*Perca fluviatilis*	182	88
Fyke Net	*Perca fluviatilis*	135	34
Fyke Net	*Perca fluviatilis*	106	13
Fyke Net	*Perca fluviatilis*	124	26
Fyke Net	*Perca fluviatilis*	137	31
Fyke Net	*Perca fluviatilis*	139	36
Fyke Net	*Perca fluviatilis*	118	22
Fyke Net	*Perca fluviatilis*	129	23
Fyke Net	*Perca fluviatilis*	126	23
Fyke Net	*Perca fluviatilis*	180	86
Fyke Net	*Perca fluviatilis*	155	49
Fyke Net	*Perca fluviatilis*	213	146
Fyke Net	*Perca fluviatilis*	103	17
Fyke Net	*Perca fluviatilis*	156	46
Fyke Net	*Perca fluviatilis*	134	38
Fyke Net	*Perca fluviatilis*	158	52
Fyke Net	*Perca fluviatilis*	176	85
Fyke Net	*Perca fluviatilis*	111	16
Fyke Net	*Perca fluviatilis*	128	33
Fyke Net	*Perca fluviatilis*	136	37
Fyke Net	*Philypnodon grandiceps*	110	19
Fyke Net	*Philypnodon grandiceps*	73	
Fyke Net	*Philypnodon grandiceps*	101	

Fyke Net	*Philypnodon grandiceps*	85	
Fyke Net	*Philypnodon grandiceps*	88	
Fyke Net	*Philypnodon grandiceps*	77	
Fyke Net	*Philypnodon grandiceps*	83	
Fyke Net	*Philypnodon grandiceps*	95	
Fyke Net	*Philypnodon grandiceps*	106	
Fyke Net	*Philypnodon grandiceps*	76	
Fyke Net	*Salmo trutta*	444	1143
Fyke Net	*Salmo trutta*	394	621
Fyke Net	*Salmo trutta*	519	1500