Wimmera Native Fish Management Plan

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July 2022

Arthur Rylah Institute for Environmental Research

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Acknowledgment

We acknowledge and respect Victorian Traditional Owners as the original custodians of Victoria's land and waters, their unique ability to care for Country and deep spiritual connection to it. We honour Elders past and present whose knowledge and wisdom has ensured the continuation of culture and traditional practices.

We are committed to genuinely partner, and meaningfully engage, with Victoria's Traditional Owners and Aboriginal communities to support the protection of Country, the maintenance of spiritual and cultural practices and their broader aspirations in the 21st century and beyond.

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Citation: O'Connor, J., Cornell, G. and Stuart, I. (2022). Wimmera Native Fish Management Plan. Unpublished Client Report for the Wimmera CMA. Arthur Rylah Institute for Environmental Research, Department of Environment, Land, Water and Planning, Heidelberg, Victoria.

Front cover photo: Jeparit Weir

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Unpublished Client Report for the Wimmera CMA

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Acknowledgements

We thank the following people for attending a workshop and contributing valuable information: Dion Lervasi, Bruce McInnes, Dave Brennan, Greg Fletcher, Rachel Austin, Zeb Tonkin and Tarmo Raadik. We are grateful for detailed comments from reviewers including Dave Brennan, Greg Fletcher, Bruce McInnes, Dean Lawson, Deb Nitschke and for feedback from the Project Community Steering Committee.

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Summary Scope and vision

The Wimmera River in western Victoria is Victoria's largest terminal river system, with a valuable native fish community consisting of many indigenous and translocated species.

Native fish in the region have been strongly degraded by declining stream flows, reduced connectivity, impacts of invasive species and habitat loss. Major loss of aquatic biodiversity occurred during the Millennium Drought when several species disappeared from large parts of their range.

However, enhancements in waterway condition through riparian protection works and environmental watering provides an opportunity to reverse these declines and achieve sustainable improvements in local fish populations.

To assist in recovery of aquatic biodiversity, the Wimmera Catchment Management Authority (Wimmera CMA) commissioned the Arthur Rylah Institute to produce a Wimmera Native Fish Management Plan ("the Plan"). The principal objectives of the Plan are to guide strategic management, environmental flow regimes, cost-effective investment and recovery of native fish communities in the region. The overarching vision of the Plan, over its 20-year implementation horizon, are that:

"The waterways of the Wimmera River catchment have abundant and diverse native fish populations that enhance the region's environmental, cultural and socio-economic values."

The Plan recognises how improving circumstances to promote and enhance fish populations, while part of an important environmental-health picture, also has broad value in promoting and stimulating community liveability through recreational angling and cultural opportunities.

Methods

To identify opportunities for fish recovery, the Plan was built on a framework of stakeholder workshops, site inspections and a literature/data review. It divided the Wimmera catchment into five bioregions to assist in identifying native fish recovery opportunities and then applying a transparent multi-criteria prioritisation process.

Many of the priorities were set within a context of translocation of fish to re-establish their past historic range (i.e., prior to the Millennium Drought) and to take advantage of more reliable baseflows following the completion of the Wimmera-Mallee Pipeline.

In addition, there are several opportunities to test and potentially augment local fish recruitment during wet and average inflow years.

Target Wimmera River catchment bioregions:

1. Lower Wimmera River
2. Upper Wimmera River and tributaries
3. Mt William Creek
4. South-western tributaries – MacKenzie River
5. Northern distributaries

New Directions

A number of potential fish-recovery opportunities were identified which the Plan examines in detail, synthesising hydrological and ecological information, to guide management.

In the upper Wimmera system (e.g., MacKenzie River, Mount William and Mount Cole Creeks) there are immediate opportunities to re-establish several native fish species (e.g., River Blackfish and Southern Pygmy Perch) within their former range via translocation.

While in the mid and lower reaches of the Wimmera River we recommend refining the current hydrographs to provide improved opportunities for nesting species, such as Freshwater Catfish, River Blackfish and Murray Cod.

The Plan also recognises that flows are becoming scarce in the Wimmera catchment due to changes in rainfall and runoff and accounts for this by proposing dry, average, and wet-scenario recovery actions.

In wet years there is an opportunity to experimentally test a mid-catchment (i.e. Horsham area) flow regime to support Golden Perch spawning. By contrast, in dry years, the Plan recommends protecting drought refuges which become sources of fish to recolonise when flows return.

For recreational anglers, the Plan highlights several practical ways to support recreational fishing species including reaches where complementary river recovery actions, such as re-snagging, fishways, and riparian restoration is a priority. The Plan provides a strategic direction for enhancing native fish communities and for the Wimmera system to meet a more multifaceted role, of water supply, conservation, recreation and broader economic benefits. The Plan provides value by providing a pathway to: (i) increase the diversity and resilience of native fish, (ii) increased regional investment, and (iii) increase angling opportunities in the region.

Priority 1

Translocations

- Re-establish River Blackfish populations, via translocation, in the MacKenzie River between Dad and Dave Weir and Distribution heads

Stocking

- Investigate stocking of GP into Lake Lonsdale during wet year scenarios, especially where there is high primary productivity and link with experimental efforts to cue spawning/recruitment in the mid-lower Wimmera River.

Communication/recreation

- Promote Wimmera as a peak fishing destination and managing potential impacts through improved access and responsible behaviour

Habitat

- Enhance woody habitat in priority areas (e.g. refuge pools, de-snagged stretches devoid of future natural supply of woody habitat due to a lack of riparian vegetation).

Priority 2

Translocations

- Re-establish River Blackfish populations, via translocation, in Mt Cole Creek downstream of Warrak.
- Re-establish Southern Pygmy Perch populations, via translocation, in Mt William Creek (including Roses Gap Road).

Habitat

- Investigate riparian habitat improvements (including riparian fencing) and vegetation control in Glenlofty Creek in preparation for future River Blackfish reintroduction.

Flows

- Investigate Golden and Silver Perch spawning and recruitment ecology and links to managed flows, movement and habitat in the mid/lower Wimmera River (Horsham to Dimboola).
- Investigate optimising Wimmera River (and tributaries) hydrographs for the maintenance and improvement of the entire fish community (including naturally spawned (i.e. Freshwater Catfish and River Blackfish) and stocked fish (i.e. Golden Perch).

Monitoring

- Conduct fish surveys in the mid to upper Wimmera River (i.e. upstream and downstream of Glenorchy) to assess potential and appropriateness of future fish translocations.

Priority 3

Translocations

- Re-establish River Blackfish populations, via translocation, in Burnt Creek and lower MacKenzie River (downstream of Distribution Heads).

- Ranch Billabong- investigate with Barengi Gadjin Land Council, a collaborative reintroduction of small-bodied fish species including Southern Pygmy Perch or angling species such as Golden Perch.

Introduced species

- Investigate optimal management of invasive Carp from Jeparit Weir to Lake Hindmarsh

Priority 4

Translocations

- Establish populations of native, small bodied fish, including Southern Pygmy Perch, into six securely watered refuge pools
- Investigate River Blackfish and Obscure Galaxias reintroduction into the Glenorchy Weir Pool area.

Introduced species

- Investigate constraints to Murray Cod spawning and recruitment and survival in mid/lower Wimmera River (in area around Horsham).

1 Introduction

The Wimmera River is unique in Victoria, being the state's largest endorheic river system, meaning that it terminates within an inland lake system instead of in the ocean. As a result, many of Victoria's iconic native fishes, such as Golden Perch (*Macquaria ambigua*) and Freshwater Catfish (*Tandanus tandanus*) are believed to be not indigenous to the system. However, there is an extensive history of stocking/breeding of these species, and the Wimmera system now supports an important recreational fishery, with several large annual fishing competitions. In addition to these introduced native species there are a number of indigenous species including River Blackfish (*Gadopsis marmoratus*), which historically formed the basis of a healthy recreational fishery, along with smaller species such as Southern Pygmy Perch (*Nannoperca australis*), Obscure Galaxias (*Galaxias oliros*), Australian Smelt (*Retropinna semoni*), Flat-headed Gudgeon (*Philypnodon grandiceps*) and even a single report of Purple Spotted Gudgeon (*Mogurnda adspersa*).

The native and indigenous fish community in the Wimmera Catchment Management Authority (Wimmera CMA) jurisdiction face significant threats from reduced connectivity, altered flow regimes (including loss of seasonal flow components), impacts of invasive species, habitat loss and climate change, and the native fish community has been severely impacted as a result. Hence, a Wimmera Native Fish Management Plan ("the Plan") is needed to manage and restore native fish populations, to prevent further species decline and, in the process, promote Wimmera as a peak conservation and recreational fishing destination. The Plan, commissioned by Wimmera CMA and developed with the assistance of key local anglers and agency representatives, will be used to guide strategic management, cost-effective investment and recovery of native fish communities in the region. The plan aims to address objectives from community, recreational anglers and Traditional Owners.

The overarching vision of the Plan is that:

*"*The waterways of the Wimmera River catchment have abundant and diverse native fish populations that enhance the region's environmental, cultural and socio-economic values."

"

The Plan will have an implementation horizon of 20 years and when fully delivered aims to:

1. Guide the delivery of environmental flow regimes to support fish populations, integrating future water use and climate change scenarios
2. Guide on-ground recovery programs for locally extinct and threatened native fish species
3. Enhance recreational fisheries, building the Wimmera system as a destination fishery
4. Where appropriate, restore the ecological connectivity of rivers and wetlands
5. Reduce the impact of invasive species and other processes threatening local native fish communities.
6. Improve riparian and instream habitat

The Plan will be underpinned by a holistic view of native fish recovery and as such will guide investment in environmental flows, enhanced recreational fisheries, habitat rehabilitation, threatened species rehabilitation, aquatic connectivity and pest management. Benefits of restoring native fish populations (including non-indigenous recreational species) in the Wimmera include increased diversity and resilience of native fish, increased regional investment, and increased angling opportunities in the region.

There were several steps involved in the production of the Plan, which incorporates the five following sub-projects:

1. Inception meeting

2. Stakeholder workshop with reference group of local angler and agency representatives to inform opportunities and background information

3. Development and presentation of literature review and opportunities report to the Project Technical Advisory Group (TAG)

4. Capture and incorporate TAG and reference group's feedback into a draft Wimmera Native Fish Management Plan

5. Incorporate comments from the TAG to produce a final Plan

Purpose and structure of this report

This report presents a draft Wimmera Native Fish Management Plan, which includes:

1. a detailed description of the study area (including suggested management units),
2. a summary of fishes in the Wimmera Recovery area (including historical, present and potential future fish populations),
3. threats to fish and
4. potential recovery actions/levers.

Further feedback from key stakeholders, the TAG, and independent reviewers will be incorporated. The background information in this section is then used as the basis for the draft fish-management plan. In the Plan, key threats and opportunities are collated, and an initial prioritisation of management actions is presented based on the expertise of the project team, with a focus on ecological outcomes. This work can be further refined in the future via a more formal prioritisation process. The report concludes by highlighting key considerations in the future development of the Plan.

1.1 Study area

1.2 General

The Wimmera River catchment, located in western central Victoria covers a total of approximately 23,000km^2. The Wimmera River mainstem begins in the Pyrenees, north-east of Ararat, and flows close to 300km (Figure 1). The system is most unique within Victoria because it does not flow into the sea or to the Murray River but terminates in a series of large freshwater lakes.

Rainfall varies throughout the catchment from approximately 700mm in the south to approximately 400mm in the north near Warracknabeal. Rainfall is also very variable between years. In some elevated areas of the Grampians, rainfall can be as high as 1100mm/year. The hydrology of the entire system is characterised by extreme fluctuations in rainfall from year-to-year and over summer and autumn waterways often become intermittent, with long periods (months) without flow. In the Millennium Drought (1997-2010) there was little rain and refuge pools were disconnected in the upper unregulated sections of the Wimmera River and its tributaries. By contrast, in a very wet period, many large waterways can experience year-round flow. Apart from the occasional wet year, since the Millennium Drought ended, the region experiences ongoing dry conditions and stream flows are limited. This is most profound in summer when it results in declining water quality (salinity, nutrient levels, temperature and dissolved oxygen) placing biota under additional stress.

In this report we have separated the system into five main areas (Figure 1):

1. the Wimmera River mainstem which runs in a south/north trending direction for just under 300 km and has four main tributary/distributary systems,
2. the Mt Cole/Glenlofty creeks (South Eastern Tributaries), which drain the south-eastern edge of the catchment and join the Wimmera River approximately 80 km upstream of Horsham,
3. the MacKenzie/Burnt creeks (South Western tributaries) which runs along the south western edge of the catchment and joins the Wimmera River mainstem near Horsham,
4. the Mount William Creek (South Central tributary) which runs in a southerly direction between these two other major tributaries and joins the Wimmera River approximate 30km upstream of Horsham and,
5. in the northern part of the catchment there are two main distributary systems, the Yarriambiack and Dunmunkle creeks, that run in a northerly direction.

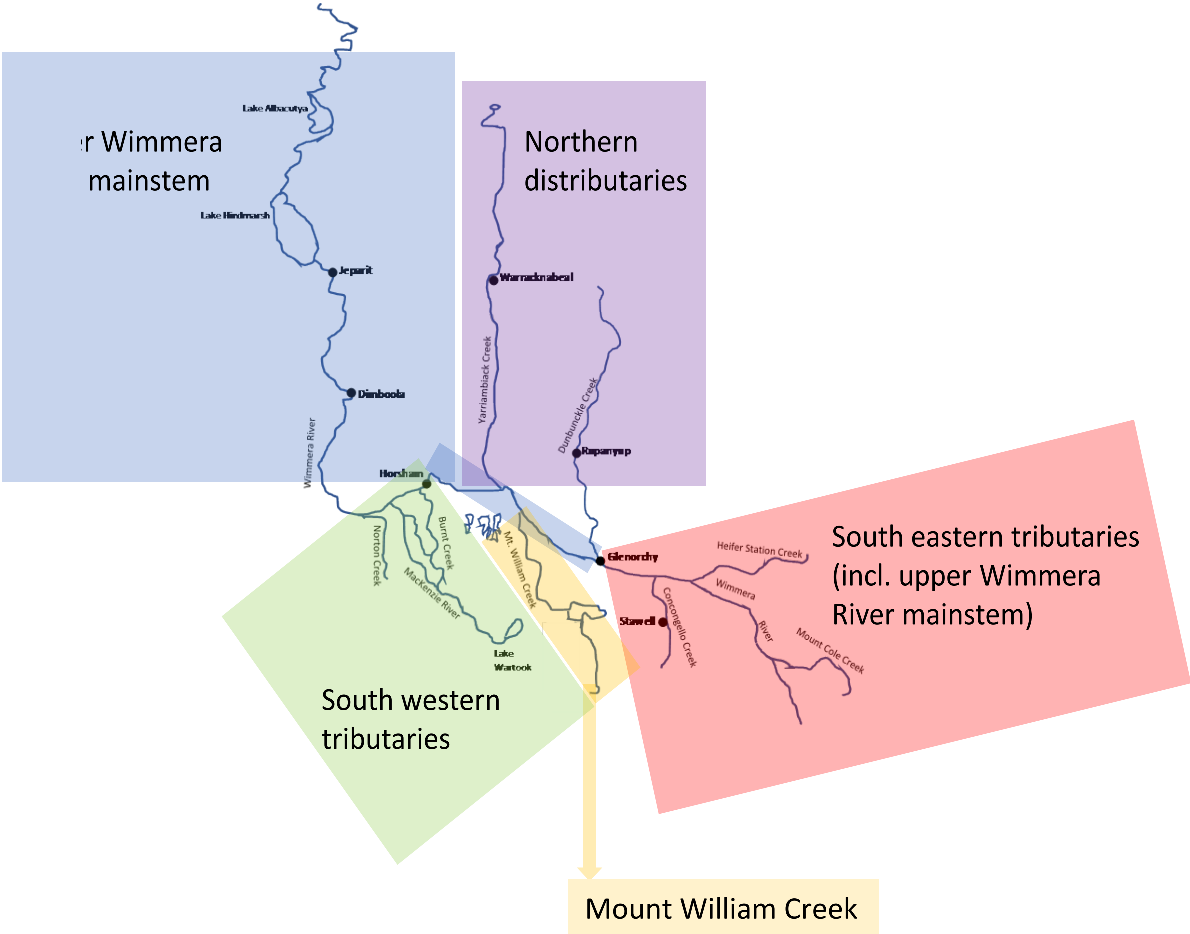

Figure 1 Map of the Wimmera River catchment and five main management areas considered in this plan

1.2.1 Wimmera River mainstem

The Wimmera River mainstem encompasses the area from Huddleston's Weir near Dadswells Bridge downstream to the terminal lakes of Hindmarsh and Albacutya. Not far downstream of Huddleston's Weir the Mt William Creek enters the Wimmera River mainstem. The river then travels a further 40km before entering the Horsham weirpool. Downstream of Horsham, the Wimmera River travels in a northerly direction for approximately 60km before entering the Dimboola weirpool. The river then travels for approximately another 50km before entering the Jeparit weirpool and then Lake Hindmarsh. During high river flows, Lake Hindmarsh fills to capacity (431 GL capacity) then spills and travels approximately 25km in a northerly direction before entering Lake Albacutya (290GL capacity) which fills approximately several times each century. In very wet years Lake Albacutya can overflow into Outlet Creek which in turn supplies a number of smaller wetlands (e.g. Lake Brambuk) and beyond this the true terminal lake of the Wimmera River is the Wirrengren Plain in the southern Mallee. Lake Hindmarsh (up to 3.4m deep when full) and Albacutya (up to 8m deep when full) are the two largest natural freshwater lakes in Victoria by area. Upstream regulation has severely impacted on the frequency of inundation of lakes Hindmarsh and Albacutya. The Barengi Gadjin Land Council, which represents the traditional owners with respect to cultural heritage, indicates a strong emphasis should be placed on the fact that flows used to regularly travel much further than Lakes Hindmarsh and Albacutya, overflowing into Outlet Creek. Interestingly, there are also some unconfirmed accounts that historically (pre-European), the Wimmera River system would overflow and continue to travel north in major floods and eventually create a link with the Murray River system.

There are three town weirs in the lower Wimmera River mainstem located at Horsham, Jeparit and Dimboola which have existed in various forms for over 100 years. These weirs create significant barriers to fish movement, and none have fishways. Indeed, fish passage has historically not been proposed for the Jeparit town weir in order to manage the movement of carp upstream into the Wimmera mainstem from Lake Hindmarsh.

Huddleston's Weir represents the first opportunity to divert water away from the Wimmera River mainstem. From here, depending on water quality (salinity and turbidity), water can be diverted from the Wimmera River and into Taylors Lake. However, since the construction of the Wimmera Mallee Pipeline this is not as frequent due to the creation of passing flow rules and water-quality considerations. Prior to the construction of the Wimmera Mallee Pipeline, all low to medium flows were harvested (up to 1600 ML/d) from the Wimmera River and into Taylors Lake and Pine Lake. However, this water can now be allowed to travel further downstream although water-quality issues and water-entitlement rules often determine how and when this is done.

The lower Wimmera River weir pools provide deep pools and refuge for aquatic fauna (notably Freshwater Catfish, Golden Perch and Silver Perch (*Bidyanus bidyanus*) during seasonal dry phases and extended droughts. By providing environmental water during seasonally dry and very dry conditions these refuge habitats are maintained, and their water quality (salinity) remains within the tolerance range of the dependent fauna.

1.2.2 South-west tributaries

The MacKenzie River is the mainstem of the south-western tributaries. Flows from the upper catchment are captured in Lake Wartook, then about 12km downstream the MacKenzie River flows to the Dad and Dave Weir. From Dad and Dave Weir water is diverted into the Mount Zero Channel, where it is harvested for Horsham's water supply. Downstream of Dad and Dave Weir, the MacKenzie River continues to Distribution Heads. During dry periods, flow (and water quality) is maintained in this reach by environmental watering. At Distribution Heads, the MacKenzie River has a confluence with the Burnt Creek (an anabranch with its own catchment). The Moora Channel, which flows out of the Moora Reservoir in the Glenelg catchment, can also supply water to the MacKenzie River at Distribution Heads.

At Distribution Heads, flows from the MacKenzie River can be diverted into Burnt Creek. The upper Burnt Creek travels from Distribution Heads for about 25km downstream to the confluence of the Toolondo Channel (the Toolondo Channel is supplied from Rocklands or Toolondo reservoirs) and Bungalally Creek. At this point water can be diverted from the Toolondo Channel into the lower Burnt Creek, Bungalally Creek or Taylors Lake. The Bungalally Creek flows for about 20km and is a high-flow creek channel that runs back into the MacKenzie River about 3km upstream of the confluence with the Wimmera River near Horsham. Bungalally Creek would naturally flow less frequently than

Burnt Creek and MacKenzie River. As a result, its channel size is much smaller and more ill-defined, not possessing large refuge pools. The Lower Burnt Creek flows downstream of the Toolondo Channel/Bungalally Creek confluence to the Wimmera River mainstem in Horsham - w.

1.2.3 Mt William Creek

The Mt William Creek catchment is comparatively large, straddling the north-eastern edge of the Grampians as well as the western side of the Black Range (near Stawell) and provides inflows to Lake Lonsdale near Hall's Gap. Lake Lonsdale supplies environmental water to some sections of the lower Mt William Creek and subsequently the Wimmera River and occasionally transfers to Taylors Lake. However, during dry years there can be long periods of cease to flow conditions, which limits pool habitat. Similarly, Lake Lonsdale is shallow and prone to drying out every few years during low rainfall periods. When water leaves Lake Lonsdale it flows for about 40km before entering the Wimmera River mainstem, approximately 20km upstream of Horsham. Downstream of Lake Lonsdale the creek splits at Dadswells Bridge and flows, apart from flood flows, travel down the eastern channel through to the Big Pipe outfall and into the Wimmera River near Huddleston's Weir.

Mt William Creek is prone to long cease-to-flow periods which can lead to poor water quality and in particular high salinity. However, upstream of Lake Lonsdale there is a refuge pool in the Mt William Creek at Mokepilly that receives environmental water diverted from the Lake Fyans Outlet Channel (a regulator was constructed in recent years to allow for this). Similarly, downstream of Lake Lonsdale refuge pools can be watered with flows released from the lake when it contains water. Potentially, refuge pools could also be supplied by the trunk main of the Wimmera Mallee Pipeline from Lake Bellfield although the feasibility of this has not been determined.

1.2.4 South-east tributaries

The south-eastern tributaries of the Wimmera River are located east of Stawell and include the upper Wimmera River mainstem, Mt Cole and Glenlofty creeks. The upper sections of these tributaries can flow reasonably frequently and support refuge pools (including groundwater-dependent ones) although further downstream these tributaries are prone to low and cease-to-flow conditions. Mount Cole Creek has experienced a decline in condition attributable to flow stress because of reduced rainfall combined with land use change and historic land practices. Wimmera CMA is exploring the opportunity to supply Mount Cole Creek with small volumes of water from nearby Mount Cole Reservoir along with water from a pipeline currently under construction (East Grampians Pipeline) to enhance refuge pools during dry periods. Opportunities to enhance fish populations might become available because of this environmental watering. It will also be complemented by a riparian works project undertaken by Project Platypus Landcare network.

1.2.5 Northern distributaries

There are two north-flowing distributary systems within the Wimmera River system: the Yarriambiack and Dunmunkle creeks. Water flows into these systems from the Wimmera River mainstem during high-flow events. The larger of the two distributaries is Yarriambiack Creek, which flows for about 120km north of its confluence with the Wimmera River (Yarriambiack Creek offtake is located about 200 metres downstream of the confluence of the Taylors Lake outlet and the Wimmera River). Modifications to the offtake at the Wimmera River confluence means that a varying proportion of flow can be diverted down this tributary depending on flows in the Wimmera River. However, typically low to medium flows very rarely reach Warracknabeal. Along the Yarriambiack Creek there are several weir pools retained for recreational use including Jung, Warracknabeal, Brim and Beulah, which are also supplemented with supplies from the Wimmera Mallee Pipeline (apart from Jung).

Yarriambiack Creek terminates in Lake Coorong (4m deep when full) while Dunmunkle Creek terminates in the southern Mallee. Only large floods reach the terminal lakes (i.e., Lake Coorong fills approximately once every 10 years) and flows beyond this point have occurred only once in the last 50 years).

2 Fishes in the Wimmera River Catchment

2.1 General

Fish fauna of the Wimmera River system can generally be divided into two separate fish communities; the upland community comprising the indigenous River Blackfish, Obscure Galaxias and Southern Pygmy Perch and the lowland fish community comprising of the indigenous Australian Smelt and Flat-headed Gudgeon, as well as the non-indigenous Murray River species, including the large-bodied Freshwater Catfish, Golden Perch, Silver Perch (Figure 2), and Murray Cod (*Maccullochella peelii)* which have been translocated/stocked into the system, largely for recreational fishing purposes, over many decades. Table 1 provides a summary of the ecological information, habitat preferences and conservation status of the Wimmera River fish community. These upland and lowland bioregions do not necessarily capture the transitional area (ecotone) gradation between the two zones, especially for several indigenous species that historically inhabited both regions (i.e., River Blackfish).

The suite of fish species considered for management actions in the Plan are those that are part of the indigenous fish community, currently occur in the Wimmera River system or are a target for recreational fishing. Numerous fish surveys have been undertaken to identify these fish communities (Table 2). Some species are rarely recorded but are not included; for example, Short-finned Eels (*Anguilla australis*) have been historically recorded (Trueman 2011), but very rarely, so they are not explicitly considered here. Likewise, the Yarra Pygmy Perch has only had a single identification (SKM 2005a), so it is also not considered here.

The Wimmera River sustains three threatened species of fish but two of these, Murray Cod and Silver Perch, are stocked and not believed to be self-sustaining. Freshwater Catfish is found in the Wimmera River and Yarriambiack Creek and are self-sustaining and popular angling species in both systems (being the only location in Victoria that they can be legally kept). Fishing competitions are huge drawcards, bringing competitors from other parts of Victoria and South Australia and generating substantial revenue for community groups and local businesses. Fishing also occasionally occurs in the MacKenzie River, Mt William Creek and Burnt Creek. Lakes Albacutya and Hindmarsh are also valued by the community when they contain water for water skiing and excellent fishing, in particular Redfin (*Perca fluviatalis*) and yabbies (*Cherax destructor*).

The fish found in the Wimmera catchment can be grouped into three broad guilds based on their associations with different habitats throughout their life cycle: **channel specialists, off-channel specialists** and **generalists** (Baumgartner et al. 2014; Mallen-Cooper et al. 2014). These habitats use categories are broad and not necessarily mutually exclusive, for instance channel specialists may temporarily access off-channel areas, and vice-versa for off-channel specialists.

1. **Channel specialists** require flowing water to spawn or recruit, and/or often preferentially occupy such areas as adults (e.g., Murray Cod require flowing water for recruitment and Golden Perch require flowing water for spawning). Most of the large- and medium-bodied species fall into this category, and they are often associated with areas of complex structural habitat within the flowing channels (Bond and Lake 2003; Broadhurst et al. 2012; Koehn and Nicol 2014) and have life-history processes related to varying river discharge (King et al. 2016; Koster et al. 2017). They may temporarily access off-channel areas to feed (Stuart and Jones 2006) and may spend longer periods in these productive areas as young fish. For these species, management priorities are likely to include restoring connectivity between flowing reaches, overcoming barriers and delivering flows that support their life-history.
2. **Off-channel specialists** (small-bodied specialist species: SBS) preferentially occupy wetlands and other off-channel areas, requiring access to these areas to complete their life cycles. They may be found in channels, usually in areas of very low or no flow, such as backwaters (e.g. Southern Pygmy Perch *Nannoperca australis*; Bond and Lake 2003). These species may use temporarily inundated floodplains to feed, disperse and spawn (Tonkin et al. 2008; Stoessel 2010; Ellis and Kavanagh 2014) with higher numbers sometimes recorded in post-flood years (Tonkin et al. 2008) although such information is lacking given the current scarcity of these species. For these species, management priorities are likely to include

rehabilitating wetland habitats, securing surface water at these sites and given their scarcity, reintroductions to some sites.

3. **Generalist species** can live and breed under a variety of conditions, with flexible habitat preferences and spawning and recruitment strategies (Baumgartner et al. 2014). When connection is provided, they may move between main channel and off-channel areas under varying conditions (Lyon et al. 2010), sometimes in large numbers (e.g. Carp Gudgeon or Australian Smelt; Papas et al. 2021). They may benefit from the presence of complex structural habitat, although these associations may not be as strong as for off-channel specialists and they will readily use areas of open water (Bond and Lake 2003; Hutchison et al. 2020). For these species, management priorities are likely to include providing access to highly productive floodplain areas and supporting productivity processes in main channels.

Figure 2 A native Silver Perch, a species stocked in the Wimmera River. Picture, Jason Lieschke.

Table 1 Summary of the ecological information, habitat preferences and conservation status of fish considered in the Wimmera River Fish Management Plan, where a significant portion of the species' range is in the Wimmera CMA. Information in this table comes from a variety of sources including: Sanger 1986; Winemiller 1992; Lintermans 2007; Tonkin et al. 2010; Llewellyn 2011; Llewellyn 2014; Koehn et al. 2020; Zukowski et al. 2021; Lyon et al. 2021

	Spawning frequency	Number of eggs	Parental care	Spawning Cues (temperature (T), flow (F))	Spawning Details	Age at maturity	Habitat preference
Large-bodied							
Murray Cod* *Maccullochella peelii*	Annual, single spawning/year	Moderate (6000-110,000)	Yes	T	Nest on hard structure in flowing water	4-6 years	Channel
Medium-bodied							
Golden Perch* *Macquaria ambigua*	Multiple spawning/year	Very high (~350,000; up to 700,000)	No	T,F	Eggs scattered in flowing water, eggs and larvae drift long distances	M: 3 years F: 4 years	Channel
Silver Perch* *Bidyanus bidyanus*	Multiple spawning/year	Very high (up to 500,000)	No	T,F	Eggs scattered in flowing water, eggs and larvae drift long distances	M: 3 years F: 4-5 years	Channel
Freshwater Catfish* *Tandanus tandanus*	Annual single spawning/year	Moderate (9000-60,000)	Yes	T	Nest built in gravel/sand in still/slow-flowing waters	3-5 years	Generalist
River Blackfish *Gadopsis marmoratus*	Annual, single spawning/year	Low (200-500)	Yes	T	Nest on hard structure such as logs and undercut banks	1-2 years	Channel
Small-bodied							
Flathead Gudgeon *Philypnodon grandiceps*	Protracted multiple spawnings/year	Low (500-900)	Yes	T	Nest on hard structure in still water	Likely ~1 year	Generalist
Australian Smelt *Retropinna semoni*	Protracted multiple spawnings/year	Low (100-1000)	No	T	Adhesive demersal eggs scattered	Likely ~1 year	Generalist
Carp Gudgeon species *Hypseleotris spp.*	Annual, single spawning/year	Low (<2000)	No	T	Adhesive deposited on vegetation or structure	Likely ~1 year	Generalist
Obscure galaxias *Galaxias oliros*	Annual, single spawning/year		No		Adhesive deposited on structure	Likely ~1 year	Channel
Southern Pygmy Perch *Nannoperca australis*	Annual, single spawning/year	Low (100-4200)	No	T	Non-adhesive scattered on vegetation in still waters	~1 year	Off-channel

*Australian Murray River native but non-indigenous fish species translocated/stocked into the Wimmera River system over many decades (largely for recreational purposes)

2.1.1 Lower Wimmera River mainstem

Historical distributions

Historically, it is likely that the fish community of the Lower Wimmera would have been predominantly Australian Smelt, Southern Pygmy Perch, Flat-headed Gudgeon and Carp Gudgeon (although there are some thoughts that this species has also been translocated into the catchment). However, there are also early reports of large numbers of River Blackfish near Jeparit (*Weekly Times,* 13 August 1904) and they were reportedly “plentiful” in Lake Hindmarsh (*Bell’s Life and Sporting Chronicle*, 26 October 1867). By the beginning of the 1900s, there are reports of declines in Blackfish numbers, with the *Bairnsdale Advertiser* (18 June 1896) stating “Perch are causing great havoc amongst the blackfish in the Wimmera and the latter are now rarely caught”, and a small note in the *Argus* (15 September 1911) stating that “blackfish seem to be disappearing fast from the Wimmera River”. Records from the 1960s onwards make no mention of River Blackfish downstream of Horsham (SKM 2005a).

The large-bodied Murray River species have been stocked in the Wimmera River throughout the 1900s, although there have been ongoing changes in the numbers and species stocked. Murray Cod were reportedly first stocked in the 1930s, Macquarie Perch (*Macquaria australasica)* as early as 1910, Silver Perch since 1979, Golden Perch since 1949 and Freshwater Catfish since 1979, but likely earlier (SKM 2005a). In 1950, Langtry (Cadwallader 1977) reported Golden Perch in Lake Hindmarsh and Golden Perch and Murray Cod near Jeparit, reportedly with some recruitment.

Contemporary distributions

Recent surveys of the Lower Wimmera River reveal a degraded fish community. Flat-headed Gudgeon are the most commonly caught native species, but usually in low numbers (SKM 2005b, 2006, 2008; Ecology Australia 2016). Carp Gudgeon, and Australian Smelt are occasionally recorded, but in low abundances (SKM 2008, 2010). Southern Pygmy Perch, Common Galaxias, Obscure Galaxias and River Blackfish are largely absent from the lower Wimmera River.

In contrast, Carp are widespread and can reach very high abundances (Ecology Australia 2016; Iervasi and Pickett 2020), with more than 100 fish recorded at some sites in some surveys. Carp can also comprise a substantial portion of fishing competition catches (G. Fletcher, pers. comm). Redfin Perch are also widespread in the lower Wimmera River, also sometimes in high numbers (Ecology Australia 2016, Austral Research and Consulting 2019). Recent trends indicate that these species, whilst still common are not as prolific as years past, potentially due to stocking and improved conditions for native species.

It is unlikely that any of the large-bodied Murray River species are self-sustaining, except Freshwater Catfish. These are no longer stocked but are consistently caught in good numbers during fishing competitions on the Lower Wimmera River system (G. Fletcher, pers. comm.). For example, at Horsham in 2020, 20 Freshwater Catfish were caught, weighing between 340 grams and 981 grams. The Wimmera River System contains one of four self-sustaining Freshwater Catfish populations in Victoria (DSE, 2005) with suitable habitat for nesting sites. Historically, Murray Cod have been stocked in the Wimmera River however the population has never become dominate. In recent years Murray Cod have only been stocked into Taylor’s Lake and can occasionally enter the Wimmera River when water is released into the river if they survive the pressures of the outlet. However, in early 2022 Murray cod were again stocked into the mid-lower Wimmera River (Jason Peters VFA pers. comm.). Silver Perch and Golden Perch are also frequently caught at these competitions.

2.1.2 MacKenzie River- South-west tributaries

General

The MacKenzie River system has some of the highest catch rates of Southern Pygmy Perch and Obscure Galaxias in the Wimmera system. In particular, abundances tend to be higher in the area upstream of Distribution Heads. Reaches of the Burnt Creek and MacKenzie River are thought to be key locations for the breeding of Southern Pygmy Perch, River Blackfish and Obscure Galaxias. However, catches of River blackfish appear to have declined in recent years (Bloink and Coates 2021), probably because of the Millennium Drought. Other small-bodied native fishes are caught occasionally in the system, but in low numbers, and few, large-bodied Murray River species are caught. Carp are sometimes caught in high numbers with Biosis (2012a) capturing 182 fish through the higher parts of the Lower MacKenzie River (downstream of Distribution Heads). Redfin and Gambusia are present through much of the system, and Brown Trout are occasionally caught in the higher reaches, being stocked in Lake Wartook (SKM 2006, Biosis 2012a, 2013).

Historical Distributions

There is little historical information on the fish fauna of the MacKenzie River system. However, it is likely that the community would have consisted of the typical upstream fishes in the higher reaches, including River Blackfish and Obscure Galaxias (as noted by Anderson and Morrison 1989). Likewise, the lower reaches would have been more typical of the lowland fish community, namely Southern Pygmy Perch, River Blackfish, Flathead Gudgeon and Australian Smelt. Since European settlement, large-bodied Murray River species have occasionally been recorded, such as Macquarie Perch in Burnt Creek in 1970 and Freshwater Catfish in 1991, but this is rare (SKM 2005a).

Contemporary distributions

Reaches of the upper MacKenzie River (i.e., upstream of Distribution Heads) and Burnt Creek contain higher abundances of fish than the lower reaches of MacKenzie River. The most abundant of these species is the Southern Pygmy Perch, with recent surveys (Bloink and Coates 2021) recording greater than 600 Southern Pygmy Perch in Burnt Creek and 37 fish in MacKenzie River (downstream of Distribution Heads). Similar trends were observed for Obscure Galaxias, although overall numbers were lower with a total of 41 fish caught. Other native species were recorded in low numbers, including Carp Gudgeon (total = 29) and Flat-headed Gudgeon (total = 4).

Similar trends have been observed in earlier surveys: in 2012, Biosis (2013) caught 1633 Southern Pygmy Perch and 1056 Obscure Galaxias at Bos, and 296 Southern Pygmy Perch and 415 Obscure Galaxias at Grahams Bridge Road. Both sites are at the upper extent of the Lower MacKenzie River (i.e. downstream of the Burnt Creek anabranch) and far fewer fish were caught at the lower sites. Similar trends were observed in Burnt Creek, with higher numbers of these two species at two upper sites and none at the lower three sites.

Wartook to Dad and Dave Weir

Historically, River Blackfish have been found in relatively high abundances in the upper MacKenzie River below Lake Wartook. A 2006 survey (SKM 2006) caught 77 River Blackfish, near Wartook Reservoir, along with 77 Obscure Galaxias and 430 Southern Pygmy Perch. Mount Zero Channel, which diverts water from the MacKenzie River at Dad and Dave Weir for the Horsham water supply, provides good habitat and water quality for River Blackfish recruitment and survival, particularly in the vicinity of syphons which funnel under waterways and roads providing blackfish refuge. This also suggests this reach might be used as a source population of River Blackfish for translocation into other reaches of the Wimmera system. Young Pygmy Perch also hide in instream vegetation throughout the Mount Zero Channel. The channel is also dredged by GWM Water to reduce silt build about every 10 years when instream habitat is removed. Mount Zero Channel has a clay base and high abundances of shrimp and yabbies (i.e., good productivity) which may be enhancing the River Blackfish populations.

Dad and Dave Weir to Distribution Heads

In the reach of river below Dad and Dave Weir, River Blackfish, Southern Pygmy Perch and Obscure Galaxias were very prevalent in the early 2000’s but these fish declined in abundance primarily due to the Millennium Drought (when the reach dried out). However, Southern Pygmy Perch and Obscure Galaxias have partially recovered, but the abundance of River Blackfish in this section of the MacKenzie River remains very low. Reaches of the MacKenzie River, particularly in the area of the Boggy Creek confluence, also have large flood zones (i.e. wide shallow areas/sheets of water) that support good populations of Southern Pygmy Perch (including Young of Year (YOY)) and Burrowing crays. Where possible these areas should not receive "cease of flow" during Southern Pygmy Perch breeding and early juvenile development in order to maintain these large flood zones which appear to be important Southern Pygmy Perch breeding areas.

Between Dad and Dave Weir and Distribution Heads the MacKenzie River is managed with environmental water (made available via the construction of the Wimmera Mallee pipeline) and water transfers to Taylors Lake. While River Blackfish continue to be poorly distributed and in low abundance in this reach it is thought that the species will now benefit due to improved access to environmental water (i.e., diminishing some previous threats). For example, a major threat in this section of river is cease to flow conditions reducing the river to a 'chains of holes'. Under these conditions the reach has drastically reduced instream habitat and native species are driven into the refuge holes where they can be predated by the Redfin Perch population. However, given the non-migratory nature of River Blackfish, re-establishment would be enhanced by translocating adult fish and stocking of hatchery-bred fish (there is a proposed native fish hatchery to be established for the breeding of small/medium sized native fish including River Blackfish and Southern Pygmy Perch).

Lower MacKenzie River downstream of Distribution Heads

Downstream of Distribution Heads the MacKenzie River splits into two channels forming the Burnt Creek anabranch. In this part of the system, River Blackfish, Southern Pygmy Perch and Obscure Galaxias were very prevalent in the early 2000's but these fish have since declined in abundance primarily due to the system drying out for several years during the Millennium Drought, as well as high levels of water extraction. However, while Southern Pygmy Perch and Obscure Galaxias have recovered to a reasonable degree, there is believed to no longer be any River Blackfish in this section of the MacKenzie River.

Burnt Creek

Prior to the Millennium Drought, Burnt Creek had a superior population of River Blackfish relative to the adjacent MacKenzie River, thought to be primarily due to more suitable habitat for that species i.e. the MacKenzie River is shallow and anatomising while the Burnt Creek has more deep pools. Furthermore, Burnt Creek was historically used as a water distribution channel to move water further downstream and therefore had a regular flow regime relative to the adjacent MacKenzie River. Downstream of the Toolondo Channel, the habitat in Burnt Creek is generally excellent and along with the potential for more environmental water this reach represents an ideal opportunity for improvements to River Blackfish populations through the translocation of fish. Indeed, future angling opportunities may also be enhanced by local council plans to construct a walking track adjacent to the creek. Downstream of the Western Highway Burnt Creek has been channelised but this is also a potential site for habitat rehabilitation through resnagging, fencing and riparian improvement.

2.1.3 Mount William Creek

Above Lake Lonsdale

A refuge pool on Mount William Creek at Mokepilly, a potentially important site for population persistence, was first surveyed in 2012 (Biosis 2012b) and has been repeatedly surveyed between 2015 and 2020 (summarised in Iervasi and Pickett 2020). Since 2015, native species richness and abundance at this site has declined. Notably, Southern Pygmy Perch were recorded in relatively high numbers in 2015 but disappeared until they were again collected in the 2022 surveys. Flat-headed Gudgeon are consistently caught, but in varying abundances, while Australian Smelt are not regularly recorded (and in low abundances). Redfin Perch are consistently caught, and in relatively high numbers. Goldfish numbers appear to have recently increased, yet Carp are not present in this reach (upstream of Lake Lonsdale). Stretches of the Mt William Creek and its tributaries are also thought to be key locations for the breeding of Southern Pygmy Perch and Mountain Galaxias. Lake Lonsdale dries out after a few very dry years and can have a salinity as high as 4000-5000 µS/cm when water levels are low. Although water quality is generally much better because of inflows coming from tributaries flowing from the north-east of the Grampians. In Lake Lonsdale there are Redfin and Flathead Gudgeon.

Of particular concern is the apparent constriction of River Blackfish distributions and decline in numbers. Extensive eDNA surveys in 2017 identified no positive samples from 12 areas in Mt William Creek and tributaries.

Below Lake Lonsdale

Water quality out of Lake Lonsdale can be very poor and the salinity levels too high for River Blackfish eggs to fertilise or hatch. Furthermore, the outcomes from environmental water coming out of Lake Lonsdale can be limited because of its high salinity. Downstream of Lake Lonsdale the area can also be prone to long periods of no flow (i.e. 6-7 months). And while at Roses Gap, Ledcourt and Dadswell Bridge there are some refuge areas, these too have dried out during drought periods.

2.1.4 South-eastern mainstem and tributaries

Historical populations

There is an extensive history of translocations of large-bodied Murray River species to the upper reaches of the Wimmera River, summarised by Trueman (2011). Murray Cod were introduced to the upper Wimmera River as early as the 1860s. Interestingly, there were subsequently reports of “numerous” small Murray Cod in the Wimmera (Argus, 6 June 1866, 14 April 1873), suggesting possible spawning.

Macquarie Perch were introduced multiple times through the early to mid-1900s (Anderson and Morison 1989). It is reported by Cadwallader (1981) that by the 1910s, Murray River species had a significant presence in the upper reaches around Ararat. There appear to be no records of Silver Perch or Freshwater Catfish from the Upper Wimmera and tributaries (SKM 2005a). Murray Cod and Golden Perch have been repeatedly stocked in Taylors Lake since the 1900s (SKM 2005a).

Contemporary surveys

Since 2015, there have been several surveys of the south-eastern mainstem and tributaries revealing a fragmented native fish population, with five indigenous species, three Australian native species and five exotic species recorded. The headwaters of the Wimmera and its tributaries have been infrequently surveyed in recent years.

In the upper Wimmera River, Flatheaded Gudgeon are widely distributed and consistently caught but in low numbers, while Southern Pygmy Perch are less frequently caught but have been recorded locally in high abundances when they are found. Australian Smelt are only caught in low numbers, and Obscure Galaxias and River Blackfish are very rare. Two surveys of the tributary Glenlofty Creek have revealed relatively high numbers of Southern Pygmy Perch and recorded some of the highest catches of Obscure Galaxias in recent years, although numbers are still relatively low compared with other areas of the Wimmera River catchment. Flatheaded Gudgeon and Carp Gudgeon are also recorded in the Glenlofty Creek, and very low numbers of Redfin Perch have been the only exotic species recorded in recent surveys. A survey of Mt Cole Creek in 2019 (Water Technology 2020) recorded three indigenous species, Southern Pygmy Perch, Obscure Galaxias and Flat-headed Gudgeon, which also included some evidence of recruitment. Smaller tributaries were sampled during dry conditions in 2018 with very little surface water present in this part of the catchment; a single sample in Glenpatrick Creek caught no fish, one in sample Sandy Creek only caught Eastern Gambusia and one sample in Tom the Taylor Creek caught a single Redfin Perch.

Of particular concern is the apparent constriction of River Blackfish distributions and decline in numbers. Since 2015, they have been very rarely recorded. Extensive eDNA surveys through much of the Upper Wimmera River and its tributaries have returned a handful of positive samples; three positive samples from 12 sites in the Upper Wimmera River, a single positive sample in Glenlofty Creek and a single positive sample at Stony Creek in 2017 from 36 sites. Bloink et al. (2016) caught a single River Blackfish at Eversley, and none of multiple other surveys in the Upper Wimmera since then have recorded River Blackfish.

Large-bodied Murray River species appear to be absent from the upper Wimmera and its tributaries. No Murray Cod, Silver Perch or Freshwater Catfish have been recorded in recent surveys, although Freshwater Catfish were present up until a few years after floods in 2011 (Jarrod Woolley pers.

comm.). Golden Perch are occasionally recorded (i.e. there is a single record of three Golden Perch from one site on the upper Wimmera at Eversley in 2015 (Bloink et al 2016).

Historically the upper south-eastern tributaries have been relatively wet compared with other parts of the system but now they dry out more frequently. There has been concerted efforts to enhance riparian habitat through this part of the catchment although improvements to fish populations are limited due to legacy issues with erosion due to land clearing, gold mining and other practices has resulted in scarce availability of pool habitat.

River Blackfish were doing well in these areas in the early 2000s (including Nowhere, Glenlofty and Mount Cole Creeks). Then following the Millennium Drought and a very dry period leading up to 2014/15 these fish have since disappeared out of the main holes.

Within this reach there are potentially some small environmental watering opportunities via the installation of the East Grampians pipeline which could supply some water to the Mt Cole Creek refuge pools. This watering opportunity, along with possible translocations to enhance River Blackfish distribution, may contribute to enhanced fish populations within the reach. Southern Pygmy Perch and Obscure Galaxias are in the same areas as the River Blackfish.

2.1.5 Northern distributaries

Yarriambiack Creek contains one of four self-sustaining Freshwater Catfish populations in Victoria (DSE, 2005) with suitable habitat for nesting sites. Freshwater Catfish is also a popular angling species in Yarriambiack Creek, being part of the only catchment in Victoria where they can be legally kept. Golden Perch are also found in Yarriambiack Creek with small numbers being regularly stocked into the Brim, Beulah and Warracknabeal weir pools.

Table 2 The years that species have been recorded in the Upper Wimmera River and its tributaries in recent surveys. If a year is repeated, there were two separate surveys in that year. The years a survey was conducted in an area are included for comparison, as not all species were recorded in each year. Absolute numbers are not included as multiple different methods were used, precluding an even comparison. * denotes a survey was eDNA targeting only River Blackfish.

	Upper Wimmera River	Mount William Creek at Mokepilly	Mt William Creek and Tributaries	Glenlofty Creek	Glenpatrick Creek	Sandy Creek	Tom the Tailor Creek	Mt Cole Creek	Stony Creek
Year that surveys have occurred	2016, 2016*, 2017* 2018	2015 x 2, 2016, 2019 x 2, 2020	2017* x 2 2015	2016, 2016*, 2017*, 2018	2016, 2017*	2018	2018	2017*, 2019	2017*
Species									
Indigenous species									
Australian Smelt	2016, 2018	2015, 2015, 2016, 2020	2015	-	-	-	-	-	-
River Blackfish	2016, 2016*	-	2015	2016*	-	-	-	-	2017*
Southern Pygmy Perch	2016, 2018	2015, 2015, 2016, 2019	2015	2016, 2018	-	-	-	2019	-
Obscure Galaxias	2016, 2018	-	-	2018	-	-	-	2019	-
Flatheaded Gudgeon	2016, 2018	2015, 2015, 2016, 2019, 2019, 2020	2015	2016, 2018	-	-	-	2019	-
Australian native species									
Carp Gudgeon	2016, 2018	2015, 2015, 2016	2015	2016, 2018	-	-	-	-	-
Golden Perch	2016	-	2015	-	-	-	-	-	-
Common Galaxias		2015, 2019, 2020	2015	-		-	-	-	-
Exotic species									
Eastern Gambusia	2016, 2018	2015, 2015, 2016, 2019	2015	-	-	2018	-	-	-
Goldfish	2016, 2018	2015, 2015, 2016, 2019, 2019, 2020	2015	-	-	-	-	-	-
Redfin Perch	2016, 2018	2015, 2015, 2016, 2019, 2019, 2020	2015	2018	-	-	2018	-	-
Carp	2016, 2018	2019	2015	-	-	-	-	-	-
Tench	2018	-	-	-	-	-	-	-	-

3 Threats to fish

3.1 General

There are a multitude of threats to freshwater fishes in the Murray Darling Basin (MDB) including within the Wimmera catchment. Koehn et al. (2020) have identified twenty threats of relevance to fishes in the Wimmera catchment (Table 3 Assessment of threats to key species in the southern Murray-Darling Basin (adapted from Koehn et al. 2020). Threats were scored from 1 (low) to 5 (high) by experts; numbers in cells indicate median scores, and colours reflect these scores (dark green = lowest level of threat; red = highest).) including threats that impact the growth and condition, survival, spawning, recruitment, and movement of fish, with each threat impacting different species in various ways.

In this section, we identify and briefly outline the major threatening processes affecting fish and fish habitats in the Wimmera catchment. We use the list compiled by Koehn et al. (2020) to ensure that all potentially relevant threats are considered. For practicability, we group some threats that might have similar impacts or management responses.

Table 3 Assessment of threats to key species in the southern Murray-Darling Basin (adapted from Koehn et al. 2020). Threats were scored from 1 (low) to 5 (high) by experts; numbers in cells indicate median scores, and colours reflect these scores (dark green = lowest level of threat; red = highest).

	Murray Cod	Golden Perch	Silver Perch	Freshwater Catfish	Southern Pygmy Perch
Flow related threats					
Decreased overbank flooding	3	4	3.5	3	3
Decreased in-channel flows	3	4	4	2	2
Altered flow seasonality	3	4	3	3	3
Reduced spawning cues	2	4	4	1.5	1
Reduced movement cues	2	4	4	2	1
Reduced movement pathways	3	4	4	3	3
Loss of lotic habitats	1	3	3	4	4
Loss of riverine lentic habitats	4	4	4	2	1
Loss of refugia	2	2	2	3	4
Non-flow related threats					
Loss into channels	3	3	3	2	1
Decreased instream structure	4	3	2.5	3	2
Decreased aquatic vegetation	2	2	3	4	5
Decreased wetlands	1	3	2.5	4	5
Barriers to longitudinal connectivity	3	5	5	3	2
Barriers to lateral connectivity	2	4	3	4	4
Sedimentation	3	2	2	4	3
Decreased water quality	4	3	3	3	3
Introduced species impacts	3	3	3	5	5

Barriers to movement

Longitudinal connectivity (upstream and downstream) is important for freshwater fishes, as it allows them to complete aspects of their life history linked with movement – such as dispersal, recolonisation, and movements to access specific habitats for spawning, growth or to use as refuges from disturbance. However, instream barriers, such as weirs, can impede the movement of fish upstream and downstream at all life stages. This can stop fish from reaching suitable habitats (e.g. spawning and nursery), that can decrease population numbers and resilience (Baumgartner et al. 2014). Barriers can also block the dispersal of fish to other areas (river reaches or tributaries) that can impact recolonisation (Koster et al. 2020a). Reduced movement pathways and barriers to longitudinal connectivity are important threats for highly mobile species like Golden Perch and Silver Perch (see Table 3 Assessment of threats to key species in the southern Murray-Darling Basin (adapted from Koehn et al. 2020). Threats were scored from 1 (low) to 5 (high) by experts; numbers in cells indicate median scores, and colours reflect these scores (dark green = lowest level of threat; red = highest).; Koehn et al. 2020). Ultimately, disrupted movement can limit resource access, restrict demographic exchange, and impede gene flow (Cosgrove et al. 2018). In contrast to this, barriers can also be useful in the management of fish species including in the preclusion of introduced species from important areas of habitat for native fish species.

Flow

Fish are influenced by multiple components of flow, in particular discharge (the amount of water moving through a system) and hydraulics (the characteristics of flowing water, e.g., depth, velocity, turbulence) (Mallen-Cooper and Zampatti, 2018). Many areas of the Murray Darling Basin have been transformed from flowing to non-flowing habitats and consequently altered fish communities. Changes from riverine specialist to generalist and non-native fishes, highlight these effects. This has relevance to the lower Wimmera River which includes a series of weir pools (three major town weirs) and other deep pools that can endure long periods without flows. However, it is understood that the Wimmera catchment would have typically endured more frequent periods of no flow than most other Victorian river systems.

Climate change poses a risk to most fish species in the MDB (Chessman 2013) and adapting to new rainfall and flow scenarios will be a key challenge for managing native fish population trajectories. The impacts of a likely warmer, drier climate are myriad and difficult to predict, but a likely result of climate change is a reduction of river flow and reduced surface-water availability, with modelling predicting a hotter drier scenario with less overall rainfall, large reductions in winter rainfall, and more intense droughts in the southern MDB by 2030 (Zhang et al. 2020). Hence, the impacts of reduced flows in streams are a good parallel for future climate-change challenges facing native fishes.

The amount of water moving through a system, and the timing of when it does so, can have profound influences on fish and fish-community structure (Ngor et al. 2018). Many species are cued to move for spawning or dispersal by flows (Taylor and Cooke 2012), with species' life-history often strongly influencing their response to flow variation (Mims and Olden 2012). Water regulation and extraction in the Wimmera River and its tributaries has altered the river's flow regime. Within the Wimmera River Catchment there are estimated to be 5,939 stock and domestic dams with a total volume of 12,950 megalitres which reduces average annual streamflows by approximately 11,000 ML/y (SKM, 2011). On top of this is the series of water storages that comprise the Wimmera Glenelg Headworks system, operated by GWM Water.

Low or no-flow periods reduce the amount of habitat for fishes (Stuart et al. 2019). For example, a lower volume of water might mean a reduction in the amount of critical habitat available for some fish species. The loss of baseflows and prolonged cease-to-flow conditions can also restrict refuges (e.g. pools drying completely) and decrease water quality (especially salinity), further restricting appropriate habitat and resulting in fish mortality (Bond et al. 2015; Theim et al. 2017).

The types of flow-dependant habitat that riverine fishes choose to occupy can vary at different scales, from to the meso-habitat type (pool vs run), to the microhabitat type within (sites with particular velocities or depths). Hydraulic diversity supports a variety of meso- and micro-habitat, in turn supporting a variety of fish within a reach. Differences in fish preference for diverse hydraulic habitat can be driven by species (Kilsby and Walker 2012), age (Ayllón et al. 2010) or as fish use different hydraulic habitats to complete different aspects of their life-history. For example, Murray Cod might occupy deeper pools, but then move to flowing-water habitat to breed and recruit (Lintermans 2007).

River regulation has decreased the hydraulic diversity of many parts of the lower Wimmera River. There are areas of still-water habitats upstream of weirs where water flowed prior to river regulation (Mallen-Cooper and Zampatti, 2018). Removal of physical habitat and simplification and straightening of the channel (i.e. Mt

William Creek downstream of Lake Lonsdale) has led to a loss of micro-scale flow diversity, while sedimentation has resulted in a loss of pool habitat, particularly in the upper catchment.

Habitat

Many fishes use instream structure as habitat. The form of this structure can vary, including rock, tree roots or the geomorphic shape of the channel (such as bars, deeper pools or undercut banks); one of the most common forms of structure is submerged woody debris, often as fallen trees. In flowing water, hard structure can create micro-scale flow diversity and provide surface for attachment of algae, periphyton and invertebrates, enhancing local productivity and creating areas for recruitment of channel-specialist species (Humphries et al. 2020). Hard structure also provides shelter for small-bodied species in off-channel areas and can support basal productivity (Crook and Robertson 1999). Hard structure provides areas for attachment of eggs of many fishes and is often used as nesting sites by species that create and protect nests (Lintermans 2007).

Across Victoria, rivers have instream woody habitat volumes on average 41% lower than those from prior to European settlement (Tonkin et al. 2016), with severe impacts on fish. Many large-bodied and medium-bodied channel-specialist fishes are particularly sensitive to removal of structural habitat and their abundances can be limited by the amount of structural habitat (Koehn et al 2009; Lyon et al. 2019). Indeed, decreased structural habitat is likely a contributing factor in the declines of many fish populations (e.g. Crook and Robertson 1999; Brooks et al. 2004; Collares-Pereira and Cowx 2004), and fish population size is often correlated with the amount of or available habitat (Tonkin et al. 2020a). Many rehabilitation projects now focus on placing woody debris in streams to provide habitat (e.g. Bond and Lake 2005, Lyon et al 2019).

Submerged or emergent aquatic vegetation in rivers likely provides shelter and spawning sites for small-bodied specialist species (e.g. Southern Pygmy Perch), many of which are associated with dense vegetation (Bond and Lake 2003; Hutchison et al. 2020). It might also be an important source of autochthonous carbon for basal productivity, particularly if there are limited external inputs. In flowing channels, aquatic vegetation can support several species of fish, particularly in slower-flowing edge areas; it can also be important structural habitat and nursery areas for young fish of larger species, particularly on shallow, warm, productive floodplains or slow-flowing areas in channels (King et al. 2009). Small-bodied generalist species are often strongly associated with such areas (Bond and Lake 2003; Bice et al. 2014) and many use them to spawn (Lintermans 2007). Juveniles of large-bodied channel specialists have been shown to occupy vegetated areas instead of bare substrates (Hutchison et al 2020), and riparian vegetation is used when inundated during high flows (Bice et al. 2014). Recent research (Grove et al 2019) identified Wimmera catchment priority areas for reintroduction of instream woody habitat.

Water quality

Fish require particular water quality (such as salinity, temperature, pH, and dissolved oxygen) to survive and reproduce. The exact parameters can differ by species; for example, some wetlands species are well adapted to low dissolved oxygen content (Zukowski et al. 2021). When the prevailing water quality is outside an individual's tolerance range, it can lead to death. Climate, flow, and geology can all alter these parameters, but there are also several types of events that can dramatically alter water-quality parameters in a short time.

Blackwater events can result in wide-scale fish kills because of low dissolved oxygen levels. These events have previously occurred in the Wimmera River, with an event observed in 2021, the effects of which were able to be moderated (in Horsham Weir Pool) by management of environmental flows into the Wimmera River from Taylors Lake (Baldwin 2021). Ecological and socio-economic impacts of blackwater were highlighted by the recent fish kills in the lower Darling River (Ellis et al. 2021; Koehn 2021). Analysis of archived dissolved oxygen concentrations in the Wimmera River, historical records of fish kills in the catchment and hydrologic records indicate that, while events like those observed at the beginning of 2021 have occurred in the past, they are not that common. The return interval for such events is probably once every 10 to 15 years on average, although this might change considering changing climate (Baldwin 2021).

Cyanobacterial blooms can result in the proliferation of algae that can be toxic to humans and have the potential to cause hypoxia and fish deaths as large amounts of algae decay (Huisman et al. 2018). There is a history of algae blooms in some areas of the Wimmera River and its tributaries and lakes including Taylors Lake and Horsham and Dimboola Weir Pools. Algal blooms were one of the proximate causes of the recent fish kills in the lower Darling River (Sheldon et al. 2021).

Non-native species

Non-native species can have negative impacts on native fishes and are a major threat to some (e.g. Freshwater Catfish, Southern Pygmy Perch; Koehn et al. 2020) through reduction in water quality, competition for food, habitat and through predation. Carp (Figure 3) are common across the Wimmera, and are powerful invaders that compete for food, damage submerged vegetation, and increase turbidity (Koehn 2004). They are often found in main channels and wetlands, where they can spawn and produce high numbers of recruits (Stuart and Jones 2006). Wimmera CMA has trialled several monitoring and control measures to try and reduce the impact of carp within the catchment. Studies using environmental DNA (eDNA) technology and flow manipulations using weirs have helped develop a greater understanding of Carp population dynamics, behaviour, and movement cues within the Wimmera River system (Austral Research and Consulting 2020). Gambusia are ubiquitous and can reach high densities in wetlands. They compete with small-bodied native fish for resources and engage in aggressive fin-nipping; they have been shown to impact the body condition of small native fishes and alter wetland fish assemblage structure when they reach high densities (MacDonald et al. 2012). There is also evidence they might prey directly on early-life history stages of native fish (Brown et al. 2018). Redfin Perch are direct predators on small-bodied native fish and can have severe impacts on these populations (e.g., Flat-headed Galaxias; McNeil 2004). They also compete for food resources with other piscivorous fishes, such as Golden Perch (Wedderburn et al. 2017) and are the main host for the Haematopoietic Necrosis Virus which affected Silver Perch, Obscura Galaxias and trout in laboratory trials but impacts in the wild are unknown (Lintermans 2007).

Figure 3 Introduced Carp can have a severe impact on native fish

3.2 Summary of key threats in the Wimmera

3.2.1 Lower Wimmera River mainstem

Flow

The lower Wimmera River is considered a flow-stressed system because of climate change (low rainfall), water-interception activities (e.g. farm dams) and numerous diversions for bulk water-supply purposes. The Wimmera River's initial diversion point is Huddleston's Weir where flow can be diverted into the Wimmera Inlet Channel to supply Taylor's Lake. However, since the construction of the Wimmera Mallee Pipeline much of the flow now continues down the Wimmera River mainstem. This provides a sharp contrast with arrangements prior to the construction of the Wimmera Mallee Pipeline, when Huddleston's Weir harvested most low-medium flows (up to 1,600 ML/d). In addition to flows from the upper Wimmera River, flow can also be provided to the lower Wimmera River from Lake Lonsdale via Mt William Creek or from Taylor's Lake via the Taylor's Lake Outlet Channel outfall along with outfalls from the MacKenzie River and its tributaries. A sharp decline in flow, particularly during drought periods over the past 20 years, has seen the decline of native species including River Blackfish and Southern Pygmy Perch.

Habitat

The instream habitat in some parts of the lower Wimmera River is considered relatively poor due to previous desnagging and riparian activities and have been prioritised for reintroduction of large woody habitat (Grove et al 2019). This is particularly the case in and around town weir pools and opportunities for natural replenishment are limited.

Water quality

Flows from the upper Wimmera River tend to be comparatively poor water quality. There are pronounced salinity impacts in tributaries flowing into the upper Wimmera River (typically 2000 - 8000 µS/cm during low or no flow conditions). Therefore, when wet conditions occur the salinity impacts are spread further down the river. In the lower Wimmera River saline groundwater typically enters at depths greater than 2 metres and salinity can increase during low flow periods to >50,000 µS/cm with poor outcomes for fish and macroinvertebrates. Since the installation of the Wimmera Mallee Pipeline, when water quality is poor, it is usual for GWM Water to allow all flows to pass downstream rather than harvest volumes into Taylors Lake.

Introduced species

Carp, Gambusia, Redfin, Tench and Goldfish are present within the lower Wimmera River. All these species apart from Tench are understood to be found in large enough numbers to impact native fish populations.

Barriers to movement

Town weirs at Horsham, Dimboola and Jeparit create barriers to fish movement. However, during high-flow events, the lower Wimmera River weirs can be opened to connectivity (removal of drop bars or opening of gates). While some fish passage might be favourable for the future rehabilitation of some species (i.e., Golden perch) it is also thought that some of these weirs play an important role in the control of carp dispersal (i.e., Jeparit Weir). There are also several low-level road crossings with culverts which can affect fish movement at low flows.

Losses to channels

There are not thought to be any major channel offtakes in the lower Wimmera River that are impacting upon native fish populations apart from the Taylor’s Lake Inlet Channel.

3.2.2 South-western tributaries

Flow

Dad and Dave Weir is used to divert water from the MacKenzie River into the Mt Zero Channel for Horsham’s water supply. This diversion impacts upon the flow downstream of Dad and Dave Weir, which often only flows due to environmental water during the drier months. At Distribution Heads flow can be diverted into the lower MacKenzie River and Burnt Creek. Only environmental water releases or spills are released into the lower MacKenzie River. Distribution Heads and in turn Burnt Creek also receive intervalley transfers as inflows from the Moora Channel which begins at Moora Moora Reservoir in the upper Glenelg River Catchment.

Burnt Creek acts as a distribution channel, with water regularly transferred through winter/spring from the MacKenzie River from Distribution Heads via Burnt Creek to the Toolondo Channel which supplies Taylors Lake. The reach of Burnt Creek that flows north from the Toolondo Channel to the Wimmera River now flows only in response to environmental water releases or during floods.

Prior to regulation, Bungalally Creek would have flowed episodically when flows in Burnt Creek were somewhere between 100-300ML/d. Bungalally Creek only now flows in response to environmental watering or flooding.

A sharp decline in flow, particularly during drought periods over the past 20 years, has seen the decline of several native species within this reach, particularly River Blackfish.

Habitat

The 2010 Index of Stream Condition (ISC) assessment indicated that large woody habitat was depleted in the MacKenzie River with average scores of 2 out of 5. However, the MacKenzie River has a virtually intact zone of riparian vegetation. The riparian vegetation along Burnt Creek is in good condition in the upper reach however the lower reach's condition is comparatively poorer with limited understorey vegetation.

Upper Burnt Creek has been modified by frequent water transfers between headworks storages leading to incision and loss of the chain of ponds, although there are still some sizable pools at its most downstream section. Lower Burnt Creek has a section about 15km long that contains an intact chain-of-ponds morphology, however between the Western Highway and Wimmera River it has largely been channelised to improve drainage.

Water quality

Water quality along these waterways is among the best in the region with streamflows from Lake Wartook and downstream tributaries containing low levels of salinity, nutrients, and turbidity. Flows from Moora Channel can be delivered to Reach 3 of the MacKenzie River, Burnt Creek and Bungalally Creek and is of low salinity, however, observations indicate it has higher turbidity than water supplied from Lake Wartook. Likewise, water that can be delivered to the lower Burnt Creek and Bungalally Creek from the Toolondo Channel is of lesser quality (salinity of approximately 1000 µS/cm (GWM Water, 2014)). Summer dissolved oxygen levels can be low but do not appear to have affected fish populations.

Introduced species

Gambusia, Carp, Redfin, Tench and Goldfish are present within the south-western tributaries. However, Carp are believed to be largely absent from the upper reaches of the MacKenzie River and upper Burnt Creek with only small numbers of carp caught downstream. Brown Trout are found in the upper MacKenzie River following regular stockings in Lake Wartook.

Barriers to movement

Dad and Dave Weir has been upgraded with a cone fishway to allow for the passage of Obscure Galaxias, Southern Pygmy Perch and River Blackfish along with the potential to enhance platypus movement. There is no fish passage at Distribution Heads and at the Toolondo Channel offtakes, however given the lack of highly migratory species within this reach, fish passage is currently not considered a high priority.

Losses to channels

Toolondo Channel runs into Burnt Creek downstream of Distribution Heads. Moora Channel is connected to Burnt Creek at Distribution Heads. At Wonwondah, the Toolondo Channel intercepts flows from upper Burnt Creek for supply to Taylor's Lake. Potential diversions from Burnt Creek into the Toolondo Channel (to fill Taylors Lake) might also divert fish.

While there are numerous channel offtakes located throughout the system, none of these are thought to be having profoundly negative impacts on native fish species. Indeed, the diversion and subsequent development of self-sustaining populations of River Blackfish and Southern Pygmy Perch (i.e., Mt Zero Channel) might provide opportunities to source fish for translocation back into the main river channel.

3.2.3 Mt William Creek

Flow

Mount William Creek dries out in reaches above Lake Lonsdale and there is no environmental water available for much of this section. However, there is a refuge pool at Mokepilly which can receive environmental water via a diversion from the Lake Fyans Outlet Channel. The lower Mt William Creek has historically been impacted by low flows when the stock and domestic channel system was in operation, being the third most flow-stressed waterway in Victoria (SKM, 2005c). However, downstream of Lake Lonsdale there is more secure water since the construction of the Wimmera Mallee Pipeline. When Lake Lonsdale contains sufficient water, environmental water releases can take place into the lower Mt William Creek which flows north towards Dadswell's Bridge and into the lower Wimmera River mainstem< However, there are issues around the quality of this water and the delivery of this water needs to be managed accordingly.

Lake Lonsdale was naturally a series of large wetlands and now is a shallow storage (up to 4m deep) with a relatively large surface area (up to 26km^2) and therefore has very high rates of evaporation. This means that with a series of dry years, volumes diminish, and the lake can contain little to no water. Downstream of Lake Lonsdale, Mt William Creek has been modified to divert water into the Wimmera Inlet Channel near Huddleston's Weir and ultimately into Taylor's Lake. Environmental water releases outfall from Mt William Creek via Big Pipe into the lower Wimmera River.

A sharp decline in flow, particularly during drought periods over the past 20 years, has seen the decline of several native species including River Blackfish and Southern Pygmy Perch.

Habitat

The 2010 Index of Stream Condition (ISC) assessment indicated that large woody habitat was depleted, with average scores of 2 out of 5 for the Mt William Creek. Streamside zone scores for the Mt William Creek (which focuses on riparian vegetation) are generally high because much of the creek is located on Crown land. Several kilometres of the lower Mt William Creek closest to Lake Lonsdale has been channelised and straightened to enhance its ability to transfer water to other parts of the headworks' system. This limits its habitat values, with very little remnant pool habitat remaining.

Water quality

The upper Mt William Creek straddles agricultural land in the east and national park in the west and so its water quality is highly variable depending on the prevailing source of runoff. During dry to average conditions, the rocky escarpments of the Grampians is the source of most runoff entering the creek.

During wet conditions, when Lake Lonsdale receives significant inflows from the entire upper Mt William Creek catchment, it is subsequently used to provide environmental water releases. However, this water is of poor quality due to runoff from the eastern agricultural land and can have salinity as high as 5000 µS/cm. Mt William Creek is also prone to long cease-to-flow periods which in turn leads to diminishing water quality, in particular elevated salinity levels.

Blue-green algal blooms are an ongoing issue due to the combination of warm temperatures, high nutrient levels and a lack of flow leading to thermal stratification. Weir pools and water storages (Lake Lonsdale) are frequently impacted by blue green algae blooms. Summer dissolved oxygen levels are variable.

Introduced species

There are Carp, Goldfish, Redfin and Gambusia in the lower Mount William Creek. There are no records of Carp in the upper Mt William Creek.

Barriers to movement

The only major barrier to fish movement is Lake Lonsdale, however given the low diversity and abundance of fish species in this area because of other threats (i.e., low flow), along with the lack of highly migratory species, fish passage on this structure is not thought to be a high priority. At Dadswells Bridge (downstream of Lake Lonsdale) there is a small weir retained by the community for aesthetic purposes. The movement of water from the lower Mt William Creek to the Wimmera River via Big Pipe makes also makes it challenging for fish to easily move between the two waterways.

Losses to channels

A low-level dropboard weir is located on the offtake of Sheepwash Creek from Mt William Creek immediately upstream of the former site of Trudgeon's Weir which the adjacent landholder operates occasionally (i.e. during floods and to divert volumes for stock watering along Sheepwash Creek). So small numbers of fish might be lost into this high-flow channel. Unless fish move through Big Pipe into the Wimmera River, they will be transferred into Taylors Lake via the Wimmera Inlet Channel.

3.2.4 South-eastern tributaries

Flow

The flow regime of south-eastern tributaries is relatively natural with no major diversions. However, there has been a reduction in rainfall and continued increases in farm-dam development and land-use change. This has impacted on the flow regime of this region, resulting in regular cease-to-flow periods and a high degree of contraction into isolated pools, that are thought to be sustained by groundwater supply.

A sharp decline in flow, particularly during drought periods over the past 20 years, has seen the decline of several native species including River Blackfish, Obscure Galaxias and Southern Pygmy Perch.

Habitat

The upper south-eastern tributaries of the Wimmera River have been subject to high levels of disturbance (e.g. riparian vegetation removal, bank erosion, stock access). In most streams the main form of cover available to aquatic fauna is submerged and emergent aquatic vegetation, with smaller amounts of coarse woody debris are also available.

Water quality

Mt Cole Creek consists of isolated pools of varying depth that have variable levels of salinity e.g., water conductivity ranging between 1000- >5000 μS/cm. Dissolved oxygen levels are variable and can be quite low during summer/autumn.

Introduced species

There are numerous introduced fish species including Carp, Goldfish, Redfin, Gambusia and Tench (rare).

Barriers to movement

There is a dam on Spring Creek in the Mt Cole Creek catchment but given there are no known migratory species this is not considered a significant barrier to fish movement. Indeed, the water in this reservoir might be used in the future to provide environmental water to flow-stressed reaches further downstream and enable the rehabilitation of some fish species. Low-level road crossings and other features such as flow gauging weirs and railway crossings with a high head differential can create local barriers at various flow rates.

Losses to channels

There are no channel diversions within the south-eastern tributaries that are thought to have major negative impacts on native fish populations.

3.2.5 Northern distributaries

Flow

Yarriambiack and Dunmunkle creeks have an episodic flow regime. Modifications to the offtake from the Wimmera River means Yarriambiack Creek receives a varying proportion of flow depending on flows in the Wimmera River. Large flood flows are required to reach the end of the creek with low-medium flows over winter/spring rarely reaching Warracknabeal. Yarriambiack Creek towns weirs are now usually supplied via the Wimmera Mallee Pipeline.

Habitat

The 2010 Index of Stream Condition (ISC) assessment indicated that large woody habitat was depleted with average scores of 1 out of 5 for the Yarriambiack Creek. Warracknabeal and Brim weirpools have also been identified for reintroduction of woody debris particularly given their high recreational value and permanence of water (Grove et al 2019) and the potential to enhance Golden perch and Freshwater Catfish populations.

The riparian zone of Yarriambiack Creek is largely intact although narrow and degraded in some places although there has been a lot of work undertaken by landholders to improve this through fencing and revegetation works. The northern distributaries also have very little erosion given the low gradient of the creek.

Water quality

Summer dissolved oxygen levels are thought to be suitable although there have been isolated fish deaths due to low levels in Brim Weir pool.

Introduced species

The northern distributary system has a population of Carp.

Barriers to movement

There are barriers on town weirs at Warracknabeal, Brim, Jung and Beulah, however given the episodic flow regime of these systems there is very little flow between these weirs except during rare high-flow events which makes introduction of fish passage on these structures of limited value. Jung Weir has a fishway.

Losses to channels

There are no channel diversions within the northern distributary system that are thought to have major negative impacts on native fish populations.

4 Wimmera Native Fish Management Plan

4.1 Potential recovery levers

A summary of threats in the Wimmera River catchment indicates that reduced flows, water-level variation, degraded habitat, poor water quality, introduced species (particularly Carp) and reduced connectivity are having a combined impact on the Wimmera River fish community. This has resulted in a reduction in the diversity and abundance of species that previously inhabited different regions of the catchment. While all these threats are contributing to a reduction in the diversity and abundance of fish populations the most limiting is the stressed flow regime of the region due to land-use practises (diversions) and exacerbated by changes in climate (reduced rainfall). Given this, there are several potential interventions such as providing fish passage or the re-introduction of fish species (i.e., River Blackfish) that will be limited by the inability to improve flow management in some regions of the Wimmera River catchment. However, in other regions, due to the construction of the Wimmera Mallee Pipeline, these threats might be partially addressed because of increased environmental water allocations. These levers include improved flow and water management, stocking of recreational fish species, re-introduction of threatened fish species (including translocations), improving habitat through the provision of instream structure and fencing to improve the riparian corridor and, in some cases, the provision of fish passage (while recognising that some weirs might be playing an important role in the control of pest species such as Carp (i.e. Jeparit Weir)).

Environmental flow management

Increasing the extent and duration of baseflows is one of the key recovery actions within the Wimmera. The exact flow that is required to maintain and improve habitats (and fish populations) is based on technical work like environmental flows studies and can be refined with hydrodynamic modelling of habitats and field trials. Improving the hydrodynamic diversity of flows can also improve fish populations through the variation of fast and slow reaches along a stream. These conditions are especially relevant for recruitment of River Blackfish, Freshwater Catfish, and potentially other species such as Golden Perch. Within weir pools and other deep pools there are slightly different objectives for spawning and recruitment of Freshwater Catfish where water levels must be kept constant during the spring spawning season.

Hydrographs

The most significant threat to fish populations in the Wimmera River catchment is periods of no flow. This exacerbates other threats including poor water quality, access to habitat, cues to movement and dispersal along with the potential to reinstate fish passage. Given this, an assessment of the hydrology of the system was undertaken to gain an understanding of how flow in the river is operated and where there might be potential through environmental water to reinstate some of the key flow components that might not be currently supporting fish communities. For example, for nesting species such as River Blackfish and Freshwater Catfish an annual rise in water level followed by a steady peak, when nest building is undertaken, is an important component of the flow regime to ensure successful breeding. It is also imperative at this stage that water levels do not fluctuate too much and result in nest abandonment. Using environmental water, these types of hydraulic conditions have been used successfully in other areas of Victoria to maximise spawning and recruitment of species such as Murray Cod (i.e. Gunbower Creek).

To examine the recent hydrology (river height) along the Wimmera River, a series of gauged hydrographs were plotted for the five management units identified; the upper Wimmera River and tributaries (Eversley), the lower Wimmera River (Horsham), the south-western tributaries (MacKenzie River), Mt William Creek and the northern distributaries (Yarriambiack Creek) from 2016 to 2021 (noting that these hydrographs represent a six-year period that may not be indicative of long-term flow data). The hydrographs were assessed for native-fish suitability including for River Blackfish and Freshwater Catfish spring nesting and spawning. This analysis showed prevailing low flows along most of the Wimmera River and a strong pattern of among year, within-season, and daily water-level variability. It is worth noting that this data provided spot measurements of flow at specific locations and that flow management would benefit from undertaking spatial modelling of the timing and duration of flows over the entire catchment.

Flows at Eversley (Figure 4) indicate that there are good spring flows that might complement spawning of nesting species, but these are often followed up by zero base flows which will impact upon Young-of-Year (YOY) recruitment and survival. To enhance the recruitment and survival of these species i.e. River Blackfish it is recommended that cease-to-flows are avoided if possible (noting that avoiding these scenarios is limited by a lack of environmental watering options).

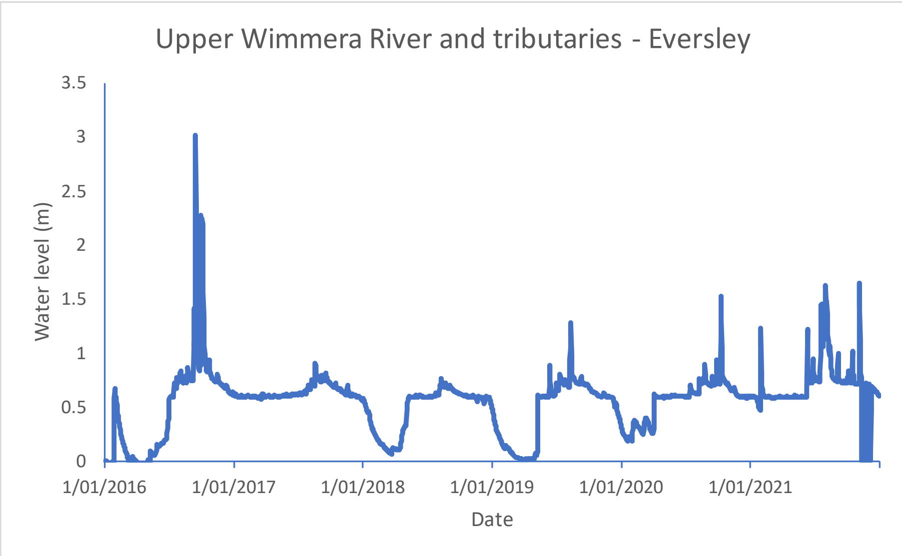

Figure 4 Upper Wimmera River and tributaries hydrograph 2016-2021 (@Eversley)

At Horsham (Figure 5) there is also large variations in flow with some high spikes and frequent periods of no flow. If this area could be improved by more continuous water and improved base flows, then there might be a case to enhance spawning for species such as Golden Perch (see Appendix 1).

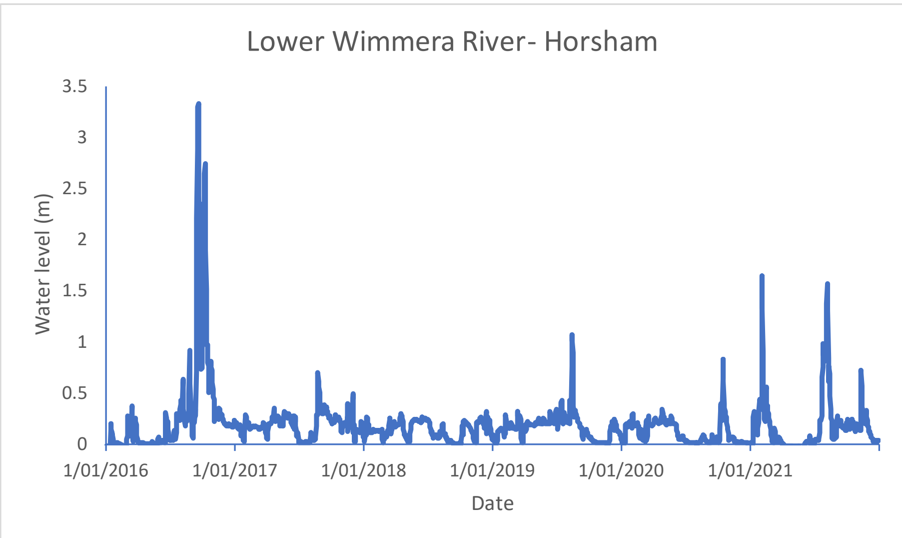

Figure 5 Lower Wimmera River hydrograph 2016-2021 (@ Horsham) indicating strong seasonal fluctuation with annual summer/autumn drawdown

In the lower MacKenzie River (Figure 6) there is also a pattern of cease-to-flow circumstances, which is not conducive to nesting species like River Blackfish. To improve flow management capabilities the provision of broader spatial coverage and real time data access including electronic flow and water-quality monitoring in Burnt Creek and MacKenzie River would also be of benefit.

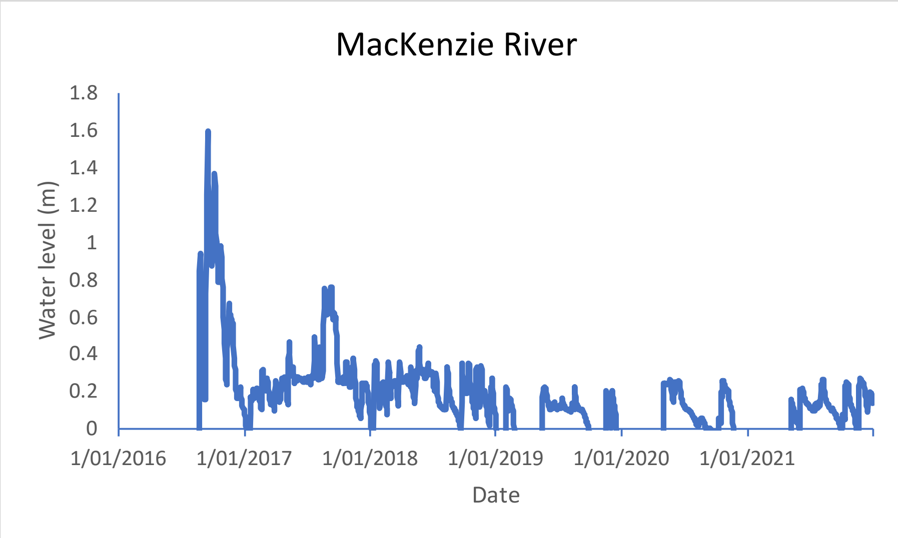

Figure 6 MacKenzie River hydrograph 2016-2021 (@MacKenzie Creek)

Flows in the lower Mt William Creek are very sporadic (Figure 7) with large variations (spikes) followed by long cease-to-flow periods indicative of the unpredictability of the water regime in the upper catchment. While maintaining a regular flow in the lower sections of this system to support species such as River Blackfish can be problematic, it is anticipated that refuge areas might be maintained to support other species such as Southern Pygmy Perch and Obscure Galaxias.

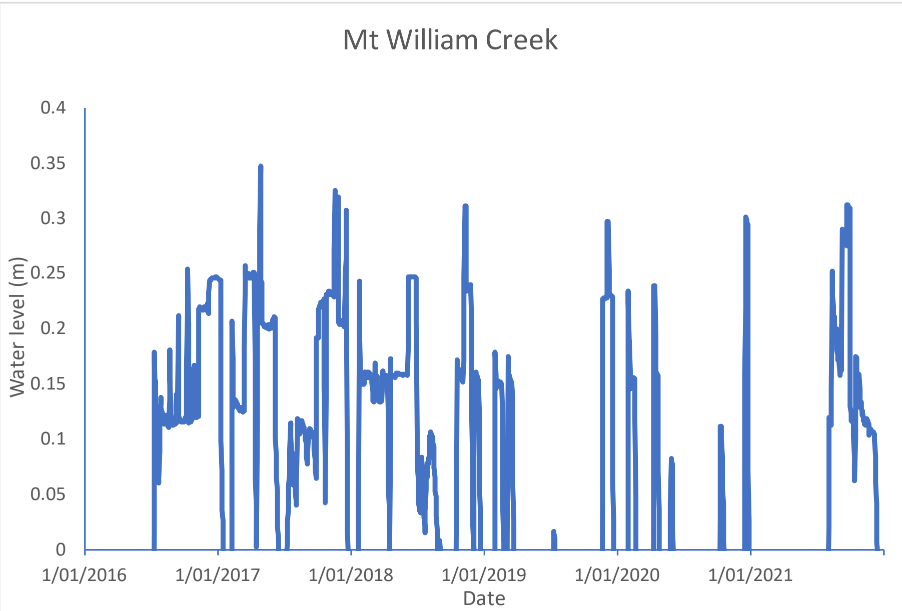

Figure 7 Mount William Creek hydrograph 2016-2021 (@Lake Lonsdale tail race)

In the northern distributaries (Figure 8) there is also large variations in flow and again some high flows followed by frequent periods of no flow and subsequently not conducive to nesting behaviour of Freshwater Catfish. Additionally, water quality might be improved through avoidance of long cease-to-flow periods, which could benefit stocked recreational species such as Golden Perch.

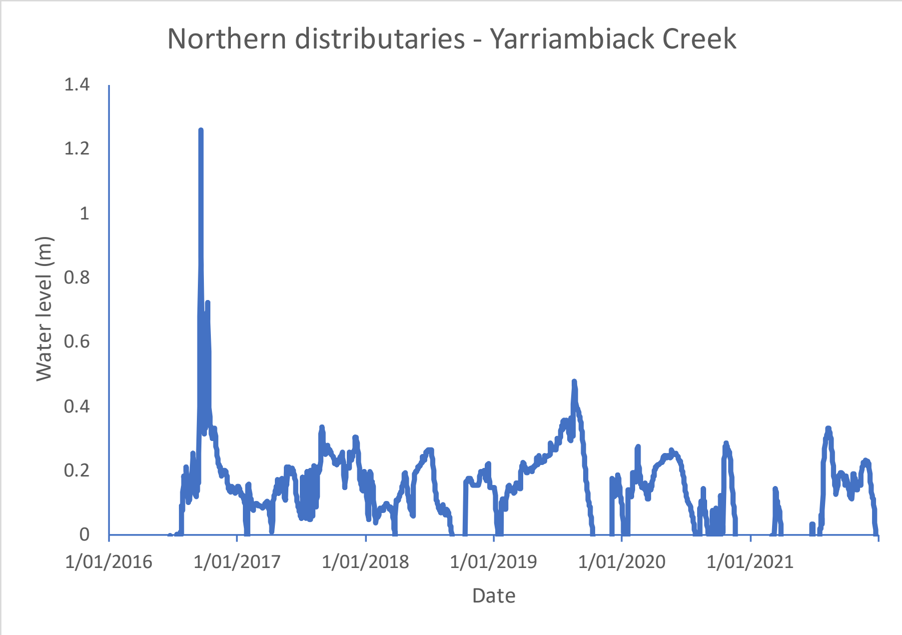

Figure 8 Northern distributaries (@Yarriambiack Creek)

Climate context for fish recovery

Within the Wimmera catchment, we propose a framework of actions for fish recovery which are tailored for the prevailing hydrological conditions. The flow components of the Wimmera River should continue to be managed by:

1. Wet years (where there are opportunities to experiment with the hydrograph)
2. Average years
3. Dry years

In wet years, additional actions can be undertaken relative to average hydrological-conditions years while in low flow or drought conditions protective actions are prioritised. This hydrological framework and integration of suites of actions is summarised in Table 4 with a conceptual hydrograph presented in Figure 9.

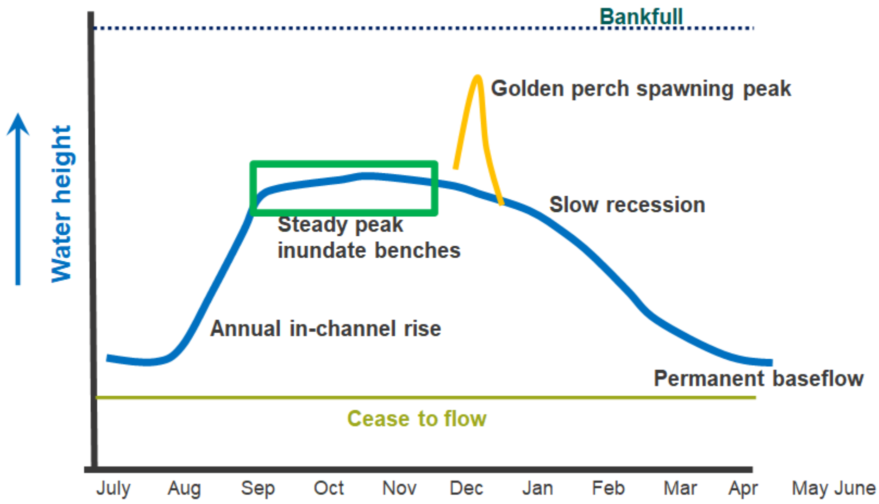

Figure 9 Conceptual model showing an ideal hydrograph (blue line) to support Murray Cod spawning with potential application to River Blackfish and Freshwater Catfish during an average or wet year scenario (from Stuart et al. 2020). This hydrograph is especially applicable in flowing riverine habitats, at the upper end of weir pools and within weir pools and is targeted toward reducing water level variability. In a wet year the additional Golden perch spawning component (yellow line) could be experimentally trialled. Permanent baseflows are necessary to maintain water quality and refuge habitats.

Table 4 Hydrological actions to support fish populations in the Wimmera catchment. Non-flow actions, such as re-snagging, re-introductions and improving connectivity would also support the flow interventions. (FC – Freshwater Catfish, GP – Golden Perch, SP – Silver Perch, MC – Murray Cod, RB – River Blackfish, SPP – Southern Pygmy Perch, OG – Obscure Galaxias)

Bioregion	**Species suite**	**Hydrological condition**		
		Dry year	**Average flow**	**Wet year**
Lower Wimmera River	FC, GP, SP, MC	Maintain weirpool refuge and water quality	• Implement spring fish nesting hydrograph for FC • Maintain refuge pools and water quality	• Implement spring fish nesting hydrograph for FC • Maintain refuge pools and water quality • Trial GP and SP spawning hydrograph
MacKenzie River	RB, SPP, OG	• Maintain refuge pools, water quality & baseflow connectivity	• Implement spring fish nesting hydrograph for RB • Maintain refuge pools, water quality & baseflow connectivity • Implement spring spawning hydrograph for SPP	• Implement spring fish nesting hydrograph for RB • Maintain refuge pools, water quality & baseflow connectivity • Implement spring spawning hydrograph for SPP
Mt William Creek	RB, SPP, OG, GP	• Maintain refuge pools, water quality & baseflow connectivity	• Maintain refuge pools, water quality & baseflow connectivity	• Maintain refuge pools, water quality & baseflow connectivity
Upper Wimmera River and tributaries	RB, SPP, OG	• Maintain refuge pools, water quality & baseflow connectivity	• Implement spring fish nesting hydrograph for RB • Maintain refuge pools, water quality & baseflow connectivity	• Implement spring fish nesting hydrograph for RB • Maintain refuge pools, water quality & baseflow connectivity
Northern distributaries	FC, GP	• Maintain refuge pools and water quality	• Implement spring fish nesting hydrograph for FC • Maintain refuge pools and water quality	• Implement spring fish nesting hydrograph for FC • Maintain refuge pools and water quality

Improved physical habitat

The main instream habitat that has degraded over a long period of time is instream woody habitat or 'snags.' Snags provide one of the fundamental elements of aquatic habitats in Murray-Darling rivers and numerous studies have shown native fish use snags as primary habitat (Lyon et al. 2019). Re-snagging is an established method of stream rehabilitation. Although not directly part of the aquatic habitat, the riparian zone is intimately linked, providing shelter, food, carbon, and woody debris. Some areas of the Wimmera have excellent riparian zones but there are other areas where it is essentially cleared land and has few trees or shrubs along the banks. The proposed action in the Plan is to implement the recommended priority areas for reintroduction of IWH (Grove et al 2019).

Improved water quality

Fish require particular water quality (such as salinity, temperature, pH, and dissolved oxygen) to survive and reproduce. The exact parameters can differ by species; for example, some wetlands species are well adapted to low dissolved oxygen content (Zukowski et al. 2021). When the prevailing water quality is outside a fish species tolerance range, it can lead to morbidity or even death. Climate, flow and geology can all alter these parameters, but there are also several types of events (i.e. blackwater) that can dramatically alter water quality parameters in a short time.

Blackwater and hypoxic events result in wide-scale fish kills because of low dissolved oxygen levels. The Wimmera River catchment has been subject to several blackwater events over the last 20 years including in early 2021. Following this event, Baldwin (2021) suggested the development of plans for managing hypoxic events in the Wimmera River to include identifying target reaches/refuges, potential interventions (i.e. environmental flow), potential trigger points (i.e. rainfall) and the development of a communication plan. Actions such as riparian revegetation and protection and erosion control can further minimise the impact of blackwater events occurring.

Cyanobacterial blooms can result in the proliferation of algae that can be toxic to humans and have the potential to cause hypoxia and fish deaths as large amounts of algae decay (Huisman et al. 2018). There is a history of algae blooms in some areas of the Wimmera River and lakes including Taylors Lake, Horsham Weir Pool and Dimboola Weir Pool.

Introduced species control

There are six non-native fish species known within the Wimmera River catchment: Carp, Gambusia, Goldfish, Redfin perch, and Tench. Of these, Carp are likely to have the greatest negative impact on habitats and native fish. Management of these species requires an Integrated Pest Management Plan; this can include localised actions. Rather than eliminating pest species the objective would be to reduce their abundance to a level that has acceptable impacts on habitats and enables native fish populations to recover. The Wimmera Carp Management Plan (Iervasi and Pickett 2020) identifies a variety of management tools available to reduce the impact of carp with many already successfully trialled within the Wimmera catchment and includes flow management (to help avoid large scale spawning events), removal options and the use of supplementary tools such signage and disposal bins promoting the responsible removal of angled Carp.

Improved connectivity

Providing for fish passage can include barrier removal, providing flows to improve depth and submerge barriers, weir management (lifting gates to provide passage when a structure is not in use i.e., lower Wimmera River weirs during high-flow periods), or more commonly - providing fishways. Fishways are one of the most widely used methods for rehabilitating freshwater fish populations worldwide. A new cone fishway has been installed on Dad and Dave Weir to enhance the movement of Southern Pygmy Perch, Obscure Galaxias, River Blackfish and platypus. Along the mainstem of the Wimmera River there are several barriers and providing fish passage on these is likely to represent a high capital investment. Horsham Weir appears to represent a case study of restoring fish passage to evaluate benefits (i.e., Golden Perch) before a broader program can be assessed, particularly in the knowledge that other weirs (i.e. Jeparit) are probably playing a key role in the management (and dispersal) of pest species such as Carp.

Reintroduction

Develop and implement a fish translocation plan to reintroduce species that have been decimated by low/no flow scenarios (including the Millennium Drought) but now have the potential to survive in areas using environmental water made available because of the Wimmera Mallee pipeline. Translocated fish could be sourced from local areas where fish numbers continue to be healthy and supplemented by fish bred at the soon to be constructed conservation breeding facilities at the existing Snobs Creek Fish Hatchery. In 2021, the Victorian and Federal governments, through the Bushfire Biodiversity Recovery program funded the construction of these facilities to enable the captive breeding of key freshwater taxa to reduce the long-term risks to population persistence from increasing episodic risks (e.g. bushfires and drought). A breeding and stocking strategy is being developed based on conservation need, water availability and input from project stakeholders. The first species to be bred for release in the wild will be highly threatened galaxiid species from Gippsland and Macquarie Perch, with the aim to increase population sizes, improve genetic diversity and establish new populations in suitable habitat. Some funds have been committed by project partners (DELWP, VFA and VEWH) for a four-year period. In the longer term, further investment will be required to allow for the inclusion of additional species. The suite of potential taxa that may be considered for breeding and release include other freshwater fish, such as small-bodied wetland specialists (i.e., pygmy perch, gudgeons), Blackfish, Freshwater Catfish, as well as freshwater crayfish and mussels.

Screening channel offtakes

Water-diversion offtakes are a special case of downstream fish passage. As water is diverted into channels there is downstream movement of all life stages of fish, and these are lost to the river population. There are two approaches to this issue: i) allow fish to enter the channel system, provide habitat in the main channels and fishways at the inlet regulators so that fish can return to the river; or ii) screen the inlet regulators to prevent fish entering the channel system. The second approach is the one that is almost universally taken because managing fish populations in channels using habitat, managing flows and installing fishways limits the function of the channels (and this has been highlighted by GWM Water in response to enhancing habitat in the Mount Zero Channel).

4.1.1 Recovery strategy

In this section, we present a Fish Recovery Plan aimed at outlining options to help meet the goals of increasing fish populations, recovering threatened species, and creating connected, healthy fish communities in the Wimmera that are viewed as a destination, recreational fishery statewide. To meet these goals, it is essential to address and mitigate the threats that have been highlighted in earlier sections, which were identified from literature reviews, a technical workshop, and discussions with the Wimmera Native Fish Management Plan Reference Group. These threats operate at different spatial scales, ranging from individual sites (i.e. refuge pool on Mt William Creek at Roses Gap Road) within each management unit (i.e. flow management) and ultimately across the entire catchment (i.e. connectivity). We present information to help highlight and evaluate priority actions across these spatial scales.

Firstly, a semi-quantitative prioritisation of management actions at and within the five management units identified is presented. This incorporates assessments made by the project team of the likely time and cost involved in design, implementation, and maintenance of different management actions, along with the likely type of ecological response.

The main justification for the rehabilitation of these fish populations comes from the previous decline in many fish populations because of drought and cease-to-flow conditions which can now be partially addressed through the provision of environmental water (as a result of the construction of the Wimmera Mallee pipeline). Where appropriate, management actions should be implemented to improve fish populations for ecological, recreational and community benefits including the Wimmera River as a destination fishery. We propose that fish populations are re-established through a series of interventions including translocation and potential stocking (investigation of breeding fish through the soon to be established conservation hatchery). Other recovery actions include optimising the hydrograph for the breeding and recruitment of flow-dependant species (i.e., River Blackfish and Freshwater Catfish), stocking of Lake Lonsdale (with Golden Perch) and investigation of Golden Perch spawning and recruitment ecology and links to managed flows in the lower Wimmera River (with the potential to establish self-sustaining populations, supplemented by a stocking regime, to produce a premier Golden Perch fishery).

Below we outline individual management actions relevant to the five management units identified.

Lower Wimmera River

1. Investigate Golden and Silver perch spawning and recruitment ecology and links to managed flow, movement and habitat in the mid/lower Wimmera River (i.e., Horsham-Dimboola reach) see Box 1.
2. Investigate constraints to recently stocked Murray cod spawning, recruitment and survival in lower Wimmera River

3. Investigate optimal management of invasive carp including in the area downstream of Jeparit Weir to Lake Hindmarsh
4. Investigate reintroductions of small-bodied fish species including Southern Pygmy Perch in Ranch Billabong.

Upper Wimmera River and tributaries

1. Investigate River Blackfish, Southern Pygmy Perch and Obscure Galaxias reintroduction into Glenorchy Weir pool and near Campbells Bridge.
2. Investigate riparian habitat improvements (including riparian fencing), instream habitat addition and vegetation control in Glenlofty Creek in preparation for River Blackfish reintroduction in future years.
3. Conduct fish surveys in the mid to upper Wimmera River (i.e., upstream and downstream of Glenorchy) to assess potential and appropriateness of future fish translocations including River Blackfish and Southern Pygmy Perch.
4. Re-establish River Blackfish populations, via translocation, in Mount Cole Creek in area downstream of Warrak.

Mt William Creek

1. Re-establish Southern Pygmy Perch populations, via translocation, in Mount William Creek (including Roses Gap Road).
2. Investigate stocking of Golden Perch into Lake Lonsdale during wet-year scenarios, especially where there is high primary productivity and link with experimental efforts to cue spawning/recruitment in the mid-lower Wimmera River.

South-western tributaries (MacKenzie River)

1. Re-establish River Blackfish populations, via translocation, in MacKenzie River between Distribution Heads and Dad and Dave Weir.
2. Re-establish River Blackfish populations in Burnt Creek and lower MacKenzie River (downstream of Distribution Heads) via translocation.
3. Undertake electronic flow and water-quality monitoring in Burnt Creek and MacKenzie River.

Northern distributaries

1. Improve the abundance and condition of Freshwater Catfish and Golden Perch through improvements to habitat, water quality and flow manipulation (via the Wimmera Mallee Pipeline).

Whole of catchment

1. Promote Wimmera as a peak fishing destination through creating premier fishing locations, improved access (including trails and boat ramp improvement) and managing impacts through responsible behaviour.
2. Enhance woody habitat in priority areas (e.g., refuge pools, de-snagged stretches devoid of future natural supply of woody habitat due to a lack of riparian vegetation) (Grove et al 2019).
3. Investigate optimising Wimmera River (and tributaries) hydrographs for the maintenance and improvement of the entire fish community (including naturally spawned (i.e., Freshwater Catfish and River Blackfish) and stocked fish (i.e. Golden Perch, Silver Perch and potentially Murray Cod)
4. Re-establish small-bodied fish species including Southern Pygmy Perch, into six securely watered refuge pools (Wimmera CMA to determine) via conservation hatchery stockings.
5. Implement priority habitat (Grove et al 2019), Carp (Iervasi and Pickett 2020) and blackwater (Baldwin 2021) management recommendations.
6. Undertake spatial modelling of the timing and duration of flows over the entire catchment.

4.1.2 Prioritisation of actions

Multi-criteria analysis tables

To enable a semi-quantitative prioritisation of recommended actions, we provide a multi-criteria analysis (MCA) which scores criteria that describe the costs/time involved in the planning, implementation and future maintenance of different management actions, and the likely ecological response (Table 5). MCA is an established method of finding optimal solutions based on multiple, differing decision factors and incorporating decision maker's perspectives and priorities (Mateo 2012). It is well suited to environmental governance and management (Herman et al. 2007) and can consider eco-social perspectives (Mendoza and Pabhu 2005) as well as ecological and cost-based factors.

Producing the MCA

Through a review of unpublished grey literature, and scientific papers and in discussions with the Reference Group, the Technical Advisory Group, ecologists, and managers working in the Wimmera River catchment, we have identified feasible solutions and opportunities for recovery. Below, we present a list of possible actions that arose from the investigations, which are drawn from information summarised in the previous chapters.

In Table 5, we present rankings for a range of criteria that relate to the logistics involved in management actions, as well as the likely ecological response. The following criteria were included and ranked in the MCA:

1. Time and costs involved in Planning, Implementation and Maintenance. A score of 3 is low cost and short timeframe, while 1 is high cost or long timeframe. Our cost rankings are relative but is likely that 3 will represent costs of <$100K, 2 is <$1M and 1 is >$1M.
2. Magnitude of expected ecological response, which is scored on three levels, with 3 being a strong response and 1 being a weak response. This is a useful way of comparing different outcomes (for example, increased species range vs increased local abundance) at different scales (for example, at a single wetland or across a long stretch of the river) on the same scoring scale. We acknowledge that the MCA provides a semi-quantitative assessment.
3. Anticipated timeframe of ecological response, contingent on the nature of predicted response (short migrations or slow increases in reproductive output) and the magnitude of change of environmental conditions. An "immediate" response is anticipated when the mechanism of response is immediate and direct; for example, if a fishway is built, fish can immediately navigate the barrier. A "short" response would require migrations to restored areas and/or some reproductive responses, with change detected over the course of a breeding season. A "moderate" response would require longer, sustained immigration to restored areas and/or several breeding seasons for a response to be detected.
4. Certainty about the magnitude of expected ecological response. An estimate (low, medium or high) in terms of the likelihood that anticipated ecological responses occur.

These include the predicted nature of the expected ecological response (i.e. increased abundance, density, range, or occupancy) and the spatial scale and the target species (very rare species are likely to be ranked higher, even for smaller-scale responses). We have also outlined some potential dependencies for management actions (i.e. things that need to be undertaken concurrently or beforehand for ecological responses to occur), as well as potential co-benefits for non-target species.

Table 5 Details and prioritisation scores for possible actions for fish recovery in the Wimmera CMA. Scores are from 1 (low priority: high cost, long implementation time and weaker ecological response) to 3 (high priority: lower cost, shorter implementation, and stronger ecological response). Higher total score = Higher priority action. The rationale for the scoring system is included in the "Prioritisation of actions" section above. The time taken for a predicted ecological response is included as a relative estimate, and the certainty of knowledge is based an assessment of the available literature and expert elicitation. Target species: MC = Murray Cod, SP = Silver Perch, GP = Golden Perch, FC = Freshwater Catfish, RB = River Blackfish, SPP = Southern Pygmy Perch, OG = Obscure Galaxias, C = Carp.

Priority	Proposed outcome	Bio region	Planning	Implementation		Ecological response			
			Time	Cost	Time	Magnitude	Target	Time	Certainty
Equal 1	Re-establish RB populations, via translocation, in MacKenzie River between Distribution Heads and Dad and Dave Weir	MacKenzie River	3	2	2	3	RB	Short	High
Equal 1	Re-establish SPP populations, via translocation, in Mount William Creek (including Roses Gap Road).	Mt William Creek	3	2	2	3	SPP	Short	High
Equal 1	Investigate stocking of GP into Lake Lonsdale during wet year scenarios, especially where there is high primary productivity and link with experimental efforts to cue spawning/recruitment in the mid-lower Wimmera River.	Mt William Creek	3	3	2	2	MC, SP, GP, FC	Short	High
Equal 1	Promote Wimmera as a peak fishing destination and managing potential impacts through improved access and responsible behaviour.	Whole of catchment (including five management units identified)	3	3	2	2	n/a	n/a	n/a
Equal 1	Enhance woody habitat in priority areas (e.g., refuge pools, de-snagged stretches devoid of future natural supply of woody habitat due to a lack of riparian vegetation).	Whole of catchment (including five management units identified)	3	1	3	3	All native fish species	Medium	High

Equal 2	Investigate optimising Wimmera River (and tributaries) hydrographs for the maintenance and improvement of the entire fish community (including naturally spawned (i.e., FC and RB) and stocked fish (i.e. GP and potentially MC).	Whole of catchment (including five management units identified)	3	3	1	2	MC, SP, GP, FC, RB	Medium	High
Equal 2	Investigate GP and SP spawning and recruitment ecology and links to managed flow, movement and habitat in the mid/lower Wimmera River (i.e., Horsham-Dimboola reach).	Lower Wimmera River	2	2	2	3	GP, SP	Medium/ Long	Medium
Equal 2	Investigate riparian habitat improvements (including riparian fencing) and vegeatation control in Glenlofty Creek in preparation for RB reintroduction in future years.	Upper Wimmera River and eastern tributaries	3	1	2	3	RB	Medium	Medium
Equal 2	Conduct fish surveys in the mid to upper Wimmera River (i.e., upstream and downstream of Glenorchy) to assess potential and appropriateness of future fish translocations.	Upper Wimmera River and eastern tributaries	3	3	2	1	RB, SPP, OG	Short	High
Equal 3	Investigate optimal management of invasive Carp including in the area downstream of Jeparit Weir to Lake Hindmarsh	Lower Wimmera River	2	2	1	3	All native species	Medium/ Long	High
Equal 3	Re-establish RB populations in Burnt Creek and lower MacKenzie River	MacKenzie River	2	2	1	3	RB	Short	High

	(downstream of Distribution Heads) via translocation.								
Equal 3	Implement priority habitat (Grove et al 2019), Carp (Iervasi and Pickett 2020) and blackwater (Baldwin 2021) management recommendations	Whole of catchment	2	1	2	3	All species	Long	High
Equal 4	Investigate constraints (i.e., fish passage) to Murray Cod spawning, recruitment and survival in mid/lower Wimmera River (in area around Horsham).	Lower Wimmera River	2	2	2	1	MC	Medium	Medium
Equal 4	Investigate River Blackfish and Obscure Galaxias reintroduction into the Glenorchy Weirpool (along with e-water flows from Lake Lonsdale).	Upper Wimmera River and eastern tributaries	2	2	1	2	RB, OG	Short	High
Equal 4	Re-establish Southern Pygmy Perch into six securely watered refuge pools (WCMA to determine) via conservation hatchery stockings	Whole of catchment (including five management units identified)	1	2	1	3	SPP, PSG, FHG	Medium	Medium

5 Discussion

The Wimmera River and tributaries have considerable existing environmental values, including a diverse array of native fish and aquatic habitats. The present fish-management plan assists in synthesising hydrological and ecological information to identify opportunities and guide management in recovering native fish communities. In several parts of upper Wimmera system (e.g., MacKenzie River, Mount William and Mount Cole creeks) there are immediate opportunities to re-establish several native fish (e.g., River Blackfish and Southern Pygmy Perch) within their former (pre-Millennium drought) spatial range via translocation with a high chance of success. Demonstrating achievement of this type of short-term action will likely help to build momentum for the remaining mid and lower catchment medium/long-term actions outlined in the Plan.

In the mid and lower reaches of the Wimmera River there is an opportunity to refine the current hydrographs to provide improved opportunities for fish spawning and survival and this has particular application to nesting species such as Freshwater Catfish, River Blackfish and Murray Cod. The Plan presents hydrographs that have promoted improvements for some of these species in northern Victoria and hence we suggest trialling and monitoring these flows for the mid and lower Wimmera main channel (Stuart et al. 2019). Importantly, these hydrographs might not require additional water and can be embedded in the existing environmental-flow regime.

The Plan also recognises that flows are scarce in the Wimmera catchment and accounts for this by proposing dry, average, and wet scenario recovery actions. For example, in wet years there is an opportunity to field test mid-catchment (i.e., Horsham area) flow regimes to support Golden and Silver Perch spawning and monitor recruitment to determine what is required to assist a locally self-sustaining population of Golden Perch. While this element is somewhat aspirational, there has been recent success with supporting local recruitment of Golden Perch in the lower Murrumbidgee catchment (Anthony Conallin, DPIE, pers. com.). By contrast, in dry years, the Plan recommended protecting drought refuges which become sources of fish to recolonise when flows return.

For recreational anglers, the Plan highlights a key focus on supporting survival of recreational fishing species, both artificially stocked and naturally spawned. This aspect is crucial to grow opportunities for recreational anglers in the Wimmera system and thus provide benefits to a broad range of community groups. Refined flow management is a key to recovering recreational angling species, such as Golden Perch, Silver Perch, Murray Cod and Freshwater Catfish, but the Plan also recommends specific reaches where complementary river-recovery actions, such as re-snagging, fishways, and riparian restoration is a priority.

Several wetlands were also identified where there are case-study opportunities for fish recovery. This included major lakes, such as Hindmarsh and Lonsdale and also smaller wetlands, such as Ranch Billabong. At each of these wetlands, specific fish-stocking or fish-recovery actions have been considered and recommended.

6 Conclusion

The Wimmera Fish Recovery Plan provides a strategic direction for enhancing native fish communities and for a collaborative (Figure 10), multifaceted role, of irrigation, conservation, recreation and broader economic benefits. The Plan provides value by underscoring the benefits of healthy native fish communities for recreational anglers with flow-on benefits to regional communities with major opportunities and recommendations.

Major opportunities and recommendations

Priority 1 (Time Frame: 5-10 years)

Translocations

- Re-establish River Blackfish populations, via translocation, in the MacKenzie River between Dad and Dave Weir and Distribution heads

Stocking

- Investigate stocking of GP into Lake Lonsdale during wet year scenarios, especially where there is high primary productivity and link with experimental efforts to cue spawning/recruitment in the mid-lower Wimmera River.

Communication/recreation

- Promote Wimmera as a peak fishing destination and managing potential impacts through improved access and responsible behaviour

Habitat

- Enhance woody habitat in priority areas (e.g. refuge pools, de-snagged stretches devoid of future natural supply of woody habitat due to a lack of riparian vegetation).

Priority 2 (Time frame: 10-15 years)

Translocations

- Re-establish River Blackfish populations, via translocation, in Mt Cole Creek downstream of Warrak.
- Re-establish Southern Pygmy Perch populations, via translocation, in Mt William Creek (including Roses Gap Road).

Habitat

- Investigate riparian habitat improvements (including riparian fencing) and vegetation control in Glenlofty Creek in preparation for future River Blackfish reintroduction.

Flows

- Investigate Golden and Silver Perch spawning and recruitment ecology and links to managed flows, movement and habitat in the mid/lower Wimmera River (Horsham to Dimboola).
- Investigate optimising Wimmera River (and tributaries) hydrographs for the maintenance and improvement of the entire fish community (including naturally spawned (i.e. Freshwater Catfish and River Blackfish) and stocked fish (i.e. Golden Perch).

Monitoring

- Conduct fish surveys in the mid to upper Wimmera River (i.e. upstream and downstream of Glenorchy) to assess potential and appropriateness of future fish translocations.

Priority 3 (Time frame: 15-20 years)

Translocations

- Re-establish River Blackfish populations, via translocation, in Burnt Creek and lower MacKenzie River (downstream of Distribution Heads).

- Ranch Billabong- investigate with Barengi Gadjin Land Council, a collaborative reintroduction of small-bodied fish species including Southern Pygmy Perch or angling species such as Golden Perch.

Introduced species

- Investigate optimal management of invasive Carp from Jeparit Weir to Lake Hindmarsh

Previous management recommendations

- Implement priority habitat (Grove et al 2019), Carp (Iervasi and Pickett 2020) and blackwater (Baldwin 2021) management recommendations

Priority 4 (Time frame: 15-20 years)

Translocations

- Establish populations of native, small-bodied fish, including Southern Pygmy Perch, into six securely watered refuge pools
- Investigate River Blackfish and Obscure Galaxias reintroduction into the Glenorchy Weir Pool area.

Monitoring

- Investigate constraints to Murray Cod spawning and recruitment and survival in mid/lower Wimmera River (in area around Horsham).

Figure 10 Collaboration: Cobba Harrison and Bruce McInnes from Wimmera CMA, Ivor Stuart and Justin O'Connor, Arthur Rylah Institute for Environmental Research, and Victorian Fisheries Authority representative Jason Peters discuss the Wimmera Native Fish Management Plan.

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Appendix 1: The Golden perch challenge

General description/life history:

The Golden Perch is a medium- to large-bodied, long-lived top-level predator and river channel and floodplain specialist that can move large distances and typically prefers in-stream structure (mostly wood). It is known to live up to 26 years and is typically 2-3 kg. It is keenly sought by anglers. The Golden Perch remains widespread throughout most of the Murray Darling Basin although it is likely absent above some barriers. Golden Perch are mature at 3 years for males and 4 years females and have high fecundity; up to 750,000 eggs. Collective spawning is suggested to occur in shoals over a brief single period. In rivers, the species appear to seek flowing water (e.g. 0.3m/sec) habitats to spawn, and the occurrence of drifting eggs and larvae correspond to rising and falling flows. The spawning season is mainly spring and early summer (October–February).

An optimal spawning temperature of >19C has been suggested. Larval survival depends on high densities of appropriately sized zooplankton at first feeding and spawning might not necessarily translate to recruitment if this is not available. Significant increases in juvenile abundance occur in the lower Murray River in years during overbank flooding compared with low-flow years. Inundated floodplain lakes can provide juvenile nursery habitats, which might increase survival and therefore recruitment to main channel populations after reconnection. In flowing waters, pelagic eggs can drift for 1–2 days and then, after hatch, larvae might drift for a further 10–12 days. This provides a major dispersal mechanism from spawning areas for larvae to then settle in feeding and nursery areas such as terminal lakes or along channel margins (Koehn et al 2020).

Key threats:

1. Barriers to fish passage
2. Loss of large-scale reaches (e.g. 500 km) of flowing water habitats
3. Loss and disconnection of off-channel nursery areas such as deflation basins, lakes and wetlands
4. Altered flow regimes, especially loss of base flows, within-channel flow pulses, flow peaks, large, overbank floods and broad-scale connected river systems
5. Loss of flowing riverine habitats created by weir pools and floodplain regulators which might have a substantial effect on the survival of early life stages
6. Predation and poor water quality, which can affect survival in refuge pools and terminal lakes and wetland
7. Removal of in-stream woody habitat

The Wimmera River Golden Perch story

There have been numerous anecdotal accounts of Golden perch spawning behaviour in the lower Wimmera River over the last 20 years (particularly during wet years). Again in 2021 running ripe fish were observed (Dave Brennan, Wimmera CMA pers. com.). During 2021, in the lower Wimmera River, there were good flows throughout most of the year (the lower Wimmera River was flowing for five consecutive months). Following this, some high spring rain in the upper catchment corresponded to a flow of about 600ML/d in the lower Wimmera River in November 2021. Consequently, in mid to late November, over a three--day period, there are anecdotal reports (including Dave Brennan CEO WCMA) of congregations of adult Golden Perch (~40cm in length) below Horsham Weir (up to 30-40 fish), surfacing with their dorsal fins protruding out of the water. During this period the fish would not feed i.e. take a bait. After three days these Golden perch disappeared, and Silver Perch arrived below the weir. Unlike the Golden Perch the Silver Perch were feeding (one angler caught 14 Silver Perch on a fishing line in about one hour), including some running ripe females that extruded eggs on capture (without applying pressure to the abdomen). In another account by Bruce McInnes (WCMA) a female Silver Perch, that had just dropped her eggs, was angled and presented with a hollow abdomen. The vent of the fish was also red and extended in a slight prolapse. When attempting to strip the fish there were no oocytes left in the ovaries and the conclusion was that this fish had naturally spawned in the last 6 Hours (Bruce McInnes, pers. Comm.). These observations were of fish collected about 3 metres below the Horsham Weir and the water temperature was about 17oCand it appears that both Golden and Silver perch might have been displaying some form of spawning behaviour below Horsham Weir.

Knowledge gaps:
Demonstrate which parts of the life history of Golden Perch are currently being met and then identify the knowledge gaps.

1. Was there successful spawning (and if not why?) and what flows and spatial zones were important
2. Was there successful recruitment (and if not why?) and what flows and spatial zones were important

Possible limiting factors:

1. Lack of appropriate habitat i.e. long-distance fast-flowing reaches
2. Lack of appropriate spawning cues
3. Nursery habitats and food for larvae
4. Better managed wetting/drying cycles
5. Is water quality impacting on the productivity of the system?
6. Can we use the weir pools to increase productivity?

Recommended actions:

1. Confirm presence/location of larvae through surveys in key areas when spawning behaviour is observed
2. Interrogate hydrograph and monitor water temperature
3. Identify available food resources (larval)
4. Follow up surveys to confirm recruitment

Outcome:
Self-sustaining Golden Perch population during wet and average years supplemented by a stocking regime