Mallee CMA

# SDL Fish Management Plan

# Vinifera Floodplain

November 2018

***Document history***

| Version | Date | Prepared by | Issue to |
|---|---|---|---|
| Draft 1 | 22 December 2017 | Simon Harrow (GHD)<br>Corinne Thomas (GHD) | Mallee CMA |
| Draft 2 | 15 June 2018 | Simon Harrow (GHD) | Mallee CMA |
| Final | 01 November 2018 | Simon Harrow (GHD) | Mallee CMA |

# Executive summary

## Background

The Vinifera floodplain is located in the Nyah-Vinifera State Forest approximately 22 km north-west of Swan Hill. The Vinifera floodplain consists of an area 488 ha, approximately five km long and nearly two km wide in its widest point.

Seasonal wetland habitat has been lost from Vinifera Park through a reduction in the duration of spring flow peaks. High river levels now inundate wetlands only briefly, and have promoted the establishment of river red gum on former wetland beds. Flood duration is too short to support aquatic marshland vegetation and the understorey is now dominated by grasses and seasonal floodplain herbs. The decline in wetland habitat means the floodplain now only provides opportunistic habitat for aquatic fauna that recolonise the system when water is available. (Mallee CMA, 2014). Low-lying meandering watercourses and wetlands in the floodplain are referred to collectively as Vinifera Creek. The connection between the creek and the Murray River has been blocked, however, and as a result Vinifera Creek now functions as a backwater wetland.

Very few fish species are currently able to utilise Vinifera Park due to the short period of inundation.

## Basin Plan SDL Adjustment

The Vinifera floodplain Management Project is a supply measure under the Murray-Darling Basin Plan's Sustainable Diversion Limit (SDL) adjustment mechanism. Supply measures are works, river operations or rules changes that use less water whilst still achieving Basin Plan environmental outcomes. The project will allow for inundation of the floodplain more frequently than is currently the case.

## Fish Management Opportunities

The purpose of the Vinifera Fish Management Plan is:

- to provide the necessary design criteria to be incorporated into SDL detailed designs
- to provide the operational requirements that benefit native fish for the SDL site Operating Plans
- to establish prioritised ecological objectives and targets for fish at the site
- understand the context of site operations and to maximise the ecological outcomes on a reach scale

To meet these goals, conceptual models were developed, based on the literature, to clearly articulate the life-history of fish and their relationship to local hydrology. This enabled clear identification of recovery actions and knowledge gaps. The major opportunity identified is the seasonal recovery of small-bodied wetland fish species.

The successful management of floodplain wetland habitat for small-bodied wetland fish brings with it a number of risks, which can be categorised as either:

- infrastructure and operation risks; or
- fish response risks.

The preparation of this Fish Management Plan included a risk assessment to protect aquatic values of the Vinifera floodplain from potential threats posed to them. The risk assessment concluded that, of the five threats initially identified as medium risk or higher, three remained a medium risk once mitigation measures were considered. A summary of the threats and recommended mitigation measures is provided in the table below:

| Threat | Proposed mitigation measures | Residual risk |
|---|---|---|
| Inundation causes carp breeding event and population expansion and impacts | Winter fill.<br>Small inundation events.<br>Reduce frequency of operations.<br>Introduce carp herpes virus. | Medium |
| Anoxic DO event | Winter fill.<br>Small inundation events before large event.<br>Implement Blackwater Management Plan. | Medium |
| Stranding of fish on floodplain during drawdown | Develop contingency plan for emergency removal of fish.<br>Develop recession hydrograph that achieves slow drawdown to allow fish to escape from floodplain.<br>Undertake emergency watering to raise water levels. | Low |
| Wetlands support the establishment of invasive plant and animal species which may outcompete native species | Install mechanical exclusion devices when filling wetlands.<br>Introduce carp herpes virus.<br>Drawdown to allow native fish to exit and exotic species to become stranded. | Medium |
| Fish cannot exit creek from upstream end | Monitor fish exit during drawdown events and adaptively manage. Consider modification to structure if significant numbers of fish are unable to exit | Low |

The following monitoring recommendations to assess the response of fish populations to floodplain watering are provided:

| Component | Recommendation |
|---|---|
| Species composition, use of off-stream habitats, variability across site | Other than WetMAP monitoring at nearby Nyah Park no regular monitoring is completed on site. An understanding of the effects that increased floodplain inundation and has on fish population dynamics in the site will be important to monitor. |
| Exotic fish species.<br>Carp and gambusia establish in wetlands and compromise habitat. | Ongoing low-level (e.g. annual) monitoring to assess carp populations with active management of exotic fish species. |
| Stranding of native fish | Fish monitoring of drawdown period to ascertain whether fish are able to exit through both regulator upstream regulator V4 and downstream regulators V1 and V2. |

The Vinifera Park Fish Management Plan provides a practical way forward in recovering local small-bodied native fish.

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# 1. Introduction

## 1.1 Purpose

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2. to provide the operational requirements that benefit native fish for the SDL site Operating Plans
3. to establish prioritised ecological objectives and targets for fish at the site
4. understand the context of site operations and to maximise the ecological outcomes on a reach scale

## 1.2 Background

Seasonal wetland habitat has been lost from Vinifera Park through a reduction in the duration of spring flow peaks. High river levels now inundate wetlands only briefly, and have promoted the establishment of River Red Gum on former wetland beds. Flood duration is too short to support aquatic marshland vegetation and the understorey is now dominated by grasses and seasonal floodplain herbs. The decline in wetland habitat means the floodplain now only provides opportunistic habitat for aquatic fauna that recolonise the system when water is available. (Mallee CMA, 2014). Low-lying meandering watercourses and wetlands in the floodplain are referred to collectively as Vinifera Creek. However, the connection between the creek and the Murray River has been blocked and as a result Vinifera Creek now functions as a backwater wetland.

## 1.3 Basin Plan SDL Adjustment

The Vinifera floodplain Management Project is a supply measure under the Murray-Darling Basin Plan's Sustainable Diversion Limit (SDL) adjustment mechanism. Supply measures are works, river operations or rules changes that use less water whilst still achieving Basin Plan environmental outcomes. The project will allow for inundation of the floodplain more frequently than is currently the case.

## 1.4 Acknowledgements

This project was funded by the Mallee Catchment Management Authority through the Murray Darling Basin Plan Sustainable Diversion Limit (SDL) adjustment mechanism funding. We would like to acknowledge Cath Hall and Nick Sheehan from the Mallee Catchment Management Authority and Iain Ellis (NSW Department of Primary Industries - Fisheries), Brenton Zampatti (South Australian Research and Development Institute (SARDI)) and Clayton Sharpe (CPS Enviro) for their roles steering the project and providing peer review of the plans. It should be noted that the final outcomes of the project ultimately reflect the views of the authors and do not necessarily reflect those of the peer reviewers.

Wayne Koster, Jarod Lyon, Tarmo Raadik, Scott Raymond, Zeb Tonkin, John Koehn, Jason Lieschke and Pam Clunie and Diane Crowther (Arthur Rylah Institute for Environmental Research, Department of Environment, Land, Water and Planning) are thanked for their participation in the risk workshops for the project and draft reviews of the plans.

# PART A –Context (Desktop and Field Assessment)

# 2. Site context

## 2.1 Location

The Vinifera floodplain is located in the Vinifera-Vinifera State Forest in north-western Victoria and directly south (upstream) of the township of Vinifera, approximately 22 km north-west of Swan Hill. The Vinifera floodplain consists of an area 488 ha, approximately five km long and nearly two km wide in its widest point (0.5 km wide at its narrowest point).

The floodplain is oriented roughly from south-east to north-west (upstream to downstream), and in two distinct sections:

- the upstream section (approximately a quarter of the floodplain) is on private land and is separated by an existing levee, and
- the downstream section (approximately three-quarters of the floodplain) is on Murray River Reserve

## 2.2 Site context in relation to the Murray River

The Vinifera floodplain lies between the Murray River and the Mallee highland to the south and south-west, with a central creek system in the middle of this low-lying land (Figure 1). The creek system varies in depth and is at its deepest in the middle of the floodplain. The levee between the private land to the east and the public land to the west divides this floodplain and limits the inflows (at lower flood levels) from the upstream section. This section of the floodplain, which is the key focus of this investigation, is on the floodplain on Murray River Reserve.

As part of the wider Murray River scheme, the Nyah-Vinifera floodplain (RD 1356 to RD 1367) is located approximately half way between Euston Weir (Lock 15) at RD 1117 km and Torrumbarry Weir at RD 1628 upstream, so is not directly impacted by either of these features except by the inferred flow from their operation.

There are no major forest systems near the Vinifera floodplain unit, although there are a number of minor (localised) floodplain systems running parallel to the Murray River along its course. Gunbower and Koondrook-Perricoota Forests are approximately 100 km south-east of Vinifera, and the Wakool River and Murrumbidgee River enter the Murray River further downstream of Vinifera.

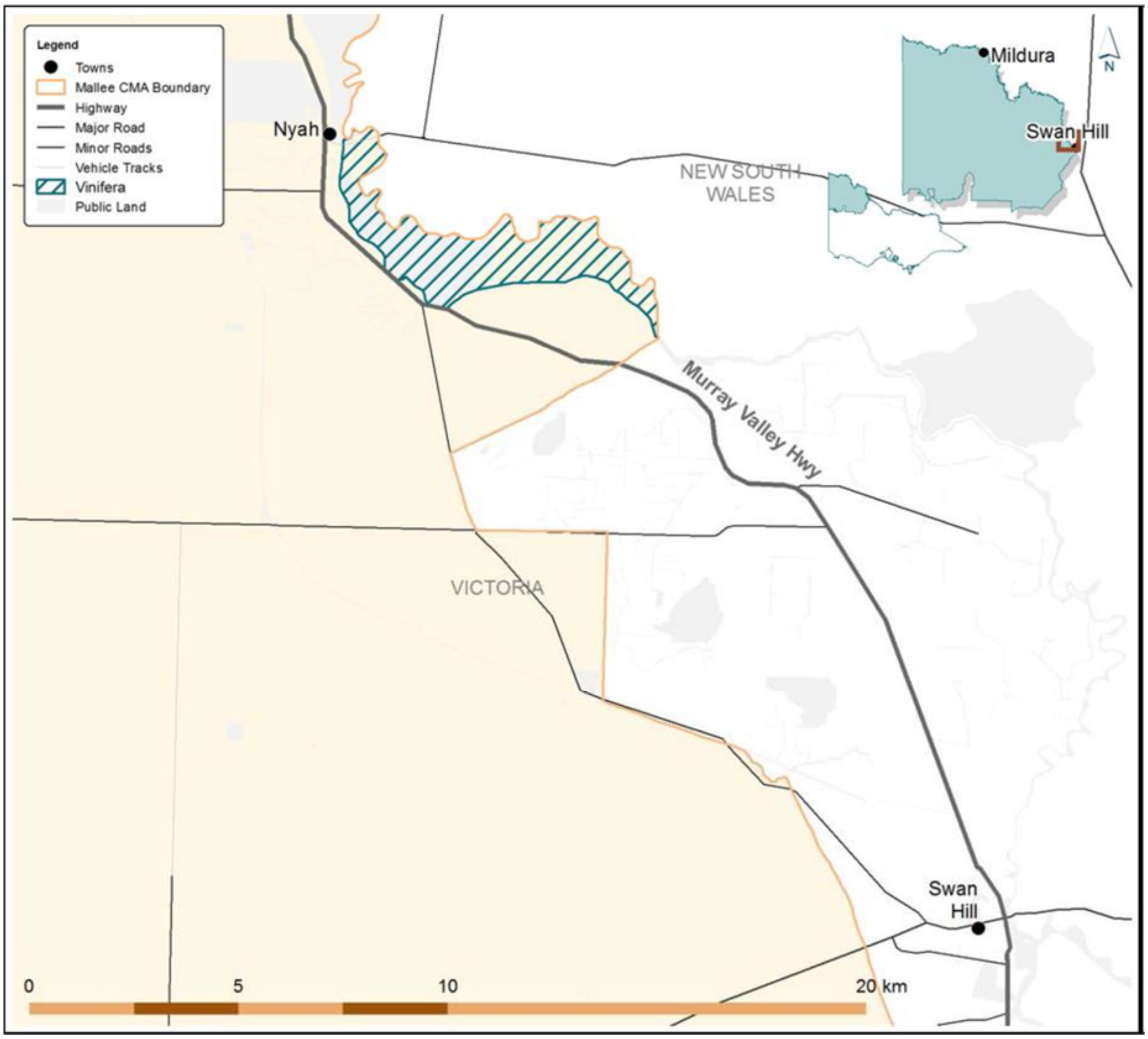



Figure 1 Location of Vinifera Park (Ecological Associates, 2014a)

# 3. Hydrology

## 3.1 History of Vinifera floodplain

The current operation of flows on the Vinifera floodplain has developed with the property ownership and usage. The system is relatively small and impacted primarily by Murray River flows. The floodplain is located far from locks and weirs but is impacted loosely by Lock 15, Euston Weir at the downstream end and Torrumbarry Weir at the upstream end. The western end of the floodplain is the key focus of this study, being on public land and separated by the levee with the private land to the east.

The following provides a timeline of key regulation works undertaken around Vinifera floodplain, from pre-regulation to current times:

- 1923 – Construction of Torrumbarry Weir and Lock
- 1932 to 1937 – Construction of Lock 15, Euston Weir
- 1990 – Torrumbarry Weir - vertical slot fishway was added (first on the Murray River)
- 1993 to 1996 – Complete reconstruction of Torrumbarry Weir and Lock
- 1999 – Torrumbarry Weir – vertical slot fishway modifications made
- 2010 to 2014 Upgrade of Euston Weir navigable pass and addition of the fishway

## 3.2 Murray River context

The Vinifera floodplain is located between Torrumbarry Weir upstream (Lock 26) upstream (RD 1628 km) and Euston Weir (Lock 15) downstream (RD 1117 river kms), almost half way between these two features at RD 1356 – RD 1367. Being so far from each of these well-spaced weirs has led to their impact on localised flows being relatively minor for this small wetland complex, which is heavily reliant on Murray River flows.

Other impacts in the system come from the following:

1. The Murrumbidgee River confluence upstream of the islands at RD 1242
2. Wakool River confluence at RD 1282
3. Loddon River (via Little Murray River) at RD 1410 and RD 1462.

Key inlets at the Vinifera floodplain are:

- CH 1359 km, Central Creek system (downstream end), which acts as both key inlet and outlet
- CH 1361 km, small inlet, minor overland flow path into the floodplain
- CH 1363.5 km, small inlet, minor overland flow path into the floodplain
- CH1366 km, the upstream end of the Central Creek system and the upper end of the floodplain. While water may enter through this way at early onset of flooding, due to the blocking bank further downstream water would not enter the key target area until larger flood levels commence.

The key outlet on Vinifera floodplain is:

- CH 1359 km, Central Creek system (downstream end), which acts as both key inlet and outlet.

The Vinifera floodplain is understood to generally fill from the downstream end of the floodplain as Murray River levels commence to rise (Ecological Associates, 2006), although this was not always the case prior to creation of the levee. Flows leave the floodplain through the same connection and through evaporation/seepage.

## 3.3 Euston Lock and Weir (Lock 15)

Euston Weir and lock was constructed from 1932 to 1937 and is located at RD 1117 km. Situated approximately 45 km downstream of Belsar Island and just west (downstream) of Robinvale, the normal operating full supply level at Euston Weir is 47.6 mAHD (Ecological Associates, 2015).

Euston Weir consists of 12 bays with concrete piers and stop logs, a fish lock chamber and a denil fishway. Euston weir pool extends up to 60 km at normal weir pool level and at this level the weir can store 76 GL of water with an approximate head difference across the weir of five metres. The upstream and downstream weir pools equalise at around 53,000 ML/d flows. The stop logs can be removed when flows rise to 40,000 to 50,000 ML/d, then replaced when flows fall in the range 30,000 to 56,000 ML/d.

Recent historical data at Euston Weir shows the weir has been operated at a range of weir pool levels in recent years, lowering 0.2 to 0.3 m below normal pool level and up to 0.6 m above weir pool level (ranging from 47.3 to 48.2 mAHD). Weir pool manipulations have been occurring on a seasonal basis in more recent years, with approximately four different weir pool level settings being used from July 2015 to June 2016.

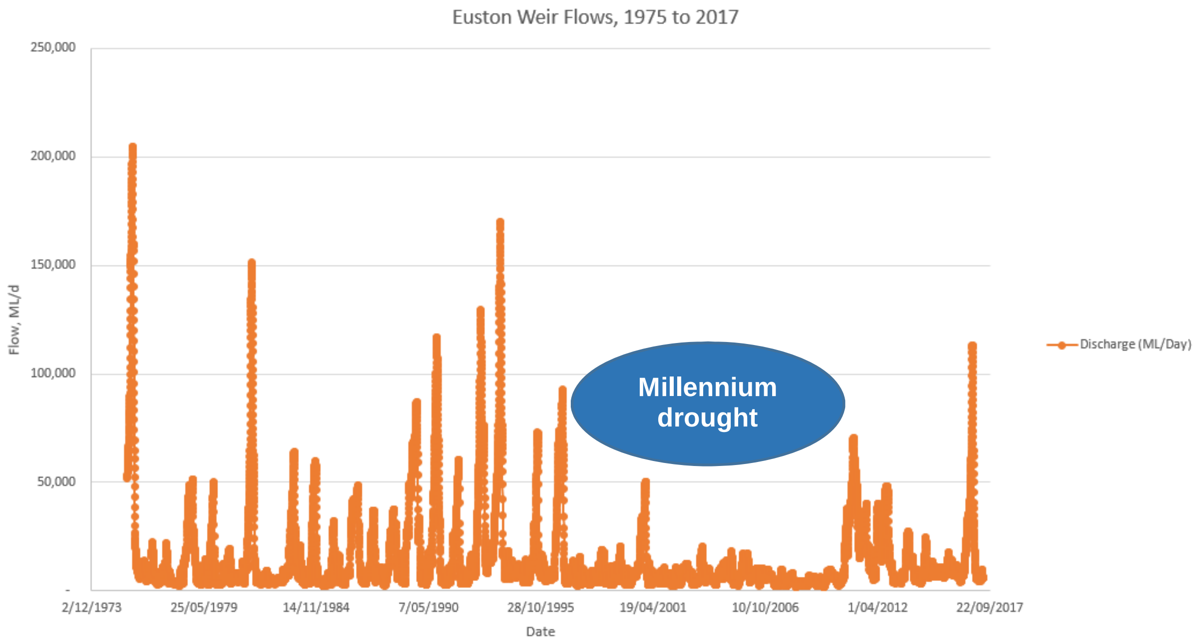



Figure 2 Flow information at Euston Weir from 1975 to 2017, MDBA (2017)

The initial Denil fishway retrofitted at Euston Weir on the right abutment (NSW side) in 1993 was based on the American salmon model and only allows passage of larger native fish. In 1996 and 2000 modifications were undertaken to install fibreglass Denil inserts to address fish passage needs for smaller fish also (adjacent to NSW bank). In 2013 two extension ramps and two exits were added, bringing a total of three exits, to enable more successful fish movement during weir pool manipulations. While this fishway generally provides passage for larger fish, the movement of juvenile or small bodied fish through the fishway remains limited.

A fishlock was constructed in 2013 adjacent to the lock chamber (on Victorian bank side), particularly targeting smelt and other small bodied fish. The upstream gate ranges from 46.20

to 48.24 mAHD and the downstream gate ranges from 42.5 to 47.64 mAHD, targeting small fish up to 44.0 mAHD and larger fish above that level (J Smart, MDBA, pers. comm.).

The fishways operate within the range of 3,500 ML/d to 35,000 ML/d, with the Denil operating up to maximum operating level. PIT (Passive Integrated Transponder) tag systems have been installed at Euston Weir to track movement of tagged fish (Ecological Associates, 2015).

## 3.4 Torrumbarry Lock and Weir (Lock 26)

Torrumbarry Weir has very little impact on the Vinifera floodplain as it is located approximately 280 km upstream. Torrumbarry Weir is run primarily for irrigation and water supply and is generally run near or at capacity for much of the year.

Torrumbarry Weir and lock was constructed around 1923, although a complete reconstruction of the weir was undertaken from 1993 to 1996 to address potential long term foundation concerns. The normal operating full supply level at Torrumbarry Weir is 86.05 mAHD. The original weir was constructed as a Dethridge weir, consisting of 14 steel trestles that run on rails from the invert of the river and can be removed by winching. The very first vertical slot fishway in the country was constructed at Torrumbarry Weir in 1990 but rebuilt in 1999 to provide improved function for smaller fish (EcoENet, 2017).

## 3.5 Floods and droughts

The Murray River has experienced a range of floods over recent times of recorded history. The most significant flooding event in living history is the 1956 flood, which has been largely regarded as approximately the 1 in 100 year event over much of the Murray River in this region.

The key recent flood events in this area are:

- 1956 Flood – no record at Euston but back noted to a flood level approximately 52.6 mAHD at Euston Weir
- 1975 Flood – recorded as peaking on 27 November at a level of 51.745 mAHD and peak flow of 204,500 ML/d
- 1993 Flood – recorded as peaking November at 51.4 mAHD, 170,000 ML/d

There have also been times of extreme dry or drought in this region of the Murray River, including the:

- Federation drought (mid- 1890s to early 1900s)
- droughts around the World War II (1937 to 1945)
- short duration drought (1982 to 1983)
- the Millennium Drought (or 2000s Drought), from 1996 to early 2010, which severely impacted this part of the Murray-Darling Basin. The drought developed with low rainfalls in 1996 to 1997, a condition which degenerated until 2003 when it was largely defined as the most severe drought on record. Drought conditions continued, with 2006 the most severe, until the drought concluded in 2010

## 3.6 Site hydrology

Flows in Murray River in the vicinity of the Vinifera floodplain have been significantly altered in magnitude, frequency and duration since regulation and storages in the catchment upstream have been introduced and since there have been increased water demands in the system, evolving over the past approximately 109 years (Mallee CMA, 2014; Ecological Associates, 2014a).

The following flow connectivity observations have been made for the Vinifera floodplain, (Mallee CMA, 2014; Ecological Associates, 2014 a;b):

- 12,500 ML/d flows – water begins to enter the creek system from the Murray River (downstream end)
- 15,000 ML/d flows – water leaves the creek system and begins to fill the forest floor
- 17,500 ML/d – most of the forest inundated
- 20,000 ML/d – outer fringe of the forest is inundated (red gum forest and black box woodland)

Modelled flows for current and natural flow events, shown below in Figure 3, indicate that there is a significant reduction in the median monthly discharge in the Murray River, particularly for flows over 10,000 ML/d. Typically, regulation of flows has reduced high flows and created extended periods of low flows, altered flooding timing and reduced the frequency and duration of inundation (Mallee CMA, 2014; Ecological Associates, 2014b).

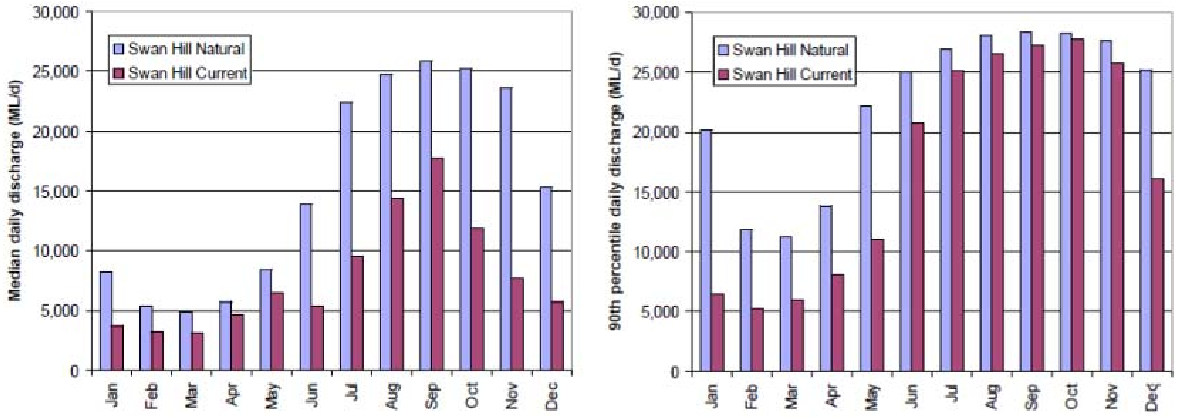



Figure 3 Median and 90th percentile flows in the Murray River through Vinifera to Robinvale for natural and current conditions. (Information based on Ecological Associates, 2006).

Further analysis of the information was undertaken on flows to compare modelled natural and baseline flows over 114 years of record on the basis of frequency, start date, median event interval and duration of the flooding event. Key observations include:

- flow events of 20,000 ML/d previously occurred 130 times every 100 years and now occur 80 times per 100 years (pre to post regulation). Median duration for these events have changed from 130 days to 45 days (pre to post regulation)
- high flow events occur on average 8 in 10 years (Ecological Associates, 2014b), not substantially different from pre-regulation
- seasonality of flows remains similar to pre-regulation
- reduction in median monthly flow peaks predominantly in the high flow months of July to January
- reduction in frequency and duration of flow peaks greater than 10,000 ML/day
- flows events of 10,000 to 15,000 ML/d have reduced in duration from five months to five weeks. These events occurred 15 years out of 10 previously (unregulated conditions)
- reduction in frequency of flow peaks around 25,000 ML/d from 10 events to five events every 10 years. Duration of these events has also reduced from 75 days to 30 days

## 3.7 Hydraulic modelling

Hydraulic modelling of the Vinifera floodplain was undertaken by Jacobs (2016) and Jacobs (2017). The hydrodynamic modelling included modelling of regulators N1a, N1b, N2 and N5, downstream levees and upgrading works (removal of obsolete structures, etc).

Hydraulic modelling of the Vinifera floodplain was undertaken by Jacobs (2016) and Jacobs (2017). The hydrodynamic modelling including modelling of regulators V1, V2, V3 and V4 and upstream and downstream levees and upgrading works (removal of obsolete structures, etc).

Modelling was undertaken using the MIKE FLOOD (1D and 2D linked software model) hydraulic modelling package. The modelling included modelling of historic events with the planned works in place. The Big Mod run (1895 to 2009) was assessed for daily flow data and modified for the current operational scenarios and works. Sensitivity testing and calibration of the model were undertaken by assessing the performance of the modelling results.

Key outcomes from the modelling include:

- the regulators would be operated in the Murray River flow range of 15,000 ML/d to 20,000 ML/d
- when Murray River flows exceed 20,000 ML/d, natural flooding from the river will provide higher flood levels than the planned flooding can
- the modelling scenarios adopted were:
  - Low Flow Peak - from the 2001 flood with all regulators modelled in open position throughout the time, aiming to model this natural event which peaked at 15,000 ML/d
  - Moderate Flood Peak – using the 2001 flood as previous but with regulators V1, V2 and V4 closed, aiming for a 17,500 ML/d flow
  - High Flood Peak – using the 2004 flood and with regulators V1, V2 and V4 closed, aiming for a 20,000 ML/d flow
  - High Flood Peak – using the 1985 flood and with regulators V1, V2 and V4 closed aiming for a 25,000 ML/d flow
  - Steady state model runs for the Murray River between 12,5000 and 35,000 ML/d (Jacobs 2017)

Results of the modelling have indicated the following outcomes for the proposed works:

- modelled scenarios indicate the scheme should work well
- head difference is generally 0.06 m or less for V2, V2 and Sill 1 – considered acceptable for erosion control
- Murray River banks (Points 1, 2, 3, 4 and 5) have acceptable head differences
- Murray River bank Point 6 has a 0.13 m head difference (higher)
- regulator V4 and Murray River bank Point 7 have 0.07 m head difference – may need to consider inflow capacity
- forest track bank restricts inflow

Comments on the quality of the modelling include the following:

- calibration of the model was not able to be undertaken (lack of sufficiently detailed data)
- accuracy of the model could be improved with additional survey
- modelling has not included the rise and fall constraints of the regulators and site conditions
- no sensitivity modelling of net evapotranspiration was undertaken.

In considering the Vinifera floodplain location and interactions with the Murray River, it is apparent that there is little to no connectivity of the main creek complex system at Vinifera with the river, outside of flood events.

# 4. Water management infrastructure, operations and water regimes

## 4.1 Water management infrastructure

### 4.1.1 Current infrastructure

Currently only minor works are in place on the Vinifera floodplain, mostly with a focus on access to the forest and limitation of flood waters in the private land to the east. The existing works in place include:

- downstream end
  - existing culvert under the track (V2)
  - track over floodplain (V1)
  - drop structure – no works in place
- upstream end:
  - pipe and bank at creek crossing of levee, neither of which function well (V3)
  - 600 mm diameter culvert inlet, direct inlet from the Murray River (V4)
  - levee bank separating the private land and the public land
- low points (6 No.) – no works in place

### 4.1.2 Proposed SDL works at Vinifera

The proposed package of works for Vinifera Park has been designed to:

- allow water movement in and out of Vinifera Park on a natural flow, and
- meet targets for flood duration and frequency using flow detention and regulating structures.

Water will be detained in the floodplain basin by a combination of regulating outflows and levees, summarised below.

- downstream end:
  - large regulator and crossing, (V2)
  - regulator and crossing, (V1)
  - levee blocking bank spanning the V1 and V2 regulators and beyond
  - drop structure – downstream of the levee for controlled release into the Murray River
- upstream end:
  - regulator and crossing (V3)
  - regulator at direct inlet from the Murray River (V4)
  - upgrade of levee bank separating the private land and the public land
- Low points (6 No.) – levees to be put in place

Figure 4 shows the site locations of the proposed works.

No specific fish passage provisions are planned for any of the anticipated works although all gating choices have been selected on the basis of providing passive fish passage where possible.

There is no provision in the Business Case for passing flows through the regulators while operational unless the structure is by default open during operation.  There has been no discussion as yet on overall turnover volume or additional attraction flows during the operation of these structures.

Table 1 SDL works and inundation area

| Proposed works | Purpose/Operation | Area inundated (maximum) |
|---|---|---|
| V1 | Downstream flow control | 349.6 ha |
| V2 | Downstream flow control | |
| Drop structure | Provides a plunge pool for downstream fish passage | |
| Main levee, raised tracks and overflow sills | Enables passing of local drainage flows, pass overland flows in large events and prevent backflow onto private land during a managed event | |
| V3 | Enables passing of local drainage flows, pass overland flows in large events and prevent backflow onto private land during a managed event. | |
| V4 | Allows inflows from the Murray River and prevent backflow into the Murray River when retaining water in the forest during a managed event. | |

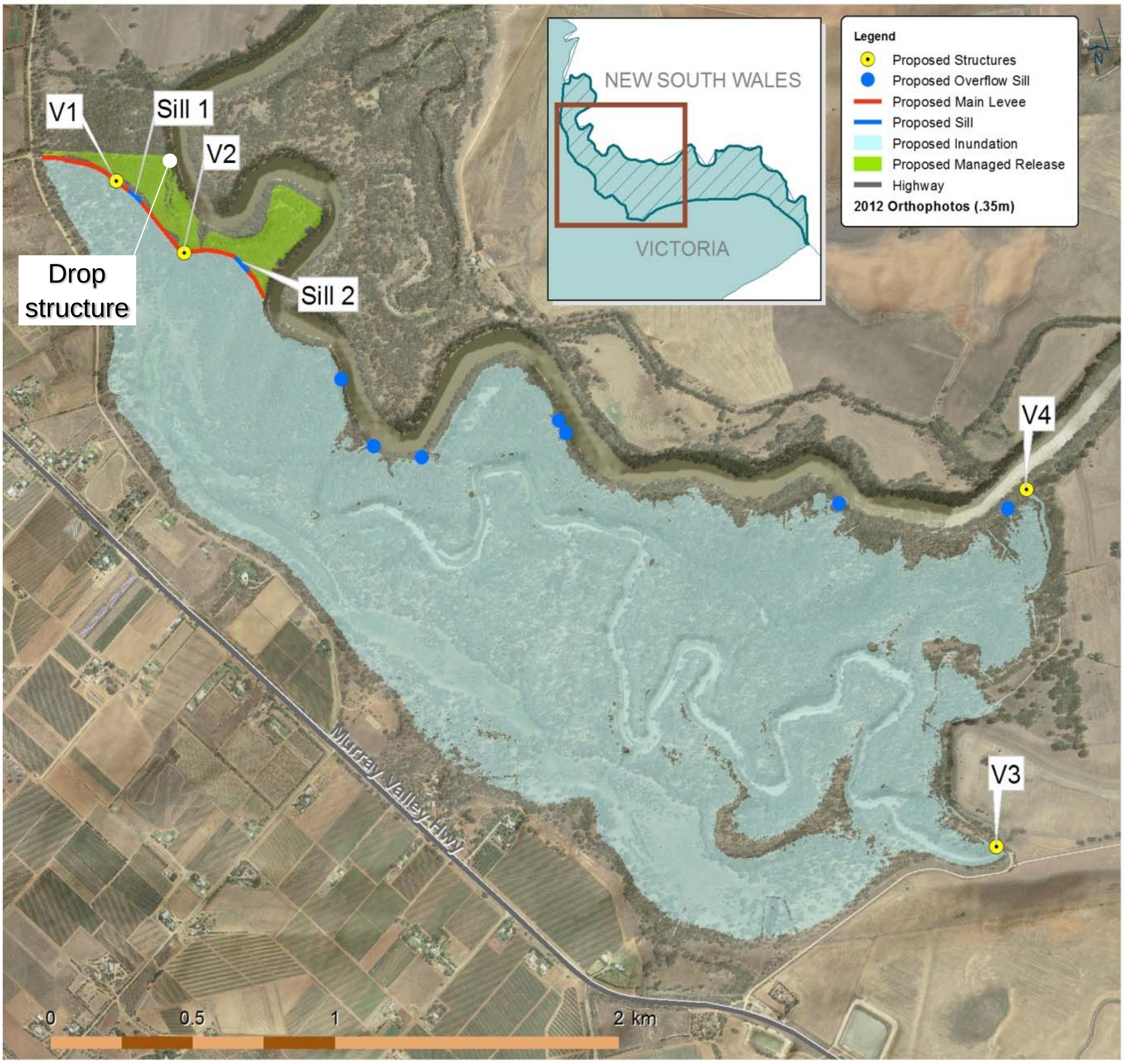



Figure 4 Vinifera floodplain – key structures for planned works

## 4.2 Proposed operations

The Vinifera floodplain water management works have been designed to provide maximum operational flexibility and can be used to complement Basin Plan flows or to deliver environmental benefits. Five scenarios have been developed to illustrate how these works can be used to achieve environmental outcomes. Scenarios include:

- default
- seasonal fresh
- Vinifera intermediate
- Vinifera maximum
- natural flooding

Each of the scenarios align with the water regime classes for Vinifera Park, as illustrated in Table 2 below and presented graphically in Figure 5.

Table 2 Links between the operating scenario and water regime class (Mallee CMA, 2014)

| Water Regime Class | Corresponding river flow (ML/day) | | | |
|---|---|---|---|---|
| | **>13,000** | **Up to 17,500** | **Up to 20,000** | **>20,000** |
| Seasonal anabranch | **Seasonal Fresh** | **Vinifera Intermediate** | **Vinifera Maximum** | **Natural flows**<br>**All structures open** |
| Seasonal wetland | | | | |
| Red gum swamp forest | | | | |
| Red gum forest and woodland | | | | |

### 4.2.1 Default

This scenario is the default configuration for Vinifera water management structures, in normal regulated river conditions when environmental watering is not required.

In this scenario all environmental structures are to be open.

### 4.2.2 Seasonal fresh

The seasonal fresh scenario would provide flow along Vinifera Creek and is achieved through suitable Murray River flow.

During this scenario all environmental regulators would remain in their default position of open.

### 4.2.3 Vinifera intermediate

Intermediate operation of the Vinifera regulators and their associated support structures will enable watering of Vinifera Creek and the lower floodplain more frequently without inundating upper floodplain areas. This scenario requires the opening of structures V1, V2 and V4 and the closure of V3 during Basin Plan or natural flows. Once flows begin to recede, structures V1, V2 and V4 are closed to manage inundation to the desired target level for an appropriate duration. Natural inflows maybe augmented by temporary pumps.

#### 4.2.4 Vinifera maximum

Maximum operation of the Vinifera regulators and their associated support structures will enable watering of Vinifera Creek and the upper floodplain areas. This scenario requires the opening of V1, V2 and V4 and the closure of V3 during Basin Plan or natural flows. Once flows begin to recede, structures V1, V2 and V4 are closed to manage inundation to the maximum operating level for an appropriate duration. Natural inflows maybe augmented by temporary pumps.

#### 4.2.5 Natural flooding

To minimise the impact of the infrastructure on natural flooding patterns, all regulating structures will be open during natural events, to allow full connectivity between the Murray River, Vinifera Creek and the floodplain.

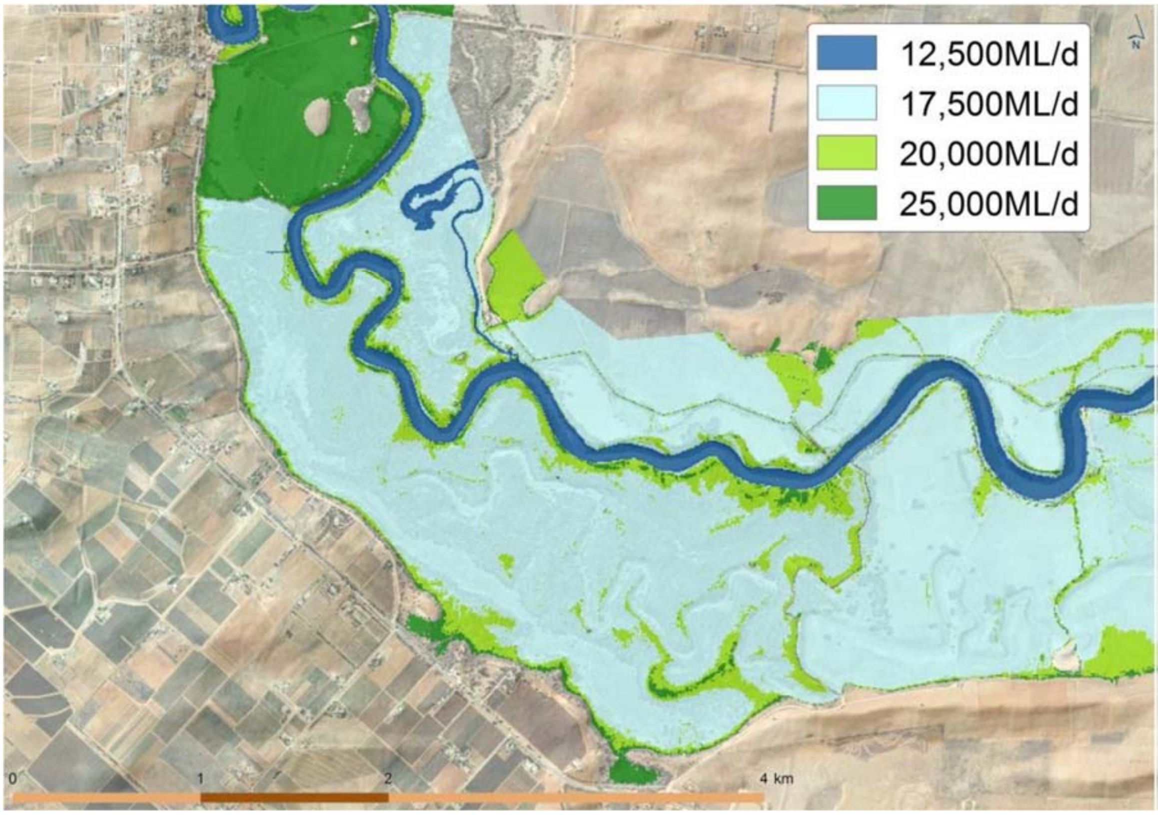



Figure 5 Vinifera floodplain inundation at flows of 12,500, 17,500, 20,000 ML/day (Jacobs, 2014)

#### 4.2.6 Transition between operating scenarios

It may be necessary to change between operation scenarios during the course of a watering event. Factors that may influence a decision to transition between scenarios may include:

- inflows causing increase in environmental water allocations
- inflows generating natural flooding
- response to ecological opportunities or to mitigate risks
- response to operational opportunities or to mitigate risks
- response to water quality risk mitigation requirements

## 4.3 Watering regimes

The proposed SDL works will provide flexibility to deliver a wide range of environmental watering events to meet the ecological objectives described in Section 9.1.

Table 3 provides a comparison of the water regime that can be provided by the proposed measure with the following water regimes:

- natural
- baseline condition (current condition)
- basin Plan (2750) without the measure

Basin Plan flows will contribute toward achieving the environmental water requirement of Vinifera Park compared to baseline conditions. The proposed measure is required to bridge the gap between Basin Plan flows and the environmental water requirements of Vinifera Park.

Table 3 Comparison of water regimes provided by natural, baseline, Basin Plan and the Vinifera Park measure. Natural, baseline, Basin Plan (Gippel, 2014, in Mallee CMA, 2014)

| Threshold (ML/d) | WRC | Scenario | Frequency mean (/100 years) | Interval Median (days) | Duration Median (days) | Event start date median (day of year, 1 Jan =1) | Prevalence years with event 5 |
|---|---|---|---|---|---|---|---|
| 15,000 | Seasonal Wetland | With measure | 100 | 190 | 150 | 152 | 100 |
| | | Natural | 100.9 | 172 | 174 | 170 | 95 |
| | | Baseline | 80.7 | 274 | 82 | 196 | 74 |
| | | Basin Plan 2750 without measure | 86 | 230 | 133 | 179 | 82 |
| 17,500 | Red Gum swamp forest | With measure | 90 | 210 | 120 | 152 | 90 |
| | | Natural | 98.2 | 191 | 157 | 181 | 94 |
| | | Baseline | 68.4 | 290 | 84 | 198 | 65 |
| | | Basin Plan 2750 without measure | 85.1 | 344 | 110 | 185 | 81 |
| 20,000 | Red Gum Forest and Woodland | With measure | 90 | 220 | 120 | 182 | 90 |
| | | Natural | 100 | 205 | 143 | 190 | 92 |
| | | Baseline | 61.4 | 307 | 72 | 201 | 59 |
| | | Basin Plan 2750 without measure | 78.9 | 259 | 93 | 192 | 72 |

# 5. Native fish

## 5.1 Species listed under Federal and Victorian legislation

Searches of State and Commonwealth databases indicate very few fish survey records in (or in the vicinity of) Vinifera Park. In terms of listed species, records exist of Murray hardyhead (*Craterocephalus fluviatilis*), at Woorinen North Lake (approximately 15 km upstream from Vinifera Park) but this population is now considered extinct (Ellis et al., 2013). Vinifera Park is also unlikely to provide conditions that will support the species. Surveys carried out as part of DELWP's 2017 Wetland Monitoring and Assessment Program (WetMAP) in nearby Nyah Park provide an understanding of fish likely to inhabit Vinifera Park. The 2017 survey indicated that only two native fish - carp gudgeon (*Hypseleotris spp.*) and Australian smelt (*Retropinna semoni*) and two exotic fish species - gambusia (*Gambusia holbrooki*) and carp (*Cyprinus carpio*) currently inhabit Nyah and these species are also therefore likely to inhabit Vinifera.

Listed species that may occur in the Murray River or floodplain wetlands of Vinifera Park include the freshwater catfish (*Tandanus tandanus*), golden perch (*Macquaria ambigua*), Murray cod (*Maccullochella peelii*), Murray-Darling rainbowfish (*Melanotaenia fluviatilis*) and silver perch (*Bidyanus bidyanus*). Table 4 provides a list of fish likely to occur in the vicinity of Vinifera Park (Ho et. al. 2004, Henderson et. al. 2012).

Table 4 Native fish species expected to occur in Vinifera Park

| Common Name | Scientific Name | EPBC Act Status | FFG Act Status | DELWP Advisory | Likelihood of Occurrence |
|---|---|---|---|---|---|
| Flathead galaxias | *Galaxias rostratus* | CR | N | V | Unlikely |
| Freshwater catfish | *Tandanus tandanus* | - | L | EN | Possible |
| Golden perch | *Macquaria ambigua* | - | L | NT | Likely |
| Macquarie perch | *Macquaria australasica* | EN | L | EN | Unlikely |
| Murray cod | *Maccullocella peelii* | VU | L | V | Likely |
| Murray hardyhead | *Craterocephalus fluviatilis* | EN | L | CR | Unlikely |
| Murray-Darling rainbowfish | *Melanotaenia fluviatilis* | - | L | V | Possible |
| Silver perch | *Bidyanus bidyanus* | CR | L | V | Likely |
| Unspecked hardyhead | *Craterocephalus stercusmuscarum fulvus* | - | - | - | Likely |
| Carp gudgeon | *Hypseleotris klunzingeri* | - | - | - | Certain |
| Bony herring | *Nematalosa erebi* | - | - | - | Likely |
| Flathead gudgeon | *Philypnodon grandiceps* | - | - | - | Likely |

| Common Name | Scientific Name | EPBC Act Status | FFG Act Status | DELWP Advisory | Likelihood of Occurrence |
|---|---|---|---|---|---|
| Dwarf flat-headed gudgeon | *Philypnodon macrostomus* | - | - | - | Likely |
| Australian smelt | *Retropinna semoni* | - | - | - | Certain |
| Environment Protection and Biodiversity Conservation Act (EPBC Act) status: EXtinct, CRitically endangered, ENdangered, VUlnerable, Conservation Dependent, Not Listed<br>Flora and Fauna Guarantee Act (FFG Act) status: Listed, Nominated, Delisted, Never Listed, Ineligible for listing<br>DELWP Advisory status: presumed EXtinct, Regionally Extinct, Extinct in the Wild, CRitically endangered, ENdangered, Vulnerable, Rare, Near Threatened, Data Deficient, Poorly Known, (DSE 2013) | | | | | |

The habitat requirements and life cycles of the species likely to occur at Vinifera are described in Section 6.

# 6. Conceptual models of native fish life cycles and habitat requirements

The following information on fish describes the fish community and provides conceptual models to guide the fish recovery strategy. Conceptual models are representations of complex systems that use available data and the present understanding of causal factors to show links, interactions and processes. The strength of conceptual models is that they link components of a system together to present a holistic view. The model, and the process of constructing the model, can highlight knowledge gaps, identify research and monitoring priorities, and clarify and synthesise thinking.

A potential weakness of conceptual models is that the relative strengths of various links, based on the data, are often not explicit and the model can sometimes be viewed as having more validity than the data suggests. Conceptual models need to be viewed as tools that need constant review and updating, rather than providing an absolute explanation. They are presented in this report as a resource to describe the present understanding and to be constantly refined.

Conceptual models are useful in natural resources management as they attempt to provide an understanding of why biota are present or absent in different habitats (i.e. reasons or causes), rather than only a description of distribution (i.e. effects). A good example of these differences is the area of fish passage. Providing fishways enable fish to move past a barrier (i.e. effect) but the conceptual model behind it may be that fish are moving to spawning habitat, feeding habitat, or countering downstream displacement as larvae. The conceptual model would then provide guidance for complementary actions, such as improving spawning habitat.

The conceptual models below contain life-history, ecology, obligate habitat requirements and associated hydrological/flow requirements for these species in the southern Murray-Darling Basin. The models are based on the recent published and unpublished research. For each species/group a concise description in text is provided, followed by a pictorial representation of the model.

## 6.1 Murray cod

Murray cod (*Maccullochella peelii* [Mitchell]) occasionally grow to 1.5 m long and 50 kg and can live for up to 50 years. Murray cod inhabit many of the waterways of the Murray-Darling Basin (MDB) (ACT, SA, NSW, Qld and Vic) and live in a wide range of aquatic habitats that range from clear, rocky streams to slow flowing turbid rivers and billabongs (Lintermans, 2007).

Table 5 Conceptual model Murray cod

**Habitat use**

1. Prefer permanent flowing river reaches and creeks with hydraulic complexity/diversity.
2. Require woody debris (snags), debris piles and bank side vegetation (e.g. Murray River, Mullaroo Creek; Kaye and Sharpe 2009).
3. In the southern reaches of the MDB, the status of Murray cod populations is influenced by habitat availability, flow regime, hydrodynamic diversity (water velocity, depth and turbulence) and connectivity (Henderson et al. 2010a,b; Mallen-Cooper et al., 2013; Mallen-Cooper and Zampatti, 2015a; Bice et al. 2017; Wedderburn et al. 2017; Mallen-Cooper and Zampatti 2017).
4. Recruitment potential may be increased when additional habitat resources such as food and shelter are created as river benches, snags and rocks and riparian zones are inundated by rising flows.
5. Eggs and larvae require a steady flow increase and very little daily variations in water level (e.g. 0.1 m) to maximise spawning success.

**Diet**

6. Diet changes with age with the typical adult diet consisting of spiny crayfish, yabbies and shrimps (National Murray Cod Recovery Team 2010)
7. Predominantly piscivorous and feed on native and exotic fish species e.g. [native species - other cod (*Maccullochella* spp.), golden perch, bony bream (*Nematalosa erebi*), freshwater catfish, western carp gudgeon (*Hypseleotris klunzingeri*)], [exotic species - redfin perch (*Perca fluviatilis*), carp (*Cyprinus carpio*) and goldfish (*Carassius auratus auratus*)].
8. Less common animals found in the diet include ducks, cormorants, grebes, tortoises, water dragons, snakes, mice, frogs and mussels (Rowland, 1996).
9. Upon hatching, larvae are 5–8 mm long and within 8–10 days can feed on zooplankton. After reaching a length of 15–20 mm, they are also able to feed on aquatic insects (King, 2005).

**Spawning**

10. Occurs annually during October, November and December each year (Humphries, 2005; Koehn and Harrington, 2005), during base flows and during river rises (King et al., 2009a; Ye et al., 2008).
11. Display complex pre-spawning courtship behaviour (during winter and spring) and females may spawn with more than one male.
12. Females lay their eggs into nests (i.e. stable habitat such as logs, rock and root ball hollows). The male guards the nest for up to two weeks while the eggs hatch. Juveniles leave the nest and move into littoral or snag habitats.

13. Despite often being classified as a ‘flow independent spawner’ Murray cod do require permanent flowing water for optimal recruitment (Stuart and Sharpe, 2017; 2018; Bice et al. 2017; Mallen-Cooper and Zampatti 2017; Wedderburn et al. 2017; Tonkin et al. 2018).
14. Can spawn and recruit during low stable flows, rising flows and floods.
15. Floods are not necessary for spawning but in some cases, appear to enhance subsequent recruitment (King et al., 2009a).

**Recruitment**

16. Recruitment is almost always associated with flowing water habitats (Sharpe and Stuart 2016; 2018).
17. There is high mortality of young fish but those that survive their first summer and winter and grow to 90-140 mm long tend to have a good chance of recruiting into the sub-adult population (250-600 mm long) (Baumgartner et al., 2006).
18. Mature late (3-5 years) and at a reasonably large size (>600 mm long) but females have relatively low egg numbers (fecundity).
19. Long-lived (>40 years) and can grow to a large size (e.g. 1.4 m and 45 kg) where they become the apex aquatic predator (Anderson et al., 1992a; Ebner, 2006).
20. Where riverine stocking occurs there can be significant augmentation of natural populations (Forbes et al., 2016).

**Movement and migration**

21. May move large distances (e.g. up to 120 km) but generally only up to 30 km (Leigh and Zampatti, 2011; 2013; Saddlier et al. 2008).
22. Move from their home snag to spawning areas in July/August/September on rising water temperature in winter and early spring (Jones and Stuart, 2007; Saddlier et al. 2008).
23. Both adult and juvenile fish are strongly associated with snags with a ‘home’ snag with adult fish often returning to the same snag (Koehn, 2009).
24. In recent years, the need to provide fish passage for Murray cod to escape anoxic ‘black water’ events has been demonstrated in the lower Murray, most recently in late 2016, when large numbers of fish were killed in the lower and mid-Murray River, Edward-Wakool system, Frenchman’s Creek, Rufus River and Mullaroo Creek (Tonkin et al., 2017).

**Implications for Victorian environmental flows**

25. A specific Murray cod hydrograph should be implemented where population recovery is required (Sharpe et al. 2015; Sharpe and Stuart 2018).
26. Fast flowing riverine sites (e.g. >0.3m/s) can be considered ecological priorities for Murray cod recovery.
27. Application of the Murray cod hydrograph, especially permanent flow in winter, is required on an annual basis (Sharpe and Stuart 2015; Sharpe and Stuart 2018).

**Implications for flow monitoring**

28. Flow-event monitoring is crucial to identify the specific components of the hydrograph (shape, timing, frequency, duration, height, discharge, velocity) that influence population dynamics.

**Threats**

29. Lack of fast flowing water habitats with a low density of snags because of past de-snagging, regulation transforming the hydrodynamic nature of many rivers from

flowing rivers to weir pools and cold water discharge from large river storage dams (Mallen-Cooper and Zampatti 2017).

30. Loss of permanent flows when rivers and anabranches are de-watered during winter.

31. In many regulated rivers and anabranches (e.g. Gunbower Creek, Gulpa Creek, Edward River, Mullaroo Creek) there are two major hydrological constraints on Murray cod population recovery

    - intense fluctuation in river discharge causing rapid decreases in river level and interruption of spawning/recruitment processes,
    - low or zero winter flows that appear to be population 'bottlenecks' because this forces all fish into the deeper refuge pools for up to 3 months each year (Sharpe and Stuart, 2015).

**Knowledge and data limitations**

32. Wide-scale implementation, refinement and evaluation of the Murray cod hydrograph

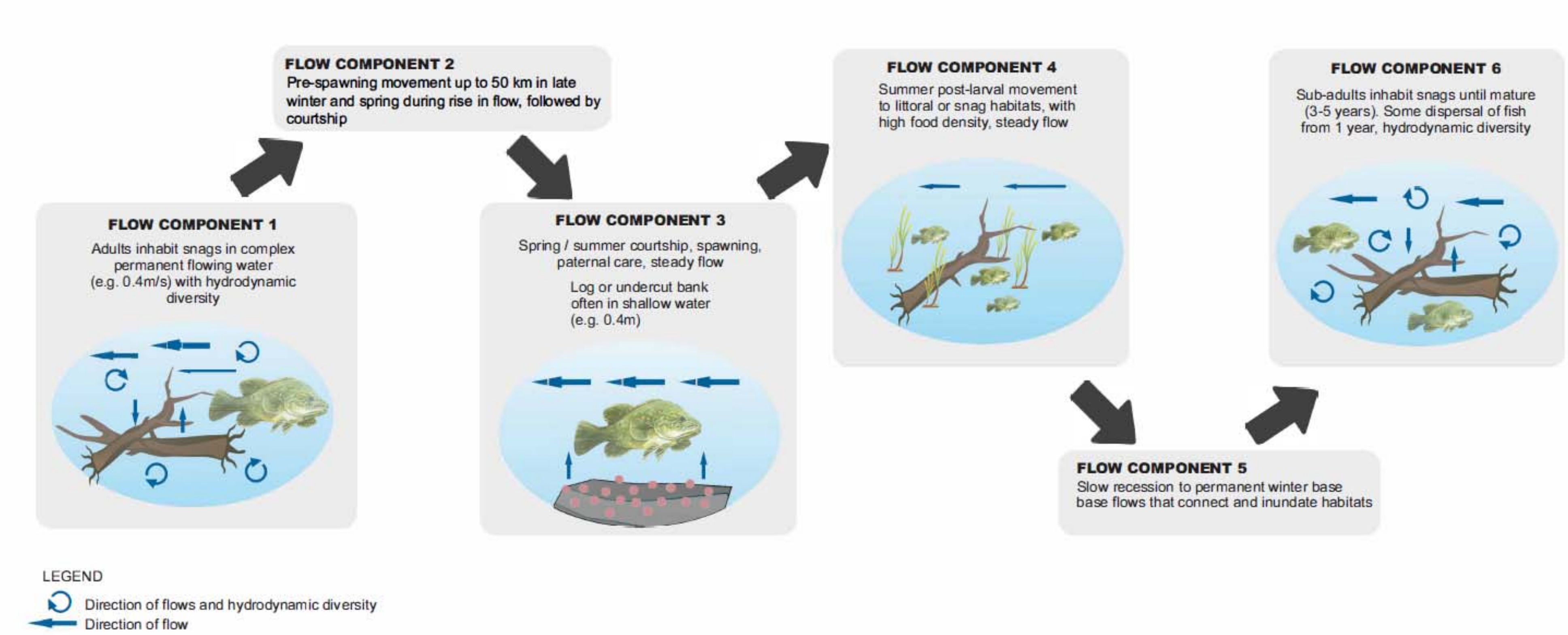
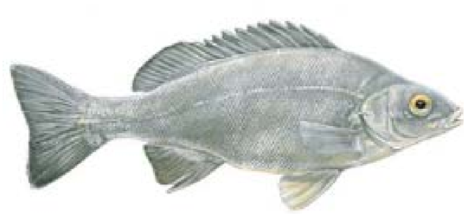



Figure 6 Conceptual model Murray cod

## 6.2 Silver perch



Silver perch (*Bidyanus bidyanus* [Mitchell]) long-lived, river channel specialist with drifting egg/larvae stages. Commonly grows to 400 mm long and 1.5 kg. They can live for 25+ years but most riverine fish are <10 years old (Mallen-Cooper and Stuart, 2003).

The main MDB silver perch population is centred in the mid-Murray River (Yarrawonga to Euston), with occupancy in the Edward-Wakool, Lower Darling, Murrumbidgee, Warrago/Condamine, Victorian tributaries (Loddon, Campaspe, Goulburn, Ovens) with low numbers present in SA. Since European settlement their distribution and abundance has severely declined with their remaining stronghold in the Lock 11 to Lock 26 reach of the Murray River (Mallen-Cooper and Brand, 2007; Lintermans, 2007). Catches of silver perch in the mid-Murray have declined by 94% over a 50-year period (Mallen-Cooper and Brand, 2007).

Despite annual stocking few other self-sustaining populations exist though they can still be found in the Murrumbidgee River and several other NSW and Victorian tributaries.

Table 6 Conceptual model for silver perch

| **Habitat use** |
|---|
| 1. Main river channel habitats used for feeding, refuge, spawning, survival and recruitment. |
| 2. Found in the Lock 11-26 reach of the Murray River because this encompasses the longest unregulated river reach on the main stem of the Murray River and thus provides 500+ km of their preferred flowing water habitat. |
| 3. Habitat specialists (obligate riverine species) predominantly occupying large fast flowing river regions (e.g. Murray, Darling) over sand and structure (Clunie and Koehn, 2001a; Merrick and Schmida, 1984) to the slow flowing, turbid waters of lower reaches (Rowland 1995) while Cadwallader and Backhouse (1983) suggest they prefer open waters devoid of snags. Small numbers of fish utilise tributaries of main channel. |
| 4. Consistently reported by anglers and researchers to show a general preference for faster-flowing water, including rapids and races, and more open sections of river, throughout the MDB. |
| 5. Are rarely collected in floodplain lakes. |
| 6. Winter is a critical period for young-of-year fish survival (i.e. fish that are less than one year old and the result of spawning in the previous spring). |
| **Diet** |
| 7. Adults are omnivorous, taking a variety of small prey including zooplankton, aquatic insects, molluscs, small crustaceans and worms as well as algae. |
| **Spawning** |
| 8. Long-lived (17 years [river], 27 years [dam]), show variable growth, (Mallen-Cooper and Stuart, 2003) and no parental care. |
| 9. Widespread spawning from Mildura to Upper Victorian tributaries (King et al., 2009b) including Lower Darling. |
| 10. Sexually dimorphic species: males maturing at three years (250mm) and females at 4-5 years (300mm). |

11. Seek flowing water (e.g. 0.3 m/s) in river channel habitats in which to spawn, so their eggs and larvae can drift downstream.
12. Spawning occurs annually in spring and early summer (late-October to mid-February King et al., 2005; King et al., 2009a; Raymond et al., 2014).
13. First major spawning event during a coinciding rise in water temperature (2.5°C in prior seven days) and a rise in water level and a second major spawning event in December 2005 as flows were declining (King et al., 2009a).
14. Fecundity is high, with females often laying 300,000 or more non-adhesive, semi-pelagic eggs (Merrick and Schmida, 1984; Merrick, 1996, Rowland, 2009).
15. Eggs sink in the absence of current (Lake, 1967), hatch within 30 to 36 hours, and have a two-week larval stage (NSW DPI, 2006).
16. An aggregate spawning species, with large schools forming around known spawning period following upstream migration (Lintermans, 2007; Koehn and O'Connor, 1990).
17. Spawning intensity increased with greater flows, particularly above flood levels and was enhanced when temperatures were rising (King et al., 2016). Spawning intensity declined with increasing number of flood days in preceding three months (King et al., 2016).
18. There is no evidence that silver perch directly use ephemeral floodplains for spawning.
19. Spawning in the Upper Victorian Murray and lower Goulburn rivers does not appear to result in localised recruitment (King et al., 2009b), late-stage larvae and early juvenile fish are rare.

**Recruitment**

20. Have a drifting larval phase of up to 15 days (NSW DPI, 2006).
21. Larvae believed to be at risk of high mortality in weir pools due to; reduced flows, decreased temperature, lack of food and anoxic conditions (e.g. Yarrawonga and Torrumbarry, Euston).
22. Recruit in flood and non-flood years with some fish recruiting from offstream floodplain habitats (e.g. Lake Boga; Mallen-Cooper and Stuart, 2003; Tonkin et al. 2017).
23. The level of recruitment upstream of Torrumbarry Weir is a knowledge gap but may be low. Hence, northern Victorian rivers appear heavily reliant on re-colonisation migrations of juvenile and adult silver perch from downstream and connectivity with the Victorian Murray (Tonkin et al. 2017). However, it is also likely that a small proportion of silver perch population is derived from the Darling system where there is a flow spike or flood (Sharpe and Stuart 2018).
24. There is no evidence for enhanced silver perch recruitment from deliberate creation of 'slackwaters'.
25. Recruitment is generally believed to be tied to high flows in spring or summer that stimulate fish to move upstream and spawn, inundate floodplains and produce food for larvae (Lake, 1967; Reynolds, 1983; Gehrke, 1992; Harris and Gehrke, 1994).

**Movement and migration**

26. Most tagged fish in the lower Murray River moved upstream, with one individual recorded to move 570km in 19 months (Reynolds, 1983).

27. Juveniles in the mid-Murray River moved upstream from October to April; adults moved upstream from November to February which was believed to be spawning related (Mallen-Cooper, 1999).
28. Thousands of immature fish, that are one year and older, migrate upstream, responding to increased flow (e.g. +0.15m/24h) (Torrumbarry Weir data).
29. There is no upstream migration of YOY silver perch (Mallen-Cooper and Stuart, 2003).

**Implications for Victorian environmental flows**

30. Increase short-term flow variability (1-2 days, height changes up to 0.2m) to 50% of natural flows to stimulate silver perch movements (Koehn et al., 2014).
31. Spawning flows can be implemented in spring/early summer. Tributary (e.g. Campaspe, Loddon, Gunbower, Darling etc) flows are highly unlikely to result in spawning due to the limited spatial scale and low hydraulic diversity (unless the tributaries contribute to higher flows in the Murray, where spawning may occur).
32. Spawning flows can be 1-in-1 year in channel style events, with strong variability, and should be based on the natural hydrograph
33. Re-colonisation flows in early summer (e.g. January-March) can attract upstream migrating yearlings and juvenile fish into the Victorian Murray and tributaries in the Echuca-Yarrawonga reach, especially if synchronised with rising flows in the Victorian Murray (Sharpe, 2011; Stuart and Sharpe, 2015).
34. Using environmental flows to create hydrodynamic diversity is the major objective for successful silver perch outcomes.
35. Weir pool lowering can also be used in conjunction with environmental flows to maximise hydraulic diversity over large spatial scales (Ye et al., 2008).
36. Landscape scale planning and monitoring is required to maximise silver perch outcomes, such as providing Victorian re-colonisation flows after high flows in the lower Murray/Darling systems (Sharpe et al., 2015).
37. Protecting the integrity of flows over large spatial scales (e.g. 300-500 km), with a co-ordinated multi-state cooperation is required to enhance silver perch population dynamics.
38. Increased spawning of silver perch through environmental flows aimed at mimicking natural flood events has been demonstrated (King, 2008).
39. Increase flow rate through weir pools to > 0.3m/s, can be achieved via increased flow delivery (20,000 ML/d) or through physical lowering of weir (flows of 10,000 ML/d) to achieve the same ecological output.
40. Mitigating low winter flows (to more natural winter flows) could improve fish condition and have flow on benefits for recruitment (Koehn et al., 2014).
41. Low winter flows increase the risk to fish through increased predation and competition, habitat loss, drying, poor water quality, lower egg and larval survival rates (Koehn et al., 2014) and the potential lack of flow cues and gonad development in larger fish.

**Implications for flow monitoring**

42. Flow-event monitoring is crucial to identify the specific components of the hydrograph (shape, timing, frequency, duration, height, discharge, velocity) that influence population dynamics of silver perch.

43. Flow evaluation analysis should target the fish-and-flow event relationship through metrics such as: size/age distribution, emigration, immigration, movement, recruitment and spawning (King et al., 2009b). Broad-scale analyses of abundance (CPUE) are of very limited use.

**Threats**

44. River regulation and diversion restricts juvenile and adult movement, prevents dispersal and recolonization of extensive stretches of river and increases risk of localised extinction and fragmentation.
45. Impact and loss of in channel peaks, including the loss of small floods (5000-10,000ML/d) occurring in the Murray River have decline by half over the past 50 years (Close, 1990).
46. Weirs may trap eggs and early larvae causing them to settle and die (Baumgartner et al., 2014a).
47. Undershot weirs kill >90% of larvae (Boys et al., 2010)
48. Thermal issues will limit spawning below weirs and possibly increase larvae survivorship.
49. Silver perch are highly susceptible to several diseases including EHNV (Langdon 1989).
50. Low level of genetic variation in natural silver perch populations (Keenan et al., 1996).

**Knowledge gaps and data limitations**

51. Downstream movement of silver perch
52. Recruitment dynamics and relationship with flows have components which remain unclear. The role of larger floods in the life-history of silver perch is also still unclear; with observations of increased spawning at Barmah but this does not always result in recruitment. Ellis and Pyke (2011) indicate that successful recruitment can occur via pumping (to Margooya Lagoon) when carp exclusion screens are in place.
53. Impact of weir pools on survivorship of larvae.
54. A major knowledge gap is larval drift distance and survival upon entering a weir pool (e.g. larvae from the lower Goulburn River and mid-Murray River drifting into the Torrumbarry Weir pool)
55. Improve knowledge of recruitment links to flows (intervention and monitoring).

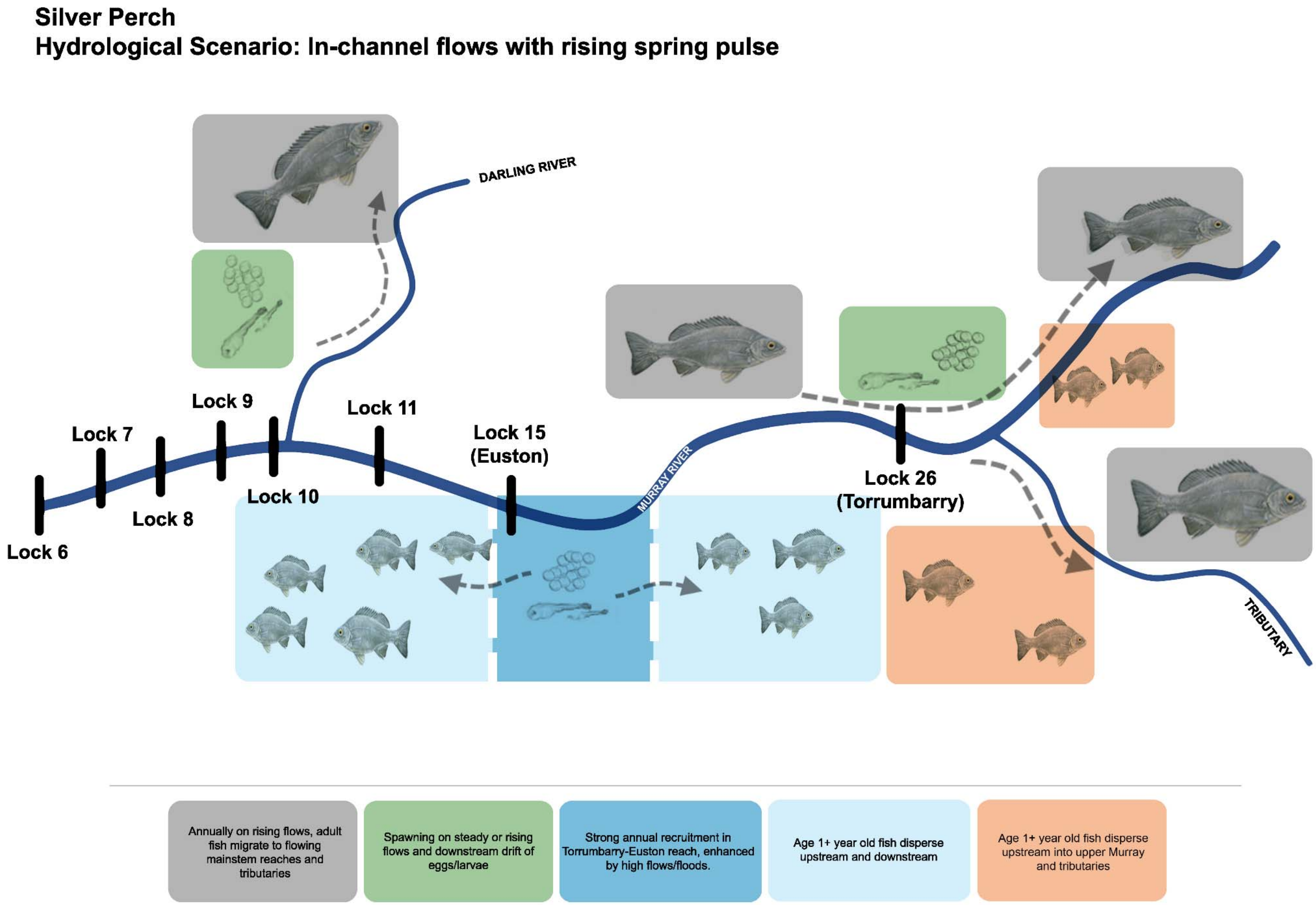



Figure 7 Conceptual model for silver perch

## 6.3 Golden perch

Golden perch (*Macquaria ambigua* [Richardson]), which commonly grow to 600 mm long and 3 kg are widespread throughout the Murray-Darling Basin, especially in the lower and mid reaches, but have severely declined above dams in the upper reaches of most tributaries. They are predominantly found in the lowland, warmer, turbid, slow flowing rivers. Golden perch have a maximum life-span of 25 years and commonly reach 600 mm long.

Table 7 Conceptual model for golden perch

| Habitat use |
|---|
| 1. Inhabit a wide variety of aquatic habitats, including slow flowing rivers, fast flowing rivers at landscape scales (e.g. 500 km; Mallen-Cooper and Zampatti, 2015b), lakes, anabranches and billabongs.<br>2. Diverse aquatic habitats are important to provide shelter and a productive food web, especially so these fish can feed in winter.<br>3. Main river habitats are used for feeding and are also an important refuge and overwintering habitat.<br>4. Habitat generalists often associated with physical habitat (‘snags’), drop offs and deep water (Crook et al., 2001).<br>5. Winter is a critical period for young-of-year fish survival (i.e. fish that are less than one year old and the result of spawning in the previous spring). |
| **Diet** |
| 6. The species is an opportunistic carnivore. The diet of adults consists mainly of shrimps, yabbies, small fish and benthic aquatic insect larvae (Baumgartner 2007).<br>7. Juveniles consume more of the smaller items such as aquatic insect larvae and microcrustaceans (Lintermans, 2007). |
| **Spawning** |
| 8. Long-lived, show variable growth and females are highly fecund, they display no parental care (Anderson et al., 1992b; Mallen-Cooper and Stuart, 2003).<br>9. Spawning occurs in spring and summer with the Darling River potentially later (October-March; >17°C; King et al., 2009a; Sharpe 2011; Sharpe and Stuart 2018).<br>10. Fish spawn during 1-in-1 year bank full flows that have variability (e.g. 0.15 m/24 h) and during over bank flows.<br>11. A small to large rise in water level, or flow pulse (e.g. 0.3 m/s), is the proximate cue to initiate spawning so eggs and larvae can drift downstream (Lake, 1967; King et al., 2009a; Sharpe, 2011).<br>12. Eggs hatch after 1-2 days and larvae drift downstream, where larval transition to early juveniles occurs in the main river channel if sufficient food resources for young fish also occur (Sharpe, 2011). Drift can be prolonged at up to 35-40 days and travel distances at >1000 km where larvae settle into floodplain lakes or along the channel margins (Sharpe and Stuart 2018).<br>13. Larval passage through under-shot weir gates results in high mortality (Baumgartner et al. 2006). Irrigation offtakes also receive drifting larvae, depending on the proportion of flow diverted (King and O’Connor, 2007). |

14. There is no evidence that golden perch directly use ephemeral floodplains for spawning in the Murray system but floodplain lakes are important nurseries.
15. Outside of the Murray main river channel (and associated anabranches) spawning has only been recorded in the Goulburn River, with no other confirmed records of spawning in Victorian rivers (e.g. Ovens, Broken and Campaspe rivers). Spawning is regularly documented in the Darling and Murrumbidgee rivers (Sharpe and Stuart 2018). Most of the Lower Murray golden perch population are likely to be derived from a combination of Murray and Darling system spawnings.
16. Spawning in the Upper Victorian Murray and lower Goulburn rivers does not appear to result in localised recruitment (King et al., 2009a; Koster et al., 2014) whereby records of late-stage larvae and early juvenile fish are rare.

**Recruitment**

17. Recruitment occurs during within-channel flows and especially during over-bank flows when ephemeral floodplains are inundated increasing productivity and larval survival (Mallen-Cooper and Stuart, 2003; Ye et al., 2008; Ebner et al., 2009; Sharpe 2011; Zampatti and Leigh, 2013; Sharpe and Stuart 2018).
18. Recent research indicates that the juvenile population, in the lower Murray and at least upstream to Torrumbarry, can be made up of significant numbers of fish spawned in the Darling River, with 1+ fish migrating downstream in the Darling and then upstream in the Murray River (Zampatti et al., 2015; Sharpe and Stuart 2018).
19. The level of recruitment in the Murray River upstream of Torrumbarry Weir is a knowledge gap but may be low. Hence, northern Victorian rivers appear heavily reliant on re-colonisation migrations of juveniles and adults from downstream and connectivity with the Victorian Murray.
20. There is no evidence for enhanced recruitment from deliberate creation of ‘slackwaters’ (Sharpe, 2011; Mallen-Cooper et al., 2013).
21. Young fish settle into off-stream floodplain or littoral riverine nursery habitats (Sharpe 2011).
22. Populations in the Murray River and tributaries are episodic in age structure, often being dominated by only a few distinct year classes. Strong natural recruitment occurs following high flow or flood years (Ye et al., 2008; Mallen-Cooper and Stuart, 2003; Sharpe, 2011; Ferguson and Ye, 2012; Zampatti et al., 2015; Crook et al., 2016).
23. In extreme cases, one year class can represent more than 60% of the adult population in broad reaches of the Murray River (Zampatti et al., 2015).
24. In particular rivers, low-levels of recruitment occur in most years, such as the Goulburn (Zampatti et al., 2015; Crook et al., 2016) but in others such as the Murray and Edward-Wakool (an anabranch of the Murray) there are successive years of recruitment failure and populations are dominated by particular year classes, when strong natural recruitment and emigration has occurred (Ye et al., 2008; Zampatti et al., 2015; Thiem et al., 2017).
25. In those rivers, fragmented demographics have been attributed to a combination of spawning limitations, recruitment failure and barriers to dispersal (Mallen-Cooper and Stuart, 2003; Leigh and Zampatti, 2011, 2013, Stuart et al., 2008; Sharpe, 2011; Sharpe et al., 2015; Zampatti et al., 2015; Thiem et al., 2017).

## Movement and migration

26. During in-channel flows, especially in tributaries, golden perch often display site fidelity but there can be major home range shifts (Crook, 2004) and there is strong movement between the Murray River and tributaries (Koster et al., 2014).
27. Adults move upstream in the mainstem, often through fishways, of the Murray River in spring and summer and this is often spawning related (Mallen-Cooper, 1999; Stuart et al., 2008; Baumgartner et al., 2014a).
28. Movement is strongly cued by rising/falling flow and water temperature with much less migration in stable flow and in winter.
29. Also move downstream in spring, summer and autumn (O'Connor et al., 2005).
30. Thousands of immature golden perch, that are one year and older, migrate upstream, responding to increased flow (e.g. +0.15m/24h) and these migrate into early autumn.
31. Mature and immature fish may aggregate for days or weeks at weirs, if flows provide sufficient stimulus, or they may return downstream to seek alternative migration pathways. Aggregations below barriers can quickly disperse downstream as flows recede.
32. Juveniles make staged re-colonisation migrations, responding to a flow in a movement pulse and then stopping during stable flows.
33. Migrations are usually over the scale of 100s of kilometres although some can be over 10s of kilometres (Reynolds, 1983; O'Connor et al., 2005; 2015).
34. A greater proportion of the fish population migrates during major over-bank flood events such as the 2010/11 floods. For example, major increases in abundances and biomass within the Victorian upper Murray reach were a result of adult immigration from downstream sources (Lyon et al., 2014).

## Implications for Victorian environmental flows

35. Designing flows to cue fish migration and movement through Victorian fishways is possible by releasing near bank full flows for short periods (days to weeks per event) in spring and summer.
36. Spawning flows can be implemented in the Victorian Murray and lower Goulburn rivers in spring/early summer. Tributary (e.g. Campaspe, Loddon, Gunbower etc) flows are highly unlikely to result in spawning due to the limited spatial scale and low hydraulic diversity.
37. Spawning flows can be 1-in-1 year bankfull events, with strong variability, and should be based on the natural hydrograph.
38. Prioritising 'slackwater' habitats for larvae in these tributaries is highly unlikely to result in enhanced recruitment.
39. Re-colonisation flows in early summer (e.g. January-March) can attract upstream migrating yearlings and juvenile fish into Victorian tributaries and in the Victorian Murray in the Echuca-Yarrawonga reach, especially if synchronised with rising flows in the Victorian Murray (Sharpe, 2011; Stuart and Sharpe, 2015).
40. Using environmental flows to create a hydrodynamic diversity is the major objective for successful golden perch outcomes (Zampatti and Leigh, 2013; Koster et al., 2014; Sharpe et al., 2015). The 'slackwater' model has little empirical support.
41. Weir pool lowering can also be used in conjunction with environmental flows to maximise hydraulic diversity over large spatial scales (Ye et al., 2008).

42. Protecting the integrity of flows over large spatial scales (e.g. 300-500 km), with a co-ordinated multi-state cooperation is required to enhance golden perch population dynamics.
43. Landscape scale planning and monitoring is required to maximise golden perch outcomes, such as providing Victorian re-colonisation flows after high flows in the lower Murray/Darling systems (Sharpe et al., 2015).

**Implications for flow monitoring**

44. Flow-event monitoring is crucial to identify the specific components of the hydrograph (shape, timing, frequency, duration, height, discharge, velocity) that influence population dynamics of golden perch.
45. Flow evaluation analysis should target the fish-and-flow event relationship through metrics such as: size/age distribution, emigration, immigration, movement and spawning. Broad-scale analyses of abundance (CPUE) are of very limited use.

**Threats**

46. Loss of connectivity to floodplain nursery habitats
47. River regulation and diversion restricts juvenile and adult movement, prevents dispersal and recolonization of extensive stretches of river and increases risk of localised extinction and fragmentation
48. Weirs may trap eggs and early larvae causing them to settle and die (Baumgartner et al., 2014a)
49. Undershot weirs kill >90% of larvae (Boys et al., 2010)
50. Thermal issues will limit spawning below weirs and possibly decrease larvae survivorship
51. Loss of off-channel floodplain nursery habitats
52. Impoundment of riverine flowing water habitats

**Knowledge and data limitations**

53. Implementation of catchment scale flow planning to recover populations
54. A major knowledge gap is larval drift distance and survival upon entering a weir pool (e.g. larvae from the lower Goulburn River and mid-Murray River drifting into the Torrumbarry Weir pool).

**Golden Perch**
**Hydrological Scenario: rising in-channel flows in lower Murray River and tributaries**

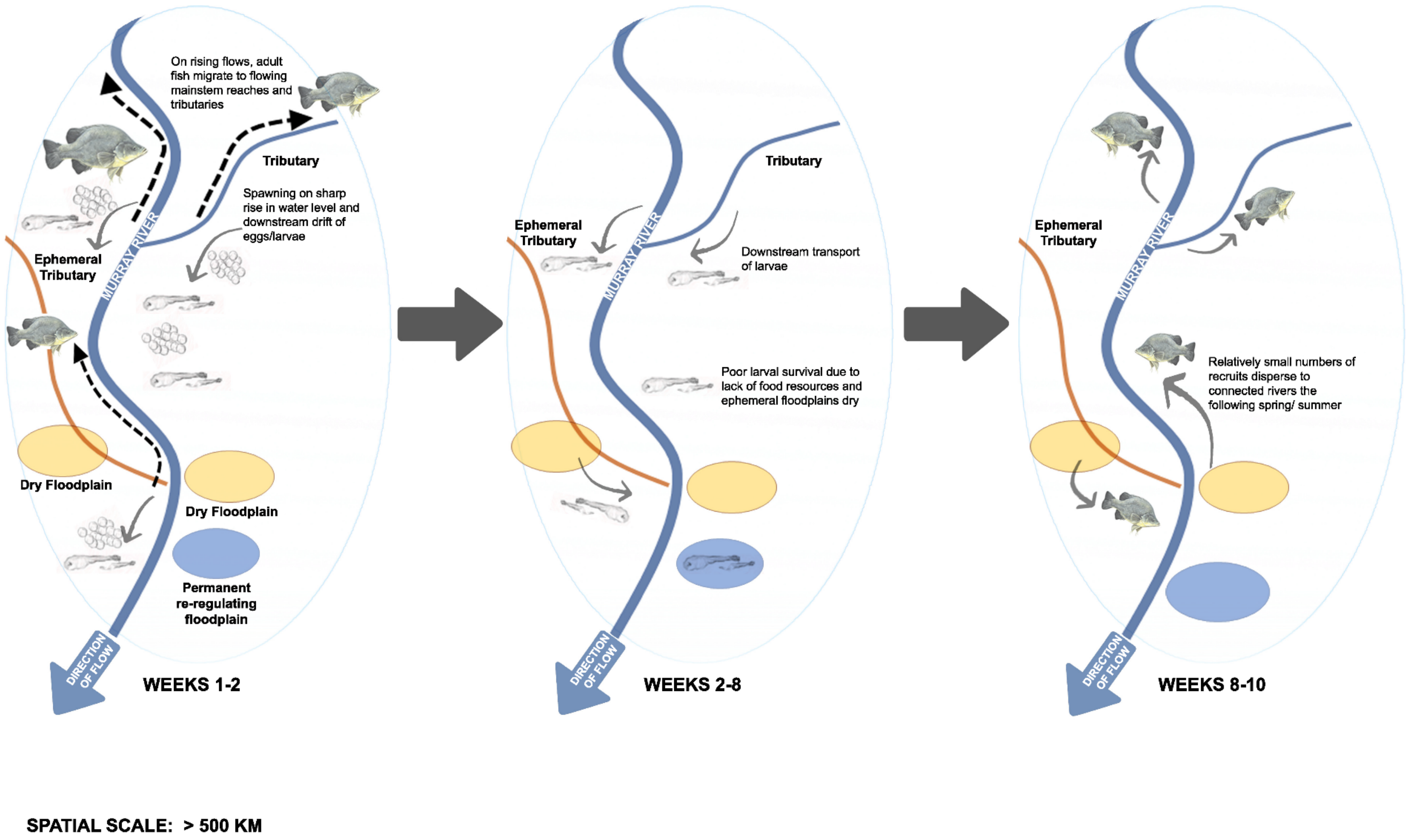
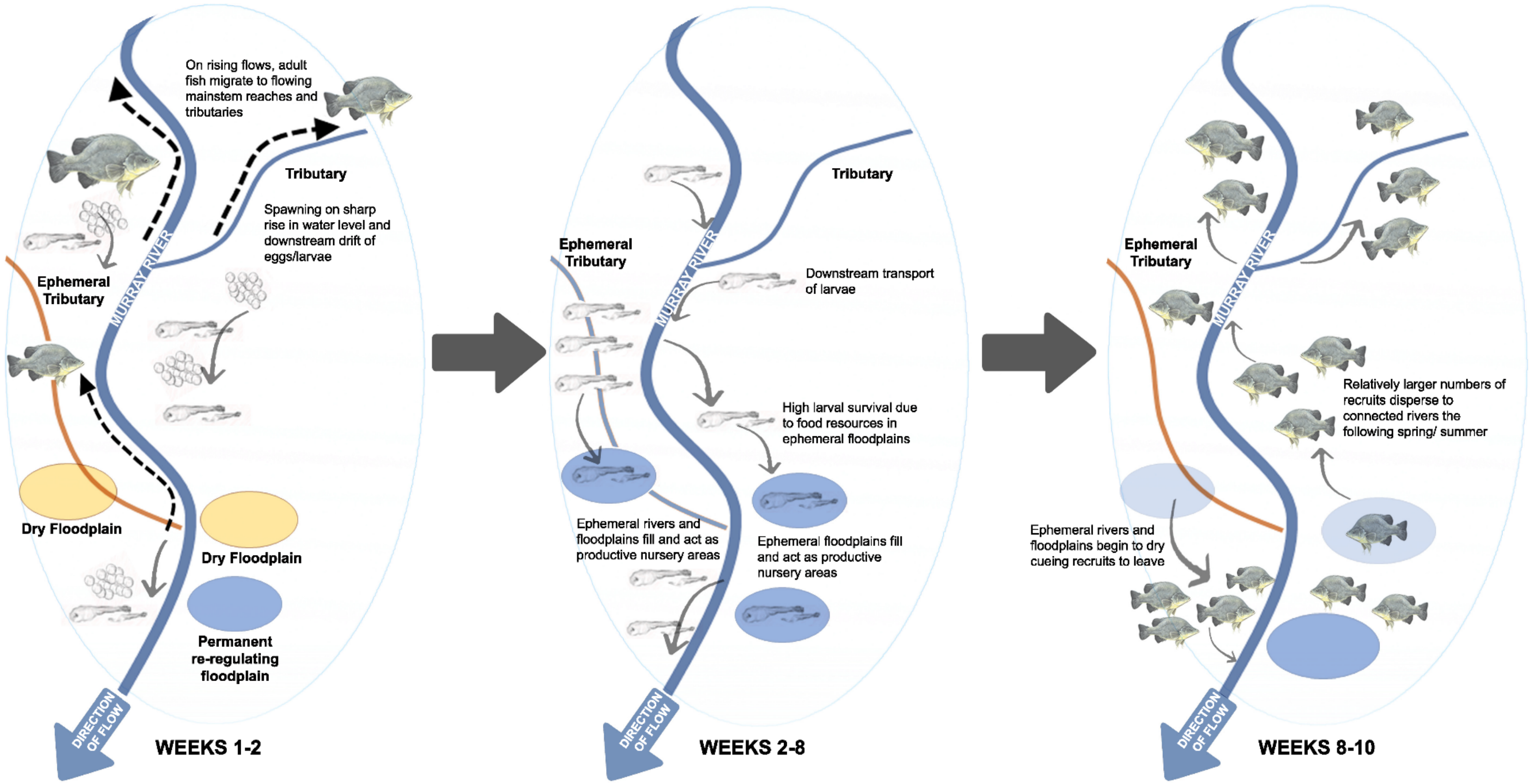



Figure 8 Conceptual model for golden perch

## Golden Perch
## Hydrological Scenario: over-bank flows in lower Murray River and tributaries

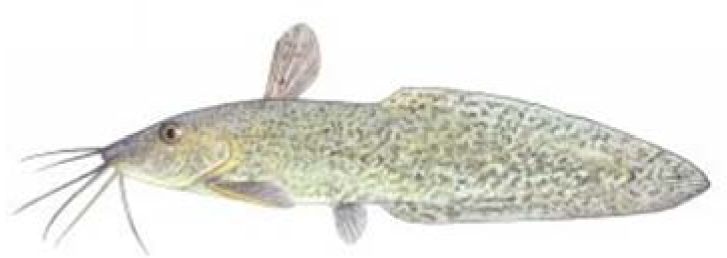



**SPATIAL SCALE: > 500 KM**

Conceptual model for golden perch (continued)

## 6.4 Freshwater catfish

Freshwater catfish (*Tandanus tandanus* [Mitchell]) are a large, stocky, largely benthic freshwater fish that are an opportunistic carnivore. They commonly reach lengths of 500 mm and 2 kg in weight and can live for 10-12 years.



Freshwater catfish occur throughout the lowlands of the MDB and east coast rivers. In the southern MDB, populations persist in the main channel of the Murray, Darling and several small and large tributaries. In the Mallee, catfish can be found in the Murray River, Mullaroo Creek, Kings Billabong, Sandilong Creek and some local irrigation networks. The Mallee region is one of only four self-sustaining populations of freshwater catfish in Victoria.

Freshwater catfish have severely declined throughout their range and they are listed as endangered in Victoria and NSW.

### Table 8 Conceptual model for freshwater catfish

| Habitat use |
|---|
| 1. Benthic species, preferring permanent flowing rivers, creeks, lakes, waterholes and wetlands with complex physical structure (e.g. snags, undercuts, rocks and vegetation). |
| 2. Can be found in highly turbid habitats with fine silt substrates or clear streams with sand, gravel or cobble substrates, |
| 3. Can be found in slow flowing habitats and (although not found in the Lower Murray) also inhabits pool-run sequences and flowing waters. |
| 4. Prefers steady water levels, with small (e.g. <0.1 m) daily variations in water level, where courtship, nesting and recruitment processes can be completed. |
| 5. A survey in northern Victoria found that freshwater catfish only occurred in standing waters such as lakes if there was low turbidity and abundant aquatic plants. |
| 6. Other sites where populations have been known to have existed in Victoria (such as Cardross Lakes, Lake Victoria [near Maryborough], Tahbilk Lagoon) also possess abundant submerged and emergent aquatic plants. |
| 7. Recruitment potential may be increased when additional habitat resources such as when food and shelter are created as river benches, snags and rocks and riparian zones are inundated by rising flows. |
| 8. Juveniles often found in proximity to macrophytes and littoral areas with structural habitat (e.g. snags). |
| **Spawning** |
| 9. In the temperate reaches of northern Victoria, southern NSW and SA, Murray cod spawn in October/November and sometimes December each year. |
| 10. Spawning occurs annually in spring and summer in water temperatures above 24°C (Lake, 1967). In Lake Victoria (near Maryborough), however, spawning was recorded in water temperatures from 21°C to 28.6°C (Pam Clunie, ARI pers. comm.) and extended from November to February. |

11. Spawning occurs during base flows and river rises. Often use permanent floodplain lakes as spawning habitat.
12. Although rising water levels may hasten spawning, they are not a necessary trigger. Strong daily fluctuations in water level, such as when small lagoons are pumped, likely reduce nesting/recruitment success since fish often build nests along the shallower edges of waterbodies.
13. Pair formation occurs prior to spawning and adults display complex pre-spawning courtship behaviour. Females may spawn with more than one male. Spawning occurs 1-4 weeks after nest construction.
14. Males build neat circular nests, up to 0.5 to 2.5 m wide, from sand, pebbles and gravel in shallow warm habitats. Several males may use a single nest site during the breeding season, and males may attract multiple females to the one nest (Clunie and Koehn, 2001b).
15. In Lake Victoria, nests have been recorded in water depths ranging from 0.35 m to 1.6 m (usually <1 m).
16. The female deposits the eggs within the nest before leaving. Up to 20,000 eggs are laid, and they hatch after approximately seven days. The larvae are free swimming by 12-14 days and feeding by 20 days (Lake, 1967). Males guard the eggs.

**Recruitment**

17. Recruitment appears to be linked to floods where there is enhanced survival of juveniles associated with increased productivity and connectivity of floodplains and rivers. Significantly increased numbers of juvenile and adult catfish were reported following the 2010/11 flood but few were reported in the decade of drought preceding.

**Movement and migration**

18. Generally considered non-migratory but conflicting evidence has been collected from different locations in Australia.
19. Early tagging studies indicated most fish stay within 5 km of home locations. A more recent active tagging project in Tahbilk Lagoon also indicated limited home range.
20. Can be found in fishways in very low numbers or occasionally in the north of the MDB in reasonable numbers associated with a river rise.
21. Predominately nocturnal with less movement during daylight.
22. Post-larval fish which leave the nest tend to ‘scatter’ into littoral habitats.

**Implications for Victorian environmental flows**

23. Flows which connect floodplains and rivers appear important for the species’ recruitment and movement.
24. Steady water levels in permanent wetlands are important, especially for nesting and recruitment into littoral macrophytes. Wetlands with highly variable water levels (i.e. when there is rapid irrigation drawdown) can negatively impact on breeding processes.
25. Provision of water to permanent high-quality floodplain wetlands important for maintaining populations (e.g. Kings Billabong).
26. For the few remaining permanent wetlands where catfish still reside there are significant risks of returning to a ‘natural’ wetting/drying regime.

27. Controlling carp, which negatively impact on water quality and macrophytes, is a priority in wetlands.

**Implications for flow monitoring**

28. Implementation of a catfish hydrograph in high priority wetlands is required. The hydrograph needs to include: steady water levels during the breeding season and opportunities for fish to disperse to other nearby permanent wetlands and rivers.

**Threats**

29. Loss of permanent floodplain wetlands which support populations.
30. Regulation of rivers, loss of minor and moderate floods and overt water level variation in remaining habitats.
31. Impacts of carp and loss of macrophytes and negative interactions with other non-native fish (e.g. redfin).

**Knowledge and data limitations**

32. Prioritisation of remaining permanent wetlands for recovery and hydrographs with key components to support catfish populations, such as: (i) stable water levels for nesting and (ii) littoral inundation for recruitment.
33. Connectivity requirements for population dispersal and movement.

## 6.5 Small-bodied wetland generalists

Wetland generalists are characterised by species that are short-lived, inhabit backwaters and floodplain wetlands rather than rivers and require over-bank flooding to facilitate dispersal and re-colonisation of floodplain wetlands.

They have flexible spawning and recruitment strategies, and move among habitats over a broad range of flow conditions (Baumgartner et al., 2014b). These fish are generally only limited by habitat availability.

The small-bodied wetland generalists are presented here as a guild, rather than individually as many aspects of their life-history and ecology are similar. Carp gudgeons (*Hypseleotris spp.*), flat-headed gudgeons (*Philypnodon grandiceps* [Krefft]), dwarf flat-headed gudgeons (*Philypnodon macrostomus* [Hoese & reader]), unspecked hardyhead (*Craterocephalus fulvus* [Ivantsoff, Crowley & Allen]) and Murray-darling rainbowfish (*Melanotaenia fluviatilis* [Castelnau]) are the predominant small-bodied native fish found throughout the Mallee SDL sites.

Table 9 Conceptual model for small-bodied wetland generalists

| **Habitat use** |
|---|
| 1. Can inhabit riverine or wetland habitats, prefer floodplains with complex and diverse macrophyte assemblages, and usually prefer slow flowing habitats but often found where there is hydraulic diversity (Baumgartner et al., 2014b). |
| 2. Often found in small shallow ephemeral floodplain wetlands, which flood regularly and have intact riparian canopy. |
| 3. Are usually tolerant to a broad range of water quality conditions but are intolerant of low dissolved oxygen and high salinity (McNeil and Closs, 2007). Some species can survive and even thrive in wetlands which have significantly degraded habitats and/or water quality). |
| 4. Generally there are population declines with increasing salinity. |
| 5. The greatest diversity of generalist species usually inhabits permanent wetlands that reconnect to the main river via small floods, or are permanently inundated as their inlets are connected to weir pools, or they are in close proximity to permanent rivers/creeks or temporary flood runners that have a relatively regular commence-to-flow frequency (i.e. 1-in-1 year; Lyon et al., 2010). |
| 6. Can do well in permanent weirpool low-productivity style wetlands and do not require flooding. |
| 7. A mosaic of wetland types and regular connection is essential for wetland specialists but these fish probably need at least three floods per decade to maintain populations (McNeil et al., 2008; Baumgartner et al., 2014b). |
| **Diet** |
| 8. Appear to require flooding of new floodplain habitats and productivity boom with a variety of food organisms (e.g. invertebrates, zooplankton and shrimp). |

9. Do not thrive in permanent low-productivity style wetlands.

**Spawning**

10. Generally they are highly fecund and spawn over a protracted period independent of river flows.
11. Eggs are sticky and demersal, laid onto aquatic vegetation in shallow water habitats (e.g. <0.3 m deep) (Lintermans, 2007).
12. Fish spawn annually, most often in spring, and there is no parental care except for carp gudgeons.
13. Hatching occurs after 2-10 days with larvae feeding on plankton.

**Recruitment**

14. Recruitment occurs annually and is influenced by food and physical habitat resources – healthy and diverse macrophytes may increase recruitment rates.

**Movement and migration**

15. Move among riverine and floodplain habitats, usually in spring and summer, when wetlands become available as the river rises (Stuart et al., 2008; Lyon et al., 2010).
16. Movement ecology is unusual among the broader native fish community and requires specific and regular management to achieve connectivity objectives. Wetland species require regular flooding to disperse to new floodplain wetland habitats where a healthy fish community is one which is present in multiple wetlands.
17. During a floodplain inundation event, these fish appear to be 'first colonisers' of newly inundated wetlands (Hammer and Wedderburn, 2008).
18. Tend to move on low regulated flows with relatively little riverine movement during high flows and floods.
19. Can recover quickly where there is connectivity to the main river channel.

**Implications for Victorian environmental flows**

20. Water management to suit macrophytes is advantageous since these species prefer floodplains with complex and diverse macrophyte assemblages, and slow flowing habitats.
21. Inhabit a variety of wetland types but these are generally slow-flowing habitats.
22. Require regular (annual) flooding and populations which can likely be enhanced with wetland water level variation and environmental watering of floodplains to recreate wetland mosaics.
23. Fish move at low regulated flows. They often suffer severe population declines during major floods but usually recover quickly where connectivity is adequate.
24. Fish are resilient to low flows.
25. The ecological priority for Vinifera Park is to maintain and enhance the small-bodied generalist native fish community. This can be achieved via establishing diverse and complex macrophytes and by keeping wetlands full and periodically connected so that fish can use source populations to establish in newly inundated wetlands.

**Threats**

26. Predation, competition and habitat damage by invasive fish, especially carp, redfin and gambusia (*Gambusia holbrooki*) (Macdonald et al., 2012; Tonkin et al., 2008).
27. Drying of wetlands with diverse macrophytes and small-bodied fish assemblages.
28. Changes to hydrology have reduced altered diversity and accessibility of wetland habitats (King et al., 2007).
29. Strong regular variations in wetland water levels.
30. Loss of wetland macrophytes.
31. Significant reduction in connectivity to main channel habitats; regulated conditions have caused loss of small and medium flood events. Connectivity is required for regular exchange of fish and nutrients and to prevent complete drying.

**Knowledge and data limitations**

32. Application of conceptual model and reference sites consisting of high quality wetlands and fish communities to test and inform interventions to recover degraded wetlands.

Wetland fish model: regulated flow conditions

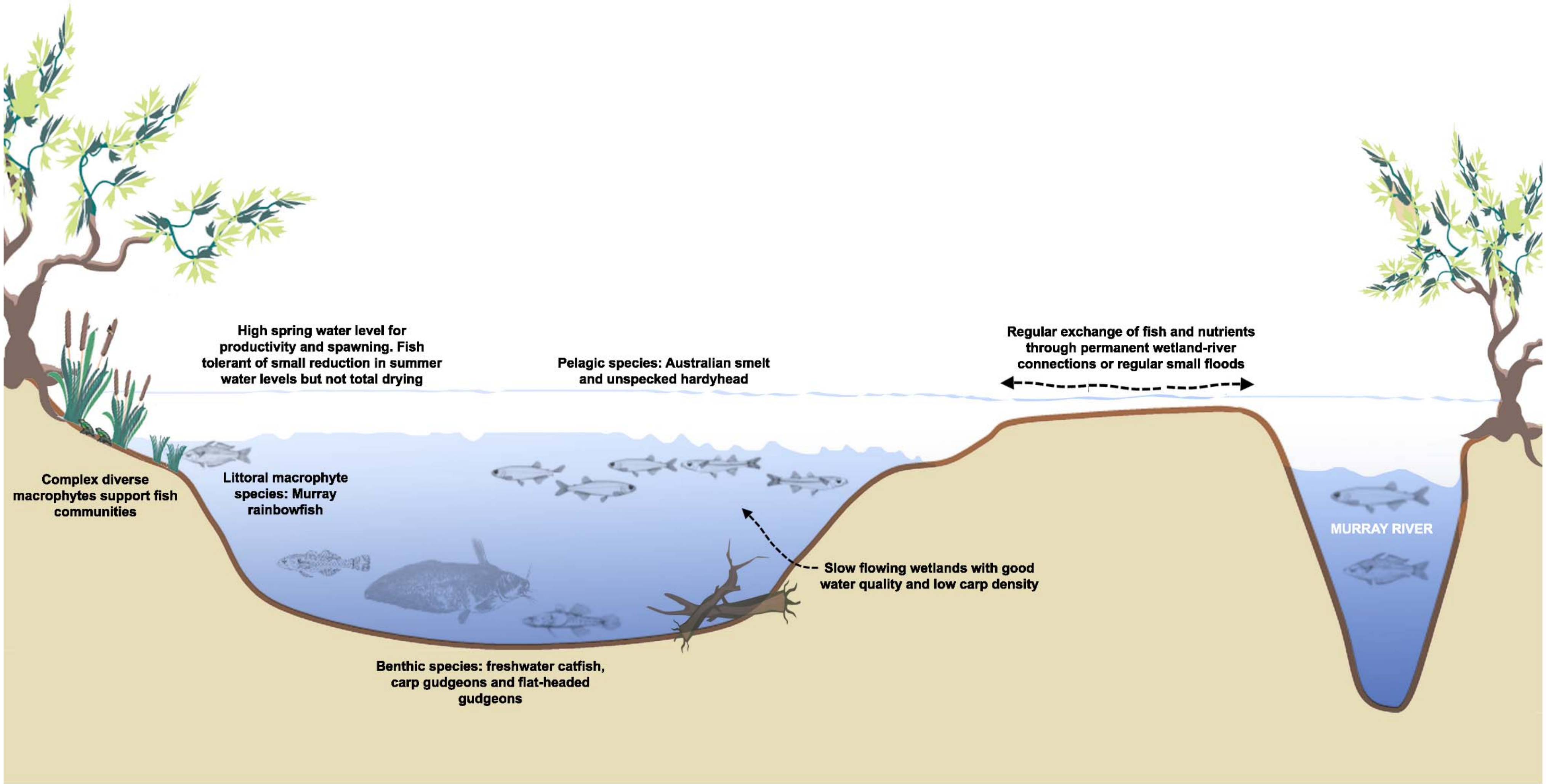



Figure 9 Conceptual model for wetland fish

# 7. Exotic fish

## 7.1 Exotic fish species present and their threat

Five exotic fish species are likely to be present at Vinifera or in the nearby Murray River, including carp, goldfish, redfin perch, oriental weatherloach and gambusia (Ho et al. 2004, Henderson et. al. 2012). These fish all pose a risk to native fish, water quality and macrophyte outcomes for the site.

### 7.1.1 Carp

Carp are very efficient invaders and colonisers, and have established themselves in river systems all over the world (Koehn, 2004; Koehn et al., 2017). The Vinifera Park wetlands are likely to favour carp because the floodplain inundation will create shallow warm waters with low velocity, which is ideal for carp spawning (Stuart and Jones, 2006). They can survive a wide range of aquatic conditions, including high temperatures and low oxygen levels, and they breed prolifically (Koehn et al., 2000).

Carp could affect the natural values of the Vinifera floodplain in many ways, including directly competing with native fish for food and space, damaging macrophyte beds and re-suspension of sediment and nutrients (Koehn et al., 2000; Gilligan et al., 2011).

Carp screens could provide an additional benefit by restricting the return of adult Carp to the river system during the drying phase, effectively trapping them on the floodplain such as occurs 'naturally' at the Menindee Lakes (Scholz and Gawne, 2004). It should be noted that the practicality of using screens on outlet structures in Vinifera Park may preclude their use. Large amounts of debris could become trapped on the screens, lowering the efficiency of regulators.

A "*Carp Management Strategy for Hattah Lakes*" was developed in 2013 for the nearby Hattah Lakes SDL site, which made recommendations for operational regimes and interventions to control carp (Stuart, 2013). The report emphasised Integrated Pest Management (IPM) principles, including setting clear objectives and controlling the damage done by carp to an acceptable level (i.e. managing environmental values), rather than simply reducing carp numbers (Stuart, 2013). More recent population modelling has also emphasised the regional contribution that managed flooding can make to carp populations and mitigation strategies (Koehn et al., 2017).

### 7.1.2 Goldfish, redfin perch, weatherloach and gambusia

The other four exotic fish species likely to be found within the region of Vinifera Park are abundant in inland waterways and have a range of potential impacts. Goldfish and weatherloach compete for food and space with native fish while also re-suspending nutrients and sediments (Keller and Lake 2007). Redfin perch and gambusia directly prey upon native fish and can influence the structure of fish communities (Macdonald et al., 2012). These species pose a reasonable level of threat to the natural values of Vinifera Park and are likely advantaged by managed static flooding.

## 7.2 Potential carp herpes virus impacts

A National Carp Control Plan (NCCP) is being prepared to explore the release of the carp virus cyprinid herpesvirus-3, or CyHV-3. The virus is highly contagious for carp and is most effectively transmitted through carp-to-carp contact and can survive in water without a host for approximately three days. The virus damages the kidneys, skin and gills of carp, the later causing death as soon as 24 hours after these signs develop.

A range of research projects are currently underway and these are due for completion in late 2018, informing the final decision concerning the virus release.  If the carp virus is released in Australia, it is expected to initially kill more than 70% of infected carp. Carp that survive will carry the virus for life and, when stressed, may eventually succumb to disease. They will also continue to pass the virus on to uninfected carp, a process expected to provide long-term carp control.

As Vinifera will be operated as a seasonal wetland the effectiveness of the virus will depend on the number of fish that become established in the wetland and for those fish, whether they come into contact with infected fish. Habitat conditions within the seasonal wetlands (i.e. relatively shallow, warm water) are likely to provide conditions that are suitable for high efficacy rate for the virus.

Depending on the carp population size in Vinifera Park there is a strong likelihood of mass carp die-offs, especially in the first spring/summer following virus release.  The National Carp Control Plan includes a series of projects to help plan for clean-up of dead carp, estimation of tonnages and potential off-target impacts (e.g. water quality).

# 8. Previous watering outcomes for fish

Where there has been monitoring of fish response to infrastructure-style managed floodplain inundations, at Koondrook-Pericoota, Gunbower, Hattah and Chowilla, the large-bodied native fish response has been poor.  Murray cod, golden perch and silver perch have not utilised the floodplain proper, with the exception of Hattah where the fish were pumped (Vilizzi et al., 2013). This can be explained because fewer large-bodied native fish appear to enter floodplains during the managed floods as there are no environmental cues (e.g. chemical floodplain cues) at the upstream floodplain intake compared to natural landscape flooding. There have however, been major responses by some small-bodied fish, such as Australian smelt and carp gudgeons, with spawning and recruitment on the floodplain.

The flooding of Vinifera Park will only occur during flood events and as such the fish response will be based on fish that are able to enter through regulators N2 and N5. This means that fish present in the main Murray River channel have the potential to enter the Park during flood events but that the fish most likely to enter would be small-bodied or juvenile large-bodied fish. For example, it is unlikely that significant numbers of mature Murray cod would enter via regulators given their cautious nature and the need to pass through a 10 metre structure prior to entering Vinifera Creek.

Evaluation of some of these floodplain sites has shown that there can be intense periods of fish migration where many thousands of fish migrate, especially as the floodplain begins to draw down.  At Gunbower forest in autumn 2015, many thousands of recruiting Australian smelt migrated from the forest back to permanent water in Gunbower Creek through a new fish lock (Sharpe et al., 2016).  The benefit of this migration was that a major floodplain recruitment event was transferred back into the permanent waters of the creek and Murray River. The main difference between the Gunbower site and Vinifera Park is that the former has a ‘moving’ flood and is not regulated at the downstream end.  At Vinifera the flood is ‘backed up’ and has thus a very different hydrodynamic environment.

The learning from these studies is that fish biomass moving between main channel waterways and the floodplain is highly variable and that large numbers of native small-bodied fish and non-native carp can dominate the native fish community, especially in spring, summer and autumn. Hence, providing efficient fish passage can be crucial during the floodplain filling and drying phase.

# 9. Ecological objectives and targets

## 9.1 Sustainable diversion limit business case

Ecological objectives have been developed for the Vinifera Park site, drawing on a range of approaches and recommended lines of enquiry including:

- the overarching objectives in Schedule 7 of the Murray-Darling Basin Plan (MDBA, 2014)
- the Basin-wide Environmental Watering Strategy (MDBA, 2014)
- a review of relevant literature including monitoring data from the TLM initiative (Henderson et al., 2012; Henderson et al., 2013; Henderson et al., 2014)
- desktop and field based flora and fauna surveys (GHD, 2013; Brown et al., 2013)
- site visits
- an ecological objectives workshop with an expert panel comprised of aquatic, wildlife and restoration ecologists and key project stakeholders from DEPI and the Mallee CMA (Ecological Associates, 2014a) and
- the site Environmental Water Management Plan (Mallee CMA, 2015).

The overarching objective of water management in the Vinifera Park site is:

***"to protect and restore the key species, habitat components and functions of the Vinifera Park ecosystem by providing the hydrological environments required by indigenous plant and animal species and communities (Ecological Associates, 2014a)***

The proposed works will enable wide spread inundation of Vinifera Creek and adjoining wetlands and floodplain. The works have been designed to operate under low Murray River flows (5000 ML/d) and can be operate to protect this system through droughts.

Table 10 SDL ecological objectives and targets

| Specific objective | Ecological targets | Water regime class | Associated Basin Plan Objective |
|---|---|---|---|
| Restore the vegetation structure of wetland plant communities | The projected red gum canopy cover in seasonal wetlands decreases by 50% from 2015 levels by 2030.<br>The projected aquatic macrophyte plant cover in December in seasonal wetlands exceeds 50% by 2030. | Seasonal Wetlands<br>Red Gum Swamp Forest<br>Red Gum Forest and Woodland | 1,2,4,6,7,8,9,10, 11,12,13,14 |
| Re-establish resident populations of frogs and small fish | At least four native fish species are present in seasonal wetlands every spring between 2025 and 2035.<br>At least three frog species are present in seasonal | Seasonal Wetlands<br>Red Gum Swamp Forest<br>Red Gum Forest and Woodland | 1,2,4,6,7,8,9,10, 11,12,13,14 |

| Specific objective | Ecological targets | Water regime class | Associated Basin Plan Objective |
|---|---|---|---|
| | wetlands every spring between 2025 and 2035. | | |
| Provide reliable breeding habitat for waterbirds, including colonial nesting species | Any species of waterfowl, crake, rail, waterhen or coot breeds every year between 2025 and 2035 at Vinifera Park.<br>Cormorants and / or nankeen night heron breed at Vinifera Park on at least six occasions between 2025 and 2035. | Seasonal Wetlands<br>Red Gum Swamp Forest<br>Red Gum Forest and Woodland | 1,2,4,6,7,8,9,10, 11,12,13,14 |
| Restoring floodplain productivity to maintain resident populations of vertebrate fauna including carpet python, sugar glider and grey-crowned babbler | All red gum stands within the project area achieve a health score of moderate or better under Cunningham (2011) tree health monitoring for all years between 2025 and 2035.<br>Total bat abundance increases by 25% from 2015 levels by 2030. | Red Gum Swamp Forest<br>Red Gum Forest and Woodland | 1,2,4,6,7,8,9,10, 11,12,13,14 |
| Contribute to the carbon requirements of the Murray River channel ecosystem | The average annual carbon load (dissolved and particulate) to the Murray River from Vinifera Park for the period 2025 to 2035 is double 2015 to 2020 levels. | Red Gum Swamp Forest<br>Red Gum Forest and Woodland | 1,2,4,6,7,8,9,10, 11,12,13,14 |

## 9.2 Basin Plan

The environmental objectives set by the Basin Plan which have been attributed to the Nyah floodplain are all of those listed below with the exception of number 5.

1. to protect and restore a subset of all water-dependent ecosystems in the Murray-Darling Basin ensuring that:
    a. declared Ramsar wetlands that depend on Basin water resources maintain their ecological character: and
    a. water-dependent ecosystems that depend on Basin water resources and support the lifecycles of species listed under the Bonn Convention, CAMBA, JAMBA or ROKAMBA continue to support those species: and
    b. water-dependent ecosystems are able to support episodically high ecological productivity and its ecological dispersal.
2. to protect and restore biodiversity that is dependent on Basin water resources, including by ensuring that: are protected and, if necessary, restored so that they continue to support those life cycles
    a. water-dependent ecosystems that:
        - Depend on Basin water resources: and

- Support the lifecycles of a listed threatened species or listed threatened ecological community, or species treated as threatened or endangered in State or Territory law.

b. representative populations and communities of native biota are protected and if necessary restored.

3. that the water quality of Basin water resources does not adversely affect water-dependent ecosystems and is consistent with the water quality and salinity management plan.

4. to protect and restore connectivity within and between water-dependent ecosystems including by ensuring that:

   a. the diversity and dynamics of geomorphic structures, habitats, species and genes are protected and restored; and

   b. ecological processes depend on hydrologic connectivity longitudinally along rivers, and laterally, between rivers and their floodplains (and associated wetlands) are protected and restored: and

   c. the Murray Mouth remains open at frequencies, for durations and with passing flows, sufficient to enable the conveyance of salt, nutrients and sediment from the Murray-Darling Basin to the ocean: and

   d. the Murray Mouth remains open at frequencies, and for durations, sufficient to ensure that the tidal exchanges maintain the Coorong's water quality within the tolerance of the Coorong ecosystems' resilience and

   e. barriers to the passage of biological resources (including biota, carbon and nutrients) through the Murray Darling Basin are overcome or minimised.

5. that natural processes that shape landforms (for example, the formation and maintenance of soils) are protected and restored.

6. to provide habitat diversity for biota at a range of scales (including, for example, the Murray–Darling Basin, riverine landscape, river reach and asset class).

7. to protect and restore food webs that sustain water-dependent ecosystems, including by ensuring that energy, carbon and nutrient dynamics (including primary production and respiration) are protected and restored.

8. to protect and restore ecosystem functions of water-dependent ecosystems that maintain populations (for example recruitment, regeneration, dispersal, immigration and emigration) including by ensuring that;

   b. flow sequences, and inundation and recession events, meet ecological requirements (for example, cues for migration, germination and breeding); and

   c. habitat diversity that supports the life cycles of biota of water dependent ecosystems (for example habitats that protect juveniles from predation) is maintained

9. to protect and restore ecological community structure and species interactions.

10. that water-dependent ecosystems are resilient to climate change, climate variability and disturbances (for example, drought and fire)

11. to protect refugia in order to support the long-term survival and resilience of water-dependent populations of native flora and fauna, including during drought to allow for subsequent re-colonisation beyond the refugia.

12. to provide wetting and drying cycles and inundation intervals that do not exceed the tolerance of ecosystem resilience or the threshold of irreversible changes.
13. to mitigate human-induced threats (for example, the impact of alien species, water management activities and degraded water quality).
14. to minimise habitat fragmentation.

## 9.3 Basin-wide environmental watering strategy

The Basin-wide Environmental Watering Strategy (MDBA, 2014) builds on the Basin Plan and is intended to help environmental water holders, Basin state governments and waterway managers plan and manage environmental watering at a Basin scale and over the long term to meet the environmental objectives.

The expected environmental outcomes that can be achieved beyond 2019 by the Basin-wide Environmental Strategy for fish to "Maintain current species diversity, extend distributions, improve breeding success and numbers" are:

***Improved distribution:***

- of key short and long-lived fish species across the Basin

***Improved breeding success for:***

- short-lived species (every 1-2 years)
- long-lived species in at least 8/10 years at 80% of key sites
- Mulloway in at least 5/10 years

***Improved populations of:***

- short-lived species (numbers at pre-2007 levels)
- long-lived species (with a spread of age classes represented)
- Murray cod and golden perch (10-15% more mature fish at key sites)

***Improved movements:***

- more native fish using fish passage

Vinifera Park was not identified in the Basin-wide Environmental Water Strategy as an important Basin environmental asset for native fish.

## 9.4 Summary ecological objectives for fish

A summary of the fish related ecological objectives for the site is provided in Table 11.

Table 11 Summary of current ecological benefits and objectives

| Strategic Link | Ecological benefits or objectives |
|---|---|
| SDL Ecological benefits | 1. Restore the vegetation structure of wetland plant communities |
| | 2. Re-establish resident populations of frogs and small fish |
| Basin Plan ecological objectives | 3. Water-dependent ecosystems are able to support episodically high ecological productivity and its ecological dispersal |
| | 4. To protect and restore ecosystem functions of water-dependent ecosystems that maintain populations (for example recruitment, |

| Strategic Link | Ecological benefits or objectives |
| --- | --- |
| | regeneration, dispersal, immigration and emigration) including by ensuring that;<br>• flow sequences, and inundation and recession events, meet ecological requirements (for example, cues for migration, germination and breeding); and<br>5. Habitat diversity that supports the life cycles of biota of water dependent ecosystems (for example habitats that protect juveniles from predation) is maintained |
| Basin-wide environmental watering strategy | *6.* ***Improved distribution:***<br>• of key short and long-lived fish species across the Basin<br>*7.* ***Improved breeding success for:***<br>• short-lived species (every 1-2 years)<br>• long-lived species in at least 8/10 years at 80% of key sites<br>*8.* ***Improved populations of***<br>• short-lived species (numbers at pre-2007 levels)<br>• long-lived species (with a spread of age classes represented)<br>• Murray cod and golden perch (10-15% more mature fish at key sites)<br>*9.* ***Improved movements:***<br>• more native fish using fish passage |

# PART B – Outcomes and Recommendations

# 10. Fish related opportunities

Vinifera Park has the potential to provide a number of water regime classes that would benefit native fish at a local scale. Currently the flood duration in Vinifera Park is too brief to support small-bodied wetland species.

Seasonal wetland habitat has been lost from Vinifera Park through a reduction in the duration of spring flow peaks. There has been encroachment of river red gums and a shift from aquatic marshland vegetation to an understorey dominated by grasses and herbs. The wetlands now only provide opportunistic habitat for aquatic fauna that colonise the system when water is available.

Opportunities therefore exist to increase flood duration in the Park that would provide wetland inundation conditions that would support a seasonal small-bodied fish population composed of generalist species. The feasibility of this option is discussed below.

The rarity of wetland specialist species within the vicinity of Vinifera Park means there is limited opportunity for recruitment and population re-establishment for these species.

The SDL ecological objectives focus on the seasonal wetland component of the water regime to meet ecological objectives for fish. To meet the objectives the SDL operating plan will provide:

- inflows to Seasonal Wetlands in nine out of 10 years for a period of between 6-9 months each year
- inflows to Red Gum Swamp Forest in nine out of 10 years for a period of between 5-7 months each year
- inflows to Red Gum Forest and Woodland in nine out of 10 years for a period of between 2-6 months each year

The logic of fish recovery actions for the Vinifera floodplain is presented in Figure 10.

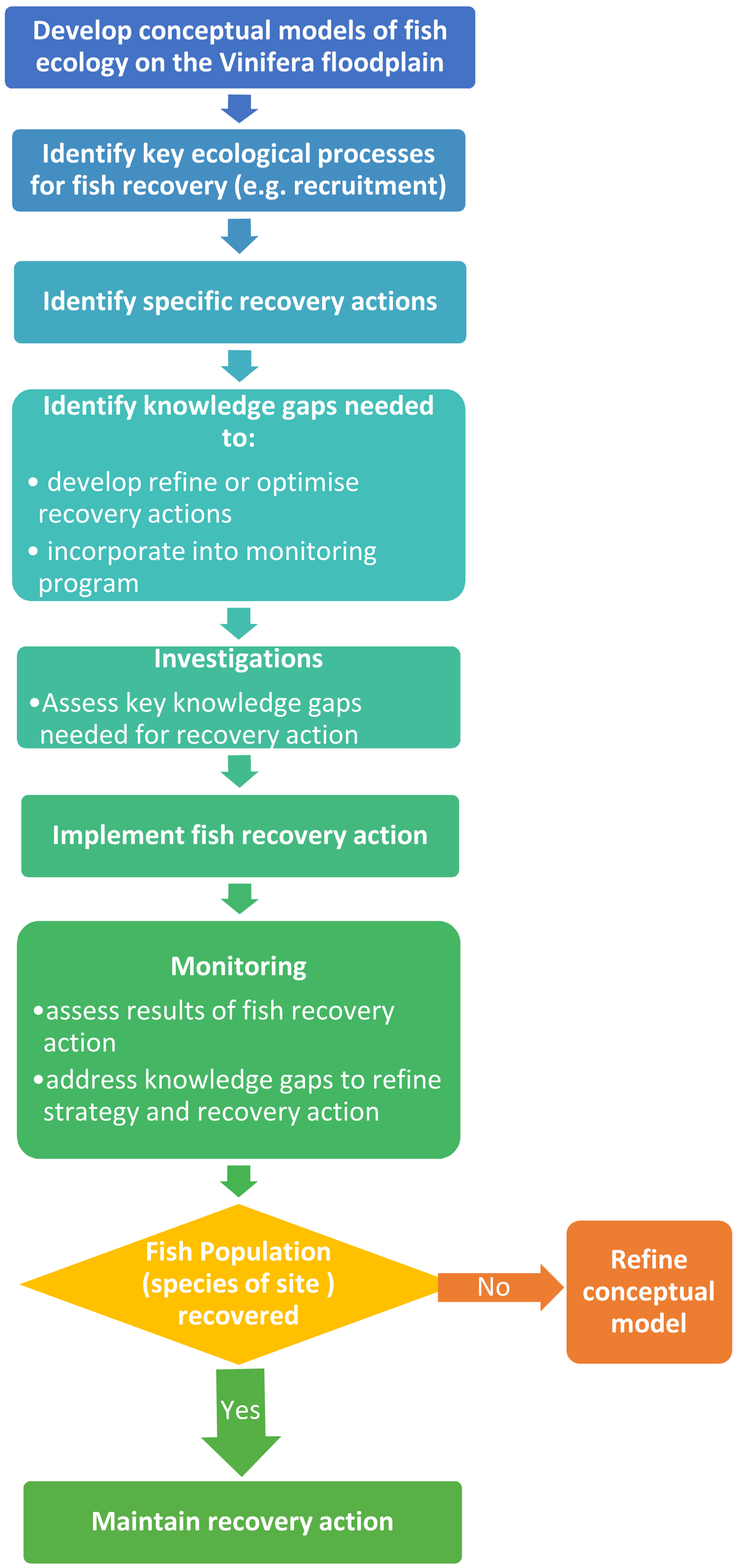



Figure 10 Vinifera floodplain recovery actions flow chart.

## 10.1 Recovery of small-bodied wetland generalist species

### 10.1.1 Background

The Vinifera floodplain features broad wetland depressions that retain water to a depth of one m or more on the flood recession. While shallow, the wetlands experienced persistent and frequent flooding under natural flow conditions and frequently remained flooded throughout the year (Ecological Associates, 2014a). With increased flood duration the wetlands would support dense aquatic vegetation, algae and biofilms, which would provide a productive food source and physical habitat for zooplankton, macroinvertebrates and small fish (Ecological Associates 2014a).

The seasonal (low level) floodplain wetlands receive inflows when Murray River flows exceed 15,000 ML/day. The red gum swamp forest, which is an extension of the seasonal wetlands, fills at flow levels of 17,500 ML/day and the red gum forest and woodland receive inflows at Murray River flows over 20,000 ML/day. Proposed operating conditions would include the opening of regulators V1, V2, V3 and V4 to allow passing flows. None of these structures include a fishway. Once passing flows reach their peak or begin to recede, the regulators would be closed to manage inundation at the desired target level for an appropriate duration to meet required objectives. As the regulators are closed to maintain wetland inundation there would be no opportunity for fish passage under these conditions.

The greatest opportunity for the Vinifera Park floodplain wetlands is to provide habitat and breeding sites for generalist small-bodied species such as carp gudgeons, flat-headed gudgeons and dwarf flat-headed gudgeons and habitat for unspecked hardyhead and Murray-Darling rainbowfish.

From the conceptual model of small bodied generalist fish, the ideal characteristics of wetlands is a diversity of productive habitat types, with aquatic macrophytes and large littoral zones to provide opportunities for seasonal populations. The Vinifera Park wetlands represent a potential opportunity to  apply a fish hydrograph to aid fish restoration but the fish requirements would necessitate a change to the current water scenarios.

### 1.1.1 Rationale

As no permanent wetlands exist within the site the ability to restore the small-bodied fish population is limited to seasonal opportunities. With limited connectivity fish colonisation can only occur during flood inundation from the downstream end of the Park. As such, for fish to successfully colonise and breed within the floodplain wetland areas the minimum flows required will be those that flood the low-lying seasonal wetlands (Murray River @ 15,000 ML/day). The use of temporary pumps (in the absence of suitable Murray River flows) can be used to provide flows directly to the wetland areas. However, using this method to provide water may have adverse impacts on fish passing through the pump system.

The fish that colonise the seasonal wetlands will be those that are present within the Murray River at times of increased flow and are likely to include common small-bodied native fish and non-native fish (Table 12).  Under current conditions water enters via overbank flows and only remains on the floodplain for a duration of five weeks. The ability to retain water on the floodplain for between six to nine months will allow for small-bodied fish to inhabit and breed in the inundated floodplain habitat.

These conditions would provide habitat and periods of inundation that would support small-bodied generalist fish within Vinifera Park, provided a fish exit strategy is developed to allow for fish to enter the Murray River as the floodplain wetlands are drawn down.

## Table 12 Small-bodied native fish and exotic species that may recolonise Vinifera Park wetland

**Abundance**: ✓✓✓✓ Abundant, ✓✓✓ Common, ✓✓ Uncommon, ✓ Rare

**Population Trend in Vinifera Park:**
⬆ Slight increase
⬆⬆ Moderate increase
⬆⬆⬆ Major increase

| | Past abundance | Present abundance | Predicted Population in Vinifera Park with a seasonal operating scenario |
|---|---|---|---|
| **Small-bodied (20-90 mm)** | | | |
| Carp gudgeons | ✓✓✓ | - | ⬆⬆⬆ |
| Flat-headed gudgeon | ✓✓✓ | - | ⬆ |
| Un-specked hardyhead | ✓✓✓ | - | ⬆ |
| Australian smelt | ✓✓✓ | - | ⬆ |
| Dwarf flat-headed gudgeon | ✓✓✓ | - | ⬆ |
| Murray–Darling rainbowfish | ✓✓✓ | - | ⬆ |
| **Exotic fish** | | | |
| Carp | ✓✓✓ | - | ⬆⬆⬆ |
| Goldfish | ✓✓ | - | ⬆⬆ |
| Gambusia | ✓✓✓ | - | ⬆⬆⬆ |

### 10.1.2 Actions to recover small-bodied wetland generalists

The actions required to assist in the recovery of small-bodied generalist fish species would depend on:

- the ability for fish to enter Vinifera Creek and adjacent wetlands on a seasonal basis, during winter-spring high flow events (>13,000 ML/day for Vinifera Creek and >15,000 ML/day for seasonal wetlands)
- suitable habitat (i.e. submerged and emergent macrophytes) being present
- food source availability (zooplankton, macroinvertebrates)
- closing of regulators once the required seasonal inundation level is met (e.g. DWL)
- maintenance of water levels and water quality
- an annual drawdown event – to allow fish to exit the floodplain and enter the Murray River in late spring (see Section 10.1.3)

### 10.1.3 Fish exit strategy

Once regulators are closed to maintain floodplain wetland water levels there is limited capacity for fish to exit Vinifera Park other than through a major flood event. Facilitating fish movement off the floodplain and back to the Murray River is a key challenge in the management of the Vinifera Park floodplain for fish. Therefore, there is a requirement for the SDL structures to be managed to allow for native fish to exit and exotic fish (specifically carp) to remain stranded on the floodplain. Rapid river channel drawdown may strand fish in unsuitable floodplain areas, with reduced opportunity to move to deeper wetland or channel habitats as water levels recede (see Lyon et al., 2010; Ellis and Pyke 2010; 2011).

Fish exit hydrographs have recently been successful in terms of stimulating small-bodied generalist species to leave a managed inundation on Gunbower floodplain (Sharpe et al. 2016). Key concepts in developing the Gunbower hydrograph were underpinned by detailed studies of lateral fish movements undertaken elsewhere in the Murray River system (Jones and Stuart 2008; Conallin et al. 2010; Lyon et al. 2010; Koehn and Nicol 2014). Those studies inform a conceptual understanding of the expected movement patterns of native (and non-native) fish during managed inundations.

The development of a fish exit strategy for Vinifera Park will depend on the status of Murray River flow at the time of drawdown, and as such two scenarios have been developed. Replicating the Sharpe et al. (2016) fish exit hydrograph (see Figure 11) will either require relatively high Murray River flows (i.e. >13,000 ML/day) or the ability to pump water through regulator V4 to partially refill the wetland after the initial drawdown. If these conditions are not possible during the planned drawdown event (e.g. if Murray River flows are low) then a staged drawdown should be followed; water would be partially drawn down, then held for a short period before the remaining drawdown is completed (Figure 12).

The drawdown process could be initiated in autumn, which would follow a natural drying regime. However, to avoid movement of young-of-year carp from Vinifera Park into the Murray River the drawdown could be initiated in late spring. Sharpe et al. (2016) reported that a late spring drawdown allowed for the exit of small-bodied fish but limited movement of juvenile (<35mm length) carp. This timing would give small-bodied fish time to mature in the floodplain wetland and then released into the Murray River.

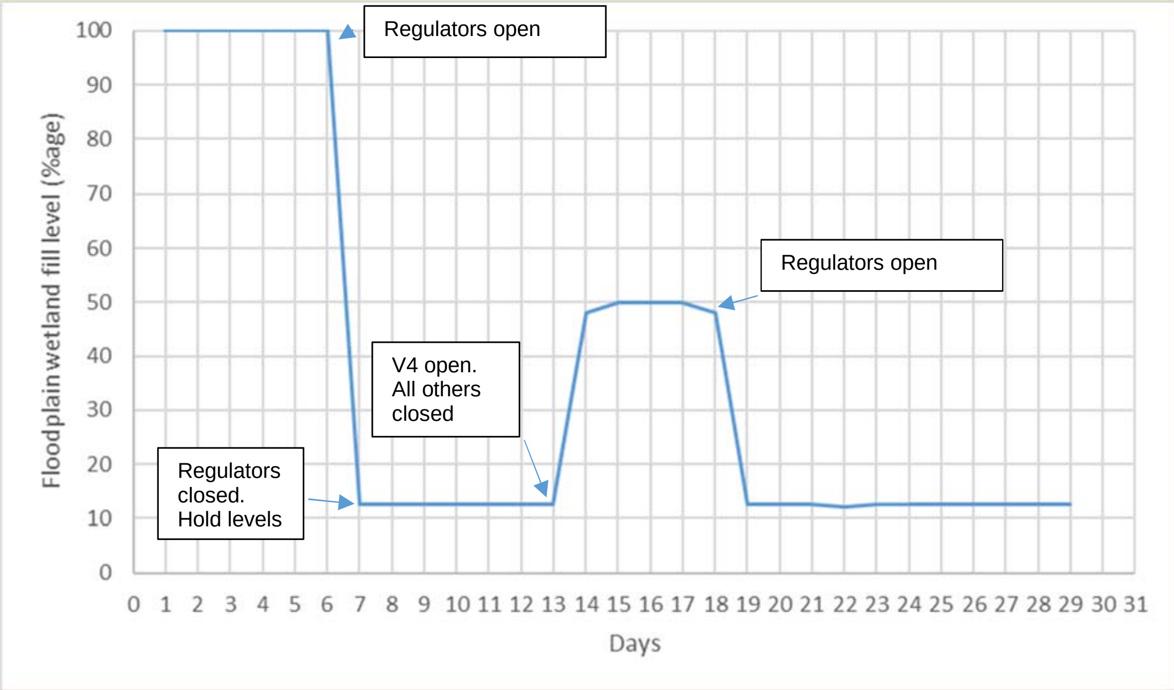



Figure 11 Fish exit hydrograph (using Murray River flows >13,000 ML/day or using pumped water)

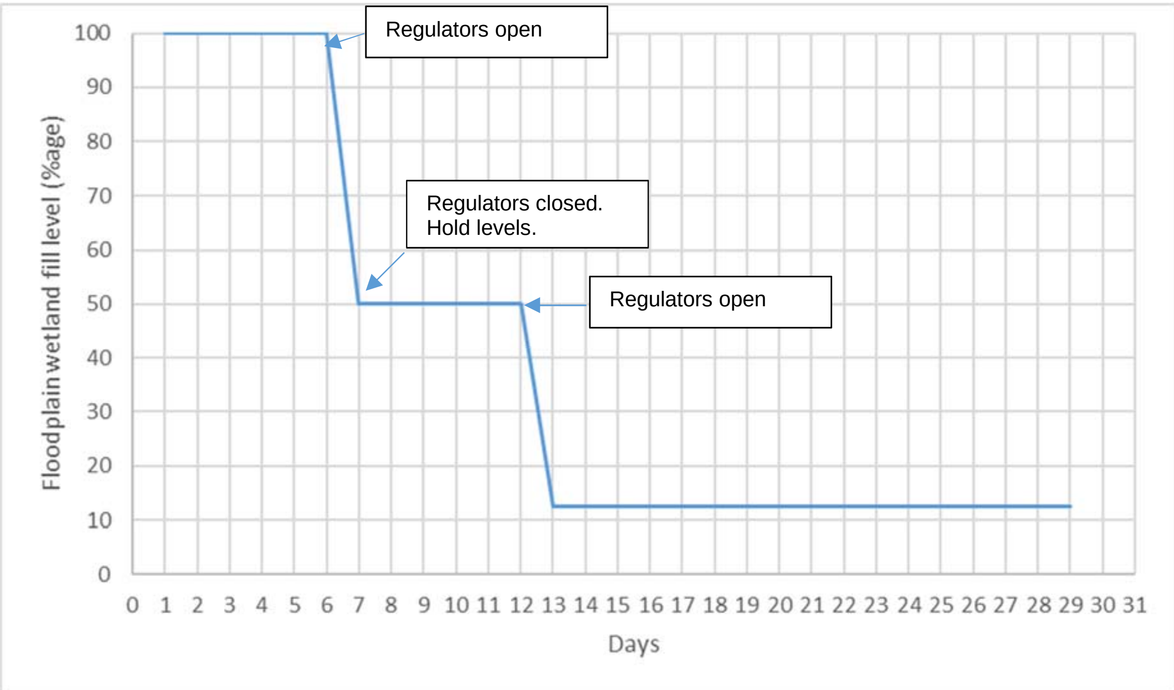



Figure 12 Fish exit hydrograph (low Murray River flows <13,000 ML/day)

### 10.1.4 Uncertainty and adaptive management

In the last decade there has been substantial research on the behaviour of fish on floodplains. Predictions can be made on fish behaviour, based on the conceptual models presented in Section 6, but the certainty around these is variable, especially given that the small-bodied generalist guild contains a number of species that, although broadly similar in their habitat preferences, will respond to the changed flow regime differently.

The approach to address these knowledge gaps and uncertainty is to use adaptive management. The objective is to maximise spawning and recruitment of small-bodied fish on the Vinifera Park floodplain. The response of fish will be totally reliant on the inundation regime and may not be fully planned for until the event and monitoring are underway. Hence, adaptive management as the event unfolds would be the most effective method to minimise risks and optimise outcomes.

This adaptive management will require data on entry success, fish growth and survival and exit success from the floodplain to provide guidance on flow management and in particular, timing and duration of watering to give fish appropriate growing conditions and exit pathways back to the Murray River. These aspects require responsive management and co-operation with fish biologists and the asset/regulator operators.

#### 10.1.5 Operational implications and risks

Increasing the floodplain inundation time at Vinifera Park will lead to conditions that are closer to natural conditions within the park (i.e. seasonal inundation for between 9-12 months). However, the inundation regime will rely on relatively high flows to fill the wetland and/or the use of temporary pumps to top up water levels. The exit of fish from the wetland will require the management of regulators V1, V2 and V4 at an appropriate time to allow fish to exit the floodplain.

The successful management of floodplain wetland habitat for small-bodied fish brings with it a number of risks, which can be categorised as either

- infrastructure and operations; or
- fish responses.

These risks and mitigation measures are listed in Table 13.

Table 13 Risks and mitigation measures of increasing small-bodied fish population within Vinifera Park

| Risk | Mitigation Measure |
|---|---|
| **Infrastructure and Operation** | |
| Wetlands not filled at appropriate time | Operators aware of critical timing for floodplain inundation |
| Regulator operation not optimised | O&M to include operation for fish objectives.<br>Operators trained and supportive of fish objectives.<br>Liaison with operating staff; include annual meeting to receive feedback from operators. |
| **Fish Responses** | |
| Exotic fish species:<br>Carp and gambusia establish in wetlands and compromise macrophyte habitat | Ongoing low-level (e.g. annual) monitoring to assess carp populations.<br>Active management of non-native fish species. |
| Knowledge Gaps<br>Unknown aspects of fish biology and recruitment conditions.<br>Fish passage (entry and exit) | Monitoring of populations, with scope for more detailed investigations if poor response to flood events observed. |

Table 14 A wetland management plan for small-bodied generalist native fish with potential application at Vinifera Park

| Hydrological scenario | Target native fish | Objective | Justification for hydrograph | Hydrology |
|---|---|---|---|---|
| Natural inflows (Murray River >15,000 ML/d) | Small-bodied wetland generalists | Dispersal of fish to newly inundated habitats to maximise spatial distribution<br><br>Spawning and recruitment<br><br>Maximise macrophyte diversity and complexity | Spring fish spawning in shallow littoral habitats (e.g. < 20 cm depth)<br><br>Stimulate primary productivity and macrophytes<br><br>Maintain water levels in refuge habitats | Winter-spring fill event (July-November) |
| Drawdown | Small-bodied wetland generalists<br><br>Non-native fish | Allow for native fish exit from wetlands<br><br>Periodic drying to manage non-native fish | Fish exit strategy to allow for native fish to exit and non-native fish to become stranded.<br><br>Dry wetland to enhance productivity of consequent filling events | Late spring drawdown |

## 10.2 Connection to other sites

The Vinifera Fish Management Plan connects to other sites within the region and links most closely to Nyah Park via the Murray River. Any benefits, particularly if suitable conditions are created for juvenile riverine species, could have benefits more broadly.

## 10.3 Complementary measures

Complementary measures are activities that address non-flow related threats to achieving Basin Plan Objectives. Whilst flows and habitat restoration will improve fish communities, the most significant impact will be through a combination of interventions. Examples of fish related complementary measures include fish passage structures, fish friendly pump screens, in-stream habitat, carp control, and native fish re-stocking.

Complementary measures that could improve outcomes for native fish in addition to the recommendations in this plan include (ranked in order of relevance):

- carp control through the potential release of the carp virus could substantially improve localised outcomes for small bodied native fish within Vinifera Park
- improvements in Murray main channel habitat through targeted re-snagging programs could aid survival of fish which were returned to the river from this site
- broader flow connectivity for the southern connected Murray River basin may result in more regular recruitment and dispersal of golden perch and silver perch (Stuart and Sharpe, 2017)

# 11. Proposed ecological objectives and targets

Fish related opportunities and objectives are entwined with other ecological objectives set for the site, including vegetation and birds. A balance between all ecological objectives and their required hydrological requirements will need to be assessed by water managers. Proposed ecological objectives, with links to previous objectives are outlined in Table 15.

Table 15 Proposed ecological objectives for fish

| Target fish community | Ecological objective | Links to previous objectives |
|---|---|---|
| Small-bodied generalist native fish | Re-establish seasonal populations of small-bodied fish<br><br>Annual spawning and recruitment of small-bodied wetland generalist fish populations<br><br>Maximise macrophyte diversity and complexity<br><br>Dispersal of wetland generalist fish among wetlands and maximise spatial distribution | 1, 2, 4, 5, 6, 8, 9, 10 |

# 12. Recommended SDL design criteria for native fish

The proposed SDL designs are detailed in Section 4.1 and summarised as:

- regulator V1 and V2: Downstream flow control
- drop structure: Provides plunge pool for fish moving downstream from regulator V2
- raised tracks and overflow sills: Main mechanism to retain water on floodplain
- regulator V3: To pass local drainage flows, pass overland flows in large events and prevent backflow onto private land during a managed event
- regulator V4: To prevent backflow into the Murray River when retaining water in the forest and allow inflows from the Murray River

The specifications outlined in the design report for the Vinifera SDL infrastructure (Jacobs, 2017) broadly satisfy fish passage requirements. The inclusion of carp exclusion screens on the regulator structures would benefit the small-bodied native fish species that are likely to inhabit Vinifera Park.

Table 16 Design specifications for Vinifera Park

| Major fish passage requirement | Vinifera Park detailed design specification | Design change recommendation |
|---|---|---|
| Fishway for upstream fish passage | Not provided, unlikely to be required due to local hydraulic conditions and low abundance of migratory fish. | nil |
| Fish passage through regulators | No specific provision is made for upstream or downstream fish passage at regulator V4 although some limited passage would be available.<br>The main regulators (V1 and V2) - cater for upstream and downstream fish passage when the regulators are fully open.<br>Fish passage not required at regulator V3 as main purpose is to drain private land. | Carp Exclusion Screens |
| Water velocities through regulators to be within fish swimming tolerances | The velocity would be acceptable for fish passage at 0.01-0.04 m/s.<br>Proposed roughening to the side of the regulator outer walls to improve upstream fish passage at peak flow.<br>Culvert floor below bed level | nil |
| Over-shot gates for safe fish passage | Provision of split leaf gates with overshot functionality at the main regulator V2. | nil |
| Drop structure provides safe hydraulics for downstream migrating fish | 40% of differential head is preferred.<br>In the design of V2 regulator the plunge pool is to be established by having a tailwater over the length of the outflow channel, supplemented by the drop structure, and a dedicated plunge pool is not included.<br>Culvert floor below bed level | nil |
| Gates to be operated as either fully open or fully closed – not in regulating mode | Recommended in detailed design report. | nil |

# 13. Recommended operational regimes

Table 17 outlines the proposed ecological objectives and the operational regimes required to meet them.

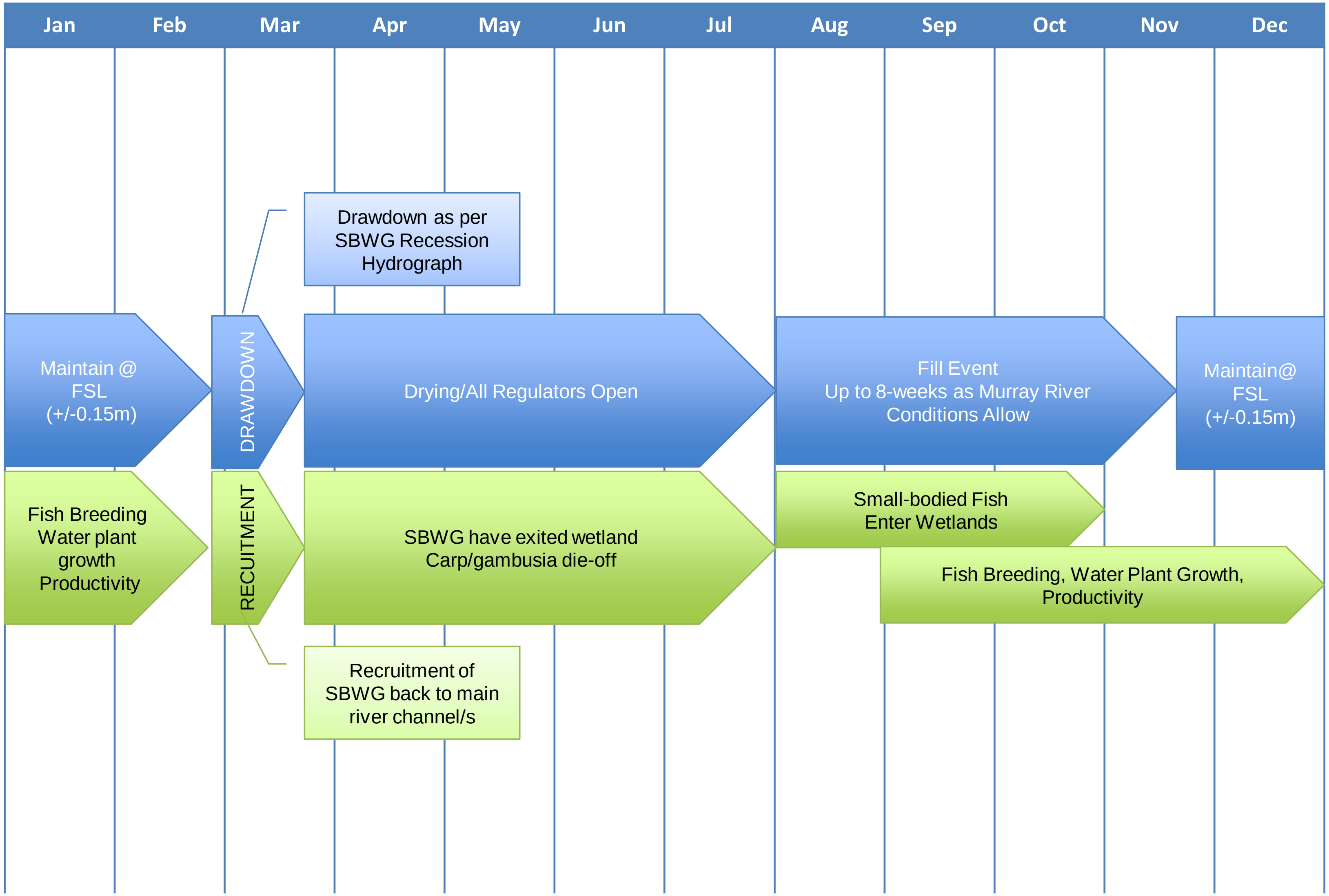
Table 17 Proposed ecological objectives for fish

| Ecological objective | Hydrological scenario | Operational regime |
|---|---|---|
| Re-establish seasonal populations of small-bodied fish<br>Annual spawning and recruitment of small-bodied wetland generalist fish populations<br><br>Maximise macrophyte diversity and complexity<br><br>Dispersal of wetland generalist fish among wetlands and maximise spatial distribution | >15,000 ML/day | All regulators open. Once passing flows reach their peak or begin to recede, regulators are closed.<br><br>Maintain through flow where possible.<br><br>Water level variation <0.1m/day in spring<br><br>Water level variation in winter and can be at up to 0.25 m/day to stimulate primary productivity processes<br><br>**Drawdown**<br>Release water as a staged process.<br>Open regulators V1 and V2 to partially lower water levels.<br>Close V1 and V2. Hold water level steady for 2-3 days.<br>If possible, augment hydrograph using flows from regulator V4 or pumped flows to partially refill wetland.<br>Open all regulators to release water at a slow rate. |

# 14. Conceptual models of water management options

A conceptual model detailing the hydrological conditions and expected ecological outcomes for the managed action is provided on the following page.

## TEMP. MANAGED FLOODPLAIN OPERATIONS MODEL: Small-bodied wetland generalists (SBWG)



# 15. Risk assessment

## 15.1 Risk management

The purpose of risk assessment is to inform decisions based on the outcomes of the risk analysis. Once the level of risk has been determined, a decision can be made on whether the risks are acceptable, or whether they require further treatment to lower the level of risk prior to the action going ahead. An approach to risk management is presented in Table 18.

Table 18 Risk management rating and action definitions

| Rating | Action |
|---|---|
| Severe | Do not go ahead with action unless significant treatments result in mitigation of risk to acceptable level |
| High | Do not go ahead with action unless treatments result in mitigation of risk to acceptable level |
| Medium | Risks rated at this level should be considered for further treatment, but action may still go ahead under defined conditions |
| Low | Risks considered to be adequately managed and not requiring further treatment |

## 15.2 Risks assessed as part of proposed SDL operations

A risk assessment was undertaken as part of the SDL Business Operating Plan in line with the requirements of AS/NZS ISO 31000:2009. It is important to note that the majority of the risks identified existed in both an “existing conditions” or “Basin Plan without works” scenario, but were included because the proposed works provided mitigation opportunities.

Table 22 contains a sub-section of this risk assessment that relate either directly or indirectly to fish. No risks were considered more than moderate post mitigation.

## 15.3 Risks assessed as part of the Fish Management Plan

A risk assessment was undertaken as part of the Fish Management Plan development process. The risk assessment followed the EPA Victoria-developed Ecological Risk Assessment process:

- Identification of the values associated with the waters to be stocked and any connected waterways;
- Identification of the threats posed to the values associated with the proposed translocations;
- Undertake a preliminary risk assessment with existing information and local knowledge;
- Documentation of gaps identified and assumptions made during the process; and,
- Recommendations for appropriate risk mitigation actions to protect values and reduce threats to these values.

The process allowed for a qualitative risk assessment, based on known data or literature and extrapolated to the site. The risk assessment required the determination of a consequence level and likelihood (or probability) rating of each threat causing any impacts to each identified value.

An initial risk workshop was completed on 16 November 2017, with a second workshop completed on 13 December 2017 as part of the overall SDL Fish Management Plan preparation. Attendees are listed below:

**Workshop 1 (16 November 2017)**

Pam Clunie (DELWP)

Wayne Koster (DELWP)

Jarod Lyon (DELWP)

Ivor Stuart (DELWP)

Tarmo Raadik (DELWP)

Scott Raymond (DELWP)

Zeb Tonkin (DELWP)

Cath Hall (Mallee CMA)

Nick Sheehan (Mallee CMA)

Faith Deans (GHD)

Simon Harrow (GHD)

**Workshop 2 (13 December 2017)**

John Koehn (DELWP)

Jason Lieschke (DELWP)

Ivor Stuart (DELWP)

Clayton Sharpe (CPS Enviro)

Brenton Zampatti (SARDI)

Cath Hall (Mallee CMA)

Nick Sheehan (Mallee CMA)

Simon Harrow (GHD)

The matrix used to assess risk as part of the Fish Management Plan preparation is presented in Table 19 based on the likelihood and consequence descriptors in Table 20 and Table 21.

Results from the risk assessment process are presented in Table 23. No risks were considered more than moderate post mitigation.

Table 19 Risk assessment matrix

| Likelihood | Consequence | | | | |
|---|---|---|---|---|---|
| | 1-Insignificant | 2- Minor | 3- Moderate | 4- Major | 5- Critical/Severe |
| 5-Almost certain | Low | Medium | High | Severe | Severe |
| 4- Likely | Low | Medium | Medium | High | Severe |
| 3- Possible | Low | Low | Medium | High | Severe |
| 2- Unlikely | Low | Low | Low | Medium | High |
| 1 Rare | Low | Low | Low | Medium | High |

Table 20 Likelihood ratings for threats to the values of the study area

| Likelihood Rating | Descriptor | Definition |
|---|---|---|
| 5 | Near certain | Confident that the threat will occur |
| 4 | Highly likely | The threat is expected to occur |
| 3 | Likely | The threat is likely to occur |
| 2 | Unlikely | The threat is unlikely to occur |
| 1 | Highly | Confident that threat will not occur |

Table 21 Consequence levels of impacts on the values of the study

| Consequence Severity Level | Descriptor | Consequence |
|---|---|---|
| 5 | Critical | Long term impacts at a broad scale |
| 4 | Major | Long terms impact at a local scale |
| 3 | Moderate | Broad short term impacts |
| 2 | Minor | Short term local impacts |
| 1 | Insignificant | No impact |

Table 22 Vinifera Park Business Case Risk Assessment

| Threat | Description | L | C | Risk without mitigation | Mitigation | Residual Risk |
|---|---|---|---|---|---|---|
| **Low dissolved oxygen (DO) levels** | Low dissolved oxygen (DO) concentrations can occur through a variety of processes, including blackwater events, algal and cyanobacterial blooms, high organic matter loadings and stratification. Low DO can cause the death of aquatic fauna and have negative impacts on the health of wetland communities in general.<br>More frequent inundation (i.e. through managed watering events) will reduce the accumulation of organic matter on the floodplain between inundation events. | 4 | 5 | High | Planning phase:<br>• monitor antecedent floodplain conditions (i.e. organic matter loads) to assess risk of a hypoxic event occurring.<br>• consider seasonal conditions (e.g. temperature, algae) prior to watering.<br>Operations phase:<br>• commence watering as early as possible to move organic matter off the floodplain while temperatures are low<br>• maintain through-flow where possible in other areas to maximise exchange rates and movement of organic material<br>• monitor DO and water temperature to identify hypoxic areas to inform consequence management (see below).<br>Managing consequences:<br>• ensure dilution of low DO water by managing outflow rates and river flows<br>• delay outflows if river flows are too low<br>• dispose of hypoxic water by pumping to higher wetlands where possible.<br>• agitate water using infrastructure to increase aeration. | Moderate |
| **Poor water quality** | Water manipulations may lead to suspension of sediments and/or organic matter causing elevated nutrients, high turbidity and/or low dissolved oxygen (DO) levels. This may impact reduce food sources and possibly toxic algal blooms upon wetland | 3 | 3 | Moderate | As above. | Low |

| Threat | Description | L | C | Risk without mitigation | Mitigation | Residual Risk |
|---|---|---|---|---|---|---|
| | community health, threatened species, fish and other aquatic fauna communities, and waterbird communities (via impacts). The risk assessment for low DO water is presented above. | | | | | |
| **Increased carp populations** | Carp will breed in response to both natural and managed floods. High numbers of carp can threaten the health and diversity of wetland vegetation, affecting native fish and other aquatic fauna. This has potential impacts both within the project site and at the reach scale. | 5 | 5 | Severe | Tailor watering regimes to provide a competitive advantage for native fish over carp.<br><br>Dry wetlands that contain large numbers of carp.<br><br>Manage the drawdown phase to provide triggers for native fish to move off the floodplain and, where possible, strand carp. | Moderate |
| **Managed inundation regimes do not match flow requirements for key species** | The delivery of an inappropriate water regime may occur through inadequate knowledge of biotic requirements or conflicting requirements of particular species with broader ecological communities. This may lead to adverse ecological outcomes, e.g. failure of waterbird breeding events, lack of spawning response in fish, spawning response but no recruitment. | 3 | 3 | Moderate | Consider the various requirements of key species/communities when developing operating strategies and planning for watering events.<br><br>Assess the response of species of concern during and after managed watering events and adjust operational arrangements if required.<br><br>Update operating strategies to capture new information on the water requirements/ response of key species/communities.<br><br>Target different taxa at different times (e.g. target vegetation one year and fish the next). | Low |
| **Stranding and isolation of fish on floodplains** | Stranding can occur through sudden changes in water levels and/or new barriers preventing native fish from | 3 | 3 | Moderate | Develop a ‘Fish Exit Strategy’ to inform regulator operation during the drawdown phase to maintain fish passage for as long as possible and to provide | Low |

| Threat | Description | L | C | Risk without mitigation | Mitigation | Residual Risk |
|---|---|---|---|---|---|---|
| | escaping drying areas during flood recessions. This may result in the death of a portion of the native fish population. | | | | | |
| **Barriers to fish and other aquatic fauna movement** | Installation of regulators in waterways and wetlands creates barriers to the movement of fish and other aquatic fauna. This can reduce access to feeding and breeding habitat, and limit migration or spawning opportunities. | 3 | 3 | Moderate | Determine fish passage requirements and incorporate into regulator design (as in Hames, 2014). Continue to build on knowledge and understanding through current studies relating to fish movement in response to environmental watering and cues. | Low |
| **Inability to discharge poor quality water (in-channel and floodplain)** | Inability to discharge water of poor water quality during a managed flow event, due to downstream impacts (e.g. increases in instream salinity), could result in impacts on floodplain vegetation (due to extended inundation) or formation of blackwater/algal blooms. | 3 | 5 | High | Schedule watering events to make use of dilution flows where possible.<br>Maintain good relationships with other water managers.<br>Integrate water management with other sites in seasonal water planning process.<br>Where possible and useful, water can be disposed within the site (pump to higher wetlands).<br>Continue to undertake water quality monitoring before, during and after watering events to inform adaptive management strategies and real-time operational decision making. | Low |

Table 23 Potential risks from actions proposed in Fish Management Plan

| Value | Threats | Likelihood | Consequence | Risk | Rationale | Possible Treatments | L | C | Residual Risk |
|---|---|---|---|---|---|---|---|---|---|
| Low carp populations | Inundation causes carp breeding event and population expansion and impacts | 5 | 5 | Severe | • Conditions (scale, timing, hydraulics) are ideal for carp breeding | • Winter fill<br>• Small inundation events<br>• Reduce frequency of operations<br>• Introduce carp herpes virus | 5 | 2 | Med |
| Good water quality | Anoxic DO event | 4 | 4 | High | • Floodplain watering may cause localised blackwater events | • Winter fill<br>• Small inundation events before large event<br>• Blackwater management plan | 4 | 2 | Med |
| Seasonal occupation of floodplain by small bodied native fish | Stranding of fish on floodplain during drawdown | 4 | 4 | High | • Rapid drawdown of water levels may result in fish stranding | • Develop contingency plan for emergency removal of fish<br>• Develop recession hydrograph that achieves slow drawdown to allow fish to escape from floodplain<br>• Undertake emergency watering to raise water levels | 3 | 2 | Low |
| | Wetlands support the establishment of invasive plant and animal species which may outcompete native species | 5 | 3 | High | • Stable water levels provide competitive advantages for invasive species (carp and gambusia) | • Install mechanical exclusion devices when filling wetlands<br>• Introduce carp herpes virus<br>• Drawdown to allow native fish to exit and exotic species to become stranded | 5 | 2 | Med |

| Value | Threats | Likelihood | Consequence | Risk | Rationale | Possible Treatments | L | C | Residual Risk |
|---|---|---|---|---|---|---|---|---|---|
| | Wetland generalist fish species displace wetland specialists (including listed species) | 1 | 1 | Low | • Very few wetland specialists likely to inhabit the Vinifera floodplain | No mitigation measures recommended | | | Low |

Note: L=likelihood; C=consequence

# 16. Monitoring recommendations

Table 24 outlines the broad monitoring recommendations to assess the success of operating the SDL structures to benefit fish.

Table 24 Monitoring recommendations

| Gap | Recommendation |
|---|---|
| Species composition, use of off-stream habitats, variability across site | Other than WetMAP monitoring at nearby Nyah Park no regular monitoring is completed on site. An understanding of the effects that increased floodplain inundation and has on fish population dynamics in the site will be important to monitor. |
| Exotic fish species.<br>Carp and gambusia establish in grow-out wetlands and compromise habitat for small-bodied fish. | Ongoing low-level (e.g. annual) monitoring to assess carp populations with active management of exotic fish species. |
| Stranding of native fish. | Fish monitoring of drawdown period to ascertain whether fish are able to exit through both regulator upstream regulator V4 and downstream regulators V1 and V2. |

# 17. Conclusion

Vinifera Park has the potential to provide a number of water regime classes that would benefit native fish at a local scale. Currently the flood duration in Vinifera Park is too brief to support small-bodied wetland species. Seasonal wetland habitat has been lost from Vinifera Park through a reduction in the duration of spring flow peaks. There has been encroachment of river red gums and a shift from aquatic marshland vegetation to an understorey dominated by grasses and herbs. The wetlands now only provide opportunistic habitat for aquatic fauna that colonise the system when water is available.

The SDL ecological objectives focus on the seasonal wetland component of the water regime to meet ecological objectives for fish. To meet the objectives the SDL operating plan will provide:

- inflows to Seasonal Wetlands in nine out of 10 years for a period of between 6-9 months each year
- inflows to Red Gum Swamp Forest in nine out of 10 years for a period of between 5-7 months each year
- inflows to Red Gum Forest and Woodland in nine out of 10 years for a period of between 2-6 months each year

This fish management plan has therefore identified the following opportunity for the Vinifera floodplain:

- Seasonal recovery of small-bodied wetland fish species. These include carp gudgeons, flat-headed gudgeons and dwarf flat-headed gudgeons and habitat for unspecked hardyhead and Murray-Darling rainbowfish.

The preparation of this Fish Management Plan included a risk assessment to protect aquatic values of the Nyah floodplain from potential threats posed to them. This identified several risks to native fish communities, some of which could only be partially mitigated. These included risks to fish in relation to escape from anoxic blackwater, increased carp breeding and the implications of seasonally low Murray River flows.

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