

Enhancing native fish populations using environmental flows: a synthesis of outcomes from the Victorian Environmental Flow Monitoring and Assessment Program

Tonkin Z¹, Amtstaetter F¹, Koster W¹, Jones M¹, O'Connor J¹, Stuart I¹, Yen J¹, Todd C¹, Harris A¹, Clunie P¹, Brooks J², Lyon J¹

1 Arthur Rylah Institute for Environmental Research, Department of Environment, Land, Water and Planning, Heidelberg, Vic.

2 Catchments, Waterways, Cities and Towns, Water and Catchments. Department of Environment, Land, Water and Planning East Melbourne, Vic

Corresponding email: Zeb.Tonkin@delwp.vic.gov.au

Key Points

- Event-based and long-term monitoring were used to assess responses of fish dispersal, recruitment and population dynamics to environmental flows.
- Evidence of benefits from environment watering for native fish across a broad range of Victoria's regulated river systems.
- Information collected were used to fill knowledge gaps to improve planning, delivery and evaluation of environmental water management.
- Population models were used for counterfactual assessment and forecasting of outcomes from managed flows.

Abstract

A fundamental objective of water for the environment is to enhance native fish populations, whereby flows are managed to specifically promote key processes such as dispersal, recruitment and survival. Monitoring how these processes respond to environmental flows, and how they influence population dynamics is vital to continuously improve how water can be managed for environmental outcomes. The Victorian Environmental Flows Monitoring and Assessment Program's (VEFMAP) fish monitoring theme has been examining the role of environmental flows in promoting these key functional processes and how they influence population dynamics of native fish across Victoria's priority regulated rivers.

This paper provides a synthesis of some key results from the fish monitoring theme such as: dispersal responses by native fish to specific flow events; links with trends in population demography and dynamics; and how quantitative estimates are used to evaluate long-term projections of native fish population outcomes under a range of management scenarios. The results have improved the way Victorian waterway managers and policy agencies communicate ecological outcomes of environmental water management to the community and water industry stakeholders, identify ecosystem outcomes from environmental water, and fill knowledge gaps to improve planning, delivery and evaluation of environmental water management.

Keywords

Environmental water, Native fish, Population processes, Population dynamics, Population modelling, Management

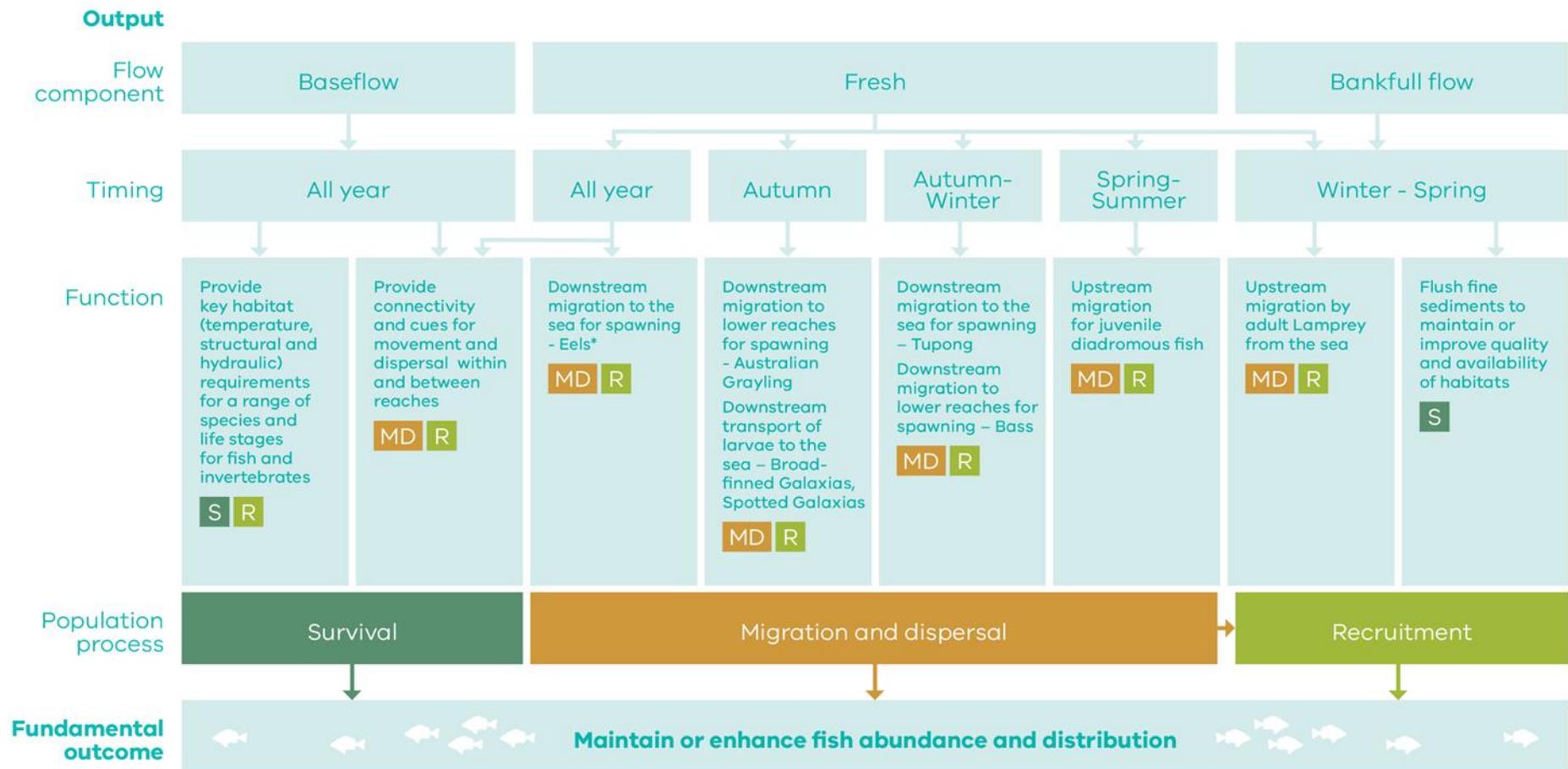
Background

Water for the environment (or 'environmental flows') is increasingly used to reduce the impacts of river regulation on ecosystem function and help recover native flora and fauna. For Victoria, a fundamental objective of water for the environment is to enhance native fish populations. Quantifying relationships between fish population outcomes and the delivery of environmental water help with the adaptive management of flows by providing evidence to support decisions about environmental water delivery and justify expenditure. The cultural, recreational and economic value of native fish is an important point of engagement with the public, and research on native fish generates valuable opportunities for environmental water managers to engage with other stakeholders (Tonkin et al. 2020a).

The magnitude and rate at which fish populations change are determined by the interplay between four key population processes: recruitment, mortality, immigration and emigration (Wootton 1998; Milner et al. 2003; Harris et al. 2013). Each of these population processes are themselves governed by several key sub-processes, such as growth and spawning, all of which are influenced by a variety of factors, including attributes of a rivers flow regime. Optimising the benefits of environmental water delivery for fish is therefore contingent on restoring key aspects of the flow regime that are linked to the processes governing population dynamics. Monitoring how these processes respond to environmental flows, and how they influence population dynamics is vital to continuously improve how water can be managed for environmental outcomes.

The Victorian Environmental Flows Monitoring and Assessment Program (VEFMAP) was established by the Victorian Government in 2005 to monitor and assess ecosystem responses to environmental watering in priority rivers across Victoria. In recent years, Key Evaluation Questions (KEQs) formed the basis of examining the role of environmental flows by promoting these key processes and how they influence population dynamics of native fish (Tonkin et al. 2020a). The KEQs and also recent environmental flow planning and delivery by waterway managers, were developed in accordance with broad conceptual models depicting how environmental water is currently managed to influence several key processes governing the population dynamics of native fish (see Figure 1 for an example from coastal rivers).

The program used a combination of event-based intervention monitoring, annual condition monitoring and stochastic population modelling to examine the effects of environmental flows on the distribution, dispersal, recruitment, abundance and population trends of key species across Victoria's priority regulated rivers. Here we synthesise some of the key results from the VEFMAP fish monitoring theme aimed at: *assessing key population processes* such as immigration and dispersal by native fish in response to specific flow events, both in coastal and inland rivers; *filling key knowledge gaps* in the conceptual understanding used to plan and deliver environmental water for native fish outcomes; and *assessing long-term trends in populations* and incorporating quantitative estimates of population processes to evaluate long term projections of native fish population outcomes under a range of management scenarios.



S = spawning; R = recruitment; MD = migration and dispersal

Figure 1. Conceptual model depicting how environmental water is currently managed to influence key processes governing the population dynamics of diadromous fish species in Victorian coastal rivers. Figure from Tonkin et al. 2020a.

Approach

Assessing key population process responses to managed flow events

Since 2016, VEFMAP has had a strong focus on linking and quantifying the role of environmental flows in promoting key processes such as immigration, dispersal and recruitment. This largely involved event-based monitoring, both in coastal and inland waterways. For coastal rivers, focus was given to diadromous species that comprise almost 70% of native fish species in coastal catchments (Harris 1984). The life history strategy of diadromous fish encompasses obligatory migrations between estuarine or marine, and freshwater environments to complete their life cycle. Environmental water is increasingly being used to enhance this process, both for downstream adult spawning migration (Amtstaetter et al. 2016) and juvenile fish returning to freshwater. For the latter, ‘freshes’ (a short period of elevated river discharge) delivered during summer and early autumn are often aimed at increasing the number of juvenile fish moving upstream; however, empirical evidence of whether these interventions are achieving their objective was lacking. In recognition of this shortfall, one of the KEQs specifically assessed whether upstream dispersal (the migration of juvenile diadromous fishes) can be enhanced using environmental flow releases. The project used netting data from two coastal systems over a period of three years to determine how the upstream juvenile movement of three diadromous species, common galaxias (*Galaxias maculatus*), short-finned eel (*Anguilla australis*) and tupong (*Pseudaphritis urvillii*), changed between periods of baseflows and summer/early autumn fresh releases. Surveys before and during environmental flow releases found almost six times as many juvenile common galaxias and short-finned eels and 40% more juvenile tupong moving upstream during freshes compared to baseflow conditions (Figure 2; Amtstaetter et al. 2021). This is the first time the effectiveness of these types of environmental flow releases has been assessed for diadromous fishes and provides support for their continued use. Nevertheless, not all sites yielded such results. In the Moorabool River, common galaxias and juvenile tupong were absent during monitoring, likely due to the man-made barrier downstream of the study site that blocked the passage of fish during the preceding low to moderate discharge. In streams with barriers, environmental flows may have little or no benefit for diadromous fishes until the barriers are removed or circumvented (e.g. using fishways).

Fishways and their functionality were however incorporated into a similar KEQ in northern river system looking at the role of environmental flows in supporting immigration of native fish into, and dispersal throughout, northern Victorian river networks. One of the studies supporting this KEQ assessed whether environmental flows cue fish movement and improve fishway functionality in the lower Loddon River system. A hydraulic assessment revealed environmental flow events rose tailwater levels and improved opportunities for fish movement across the barriers. Subsequent acoustic telemetry and fishway trapping showed upstream movement of both large- and small-bodied species increased substantially during environmental flow releases in comparison to low baseflow conditions (Jones et al. 2020; O’Connor et al. 2020).

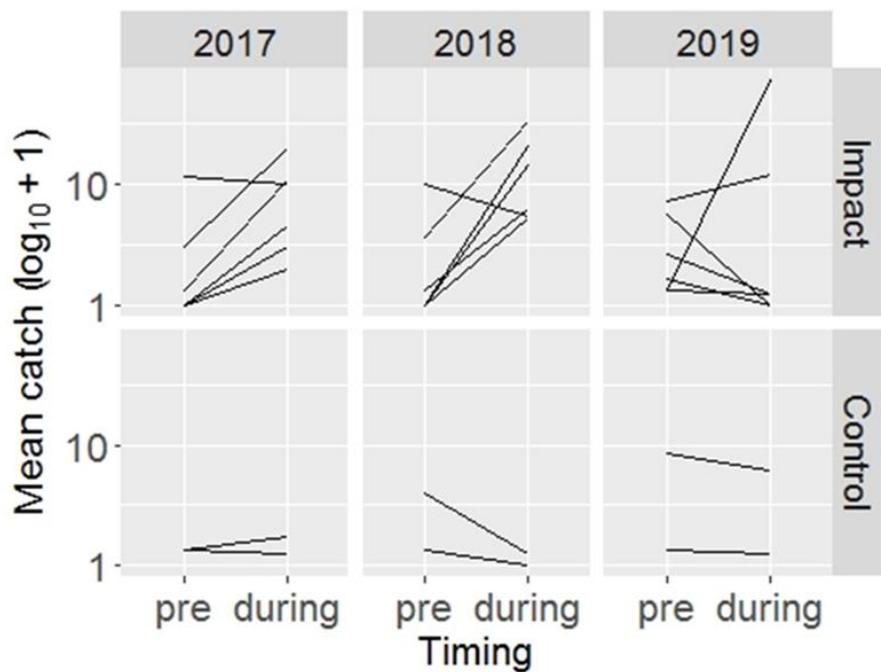


Figure 2. Mean catches of juvenile common galaxias per 24 h fyke net set at each site in the Glenelg (impact) and Stokes (control) rivers before and during summer or early autumn environmental flows in the Glenelg River (2017-2019). Figure from Amtstaetter et al. 2021.

Filling key knowledge gaps in conceptual models to improve flow management

Environmental flow planning and delivery by waterway managers are generally developed in accordance with broad conceptual models depicting how flow influences key processes governing the population dynamics of a species or group thereof (Figure 1). While many of these links have been specifically tested and quantified, others remain purely conceptual without any supporting empirical data; often unquantified and remaining broad in aspects such as the timing and magnitude of flow related functions. VEFMAP is identifying and addressing many of these knowledge gaps to help refine these conceptual models, quantify these processes and how they influence population dynamics (see below) and ultimately, improve how flows are managed for native fish outcomes.

A study assessing the role of flows in governing recruitment of Murray cod (*Maccullochella peelii*) across northern Victorian waterways is one such example (Tonkin et al. 2020b). Long-term monitoring data from the Goulburn, Broken, Ovens and King rivers were used to examine effects of flow on the recruitment of Murray cod. While specific links between river flows and recruitment varied across rivers, results provide strong evidence that managing flows in line with a more natural flow regime will significantly improve outcomes for Murray cod (Figure 3). This is also likely to apply to species with similar breeding strategies, such as trout cod and river blackfish. The results emphasize that to achieve recruitment success for long-lived species such as Murray cod, managers must consider the whole flow regime whereby ideal flow conditions provided for reproductive success in spring can be offset by negative effects of high summer or low winter flows on juvenile fish.

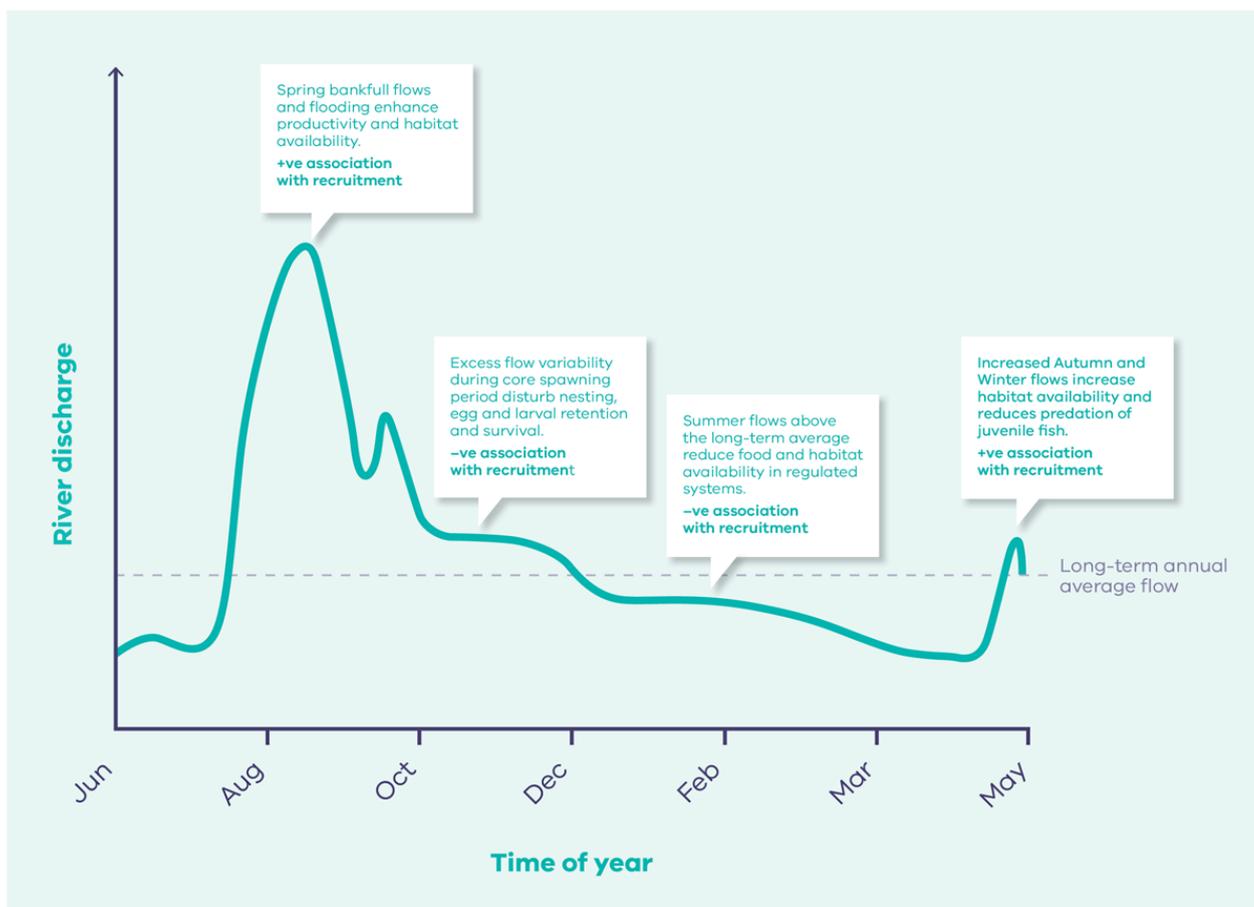


Figure 3. Updated conceptual model showing key flow components influencing recruitment of Murray cod in northern Victorian regulated rivers based on the findings of Tonkin et al. 2020b. Figure from Tonkin et al. 2020a.

Another example of improving knowledge to enhance management outcomes was a study that assessed silver perch (*Bidyanus bidyanus*) movement in the mid-Murray River region (Koster et al. 2021). Researchers used acoustic telemetry to assess the timing and extent of movement of this threatened and wide-ranging species. The study aimed to identify potential environmental variables (including river discharge) that might help predict when movements occur so that more targeted management actions could be developed to support the conservation management of these species. Silver perch occupied extended reaches of river (hundreds of kilometres) and multiple habitats throughout the river network, ranging from a large mainstem river to inflowing tributaries, anabranches and floodplain habitats. Discharge and time-of-year were important drivers of movement within and between habitats. The results also highlighted the importance of managing the species in a riverscape context rather than at reach or river scales. Specific actions to recover silver perch populations include restoring suitable flow conditions for colonization (immigration), along with improving fish passage; incorporating small to moderate variations in flow, especially between September and February, to promote upstream movement along the Murray River; and considering flow conditions interdependently across rivers.

Assessing long-term trends in fish populations and predicting responses to flow management

While much of the data collected for the fish monitoring theme was used to assess how key population processes respond to individual flow events, maintaining or enhancing native fish populations is a fundamental objective of the Victorian Waterway Management Strategy and embedded in many Environmental Water Management Plans. Consequently, environmental flows are often intended to increase native fish population abundance, distribution or resilience. Since its inception, a key component of VEFMAP

has been the establishment and continuation of a long-term fish population monitoring program at priority managed rivers across the state, to help track progress towards this fundamental objective. Measuring the effects of flow management on population trends is challenging, as many species respond to sequences of flow events occurring over multiple years; in addition, population trends are further influenced by other modifiers such as exotic species, habitat availability and stocking. VEFMAP has been using a variety of approaches to help address some of the challenges of measuring the effects of flow management on fish population trends across Victorian rivers.

Firstly, long-term condition monitoring data generated from standardised electrofishing has been underway within VEFMAP since 2007 (and for other programs since 1999). This has, and continues to, enable researchers to assess trends in the dynamics of key species, such as relative abundance and distribution, to help assess the role of flows in achieving improvements to native fish populations. For example, an analyses of long-term monitoring data in the Glenelg River found tupoong and common galaxias numbers increased by 16.0 and 5.8 times respectively over the same period when changes were made to summer and early autumn environmental flow deliveries (higher baseflows and one to two fresh releases each year since 2017). This indicated that the successful reinstatement of a flow regime better suited diadromous fishes (Amtstaetter and Koster 2020). Analysis of data from northern rivers (Yen et al. 2020) showed that for most species assessed, there was a declining trend in fish abundance through the millennium drought, with increasing or stabilising trends once flows returned as a result of both natural flows and an increase in environmental flows. Species and systems that typified this trend include Murray cod, Murray-Darling rainbowfish and golden perch in the Campaspe and Broken rivers. There were, however, some variations to this general trend between systems and species. For example, unlike most other systems in the period following the millennium drought, the Loddon River fish population had the lowest rate of increase or remained at low stable levels, most likely because the extreme low flows limited the survival and retention of fish (O'Connor et al. 2020).

The analysis of long-term data also partitioned the effects of flows from other modifiers, finding that a large proportion of variation in population trends was not explained by flows (Yen et al. 2020). Any assessment of population trajectories must therefore also consider other drivers, such as stocking, habitat restoration and recreational angling. Indeed, VEFMAP has started using stochastic population models previously developed (Todd and Koehn 2008) to predict long-term trends and risk to populations of Murray cod and silver perch in the Goulburn and Campaspe rivers under a range of managed flow scenarios (Todd et al. 2020). The models incorporate the quantified links between flow and key population processes generated in the KEQ studies (e.g. Murray cod recruitment and migration rates of silver perch), with other influential intrinsic (e.g. fecundity) and extrinsic (e.g. fish stocking and fishing) modifiers to compare population trends and risk in each population from 2004 – 2019 under a range of managed flow scenarios. Model predictions indicate environmental water is assisting native fish populations in the Goulburn and Campaspe rivers, but this is occurring in different ways and through different mechanisms between sites, species and life stages. Assistance comes through increasing recruitment, movement and supporting stocked fish and should be refined within a framework of adaptive management to further improve outcomes. Model predictions for Murray cod show a generally stable adult population that fluctuates with gross flow patterns in the Goulburn River, whereas for the Campaspe River the adult population shows an increasing trend since 2009. This aligns with the general trends observed in the monitoring data and associated analysis. Of the scenarios tested for Murray cod in the Campaspe River, the current flow recommendations produced the best population outcomes and the least risk to populations (Figure 4).

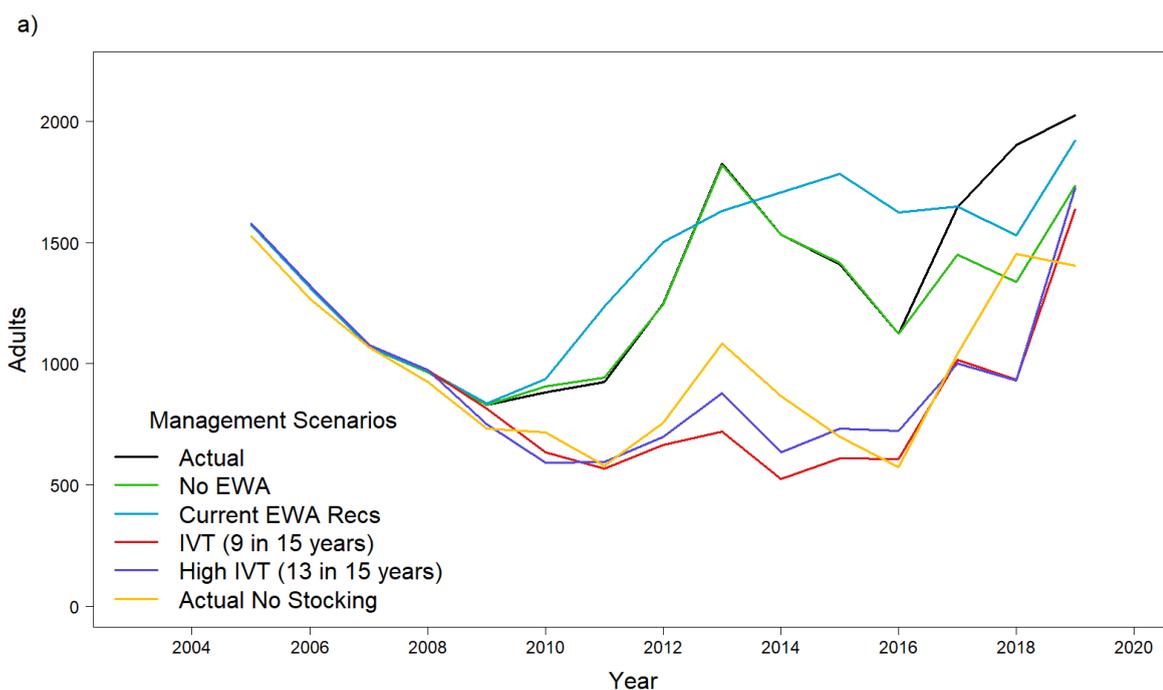


Figure 4. Population model outputs for Murray cod in the Campaspe River estimating the average adult population size trajectory for each of the management scenarios. Scenarios were: Actual = actual flow, temperature and stocking values; No EWA = actual temperature, stocking and flow values minus the environmental water allocation; Current EWA recs = actual temperature, stocking and flow values modified to meet current flow recommendations for each year; IVT = actual temperature, stocking and flow values modified to a 9 in 15 year summer intervalley trade; High IVT = actual temperature, stocking and flow values modified to a 13 in 15 year summer intervalley trade; Actual No stocking = actual flow and temperature values without stocking. Figure from Todd et al. 2020.

Conclusions

The results from the program provide clear evidence of benefits from environmental watering for native fish across a broad range of Victoria's regulated river systems. The combined approach of event-based and long-term monitoring has enabled researchers to identify and quantify key pathways linking attributes of river flows to the processes governing native fish population dynamics across Victoria. Establishing and quantifying links between river flows and population processes within our KEQ framework has provided much-needed empirical evidence to support delivery of environmental water for enhancing native fish populations. Most notably, our assessments of fish movement in response to specific flow events generated overwhelming evidence and support for the use of environmental flows as an effective management tool to enhance migration, dispersal and subsequent populations of native fish species in coastal rivers such as the Glenelg and Moorabool, and inland rivers such as the Campaspe, Loddon and Goulburn. The addition of population modelling to this approach is providing an important tool, both as a counterfactual assessment of outcomes, and also to help predict long-term population outcomes from a variety of managed flow scenarios and other interventions such as stocking. The program has improved the way Victorian waterway managers and policy agencies communicate ecological outcomes of environmental water management to the community and water industry stakeholders, identified ecosystem outcomes from environmental water, and filled knowledge gaps to improve planning, delivery and evaluation of environmental water management.

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