Setting the trend: Integrating long-term monitoring data to assess trends in riverine fish populations and inform management outcomes across Victoria

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Abstract

- Sustaining or improving native fish populations is a fundamental objective of many waterway management plans and interventions. Changes to fish populations often occurs over large spatial scales and extended periods that exceed that of restoration projects, with this misalignment presenting a challenge for managers and scientists, both for legislative requirements of evaluation and in the adaptive management space.
- We integrated more than two decades of fish monitoring data spanning 26 waterways across Victoria to assess long term trends in native fish abundance and recruitment. We used a hierarchical Bayesian model to estimate trends in fish catch through time, while also examining how these trends were influenced by a series of flow and non-flow covariates.
- Broadly, most native fish populations underwent substantial declines until 2010, coinciding with the low flow conditions associated with the Millenium drought. Since this time most species have undergone some recovery, the degree of which varies across species and waterways with some areas subject to major interventions such as environmental water. The modelling approach showed strong predictive power, generating quantitative links between population change and covariates including existing population size, carp abundance, different attributes of the flow regime and temperature.
- We present an evaluation of native fish population dynamics across an expansive spatial and temporal scale, with results directly informing progress towards fundamental objectives embedded in management plans and interventions such as flow management that target native fish population outcomes.

Background

Sustaining or improving native fish populations is a fundamental objective of many waterway management plans and interventions. While restoration projects usually occur over short time periods (1-3 years), changes to fish populations usually exceed this timeframe and often occur at spatial scales beyond the footprint of the intervention. The Department of Sustainability and Environment (DSE) established the Victorian Environmental Flow Monitoring and Assessment Program (VEFMAP) in 2005. Since its inception, a key component of VEFMAP has been the establishment of a long-term fish population monitoring program at priority managed rivers across the State to track progress towards achieving the fundamental objective of improving native fish populations. The broad aims of this project are to:

- Describe long-term trends in relative abundance, distribution and recruitment for priority native fish species and quantify links with environmental covariates, particularly key aspects of river flow;
- Meet Victoria's monitoring and reporting obligations under the Commonwealth Murray-Darling Basin Plan (MDBP), particularly for reporting on Schedule 12, Matter 8 (the achievement of environmental outcomes at an asset scale); and provide data to support legislative reporting needs for the Victorian Long-Term Water Resource Assessment (VLTWRA).

Methods

More than two decades of fish monitoring data spanning 26 waterways across Victoria were integrated to assess long-term trends in native fish abundance and recruitment. Waterways and data sets integrated in this project focused on 18 native fish species of one or a combination of conservation, cultural and recreational value spanning a range of life-history strategies occupying mid-lowland river reaches across Victoria. A hierarchical Bayesian model that incorporated a number of flow (variation, low-flow days and antecedent conditions) and non-flow (e.g. temperature, stocking and Carp density) covariates was used to estimate trends in standardised fish catch during 2000-2023. Data on all species and waterbodies were modelled simultaneously using a hierarchical model structure that shared information among species and waterbodies (i.e., trend estimates for locations with less data are informed by those with more data). The model structure relates catch to the previous year's catch, which means that the remaining predictor variables are used to estimate changes in population growth rate (changes in population size from one year to the next). A focus on growth rates is appropriate for many fish species, especially long-lived, large-bodied fish species because environmental conditions typically determine changes in fish abundance rather than absolute abundance in a single year (i.e., environmental conditions in a single year do not determine total fish population abundance, they simply change its abundance relative to the previous year). See Tonkin et al. (2024) or contact the author for full description of the methods.

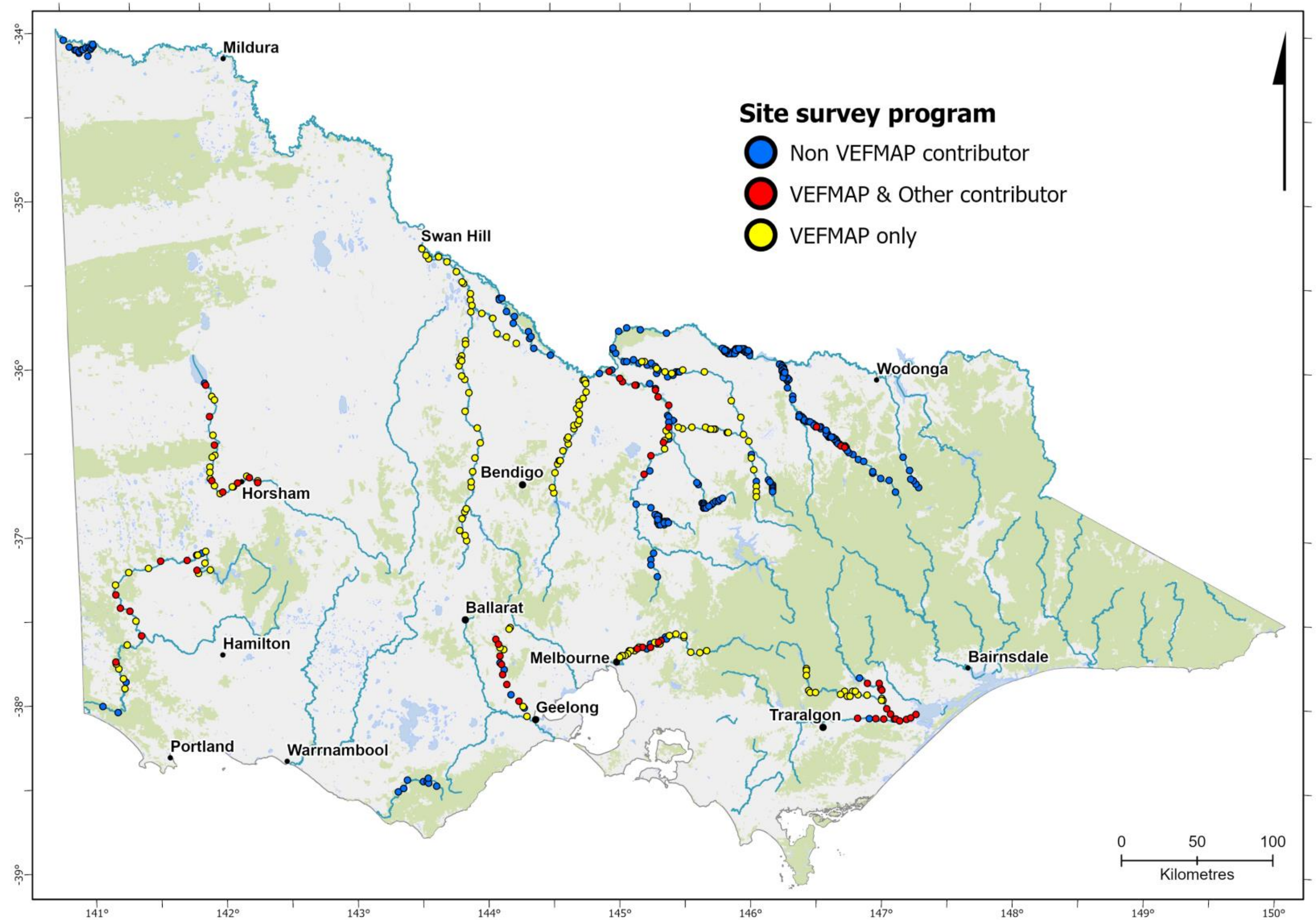

Figure 1. Map illustrating spatial coverage of monitoring sites and associated program for all data used in the assessment of fish populations. Figure from Tonkin et al. 2024

Results

The trends models had strong predictive power for most species, with model fit mostly moderate to high for all species with r^2 values ranged from 0.3 to 0.9 with majority 0.5 – 0.9. The outputs generated reach, catchment and whole of state level assessments for the priority species, with changes in catch per unit effort (CPUE) documented at annual to decadal time steps. Figure 2 presents an example of such at a state level, with values in red and orange indicate declines in population abundance over a period, whereas values in light and dark blue indicate increases in population abundance. Strong trends were defined as those with 90% credible intervals not overlapping zero, with all other estimated trends defined as "weak trends". Note proportional change in CPUE does not reflect Absolute CPUE, but rather should be interpreted alongside absolute CPUE values presented above. At a state level (Figure 2), most species declined throughout the 2000–2010 period (coinciding with the Millennium Drought) followed by increasing trends resulting in CPUE levels (and often reporting rates) exceeding those of 2010. For coastal rivers, the increasing trend since 2010 was most pronounced for Eel (both Short- and Long-finned, estimated 2-fold increase in CPUE from 2010 to its average value in 2020–2023), Common Galaxias (11.1-fold increase), River Blackfish (2.6-fold increase), Tupong (1.8-fold increase), and Australian Grayling (1.6-fold increase). In northern catchments (MDB), an increase was recorded for Murray Cod (8.2-fold increase), Trout Cod (8.4-fold increase), Golden Perch (3.2-fold increase) and Macquarie Perch (5.6-fold increase). By contrast, Unspecked Hardyhead, Silver Perch, Murray-Darling Rainbowfish, and Two-spined Blackfish had mixed trends in abundance since 2010, but all had CPUE estimates in 2023 that were similar to or lower than those in 2010.

The outputs from our trends models and long term data sets also generated waterway specific outputs required for asset scale reporting for MDBP and VLTWRA. More specifically, waterway specific trends in abundance, condition (for each reach where a species was regularly detected, we calculated the proportion of sites at which that species was detected in for a given time period) and recruitment success using a binary measure on the presence of 0+ and 1+ aged juvenile conspecifics (see Tonkin et al. 2024 for detailed outputs).

Long-term trends and covariate effects also provided insight into the flow regimes most closely associated with trends in fish populations. Associations between flow and non-flow variables and CPUE varied across species and systems with flow variables most mostly closely associated with CPUE Long-term trends being the number of days per year with low flows (below Q90) and flow variability. Specifically, for many species (e.g., Murray Cod, River Blackfish, Macquarie Perch, and most diadromous species), consistent discharge and a small number of low-flow days in a year was associated with substantial increases in fish population abundances and reporting rates, with this association apparent in several regulated systems (Glenelg, Campaspe, Thomson, and Goulburn rivers). Conversely, for summer-spawned small species such as Murray-Darling Rainbowfish, increasing populations were associated with years of low discharge and a high number of low-flow days likely due to a greater availability of warm water and higher concentrations of prey for early life stages.

Of the non-flow effects, Carp had the greatest influence on CPUE, having a negative association with most native fish species, with exceptions being Unspecked Hardyhead, Silver Perch (in the Goulburn River; weak association), Golden Perch (in the Lindsay and Wimmera rivers), and Murray-Darling Rainbowfish (in the Lindsay River and Mullaroo Creek). Trout Cod and Golden Perch (outside of the Lindsay and Wimmera rivers) had generally weak associations with Carp. The autoregressive model structure, which relates CPUE to its value in the previous year, explained substantially more variation than the flow or non-flow factors included in the model. Effect sizes relating CPUE to the previous year's value were typically an order of magnitude larger than those of any other factor in the model, which suggests that standing stock plays a major role in determining fish population dynamics.

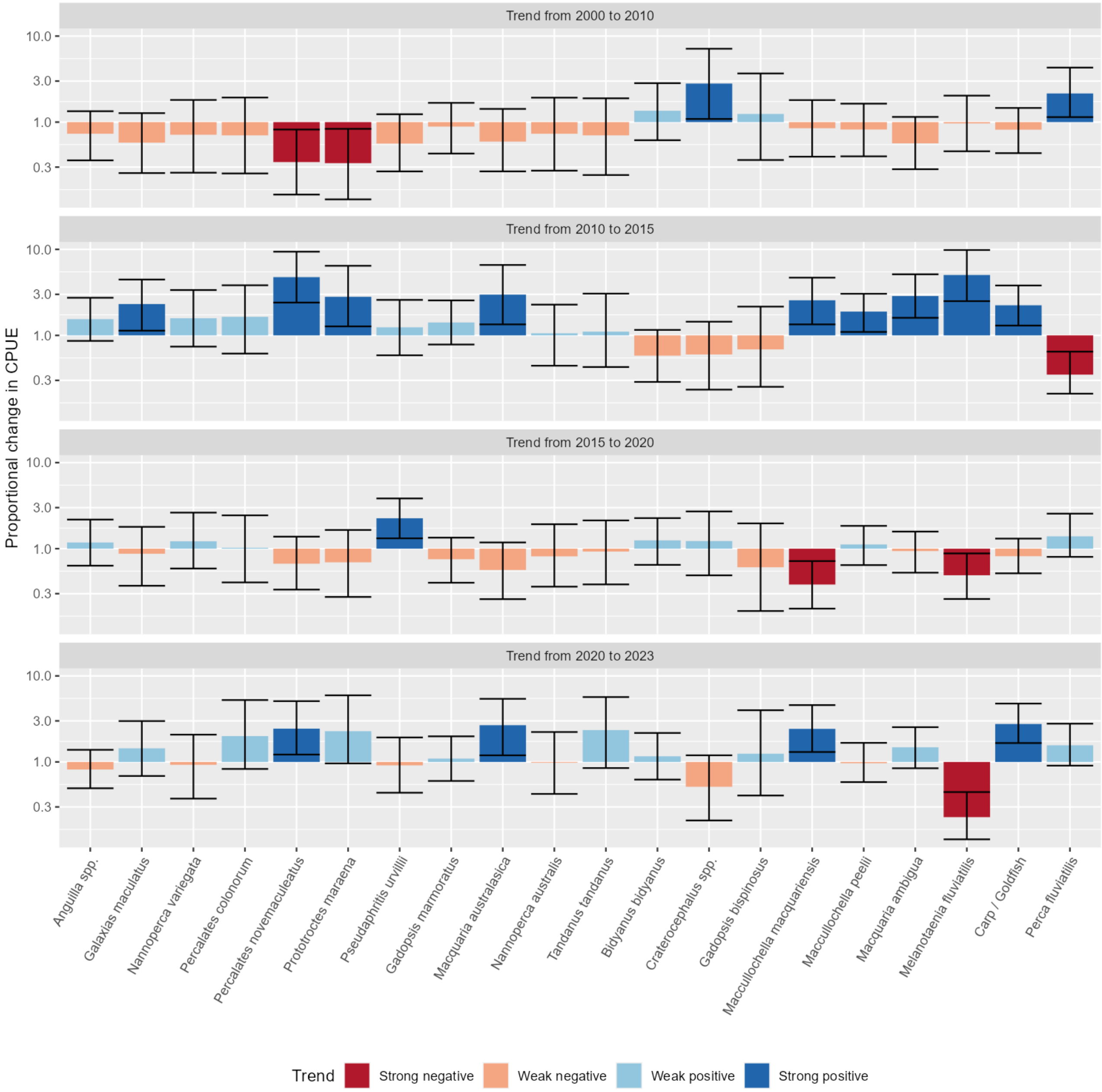

Figure 2. State-wide trends in riverine fish populations over four distinct time periods from 2000 to 2023. Trends represent the proportional change in catch per unit effort (CPUE) from the start to end of each time period. Solid bars are median values and thin black error bars bound 90% credible intervals.

Conclusions

The results of this study provide the most comprehensive assessment of long-term population dynamics of native fish populations for Victoria to date, generating decadal trends of important native riverine fish abundance and recruitment across mid and lowland regulated and unregulated river reaches. Our results provide outputs required to assess fundamental objectives related to native fish populations outlined in waterway management strategies and Environmental Watering Management Plans (EWMPs), as well as reporting obligations under the Commonwealth Murray-Darling Basin Plan (MDBP), and the Victorian Long-Term Water Resource Assessment (VLTWRA). Our results also provide important information to help communicate outcomes to key stakeholder groups such as waterway managers, Traditional Owners, and recreational fishers.

Quantitative link between annual population change and the number of low flow days in a year and flow variability provide support for current hypotheses linking flows and fish populations across many waterways (e.g. Tonkin et al. 2021; Humphries et al. 1999) and can be used to guide flow management planning such as seasonal watering plans in Victoria. Despite generating strong predictive models on trends, the ability to quantify the role of flow events in governing population dynamics at annual time steps was still limited. We suggest the magnitude, direction, and relative importance of flow and non-flow associations are clearest when assessing individual ecological processes (e.g., spawning, recruitment, mass mortality), with examples of insights into these links provided by several related projects (e.g., Amtstaetter et al. 2021; Tonkin et al. 2021; Koster et al. 2021).

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