Spatially explicit population models for fish in the Darling (Baaka) River system

Luke McPhan and Nick Bond, La Trobe University

Australian Government

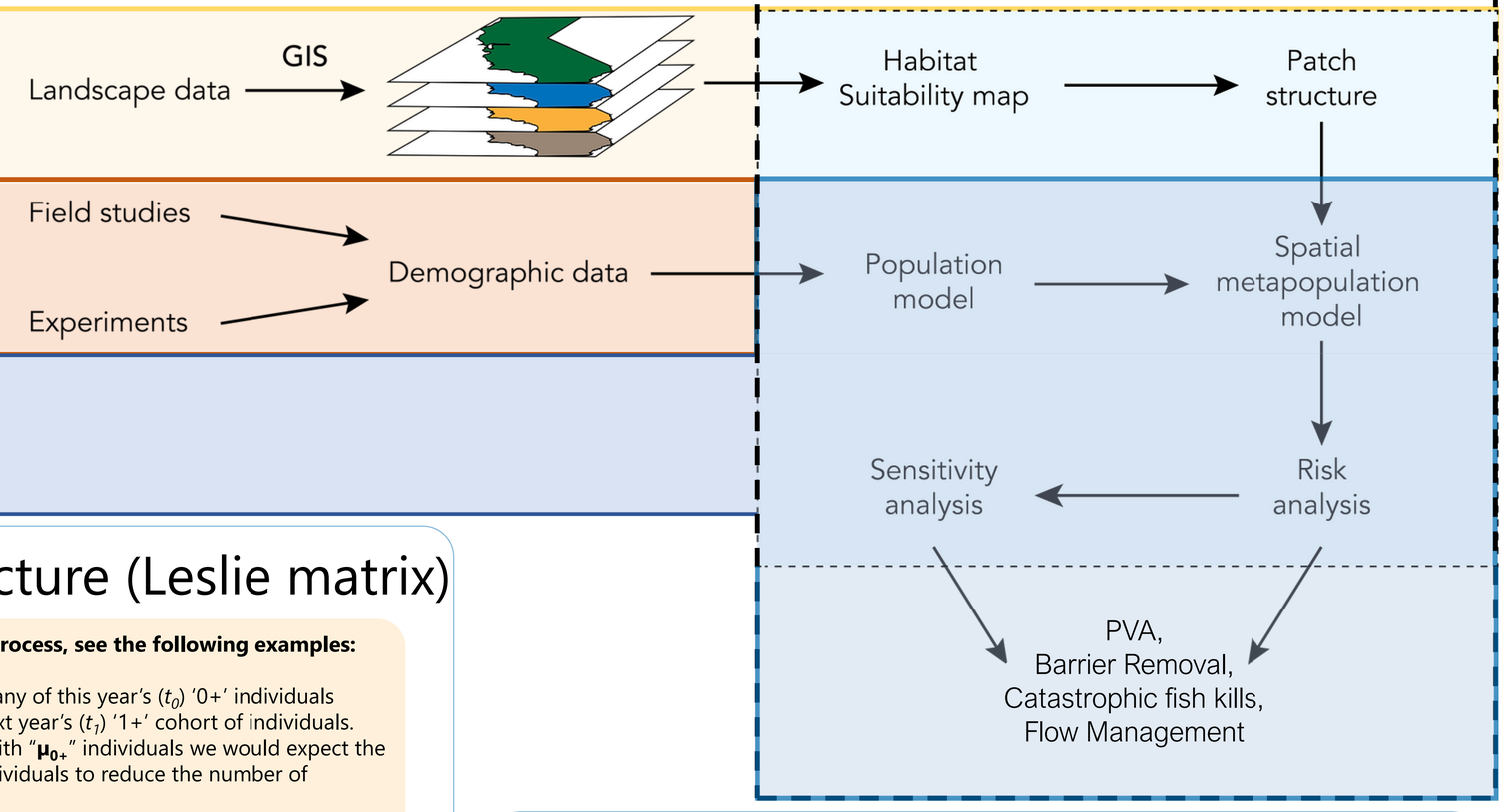
Murray–Darling Water & Environment Research

Project Outcomes

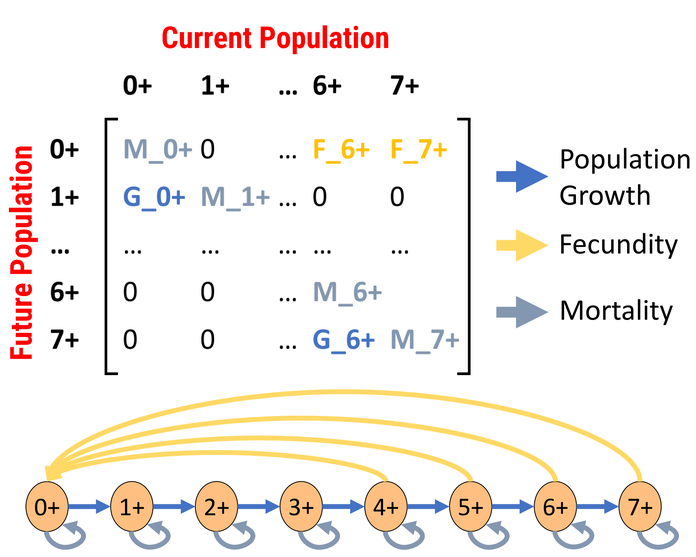
1) Characterise landscape-scale waterhole dynamics
- Waterhole persistence modelling
- Integrate with hydrologic time series

2) Demographic analysis
- Fish dispersal
- Survival/growth/carrying capacity of pools

3) Population modelling
- Sensitivity analysis
- Scenario development (including end-user consultation)
- Scenario modelling



Fish population growth rates - Age structure (Leslie matrix)



To illustrate this process, see the following examples:

1) To know how many of this year's (t_0) '0+' individuals survive into the next year's (t_1) '1+' cohort of individuals. For a population with "μ_{0+}" individuals we would expect the mortality of 0+ individuals to reduce the number of survivors:

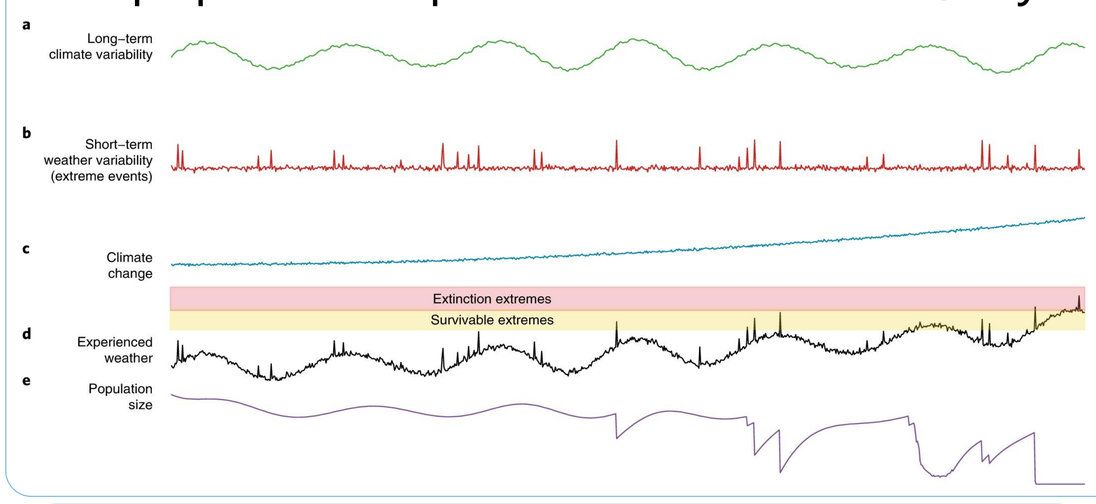
(t_1) '1+' cohort = μ_{0+} * M_0+

2) For the number of '0+' individuals in the following year we have to account for the breeding of mature individuals (i.e. μ_{6+}, μ_{7+})

(t_1) '0+' cohort = (μ_{6+} * F_6+) + (μ_{7+} * F_6+)

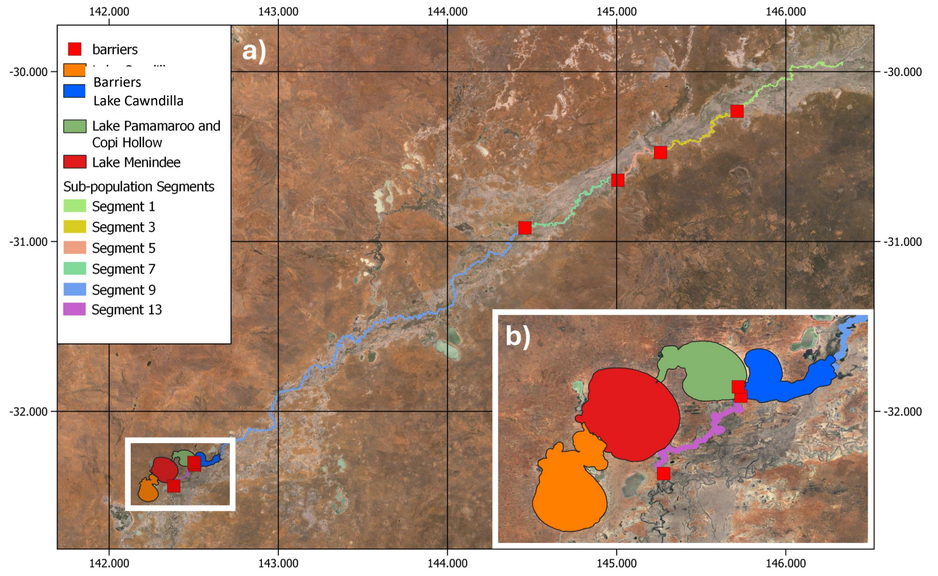
In a meta population model like ours, individuals will also be controlled by the available habitat and resources in a reach (this is the carrying capacity of a population) and the difference in the immigration and emigration (movement into and out of) between reaches.

Will populations persist under a hotter/dryer climate?

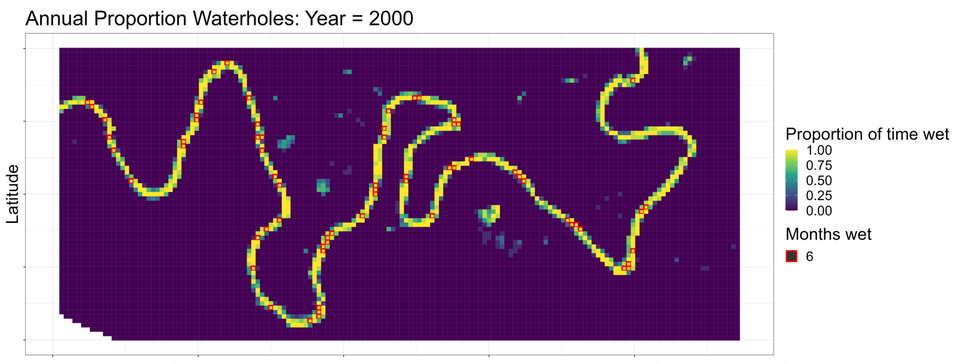


Harris, R.M.B., Beaumont, L.J., Vance, T.R. *et al.* (2018) Biological responses to the press and pulse of climate trends and extreme events. *Nature Climate Change* **8**, 579–587.

Study map and remotely sensing waterholes

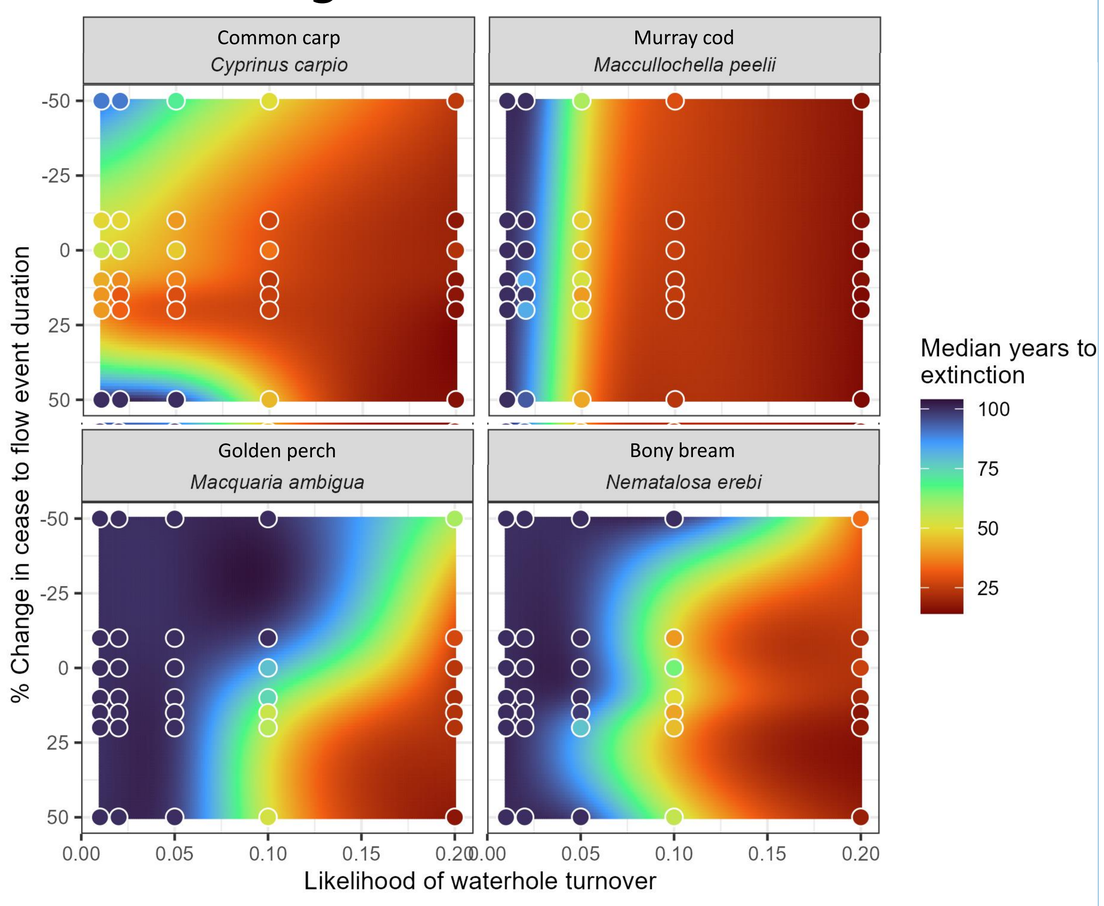


Modelled extents of the Darling showing: a) the entire reach with each reach of sub-population segments between barriers (red squares); b) a close view of the Menindee lakes system.



Example 5km reach showing the annual waterhole persistence of 900 m^2 gridded areas of the river for the year 2000. This persistence was used to calculate the annual available habitat and carrying capacity of each reach alternate scenarios of cease to flow conditions.

Results: Likely time to extinction under future climate change



Time to quasi-extinction (< 5th percentile abundance) across all scenarios of waterhole turnover and cease to flow duration. Points show the median time to quasi-extinction for each of the simulated models and the surface below is the smoothed tensor spline modelled from these model results.

Summary of findings

- **What is the current state of Meta-populations?**
  - Murray cod particularly are in a poor state in the Darling (Baaka) River, with rates of population replacement well below 1 per individual. Populations are most impacted above the Main weir at Menindee.
- **What is the likely population persistence given these vectors of change?**
  - Most populations have significant sensitivity to increased likelihood of hypoxic events e.g. waterhole turn over.
  - All native species show high tolerance to decreased waterhole persistence.
  - Although, significant sensitivity to cease to flow events.

Recommendations

- Native species responses to increased disconnection is dependent on waterhole stratification, thus, ensuring flows through the system reconnect isolated waterholes is key for native fish population persistence.
- Increased movement from areas of high recruit density (e.g. Menindee lakes) would support healthy upstream populations, particularly after localised waterhole turnover events or more widely spread reductions in fish numbers (e.g. drier years with reduced carrying capacity).
- Better projections of low flows in the Darling under future scenario's would allow a better comparison of populations in changed states vs across difference rates of change.

The authors pay respect to the Traditional Owners and their Nations of the Murray–Darling Basin. We acknowledge their deep cultural, social, environmental, spiritual and economic connection to their lands and waters.

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The MD-WERP Environmental Outcomes theme brings together researchers from La Trobe University, Griffith University and Sarah Martin Consultant Archaeologist.