Technical supplement to Basin-scale evaluation of 2019–20 Commonwealth environmental water: Fish

Commonwealth Environmental Water Office (CEWO): Monitoring, Evaluation and Research Program

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Cover photograph

Releasing a Murray cod
Photo credit: Arthur Rylah Institute

Important disclaimer

Overview of Flow-MER

Flow-MER is the Commonwealth Environmental Water Office's (CEWO) Monitoring, Evaluation and Research Program. Its objective is to monitor and evaluate the ecological responses to the delivery of Commonwealth environmental water in the Murray–Darling Basin. It provides the CEWO with evidence to inform our understanding of how water for the environment is helping maintain, protect, and restore the ecosystems and native species across the Basin. This work will support environmental water managers, demonstrate outcomes, inform adaptive management and fulfil the legislative requirements associated with managing Commonwealth-owned environmental water.

The Program runs from 2019 to 2022 and consists of 2 components: monitoring and research in 7 Selected Areas (Selected Area projects); and Basin-scale evaluation and research (the Basin-scale project) (Figure 1). The Basin-scale project is led by CSIRO in partnership with the University of Canberra, and collaborating with Charles Sturt University, Deakin University, University of New England, South Australian Research and Development Institute, Arthur Rylah Institute, NSW Department of Planning, Industry and Environment, Australian River Restoration Centre and Brooks Ecology & Technology.

It builds on work undertaken through the Long Term Intervention Monitoring (LTIM) (2014–2019) and Environmental Water Knowledge and Research (EWKR) (2014–2019) projects.

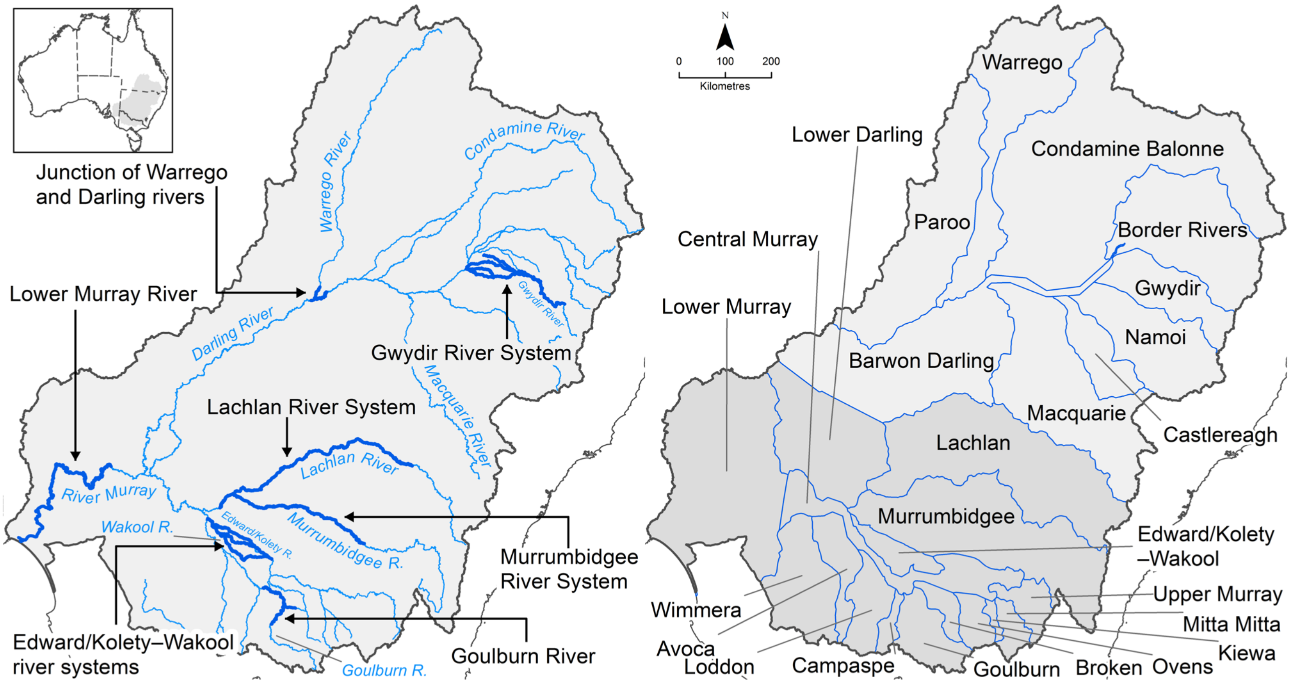

Figure 1 The 7 Selected Areas and 25 valleys established for long-term monitoring of the effects of environmental watering under the LTIM Project and Flow-MER Program (2014–15 to present)

The Flow-MER evaluation adopts an adaptive management framework to acknowledge the need for collectively building the information, networks, capacity and knowledge required to manage environmental water at Basin scale. While knowledge of ecological response to instream flow and inundation has advanced significantly in recent years, substantive challenges remain in understanding the similarities and differences in species' response across time and space, as well as the interaction between species at a community and ecosystem scale.

The Basin-scale evaluation is being undertaken across 6 Basin Themes (Figure 2) based on ecological indicators developed for the LTIM Project and described in the Environmental Water Outcomes Framework. It is undertaken in conjunction with the Selected Area projects, which provide data, research and knowledge for ecological outcomes within the 7 Selected Areas. The Basin-scale evaluation integrates across Selected Areas, themes, datasets, approaches and different types of knowledge.

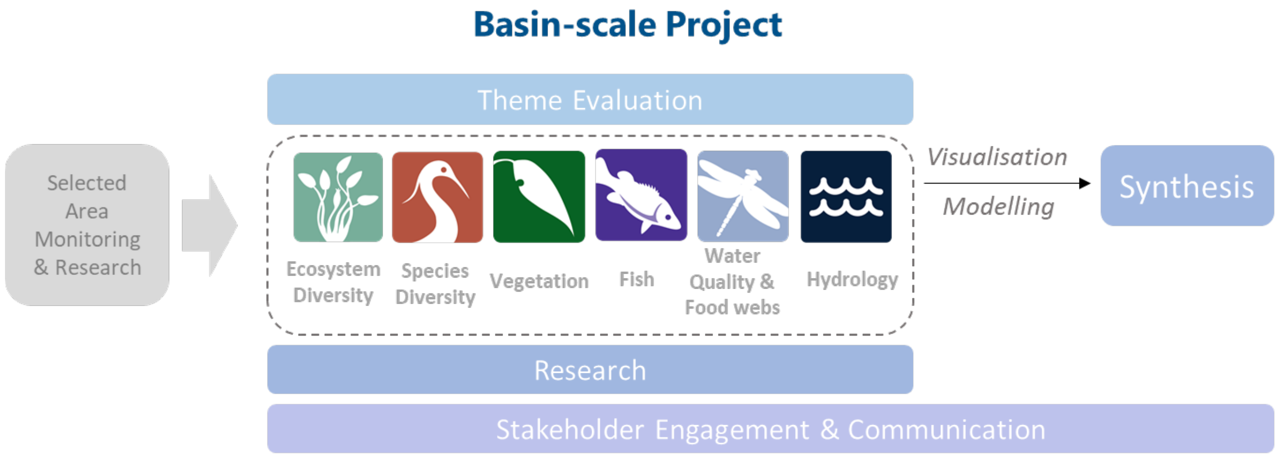

Figure 2 Basin-scale Project evaluation reports on Commonwealth environmental water outcomes for the 6 Basin Themes as well as a high-level Basin-scale synthesis
The evaluation is informed by Basin-scale research projects, stakeholder engagement and communication, including Indigenous engagement, visualisation and modelling, as well as the 7 Selected Area projects.

About the Basin-scale evaluation

Water delivery and outcomes data provided by CEWO is used in conjunction with monitoring data provided by the 7 Selected Areas and other publicly available data to undertake the Basin-scale evaluation. The research and evaluation content is structured into 6 disciplinary themes. Technical reports for each of the 6 themes are available from the Commonwealth Environment Water Office's website.

The evaluation aims to address theme specific questions in relation to how Commonwealth environmental water contributed to, supported, or influenced environmental outcomes. Commonwealth environmental water is often delivered in conjunction with other environmental water holdings, and non-environmental water releases (such as for irrigation or during high-flow events). The evaluation consequently draws on available information to estimate (where possible) the specific contribution of Commonwealth environmental water to particular environmental outcomes. The way in which this contribution is assessed varies between the 6 themes depending on the data and tools currently available:

1) modelling to estimate and compare outcomes both with and without Commonwealth environmental water (counterfactual modelling): hydrology (instream); fish (multi-year evaluation)
2) identification of ecological response in locations that received Commonwealth environmental water (potentially in conjunction with other sources of environmental water or non-environmental water), and where feasible, comparison with areas that did not receive Commonwealth environmental water: ecosystem diversity, species diversity, vegetation
3) use of flow and water quality metrics to infer likely outcomes: hydrology (inundation); food webs and water quality
4) synthesis of findings across Selected Areas: fish (annual); vegetation; food webs and water quality.

This report

This report is a Technical Supplement to the *2021 Basin-scale evaluation of Commonwealth environmental water: Fish* (Hladyz et al. 2021). It contains details of the analyses that are summarised and presented in that report.

Abbreviations, acronyms and terms used in this report

Term	Description
CEWO	Commonwealth Environmental Water Office
CPUE	Catch per unit effort
CrI	Credible intervals
fyke	A bag net for catching fish
GLMM	Generalised linear mixed model
LMM	Linear mixed model
STAN	A type of statistical language
ZINB	Zero-inflated negative binomial (mixture model)

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1 Summary

1.1 Graphical summary of analyses

The effects of Commonwealth environmental water on fish are presented graphically using the metrics shown in Figure 1.1, with results for each Selected Area shown in Figure 1.2.

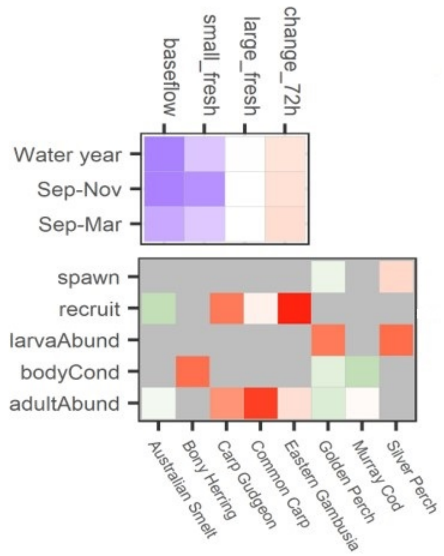

Figure 1.1 Legend for graphical summary diagram

The top panel shows the relative change in each flow metric (x-axis: baseflows, small freshes, large freshes, flow variability - as change_72h) during key time periods for fish life stages (y-axis: water year [July to June], September to November, September to March). Flow colour legend shows direction and relative effect size, with darker purple colours indicating larger positive effects, white indicating no effect, and redder indicating negative effects.

The bottom panel shows the strength of support for a positive (green) or negative (red) effect of Commonwealth environmental water on a given life stage (y-axis) for each species (x-axis). Confidence colour legend indicates relative magnitude and direction, white indicates no confidence (probability of a positive effect near 0.5), light colours denote low confidence (probability of an effect between 0.5-0.8), medium colours denote moderate confidence (probability between 0.8 and 0.95), and dark colours denote high confidence (probability greater than 0.95) noting that effects can be positive (green) or negative (red). Grey squares indicate no data for that cell (e.g. a species not sampled for that life stage or insufficient data for an analysis).

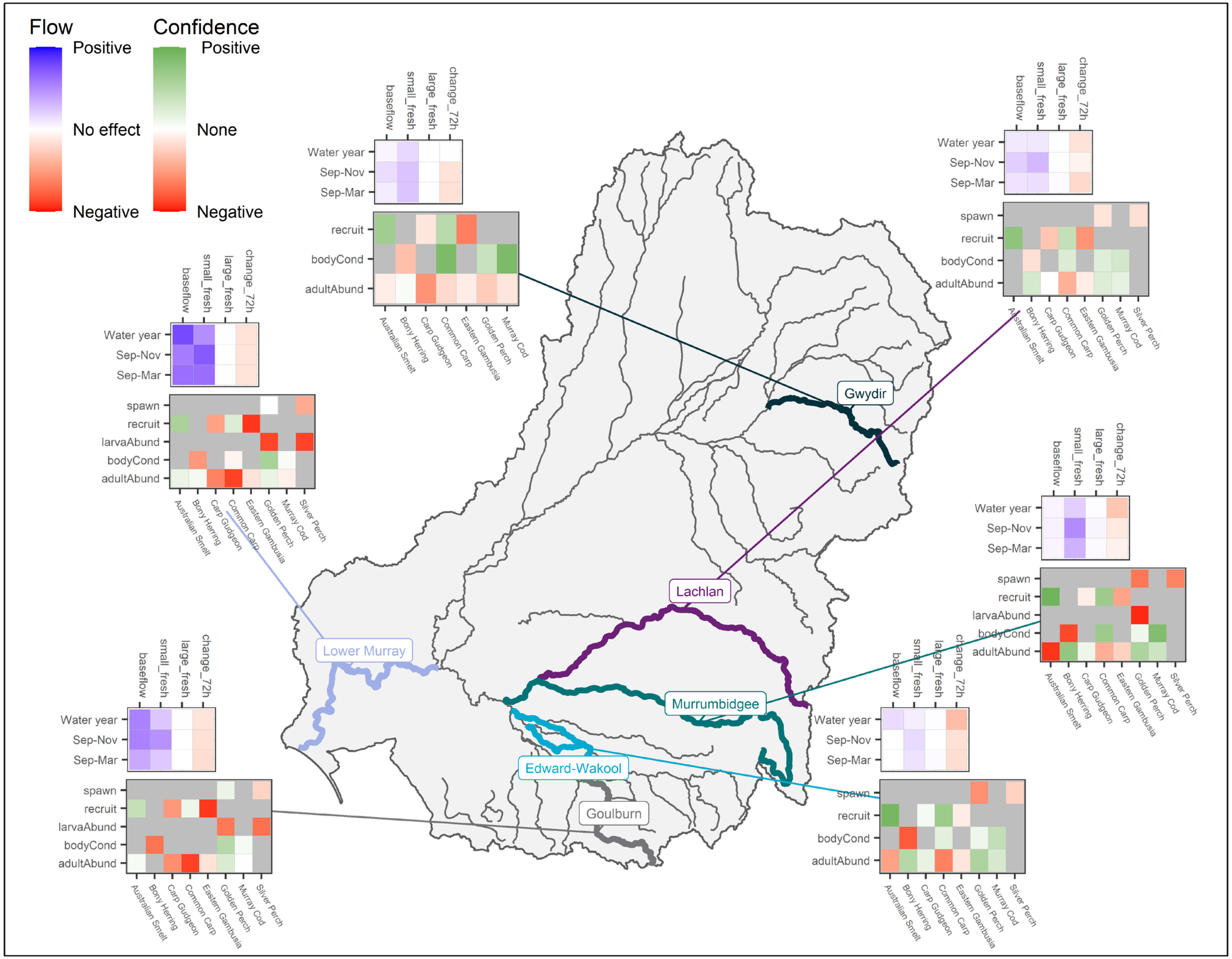

Figure 1.2 Map showing the magnitude of Commonwealth environmental water effects on flow metrics (top panel) and on fish responses in each Selected Area (bottom panel)

1.2 Recommendations for future analyses

1.2.1 Adjustments to flow metrics

As noted in the sections below, the analyses presented here may be improved by better temporal alignment of flow metrics with the response variable. Rather than using coarse temporal alignment (e.g. by season or whole water year), the flow metric could be fine-tuned based on sampling date to ensure only flow events in the relevant past are included and not future events. Part of this process would be ensuring that all sampling date information was available (e.g. missing recruitment sampling dates). Then using flow data for each program, a flow algorithm could calculate a specific metric based on each sampling date for each response variable. Explicit conceptual models of the population processes for each species would facilitate this process, as would the development of generalizable flow metrics linked to specific sampling events. These adjustments to flow metrics would be supported by event-based monitoring and the availability of more-resolved hydrodynamic information (e.g., river hydraulics).

1.2.2 Improvement to database

One major issue with the current database was the lack of a sampling/survey table. As part of the analysis, it was necessary to infer if a sampling event occurred and, if it did occur, which fish species were sampled with which fishing method. This step was essential as not catching any fish (zeroes) is fundamentally different from not sampling for that fish. Therefore, ensuring that the data used in the statistical models are reflecting the actual sampling design is essential. The SRA database (and other large fish databases) can provide an example of the survey table needed.

1.2.3 Analysis improvements

For spawning and larva data, it may be preferable to run a mixture model (e.g. zero-inflated negative binomial (ZINB)) in which annual flow metrics dictate the probability of spawning and event-based flow metrics dictate larval abundances. The substantial presence of zeroes required modification to the larval abundance model, essentially treating it (with the spawning data) as a two-step hurdle model. The ZINB approach would be a more natural approach to these data. Similarly, recruitment models could benefit from a ZINB model and potentially some integration might be possible among the models, though this would require custom scripts using STAN (Stan Development Team 2020) or an appropriate wrapper package, such as brms.

Catch curves were performed without flow metrics due to the lack of flow data prior to 2014. Once these data are obtained, these models can be re-run to include flow metrics to predict year class strength.

For adult abundance, the analysis focused on growth rate as the response variable to reflect the population process. The ratio of 2 random variables can lead to distributional issues, which were mitigated through transformations in the analyses here. These models conflate observation and process errors, discussing power to detect process-level flow effects. With some assumptions, it may be possible to implement state-based population models (in sensu Kery and Schaub) to dissect process and observation level errors. However, these models would require additional work to fully incorporate into the current analysis pipeline and it should be discussed whether the potential benefits offset the additional work. The development of such models would directly support efforts to develop population models for these systems.

1.2.4 Quantifying/interpreting effect sizes

As the analyses here dealt with multiple response variables (e.g. spawning rates, larval abundance) related to important population processes (e.g. reproduction, survival), it may be desirable to improve interpretation of the analysis results by integrating this study with current efforts with population models. A complicating aspect with the analysis here is translating estimated counterfactual predictions into population consequences. Is a 5% increase in spawning rate comparable to 5% in adult growth rate? Does a statistically significant 1% affect the population dynamics?

The following analyses provided estimated effect sizes on the measured response metric (e.g. spawning presence, CPUE) and focused on the magnitude of change. Translating these effect sizes to population processes is unclear, as well as they may differ by the species life history strategies (r vs. K-species). Possibly as a first step, consultation with a population modeler may provide initial insights into the sensitivity of each population process explored here for each species. Using these sensitivities, it may then be possible to weigh effect sizes differently to allow for better comparison between response variables, and hence making management decisions.

A possible next step would be using purpose-built population models to simulate fish populations for each species and then overlay a similar sampling design used for the study here to map the results here to likely simulated scenarios. Such integration would greatly improve how to interpret the finding here, as well as be useful to delineating strengths/weaknesses of the sampling used here for understanding population processes for each species.

1.2.5 Extending analysis to include unmonitored locations

A possible extension of this study is extrapolating the findings to other systems not sampled. Our assessment of this extension can be viewed from two main viewpoints: mechanics (e.g. writing the analysis code) and statistical (e.g. interpretation).

From a mechanics viewpoint, the amount of additional work to create predictions from the current model is minimal (1 or 2 days), requiring only the hydrological data with predicted counterfactuals and some minor edits to analysis scripts.

From a statistical viewpoint, such an extension could prove to being useful, if accompanied by field data to assess the predictions. Predicting to other river systems would require extrapolation beyond the sampling frame of the study. As noted in this report, the initial selection of the Selected Areas unlikely reflect a random sample and hence care is needed in extrapolating beyond the sites. In particular, careful consideration about whether the flow metrics used here can be extrapolated the new Selected Areas, as well if the ecology of the different species. If the extrapolations likely have some validity (following the assessments), these extrapolations could provide very beneficial as a validation of the current models if field data could be incorporated as well. A desktop analysis of the hydrology of large swath river systems could identity systems that have large effect sizes with Commonwealth environmental water events. Using this analysis, it would be possible to strategically delineate river systems for testing unique predictions from the models.

1.3 Current status of analysis pipeline

For this report, an analysis pipeline was created that can be used for future analyses. This process included import and cleaning of data, separate analysis programs that set-up analysis-ready datasets, produce exploratory graph outputs, run models for each selected species, display model fit plots, and finally collate the key results for the report. The current report code updates figures, tables, and select variables of interest; however, text is not updated and left as a manual process.

At this point, the main future improvements are:

- The import process relies on intermediate datasets extracted from the database. Direct communication with the database would streamline this process.
- The incorporation of a flow metric function into the analysis pipeline to improve temporal alignment of flow metrics to sampling dates.
- If a ZINB model for spawning/larval data is implemented, some minor modifications of analysis script and reporting scripts will be needed to concatenate two response variables, one using an annual metric and another using an event-based metric, into a single script.
- It would be ideal to convert the body condition model to a Bayesian framework for consistency and interpretation benefits. Currently, the computation time is prohibitively long for this set of data, likely due to the complex random-effects structure. With more time, it should be possible to identify possible remedies to this issue.

2 Fish analyses

2.1 Overview

2.1.1 Background

These fish analyses explore the effect of Commonwealth environmental water events on key population processes for a range of species. As the study design lacks controls (e.g. comparable river systems that did not receive the Commonwealth environmental water), the study design relies on using variation flow events over multiple years and areas to build a model of how flow may affect key population processes (Figure 2.1). Then, the potential consequences of Commonwealth environmental water are predicted from those models by using estimated counterfactual flows (e.g. likely flow conditions if Commonwealth environmental water was not provided). The models predict the change in response variable by the reduction in flow and this change is used as a prediction of the Commonwealth environmental water effect. This approach is static and does not explore knock-on effects for population dynamics. The research theme F1: Fish population models will investigate this component further.

2.1.2 General analyses

All analyses in this report were performed using R v3.6 (R Core Team (2019)) using *rstanarm* package (Goodrich et al. 2020), except for the body condition data which was analysed using *lme4* package (Bates et al. 2015) due to prohibitively long computation times. A Bayesian linear model approach was used to better deal with estimation issues with some generalised model due to limited data (e.g. zero spawning in some programs). Specific details about each analysis are outlined in the sections below, but the models had similar basic structures and these shared similarities are outlined directly below.

First, each species was modelled separately for each response variable of interest. The model structure was broken into 3 components:

- response variable (possibly transformed; described in each section below)
- flow covariates (annual or event metrics; see section 2.2)
- spatial/temporal effects that were either fixed or random.

As the first 2 components (response variable and flow metrics) are described in the specific analysis sections, only the spatiotemporal component is delineated here.

For the spatial/temporal effects, the following logic was adopted. Program (assumed to be Basin as listed in the analysis brief) was treated as a fixed effect as it appears the experimental design is not random (the Basins were selected nonrandomly (based on certain attributes and locations) and hence extrapolation is likely dubious). Within each program, site (aka sample point) was assumed to be roughly randomly selected and hence treated as random effect. For simplicity, constant site variation across programs was assumed (this could be looked more at in the future). For the temporal component, water year was assumed to be nested in program (i.e. assumed independence across basins conditioned on the flow metrics). Again, constant variability across programs was assumed. Finally, sites were assumed to vary independently across years (even within program) and, where appropriate, there is a site-by-year random effect.

After fitting the model, validity of model assumptions was assessed through graphical analysis of Pearson residuals testing main assumptions: normality (where appropriate), heteroscedasticity, nonlinearities (residuals vs. each predictor), posterior predictive checks (except body condition) and looking for potential outliers (high leverage points). Variable transformations (noted in each analysis section) were used to correct if appropriate or a different statistical distribution if possible.

To model the counterfactual scenario, I used the final model to predict change in mean response using the provided counterfactual flows. For the annual flow models, I estimated the difference between predicted flows with and without Commonwealth environmental water using *posterior_linpred()*, conditioning on the random effects (Goodrich et al. 2020). For event-based models, it is less clear as to how the counterfactual scenario can be approached. For instance, with spawning, the sampling only records a fraction of the Commonwealth environmental water events that did occur and I may have missed the largest Commonwealth environmental water effects. For this report, I took the **maximum Commonwealth environmental water scenario for each water year in each program (basin)**. I did this by getting the difference between with and without Commonwealth environmental water for each flow metric and then ranked for flow metric the magnitude of the difference. Then I summed the ranks and chose the sampling conditions that had the highest rank. Thus, I weighed each flow variable equally, even if the best model suggests unequal effects (this could be improved in the future). A similar approach was taken for body condition, except I used parametric bootstrapping rather than the posterior distributions.

Finally, I present model results with 95% credible intervals (95% CrI) [or 95% CI confidence intervals for body condition].

Table 2.1 Summary of statistical formulas used for each analysis

Rationale for approach is explained in each section below this table

Analysis	Species	Equation	Link function	Family
spawn	golden perch silver perch	cbind(n_spawned, n_survey - n_spawned)~baseflow_sep_nov + small_fresh_sep_nov + large_fresh_sep_nov + change_72h_sep_nov + program + tot_effort + (1 | program: water year)	logit	binomial
larvaAbund	golden perch silver perch	cpue~seven_day_range + days_increasing + seven_day_median + program + ad_cpue + (1 | program: water year) + (1 | samplepoint)	log	gaussian
recruit	Australian smelt carp gudgeon common carp eastern gambusia	count~baseflow_sep_mar + small_fresh_sep_mar + large_fresh_sep_mar + change_72h_sep_mar + n_sites + program	log	poisson
catchCurveAge	Murray cod golden perch bony herring	n_fish~age + program + (1 | program:birthyear)	log	negative binomial
adultAbund	golden perch Murray cod carp gudgeon bony herring common carp eastern gambusia Australian smelt	r~baseflow_water_year + small_fresh_water_year + large_fresh_water_year + change_72h_water_year + program + do_last_year + (1 | program: water year) + (1 | samplepoint)	log	gaussian
bodyCond	bony herring common carp Murray cod golden perch	fulton_index~baseflow_water_year + small_fresh_water_year + large_fresh_water_year + change_72h_water_year + program + (1 | program: water year) + (1 | samplepoint) + (1 | samplepoint: water year)	identity	gaussian

2.2 Selecting flow metrics

To prevent redundant flow metrics and overly parameterised models, I explored the relationships between proposed flow metrics to reduce the list of metrics included in the models. First, I show the daily flow without and with Commonwealth environmental water events. Next, I focus on 2 sets of flow metrics: annual and event-based. I assessed each group separately. I used correlations >0.7 as a coarse threshold of redundant information. Sections below give a brief overview of the process and results.

2.2.1 Flow profiles for each region

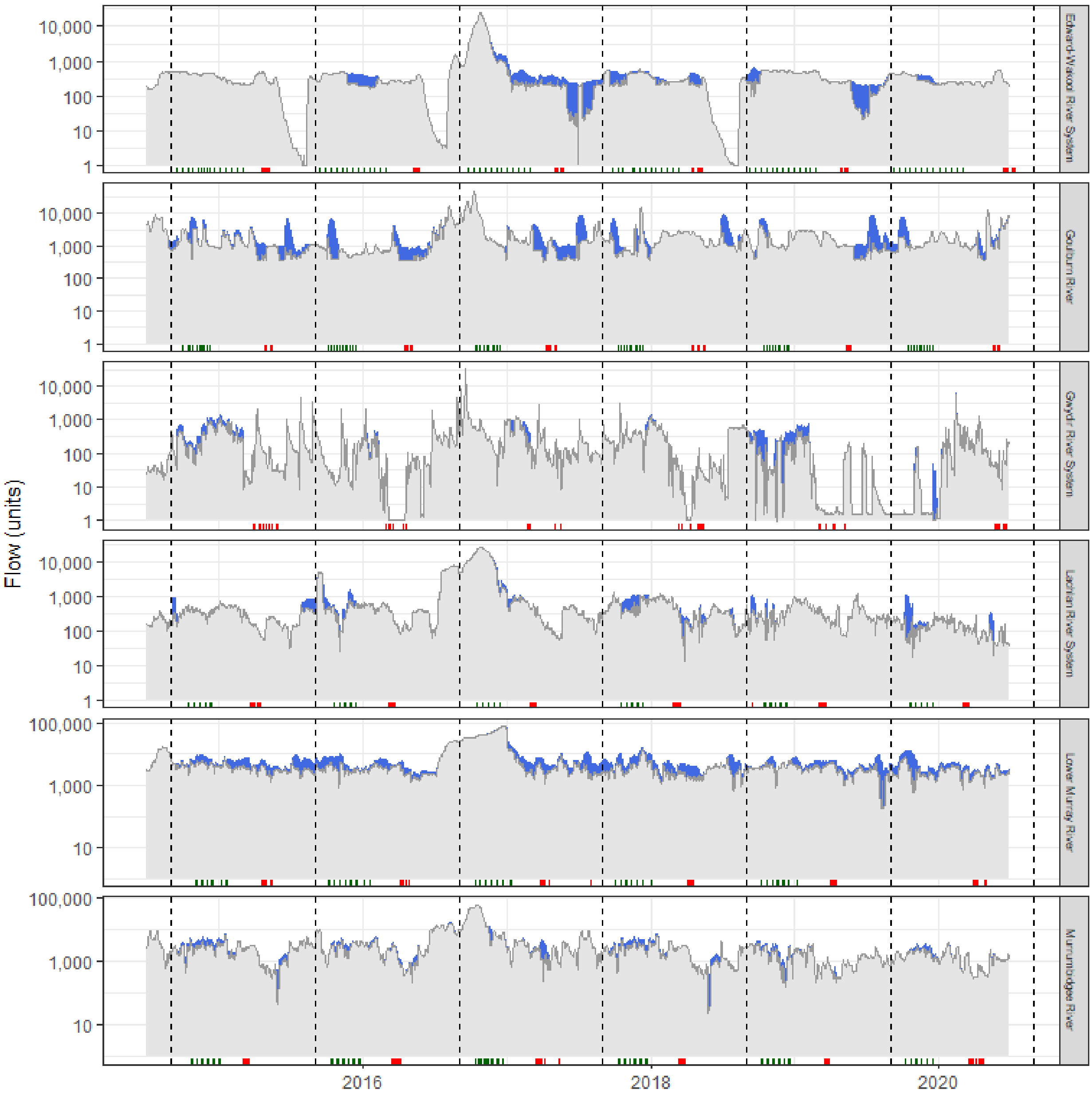

Figure 2.1 Flow profiles for each program

Grey area shows flow when no Commonwealth environmental water is present. Blue areas show added Commonwealth environmental water amount. Green rug shows timing of larval surveys and red show adult surveys. Vertical dotted lines are temporal boundaries for each water year. Note that y-axis is logged scaled.

2.2.2 Annual metrics

Selecting main metrics

Comparing correlations between groups of annual metrics (baseline_xxx, xxx_fresh_xxx, overbank_xxx,change_xxx) revealed several key results.

- *baseflow_xxx:* baseflow_water_year was correlated with every metric >0.7. Thus, I only kept **baseflow_water_year** from this group.
- *small_fresh_xxx:* small_fresh_water_year was correlated with every small_fresh_xxx >0.7. It was positively correlated with large_fresh_xxx at ~0.5. Thus, I kept just _small_fresh_water_year__ and looked at large_fresh_xxx as a separate group.
- *large_fresh_xxx:* large_fresh_water_year was correlated strongly with spring fresh variables but not summer/autumn. Surprisingly, large_fresh_jan_jun and large_fresh_mar_may were weakly correlated. Therefore, I kept **large_fresh_water_year**, **large_fresh_jan_jun**, and **large_fresh_mar_may**.
- *overbank_xxx:* overbank was strongly correlated with large_fresh, except for overbank_jan_jul. Thus, I kept **overbank_jan_jul**.
- *change_xxx:* change_72h_water_year was moderately to strongly correlated (>0.6) with all other change_xxx metrics. Given the large redundancy in information, I kept just **change_72h_water_year**.

Thus, the final list and their correlations are shown in Figure 2.2.

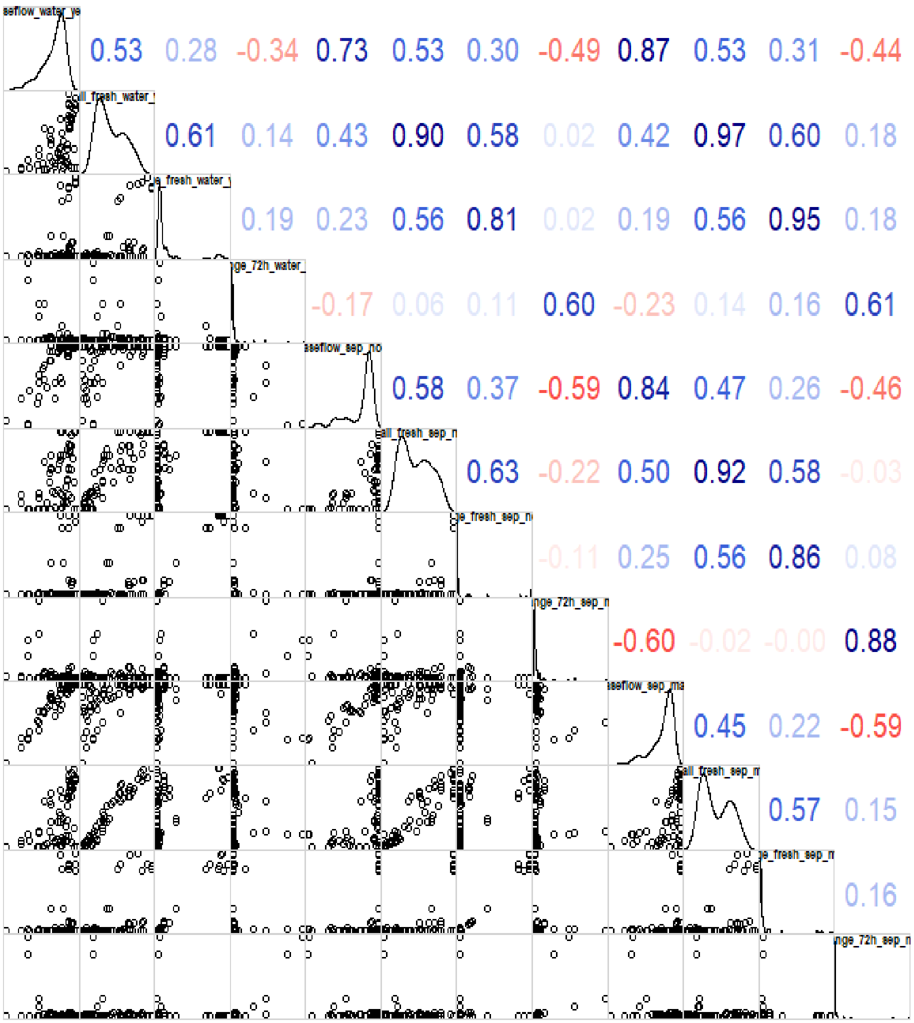

Figure 2.2 Correlation matrix for annual flow metric. Numbers show Spearman rank correlations

Counterfactual effect sizes

Prior to the analysis, it is essential to understand the magnitude of effect sizes between actual and counterfactual flows. I summarised those effect sizes in Figure 2.3. For proportion scale variables (e.g. baseflow_xxx, small_fresh_xxx), I used raw scale (here) and for discharge variables (change_xxx), I used log-scale as proportional change is likely more ecologically relevant.

As expected, Commonwealth environmental water flows had positive effect on all metrics, sans change_72h_water_year. Checking Figure 2.1, I can see that Commonwealth environmental water flows appears to have prevented rapid drops in water conditions. Large_fresh_xxx and overbank_xxx have only a few instances in which they differed (e.g. a single large_fresh_mar_may).

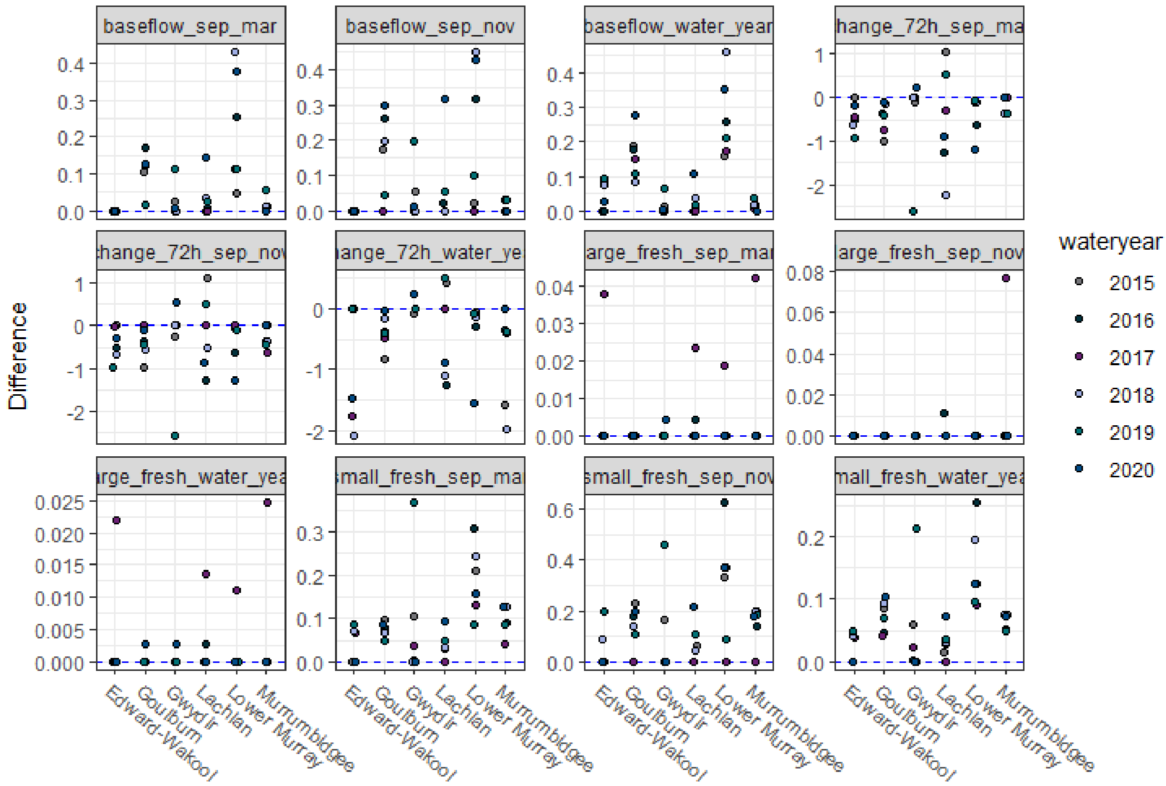

Figure 2.3 Differences in Commonwealth environmental water flows and counterfactual flows for each flow variable kept for each program

Each point (slightly jittered) shows the difference for each year.

Extrapolation potential

Furthermore, it is important to understand if and where extrapolation in flow metrics may occur to delineate potential red flags for predictions. Here, I take a simplistic approach and look for extrapolation univariately (rather than multivariate parameter space). Extrapolation cases are shown in Figure 2.4.

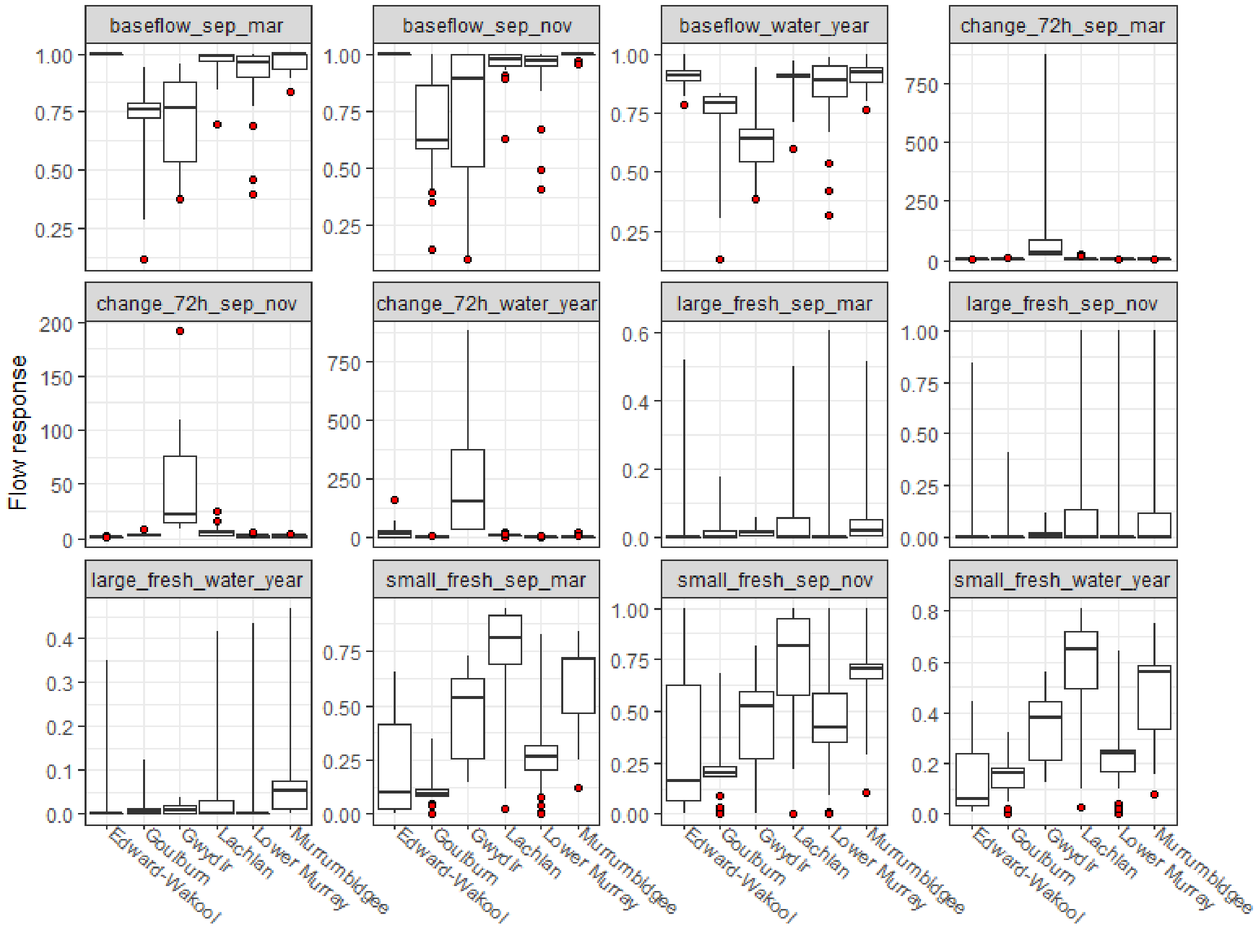

Figure 2.4 Exploratory plots looking for extrapolation in flow metrics
Red dots show instances that the counterfactual lies outside the sampling range for that program

2.2.3 Event-based metrics

There were fewer event-based metrics. None of the event metrics were correlated above 0.7 (Figure 2.5) Actual_seven_day_range was strongly correlated with daily discharge, as would be expected.

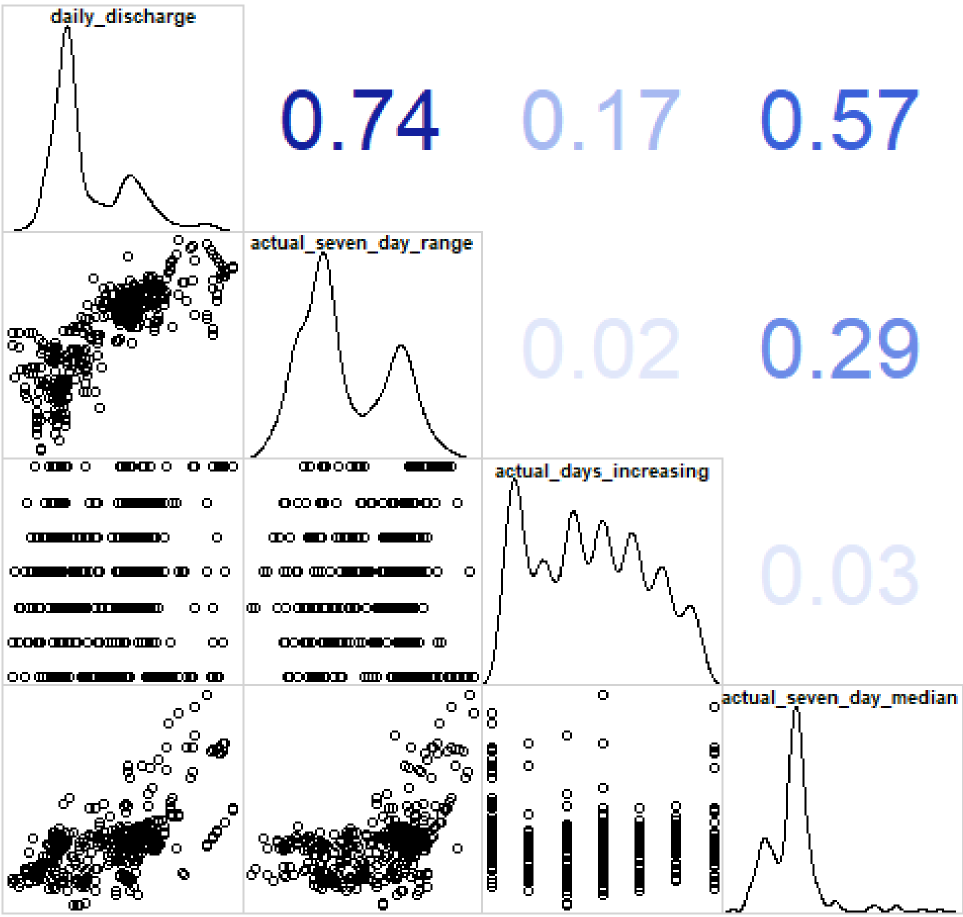

Figure 2.5 Correlation matrix for event-based flow metrics, with the addition of daily discharge to elucidate its relationships to the metrics

Numbers show Spearman rank correlations. Note - Daily discharge, seven day range and seven day median were log-transform.

Counterfactual effect sizes

Prior to the analysis, it is essential to understand the magnitude of effect sizes between actual and counterfactual flows. I summarised those effect sizes in Figure 2.6. For proportion scale variables (e.g. baseflow_xxx, small_fresh_xxx), I used raw scale (here) and for discharge variables (change_xxx) I used log-scale as proportional change is likely more ecologically relevant.

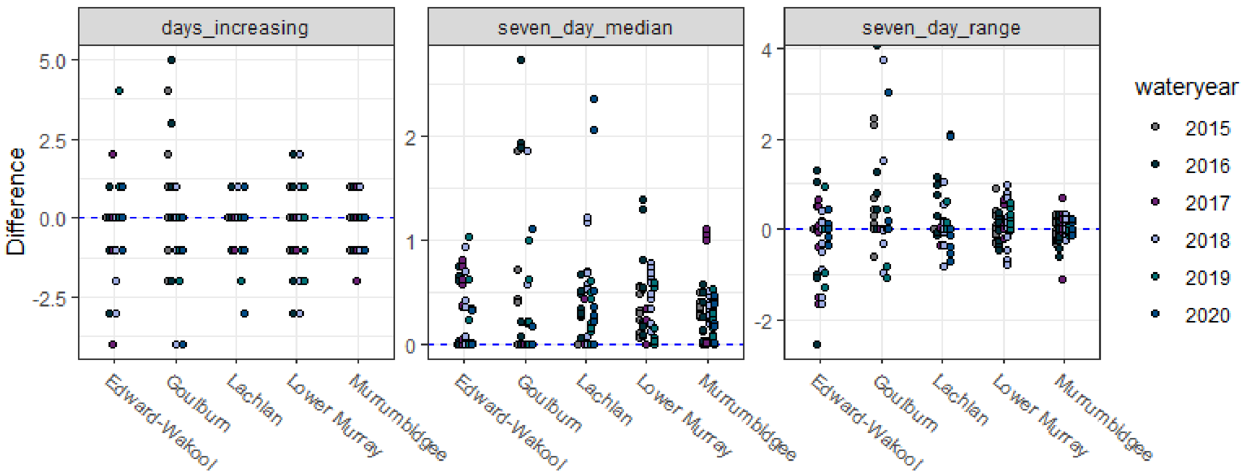

Figure 2.6 Differences in Commonwealth environmental water flows and counterfactual flows for each flow variable kept and program

Extrapolation potential

No Commonwealth environmental water prediction conditions were outside the sampling range (Figure 2.7).

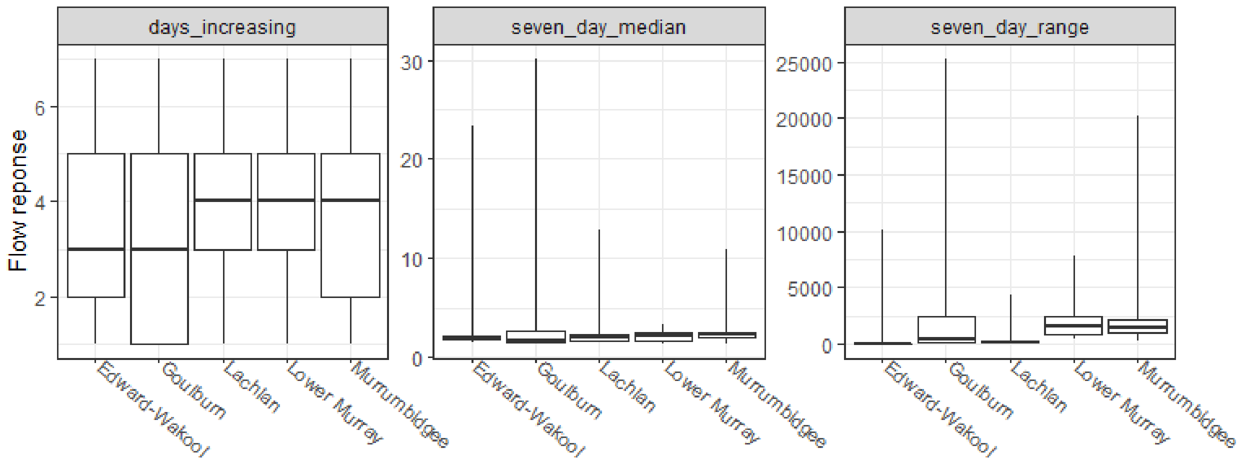

Figure 2.7 Exploratory plots looking for extrapolation in flow metrics
If red dots are present, they show extrapolation outside the observed range for that program and that flow variable.

2.3 Analysis: Spawning analysis

2.3.1 Logic, study design, and data trimming

Logic

For flow-cued spawners, flow conditions affect the spawning triggers and survival of recruits. Triggers likely include rapid changes in flow conditions as well as baseline flow levels.

Study design

One key aspect to check is the temporal alignment of annual flow metrics alignment with sampling dates for body condition for each program and assess whether the alignment is appropriate for the biological hypotheses.

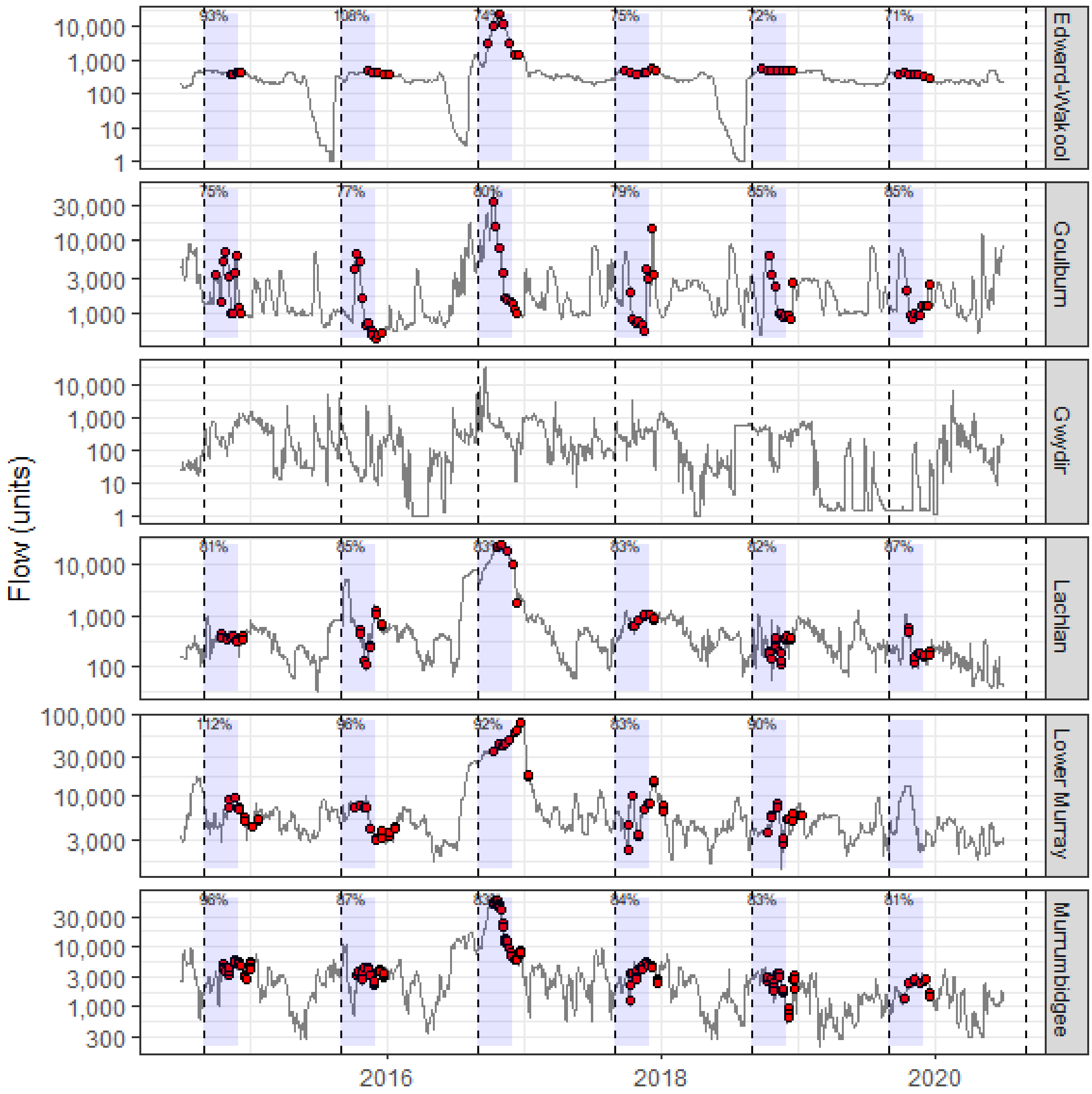

Figure 2.8 Sampling dates for spawning surveys (red dots) in relation to water year windows for each program
Percentage shows the proportion of the water year fish experienced prior to the first sampling date (i.e. 70% means that the fish experienced 70% of the flow data included in the flow metrics at the time of first sampling event). Blue bands show the range for the flow metric.

Data trimming

Total samples sizes are shown in Table 2.2. Two flow-cued spawning species were selected for the analysis: *Macquaria ambigua* and *Bidyanus bidyanus*.

Table 2.2 Summary of sample sizes for spawning dataset

Species	Programs	Sites	Years	Percentage zero catch
Silver perch	Edward-Wakool	9	6	100.0%
	Goulburn	6	6	94.0%
	Lachlan	6	6	100.0%
	Lower Murray	6	5	99.1%
	Murrumbidgee	6	6	100.0%
Golden perch	Edward-Wakool	9	6	100.0%
	Goulburn	6	6	90.2%

Species	Programs	Sites	Years	Percentage zero catch
	Lachlan	6	6	100.0%
	Lower Murray	6	5	93.8%
	Murrumbidgee	6	6	97.5%

Key exploratory graph(s)

To explore patterns in the data, I looked at temporal patterns in the **proportion** of sites that recorded spawning each water year (Figure 2.9).

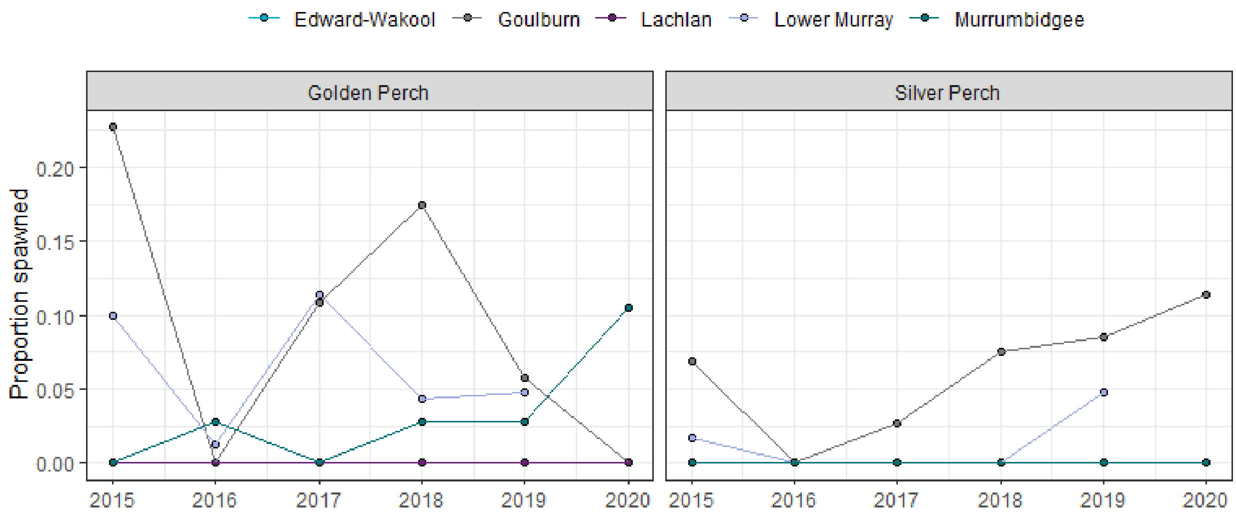

Figure 2.9 Exploratory graph showing temporal pattern in proportion of sites with spawning events

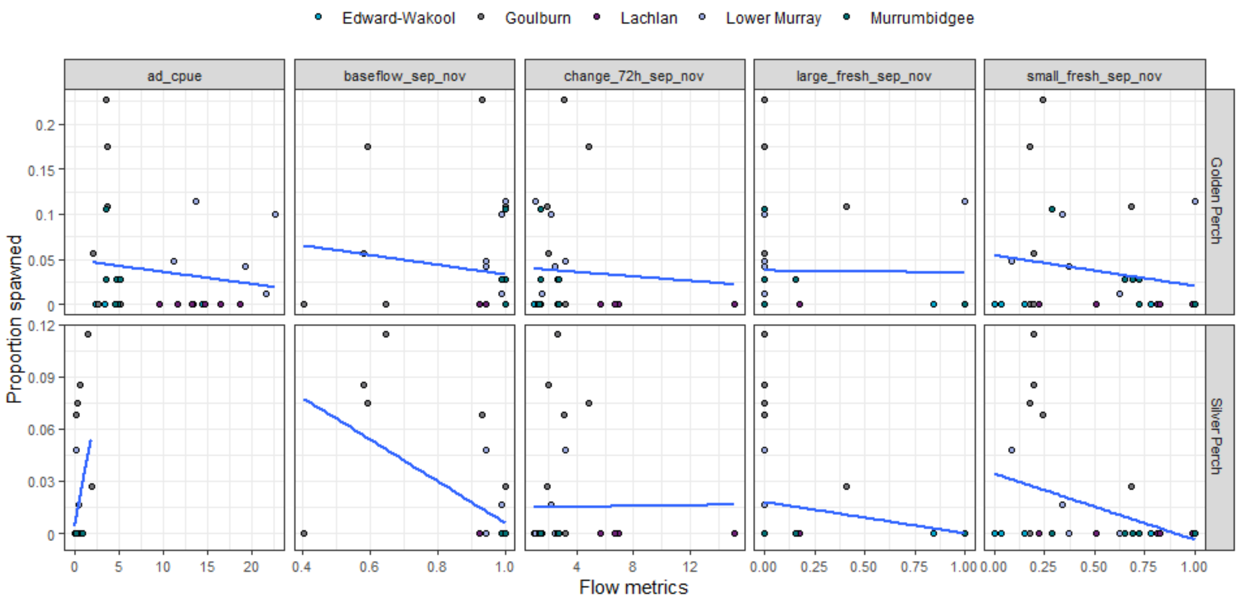

Figure 2.10 Exploratory graph for spawning analysis showing relationships between flow metrics and spawning rates

Each dot represents proportion of sites with spawning. Blue line shows exploratory regression line (not corrected for other covariates).

2.3.2 Data analysis

To test for the effects of flow metrics on spawning, I modelled the probability that a spawning event is detected based on flow conditions.

Using the above approach, a GLMM (generalised linear mixed model) was run with a binomial distribution (in a Bayesian framework). As the metrics were the same within a program, I summed together all sampling events within a program and used total number of spawning events detected as the response variable. I included the selected annual flow metrics, total volumetric effort (log-scaled), current water year's adult CPUE, and program as fixed effects. Program-by-water year was included as a random effect, which helps account for potential overdispersion in the data.

2.3.3 Results

Flow coefficients

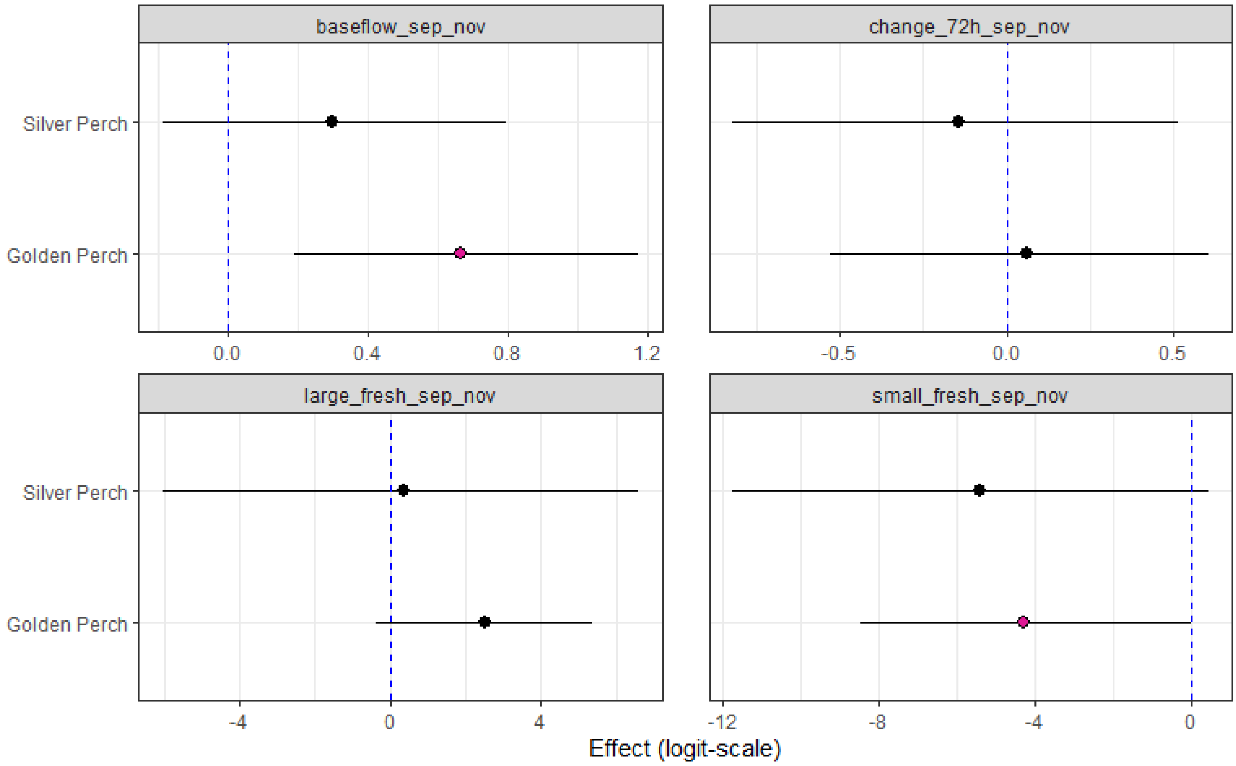

Figure 2.11 Effect of each flow variable on spawning occurrence for each species on the logit scale
Spawning rates lead to large standard errors and hence easier to present on logit scale. Error bars are 95%CrI. Pinkish dots indicate 95%CrI does not overlap 0.

Counterfactual predictions

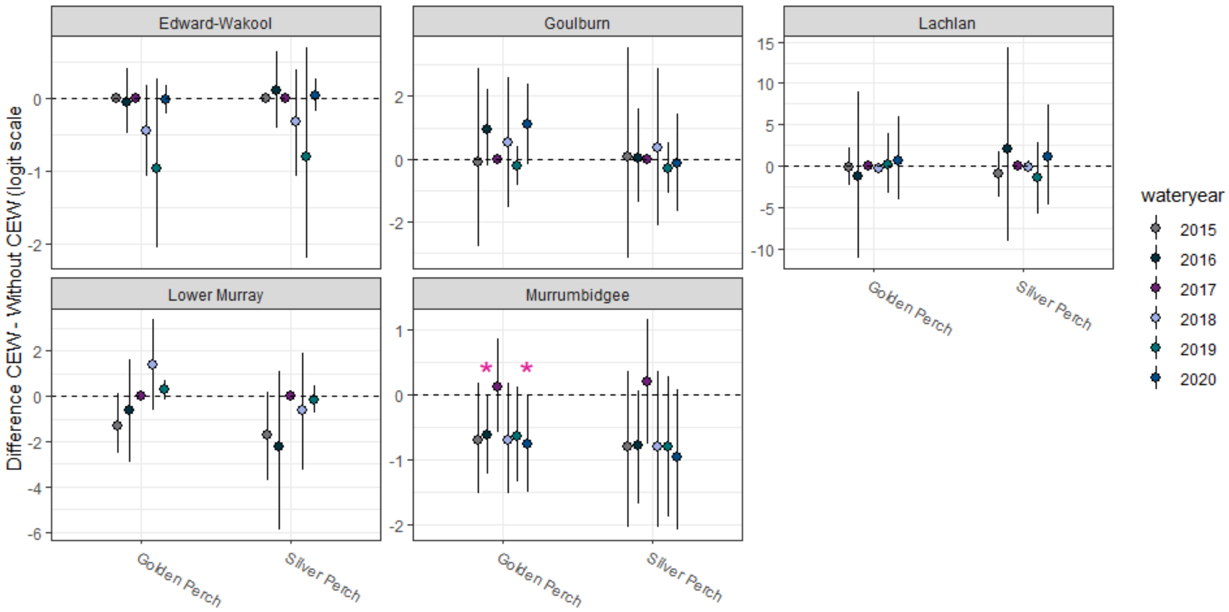

Figure 2.12 Predicted change (logit scale) on spawning rates with and without Commonwealth environmental water for each species, broken up by year and program

* indicates the 95%CrI of the difference between with and without Commonwealth environmental water does.

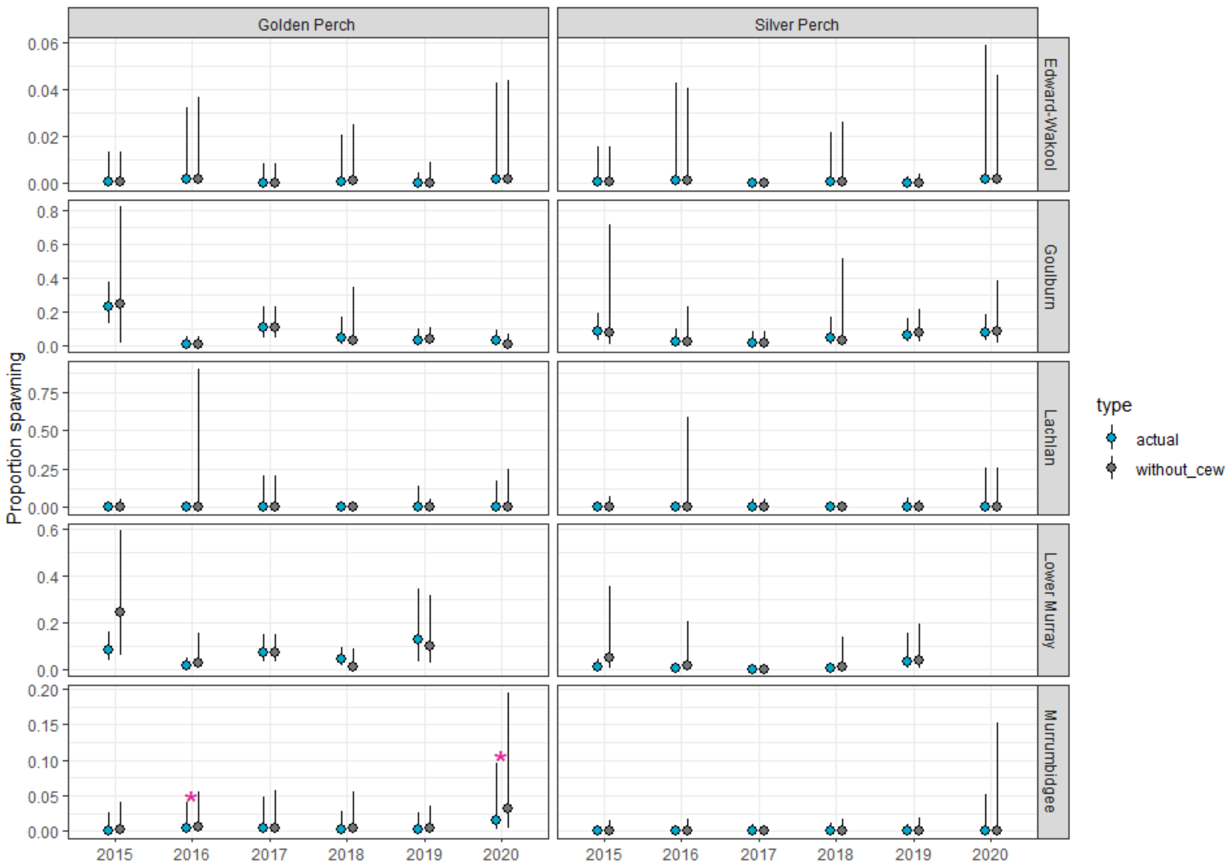

Figure 2.13 Predicted spawning rates with and without Commonwealth environmental water for each species, broken up by year and program

* indicates the 95%CrI of the difference between with and without Commonwealth environmental water does not include zero. Error bars are 95%CrI.

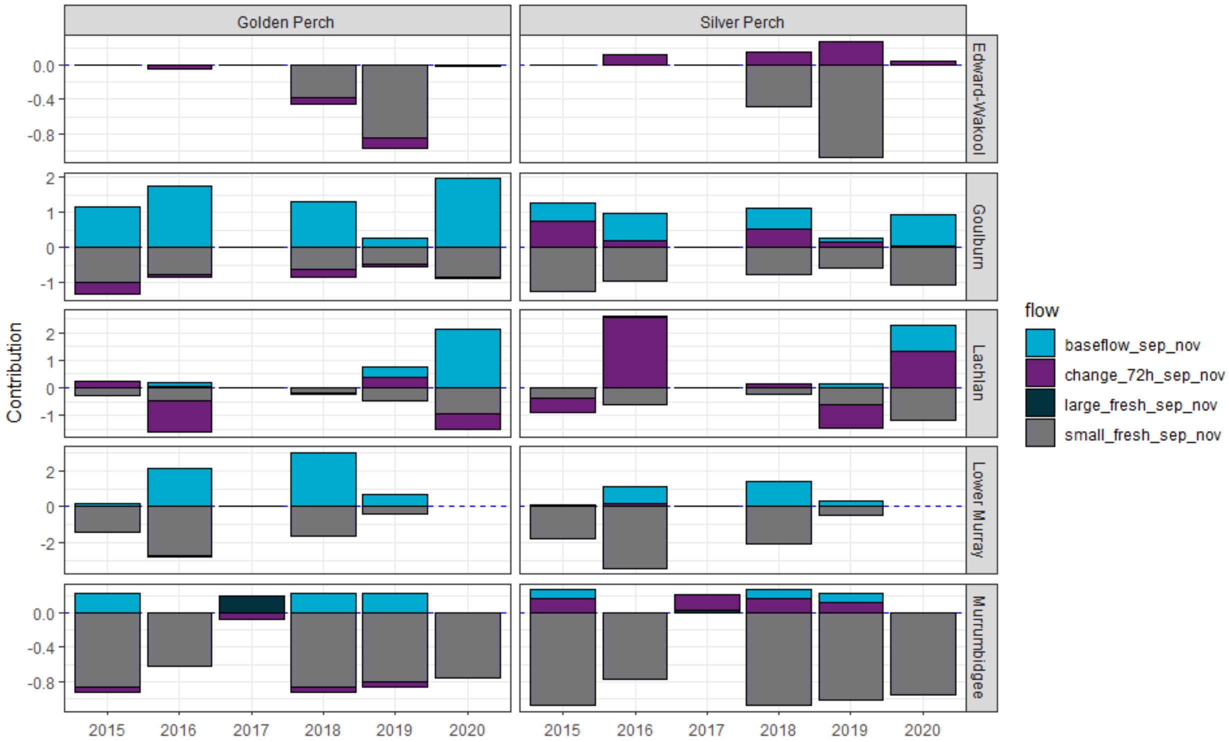

Figure 2.14 Contribution of each flow variable on the predicted Commonwealth environmental water effect
Negative effects are shown as bars below 0 and positive effects above. Effect sizes are on link scale.

2.4 Analysis: Larval abundance analysis

2.4.1 Logic, study design, and data trimming

Logic

The previous section estimated the effect of flow on spawning rates across sites, investigating if Commonwealth environmental water increased spawning occurrence. This section looks specifically at larval abundance, given that a site had a spawning event. I dropped non-spawning sites as this information was contained in the previous section and it leads to distribution issues due to the excess zeros.

Study design

The sampling design follows the spawning design (see Figure 2.8), though the flow metrics are event-based in this design and hence temporal alignment is different.

Total samples sizes are shown in Table 2.3. The analysis includes 2 flow-cued spawning species: *Macquaria ambigua* and *Bidyanus bidyanus*.

Table 2.3 Summary of sample sizes for larval abundance dataset
Note - this is basically same as spawning, except displaying percentage of surveys with nonzero CPUE (and dropped effort == 0 surveys).

Species	Programs	Sites	Years	Percentage nonzero CPUE
Silver perch	Edward-Wakool	9	6	0.0%
	Goulburn	6	6	6.0%
	Lachlan	6	6	0.0%
	Lower Murray	6	5	0.9%

Species	Programs	Sites	Years	Percentage nonzero CPUE
	Murrumbidgee	6	6	0.0%
Golden perch	Edward-Wakool	9	6	0.0%
	Goulburn	6	6	9.8%
	Lachlan	6	6	0.0%
	Lower Murray	6	5	6.2%
	Murrumbidgee	6	6	2.5%

Key exploratory graph(s)

To explore patterns in the data, I looked at temporal patterns in the average number of larva for each water year (Figure 2.15).

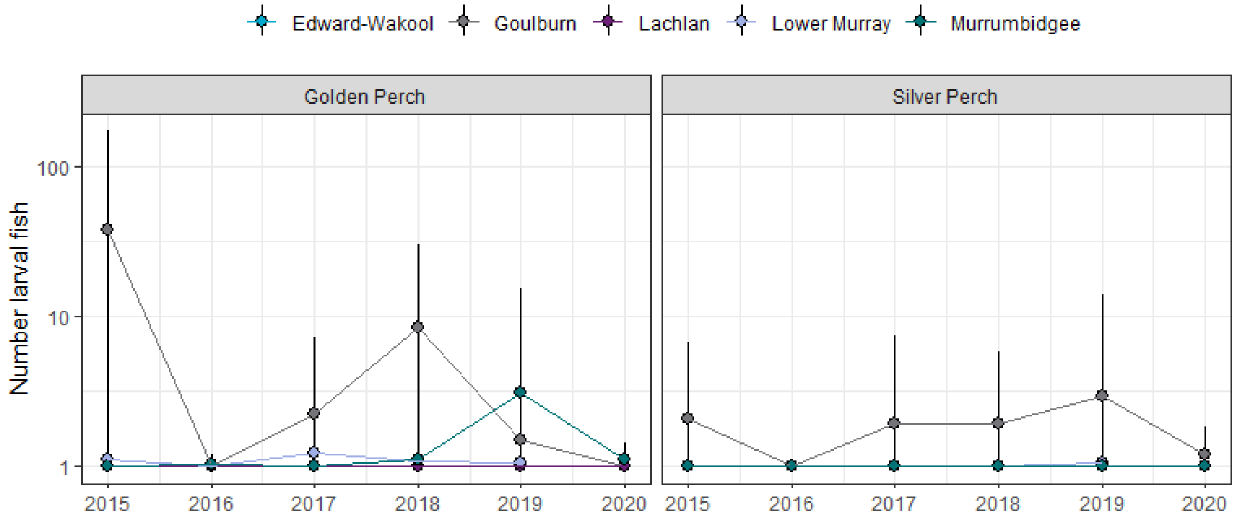

Figure 2.15 Average number of larva across all sites for each water year by program
Each panel shows a different species. Error bars are ±SD.

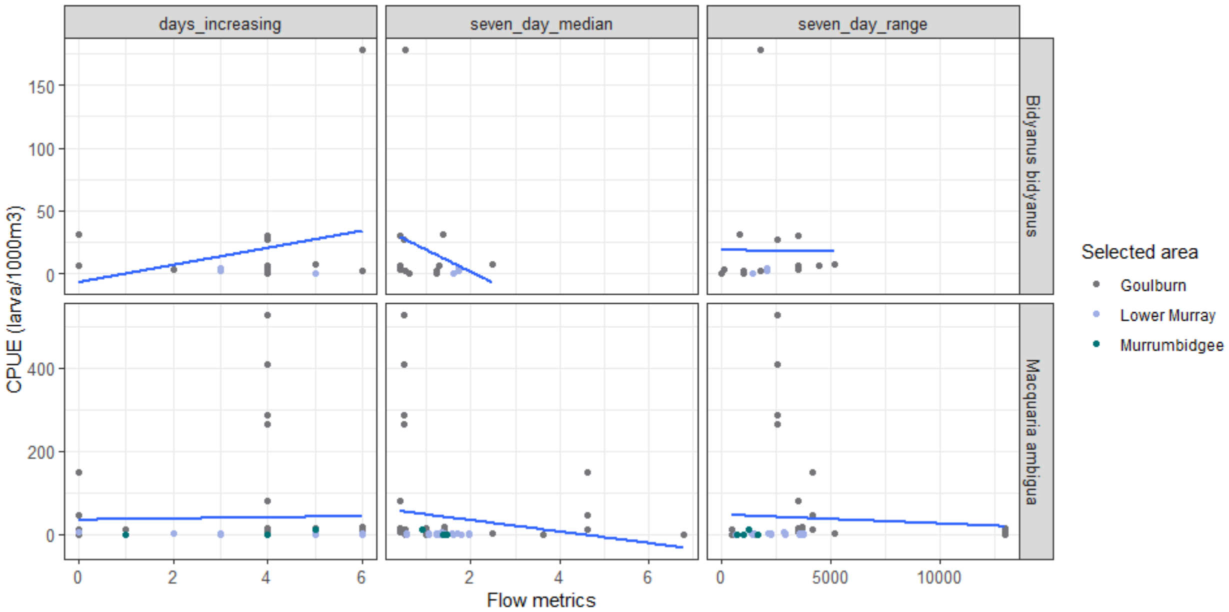

Figure 2.16 Exploratory graph showing relationships between flow metrics and larval CPUE
Each dot represents number of larva (per 1000 m^3). Blue line shows exploratory regression line (not corrected for other covariates).

2.4.2 Data analysis

As noted above, larval abundance data were mostly zeros and as expected, these zeros (plus some high numbers) led to model fitting issues with negative binomial. After assessing potential alternatives and keeping the analysis plan structure the same (keep spawning analysis separate instead of incorporating into a zero-inflated model), I focused solely on data in which I knew that spawning had occurred (count > 0). Using just this data, I ran a linear mixed model using CPUE (log-transformed; number fish/1000 m^3) as the response variable. Event flow variables were included as predictors (correlations between flow metrics with reduced dataset all <0.3). Program was included as a fixed effect. Water year (nested in program) and site were included as random effects.[1]

2.4.3 Results

Flow coefficients

Surprisingly, increasing the seven_day_median was associated with decrease in larval CPUE for Golden perch (Figure 2.17).

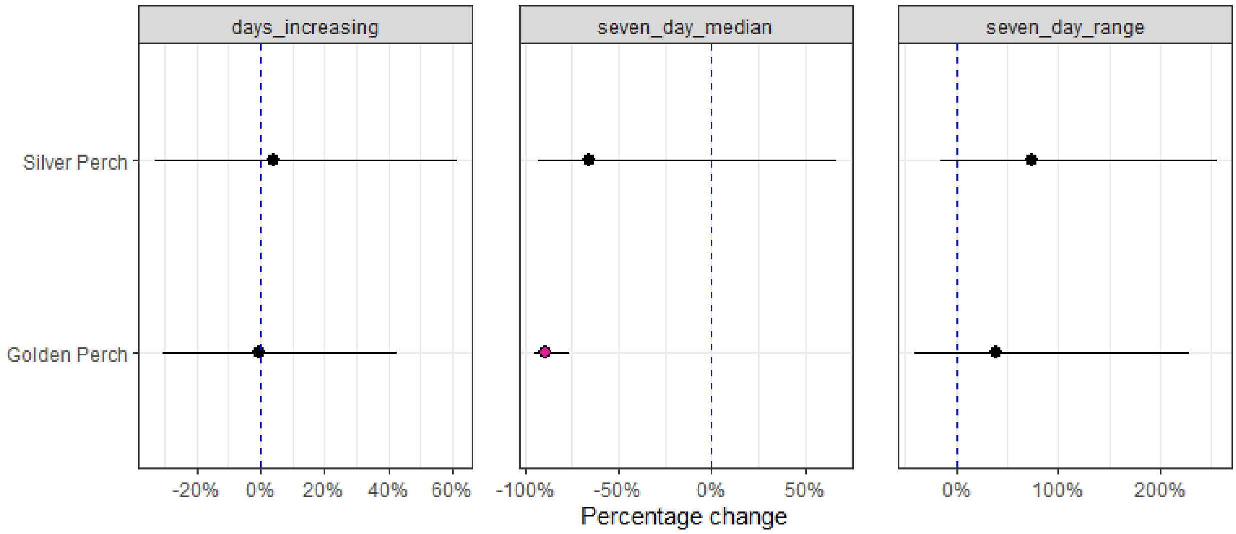

Figure 2.17 Effect of each flow variable on larval abundance for each species
Error bars are 95%CrI. Pinkish dots indicate 95%CrI does not overlap 0

Counterfactual predictions

The percentage change in larval CPUE without Commonwealth environmental water is shown. The positive changes show Commonwealth environmental water improved larval abundances (Figure 2.18).

[1] Notes: Time of year not yet included as nonlinear

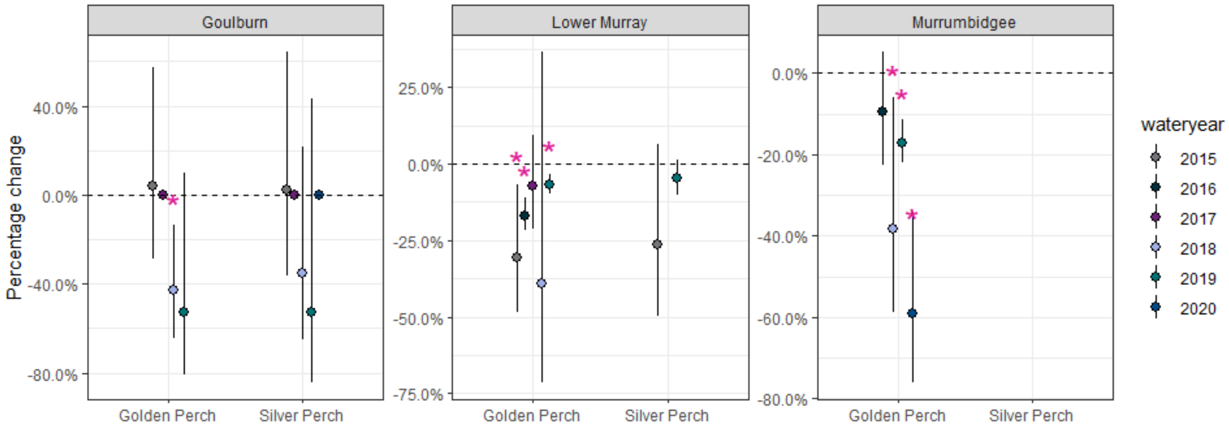

Figure 2.18 Predicted percentage change in recruit abundance without Commonwealth environmental water for each species, broken up by year and program

Positive changes indicate Commonwealth environmental water improved larval abundance. Error bars are 95%CrI. * indicates the 95%CrI of the difference between with and without Commonwealth environmental water does not include zero.

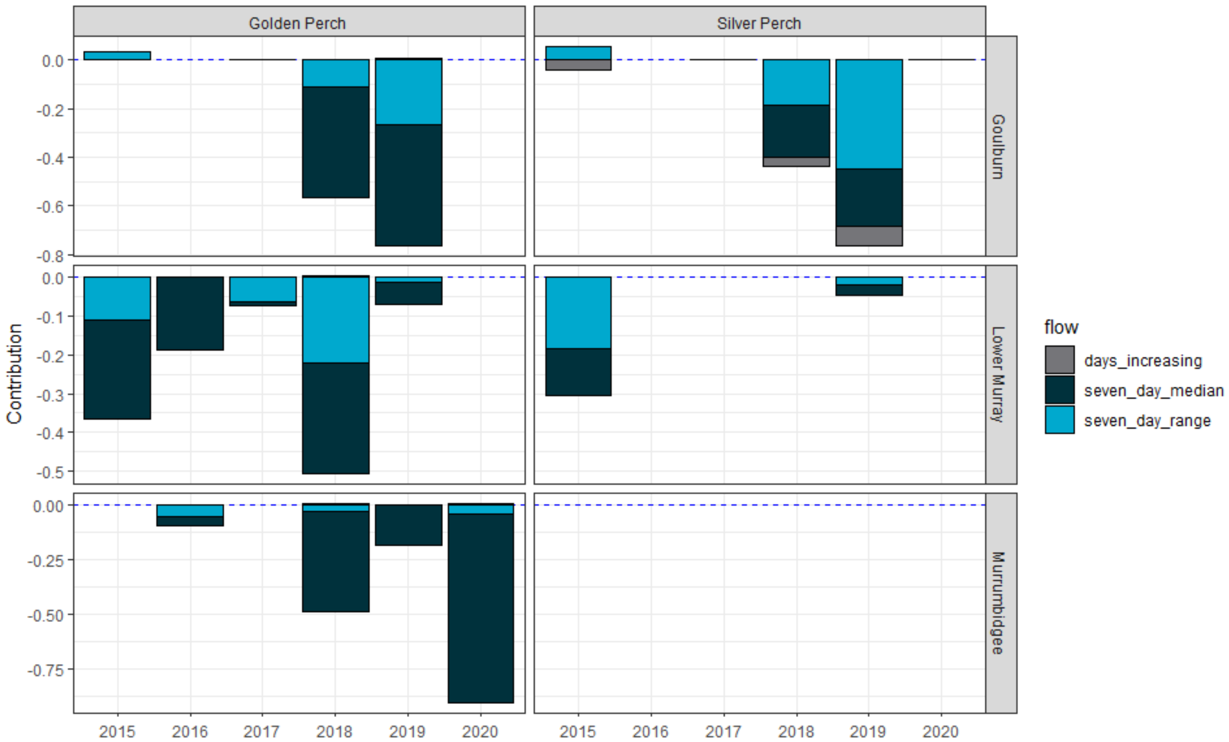

Figure 2.19 Contribution of each flow variable on the predicted Commonwealth environmental water effect on recruit abundance

Negative effects are shown as bars below 0 and positive effects above. Effect sizes are on link scale.

2.5 Analysis: Recruit analysis

2.5.1 Logic, study design, and data trimming

Logic

Recruits numbers reflect multiple population processes: reproductive output and larval survival. The annual flow metrics were included as predictors affecting these processes.

Study design

The recruit data lacked information on effort and sampling dates. Furthermore, multiple sampling methods were used as well. Therefore, a few assumptions were necessary. First, I looked at sampling methods used and which water years (Figure 2.20). As coarse fyke was only used in 2019/2020, I dropped this method from further consideration. As I did not have any information about total effort, I simplified the dataset by summarising across all methods for a given water year and selected area. Effort was then number of sites that water year.

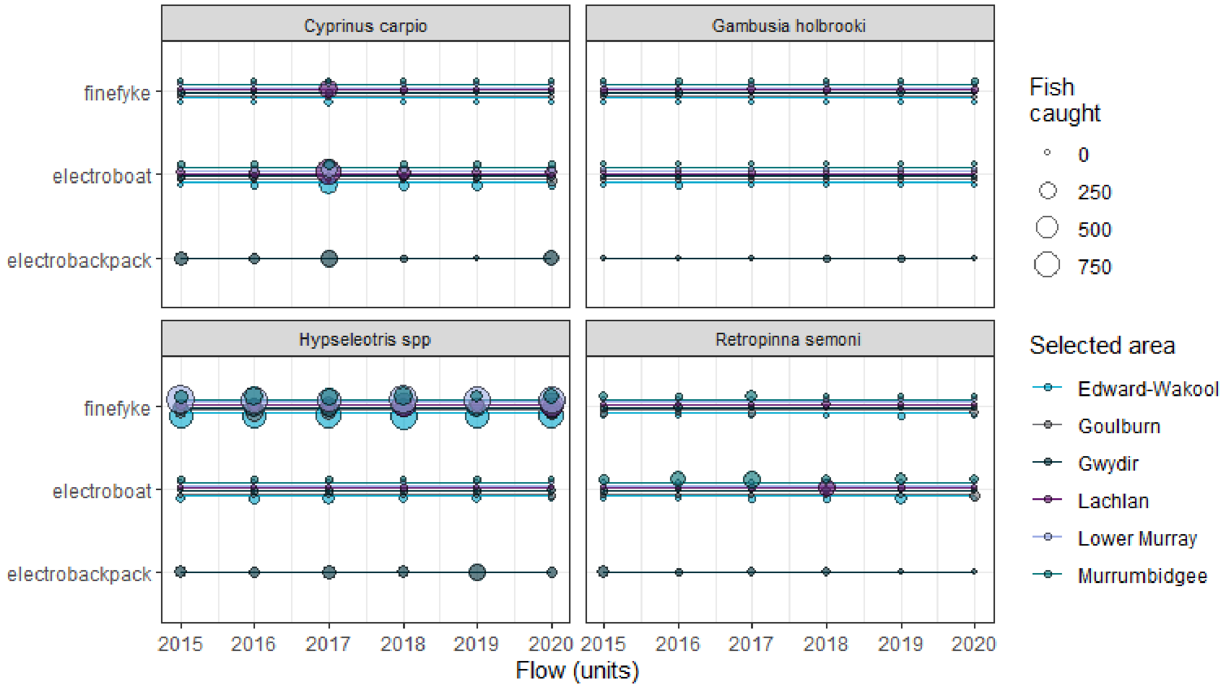

Figure 2.20 Sampling methods used for each species and total catch for each method (for each water year)

Table 2.4 Summary of sample sizes for recruit dataset

Species	Total fish	Method	No. fish	No. programs	No. sites	No. years	Percentage zero CPUE
Carp gudgeon	15,658	coarsefyke	21	1	9	2	60.0%
		finefyke	14,681	6	61	6	5.7%
		electroboat	329	6	61	6	75.6%
		electrobackpack	648	1	9	6	22.7%
Common carp	3,015	coarsefyke	450	1	9	2	6.7%
		finefyke	404	6	61	6	89.9%
		electroboat	1,953	6	61	6	53.9%
		electrobackpack	658	1	9	6	36.4%
Australian smelt	1,321	coarsefyke	2	1	9	2	86.7%
		finefyke	200	6	61	6	83.9%
		electroboat	987	6	61	6	73.3%
		electrobackpack	134	1	9	6	63.6%
Eastern gambusia	144	coarsefyke	0	1	9	2	100.0%
		finefyke	115	6	61	6	85.7%
		electroboat	16	6	61	6	97.5%
		electrobackpack	13	1	9	6	86.4%

Key exploratory graph(s)

To explore patterns in recruit CPUE data, I investigated temporal patterns among species and programs (Figure 2.21).

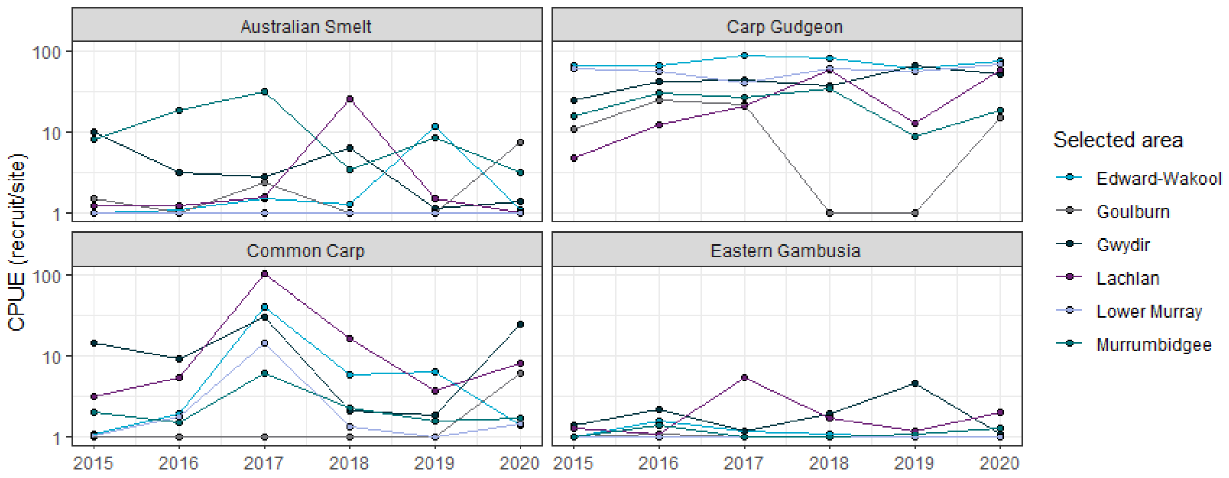

Figure 2.21 Average number of recruits per site across all sites for each water year by program
Each panel shows a different species.

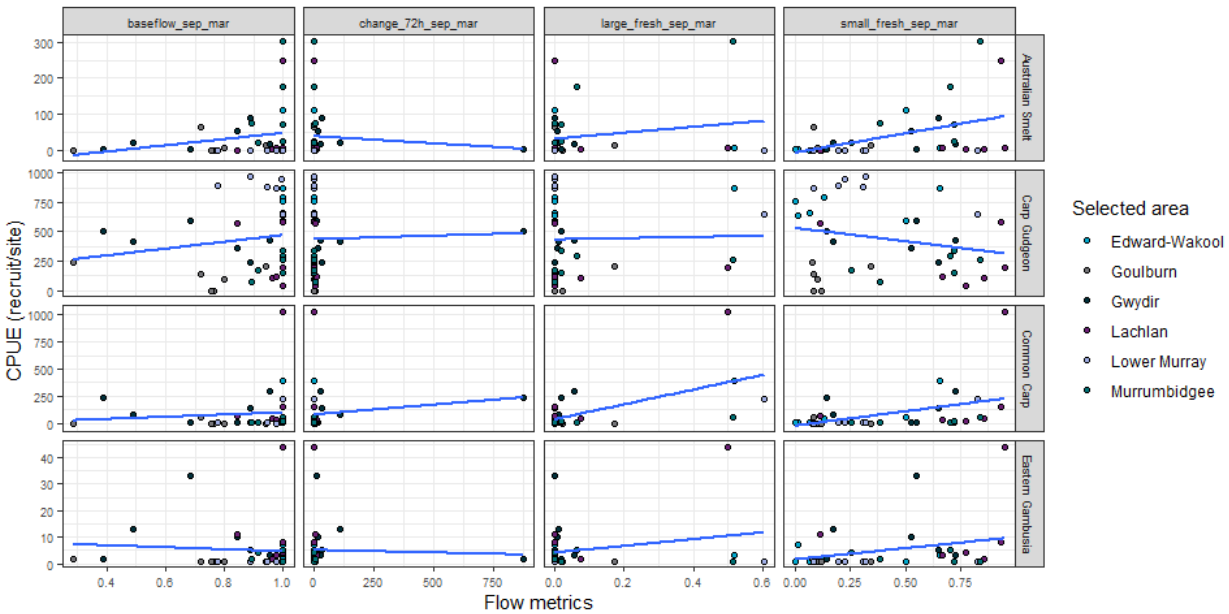

Figure 2.22 Exploratory graph showing relationships between flow metrics and recruit CPUE
Each dot represents number of recruits per site. Blue line shows exploratory regression line (not corrected for other covariates).

2.5.2 Data analysis

Using the total recruits (per water year in each program) as the response variable, I ran a GLMM assuming a Negative Binomial distribution. For the fixed factors, I included flow metrics, program, and number of sites (log-transformed). Water year nested in program was the random effect.

2.5.3 Results

Flow coefficients

Estimates of flow coefficients for each species in shown in Figure 2.23.

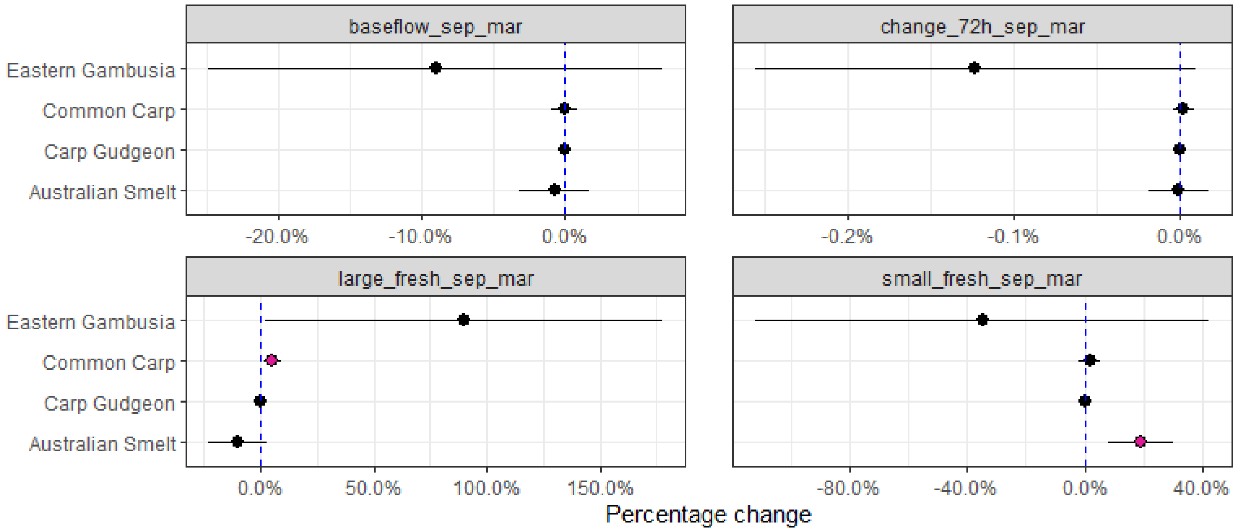

Figure 2.23 Effect of each flow variable on recruit CPUE for each species
Error bars are 95%CrI. Pinkish dots indicate 95%CrI does not overlap 0

Counterfactual predictions

Australian smelt are split from the other fish species for better visual clarity.

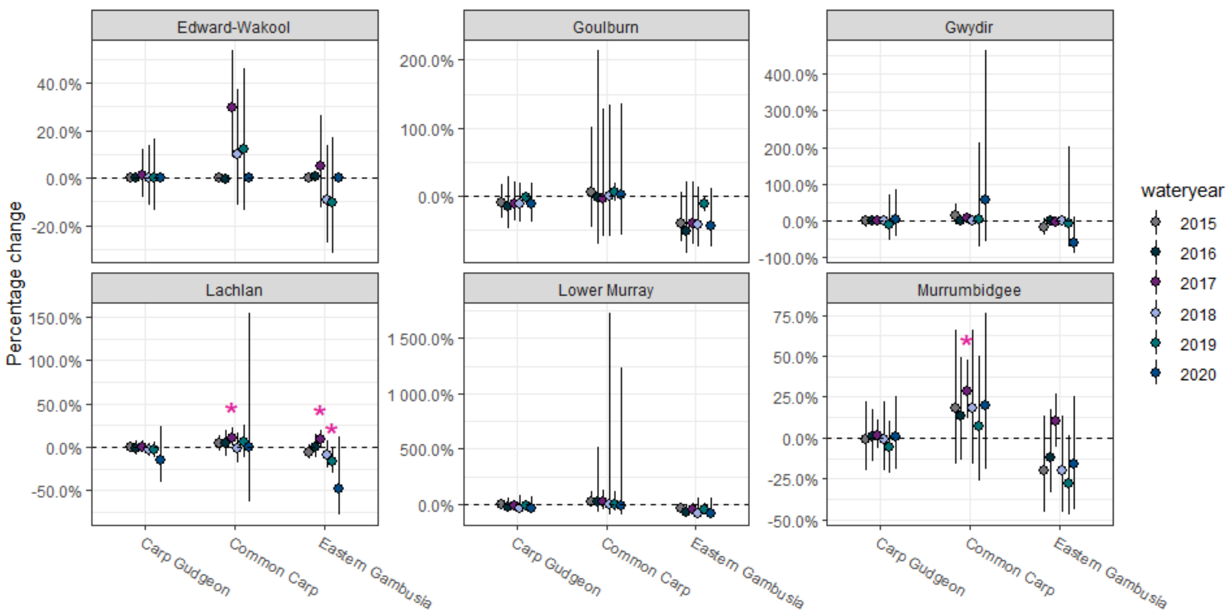

Figure 2.24 Predicted percentage change in recruit CPUE without Commonwealth environmental water for each species (except Australian smelt see Figure 2.25) broken up by year and program
Positive changes indicate Commonwealth environmental water improved recruit abundance. Error bars are 95%CrI.

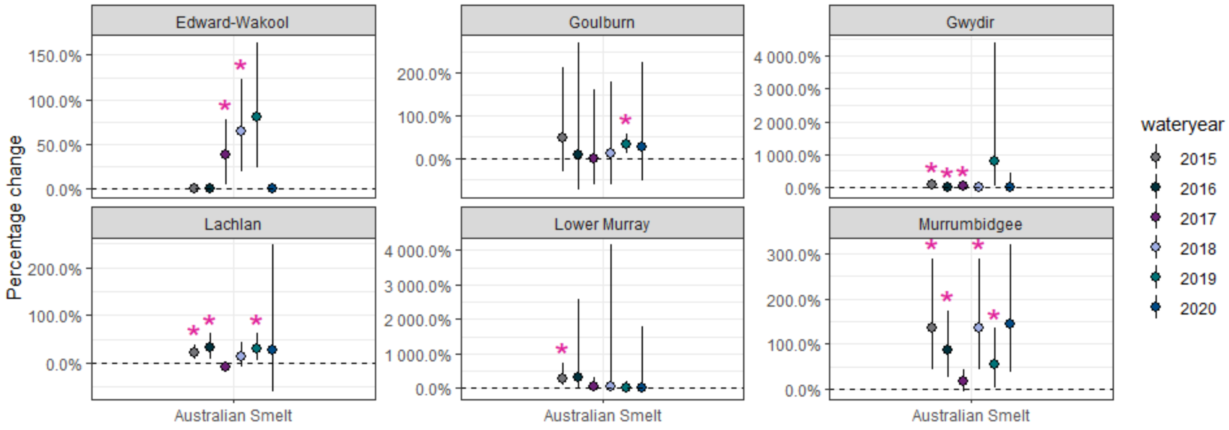

Figure 2.25 Predicted percentage change for Australian smelt in recruit CPUE without Commonwealth environmental water for each species, broken up by year and program

Positive changes indicate Commonwealth environmental water improved recruit abundance. Error bars are 95%CrI. * indicates the 95%CrI of the difference between with and without Commonwealth environmental water does not include zero.

Figure 2.26 Contribution of each flow variable on the predicted Commonwealth environmental water effect on recruit abundance

Negative effects are shown as bars below 0 and positive effects above. Effect sizes are on link scale.

2.6 Analysis: Catch curve analysis

2.6.1 Logic, study design, and data trimming

Logic

- No statistical analysis relating annual flow metrics with recruitment strength was run for the following reasons: 1) no access to water data prior to 2014; 2) catch curve regressions work best above a threshold age when mortality and detection rates become constant; and 3) sample sizes were sparse once fish born before 2014.

- Instead, a standard catch curve regression was performed to quantity high (and low) recruitment years for the following species: *Maccullochella peelii*, *Macquaria ambigua*, *Nematalosa erebi*.

Study design

Overall sample sizes caught per water year by selected areas is shown in Table 2.5. Distribution of ages are shown in Figure 2.27.

Table 2.5 Summary of sample sizes for catch curve dataset

Species	Selected areas	2014	2015	2016	2017	2018	2019	2020
Murray cod	Edward-Wakool	11	64					
	Goulburn	35	16					
	Lachlan		54					
	Lower Murray		10	12	7	9	18	157
	Murrumbidgee		51					
Golden perch	Edward-Wakool	7	38					
	Goulburn	19	29	1		44		
	Gwydir		58			64		
	Lachlan		61					
	Lower Murray		137	128	111	105	113	121
	Murrumbidgee		8			78		
Bony herring	Edward-Wakool		46					
	Gwydir	10	49	117	100	105	76	
	Lachlan		53	109	103	108	100	98
	Lower Murray			124	114	119	122	100
	Murrumbidgee		51	113	110	101	100	100

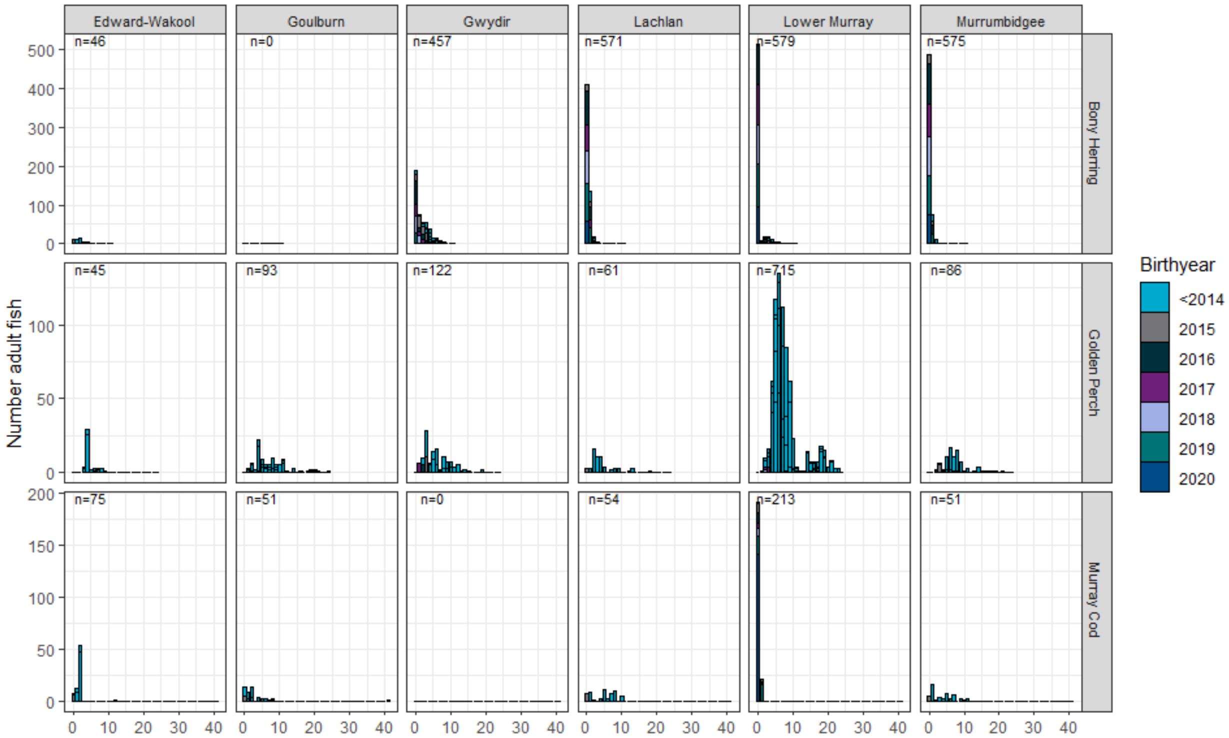

Figure 2.27 Histogram showing distribution of ages across the selected areas
Each panel shows the total number of fish aged (n=XX).

Data trimming

As mortality rates and detection rates can vary with younger fish, I developed a cutoff threshold for each species. For Murray cod and golden perch, the age cutoff was 4+. This criterion was based on a large combined data of golden perch data showing the characteristic hump around 4 years old. For now, I assumed a similar pattern for Murray cod since was a large body fish as well. As for Bony herring, threshold information was limiting, so I kept 2+ fish.

2.6.2 Data analysis methods

For the analysis, I ran a catch curve regression on each species. For each species, the dataset was expanded to include all possible ages for sampling, up to the max age caught (for that species). The response variable was number of fish caught at each age and was assumed to follow a negative binomial distribution. The fixed effects were age and program. Birthyear nested in program was included as a random effect.

2.6.3 Key results

Estimated mortality rates

As part of the catch curve, I can estimate annual survival rates. Annual survival rates were 0.51 (0.44, 0.58), 0.79 (0.71, 0.85), 0.78 (0.74, 0.82) for bony herring, Murray cod, golden perch, respectively.

Recruitment strength

Recruitment strengths for each birthyear were estimated for each species. Model results only delineated varying recruitment strengths in only Golden perch (Figure 2.28), mainly in the Lower Murray where I had substantial data and hence higher statistical power.

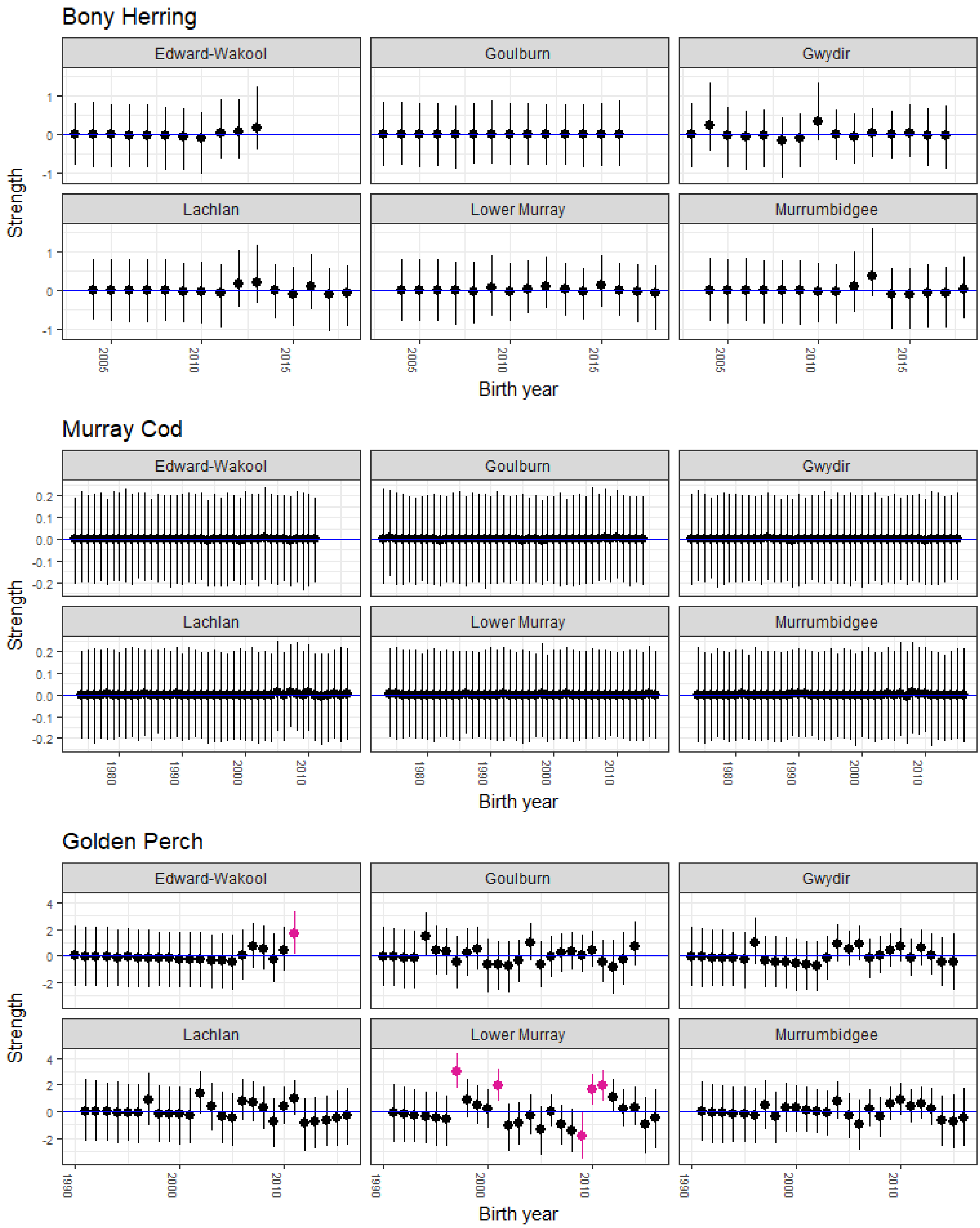

Figure 2.28 Recruitment strength estimates for each species

Coloured dots show estimates in which credible interval does not include zero. Error bars are 95%CrI.

2.7 Analysis: Adult abundance

2.7.1 Logic

- Flow metrics may affect adult survival across the years.

2.7.2 Survey design and modification

Following the analysis plan, I only kept the following species: *Macquaria ambigua*, *Maccullochella peelii*, *Hypseleotris spp*, *Nematalosa erebi*, *Cyprinus carpio*, *gambusia holbrooki*, *Retropinna semoni*. Basic sampling information about each species can be found in Table 2.6.

Table 2.6 Summary of sample sizes for adult abundance dataset

Species	Fish	Programs	Sites	Years	Percent zero catch
Carp gudgeon	178,565	6	61	6	3.9%
Bony herring	73,098	6	61	6	23.1%
Eastern gambusia	22,779	6	61	6	23.5%
Common carp	12,578	6	61	6	0.0%
Murray cod	2,928	6	61	6	14.4%
Golden perch	2,270	6	61	6	14.4%
Australian smelt	1,063	6	61	6	62.3%

2.7.3 Data analysis methods

For the analysis, the main hypotheses are focused on the effect of flow on growth rate between years. Consequently, I modelled log growth rate as the following:

$$R = \log({CPUE_{t-1}+1}) \qquad (1)$$

expect for Bony herring, Australian smelt, and Eastern gambusia, which used the following:

$$R = \log({CPUE_{t-1}+0.01}) \qquad (2)$$

This difference was purely statistical convenience to satisfy statistical assumptions.

A linear mixed model (LMM) in a Bayesian framework was run and included annual flow metrics as the continuous predictors. Program and if last year was a DO event were included as fixed factors. Water year (nested in program) and site were included as random effects.

2.7.4 Key results

Flow coefficients

Estimates of flow coefficients for each species are shown in Figure 2.29.

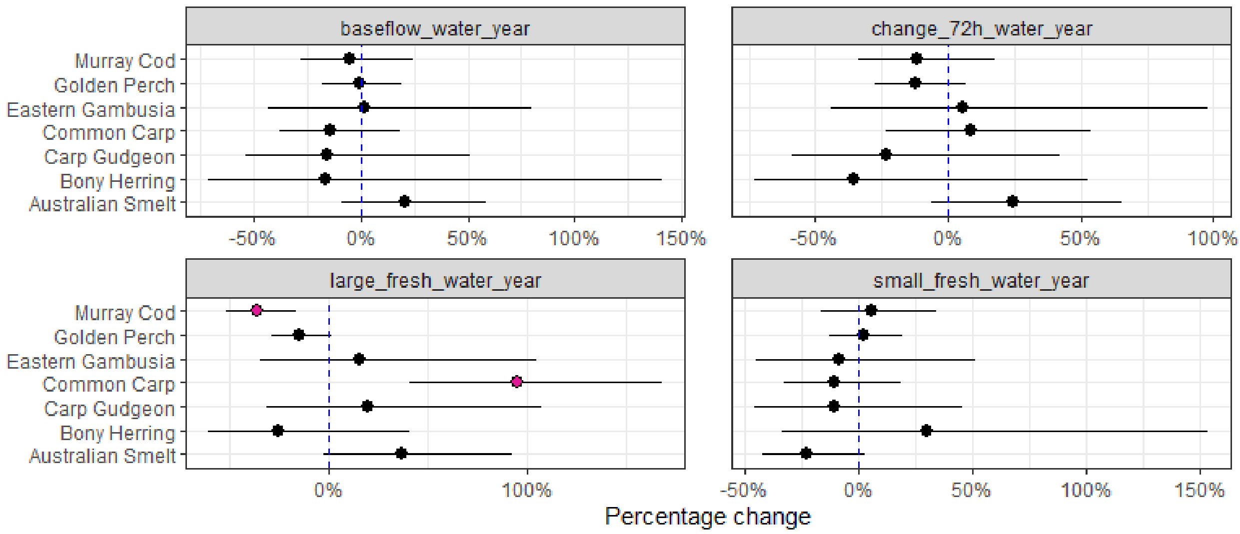

Figure 2.29 Effect of each flow variable on growth rate for each species

Error bars are 95%CrI. Pinkish dots indicate 95%CrI does not overlap 0.

Counterfactual predictions

Here, I show the percentage change in growth rate with the added Commonwealth environmental water (Figure 2.30).

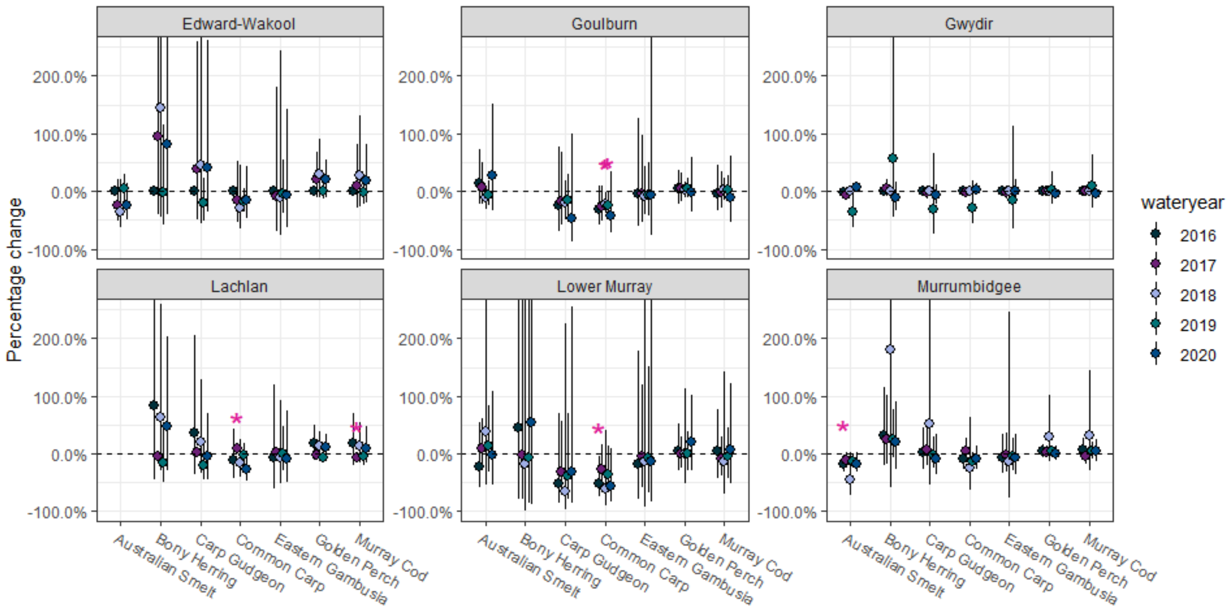

Figure 2.30 Predicted percentage change in growth rate without Commonwealth environmental water for each species, broken up by year and program

Positive changes indicate Commonwealth environmental water improved growth rate. Error bars are 95%CrI. * indicates the 95%CrI of the difference between with and without Commonwealth environmental water does not include zero. Y-axes has been truncated to help better show the less variable results.

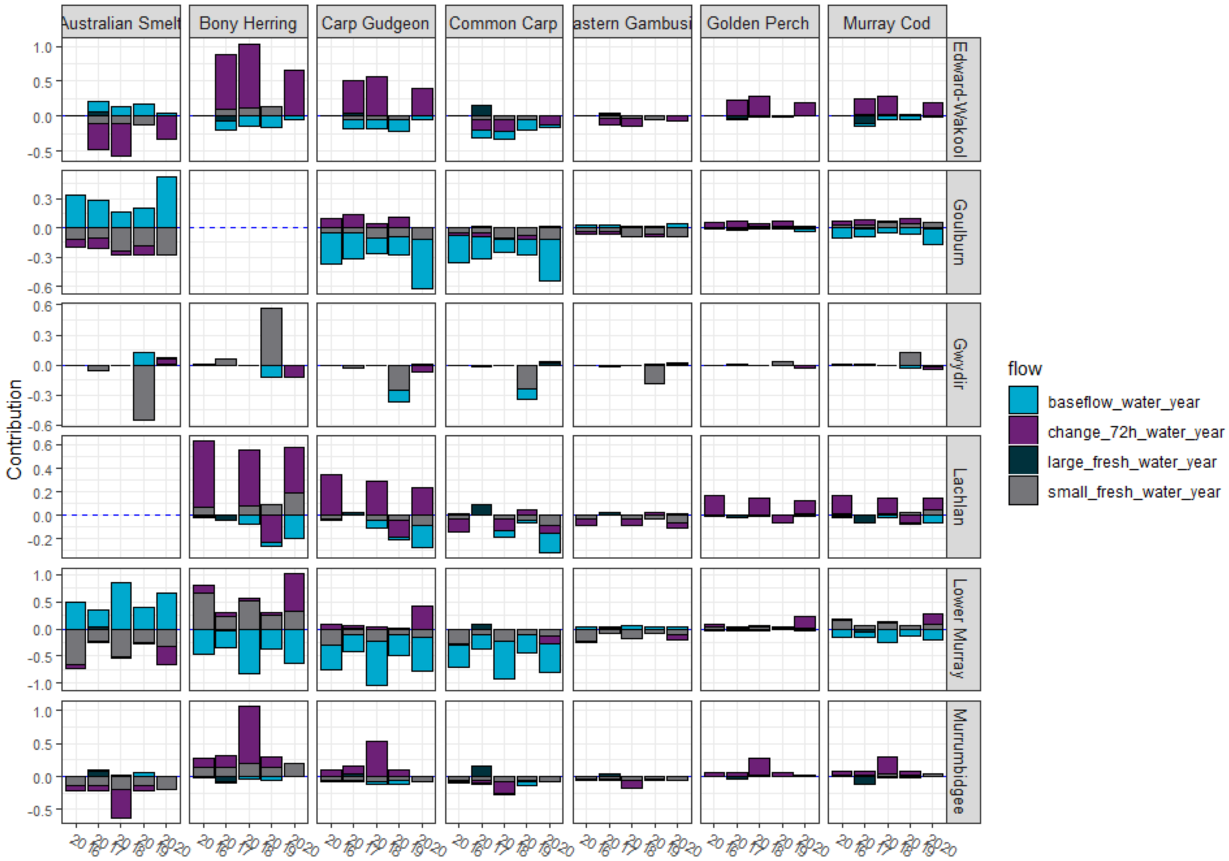

Figure 2.31 Contribution of each flow variable on the predicted Commonwealth environmental water effect on growth rate

Negative effects are shown as bars below 0 and positive effects above. Effect sizes are on link scale.

2.8 Analysis: Adult body condition

2.8.1 Logic, study design, and data trimming

Logic

- Flow conditions affect river productivity and hence have knock-on effects for fish condition.
- Body condition can be assessed similarly for all species using Fulton index: $FI = 100 * \frac{Weight}{Length^3}$
- I assumed that sampled body condition represents roughly the last 6–12 months of river conditions (beginning of water year to sampling date).

Study design

One key aspect to check is the temporal alignment of annual flow metrics alignment with sampling dates for body condition for each program and assess whether the alignment is appropriate for the biological hypotheses. Overall, the sampling dates were roughly between 50 to 85% of the water year so the flow metrics should be viewed in that perspective.

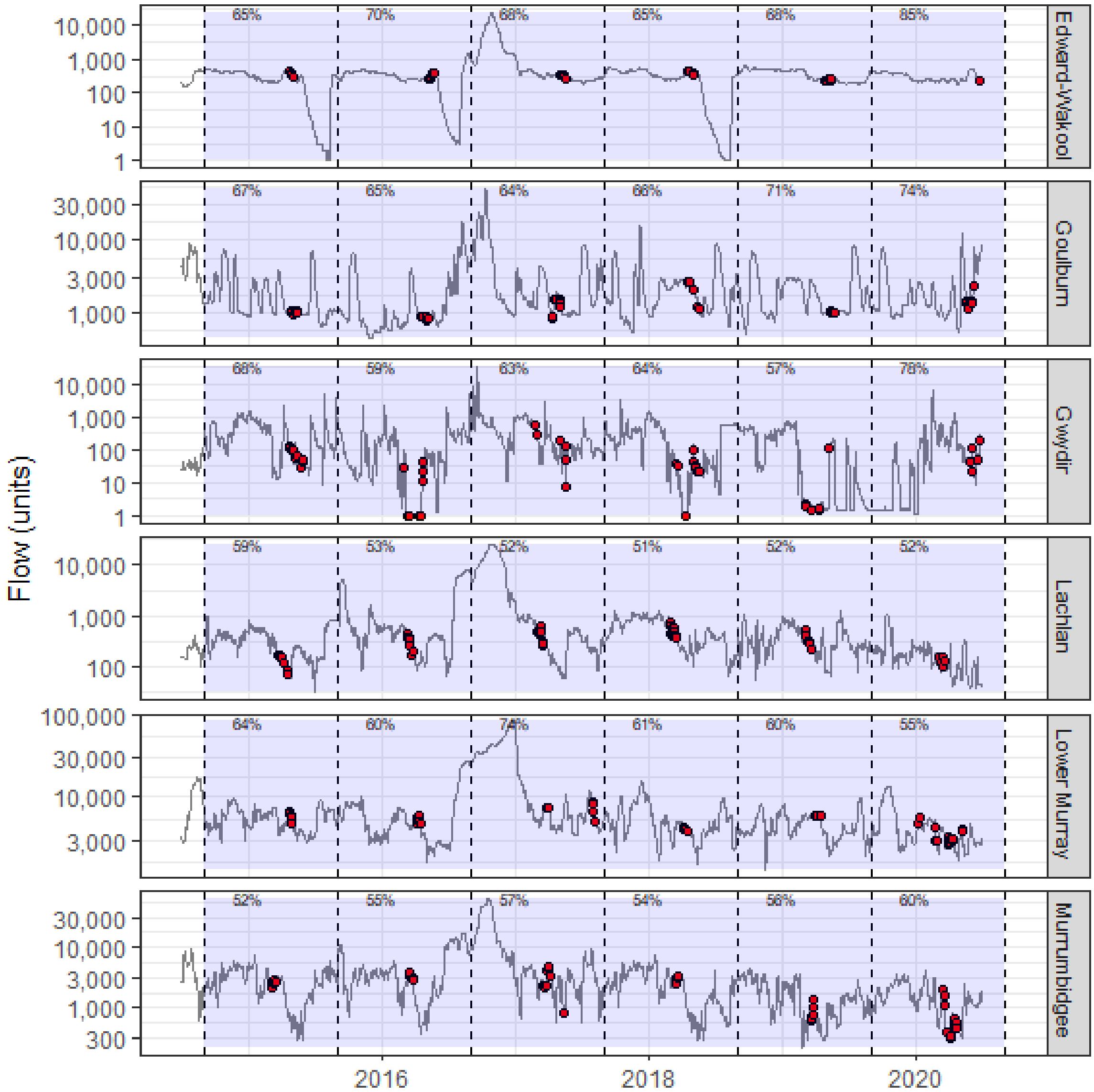

Figure 2.32 Sampling dates for body condition (red dots) in relation to water year windows for each program
Percentage shows the proportion of the water year fish experienced prior to the first sampling date (i.e. 70% means that the fish experienced 70% of the flow data included in the flow metrics at the time of first sampling event.)

Data trimming

Total samples sizes are shown in Table 2.7. Because of low sample sizes, *Hypseleotris spp* was dropped from further analyses, thus leaving 4 species for the analysis: *Nematalosa erebi*, *Cyprinus carpio*, *Maccullochella peelii*, *Macquaria ambigua*.

Table 2.7 Summary of sample sizes for body condition dataset

Species	Fish	Programs	Sites	Years
Bony herring	16,977	6	56	6
Common carp	4,675	5	41	6
Murray cod	2,805	6	61	6
Golden perch	2,268	6	56	6
Carp gudgeon	1	1	1	1

Key exploratory graph(s)

First, the relationship between length and weight was explored to assess any outliers in the data. As there were obvious outliers, I used the four times the standardised residuals method to identity those outliers. Therefore, a linear regression was run for each species (log(weight) ~ log(length)) and identified outliers (Figure 2.33). The method worked well, though could be improved for *N. erebi*. *N. erebi* had decreasing variance on log-scale, which likely reflects measurement error becoming proportionally larger at small sizes. For now (time-limitations), the outlier criteria were kept the same, but model improvements could be had with future refinements to *N. erebi*, such as using weighted regression approaches.

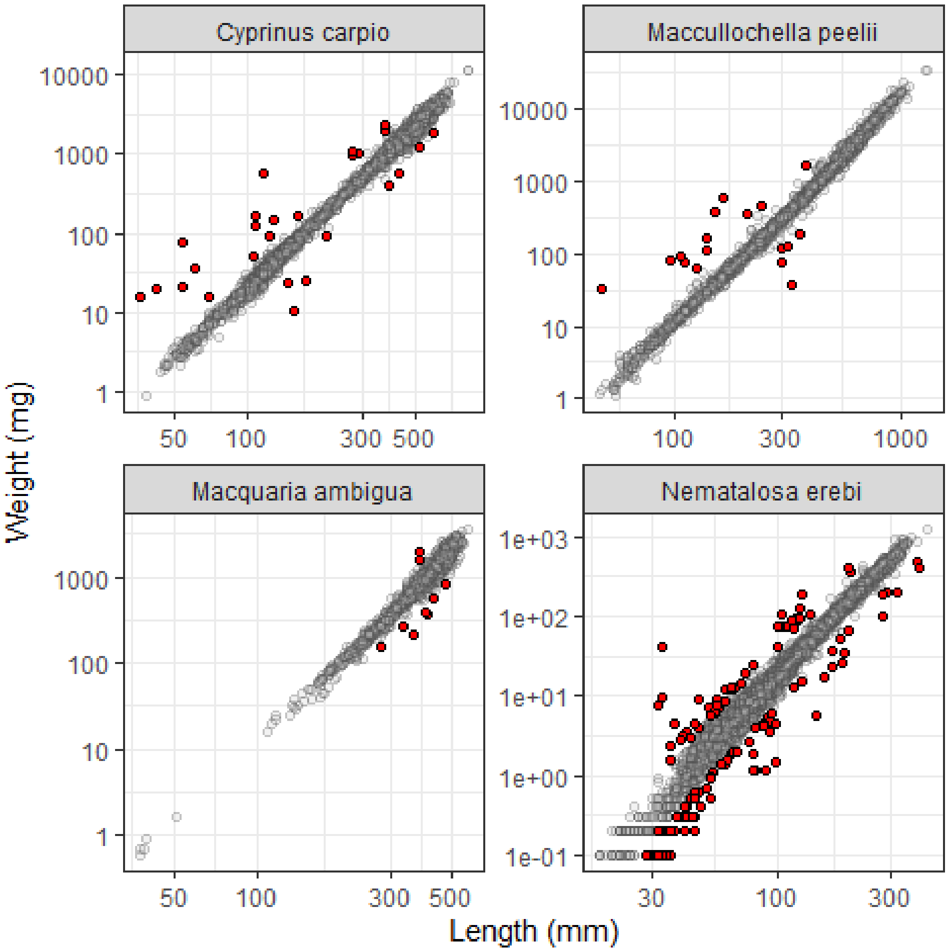

Figure 2.33 Exploratory graph looking for potential outliers
Red dots show outliers using four times the standardised residuals method. Black circles show non-outlier data

To explore patterns in the data, I regressed data against each flow metric.

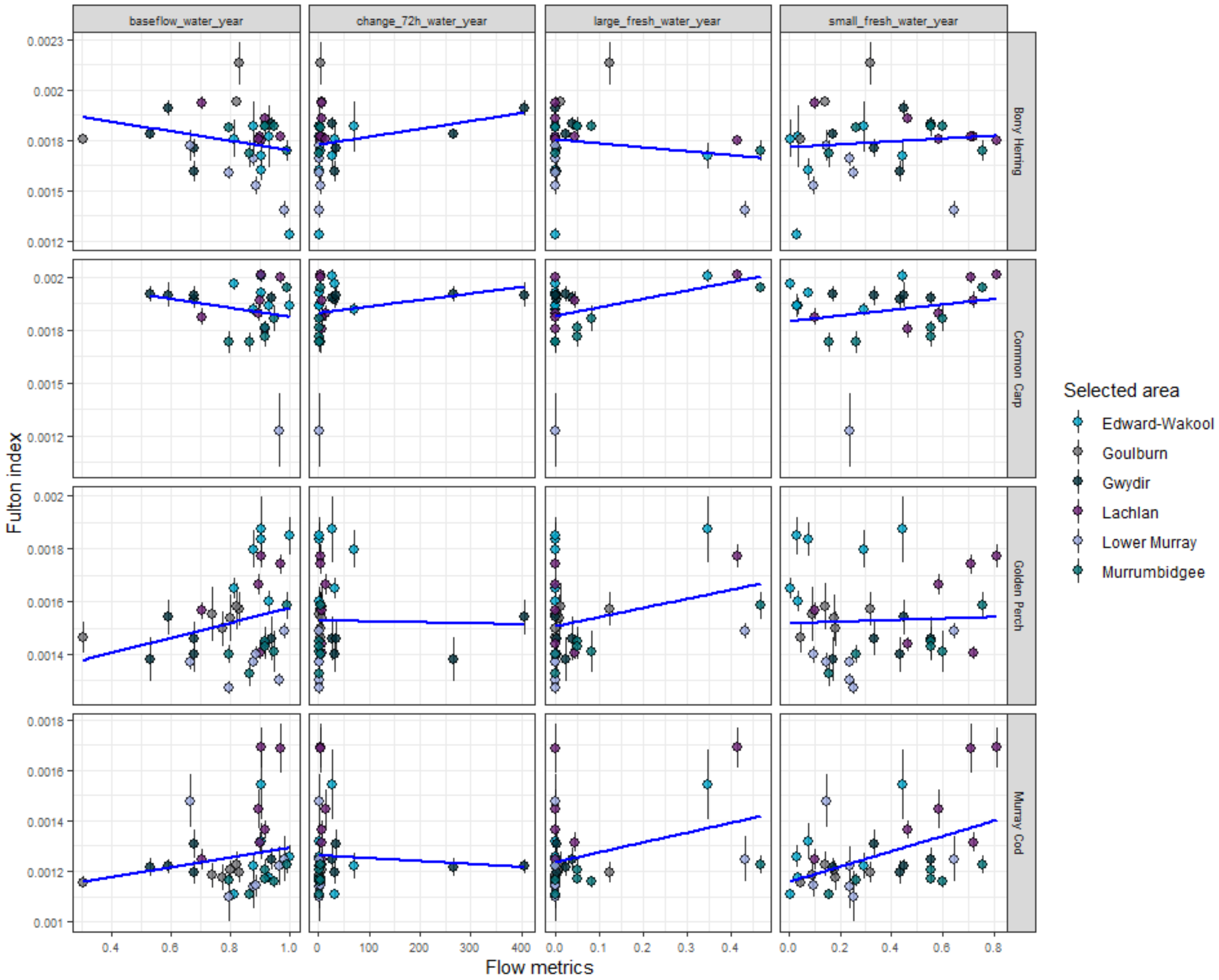

Figure 2.34 Main exploratory graph for body condition analysis

Each dot represents the mean Fulton index for each program. Black line shows exploratory regression line (not corrected for other covariates). Error bars are 95%CI for the mean.

2.8.2 Data analysis

As noted above, I removed outliers from the analysis using four times the standardised residual method. With the remaining data, I undertook the following approach.

To test for the effects of flow metrics on body condition, the Fulton Index (proxy for body condition) was modelled in relation to the kept annual flow metrics. A linear mixed model (LMM) with an untransformed Fulton Index was used and included annual flow metrics as the continuous predictors. Program was included as a fixed factor. Water year (nested in program), site, and site-by-year were included as random effects. Due to computation slowness using a Bayesian approach, lmer() from the *lme4* package (Bates et al. 2015) was used.

2.8.3 Results

Flow coefficients

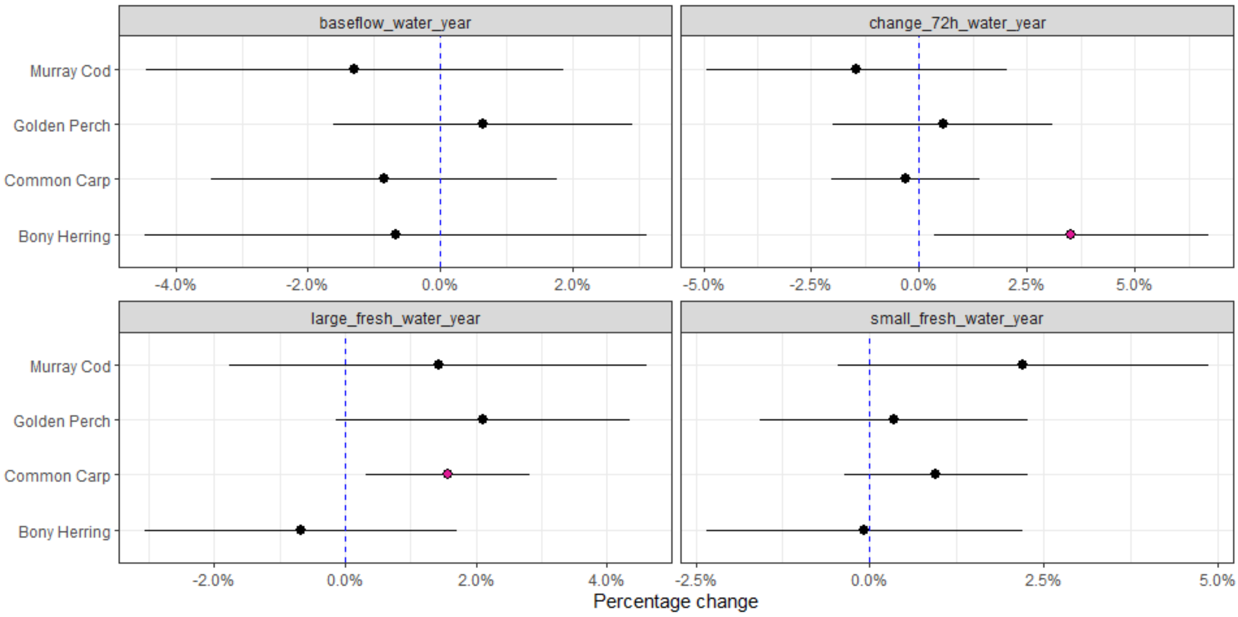

Figure 2.35 Effect of each flow variable on body condition for each species
Error bars are 95%CI. Pink dots indicate significant effects at p<0.05 threshold.

Counterfactual predictions

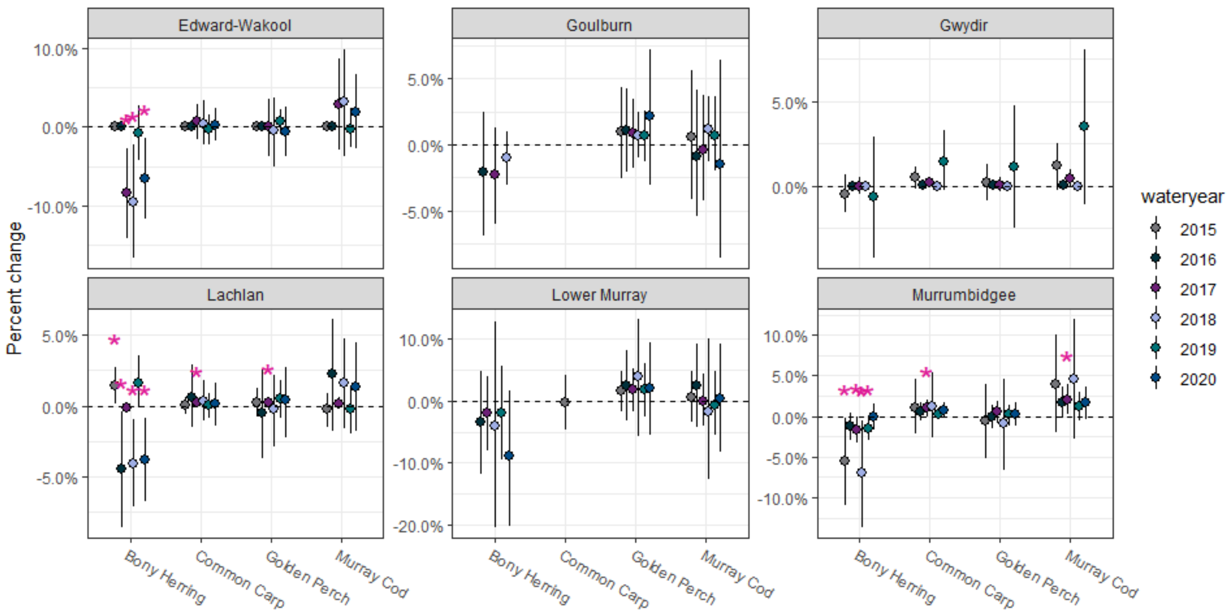

Figure 2.36 Predicted effect of Commonwealth environmental water on body condition for each species, broken up by year and program
Effect sizes have been scaled to percentage of mean Fulton Index for each species. Error bars are 95% C.I

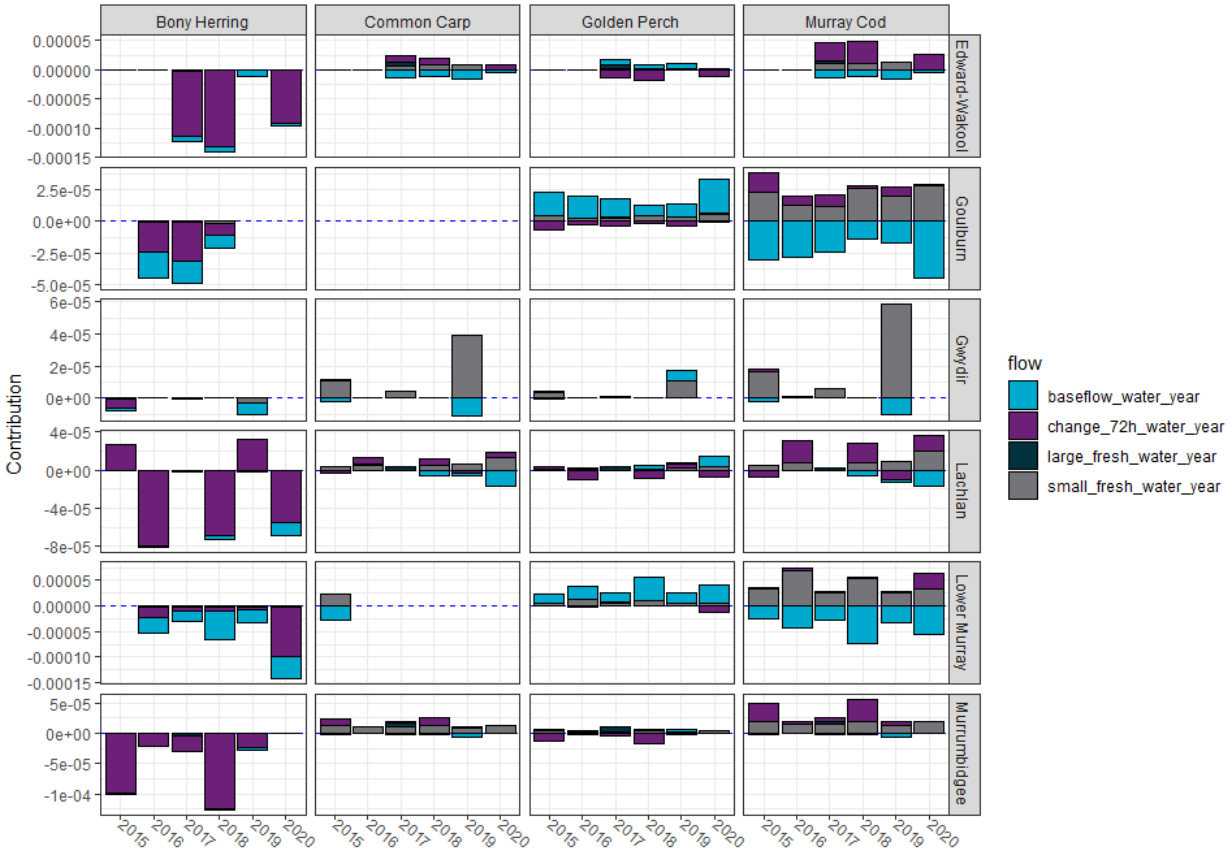

Figure 2.37 Contribution of each flow variable on the predicted Commonwealth environmental water effect for body condition

Negative effects are shown as bars below 0 and positive effects above. Effect sizes are on raw scale.

3 General summary

3.1 Summary of flow metric effects for all analyses

A summary of all the analysis indicating significant positive and negative results is provided at Table 3.1.

Table 3.1 Summary of flow metric effects for all analyses

Green indicates a positive 'significant' relationship ('+'), grey no relationship ('0'), and red a negative relationship ('-'). White cells indicate no analysis run. Significant defined as 95%CrI not overlapping zero

Species	Term	adultAbund	bodyCond	larvaAbund	recruit	spawn
Australian smelt	baseflow	0			0	
	change_72h	0			0	
	large_fresh	0			0	
	small_fresh	0			+	
Bony herring	baseflow	0	0			
	change_72h	0	+			
	large_fresh	0	0			
	small_fresh	0	0			
Carp gudgeon	baseflow	0			0	
	change_72h	0			0	
	large_fresh	0			0	
	small_fresh	0			0	
Common carp	baseflow	0	0		0	
	change_72h	0	0		0	
	large_fresh	+	+		+	
	small_fresh	0	0		0	
Eastern gambusia	baseflow	0			0	
	change_72h	0			0	
	large_fresh	0			0	
	small_fresh	0			0	
Golden perch	baseflow	0	0			+
	change_72h	0	0			0
	days_increasing			0		
	large_fresh	0	0			0
	seven_day_median			-		
	seven_day_range			0		
	small_fresh	0	0			-
Murray cod	baseflow	0	0			
	change_72h	0	0			
	large_fresh	-	0			
	small_fresh	0	0			
Silver perch	baseflow					0
	change_72h					0
	days_increasing			0		
	large_fresh					0
	seven_day_median			0		
	seven_day_range			0		
	small_fresh					0

3.2 Summary of counterfactual predictions metrics

Below shows a table of all the analysis indicating significant positive and negative results.

Table 3.2 Summary of predicted Commonwealth environmental water effect for all analyses

Green indicates a positive 'significant' relationship ('+'), grey no relationship ('0'), and red a negative relationship ('-'). White cells indicate no analysis run. Significant defined as 95%CrI not overlapping zero

Species	Selected area	Water year	adultAbund	bodyCond	larvaAbund	recruit	spawn
Australian smelt	Edward-Wakool	2015				0	
		2016	0			0	
		2017	0			+	
		2018	0			+	
		2019	0			+	
		2020	0			0	
	Goulburn	2015				0	
		2016	0			0	
		2017	0			0	
		2018	0			0	
		2019	0			+	
		2020	0			0	
	Gwydir	2015				+	
		2016	0			+	
		2017	0			+	
		2018	0			0	
		2019	0			+	
		2020	0			0	
	Lachlan	2015				+	
		2016				+	
		2017				0	
		2018				0	
		2019				+	
		2020				0	
	Lower Murray	2015				+	
		2016	0			0	
		2017	0			0	
		2018	0			0	
		2019	0			0	
		2020	0			0	
	Murrumbidgee	2015				+	
		2016	-			+	
		2017	0			0	
		2018	0			+	
		2019	0			+	
		2020	0			+	
Bony herring	Edward-Wakool	2015		0			
		2016	0	0			
		2017	0	-			
		2018	0	-			
		2019	0	0			
		2020	0	-			
	Goulburn	2016		0			
		2017		0			
		2018		0			
	Gwydir	2015		0			
		2016	0	0			
		2017	0	0			
		2018	0	0			
		2019	0	0			
		2020	0				

Species	Selected area	Water year	adultAbund	bodyCond	larvaAbund	recruit	spawn
	Lachlan	2015		+			
		2016	0	-			
		2017	0	0			
		2018	0	-			
		2019	0	0			
		2020	0	-			
	Lower Murray	2016	0	0			
		2017	0	0			
		2018	0	0			
		2019	0	0			
		2020	0	0			
	Murrumbidgee	2015		-			
		2016	0	0			
		2017	0	-			
		2018	0	-			
		2019	0	-			
		2020	0	0			
Carp gudgeon	Edward-Wakool	2015				0	
		2016	0			0	
		2017	0			0	
		2018	0			0	
		2019	0			0	
		2020	0			0	
	Goulburn	2015				0	
		2016	0			0	
		2017	0			0	
		2018	0			0	
		2019	0			0	
		2020	0			0	
	Gwydir	2015				0	
		2016	0			0	
		2017	0			0	
		2018	0			0	
		2019	0			0	
		2020	0			0	
	Lachlan	2015				0	
		2016	0			0	
		2017	0			0	
		2018	0			0	
		2019	0			0	
		2020	0			0	
	Lower Murray	2015				0	
		2016	0			0	
		2017	0			0	
		2018	0			0	
		2019	0			0	
		2020	0			0	
	Murrumbidgee	2015				0	
		2016	0			0	
		2017	0			0	
		2018	0			0	
		2019	0			0	
		2020	0			0	
Common carp	Edward-Wakool	2015		0		0	
		2016	0	0		0	
		2017	0	0		+	
		2018	0	0		0	
		2019	0	0		0	
		2020	0	0		0	

Species	Selected area	Water year	adultAbund	bodyCond	larvaAbund	recruit	spawn
	Goulburn	2015				0	
		2016	0			0	
		2017	0			0	
		2018	-			0	
		2019	-			0	
		2020	0			0	
	Gwydir	2015		0		0	
		2016	0	0		0	
		2017	0	0		0	
		2018	0	0		0	
		2019	0	0		0	
		2020	0			0	
	Lachlan	2015		0		0	
		2016	0	0		0	
		2017	+	+		+	
		2018	0	0		0	
		2019	0	0		0	
		2020	0	0		0	
	Lower Murray	2015		0		0	
		2016	-			0	
		2017	0			0	
		2018	0			0	
		2019	0			0	
		2020	0			0	
	Murrumbidgee	2015		0		0	
		2016	0	0		0	
		2017	0	+		+	
		2018	0	0		0	
		2019	0	0		0	
		2020	0	0		0	
Eastern gambusia	Edward-Wakool	2015				0	
		2016	0			0	
		2017	0			0	
		2018	0			0	
		2019	0			0	
		2020	0			0	
	Goulburn	2015				0	
		2016	0			0	
		2017	0			0	
		2018	0			0	
		2019	0			0	
		2020	0			0	
	Gwydir	2015				0	
		2016	0			0	
		2017	0			0	
		2018	0			0	
		2019	0			0	
		2020	0			0	
	Lachlan	2015				0	
		2016	0			0	
		2017	0			+	
		2018	0			0	
		2019	0			-	
		2020	0			0	
	Lower Murray	2015				0	
		2016	0			0	
		2017	0			0	
		2018	0			0	
		2019	0			0	

Species	Selected area	Water year	adultAbund	bodyCond	larvaAbund	recruit	spawn
		2020	0			0	
	Murrumbidgee	2015				0	
		2016	0			0	
		2017	0			0	
		2018	0			0	
		2019	0			0	
		2020	0			0	
Golden perch	Edward-Wakool	2015		0			0
		2016	0	0			0
		2017	0	0			0
		2018	0	0			0
		2019	0	0			0
		2020	0	0			0
	Goulburn	2015		0	0		0
		2016	0	0			0
		2017	0	0	0		0
		2018	0	0	-		0
		2019	0	0	0		0
		2020	0	0			0
	Gwydir	2015		0			
		2016	0	0			
		2017	0	0			
		2018	0	0			
		2019	0	0			
		2020	0				
	Lachlan	2015		0			0
		2016	0	0			0
		2017	0	+			0
		2018	0	0			0
		2019	0	0			0
		2020	0	0			0
	Lower Murray	2015		0	-		0
		2016	0	0	-		0
		2017	0	0	0		0
		2018	0	0	0		0
		2019	0	0	-		0
		2020	0	0			
	Murrumbidgee	2015		0			0
		2016	0	0	0		-
		2017	0	0			0
		2018	0	0	-		0
		2019	0	0	-		0
		2020	0	0	-		-
Murray cod	Edward-Wakool	2015		0			
		2016	0	0			
		2017	0	0			
		2018	0	0			
		2019	0	0			
		2020	0	0			
	Goulburn	2015		0			
		2016	0	0			
		2017	0	0			
		2018	0	0			
		2019	0	0			
		2020	0	0			
	Gwydir	2015		0			
		2016	0	0			
		2017	0	0			
		2018	0	0			

Species	Selected area	Water year	adultAbund	bodyCond	larvaAbund	recruit	spawn
		2019	0	0			
		2020	0				
	Lachlan	2015		0			
		2016	0	0			
		2017	-	0			
		2018	0	0			
		2019	0	0			
		2020	0	0			
	Lower Murray	2015		0			
		2016	0	0			
		2017	0	0			
		2018	0	0			
		2019	0	0			
		2020	0	0			
	Murrumbidgee	2015		0			
		2016	0	0			
		2017	0	+			
		2018	0	0			
		2019	0	0			
		2020	0	0			
Silver perch	Edward-Wakool	2015					0
		2016					0
		2017					0
		2018					0
		2019					0
		2020					0
	Goulburn	2015			0		0
		2016					0
		2017			0		0
		2018			0		0
		2019			0		0
		2020			0		0
	Lachlan	2015					0
		2016					0
		2017					0
		2018					0
		2019					0
		2020					0
	Lower Murray	2015			0		0
		2016					0
		2017					0
		2018					0
		2019			0		0
	Murrumbidgee	2015					0
		2016					0
		2017					0
		2018					0
		2019					0
		2020					0

3.3 Probability of effect of Commonwealth environmental water being greater than without Commonwealth environmental water

Table 3.3 Summary of the probability of Commonwealth environmental water effect for all analyses

If the probability is < 50%, then cell is white. Light green = 50-80%, medium green = 80-95%, dark green = ≥95%

Species	Selected area	Water year	adultAbund	bodyCond	larvaAbund	recruit	spawn
Australian smelt	Edward-Wakool	2015				0.00	
		2016	0.00			0.52	
		2017	0.12			0.99	
		2018	0.07			1.00	
		2019	0.67			1.00	
		2020	0.09			0.52	
	Goulburn	2015				0.85	
		2016	0.75			0.55	
		2017	0.67			0.48	
		2018	0.16			0.58	
		2019	0.26			1.00	
		2020	0.78			0.68	
	Gwydir	2015				1.00	
		2016	0.04			1.00	
		2017	0.04			1.00	
		2018	0.00			0.00	
		2019	0.06			0.99	
		2020	0.96			0.46	
	Lachlan	2015				1.00	
		2016				0.99	
		2017				0.08	
		2018				0.89	
		2019				0.99	
		2020				0.67	
	Lower Murray	2015				1.00	
		2016	0.23			0.94	
		2017	0.70			0.90	
		2018	0.73			0.61	
		2019	0.70			0.74	
		2020	0.49			0.51	
	Murrumbidgee	2015				1.00	
		2016	0.02			1.00	
		2017	0.06			0.93	
		2018	0.03			1.00	
		2019	0.03			0.97	
		2020	0.04			1.00	
Bony herring	Edward-Wakool	2015		0.00			
		2016	0.00	0.00			
		2017	0.86	0.00			
		2018	0.88	0.00			
		2019	0.47	0.34			
		2020	0.85	0.00			
	Goulburn	2016		0.19			
		2017		0.11			
		2018		0.15			
	Gwydir	2015		0.22			
		2016	0.79	0.46			
		2017	0.79	0.46			
		2018	0.00	0.00			
		2019	0.82	0.37			
		2020	0.17				
	Lachlan	2015		0.99			

Species	Selected area	Water year	adultAbund	bodyCond	larvaAbund	recruit	spawn
		2016	0.85	0.02			
		2017	0.18	0.28			
		2018	0.89	0.00			
		2019	0.25	0.97			
		2020	0.87	0.01			
	Lower Murray	2016	0.65	0.22			
		2017	0.48	0.27			
		2018	0.46	0.32			
		2019	0.47	0.31			
		2020	0.63	0.06			
	Murrumbidgee	2015		0.02			
		2016	0.87	0.07			
		2017	0.85	0.02			
		2018	0.87	0.02			
		2019	0.92	0.01			
		2020	0.79	0.46			
Carp gudgeon	Edward-Wakool	2015				0.00	
		2016	0.00			0.50	
		2017	0.74			0.61	
		2018	0.74			0.52	
		2019	0.15			0.52	
		2020	0.80			0.50	
	Goulburn	2015				0.21	
		2016	0.25			0.21	
		2017	0.29			0.20	
		2018	0.13			0.21	
		2019	0.23			0.31	
		2020	0.18			0.21	
	Gwydir	2015				0.39	
		2016	0.31			0.52	
		2017	0.31			0.52	
		2018	0.00			0.00	
		2019	0.20			0.36	
		2020	0.20			0.49	
	Lachlan	2015				0.53	
		2016	0.77			0.42	
		2017	0.74			0.59	
		2018	0.72			0.17	
		2019	0.11			0.31	
		2020	0.43			0.20	
	Lower Murray	2015				0.40	
		2016	0.12			0.23	
		2017	0.17			0.22	
		2018	0.17			0.21	
		2019	0.16			0.21	
		2020	0.31			0.21	
	Murrumbidgee	2015				0.46	
		2016	0.53			0.52	
		2017	0.66			0.61	
		2018	0.73			0.46	
		2019	0.43			0.25	
		2020	0.31			0.52	
Common carp	Edward-Wakool	2015		0.00		0.00	
		2016	0.00	0.00		0.22	
		2017	0.28	0.73		1.00	
		2018	0.16	0.63		0.81	
		2019	0.06	0.39		0.81	
		2020	0.26	0.60		0.22	
	Goulburn	2015				0.59	

Species	Selected area	Water year	adultAbund	bodyCond	larvaAbund	recruit	spawn
		2016	0.07			0.51	
		2017	0.07			0.49	
		2018	0.02			0.52	
		2019	0.02			0.79	
		2020	0.09			0.55	
	Gwydir	2015		0.93		0.83	
		2016	0.21	0.92		0.81	
		2017	0.21	0.92		0.81	
		2018	0.00	0.00		0.00	
		2019	0.09	0.96		0.55	
		2020	0.73			0.78	
	Lachlan	2015		0.53		0.86	
		2016	0.29	0.71		0.73	
		2017	1.00	1.00		0.99	
		2018	0.15	0.66		0.46	
		2019	0.41	0.53		0.77	
		2020	0.03	0.56		0.53	
	Lower Murray	2015		0.47		0.84	
		2016	0.02			0.65	
		2017	0.09			0.72	
		2018	0.07			0.53	
		2019	0.06			0.56	
		2020	0.04			0.50	
	Murrumbidgee	2015		0.75		0.83	
		2016	0.17	0.85		0.81	
		2017	0.73	0.98		1.00	
		2018	0.23	0.73		0.83	
		2019	0.04	0.82		0.68	
		2020	0.21	0.92		0.81	
Eastern gambusia	Edward-Wakool	2015				0.00	
		2016	0.00			0.96	
		2017	0.44			0.71	
		2018	0.42			0.19	
		2019	0.43			0.20	
		2020	0.43			0.96	
	Goulburn	2015				0.03	
		2016	0.47			0.06	
		2017	0.47			0.07	
		2018	0.35			0.05	
		2019	0.38			0.02	
		2020	0.46			0.04	
	Gwydir	2015				0.06	
		2016	0.36			0.18	
		2017	0.36			0.18	
		2018	0.00			0.00	
		2019	0.34			0.45	
		2020	0.58			0.04	
	Lachlan	2015				0.10	
		2016	0.42			0.52	
		2017	0.70			0.97	
		2018	0.41			0.10	
		2019	0.50			0.01	
		2020	0.38			0.05	
	Lower Murray	2015				0.05	
		2016	0.36			0.02	
		2017	0.44			0.03	
		2018	0.45			0.05	
		2019	0.44			0.04	
		2020	0.44			0.06	

Species	Selected area	Water year	adultAbund	bodyCond	larvaAbund	recruit	spawn
	Murrumbidgee	2015				0.11	
		2016	0.36			0.18	
		2017	0.42			0.91	
		2018	0.40			0.11	
		2019	0.34			0.02	
		2020	0.36			0.18	
Golden perch	Edward-Wakool	2015		0.00			0.00
		2016	0.00	0.00			0.41
		2017	0.88	0.51			0.41
		2018	0.92	0.41			0.08
		2019	0.49	0.81			0.06
		2020	0.91	0.35			0.41
	Goulburn	2015		0.70	0.57		0.45
		2016	0.61	0.73			0.95
		2017	0.68	0.73	0.00		0.00
		2018	0.66	0.80	0.01		0.69
		2019	0.76	0.73	0.04		0.20
		2020	0.48	0.79			0.97
	Gwydir	2015		0.66			
		2016	0.58	0.64			
		2017	0.58	0.64			
		2018	0.00	0.00			
		2019	0.58	0.75			
		2020	0.10				
	Lachlan	2015		0.73			0.48
		2016	0.89	0.37			0.38
		2017	0.04	0.98			0.00
		2018	0.91	0.42			0.19
		2019	0.13	0.79			0.56
		2020	0.89	0.63			0.60
	Lower Murray	2015		0.82	0.01		0.03
		2016	0.61	0.82	0.00		0.26
		2017	0.48	0.83	0.20		0.41
		2018	0.50	0.79	0.10		0.93
		2019	0.51	0.80	0.00		0.90
		2020	0.77	0.70			
	Murrumbidgee	2015		0.41			0.06
		2016	0.82	0.50	0.10		0.02
		2017	0.64	0.79			0.63
		2018	0.90	0.39	0.01		0.06
		2019	0.88	0.62	0.00		0.05
		2020	0.58	0.64	0.00		0.02
Murray cod	Edward-Wakool	2015		0.00			
		2016	0.00	0.00			
		2017	0.66	0.83			
		2018	0.80	0.81			
		2019	0.42	0.43			
		2020	0.80	0.78			
	Goulburn	2015		0.57			
		2016	0.45	0.36			
		2017	0.47	0.43			
		2018	0.61	0.81			
		2019	0.61	0.69			
		2020	0.37	0.34			
	Gwydir	2015		0.95			
		2016	0.69	0.94			
		2017	0.69	0.94			
		2018	0.00	0.00			
		2019	0.67	0.93			

Species	Selected area	Water year	adultAbund	bodyCond	larvaAbund	recruit	spawn
		2020	0.13				
	Lachlan	2015		0.36			
		2016	0.80	0.86			
		2017	0.00	0.82			
		2018	0.81	0.83			
		2019	0.26	0.41			
		2020	0.76	0.79			
	Lower Murray	2015		0.60			
		2016	0.56	0.76			
		2017	0.34	0.49			
		2018	0.41	0.38			
		2019	0.42	0.40			
		2020	0.57	0.52			
	Murrumbidgee	2015		0.89			
		2016	0.80	0.95			
		2017	0.31	0.98			
		2018	0.81	0.88			
		2019	0.80	0.91			
		2020	0.69	0.94			
Silver perch	Edward-Wakool	2015					0.00
		2016					0.67
		2017					0.67
		2018					0.20
		2019					0.13
		2020					0.67
	Goulburn	2015			0.53		0.50
		2016					0.52
		2017			0.00		0.00
		2018			0.09		0.61
		2019			0.09		0.22
		2020			0.00		0.41
	Lachlan	2015					0.25
		2016					0.64
		2017					0.00
		2018					0.40
		2019					0.27
		2020					0.64
	Lower Murray	2015			0.06		0.04
		2016					0.10
		2017					0.67
		2018					0.30
		2019			0.06		0.30
	Murrumbidgee	2015					0.09
		2016					0.04
		2017					0.67
		2018					0.09
		2019					0.07
		2020					0.04

4 References

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Appendix A Details of analyses

A.1 Summary of key species

```
## [1] "res_adultAbund.rds"
## [1] "res_bodyCond.rds"
## [1] "res_recruit.rds"
## [1] "res_spawn.rds"
```

A.1.1 Golden perch

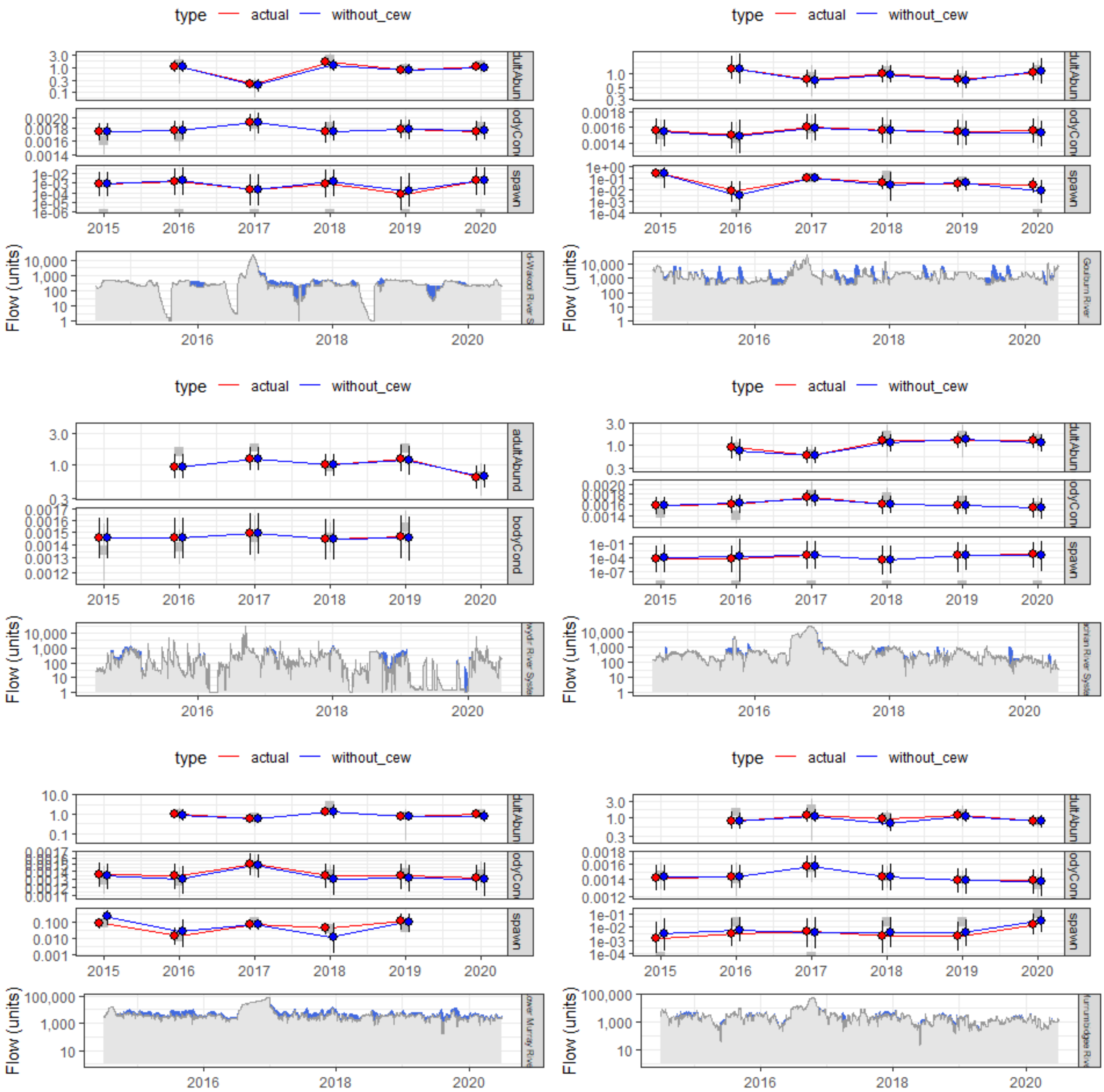

Figure A.1 Golden perch summary

A.1.2 Murray cod

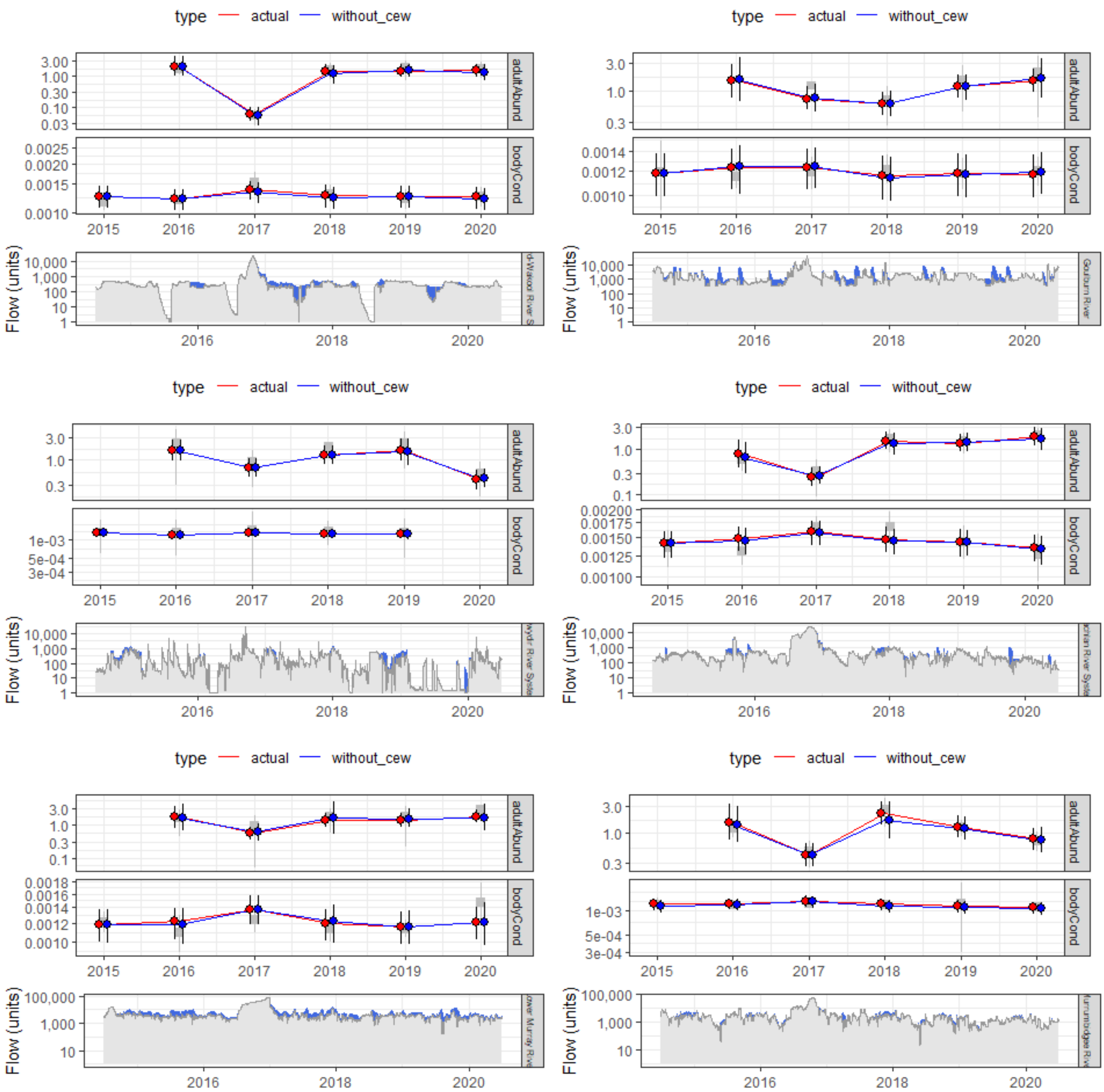

Figure A.2 Murray cod summary

A.1.3 Bony herring

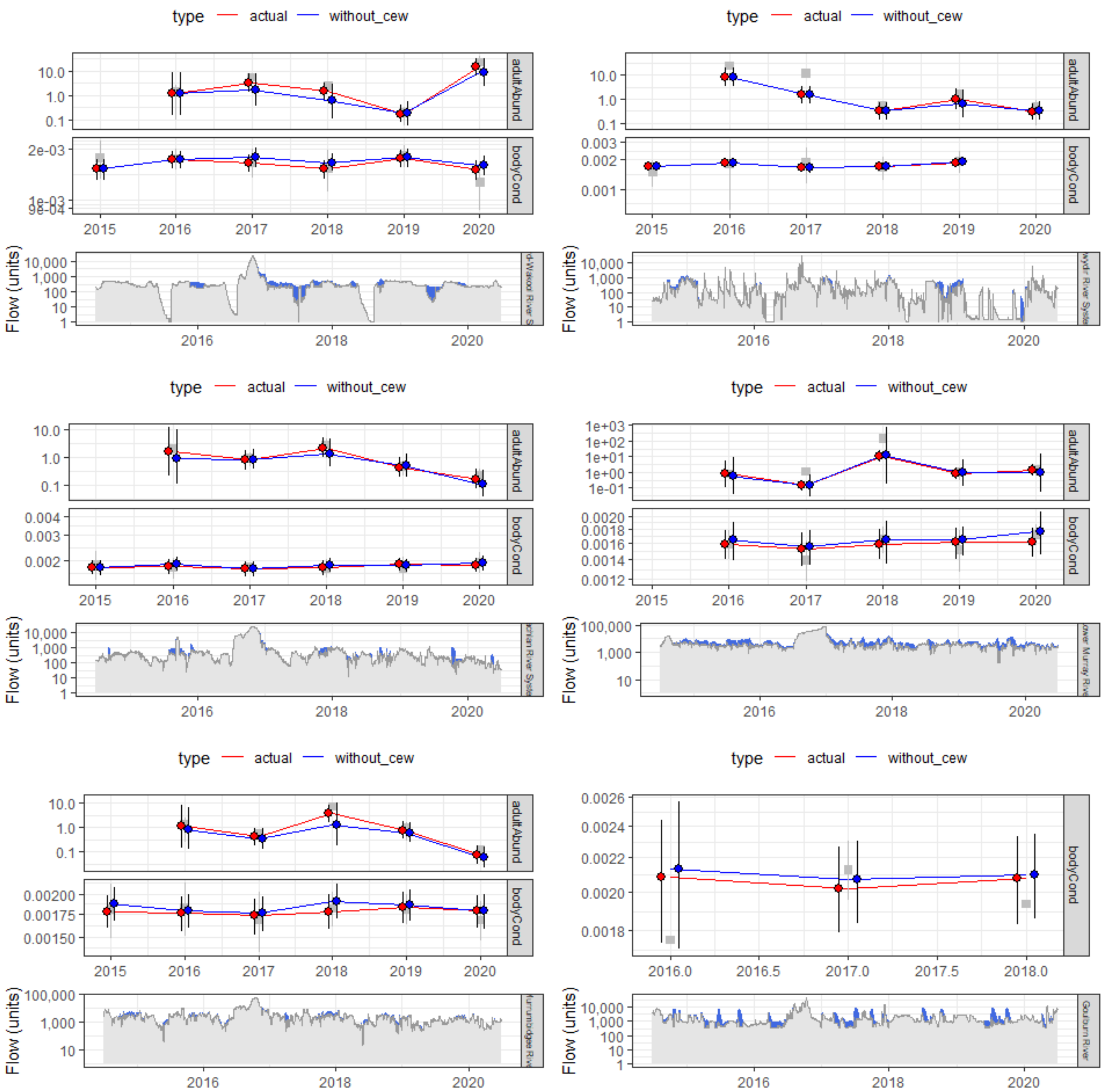

Figure A.3 Bony herring summary

A.1.4 Silver perch

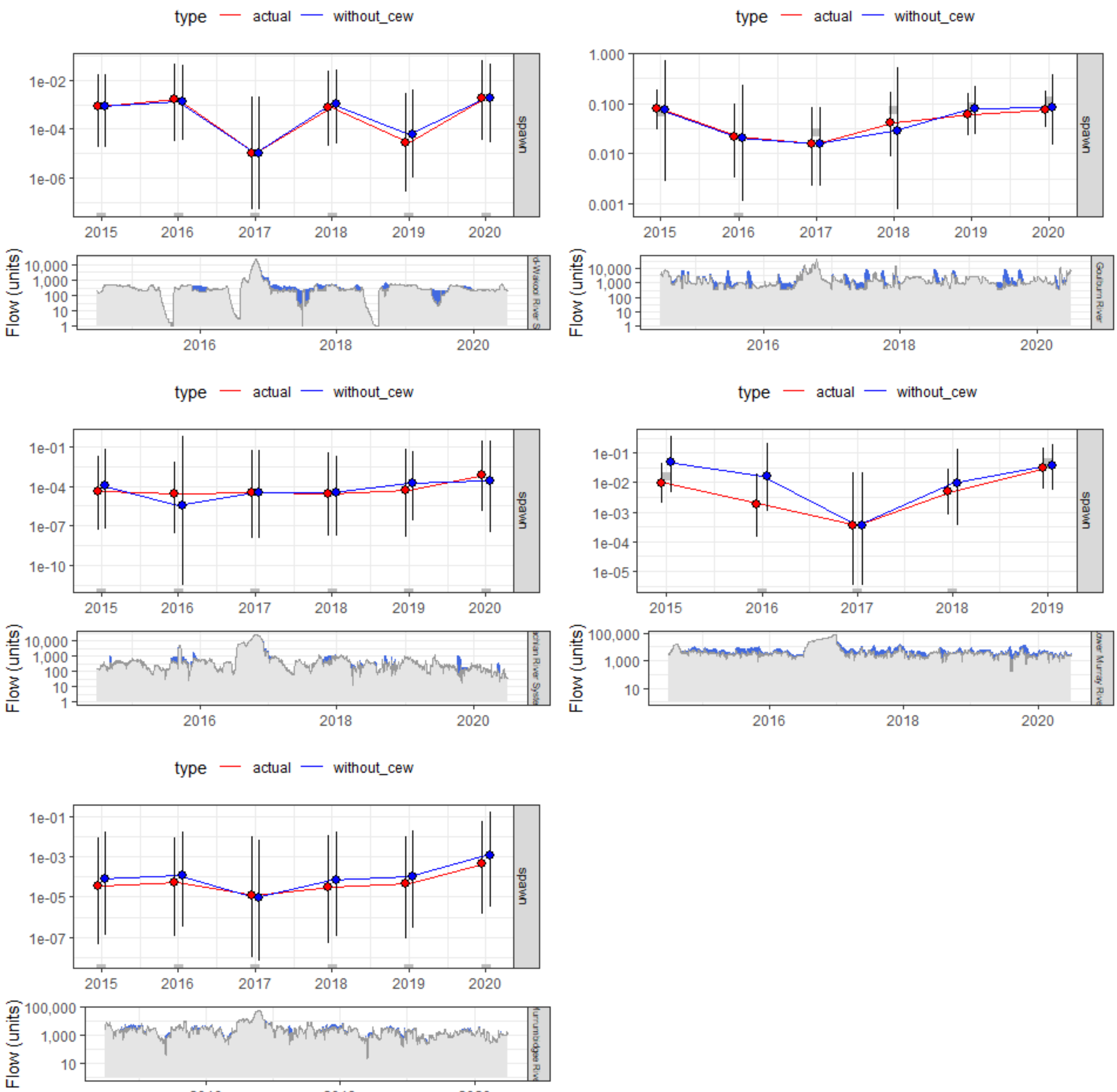

Figure A.4 Silver perch summary

A.1.5 Common carp

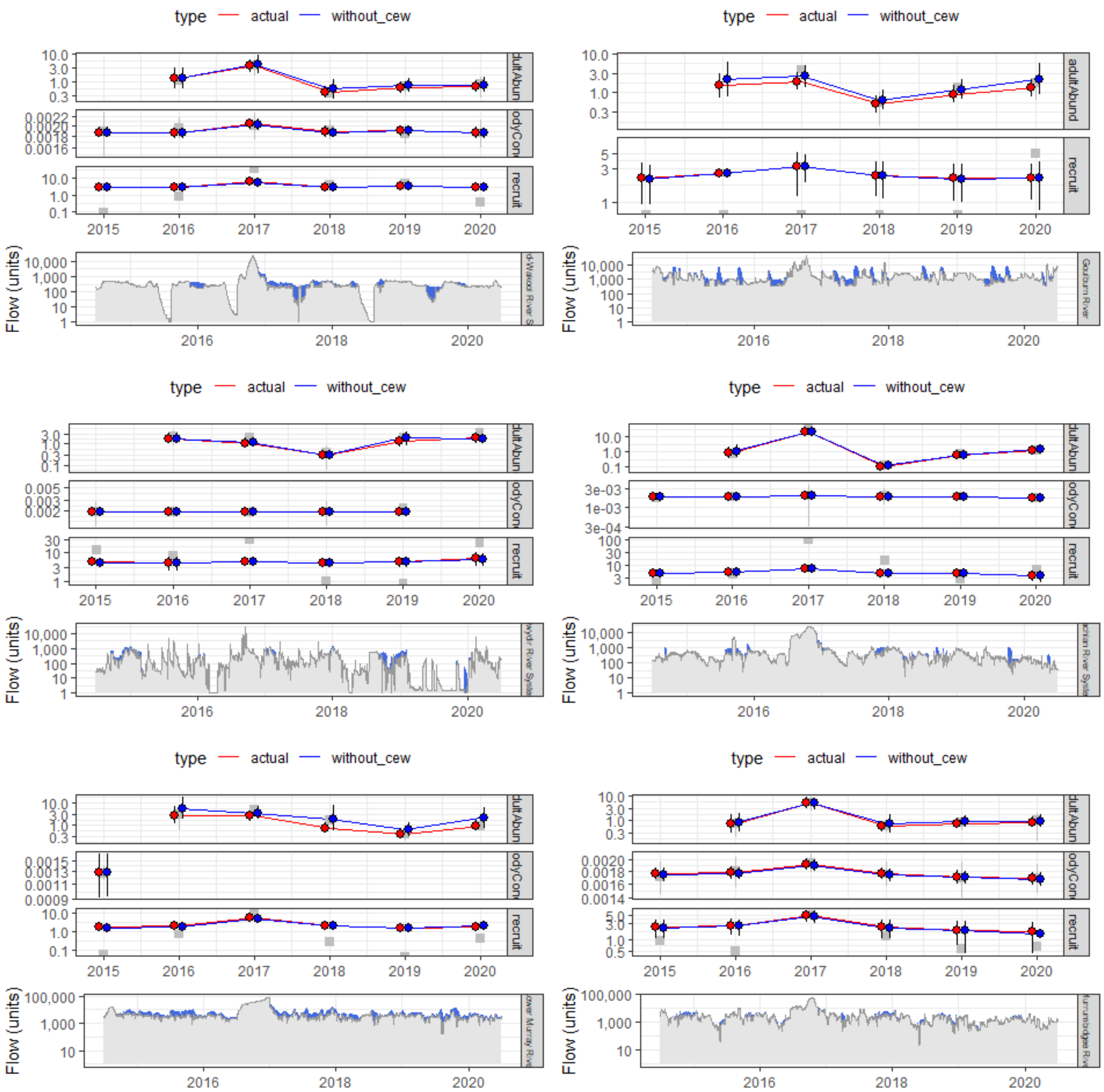

Figure A.5 Common carp summary

A.2 Statistical tables for all analyses

A.2.1 Spawning (analysis_id spawn)

Table A.1 Statistical results for fish spawning occurrence

* indicates C95%CrI does not include 0

speciesname	term	estimate	lower	upper	sig
Silver perch	(Intercept)	-19.94	-59.23	16.56	
	baseflow_sep_nov	0.30	-0.19	0.79	
	small_fresh_sep_nov	-5.43	-11.75	0.44	
	large_fresh_sep_nov	0.35	-6.02	6.59	
	change_72h_sep_nov	-0.14	-0.82	0.52	
	programGoulburn	5.65	2.33	9.54	*
	programLachlan	1.48	-6.64	8.60	
	programLower Murray	3.40	0.20	7.32	*
	programMurrumbidgee	0.28	-6.34	6.37	
	tot_effort	4.69	-10.20	21.23	
Golden perch	(Intercept)	-46.19	-86.74	-9.34	*
	baseflow_sep_nov	0.66	0.19	1.17	*
	small_fresh_sep_nov	-4.31	-8.45	-0.01	*
	large_fresh_sep_nov	2.53	-0.36	5.39	
	change_72h_sep_nov	0.06	-0.53	0.61	
	programGoulburn	5.97	2.81	9.76	*
	programLachlan	0.16	-8.17	7.54	
	programLower Murray	5.00	1.98	8.77	*
	programMurrumbidgee	2.79	-0.12	6.76	
	tot_effort	13.97	-0.89	29.59	

A.2.2 Larval abundance (analysis_id larvaAbund)

Table A.2 Statistical results for larval abundance

* indicates C95%CrI does not include 0

speciesname	term	estimate	lower	upper	sig
Golden perch	(Intercept)	-0.34	-7.56	6.12	
	seven_day_range	0.33	-0.52	1.18	
	days_increasing	-0.00	-0.36	0.36	
	seven_day_median	-2.24	-2.92	-1.39	*
	programLower Murray	-2.38	-8.72	3.54	
	programMurrumbidgee	-2.55	-5.92	0.89	
	ad_cpue	0.07	-0.29	0.48	
Silver perch	(Intercept)	-3.61	-10.56	3.72	
	seven_day_range	0.55	-0.20	1.31	
	days_increasing	0.04	-0.42	0.48	
	seven_day_median	-1.06	-2.79	0.64	
	programLower Murray	0.12	-3.54	3.71	
	ad_cpue	0.57	-1.85	2.76	

A.2.3 Recruit abundance (analysis_id recruit)

Table A.3 Statistical results for recruit abundance

* indicates C95%CrI does not include 0

speciesname	term	estimate	lower	upper	sig
Common carp	(Intercept)	2.60	-26.04	32.14	
	baseflow_sep_mar	-0.06	-0.88	0.68	
	small_fresh_sep_mar	1.40	-1.68	4.46	
	large_fresh_sep_mar	4.43	0.83	8.26	*
	change_72h_sep_mar	0.00	-0.00	0.01	
	n_sites	0.38	-12.48	13.31	
	programGoulburn	-0.99	-3.53	1.40	
	programGwydir	0.79	-1.85	3.33	
	programLachlan	0.50	-1.58	2.49	
	programLower Murray	-1.65	-7.15	4.62	
	programMurrumbidgee	-1.66	-3.67	0.21	
Eastern gambusia	(Intercept)	28.60	-6.28	67.85	
	baseflow_sep_mar	-0.36	-1.06	0.26	
	small_fresh_sep_mar	-1.39	-4.51	1.80	
	large_fresh_sep_mar	3.61	-0.29	7.48	
	change_72h_sep_mar	-0.00	-0.01	0.00	
	n_sites	-10.75	-27.29	5.92	
	programGoulburn	-3.78	-8.56	-0.46	*
	programGwydir	1.75	-0.97	4.48	
	programLachlan	2.33	0.13	4.82	*
	programLower Murray	-3.87	-13.40	4.52	
	programMurrumbidgee	0.37	-1.70	2.45	
Carp gudgeon	(Intercept)	8.97	-10.92	28.83	
	baseflow_sep_mar	-0.10	-0.40	0.17	
	small_fresh_sep_mar	0.05	-1.71	1.80	
	large_fresh_sep_mar	0.26	-2.13	2.82	
	change_72h_sep_mar	0.00	-0.00	0.00	
	n_sites	-0.58	-9.81	7.91	
	programGoulburn	-2.13	-3.48	-0.83	*
	programGwydir	-0.78	-2.25	0.75	
	programLachlan	-1.03	-2.38	0.28	
	programLower Murray	0.42	-3.19	4.86	
	programMurrumbidgee	-1.23	-2.54	0.01	
Australian smelt	(Intercept)	16.45	-35.96	67.94	
	baseflow_sep_mar	-0.29	-1.21	0.57	
	small_fresh_sep_mar	7.03	2.56	11.32	*
	large_fresh_sep_mar	-3.68	-8.42	1.31	
	change_72h_sep_mar	-0.00	-0.01	0.01	
	n_sites	-5.76	-28.46	15.65	
	programGoulburn	1.02	-1.59	3.62	
	programGwydir	-0.47	-3.53	3.19	
	programLachlan	-2.46	-5.40	0.49	
	programLower Murray	-7.50	-17.92	1.96	
	programMurrumbidgee	0.86	-1.39	3.10	

A.2.4 Catch curve regression (analysis_id catchCurveAge)

Table A.4 Statistical results for Bony herring catch curve model

* indicates C95%CrI does not include 0

speciesname	term	estimate	lower	upper	sig
Bony herring	(Intercept)	2.72	1.66	3.80	*
	age	-0.67	-0.82	-0.55	*
	programGoulburn	-7.52	-15.35	-2.83	*
	programGwydir	1.79	0.73	2.89	*
	programLachlan	-1.01	-2.17	0.10	
	programLower Murray	0.34	-0.73	1.44	
	programMurrumbidgee	-1.62	-2.87	-0.40	*
	b[(Intercept) program:birthyear:Edward-Wakool:2003]	-0.00	-0.79	0.79	
	b[(Intercept) program:birthyear:Edward-Wakool:2004]	-0.01	-0.85	0.83	
	b[(Intercept) program:birthyear:Edward-Wakool:2005]	-0.01	-0.85	0.76	
	b[(Intercept) program:birthyear:Edward-Wakool:2006]	-0.02	-0.87	0.78	
	b[(Intercept) program:birthyear:Edward-Wakool:2007]	-0.02	-0.87	0.77	
	b[(Intercept) program:birthyear:Edward-Wakool:2008]	-0.05	-0.92	0.72	
	b[(Intercept) program:birthyear:Edward-Wakool:2009]	-0.06	-0.94	0.68	
	b[(Intercept) program:birthyear:Edward-Wakool:2010]	-0.09	-1.03	0.57	
	b[(Intercept) program:birthyear:Edward-Wakool:2011]	0.05	-0.65	0.89	
	b[(Intercept) program:birthyear:Edward-Wakool:2012]	0.07	-0.63	0.89	
	b[(Intercept) program:birthyear:Edward-Wakool:2013]	0.18	-0.40	1.22	
	b[(Intercept) program:birthyear:Goulburn:2003]	0.00	-0.84	0.84	
	b[(Intercept) program:birthyear:Goulburn:2004]	-0.00	-0.80	0.85	
	b[(Intercept) program:birthyear:Goulburn:2005]	-0.00	-0.85	0.82	
	b[(Intercept) program:birthyear:Goulburn:2006]	0.00	-0.83	0.82	
	b[(Intercept) program:birthyear:Goulburn:2007]	-0.01	-0.90	0.75	
	b[(Intercept) program:birthyear:Goulburn:2008]	0.01	-0.75	0.79	
	b[(Intercept) program:birthyear:Goulburn:2009]	0.01	-0.77	0.87	
	b[(Intercept) program:birthyear:Goulburn:2010]	0.00	-0.82	0.80	
	b[(Intercept) program:birthyear:Goulburn:2011]	-0.01	-0.81	0.80	
	b[(Intercept) program:birthyear:Goulburn:2012]	-0.00	-0.81	0.78	
	b[(Intercept) program:birthyear:Goulburn:2013]	0.00	-0.80	0.78	
	b[(Intercept) program:birthyear:Goulburn:2014]	-0.01	-0.87	0.79	
	b[(Intercept) program:birthyear:Goulburn:2015]	-0.01	-0.83	0.81	
	b[(Intercept) program:birthyear:Goulburn:2016]	0.00	-0.83	0.87	
	b[(Intercept) program:birthyear:Gwydir:2003]	-0.01	-0.88	0.82	
	b[(Intercept) program:birthyear:Gwydir:2004]	0.22	-0.43	1.35	
	b[(Intercept) program:birthyear:Gwydir:2005]	-0.05	-0.86	0.70	
	b[(Intercept) program:birthyear:Gwydir:2006]	-0.07	-0.93	0.61	
	b[(Intercept) program:birthyear:Gwydir:2007]	-0.04	-0.87	0.62	
	b[(Intercept) program:birthyear:Gwydir:2008]	-0.17	-1.14	0.42	
	b[(Intercept) program:birthyear:Gwydir:2009]	-0.09	-0.88	0.54	
	b[(Intercept) program:birthyear:Gwydir:2010]	0.33	-0.17	1.33	
	b[(Intercept) program:birthyear:Gwydir:2011]	-0.01	-0.66	0.63	
	b[(Intercept) program:birthyear:Gwydir:2012]	-0.06	-0.75	0.54	
	b[(Intercept) program:birthyear:Gwydir:2013]	0.02	-0.58	0.68	
	b[(Intercept) program:birthyear:Gwydir:2014]	-0.01	-0.64	0.60	
	b[(Intercept) program:birthyear:Gwydir:2015]	0.03	-0.59	0.76	
	b[(Intercept) program:birthyear:Gwydir:2016]	-0.05	-0.83	0.66	
	b[(Intercept) program:birthyear:Gwydir:2017]	-0.04	-0.90	0.72	
	b[(Intercept) program:birthyear:Lachlan:2004]	-0.00	-0.79	0.81	
	b[(Intercept) program:birthyear:Lachlan:2005]	-0.00	-0.82	0.78	
	b[(Intercept) program:birthyear:Lachlan:2006]	-0.01	-0.84	0.80	
	b[(Intercept) program:birthyear:Lachlan:2007]	-0.01	-0.83	0.79	
	b[(Intercept) program:birthyear:Lachlan:2008]	-0.01	-0.80	0.79	
	b[(Intercept) program:birthyear:Lachlan:2009]	-0.03	-0.84	0.70	
	b[(Intercept) program:birthyear:Lachlan:2010]	-0.04	-0.89	0.73	

speciesname	term	estimate	lower	upper	sig
	b[(Intercept) program:birthyear:Lachlan:2011]	-0.08	-0.99	0.65	
	b[(Intercept) program:birthyear:Lachlan:2012]	0.14	-0.44	1.04	
	b[(Intercept) program:birthyear:Lachlan:2013]	0.20	-0.33	1.15	
	b[(Intercept) program:birthyear:Lachlan:2014]	-0.02	-0.74	0.67	
	b[(Intercept) program:birthyear:Lachlan:2015]	-0.10	-0.95	0.59	
	b[(Intercept) program:birthyear:Lachlan:2016]	0.10	-0.53	0.93	
	b[(Intercept) program:birthyear:Lachlan:2017]	-0.10	-1.08	0.57	
	b[(Intercept) program:birthyear:Lachlan:2018]	-0.07	-0.94	0.63	
	b[(Intercept) program:birthyear:Lower_Murray:2004]	-0.00	-0.82	0.80	
	b[(Intercept) program:birthyear:Lower_Murray:2005]	-0.00	-0.82	0.79	
	b[(Intercept) program:birthyear:Lower_Murray:2006]	-0.01	-0.83	0.81	
	b[(Intercept) program:birthyear:Lower_Murray:2007]	-0.02	-0.92	0.72	
	b[(Intercept) program:birthyear:Lower_Murray:2008]	-0.04	-0.87	0.71	
	b[(Intercept) program:birthyear:Lower_Murray:2009]	0.06	-0.68	0.88	
	b[(Intercept) program:birthyear:Lower_Murray:2010]	-0.03	-0.82	0.70	
	b[(Intercept) program:birthyear:Lower_Murray:2011]	0.03	-0.62	0.77	
	b[(Intercept) program:birthyear:Lower_Murray:2012]	0.10	-0.49	0.87	
	b[(Intercept) program:birthyear:Lower_Murray:2013]	0.01	-0.67	0.70	
	b[(Intercept) program:birthyear:Lower_Murray:2014]	-0.05	-0.77	0.58	
	b[(Intercept) program:birthyear:Lower_Murray:2015]	0.12	-0.44	0.91	
	b[(Intercept) program:birthyear:Lower_Murray:2016]	-0.00	-0.69	0.70	
	b[(Intercept) program:birthyear:Lower_Murray:2017]	-0.04	-0.83	0.66	
	b[(Intercept) program:birthyear:Lower_Murray:2018]	-0.09	-1.06	0.62	
	b[(Intercept) program:birthyear:Murrumbidgee:2004]	0.00	-0.80	0.82	
	b[(Intercept) program:birthyear:Murrumbidgee:2005]	-0.01	-0.86	0.79	
	b[(Intercept) program:birthyear:Murrumbidgee:2006]	0.00	-0.82	0.83	
	b[(Intercept) program:birthyear:Murrumbidgee:2007]	-0.01	-0.87	0.74	
	b[(Intercept) program:birthyear:Murrumbidgee:2008]	-0.02	-0.88	0.76	
	b[(Intercept) program:birthyear:Murrumbidgee:2009]	-0.02	-0.91	0.77	
	b[(Intercept) program:birthyear:Murrumbidgee:2010]	-0.03	-0.84	0.71	
	b[(Intercept) program:birthyear:Murrumbidgee:2011]	-0.04	-0.89	0.67	
	b[(Intercept) program:birthyear:Murrumbidgee:2012]	0.08	-0.58	1.00	
	b[(Intercept) program:birthyear:Murrumbidgee:2013]	0.36	-0.19	1.61	
	b[(Intercept) program:birthyear:Murrumbidgee:2014]	-0.11	-1.01	0.57	
	b[(Intercept) program:birthyear:Murrumbidgee:2015]	-0.10	-1.00	0.57	
	b[(Intercept) program:birthyear:Murrumbidgee:2016]	-0.09	-0.99	0.65	
	b[(Intercept) program:birthyear:Murrumbidgee:2017]	-0.08	-0.97	0.60	
	b[(Intercept) program:birthyear:Murrumbidgee:2018]	0.02	-0.75	0.86	
	reciprocal_dispersion	0.71	0.44	1.12	*
	Sigma[program:birthyear:(Intercept),(Intercept)]	0.15	0.00	0.68	*
	mean_PPD	1.46	0.80	2.64	*
	log-posterior	-369.10	-385.71	-354.13	*

Table A.5 Statistical results for Murray cod catch curve model

* indicates C95%CrI does not include 0

speciesname	term	estimate	lower	upper	sig
Murray cod	(Intercept)	-1.14	-4.01	1.50	
	age	-0.24	-0.34	-0.16	*
	programGoulburn	1.78	-0.91	4.81	
	programGwydir	-3.87	-10.46	0.78	
	programLachlan	2.11	-0.40	5.02	
	programLower Murray	-3.84	-9.97	0.70	
	programMurrumbidgee	1.78	-0.79	4.77	
	b[(Intercept) program:birthyear:Edward-Wakool:1973]	-0.00	-0.21	0.19	
	b[(Intercept) program:birthyear:Edward-Wakool:1974]	0.00	-0.20	0.22	
	b[(Intercept) program:birthyear:Edward-Wakool:1975]	-0.00	-0.20	0.20	
	b[(Intercept) program:birthyear:Edward-Wakool:1976]	0.00	-0.21	0.21	
	b[(Intercept) program:birthyear:Edward-Wakool:1977]	0.00	-0.20	0.21	
	b[(Intercept) program:birthyear:Edward-Wakool:1978]	-0.00	-0.21	0.19	
	b[(Intercept) program:birthyear:Edward-Wakool:1979]	0.00	-0.20	0.22	
	b[(Intercept) program:birthyear:Edward-Wakool:1980]	0.00	-0.20	0.21	
	b[(Intercept) program:birthyear:Edward-Wakool:1981]	0.00	-0.20	0.23	
	b[(Intercept) program:birthyear:Edward-Wakool:1982]	-0.00	-0.21	0.21	
	b[(Intercept) program:birthyear:Edward-Wakool:1983]	0.00	-0.19	0.21	
	b[(Intercept) program:birthyear:Edward-Wakool:1984]	0.00	-0.19	0.22	
	b[(Intercept) program:birthyear:Edward-Wakool:1985]	-0.00	-0.19	0.18	
	b[(Intercept) program:birthyear:Edward-Wakool:1986]	0.00	-0.20	0.21	
	b[(Intercept) program:birthyear:Edward-Wakool:1987]	0.00	-0.20	0.20	
	b[(Intercept) program:birthyear:Edward-Wakool:1988]	-0.00	-0.22	0.20	
	b[(Intercept) program:birthyear:Edward-Wakool:1989]	0.00	-0.21	0.20	
	b[(Intercept) program:birthyear:Edward-Wakool:1990]	-0.00	-0.21	0.21	
	b[(Intercept) program:birthyear:Edward-Wakool:1991]	0.00	-0.20	0.22	
	b[(Intercept) program:birthyear:Edward-Wakool:1992]	-0.00	-0.21	0.21	
	b[(Intercept) program:birthyear:Edward-Wakool:1993]	0.00	-0.19	0.21	
	b[(Intercept) program:birthyear:Edward-Wakool:1994]	-0.00	-0.22	0.18	
	b[(Intercept) program:birthyear:Edward-Wakool:1995]	-0.00	-0.22	0.21	
	b[(Intercept) program:birthyear:Edward-Wakool:1996]	-0.00	-0.22	0.19	
	b[(Intercept) program:birthyear:Edward-Wakool:1997]	-0.00	-0.22	0.21	
	b[(Intercept) program:birthyear:Edward-Wakool:1998]	0.00	-0.20	0.20	
	b[(Intercept) program:birthyear:Edward-Wakool:1999]	-0.00	-0.22	0.19	
	b[(Intercept) program:birthyear:Edward-Wakool:2000]	-0.00	-0.21	0.22	
	b[(Intercept) program:birthyear:Edward-Wakool:2001]	0.00	-0.19	0.21	
	b[(Intercept) program:birthyear:Edward-Wakool:2002]	0.00	-0.22	0.21	
	b[(Intercept) program:birthyear:Edward-Wakool:2003]	0.01	-0.19	0.24	
	b[(Intercept) program:birthyear:Edward-Wakool:2004]	-0.00	-0.21	0.21	
	b[(Intercept) program:birthyear:Edward-Wakool:2005]	-0.00	-0.22	0.20	
	b[(Intercept) program:birthyear:Edward-Wakool:2006]	0.00	-0.20	0.20	
	b[(Intercept) program:birthyear:Edward-Wakool:2007]	-0.00	-0.22	0.20	
	b[(Intercept) program:birthyear:Edward-Wakool:2008]	-0.00	-0.20	0.22	
	b[(Intercept) program:birthyear:Edward-Wakool:2009]	-0.00	-0.24	0.22	
	b[(Intercept) program:birthyear:Edward-Wakool:2010]	-0.00	-0.22	0.21	
	b[(Intercept) program:birthyear:Edward-Wakool:2011]	-0.00	-0.20	0.19	
	b[(Intercept) program:birthyear:Goulburn:1973]	0.00	-0.21	0.23	
	b[(Intercept) program:birthyear:Goulburn:1974]	0.01	-0.17	0.23	
	b[(Intercept) program:birthyear:Goulburn:1975]	0.00	-0.22	0.22	
	b[(Intercept) program:birthyear:Goulburn:1976]	0.00	-0.21	0.21	
	b[(Intercept) program:birthyear:Goulburn:1977]	-0.00	-0.21	0.20	
	b[(Intercept) program:birthyear:Goulburn:1978]	-0.00	-0.21	0.19	
	b[(Intercept) program:birthyear:Goulburn:1979]	-0.00	-0.20	0.20	
	b[(Intercept) program:birthyear:Goulburn:1980]	0.00	-0.21	0.20	
	b[(Intercept) program:birthyear:Goulburn:1981]	-0.00	-0.21	0.21	
	b[(Intercept) program:birthyear:Goulburn:1982]	-0.00	-0.22	0.20	

speciesname	term	estimate	lower	upper	sig
	b[(Intercept) program:birthyear:Goulburn:1983]	-0.00	-0.20	0.20	
	b[(Intercept) program:birthyear:Goulburn:1984]	0.00	-0.20	0.21	
	b[(Intercept) program:birthyear:Goulburn:1985]	0.00	-0.21	0.22	
	b[(Intercept) program:birthyear:Goulburn:1986]	0.00	-0.22	0.20	
	b[(Intercept) program:birthyear:Goulburn:1987]	0.00	-0.20	0.21	
	b[(Intercept) program:birthyear:Goulburn:1988]	0.00	-0.20	0.21	
	b[(Intercept) program:birthyear:Goulburn:1989]	-0.00	-0.23	0.21	
	b[(Intercept) program:birthyear:Goulburn:1990]	-0.00	-0.21	0.19	
	b[(Intercept) program:birthyear:Goulburn:1991]	0.00	-0.21	0.22	
	b[(Intercept) program:birthyear:Goulburn:1992]	0.00	-0.20	0.20	
	b[(Intercept) program:birthyear:Goulburn:1993]	-0.00	-0.21	0.20	
	b[(Intercept) program:birthyear:Goulburn:1994]	-0.00	-0.20	0.21	
	b[(Intercept) program:birthyear:Goulburn:1995]	-0.00	-0.21	0.21	
	b[(Intercept) program:birthyear:Goulburn:1996]	-0.00	-0.21	0.19	
	b[(Intercept) program:birthyear:Goulburn:1997]	-0.00	-0.20	0.20	
	b[(Intercept) program:birthyear:Goulburn:1998]	-0.00	-0.22	0.18	
	b[(Intercept) program:birthyear:Goulburn:1999]	-0.00	-0.20	0.20	
	b[(Intercept) program:birthyear:Goulburn:2000]	-0.00	-0.21	0.20	
	b[(Intercept) program:birthyear:Goulburn:2001]	-0.00	-0.22	0.21	
	b[(Intercept) program:birthyear:Goulburn:2002]	-0.00	-0.21	0.18	
	b[(Intercept) program:birthyear:Goulburn:2003]	-0.00	-0.22	0.20	
	b[(Intercept) program:birthyear:Goulburn:2004]	-0.00	-0.21	0.21	
	b[(Intercept) program:birthyear:Goulburn:2005]	-0.00	-0.21	0.20	
	b[(Intercept) program:birthyear:Goulburn:2006]	0.00	-0.21	0.24	
	b[(Intercept) program:birthyear:Goulburn:2007]	0.00	-0.19	0.21	
	b[(Intercept) program:birthyear:Goulburn:2008]	0.01	-0.19	0.23	
	b[(Intercept) program:birthyear:Goulburn:2009]	0.00	-0.20	0.20	
	b[(Intercept) program:birthyear:Goulburn:2010]	0.00	-0.19	0.23	
	b[(Intercept) program:birthyear:Goulburn:2011]	-0.00	-0.20	0.20	
	b[(Intercept) program:birthyear:Goulburn:2012]	-0.00	-0.22	0.20	
	b[(Intercept) program:birthyear:Goulburn:2013]	-0.00	-0.20	0.19	
	b[(Intercept) program:birthyear:Goulburn:2014]	-0.00	-0.21	0.20	
	b[(Intercept) program:birthyear:Gwydir:1973]	0.00	-0.21	0.21	
	b[(Intercept) program:birthyear:Gwydir:1974]	0.00	-0.20	0.23	
	b[(Intercept) program:birthyear:Gwydir:1975]	0.00	-0.20	0.21	
	b[(Intercept) program:birthyear:Gwydir:1976]	0.00	-0.19	0.19	
	b[(Intercept) program:birthyear:Gwydir:1977]	-0.00	-0.23	0.20	
	b[(Intercept) program:birthyear:Gwydir:1978]	0.00	-0.22	0.21	
	b[(Intercept) program:birthyear:Gwydir:1979]	0.00	-0.20	0.21	
	b[(Intercept) program:birthyear:Gwydir:1980]	0.00	-0.20	0.21	
	b[(Intercept) program:birthyear:Gwydir:1981]	0.00	-0.20	0.20	
	b[(Intercept) program:birthyear:Gwydir:1982]	0.00	-0.20	0.20	
	b[(Intercept) program:birthyear:Gwydir:1983]	-0.00	-0.20	0.20	
	b[(Intercept) program:birthyear:Gwydir:1984]	-0.00	-0.22	0.20	
	b[(Intercept) program:birthyear:Gwydir:1985]	0.00	-0.19	0.22	
	b[(Intercept) program:birthyear:Gwydir:1986]	-0.00	-0.20	0.20	
	b[(Intercept) program:birthyear:Gwydir:1987]	-0.00	-0.20	0.19	
	b[(Intercept) program:birthyear:Gwydir:1988]	-0.00	-0.19	0.20	
	b[(Intercept) program:birthyear:Gwydir:1989]	-0.00	-0.23	0.19	
	b[(Intercept) program:birthyear:Gwydir:1990]	0.00	-0.22	0.21	
	b[(Intercept) program:birthyear:Gwydir:1991]	-0.00	-0.21	0.19	
	b[(Intercept) program:birthyear:Gwydir:1992]	0.00	-0.19	0.20	
	b[(Intercept) program:birthyear:Gwydir:1993]	0.00	-0.20	0.20	
	b[(Intercept) program:birthyear:Gwydir:1994]	0.00	-0.21	0.22	
	b[(Intercept) program:birthyear:Gwydir:1995]	0.00	-0.20	0.19	
	b[(Intercept) program:birthyear:Gwydir:1996]	0.00	-0.21	0.22	
	b[(Intercept) program:birthyear:Gwydir:1997]	-0.00	-0.21	0.20	
	b[(Intercept) program:birthyear:Gwydir:1998]	0.00	-0.22	0.22	
	b[(Intercept) program:birthyear:Gwydir:1999]	0.00	-0.19	0.20	

speciesname	term	estimate	lower	upper	sig
	b[(Intercept) program:birthyear:Gwydir:2000]	-0.00	-0.23	0.21	
	b[(Intercept) program:birthyear:Gwydir:2001]	-0.00	-0.21	0.20	
	b[(Intercept) program:birthyear:Gwydir:2002]	0.00	-0.20	0.21	
	b[(Intercept) program:birthyear:Gwydir:2003]	-0.00	-0.21	0.19	
	b[(Intercept) program:birthyear:Gwydir:2004]	0.00	-0.20	0.20	
	b[(Intercept) program:birthyear:Gwydir:2005]	-0.00	-0.21	0.21	
	b[(Intercept) program:birthyear:Gwydir:2006]	0.00	-0.19	0.19	
	b[(Intercept) program:birthyear:Gwydir:2007]	-0.00	-0.21	0.20	
	b[(Intercept) program:birthyear:Gwydir:2008]	0.00	-0.20	0.21	
	b[(Intercept) program:birthyear:Gwydir:2009]	0.00	-0.20	0.21	
	b[(Intercept) program:birthyear:Gwydir:2010]	-0.00	-0.22	0.18	
	b[(Intercept) program:birthyear:Gwydir:2011]	-0.00	-0.21	0.22	
	b[(Intercept) program:birthyear:Gwydir:2012]	0.00	-0.21	0.22	
	b[(Intercept) program:birthyear:Gwydir:2013]	-0.00	-0.20	0.20	
	b[(Intercept) program:birthyear:Gwydir:2014]	0.00	-0.19	0.20	
	b[(Intercept) program:birthyear:Gwydir:2015]	0.00	-0.19	0.21	
	b[(Intercept) program:birthyear:Lachlan:1974]	-0.00	-0.20	0.20	
	b[(Intercept) program:birthyear:Lachlan:1975]	0.00	-0.20	0.21	
	b[(Intercept) program:birthyear:Lachlan:1976]	-0.00	-0.23	0.21	
	b[(Intercept) program:birthyear:Lachlan:1977]	0.00	-0.20	0.21	
	b[(Intercept) program:birthyear:Lachlan:1978]	0.00	-0.21	0.21	
	b[(Intercept) program:birthyear:Lachlan:1979]	0.00	-0.21	0.21	
	b[(Intercept) program:birthyear:Lachlan:1980]	-0.00	-0.20	0.19	
	b[(Intercept) program:birthyear:Lachlan:1981]	0.00	-0.20	0.21	
	b[(Intercept) program:birthyear:Lachlan:1982]	0.00	-0.20	0.22	
	b[(Intercept) program:birthyear:Lachlan:1983]	-0.00	-0.21	0.21	
	b[(Intercept) program:birthyear:Lachlan:1984]	0.00	-0.19	0.21	
	b[(Intercept) program:birthyear:Lachlan:1985]	-0.00	-0.22	0.21	
	b[(Intercept) program:birthyear:Lachlan:1986]	0.00	-0.18	0.21	
	b[(Intercept) program:birthyear:Lachlan:1987]	-0.00	-0.21	0.21	
	b[(Intercept) program:birthyear:Lachlan:1988]	-0.00	-0.20	0.20	
	b[(Intercept) program:birthyear:Lachlan:1989]	0.00	-0.20	0.22	
	b[(Intercept) program:birthyear:Lachlan:1990]	-0.00	-0.21	0.19	
	b[(Intercept) program:birthyear:Lachlan:1991]	0.00	-0.21	0.22	
	b[(Intercept) program:birthyear:Lachlan:1992]	-0.00	-0.20	0.21	
	b[(Intercept) program:birthyear:Lachlan:1993]	-0.00	-0.20	0.19	
	b[(Intercept) program:birthyear:Lachlan:1994]	-0.00	-0.23	0.19	
	b[(Intercept) program:birthyear:Lachlan:1995]	-0.00	-0.22	0.21	
	b[(Intercept) program:birthyear:Lachlan:1996]	-0.00	-0.22	0.20	
	b[(Intercept) program:birthyear:Lachlan:1997]	-0.00	-0.21	0.19	
	b[(Intercept) program:birthyear:Lachlan:1998]	-0.00	-0.21	0.20	
	b[(Intercept) program:birthyear:Lachlan:1999]	-0.00	-0.21	0.21	
	b[(Intercept) program:birthyear:Lachlan:2000]	-0.00	-0.21	0.20	
	b[(Intercept) program:birthyear:Lachlan:2001]	-0.00	-0.22	0.22	
	b[(Intercept) program:birthyear:Lachlan:2002]	-0.00	-0.23	0.19	
	b[(Intercept) program:birthyear:Lachlan:2003]	-0.00	-0.22	0.20	
	b[(Intercept) program:birthyear:Lachlan:2004]	-0.00	-0.22	0.19	
	b[(Intercept) program:birthyear:Lachlan:2005]	0.01	-0.17	0.25	
	b[(Intercept) program:birthyear:Lachlan:2006]	-0.00	-0.21	0.19	
	b[(Intercept) program:birthyear:Lachlan:2007]	0.01	-0.15	0.23	
	b[(Intercept) program:birthyear:Lachlan:2008]	0.01	-0.17	0.24	
	b[(Intercept) program:birthyear:Lachlan:2009]	-0.00	-0.20	0.20	
	b[(Intercept) program:birthyear:Lachlan:2010]	0.01	-0.17	0.23	
	b[(Intercept) program:birthyear:Lachlan:2011]	-0.00	-0.22	0.19	
	b[(Intercept) program:birthyear:Lachlan:2012]	-0.01	-0.23	0.19	
	b[(Intercept) program:birthyear:Lachlan:2013]	-0.00	-0.22	0.19	
	b[(Intercept) program:birthyear:Lachlan:2014]	0.00	-0.20	0.21	
	b[(Intercept) program:birthyear:Lachlan:2015]	-0.00	-0.22	0.22	
	b[(Intercept) program:birthyear:Lachlan:2016]	0.00	-0.21	0.21	

speciesname	term	estimate	lower	upper	sig
	b[(Intercept) program:birthyear:Lower_Murray:1974]	0.00	-0.20	0.22	
	b[(Intercept) program:birthyear:Lower_Murray:1975]	0.00	-0.21	0.22	
	b[(Intercept) program:birthyear:Lower_Murray:1976]	-0.00	-0.21	0.21	
	b[(Intercept) program:birthyear:Lower_Murray:1977]	0.00	-0.20	0.21	
	b[(Intercept) program:birthyear:Lower_Murray:1978]	-0.00	-0.20	0.21	
	b[(Intercept) program:birthyear:Lower_Murray:1979]	-0.00	-0.21	0.19	
	b[(Intercept) program:birthyear:Lower_Murray:1980]	-0.00	-0.21	0.21	
	b[(Intercept) program:birthyear:Lower_Murray:1981]	-0.00	-0.22	0.21	
	b[(Intercept) program:birthyear:Lower_Murray:1982]	-0.00	-0.20	0.20	
	b[(Intercept) program:birthyear:Lower_Murray:1983]	-0.00	-0.20	0.21	
	b[(Intercept) program:birthyear:Lower_Murray:1984]	-0.00	-0.21	0.20	
	b[(Intercept) program:birthyear:Lower_Murray:1985]	-0.00	-0.22	0.20	
	b[(Intercept) program:birthyear:Lower_Murray:1986]	0.00	-0.18	0.20	
	b[(Intercept) program:birthyear:Lower_Murray:1987]	0.00	-0.20	0.20	
	b[(Intercept) program:birthyear:Lower_Murray:1988]	0.00	-0.20	0.20	
	b[(Intercept) program:birthyear:Lower_Murray:1989]	0.00	-0.20	0.21	
	b[(Intercept) program:birthyear:Lower_Murray:1990]	0.00	-0.21	0.22	
	b[(Intercept) program:birthyear:Lower_Murray:1991]	-0.00	-0.22	0.21	
	b[(Intercept) program:birthyear:Lower_Murray:1992]	0.00	-0.21	0.22	
	b[(Intercept) program:birthyear:Lower_Murray:1993]	0.00	-0.20	0.21	
	b[(Intercept) program:birthyear:Lower_Murray:1994]	0.00	-0.22	0.19	
	b[(Intercept) program:birthyear:Lower_Murray:1995]	-0.00	-0.23	0.21	
	b[(Intercept) program:birthyear:Lower_Murray:1996]	-0.00	-0.22	0.20	
	b[(Intercept) program:birthyear:Lower_Murray:1997]	-0.00	-0.20	0.19	
	b[(Intercept) program:birthyear:Lower_Murray:1998]	0.00	-0.20	0.24	
	b[(Intercept) program:birthyear:Lower_Murray:1999]	-0.00	-0.22	0.18	
	b[(Intercept) program:birthyear:Lower_Murray:2000]	-0.00	-0.21	0.21	
	b[(Intercept) program:birthyear:Lower_Murray:2001]	-0.00	-0.20	0.21	
	b[(Intercept) program:birthyear:Lower_Murray:2002]	0.00	-0.20	0.22	
	b[(Intercept) program:birthyear:Lower_Murray:2003]	-0.00	-0.22	0.21	
	b[(Intercept) program:birthyear:Lower_Murray:2004]	-0.00	-0.22	0.20	
	b[(Intercept) program:birthyear:Lower_Murray:2005]	-0.00	-0.21	0.20	
	b[(Intercept) program:birthyear:Lower_Murray:2006]	-0.00	-0.20	0.21	
	b[(Intercept) program:birthyear:Lower_Murray:2007]	-0.00	-0.20	0.21	
	b[(Intercept) program:birthyear:Lower_Murray:2008]	0.00	-0.21	0.20	
	b[(Intercept) program:birthyear:Lower_Murray:2009]	0.00	-0.19	0.20	
	b[(Intercept) program:birthyear:Lower_Murray:2010]	-0.00	-0.20	0.20	
	b[(Intercept) program:birthyear:Lower_Murray:2011]	-0.00	-0.21	0.20	
	b[(Intercept) program:birthyear:Lower_Murray:2012]	-0.00	-0.22	0.21	
	b[(Intercept) program:birthyear:Lower_Murray:2013]	0.00	-0.21	0.21	
	b[(Intercept) program:birthyear:Lower_Murray:2014]	-0.00	-0.22	0.19	
	b[(Intercept) program:birthyear:Lower_Murray:2015]	0.00	-0.20	0.22	
	b[(Intercept) program:birthyear:Lower_Murray:2016]	0.00	-0.20	0.20	
	b[(Intercept) program:birthyear:Murrumbidgee:1974]	-0.00	-0.22	0.22	
	b[(Intercept) program:birthyear:Murrumbidgee:1975]	-0.00	-0.23	0.20	
	b[(Intercept) program:birthyear:Murrumbidgee:1976]	-0.00	-0.22	0.19	
	b[(Intercept) program:birthyear:Murrumbidgee:1977]	0.00	-0.20	0.21	
	b[(Intercept) program:birthyear:Murrumbidgee:1978]	-0.00	-0.21	0.20	
	b[(Intercept) program:birthyear:Murrumbidgee:1979]	-0.00	-0.22	0.19	
	b[(Intercept) program:birthyear:Murrumbidgee:1980]	-0.00	-0.21	0.20	
	b[(Intercept) program:birthyear:Murrumbidgee:1981]	0.00	-0.20	0.20	
	b[(Intercept) program:birthyear:Murrumbidgee:1982]	-0.00	-0.21	0.18	
	b[(Intercept) program:birthyear:Murrumbidgee:1983]	0.00	-0.21	0.22	
	b[(Intercept) program:birthyear:Murrumbidgee:1984]	-0.00	-0.21	0.20	
	b[(Intercept) program:birthyear:Murrumbidgee:1985]	-0.00	-0.21	0.20	
	b[(Intercept) program:birthyear:Murrumbidgee:1986]	-0.00	-0.22	0.20	
	b[(Intercept) program:birthyear:Murrumbidgee:1987]	-0.00	-0.22	0.19	
	b[(Intercept) program:birthyear:Murrumbidgee:1988]	-0.00	-0.21	0.20	
	b[(Intercept) program:birthyear:Murrumbidgee:1989]	0.00	-0.19	0.21	

speciesname	term	estimate	lower	upper	sig
	b[(Intercept) program:birthyear:Murrumbidgee:1990]	0.00	-0.20	0.21	
	b[(Intercept) program:birthyear:Murrumbidgee:1991]	0.00	-0.20	0.20	
	b[(Intercept) program:birthyear:Murrumbidgee:1992]	-0.00	-0.19	0.20	
	b[(Intercept) program:birthyear:Murrumbidgee:1993]	-0.00	-0.21	0.19	
	b[(Intercept) program:birthyear:Murrumbidgee:1994]	-0.00	-0.22	0.20	
	b[(Intercept) program:birthyear:Murrumbidgee:1995]	-0.00	-0.21	0.21	
	b[(Intercept) program:birthyear:Murrumbidgee:1996]	-0.00	-0.20	0.19	
	b[(Intercept) program:birthyear:Murrumbidgee:1997]	0.00	-0.20	0.21	
	b[(Intercept) program:birthyear:Murrumbidgee:1998]	-0.00	-0.21	0.21	
	b[(Intercept) program:birthyear:Murrumbidgee:1999]	-0.00	-0.24	0.19	
	b[(Intercept) program:birthyear:Murrumbidgee:2000]	0.00	-0.20	0.20	
	b[(Intercept) program:birthyear:Murrumbidgee:2001]	0.00	-0.20	0.22	
	b[(Intercept) program:birthyear:Murrumbidgee:2002]	-0.00	-0.22	0.19	
	b[(Intercept) program:birthyear:Murrumbidgee:2003]	-0.00	-0.21	0.19	
	b[(Intercept) program:birthyear:Murrumbidgee:2004]	0.00	-0.20	0.22	
	b[(Intercept) program:birthyear:Murrumbidgee:2005]	-0.00	-0.22	0.20	
	b[(Intercept) program:birthyear:Murrumbidgee:2006]	0.00	-0.19	0.25	
	b[(Intercept) program:birthyear:Murrumbidgee:2007]	-0.01	-0.23	0.20	
	b[(Intercept) program:birthyear:Murrumbidgee:2008]	0.01	-0.18	0.24	
	b[(Intercept) program:birthyear:Murrumbidgee:2009]	0.00	-0.19	0.22	
	b[(Intercept) program:birthyear:Murrumbidgee:2010]	0.01	-0.18	0.22	
	b[(Intercept) program:birthyear:Murrumbidgee:2011]	-0.00	-0.24	0.20	
	b[(Intercept) program:birthyear:Murrumbidgee:2012]	-0.00	-0.21	0.19	
	b[(Intercept) program:birthyear:Murrumbidgee:2013]	-0.00	-0.22	0.18	
	b[(Intercept) program:birthyear:Murrumbidgee:2014]	-0.00	-0.21	0.20	
	b[(Intercept) program:birthyear:Murrumbidgee:2015]	-0.00	-0.20	0.21	
	b[(Intercept) program:birthyear:Murrumbidgee:2016]	-0.00	-0.22	0.21	
	reciprocal_dispersion	0.07	0.04	0.13	*
	Sigma[program:birthyear:(Intercept),(Intercept)]	0.01	0.00	0.07	*
	mean_PPD	0.08	0.02	0.16	*
	log-posterior	-501.29	-524.76	-479.50	*

Table A-6 Statistical results for Golden perch catch curve model

* indicates C95%CrI does not include 0.

speciesname	term	estimate	lower	upper	sig
Golden perch	(Intercept)	1.42	0.32	2.55	*
	age	-0.25	-0.30	-0.20	*
	programGoulburn	1.05	-0.20	2.32	
	programGwydir	0.37	-0.84	1.62	
	programLachlan	-0.91	-2.19	0.37	
	programLower Murray	1.83	0.65	3.05	*
	programMurrumbidgee	0.43	-0.74	1.65	
	b[(Intercept) program:birthyear:Edward-Wakool:1990]	-0.02	-2.30	2.23	
	b[(Intercept) program:birthyear:Edward-Wakool:1991]	-0.06	-2.28	2.17	
	b[(Intercept) program:birthyear:Edward-Wakool:1992]	-0.08	-2.33	2.11	
	b[(Intercept) program:birthyear:Edward-Wakool:1993]	-0.08	-2.39	2.15	
	b[(Intercept) program:birthyear:Edward-Wakool:1994]	-0.12	-2.33	1.92	
	b[(Intercept) program:birthyear:Edward-Wakool:1995]	-0.11	-2.40	2.05	
	b[(Intercept) program:birthyear:Edward-Wakool:1996]	-0.15	-2.37	2.00	
	b[(Intercept) program:birthyear:Edward-Wakool:1997]	-0.18	-2.43	1.99	
	b[(Intercept) program:birthyear:Edward-Wakool:1998]	-0.17	-2.26	1.80	
	b[(Intercept) program:birthyear:Edward-Wakool:1999]	-0.21	-2.42	1.79	
	b[(Intercept) program:birthyear:Edward-Wakool:2000]	-0.24	-2.39	1.73	
	b[(Intercept) program:birthyear:Edward-Wakool:2001]	-0.30	-2.42	1.76	
	b[(Intercept) program:birthyear:Edward-Wakool:2002]	-0.31	-2.42	1.73	
	b[(Intercept) program:birthyear:Edward-Wakool:2003]	-0.36	-2.49	1.60	
	b[(Intercept) program:birthyear:Edward-Wakool:2004]	-0.38	-2.45	1.62	
	b[(Intercept) program:birthyear:Edward-Wakool:2005]	-0.46	-2.53	1.55	
	b[(Intercept) program:birthyear:Edward-Wakool:2006]	0.03	-1.82	1.95	
	b[(Intercept) program:birthyear:Edward-Wakool:2007]	0.68	-0.92	2.43	
	b[(Intercept) program:birthyear:Edward-Wakool:2008]	0.53	-1.03	2.21	
	b[(Intercept) program:birthyear:Edward-Wakool:2009]	-0.21	-2.02	1.69	
	b[(Intercept) program:birthyear:Edward-Wakool:2010]	0.41	-1.15	2.10	
	b[(Intercept) program:birthyear:Edward-Wakool:2011]	1.64	0.11	3.35	*
	b[(Intercept) program:birthyear:Goulburn:1990]	-0.06	-2.31	2.11	
	b[(Intercept) program:birthyear:Goulburn:1991]	-0.12	-2.30	2.06	
	b[(Intercept) program:birthyear:Goulburn:1992]	-0.20	-2.50	1.95	
	b[(Intercept) program:birthyear:Goulburn:1993]	-0.21	-2.50	1.89	
	b[(Intercept) program:birthyear:Goulburn:1994]	1.51	-0.07	3.17	
	b[(Intercept) program:birthyear:Goulburn:1995]	0.41	-1.41	2.23	
	b[(Intercept) program:birthyear:Goulburn:1996]	0.32	-1.46	2.08	
	b[(Intercept) program:birthyear:Goulburn:1997]	-0.41	-2.47	1.43	
	b[(Intercept) program:birthyear:Goulburn:1998]	0.25	-1.56	2.08	
	b[(Intercept) program:birthyear:Goulburn:1999]	0.54	-1.02	2.18	
	b[(Intercept) program:birthyear:Goulburn:2000]	-0.63	-2.75	1.26	
	b[(Intercept) program:birthyear:Goulburn:2001]	-0.69	-2.61	1.07	
	b[(Intercept) program:birthyear:Goulburn:2002]	-0.75	-2.74	1.08	
	b[(Intercept) program:birthyear:Goulburn:2003]	-0.40	-2.04	1.18	
	b[(Intercept) program:birthyear:Goulburn:2004]	0.96	-0.40	2.42	
	b[(Intercept) program:birthyear:Goulburn:2005]	-0.61	-2.38	1.12	
	b[(Intercept) program:birthyear:Goulburn:2006]	-0.12	-1.58	1.43	
	b[(Intercept) program:birthyear:Goulburn:2007]	0.18	-1.18	1.72	
	b[(Intercept) program:birthyear:Goulburn:2008]	0.33	-1.00	1.78	
	b[(Intercept) program:birthyear:Goulburn:2009]	0.07	-1.27	1.53	
	b[(Intercept) program:birthyear:Goulburn:2010]	0.44	-0.84	1.84	
	b[(Intercept) program:birthyear:Goulburn:2011]	-0.46	-2.03	1.20	
	b[(Intercept) program:birthyear:Goulburn:2012]	-0.84	-2.87	1.20	
	b[(Intercept) program:birthyear:Goulburn:2013]	-0.23	-2.21	1.80	
	b[(Intercept) program:birthyear:Goulburn:2014]	0.75	-0.70	2.51	
	b[(Intercept) program:birthyear:Gwydir:1990]	-0.02	-2.27	2.14	
	b[(Intercept) program:birthyear:Gwydir:1991]	-0.08	-2.35	2.05	

speciesname	term	estimate	lower	upper	sig
	b[(Intercept) program:birthyear:Gwydir:1992]	-0.12	-2.32	1.97	
	b[(Intercept) program:birthyear:Gwydir:1993]	-0.15	-2.34	1.92	
	b[(Intercept) program:birthyear:Gwydir:1994]	-0.20	-2.31	1.80	
	b[(Intercept) program:birthyear:Gwydir:1995]	-0.27	-2.44	1.74	
	b[(Intercept) program:birthyear:Gwydir:1996]	1.04	-0.67	2.85	
	b[(Intercept) program:birthyear:Gwydir:1997]	-0.35	-2.41	1.51	
	b[(Intercept) program:birthyear:Gwydir:1998]	-0.42	-2.43	1.46	
	b[(Intercept) program:birthyear:Gwydir:1999]	-0.49	-2.50	1.42	
	b[(Intercept) program:birthyear:Gwydir:2000]	-0.55	-2.63	1.29	
	b[(Intercept) program:birthyear:Gwydir:2001]	-0.62	-2.60	1.12	
	b[(Intercept) program:birthyear:Gwydir:2002]	-0.70	-2.72	1.12	
	b[(Intercept) program:birthyear:Gwydir:2003]	-0.14	-1.80	1.48	
	b[(Intercept) program:birthyear:Gwydir:2004]	0.89	-0.41	2.32	
	b[(Intercept) program:birthyear:Gwydir:2005]	0.54	-0.79	1.90	
	b[(Intercept) program:birthyear:Gwydir:2006]	0.91	-0.34	2.29	
	b[(Intercept) program:birthyear:Gwydir:2007]	-0.20	-1.72	1.28	
	b[(Intercept) program:birthyear:Gwydir:2008]	0.06	-1.32	1.50	
	b[(Intercept) program:birthyear:Gwydir:2009]	0.40	-0.84	1.70	
	b[(Intercept) program:birthyear:Gwydir:2010]	0.75	-0.46	2.07	
	b[(Intercept) program:birthyear:Gwydir:2011]	-0.17	-1.55	1.25	
	b[(Intercept) program:birthyear:Gwydir:2012]	0.56	-0.79	1.98	
	b[(Intercept) program:birthyear:Gwydir:2013]	0.06	-1.40	1.63	
	b[(Intercept) program:birthyear:Gwydir:2014]	-0.46	-2.29	1.34	
	b[(Intercept) program:birthyear:Gwydir:2015]	-0.42	-2.62	1.68	
	b[(Intercept) program:birthyear:Lachlan:1991]	0.01	-2.24	2.37	
	b[(Intercept) program:birthyear:Lachlan:1992]	-0.00	-2.20	2.30	
	b[(Intercept) program:birthyear:Lachlan:1993]	-0.01	-2.25	2.15	
	b[(Intercept) program:birthyear:Lachlan:1994]	-0.07	-2.42	2.25	
	b[(Intercept) program:birthyear:Lachlan:1995]	-0.07	-2.24	2.04	
	b[(Intercept) program:birthyear:Lachlan:1996]	-0.13	-2.40	2.04	
	b[(Intercept) program:birthyear:Lachlan:1997]	0.84	-1.09	2.86	
	b[(Intercept) program:birthyear:Lachlan:1998]	-0.17	-2.33	1.91	
	b[(Intercept) program:birthyear:Lachlan:1999]	-0.18	-2.33	1.82	
	b[(Intercept) program:birthyear:Lachlan:2000]	-0.22	-2.47	1.83	
	b[(Intercept) program:birthyear:Lachlan:2001]	-0.26	-2.41	1.69	
	b[(Intercept) program:birthyear:Lachlan:2002]	1.39	-0.16	2.97	
	b[(Intercept) program:birthyear:Lachlan:2003]	0.38	-1.48	2.17	
	b[(Intercept) program:birthyear:Lachlan:2004]	-0.40	-2.41	1.40	
	b[(Intercept) program:birthyear:Lachlan:2005]	-0.46	-2.59	1.37	
	b[(Intercept) program:birthyear:Lachlan:2006]	0.82	-0.68	2.38	
	b[(Intercept) program:birthyear:Lachlan:2007]	0.67	-0.81	2.21	
	b[(Intercept) program:birthyear:Lachlan:2008]	0.24	-1.34	1.80	
	b[(Intercept) program:birthyear:Lachlan:2009]	-0.74	-2.73	1.00	
	b[(Intercept) program:birthyear:Lachlan:2010]	0.42	-0.96	1.85	
	b[(Intercept) program:birthyear:Lachlan:2011]	0.98	-0.31	2.34	
	b[(Intercept) program:birthyear:Lachlan:2012]	-0.87	-2.95	0.94	
	b[(Intercept) program:birthyear:Lachlan:2013]	-0.77	-2.79	1.08	
	b[(Intercept) program:birthyear:Lachlan:2014]	-0.66	-2.64	1.18	
	b[(Intercept) program:birthyear:Lachlan:2015]	-0.51	-2.65	1.54	
	b[(Intercept) program:birthyear:Lachlan:2016]	-0.29	-2.51	1.78	
	b[(Intercept) program:birthyear:Lower_Murray:1991]	-0.11	-2.35	2.03	
	b[(Intercept) program:birthyear:Lower_Murray:1992]	-0.18	-2.29	1.86	
	b[(Intercept) program:birthyear:Lower_Murray:1993]	-0.28	-2.33	1.66	
	b[(Intercept) program:birthyear:Lower_Murray:1994]	-0.40	-2.44	1.46	
	b[(Intercept) program:birthyear:Lower_Murray:1995]	-0.51	-2.61	1.41	
	b[(Intercept) program:birthyear:Lower_Murray:1996]	-0.60	-2.57	1.17	
	b[(Intercept) program:birthyear:Lower_Murray:1997]	2.99	1.78	4.38	*
	b[(Intercept) program:birthyear:Lower_Murray:1998]	0.90	-0.49	2.40	
	b[(Intercept) program:birthyear:Lower_Murray:1999]	0.44	-0.95	1.90	

speciesname	term	estimate	lower	upper	sig
	b[(Intercept) program:birthyear:Lower_Murray:2000]	0.15	-1.23	1.61	
	b[(Intercept) program:birthyear:Lower_Murray:2001]	1.90	0.73	3.18	*
	b[(Intercept) program:birthyear:Lower_Murray:2002]	-1.09	-2.97	0.61	
	b[(Intercept) program:birthyear:Lower_Murray:2003]	-0.83	-2.47	0.68	
	b[(Intercept) program:birthyear:Lower_Murray:2004]	-0.31	-1.74	1.21	
	b[(Intercept) program:birthyear:Lower_Murray:2005]	-1.39	-3.27	0.35	
	b[(Intercept) program:birthyear:Lower_Murray:2006]	0.04	-1.19	1.30	
	b[(Intercept) program:birthyear:Lower_Murray:2007]	-0.99	-2.52	0.49	
	b[(Intercept) program:birthyear:Lower_Murray:2008]	-1.43	-3.09	0.16	
	b[(Intercept) program:birthyear:Lower_Murray:2009]	-1.80	-3.56	-0.11	*
	b[(Intercept) program:birthyear:Lower_Murray:2010]	1.60	0.50	2.80	*
	b[(Intercept) program:birthyear:Lower_Murray:2011]	1.88	0.73	3.10	*
	b[(Intercept) program:birthyear:Lower_Murray:2012]	1.08	-0.10	2.37	
	b[(Intercept) program:birthyear:Lower_Murray:2013]	0.20	-1.12	1.67	
	b[(Intercept) program:birthyear:Lower_Murray:2014]	0.25	-1.09	1.87	
	b[(Intercept) program:birthyear:Lower_Murray:2015]	-1.00	-3.20	1.04	
	b[(Intercept) program:birthyear:Lower_Murray:2016]	-0.53	-2.77	1.61	
	b[(Intercept) program:birthyear:Murrumbidgee:1991]	-0.02	-2.27	2.25	
	b[(Intercept) program:birthyear:Murrumbidgee:1992]	-0.12	-2.45	2.00	
	b[(Intercept) program:birthyear:Murrumbidgee:1993]	-0.12	-2.42	1.92	
	b[(Intercept) program:birthyear:Murrumbidgee:1994]	-0.16	-2.32	1.86	
	b[(Intercept) program:birthyear:Murrumbidgee:1995]	-0.22	-2.31	1.80	
	b[(Intercept) program:birthyear:Murrumbidgee:1996]	-0.28	-2.40	1.74	
	b[(Intercept) program:birthyear:Murrumbidgee:1997]	0.50	-1.39	2.36	
	b[(Intercept) program:birthyear:Murrumbidgee:1998]	-0.36	-2.42	1.46	
	b[(Intercept) program:birthyear:Murrumbidgee:1999]	0.32	-1.59	2.09	
	b[(Intercept) program:birthyear:Murrumbidgee:2000]	0.24	-1.53	1.90	
	b[(Intercept) program:birthyear:Murrumbidgee:2001]	0.12	-1.59	1.83	
	b[(Intercept) program:birthyear:Murrumbidgee:2002]	0.03	-1.64	1.67	
	b[(Intercept) program:birthyear:Murrumbidgee:2003]	-0.11	-1.87	1.53	
	b[(Intercept) program:birthyear:Murrumbidgee:2004]	0.77	-0.57	2.20	
	b[(Intercept) program:birthyear:Murrumbidgee:2005]	-0.31	-2.04	1.31	
	b[(Intercept) program:birthyear:Murrumbidgee:2006]	-0.96	-2.95	0.85	
	b[(Intercept) program:birthyear:Murrumbidgee:2007]	0.22	-1.21	1.66	
	b[(Intercept) program:birthyear:Murrumbidgee:2008]	-0.42	-1.95	1.10	
	b[(Intercept) program:birthyear:Murrumbidgee:2009]	0.53	-0.69	1.86	
	b[(Intercept) program:birthyear:Murrumbidgee:2010]	0.86	-0.30	2.13	
	b[(Intercept) program:birthyear:Murrumbidgee:2011]	0.39	-0.86	1.66	
	b[(Intercept) program:birthyear:Murrumbidgee:2012]	0.61	-0.60	1.86	
	b[(Intercept) program:birthyear:Murrumbidgee:2013]	0.23	-1.10	1.70	
	b[(Intercept) program:birthyear:Murrumbidgee:2014]	-0.72	-2.66	1.15	
	b[(Intercept) program:birthyear:Murrumbidgee:2015]	-0.77	-2.85	1.21	
	b[(Intercept) program:birthyear:Murrumbidgee:2016]	-0.45	-2.65	1.71	
	reciprocal_dispersion	0.47	0.32	0.67	*
	Sigma[program:birthyear:(Intercept),(Intercept)]	1.31	0.61	2.32	*
	mean_PPD	1.77	1.04	3.06	*
	log-posterior	-799.59	-825.87	-774.40	*

A.2.5 Adult abundance (analysis_id adultAbund)

Table A-7 Statistical results for adult abundance

* indicates C95%CrI does not include 0.

speciesname	term	estimate	lower	upper	sig
Common carp	(Intercept)	0.81	-2.49	4.36	
	baseflow_water_year	-0.15	-0.49	0.19	
	small_fresh_water_year	-0.11	-0.41	0.16	
	large_fresh_water_year	0.67	0.34	0.99	*
	change_72h_water_year	0.08	-0.27	0.44	
	programGoulburn	0.19	-1.22	1.57	
	programGwydir	0.04	-1.62	1.88	
	programLachlan	0.42	-1.17	2.09	
	programLower Murray	0.22	-1.10	1.45	
	programMurrumbidgee	0.21	-1.25	1.53	
	do_last_year	-0.22	-1.06	0.52	
Eastern gambusia	(Intercept)	-0.55	-6.68	5.34	
	baseflow_water_year	0.01	-0.58	0.61	
	small_fresh_water_year	-0.09	-0.60	0.39	
	large_fresh_water_year	0.15	-0.44	0.74	
	change_72h_water_year	0.05	-0.62	0.70	
	programGoulburn	0.41	-2.10	2.61	
	programGwydir	0.68	-2.14	3.94	
	programLachlan	0.91	-2.04	3.60	
	programLower Murray	0.01	-2.38	2.26	
	programMurrumbidgee	0.23	-2.21	2.65	
	do_last_year	0.46	-0.78	1.87	
Carp gudgeon	(Intercept)	2.31	-3.64	8.36	
	baseflow_water_year	-0.18	-0.80	0.42	
	small_fresh_water_year	-0.12	-0.61	0.40	
	large_fresh_water_year	0.18	-0.38	0.76	
	change_72h_water_year	-0.27	-0.87	0.35	
	programGoulburn	-0.40	-2.81	1.82	
	programGwydir	0.91	-1.99	4.05	
	programLachlan	0.86	-2.07	3.52	
	programLower Murray	-0.49	-2.81	1.74	
	programMurrumbidgee	0.03	-2.52	2.35	
	do_last_year	0.53	-0.66	1.81	
Murray cod	(Intercept)	0.81	-1.65	3.89	
	baseflow_water_year	-0.06	-0.34	0.21	
	small_fresh_water_year	0.06	-0.18	0.29	
	large_fresh_water_year	-0.45	-0.72	-0.18	*
	change_72h_water_year	-0.12	-0.42	0.17	
	programGoulburn	-0.14	-1.39	0.86	
	programGwydir	0.01	-1.38	1.47	
	programLachlan	-0.06	-1.42	1.26	
	programLower Murray	0.22	-0.84	1.26	
	programMurrumbidgee	0.20	-0.98	1.30	
	do_last_year	-0.29	-0.89	0.36	
Golden perch	(Intercept)	0.22	-1.79	2.09	
	baseflow_water_year	-0.01	-0.19	0.19	
	small_fresh_water_year	0.02	-0.15	0.17	
	large_fresh_water_year	-0.16	-0.35	0.02	
	change_72h_water_year	-0.13	-0.33	0.07	
	programGoulburn	-0.02	-0.82	0.71	
	programGwydir	0.38	-0.61	1.35	
	programLachlan	0.14	-0.71	1.07	
	programLower Murray	-0.08	-0.81	0.65	
	programMurrumbidgee	0.08	-0.67	0.86	

speciesname	term	estimate	lower	upper	sig
	do_last_year	0.03	-0.41	0.50	
Bony herring	(Intercept)	2.96	-7.89	13.74	
	baseflow_water_year	-0.18	-1.24	0.94	
	small_fresh_water_year	0.26	-0.44	0.87	
	large_fresh_water_year	-0.29	-0.96	0.34	
	change_72h_water_year	-0.44	-1.31	0.47	
	programGwydir	-0.35	-4.05	3.45	
	programLachlan	-2.11	-5.82	1.38	
	programLower Murray	-1.42	-4.49	1.59	
	programMurrumbidgee	-2.08	-5.41	0.93	
	do_last_year	-0.15	-2.03	1.77	
Australian smelt	(Intercept)	-1.82	-4.41	1.16	
	baseflow_water_year	0.19	-0.09	0.47	
	small_fresh_water_year	-0.26	-0.53	0.04	
	large_fresh_water_year	0.32	-0.02	0.64	
	change_72h_water_year	0.22	-0.09	0.51	
	programGoulburn	0.76	-0.36	1.80	
	programGwydir	0.37	-1.10	1.84	
	programLower Murray	0.47	-0.60	1.56	
	programMurrumbidgee	0.62	-0.61	1.76	
	do_last_year	-0.24	-0.97	0.44	

A.2.6 Body condition (analysis_id bodyCond)

Table A-8 Statistical results for body condition

* indicates C95%CI does not include 0. Note - body condition model was a Frequentist framework.

speciesname	term	estimate	lower	upper	sig
Bony herring	(Intercept)	0.001609	0.000957	0.002262	*
	baseflow_water_year	-0.000012	-0.000079	0.000055	
	small_fresh_water_year	-0.000001	-0.000042	0.000039	
	large_fresh_water_year	-0.000012	-0.000054	0.000030	
	change_72h_water_year	0.000063	0.000006	0.000119	*
	programGoulburn	0.000451	0.000156	0.000746	*
	programGwydir	-0.000024	-0.000273	0.000226	
	programLachlan	0.000198	-0.000024	0.000420	
	programLower Murray	0.000036	-0.000149	0.000222	
	programMurrumbidgee	0.000227	0.000027	0.000428	*
Common carp	(Intercept)	0.002025	0.001535	0.002515	*
	baseflow_water_year	-0.000016	-0.000067	0.000035	
	small_fresh_water_year	0.000018	-0.000007	0.000044	
	large_fresh_water_year	0.000031	0.000006	0.000055	*
	change_72h_water_year	-0.000006	-0.000040	0.000027	
	programGwydir	-0.000058	-0.000204	0.000088	
	programLachlan	-0.000124	-0.000258	0.000010	
	programLower Murray	-0.000631	-0.000996	-0.000266	*
	programMurrumbidgee	-0.000222	-0.000342	-0.000102	*
Murray cod	(Intercept)	0.001398	0.001015	0.001782	*
	baseflow_water_year	-0.000016	-0.000055	0.000023	
	small_fresh_water_year	0.000027	-0.000006	0.000061	
	large_fresh_water_year	0.000018	-0.000022	0.000057	
	change_72h_water_year	-0.000018	-0.000061	0.000025	
	programGoulburn	-0.000112	-0.000266	0.000042	
	programGwydir	-0.000080	-0.000281	0.000121	
	programLachlan	0.000065	-0.000120	0.000250	
	programLower Murray	-0.000104	-0.000252	0.000045	
	programMurrumbidgee	-0.000209	-0.000375	-0.000044	*
Golden perch	(Intercept)	0.001652	0.001320	0.001983	*
	baseflow_water_year	0.000010	-0.000024	0.000044	
	small_fresh_water_year	0.000005	-0.000024	0.000034	
	large_fresh_water_year	0.000031	-0.000002	0.000065	
	change_72h_water_year	0.000008	-0.000030	0.000046	
	programGoulburn	-0.000203	-0.000344	-0.000062	*
	programGwydir	-0.000321	-0.000510	-0.000132	*
	programLachlan	-0.000210	-0.000375	-0.000044	*
	programLower Murray	-0.000413	-0.000544	-0.000282	*
	programMurrumbidgee	-0.000373	-0.000524	-0.000223	*

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