CSIRO Ecosystem Functions research project

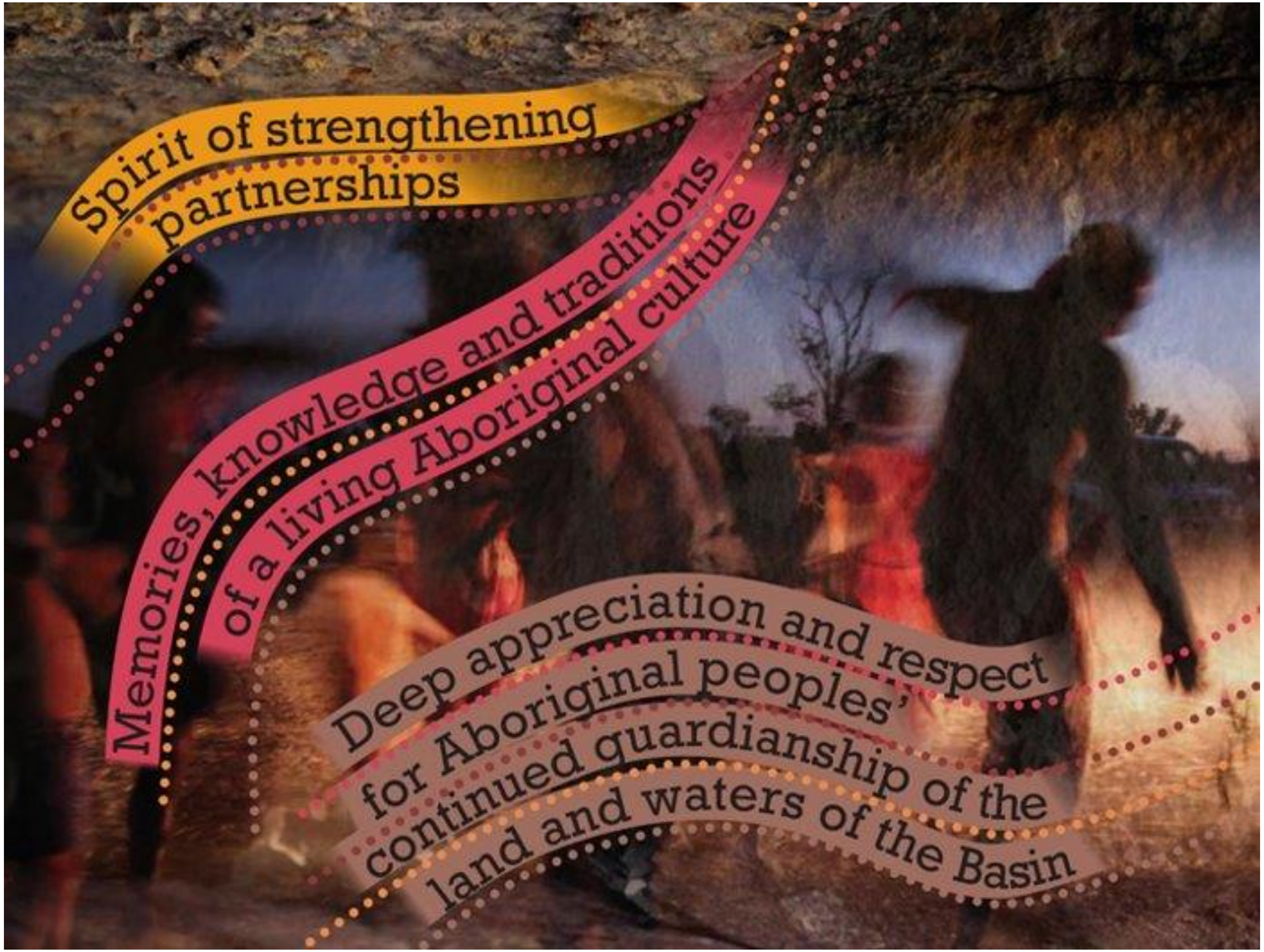
Background and overview

Science symposium and user workshops – November 2022

16th November, 2022

Australian Government

MURRAY–DARLING BASIN AUTHORITY


Spirit of strengthening partnerships
Memories, knowledge and traditions of a living Aboriginal culture
Deep appreciation and respect for Aboriginal peoples' continued guardianship of the land and waters of the Basin

Agenda – Science symposium

10.00-10.30am - Project overview

10.30-11.45am - Physical connectivity

11.45am-12.45pm – Lunch

12.45-2.15pm - Productivity

2.15-2.30pm – Break

2.30-3.30pm Biological habitat

3.30-4.30pm Biological movement

4.30-5.00pm Wrap Up

Agenda – User workshops

9.30-10am - Acknowledgement of Country/Set up

10-11am - Physical connectivity

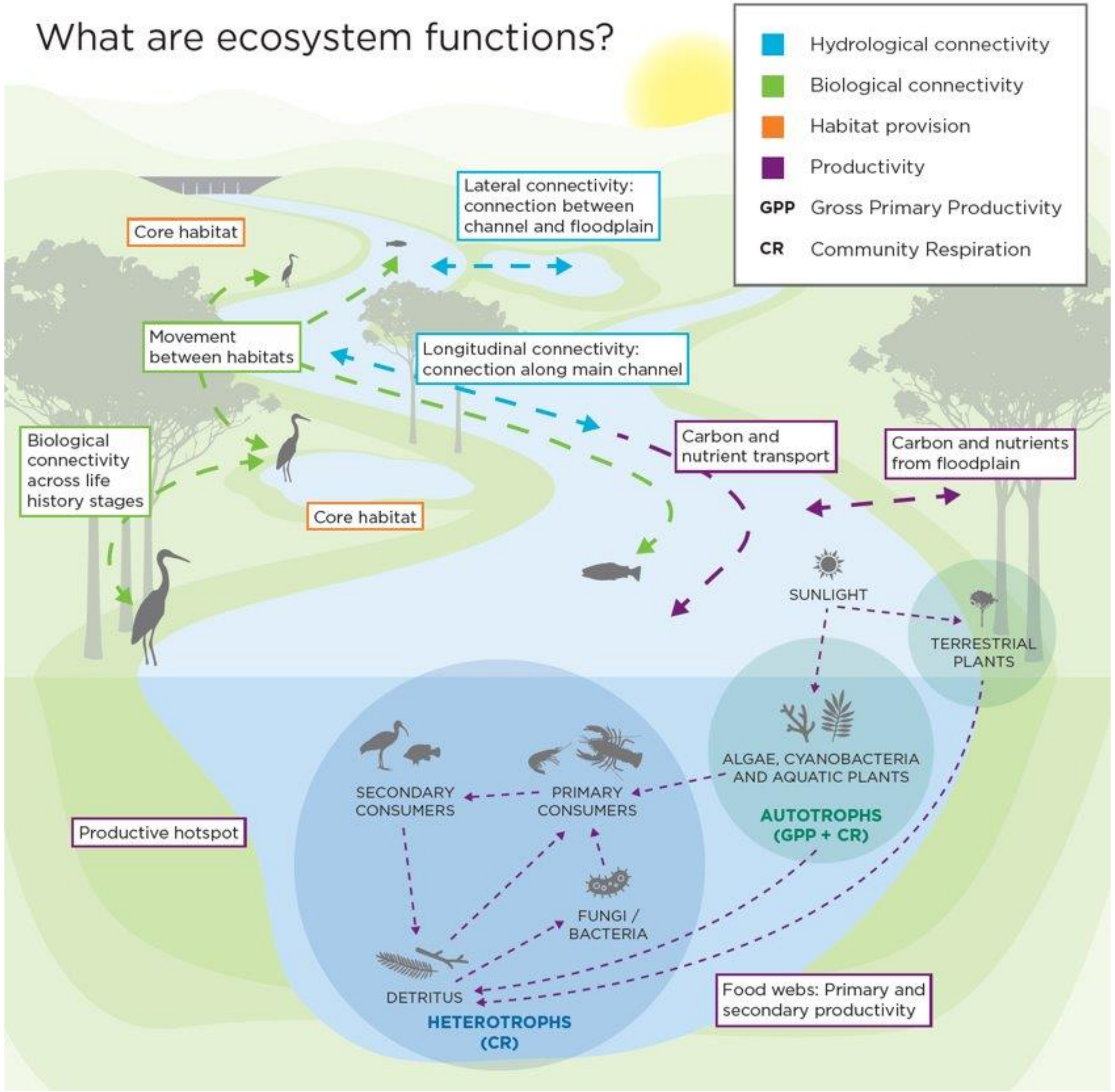
11am-12pm - Productivity

12-1pm - Lunch

1-2pm - Biological habitat

2-3pm - Biological movement

3-3.30pm - Wrap up


What are ecosystem functions?
Hydrological connectivity
Biological connectivity
Habitat provision
Productivity
GPP Gross Primary Productivity
CR Community Respiration
Core habitat
Lateral connectivity: connection between channel and floodplain
Movement between habitats
Longitudinal connectivity: connection along main channel
Biological connectivity across life history stages
Carbon and nutrient transport
Carbon and nutrients from floodplain
Core habitat
SUNLIGHT
TERRESTRIAL PLANTS
ALGAE, CYANOBACTERIA AND AQUATIC PLANTS
AUTOTROPHS (GPP + CR)
SECONDARY CONSUMERS
PRIMARY CONSUMERS
Productive hotspot
FUNGI / BACTERIA
DETRITUS
HETEROTROPHS (CR)
Food webs: Primary and secondary productivity

Alignment to Water Act and Basin Plan

Basin Plan – Chapter 8 (EWP), Schedules 7 (Targets), and 9 (Criteria)

Overall environmental objectives (s8.04, s8.06)

a) protect and restore water-dependent ecosystems of the Murray-Darling Basin

b) protect and restore ecosystem functions of water-dependent ecosystems

c) ensure water-dependent ecosystems are resilient to climate change and other risks and threats

Criterion 1: The ecosystem function supports the creation and maintenance of vital habitats and populations

Criterion 2: The ecosystem function supports the transportation and dilution of nutrients, organic matter and sediment

Criterion 3: The ecosystem function provides connections along a watercourse (longitudinal connections)

Criterion 4: The ecosystem function provides connections across floodplains, adjacent wetlands and billabongs (lateral connections)

Basin-wide environmental watering strategy (BWS)

- At the Basin scale - sets long-term quantified expected environmental outcomes for river flows and connectivity, vegetation, waterbirds and fish
- Indicators of broader Basin health
- Reviewed every 5 years
- Recommends water management strategies to achieve these outcomes

River flows and connectivity	Vegetation	Waterbirds	Fish
Improve connections along rivers and between rivers and their floodplains	**Maintain the extent and improve the condition**	**Maintain current species diversity, improve breeding success and numbers**	**Maintain current species diversity, extend distributions, improve breeding success and numbers**
Maintained base flows: • at least 60% of natural levels **Improved overall flow:** • 10% more into the Barwon–Darling[1] • 30% more into the River Murray[2] • 30–40% more to the Murray mouth (and it open to the sea 90% of the time) **Maintained connectivity in areas where it is relatively unaffected:** • between rivers and floodplains in the Paroo, Moonie, Nebine, Warrego and Ovens **Improved connectivity with bank-full and/or low floodplain flows:** • by 30–60% in the Murray, Murrumbidgee, Goulburn and Condamine–Balonne • by 10–20% in remaining catchments[3] **Maintain the Lower Lakes above sea level**	**Maintenance of the current extent of:** • about 360,000 hectares of river red gum; 409,000 ha of black box; 310,000 ha of coolibah forest and woodlands; and existing large communities of lignum • non-woody communities near or in wetlands, streams and on low-lying floodplains **Maintain the current condition of lowland floodplain forests and woodlands of:** • river red gum • black box • coolibah **Improved condition of:** • southern river red gum	**Maintained current species diversity of:** • all current Basin waterbirds • current migratory shorebirds at the Coorong **Increased abundance:** • 20–25% increase in waterbirds by 2024 **Improved breeding:** • up to 50% more breeding events for colonial nesting waterbird species • a 30–40% increase in nests and broods for other waterbirds	**Improved distribution:** • of key short and long-lived fish species across the Basin **Improved breeding success for:** • short-lived species (every 1–2 years) • long-lived species in at least 8/10 years at 80% of key sites • mulloway in at least 5/10 years **Improved populations of:** • short-lived species (numbers at pre-2007 levels) • long-lived species (with a spread of age classes represented) • Murray cod and golden perch (10–15% more mature fish at key sites) **Improved movement:** • more native fish using fish passages

Alignment to Basin Watering Strategy

BWS and Annual Environmental Watering Priorities

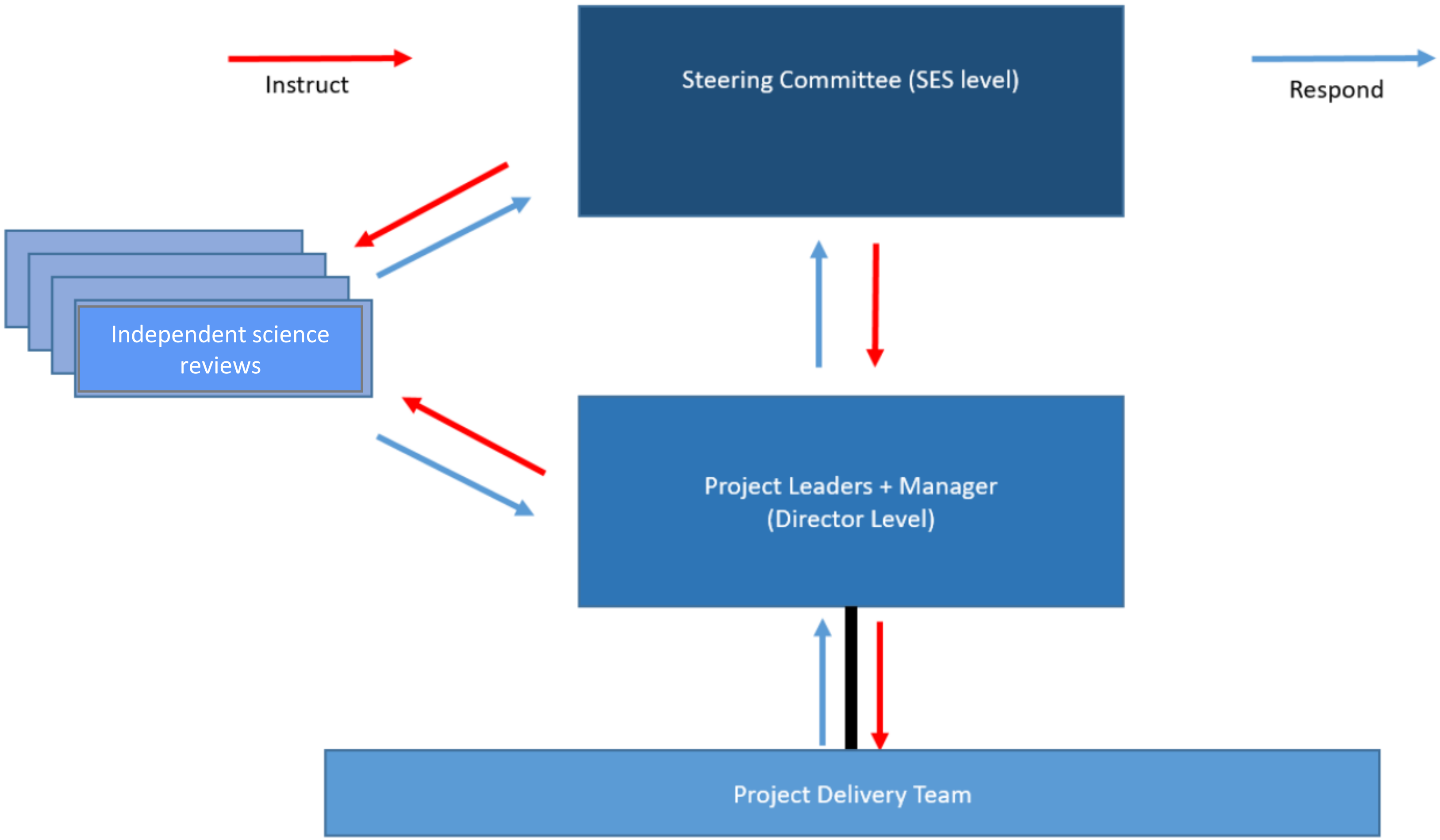
- Focus on structural ecosystem outcomes / assets (veg, fish, birds)
- Ecosystem functions addressed in the BWS:
    - ➢ flows and connectivity
    - ➢ some life-cycle processes e.g. dispersal and breeding

➢ Potential benefits of improving approach to ecosystem functions not yet realised – lots of scope here!

Governance

- 3 year research collaboration
- CSIRO/DCCEEW/MDBA/CEWO
- DCCEEW provided $3 million funding
- MDBA managing project of behalf of Commonwealth partners

Governance



Note: The arrows show lines of authority, where red lines show instructions/direction and the blue lines show response.

Project Objectives

The objectives of this project are to describe and demonstrate at the Basin-scale an understanding of

1. Ecosystem functions in the MDB for the purpose of their protection and restoration
2. Management of water for Ecosystem Function outcomes to support a healthy, working basin; and
3. Evaluation of Ecosystem Function outcomes and the contribution of management

Scoping statement

To achieve these objectives this project will focus on Basin scale connectivity as a management aim and a key driver for ecosystem function of the Basin

Outcomes and Impacts

Outcomes

- Improved capacity to understand ecosystem functions
- Improved science and tools for ecosystem functions to inform decision making for river planning and management as demonstrated through use-case(s)
- Improved ability to communicate to the Australian public the importance of ecosystem functions and their management

Impacts

- To advance science-policy tools for water management
- To have improved outcomes for water management in the Murray-Darling Basin

Thank you

Office locations

Adelaide

Albury-Wodonga

Canberra

Toowoomba

mdba.gov.au 1800 630 114

engagement@mdba.gov.au

Australian Government

MURRAY–DARLING BASIN AUTHORITY

Purpose and expectations

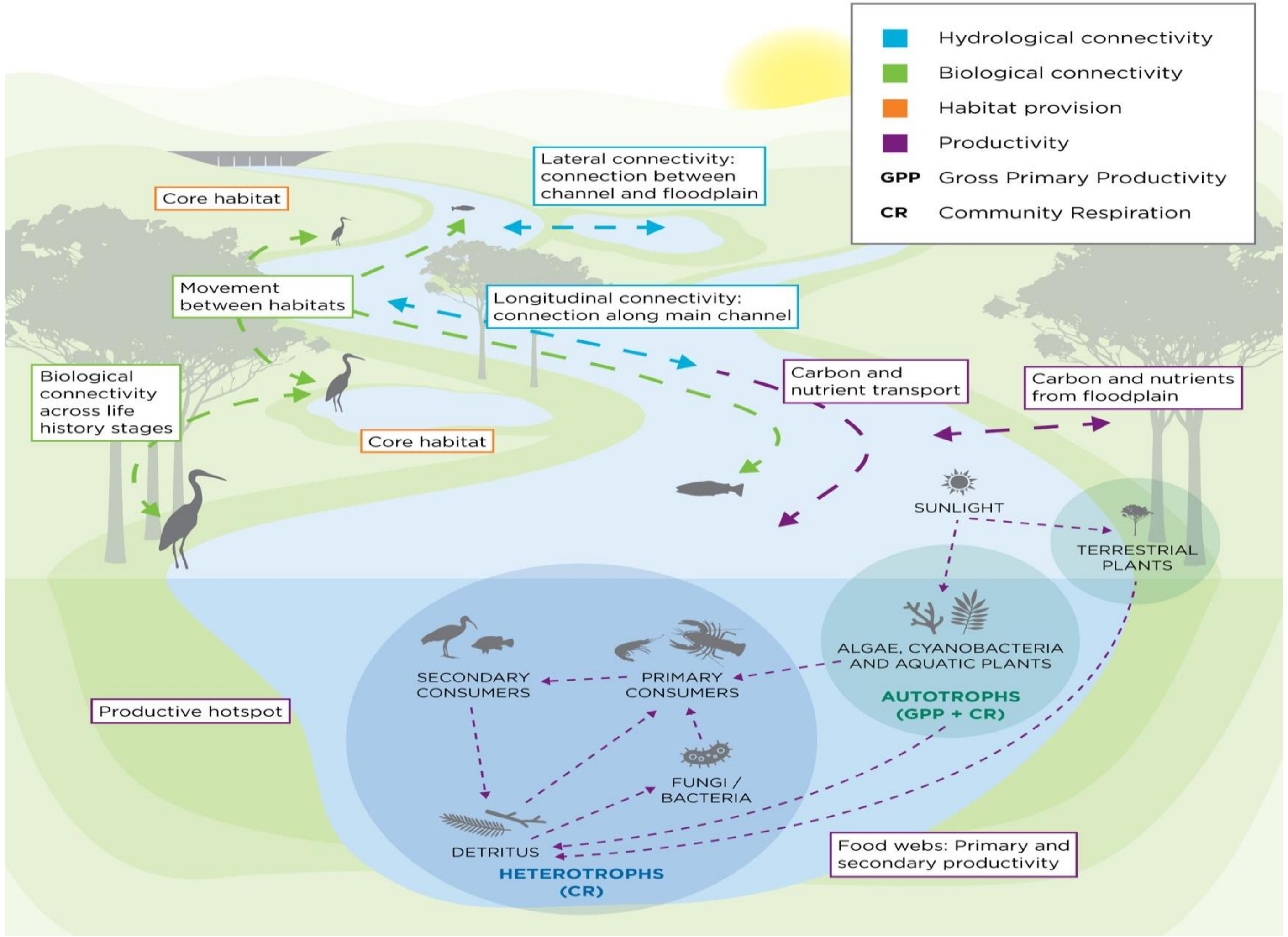
Purpose:

- Build a shared understanding of research objectives and questions
- Refine and build consensus around use-cases

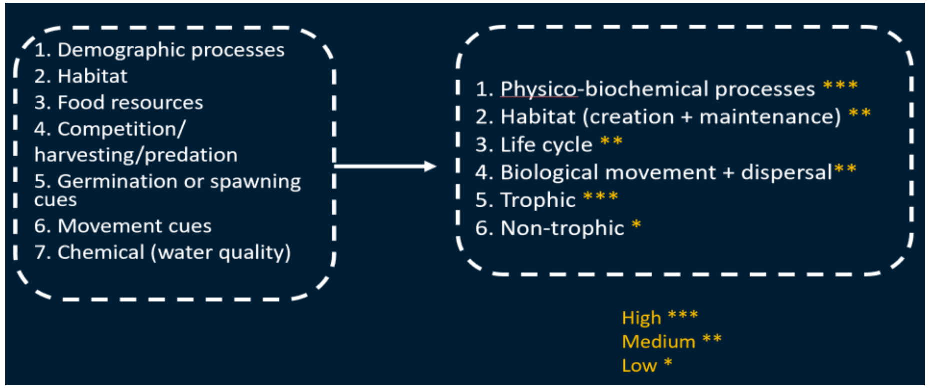
Expectations:

- This is the first of multiple workshops – begin with broad oversight, subsequent workshops in finer detail
- Seeking feedback to improve the utility of products

Ecosystem Functions Research Themes

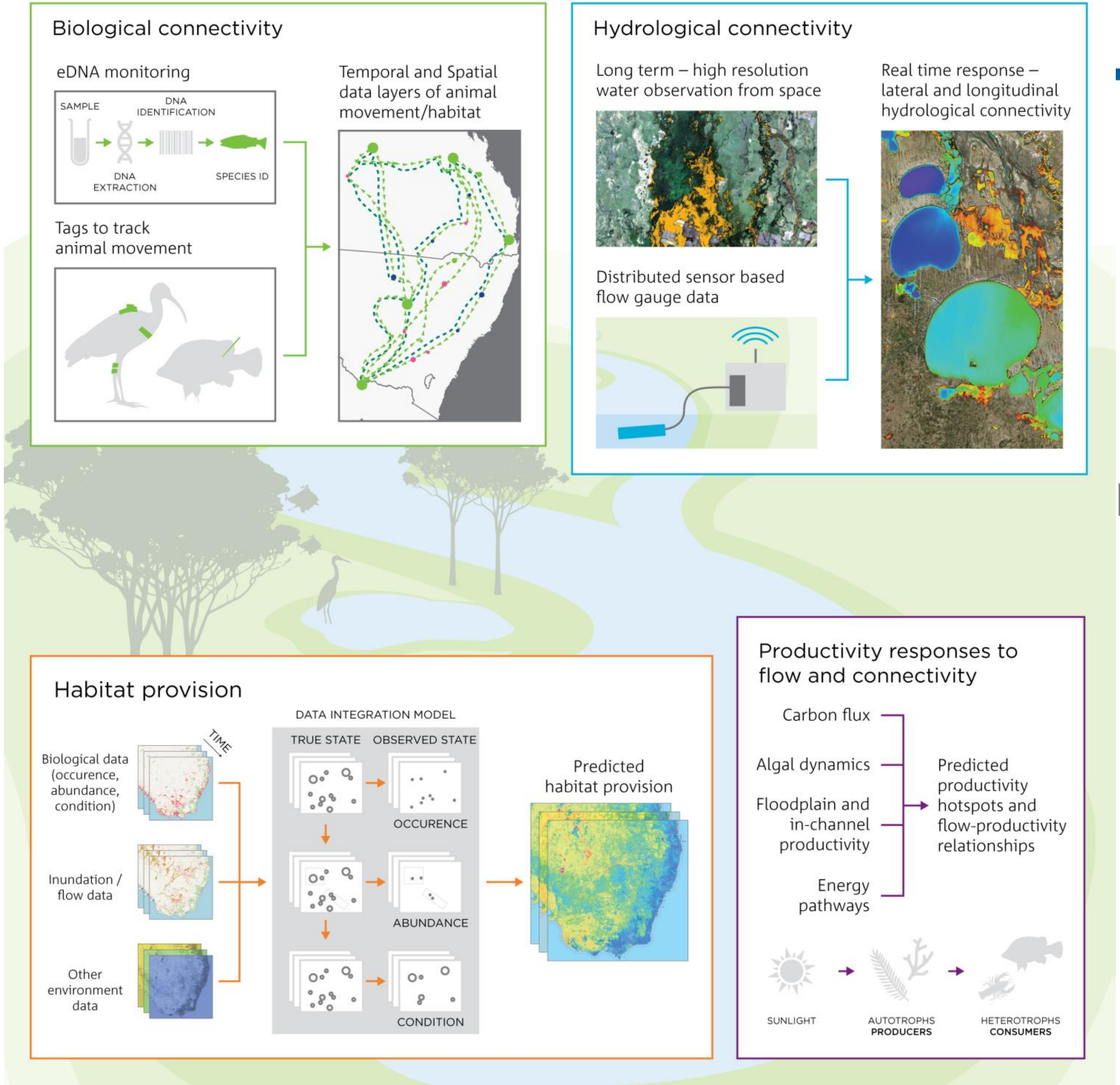


Step 1



Step 2

	How will you scale it to the Basin	Novelty	Med-long time scale	Target metric/QEO	Connectivity	What does it impact	How
Physico-biochemical processes	Satellite, hyperspectral camera, soil data, predictive modelling	Application at Basin scale, Integration across; data, scales, ecosystem function, Large scale integration with habitat, Dynamic system - looking at extremes	✓		Inundation, instream metrics/vegetation and land use impacts		Black water model, scale up blue-green algae model
Habitat (refugia)	Landsat, ANAE classification, soil data, veg mapping, water body mapping, thermal habitat		✓	Threshold related to instream waterholes, outstream wetlands	Connection and disconnection is key		Cate ticehurst will explore the mapping and threshold component
Life cycle	Species specific, hard to generalise to basin scale, other models exist		✓				
Biological movement + dispersal	Fish + acoustic tags, propagules, water bird work		✓		Connection and disconnection is key		EWKR, MER, MMCP
Trophic	End to end model, Atlantis (high novelty but low probability, food quality		✓		dynamic changes in wetting		Darren G is tackling on a conjective project, Paul I will invest a PhD
Non-trophic	Processes are site scale, not super dependent on water connectivity, competition from carp, willows (Invasives)		✓				



1. Basin Plan
2. Basin watering strategies
3. Environmental adaptive management

Stakeholder input/engagement via workshops

Use cases (application to real issues)

Use cases

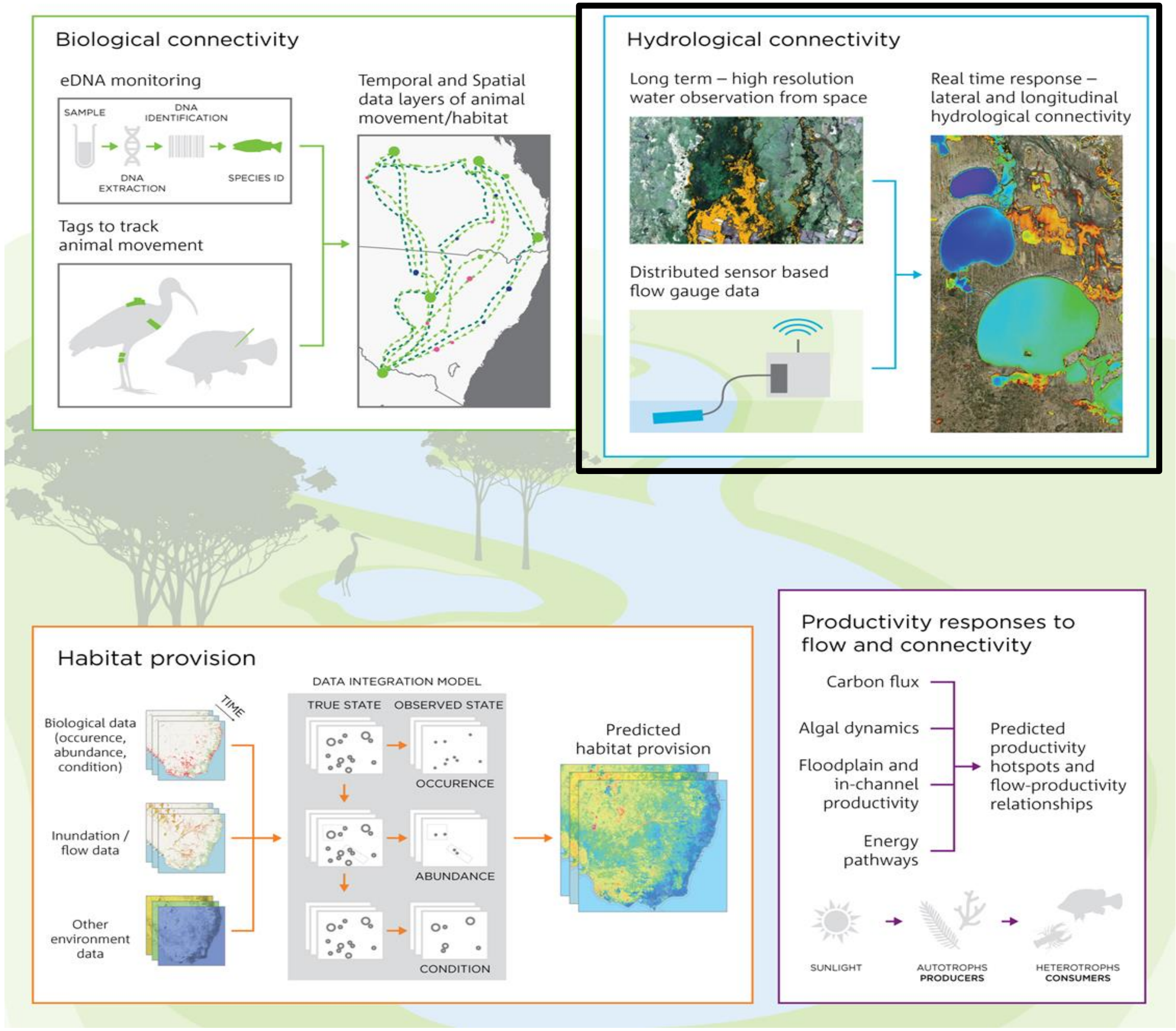
Inform basin-wide medium to long term e-watering strategies (CEWO)

- Application of response-relationships developed
- Guidance pathways that evaluates resource availability scenarios

Inform the establishment of long-term EEO(s) for ecosystem functions (MDBA)

- Inform the establishment of long term expected environmental outcomes (EEO) for ecosystem functions
- Metrics/indicators to enable monitoring and evaluation
- Define interim measures of success

Hydrological Connectivity



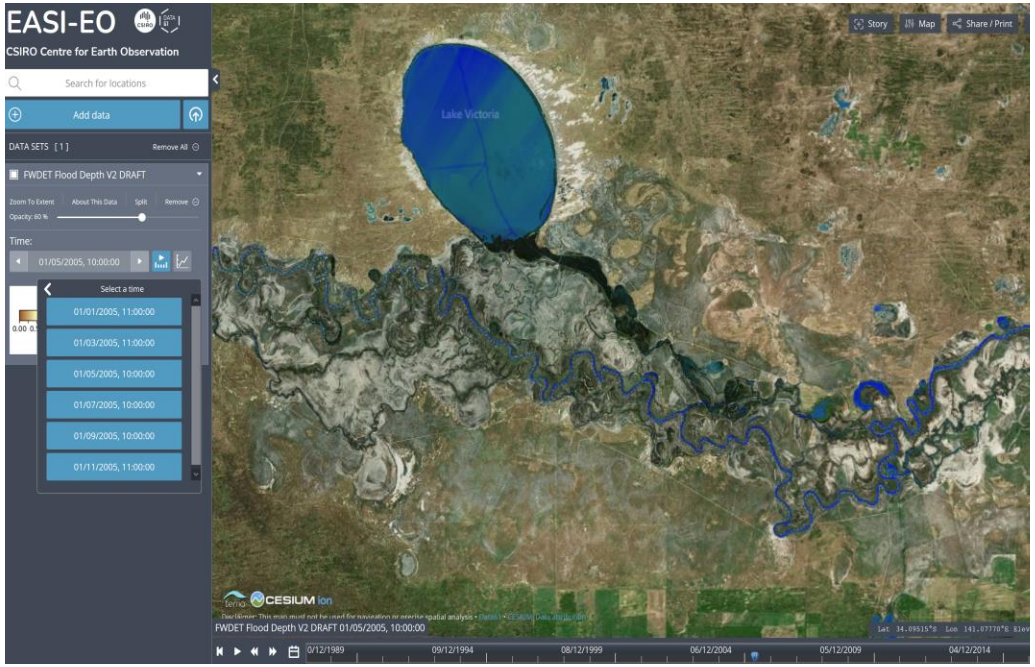
Basin Scale Lateral Connectivity

- two monthly maximum inundation mapping (30 years)
- multi-index surface water detection
- water depths at 25 m pixel
- merged lidar and stream network

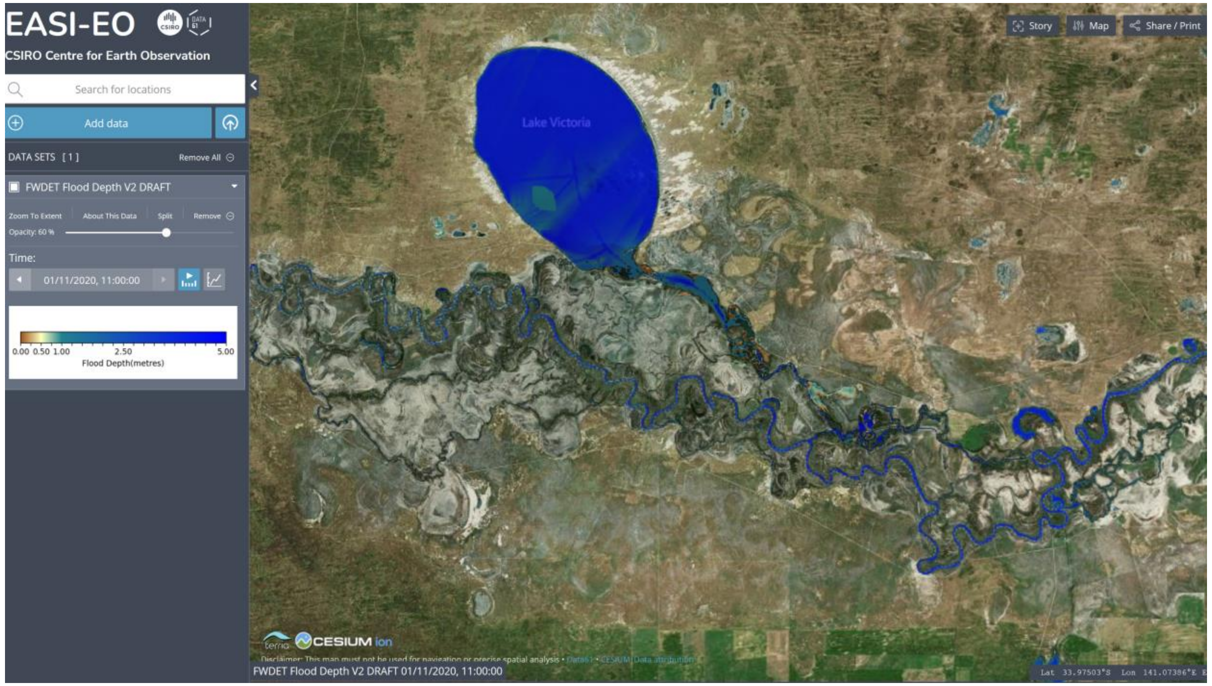
Basin Scale Longitudinal Connectivity

- barrier mapping across the Basin
- Channel segments with distance to fragmentation (1km)
- channel depth and width (currently average)
- velocity and flow at 1 km segment granularity (in development) (30 years max dependent on flow gauge data)

Depth and extent of inundation (two monthly)

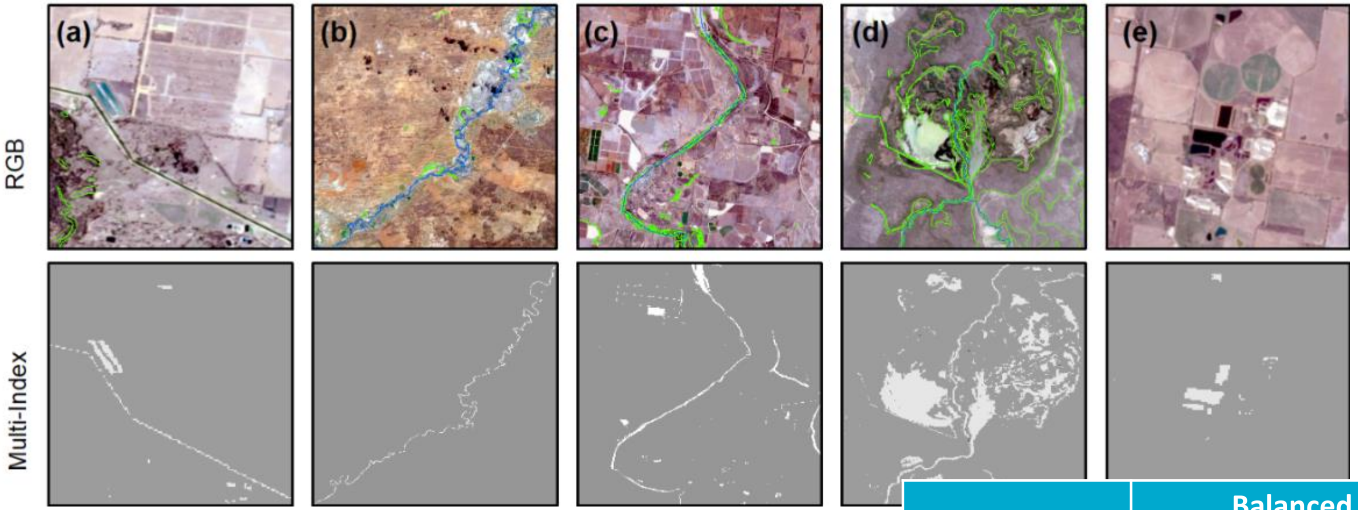


https://map.easi-eo.solutions/#share=s-5gDCU9gh91CmSurBN2uK5gKCCzt

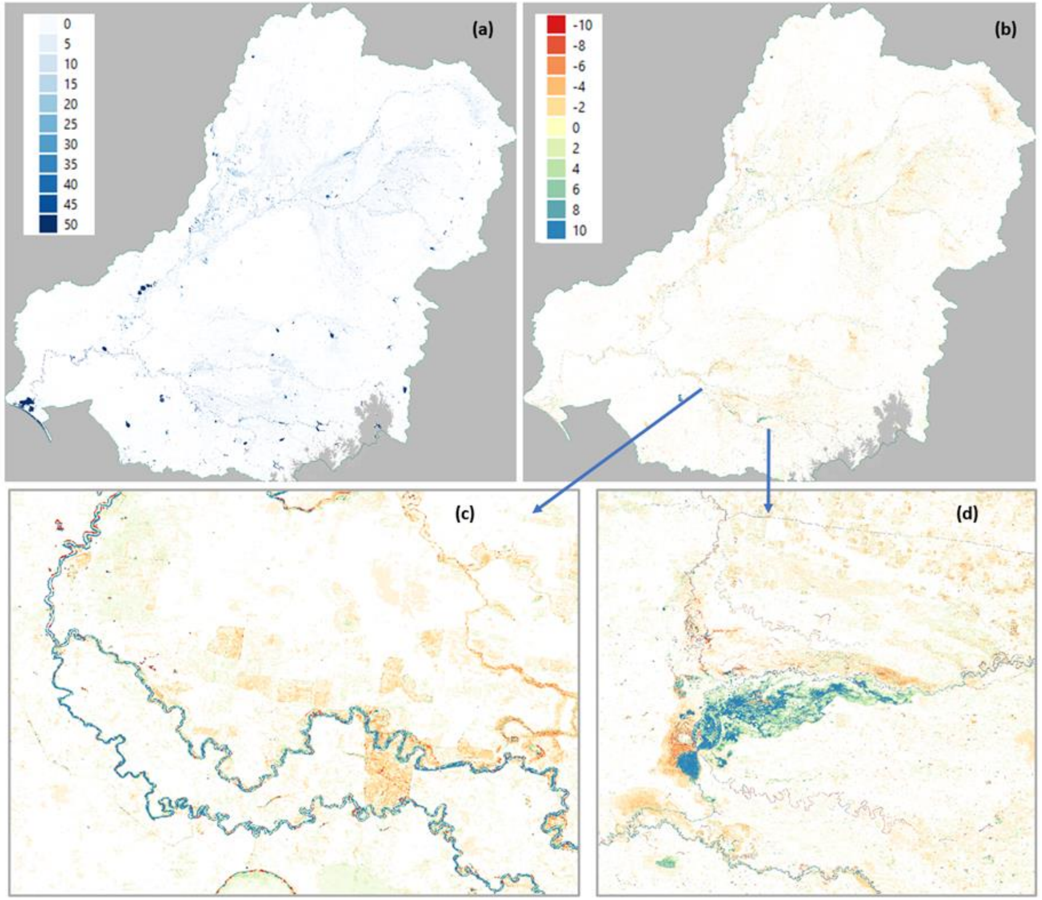


Multi-index surface water detection

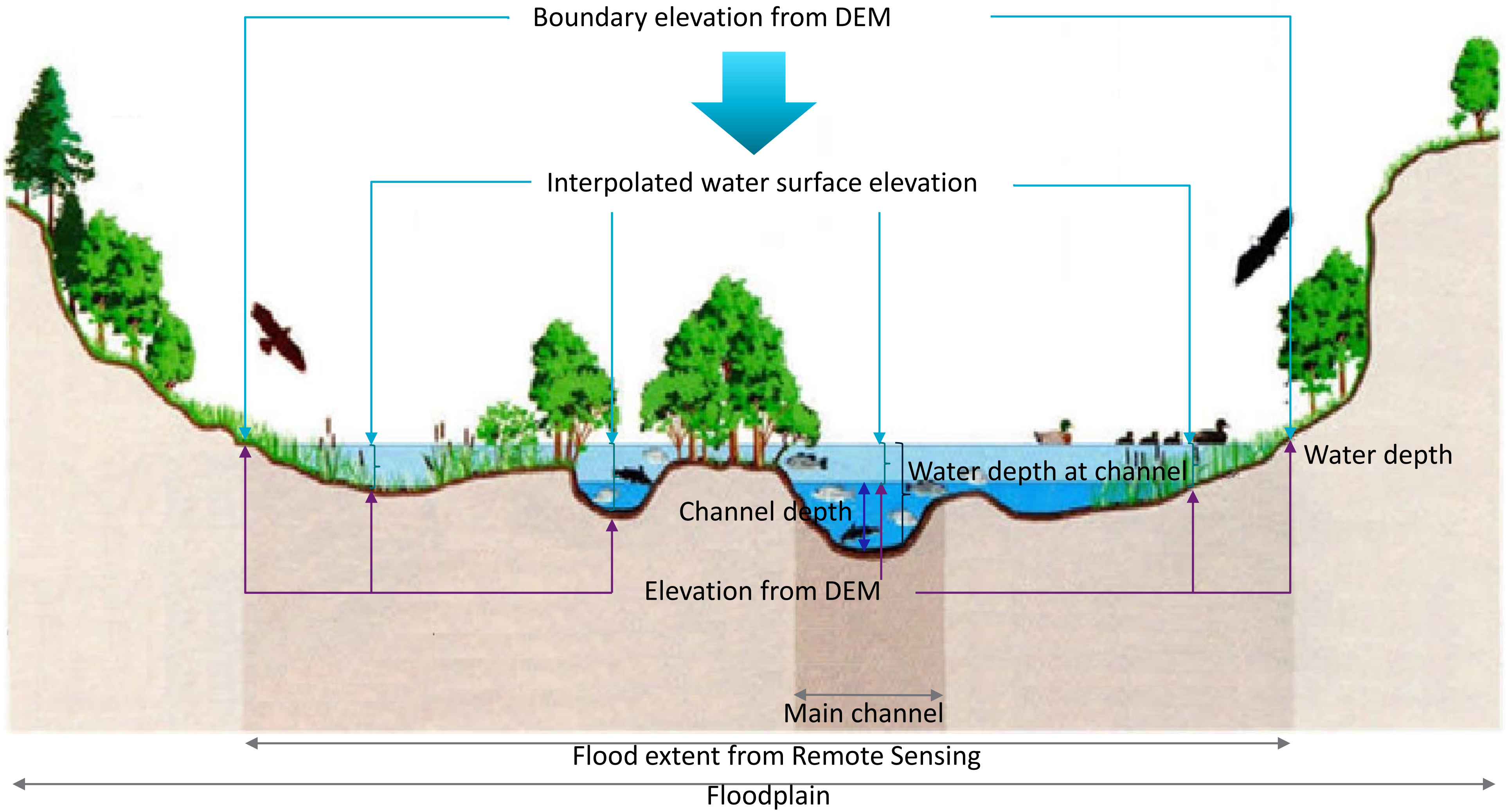
- Simple and fast
- Minimise dry pixels misclassified as water
- Identify small water bodies
- Produce two-monthly maps of surface water



Water Index	Balanced accuracy
MIM	93%
Fisher WI	91%
mNDWI>0	91%
mNDWI>-0.3	90%
TCW >-0.035	92%
TCW >-0.01	90%
WOFS	86%

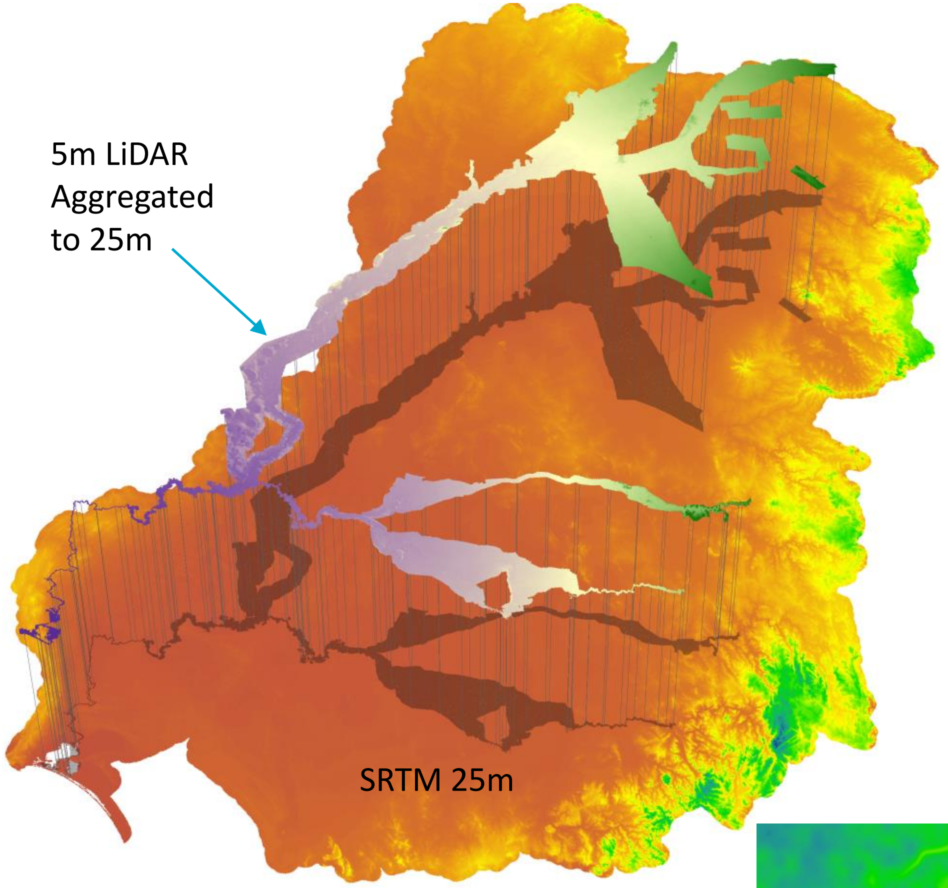


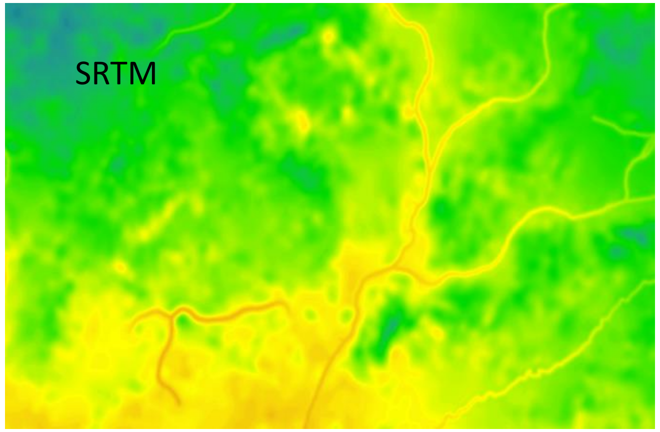
Flood Water Depth Estimation Tool (FwDET:Cohen et al.2019)

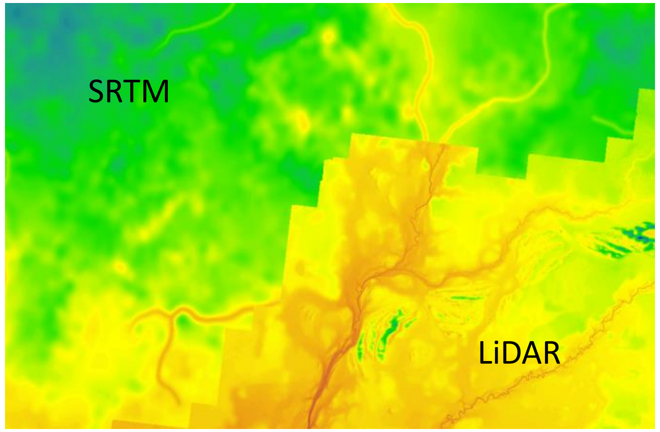


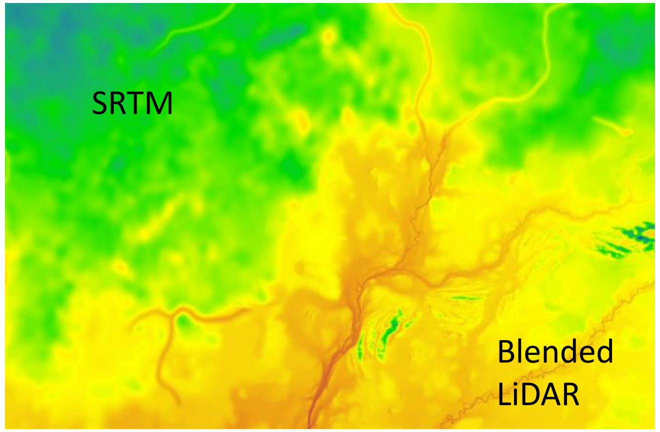
Visit https://map.easi-eo.solutions/#share=s-5gDCU9gh91CmSurBN2uK5gKCCzt to visualise the data.

LiDAR DEM and SRTM fusion

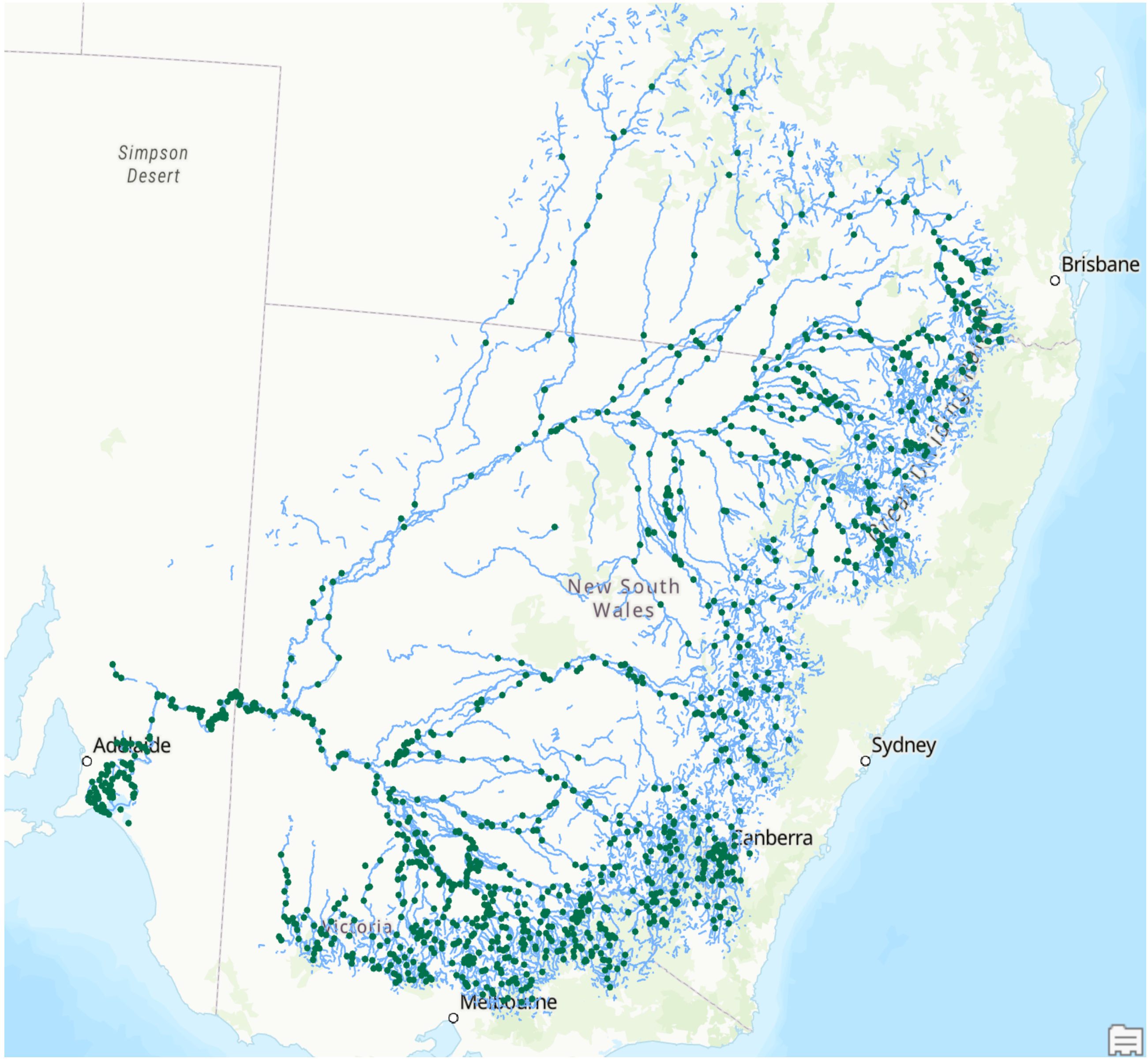






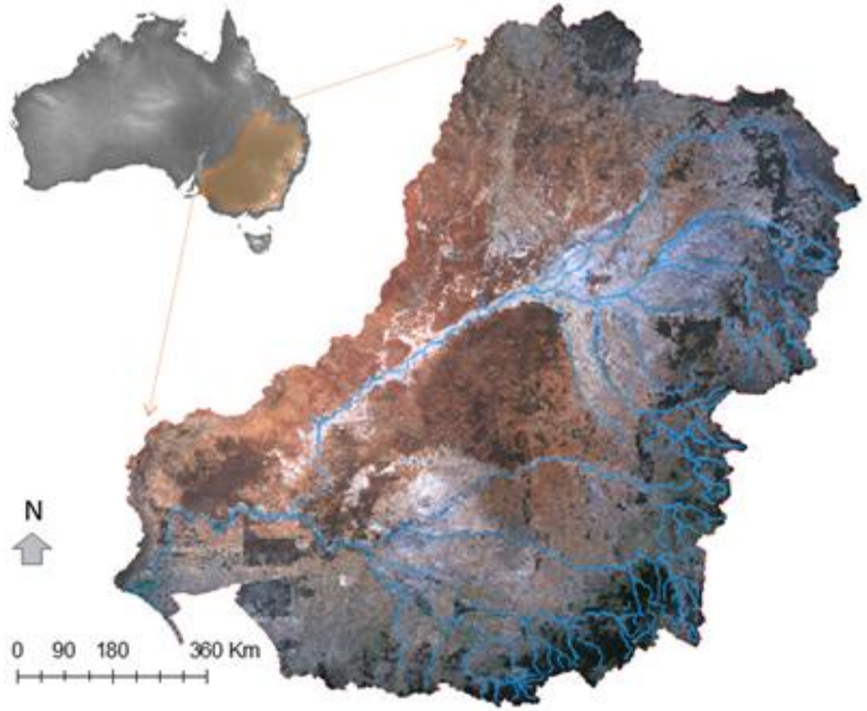


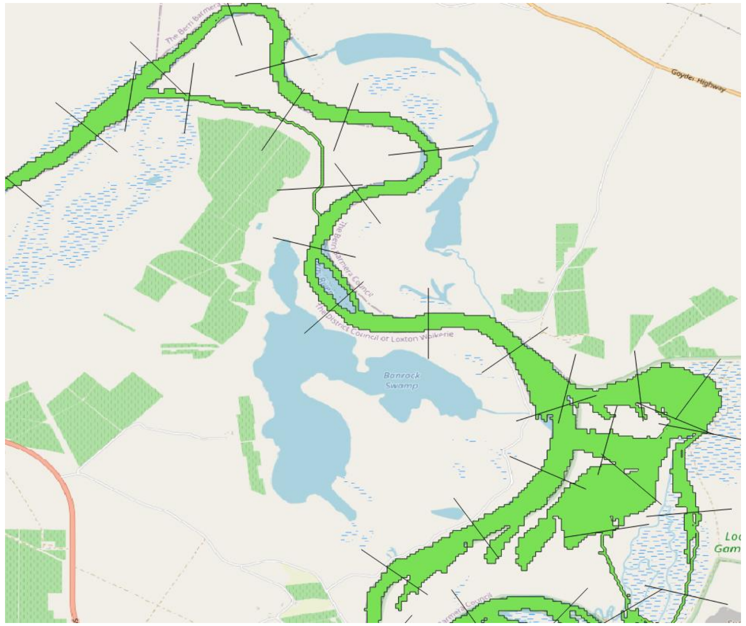
Barrier network

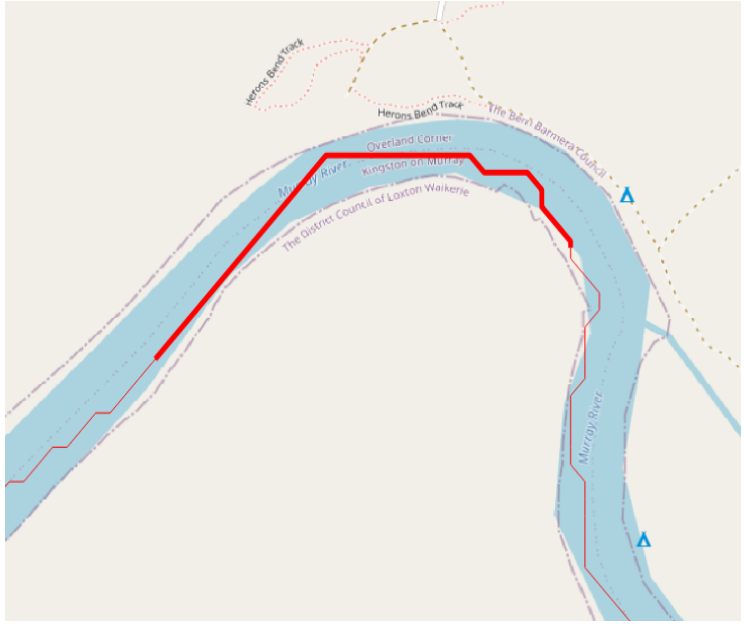


- Dataset with 1338 monitoring points
- Channel segment distance from fragmentation

Longitudinal Connectivity



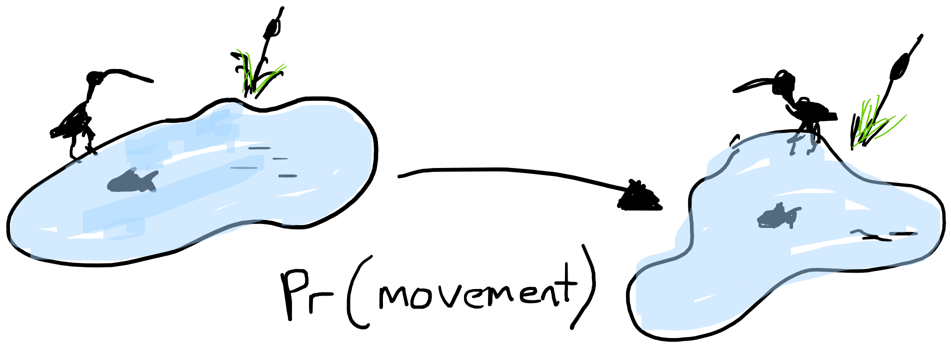


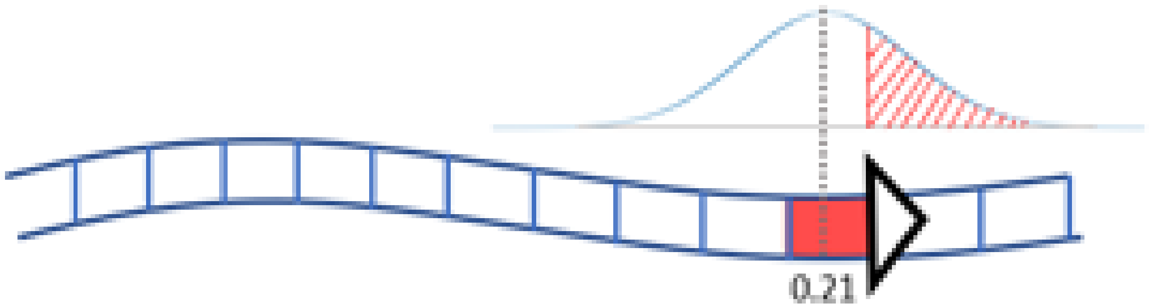


Biological Connectivity

Biological Connectivity Modelling

- Basin-scale connectivity models for waterbirds and fish
- Modelled <u>probability of movement</u> between two locations given a suite of environmental conditions





How can you use these models?

1. Provide metrics/indicators of connectivity
   - Calculate predicted movement scores between important sites in the basin
   - Visualise connectivity at the basin scale for specific scenarios

2. To determine the conditions conducive to connectivity
   - Integrates weather, inundation and landscape (birds)
   - Integrates flow, barriers (fish)

3. Evaluate connectivity under different resource availability scenarios
   - Support connectivity between important sites at required times of the year given the prevailing climatic and resource availability scenarios (e.g. wet year vs dry year)
   - Test "what-if" scenarios to evaluate proposed management actions

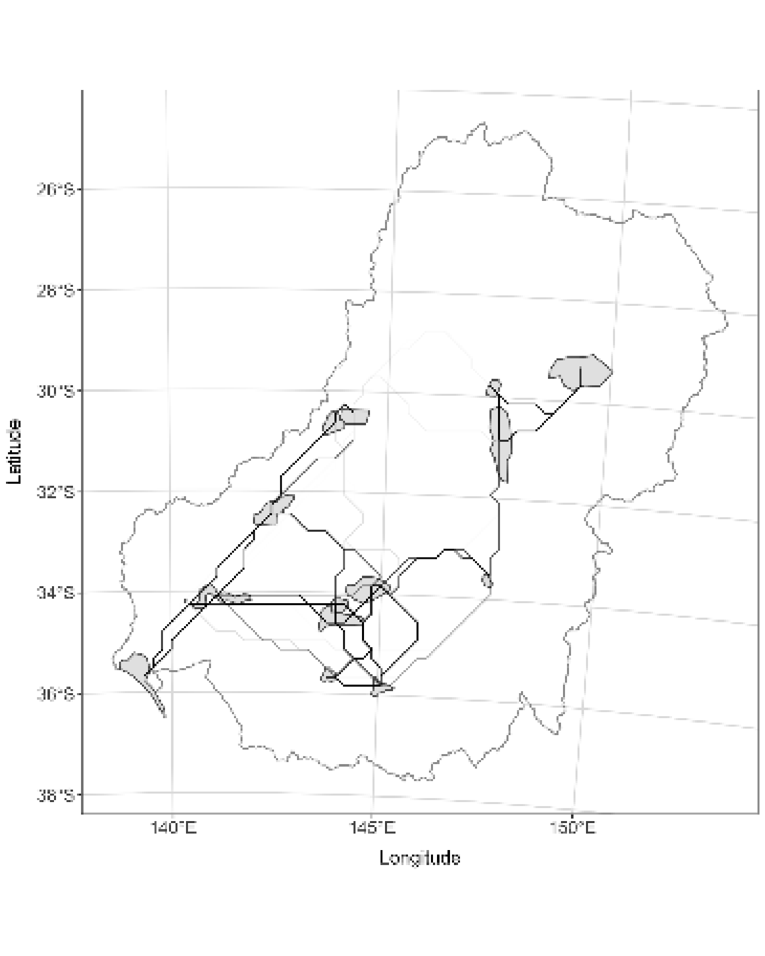
Waterbirds modelling: overview

- A calculator tool that computes the probability that ibis can move between two points in the basin (e.g. breeding sites) given environmental conditions and a resource availability scenario (e.g. wet/dry year)
  - Integrates high-resolution water, weather and landscape variables to recreate environmental conditions experienced by birds in flight.
  - Plan to make this available as either an app (e.g. Shiny) or integrated into Terria: in development
  - Daily timestep for simulated connectivity

Waterbird connectivity modelling: outputs

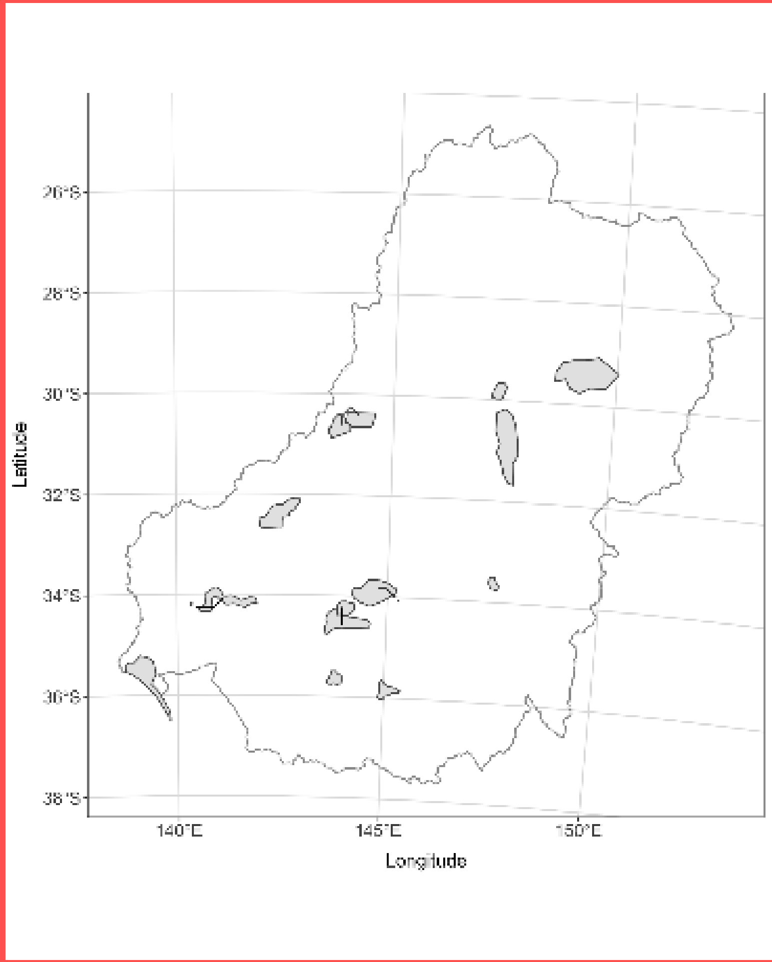
Compare predicted connectivity under different water, landscape and weather scenarios

Good conditions, high connectivity



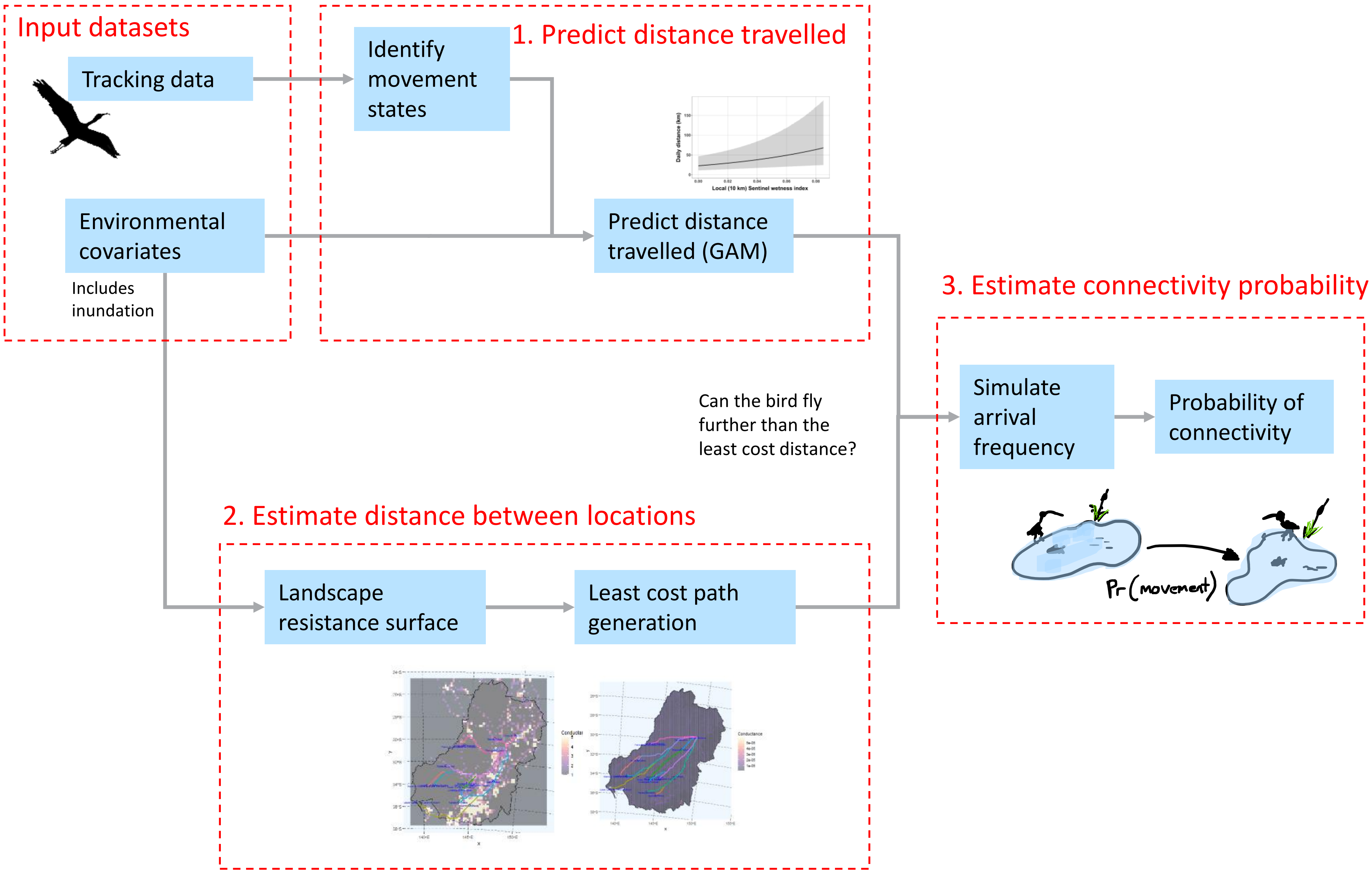
Favourable local + landscape water, wind benefit, month, morning temperature

Poor conditions, poor connectivity



Unfavourable local + landscape water, wind benefit, month, morning temperature

Waterbird connectivity modelling: under the hood

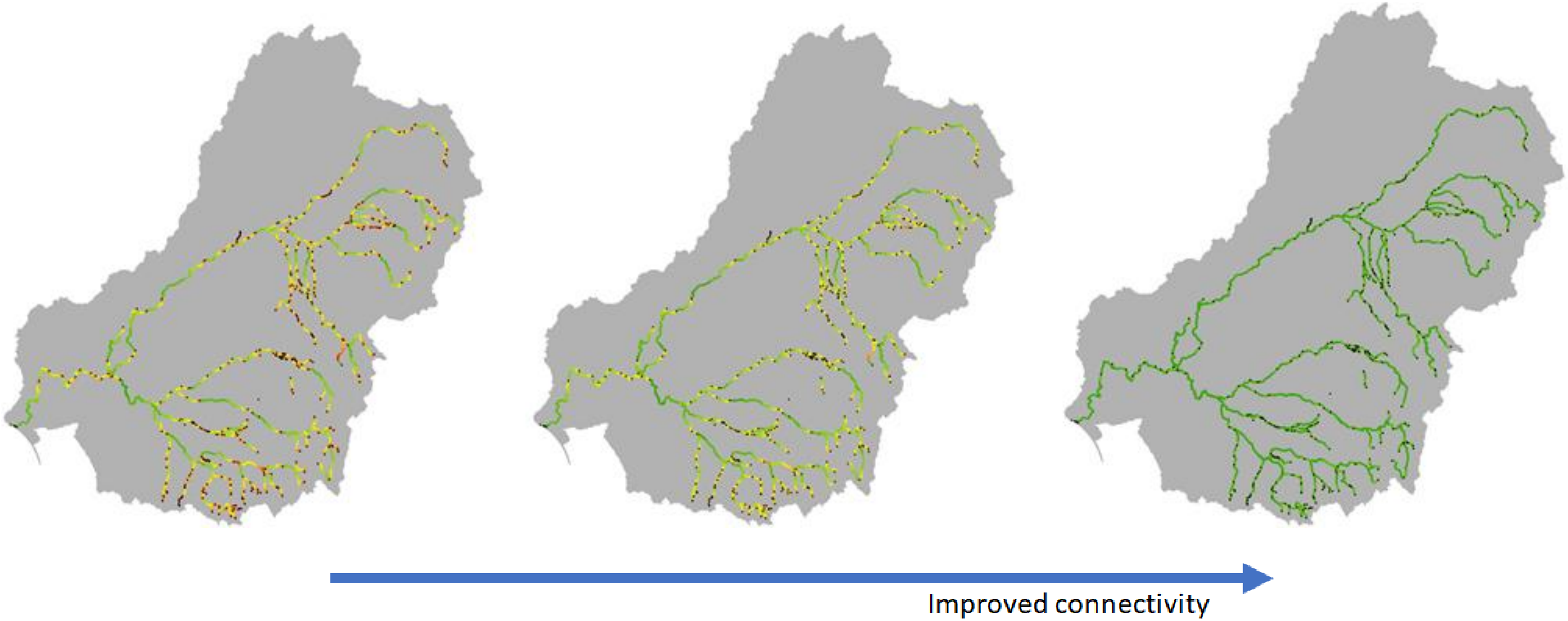


Fish modelling: overview

- An interactive layer that computes the proportion of fish movements that are unimpeded in the basin given flow conditions and a barrier network
  - Integrates modelled hydraulics, barrier characteristics and permeability
  - Plan to make this available through integration with Terria: in development
  - 1 km river segment resolution

Fish connectivity modelling: outputs

Compare predicted connectivity under different flow and barrier permeability conditions



You can also summarize specific rivers/segments, e.g.:

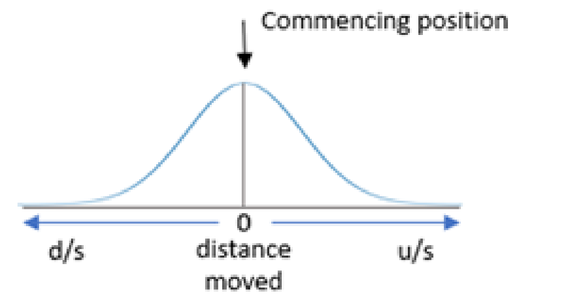
River	All barriers impassable	High barrier permeability
QUEANBEYAN RIVER	0.16	0.83
MURRUMBIDGEE RIVER	0.63	0.93
WAKOOL RIVER	0.82	0.96

Fish connectivity modelling: under the hood

(Longitudinal connectivity)

Model potential fish movement

- Distance travelled given:
  - Season
  - Flow condition
  - Species and life-stage



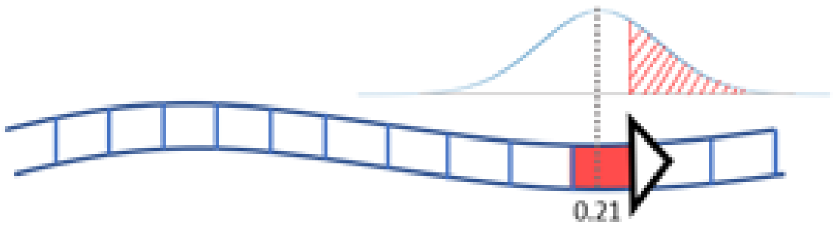
Identify Barriers

(weir information system)

- 446 barriers identified

River segmentation

- Segment river at 1km resolution
- Calculate distance to barriers



Fish connectivity

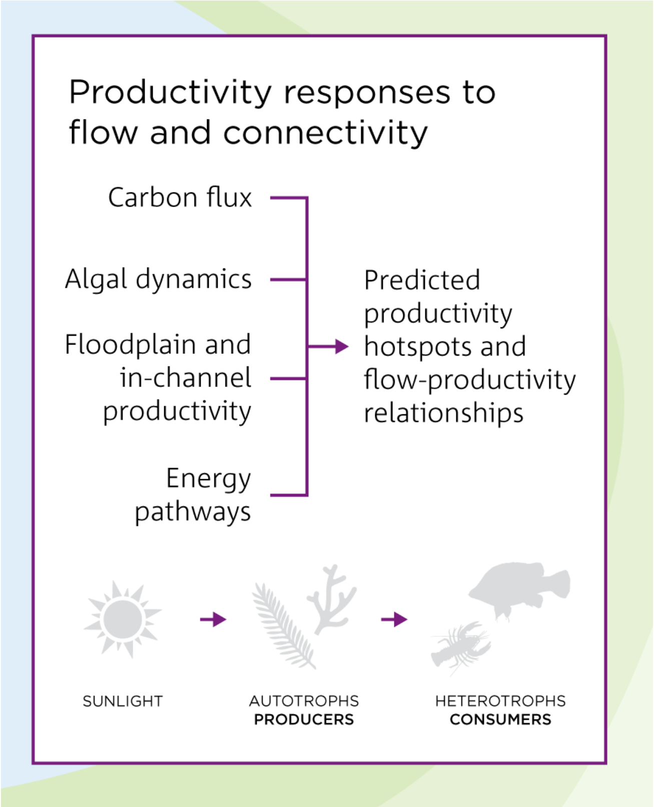
- Compute connectivity of each segment based on:
  - location,
  - barrier network
  - barrier permeability

Discussion time

Reminder of suggested uses:

1. Provide metrics/indicators of connectivity
2. To determine the conditions conducive to connectivity
3. Evaluate connectivity under different resource availability scenarios

Productivity



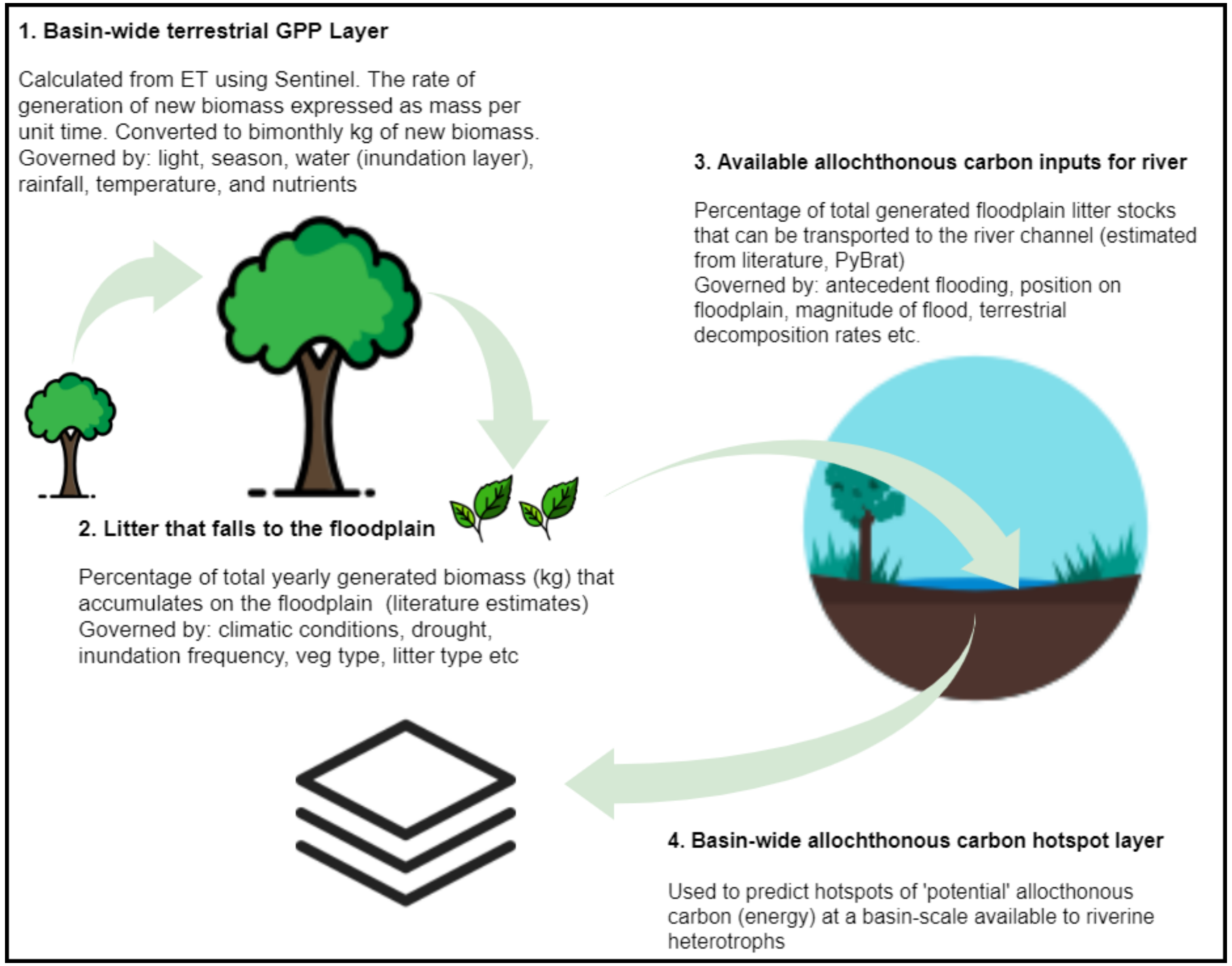
Products

1. Basin wide terrestrial GPP layer – hotspots for litter generation
2. Carbon production from floodplains
3. Mechanistic model of in-channel GPP

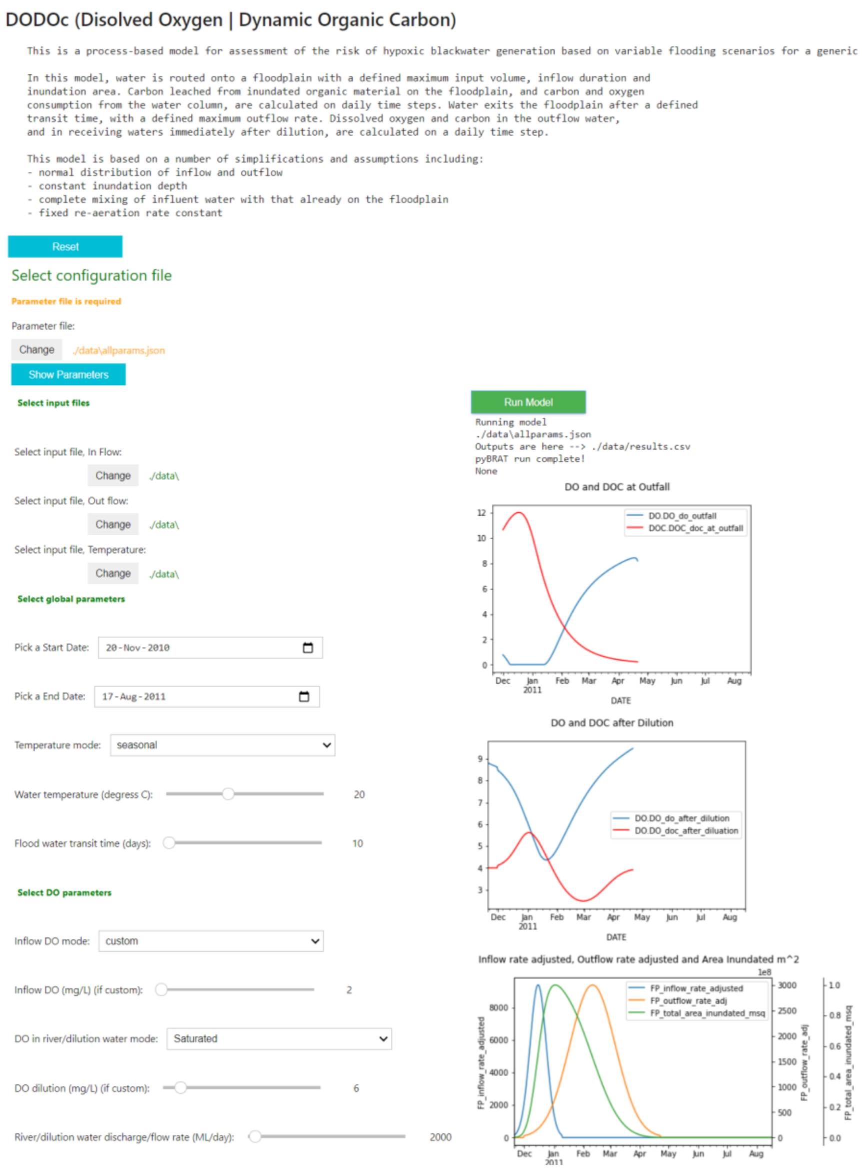
1. Basin wide terrestrial GPP layer – hotspots for litter generation

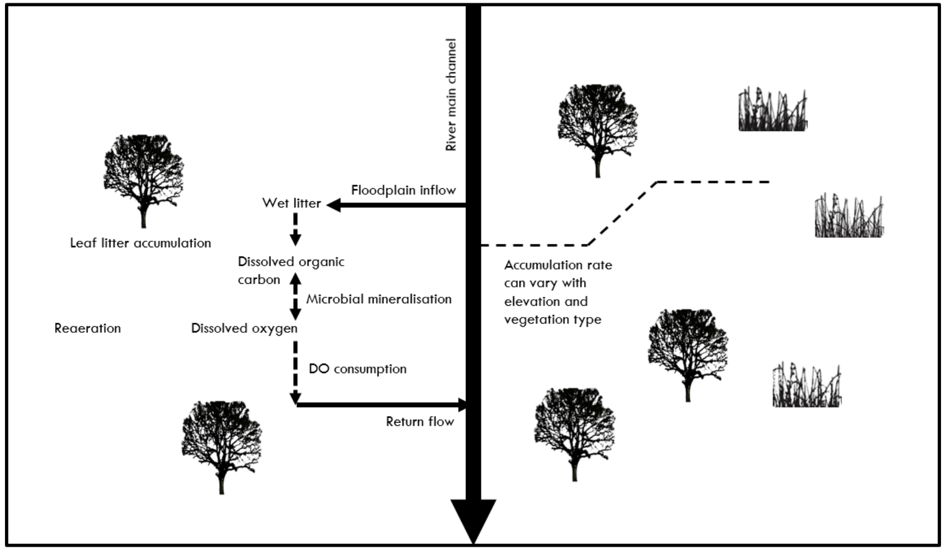
- Basin wide terrestrial GPP layer generated from remote sensing

- Identify locations in the basin that generate high quantities of carbon for incorporation into aquatic ecosystems



2. Carbon production from floodplains





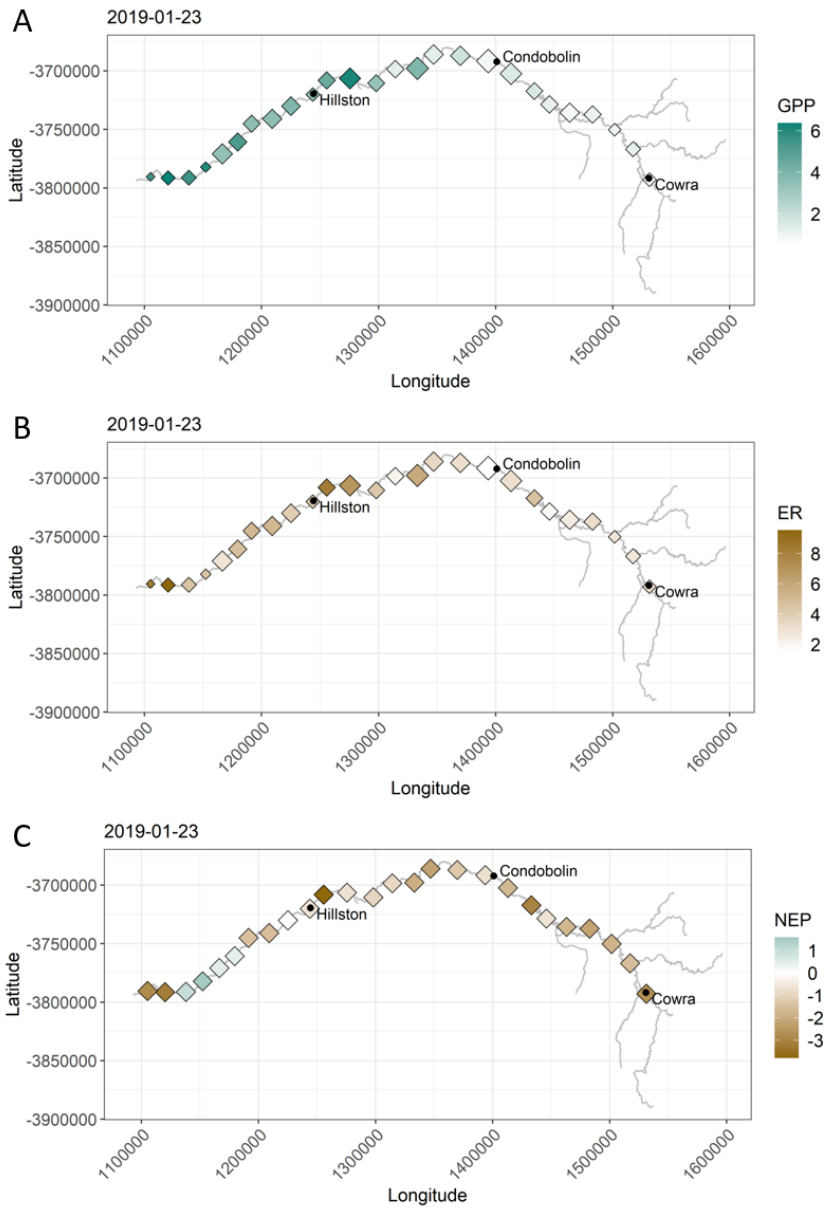
- Estimates carbon production from floodplains in response to antecedent flow conditions, habitat types and inundation

- Estimate carbon export as a function of floodplain inundation area, flow and water temperature

3. Mechanistic model of in-channel GPP

- Statistical model of in-channel gross primary productivity on the Lachlan River

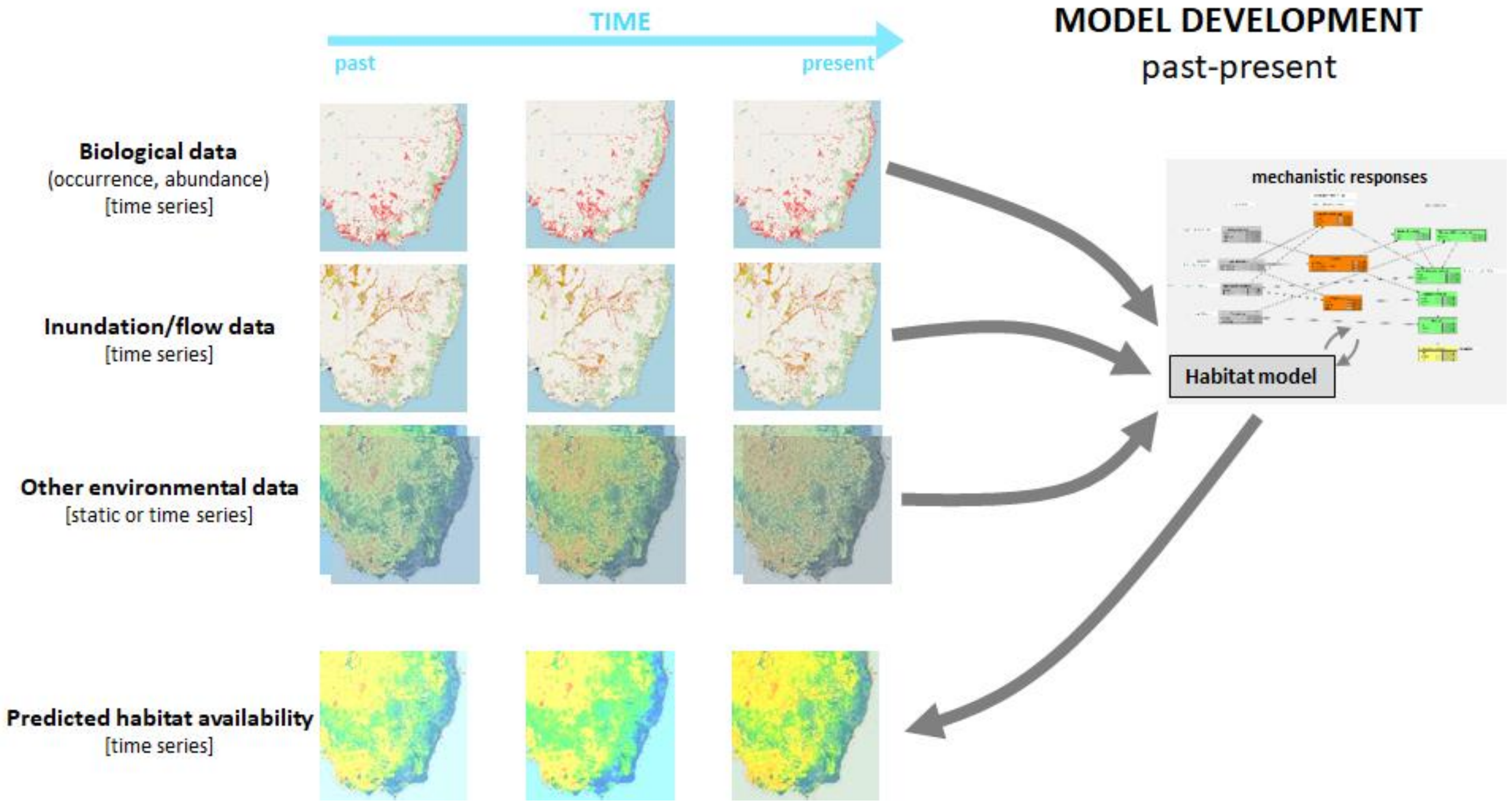
- Prediction of metabolic responses to different flow scenarios e.g. what primary productivity patterns can we expect from a given flow?



Habitat provision and maintenance

Habitat modelling

Karel Mokany, Rocio Ponce-Reyes, David Peel, Scott Foster
Andrew Freebairn, Paul McInerney, Brenton Zampatti, Heather McGinness, Danial Stratford

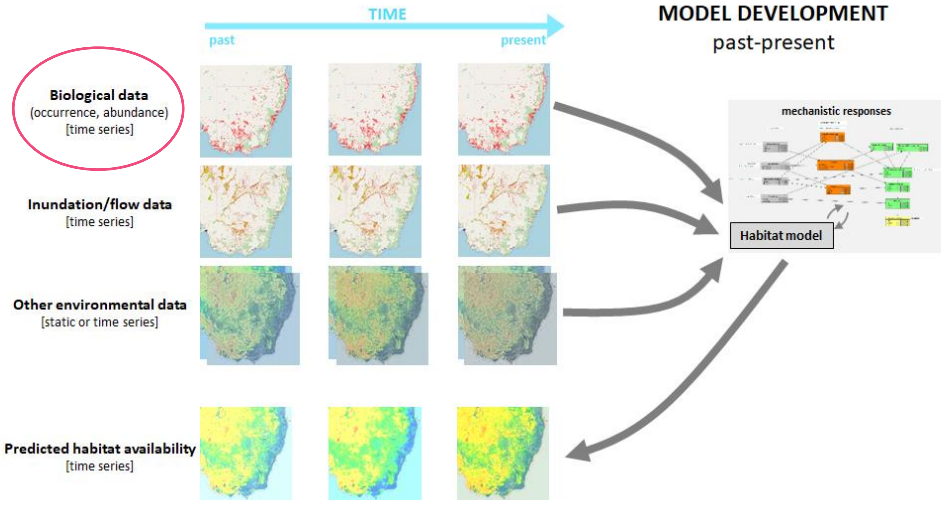


Biological data

		Selected species or groups
Fish		Golden perch, Murray cod, Pouched lamprey*
Waterbirds		Straw-necked ibis Royal spoonbill Musk duck*
Vegetation		Lignum River red gum Wetland amphibious responder*
Macroinvertebrates		Decapods (shrimp) Benthic Riverine*
Frogs		Southern Bell Frog*

* will be modelled if data and time permit

- Model-ready data
- Data preparation ongoing
- Data preparation not commenced



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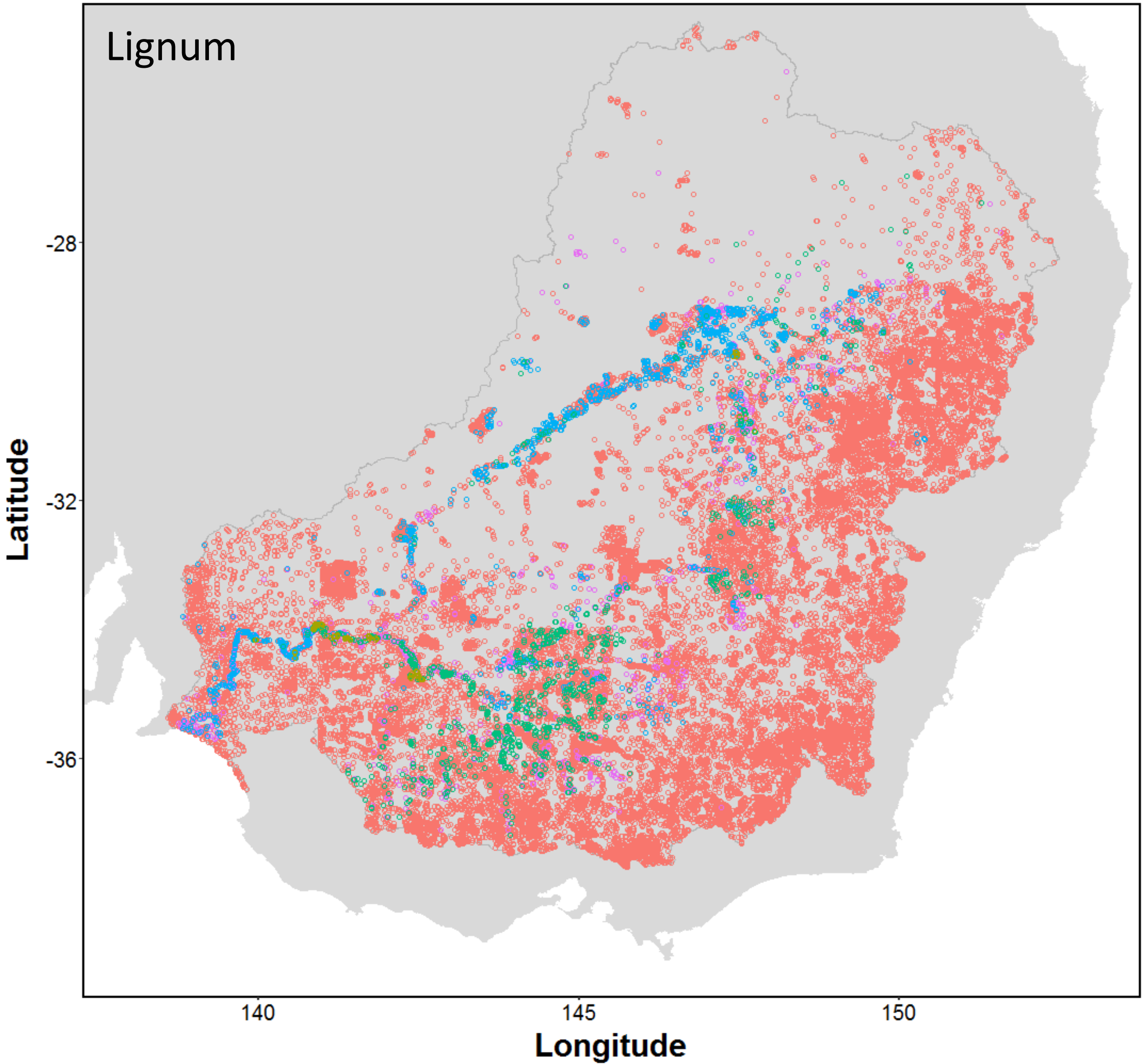
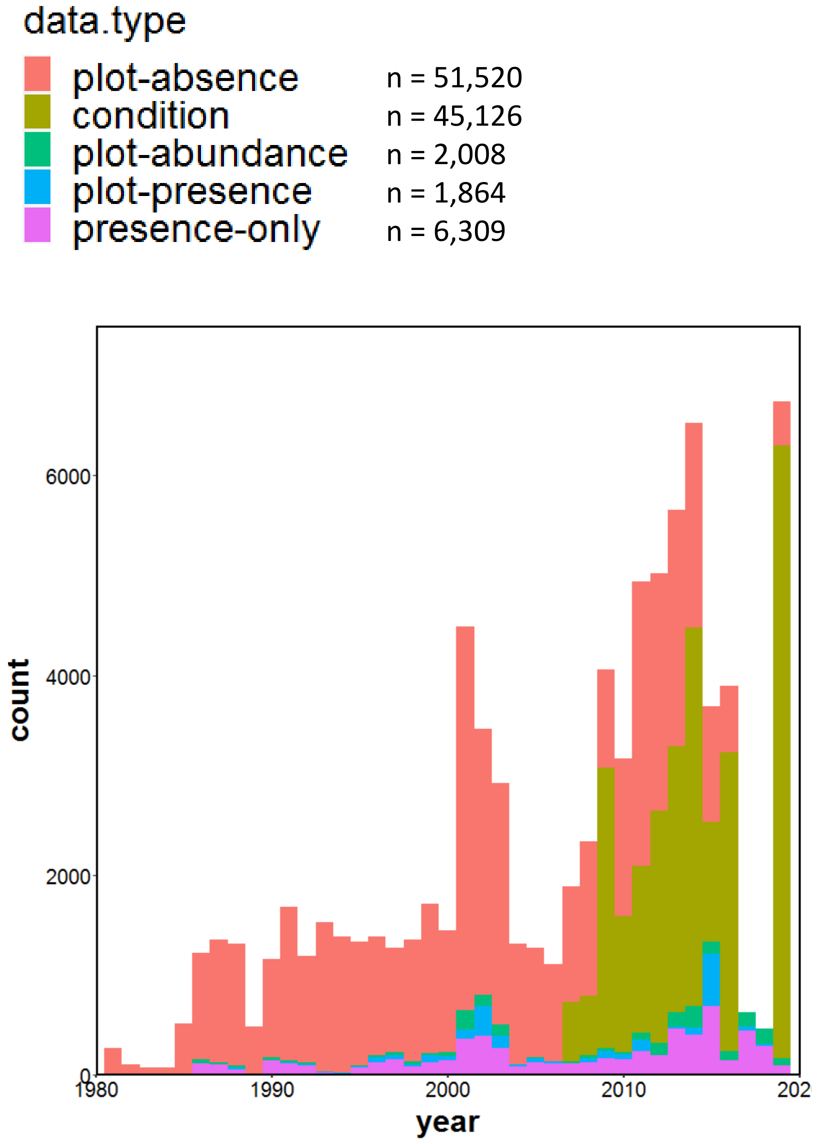
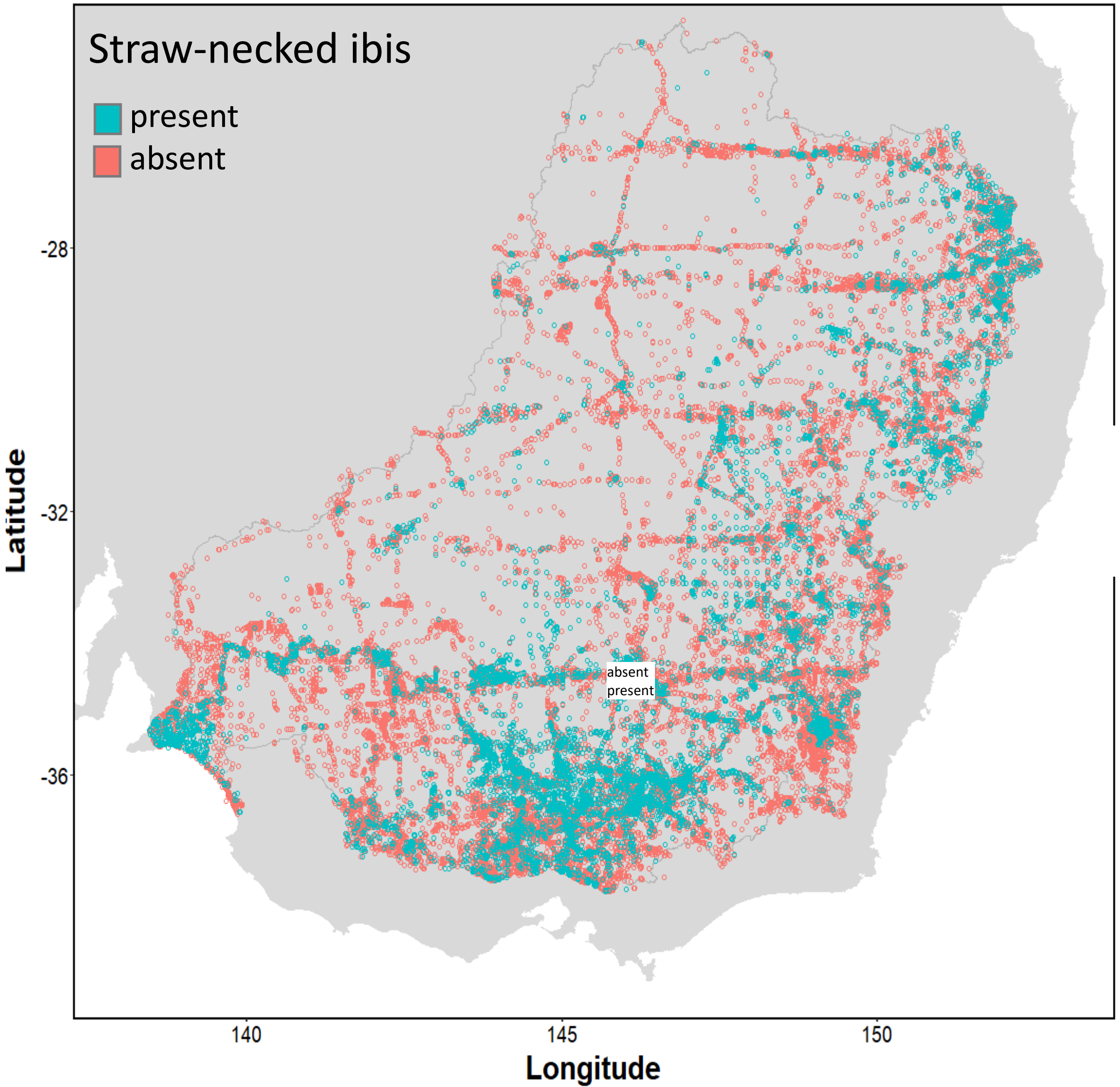
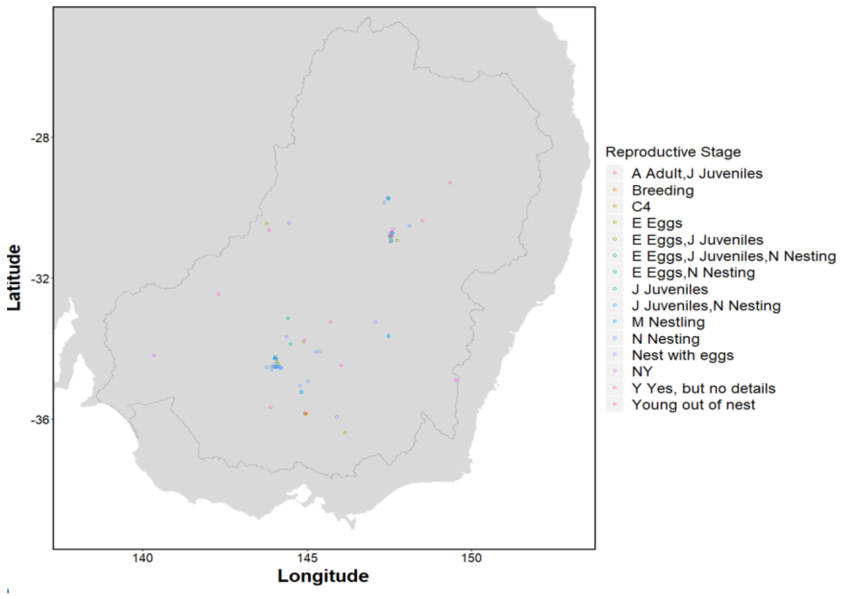
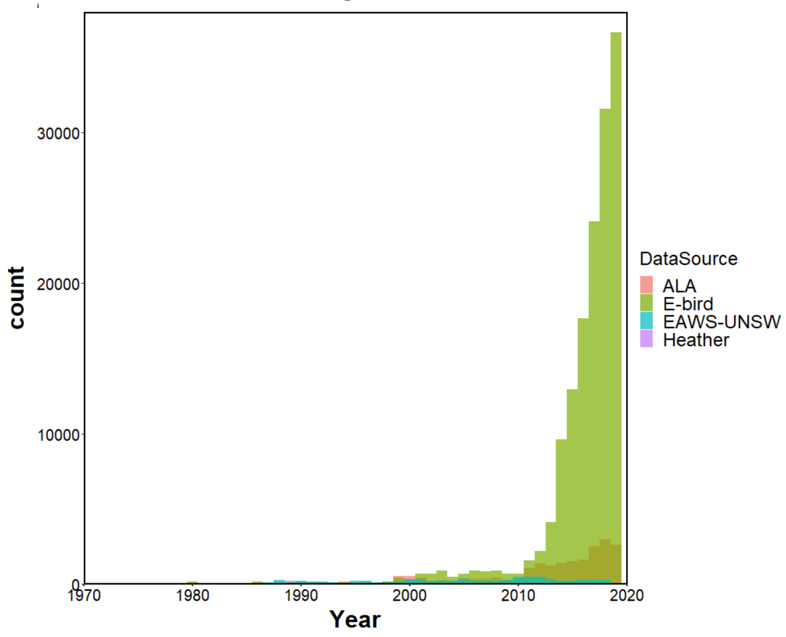




Biological data



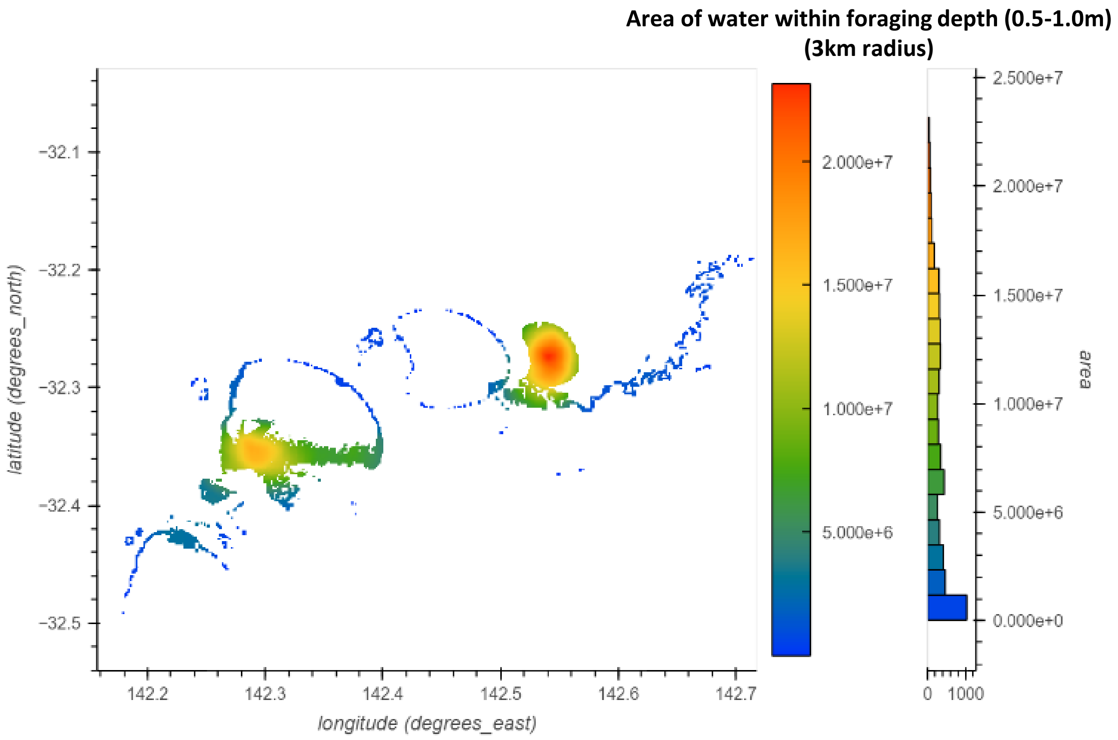


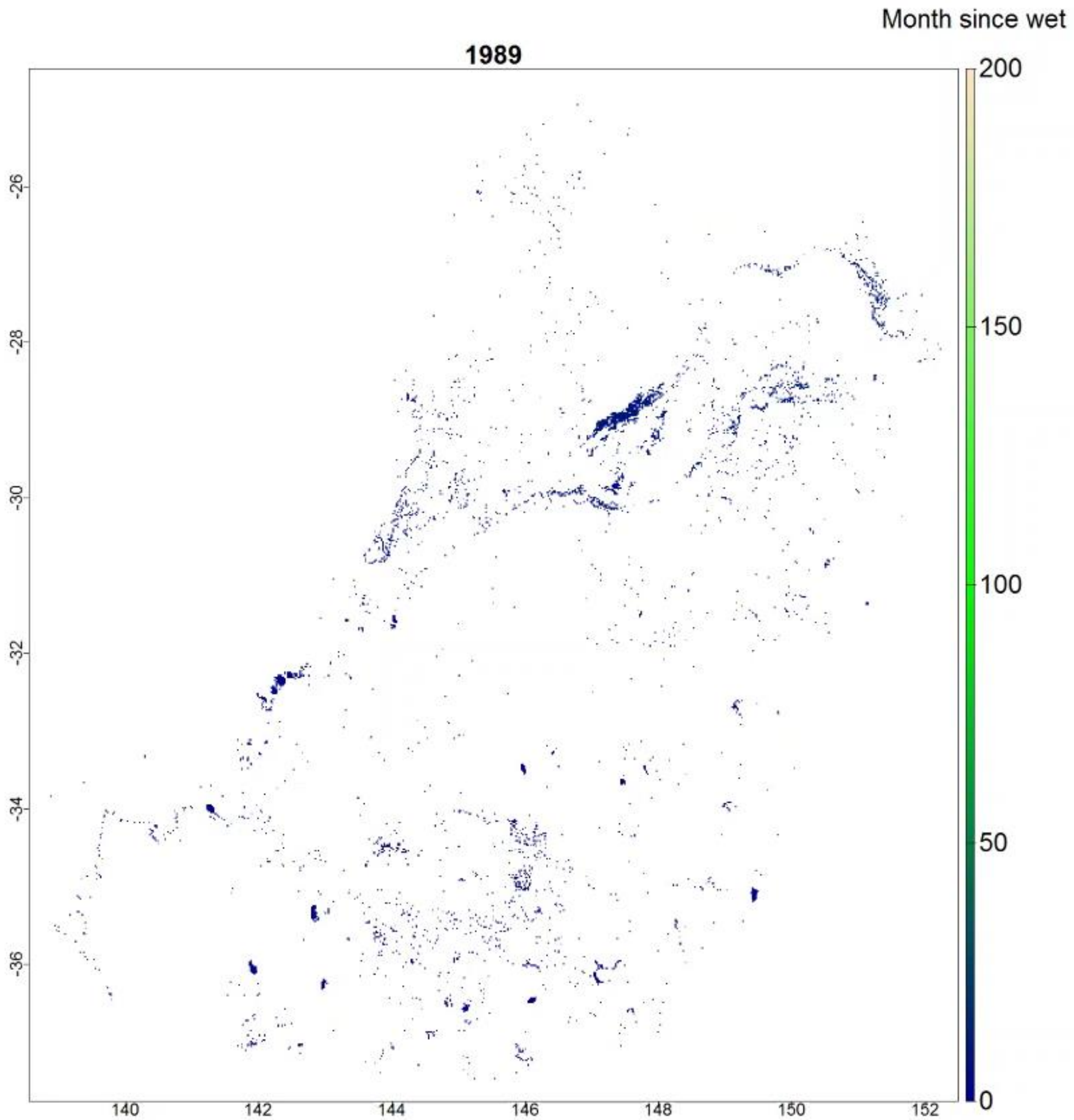


Inundation/flow data

Inundation data used to create meaningful variables :

- Number of months since last inundated
- Mean depth of inundation in the previous 5 yrs
- Area inundated to waterbird foraging depth range within foraging radius





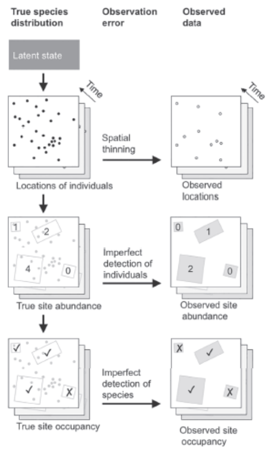
Modelling approach

Initial models

- boosted regression trees

Final models

- data integration models



Review

Data Integration for Large-Scale Models of Species Distributions

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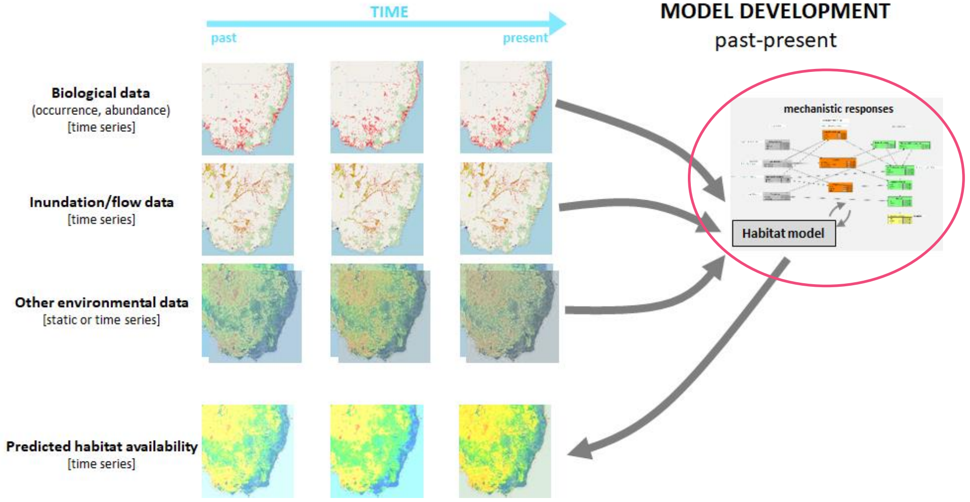
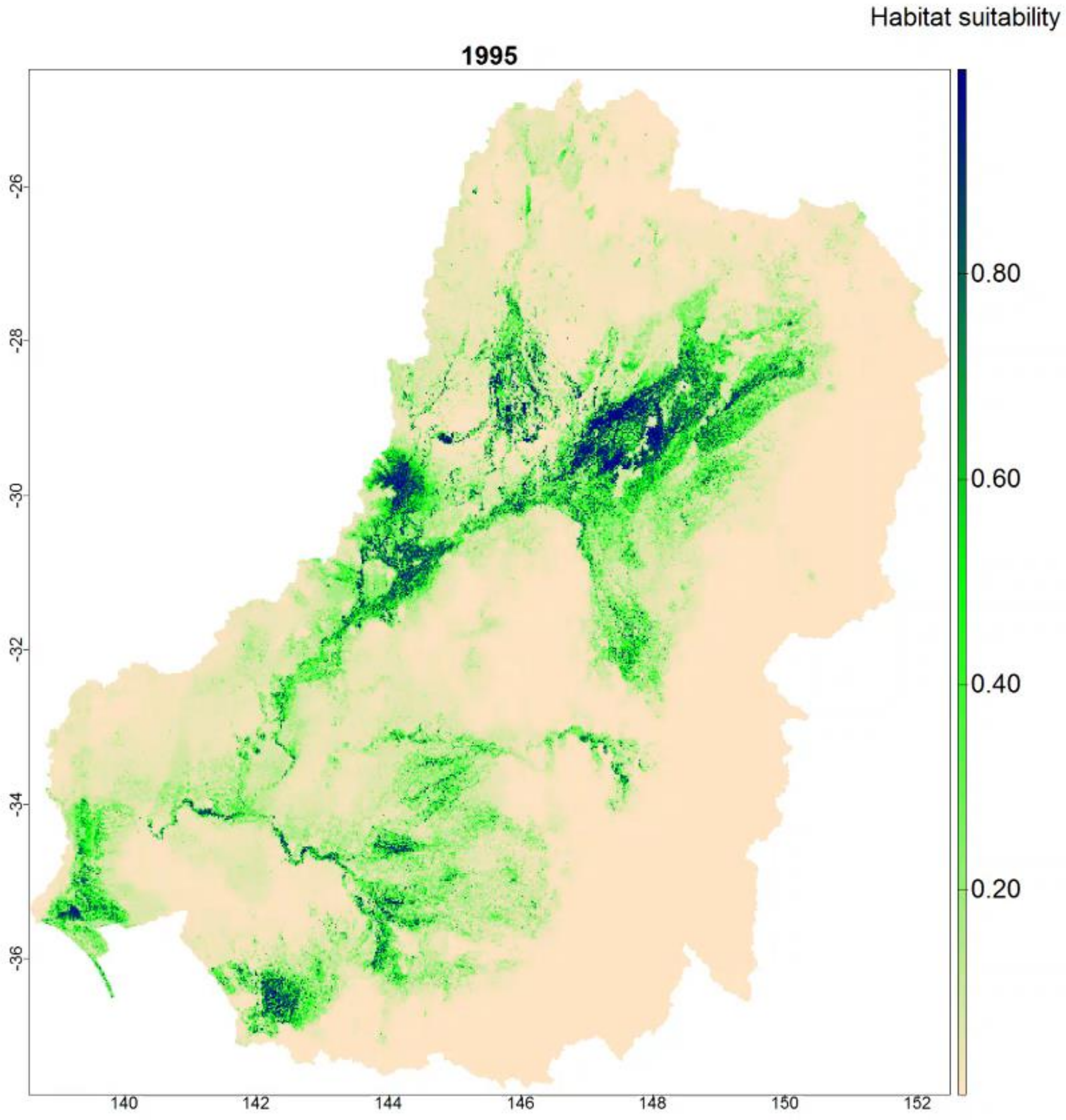
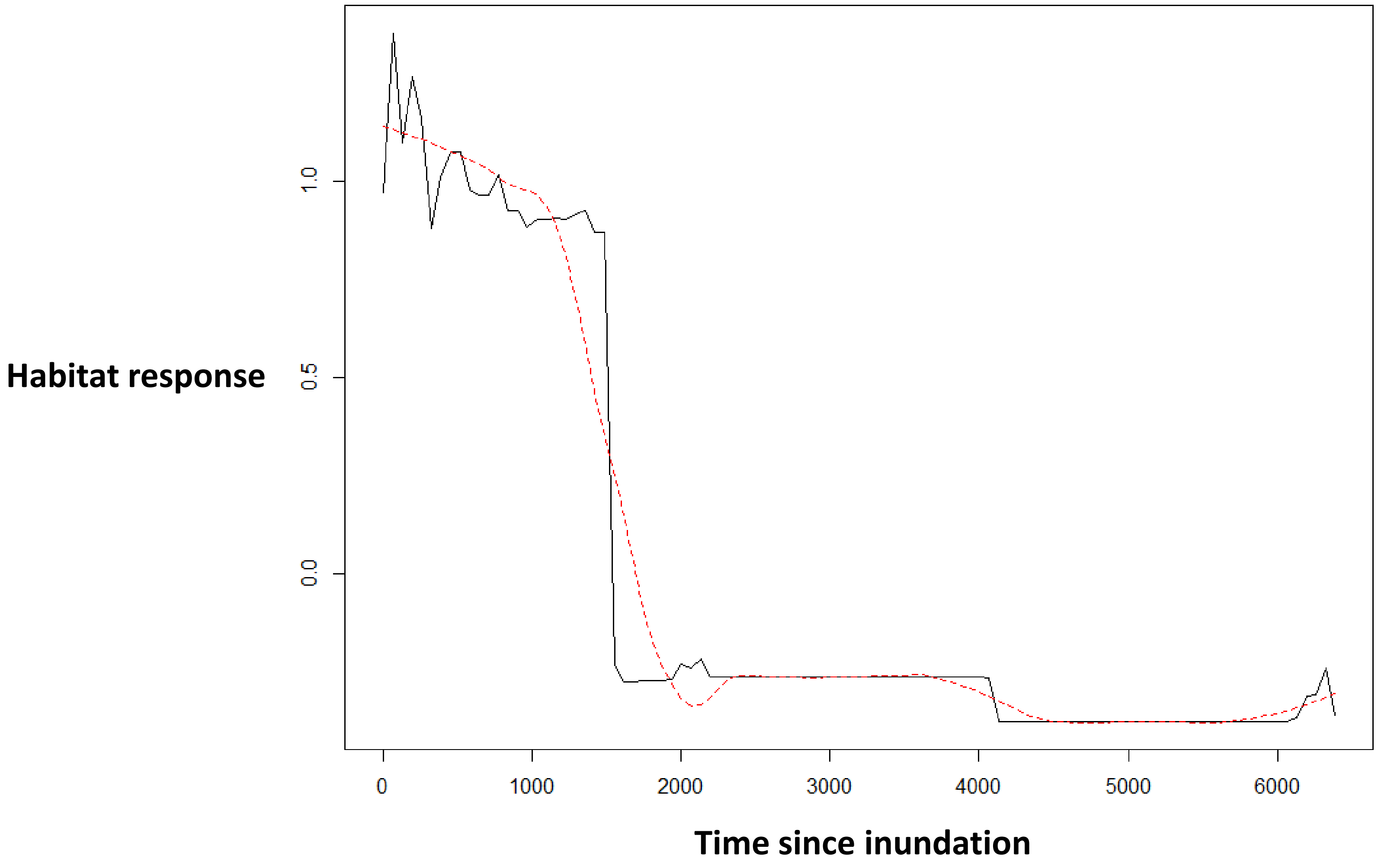


Lignum habitat



Lignum habitat – response to inundation



Use cases

Inform basin-wide medium to long term e-watering strategies (CEWO)

- Application of response-relationships developed
- Guidance pathways that evaluates resource availability scenarios

Inform the establishment of long-term EEO(s) for ecosystem functions (MDBA)

- Inform the establishment of long term expected environmental outcomes (EEO) for ecosystem functions
- Metrics/indicators to enable monitoring and evaluation
- Define interim measures of success

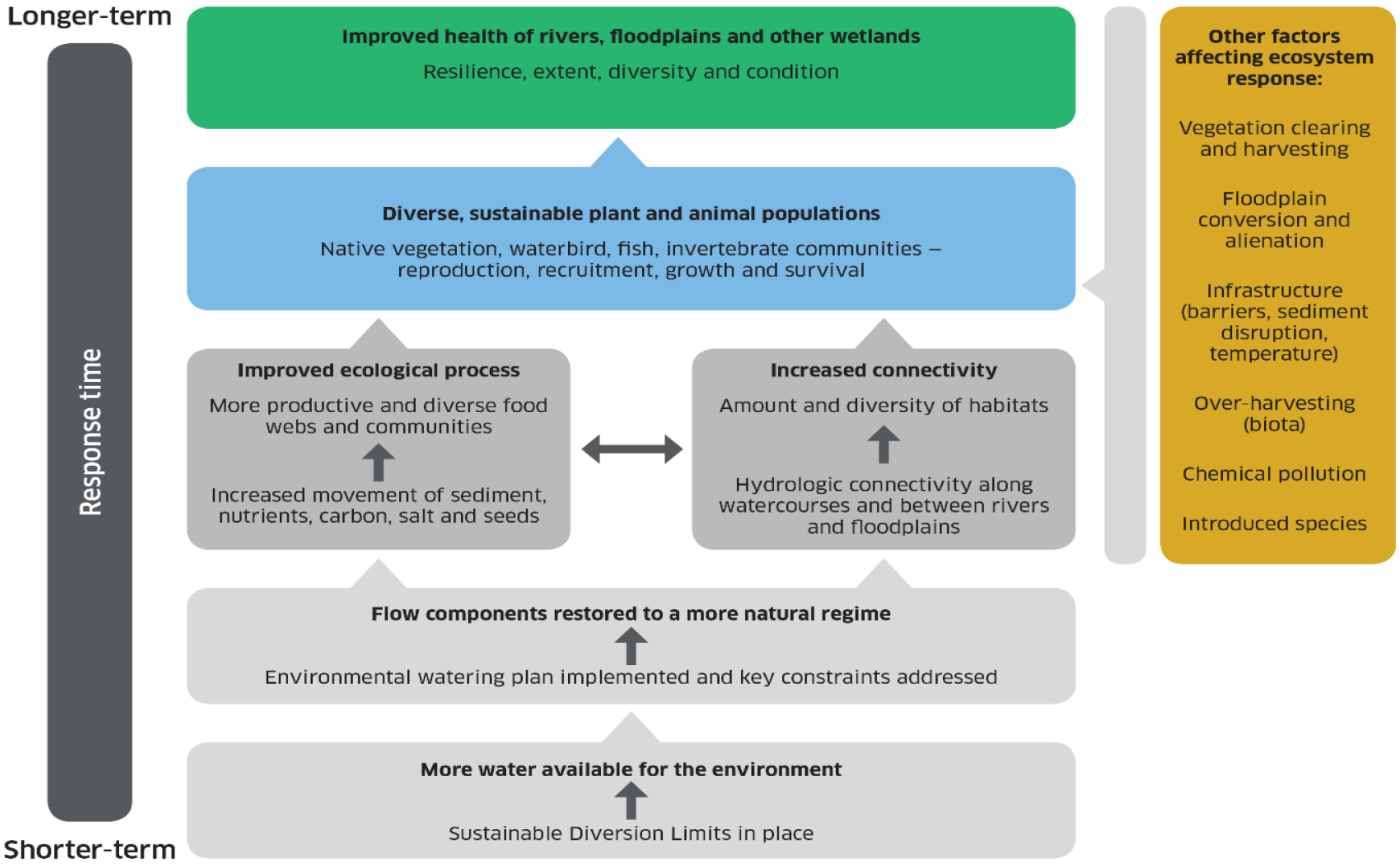
What is a medium to long term outcome?

- Assessment of four key components of the Basin’s water-dependent ecosystems are expected to respond in the medium-term given the available environmental water and the rules and arrangements in place for managing water in the Basin. The anticipated responses are expressed in terms of quantified ‘expected environmental outcomes’ (EEO)

- Long-term watering plans must identify the important environmental assets and ecosystem functions in the catchment, and their associated environmental watering requirements.

- In this multi-scale approach, long-term objectives, which are described by this Strategy and in long-term environmental watering plans, are achieved through the accumulated benefits of numerous smaller-scale, short-term interventions.

Medium to Long Term Planning



Ecosystem Functions

- Spatial and temporal capture of the Basin responses
- Identification of key variables
- Development of response relationships to drive decision making and interim EEOs and scenario testing

Annual Portfolios

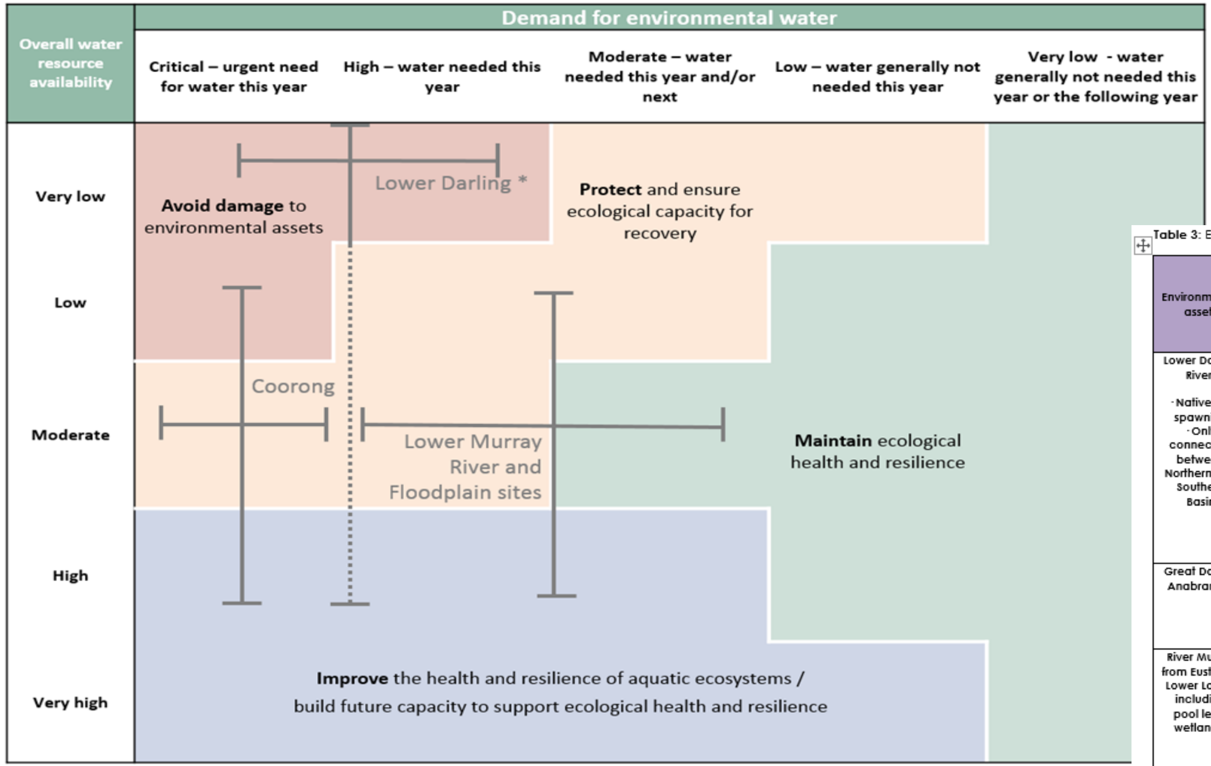
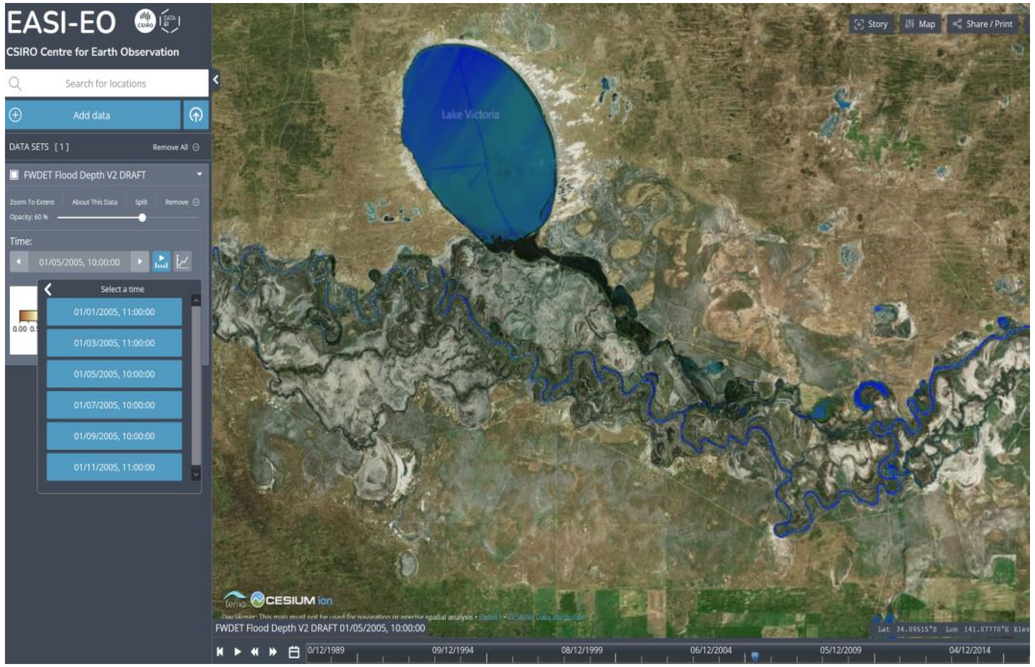


Table 3: Environmental demands, priority for watering in 2019–20 and outlook for coming year in the Lower Murray-Darling Region.

Environmental assets	Indicative demand (for all sources of water in the system)		Watering history	2019-20		Implications for future demands
	Flow/Volume	Required frequency (maximum dry interval)	(from all sources of water)	Environmental demands for water	Potential Commonwealth environmental water contribution?	Likely environmental demand in 2020-21 if watering occurred as planned in 2019-20
Lower Darling River[1] · **Native fish spawning** · **Only connection between Northern and Southern Basin**	Elevated baseflows above minimum releases through to River Murray for water quality and fish habitat requirements (400 ML/d at Weir 32).	Continuous (if limited water, focus on baseflows during spring, summer and autumn).	Very low and cease-to-flow conditions in 2014-15 and 2015-16. Small to moderate River pulse achieved in 2016-17 and baseflows maintained mostly in 2017-18. Cease to flow in 2018–19. Therefore the environmental water demand has been assessed as High.	Critical	Unlikely to receive Commonwealth environmental water due to limited resource availability, and potential delivery constraints in consideration of low lying infrastructure.	Critical
	Small to moderate river pulse (up to 7000 ML/d at Weir 32 for 10 days in summer)	1-2 in 5 years (max interval unknown)				High
Great Darling Anabranch[2]	~1100 ML/day from Menindee Lakes for ~60+ days	2 in 10 years (7 years)	A significant watering event occurred in 2016-17, allowing for dispersal of large bodied native fish and improved water quality and vegetation condition.	High	Low priority for Commonwealth environmental water. Lower Darling is a higher priority, particularly given a very low to low resource availability forecast for 2019-20.	High
River Murray from Euston to Lower Lakes, including pool level wetlands[3]	Elevated river baseflow of at least 10,000 ML/d @ SA Border for up to 60 days in spring/summer for in-channel aquatic vegetation, fish and water quality.	9 in 10 years (2 years)	All indicators met in 2012-13 and 2016-17 (the two recent floods). The years following the floods (2013-14 and 2017-18) also saw high baseflows and moderate freshes. The drier years (2014-15, 2015-16 and 2018-19) saw contributions only to the baseflows. All indicators have a high demand for 2019-20	High	A very high priority for watering in 2019–20, even in low resource availability.	High
	Moderate fresh of 15,000-25,000 ML/day SA Border for up to 90 days in spring/summer for perch spawning and survival and other ecological benefits.	2 in 3 years (2 years)			A very high priority for watering in 2019–20, noting that at least moderate resource availability (and potentially multiple water holder contributions) would be required and the full 90 day duration may be challenging.	Moderate
	Large fresh of 25,000-35,000 ML/day @ SA Border for up to 60 days in spring/summer for fish populations and other in-channel biota.	1 in 2 years (3 years)			High resource availability and tributary inflows would be required to deliver flows of this magnitude	Moderate

Depth and extent of inundation (two monthly)



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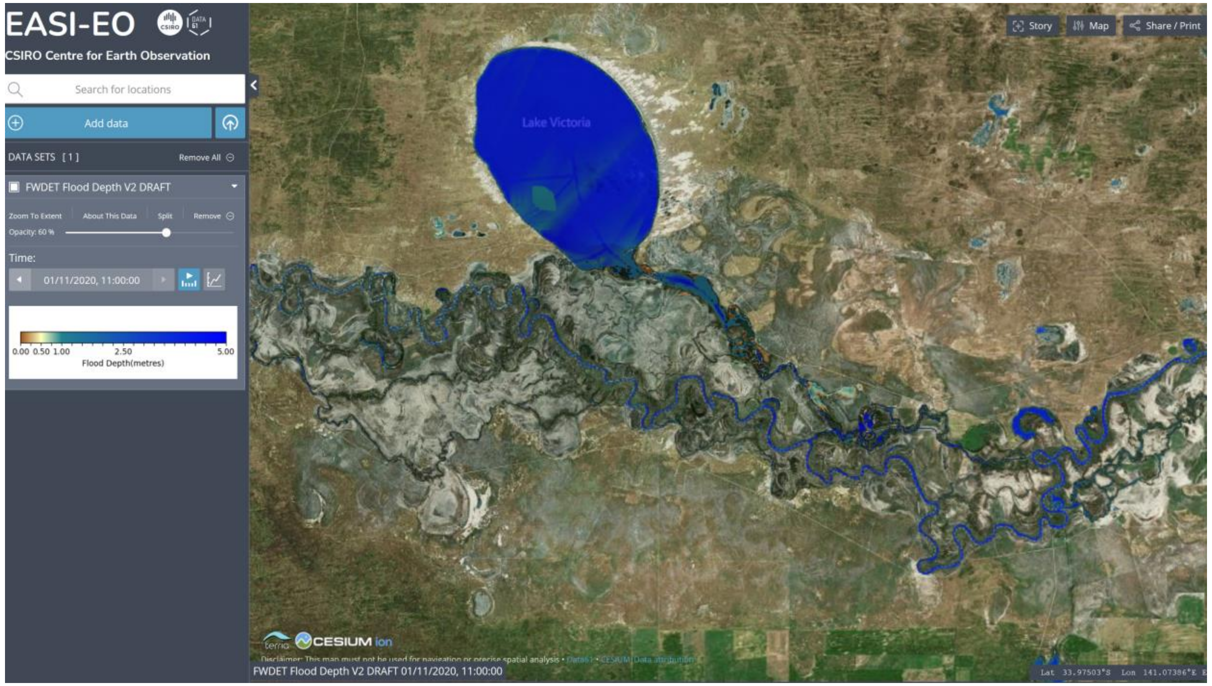
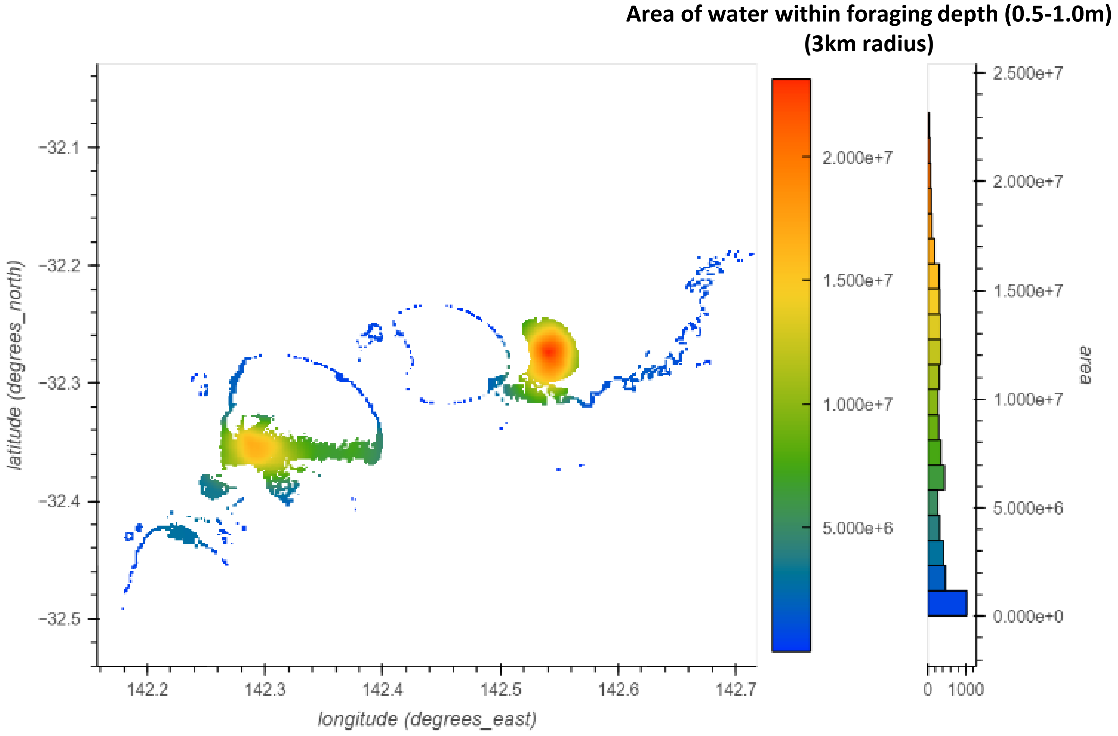
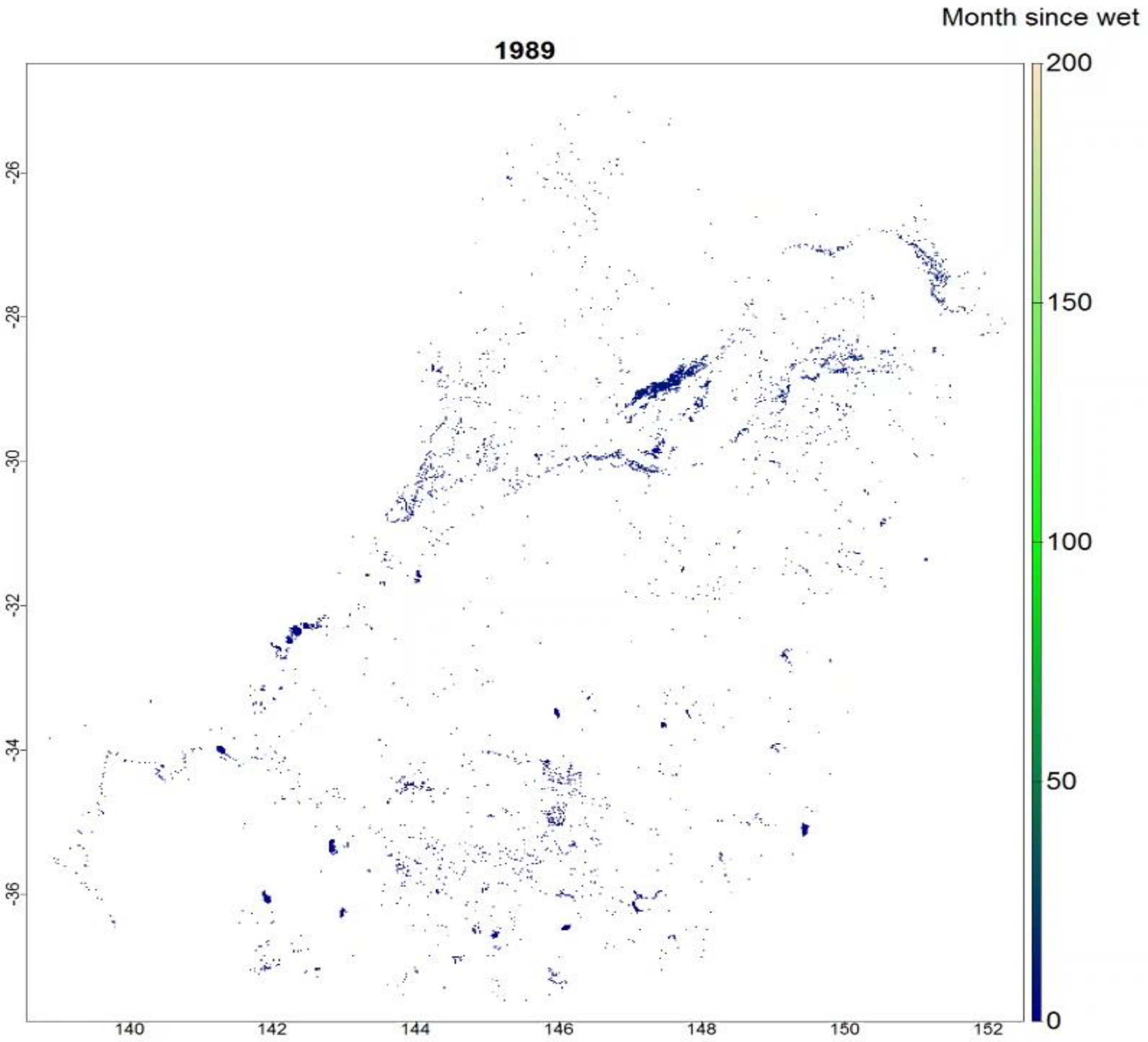


Inundation/flow data

Inundation data used to create meaningful variables :

- Number of months since last inundated
- Mean depth of inundation in the previous 5 yrs
- Area inundated to waterbird foraging depth range within foraging radius





Project outputs | Project inputs | EEO