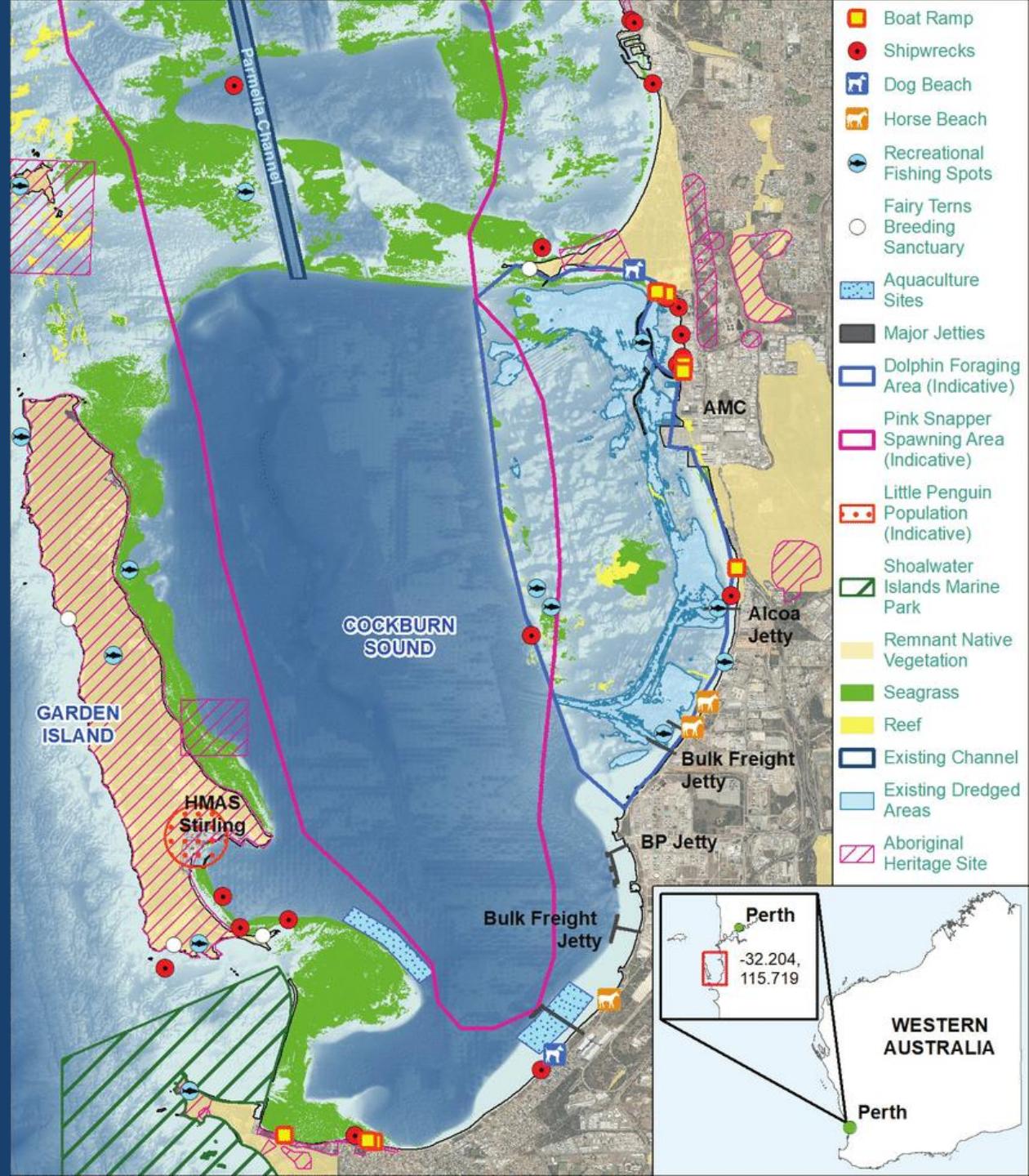
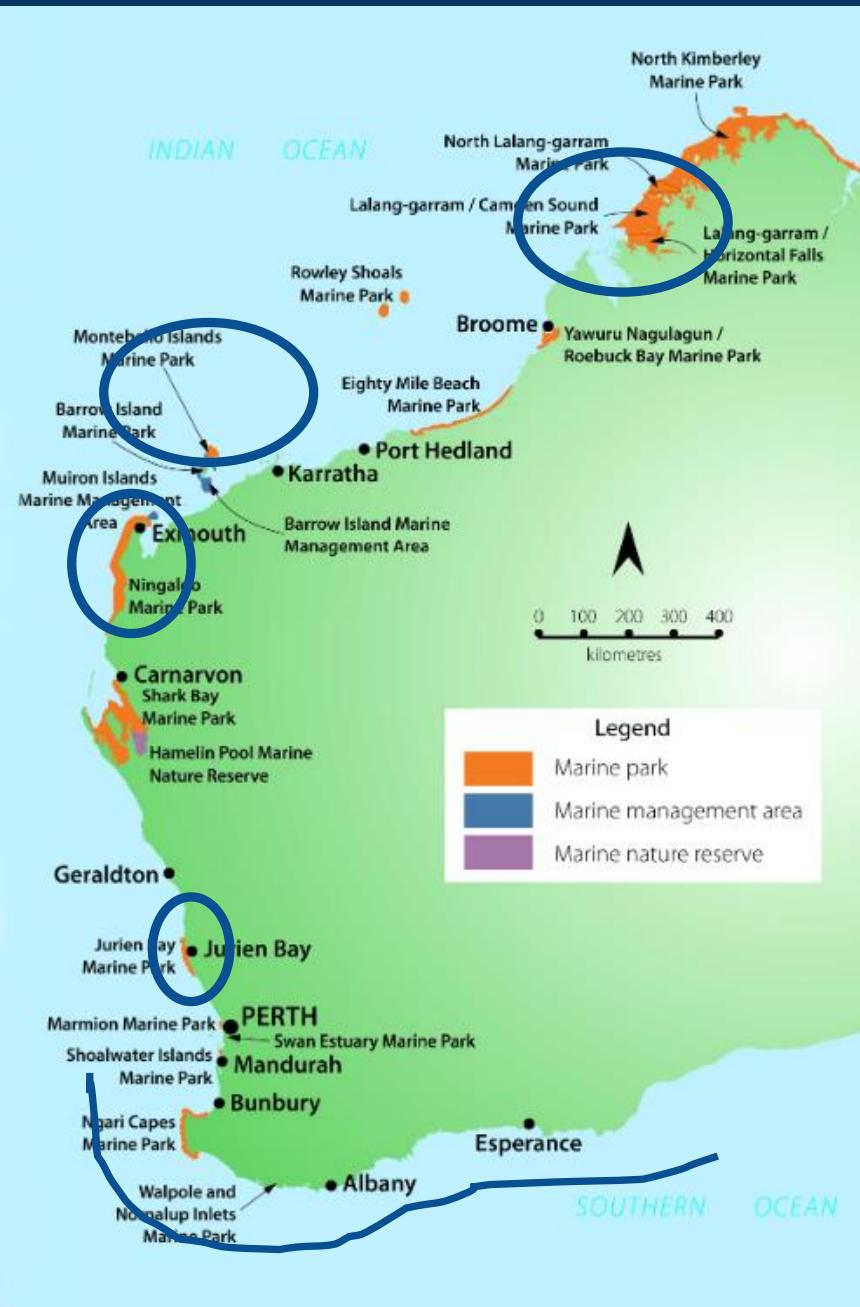


1.3 Conceptual understanding and ecosystem models of Cockburn Sound

- Workshop 1 – Intro., initial ideas
- Workshop 2 – Progress
- Workshop 3 – Findings





Models of marine systems

Kimberleys (WAMSI)

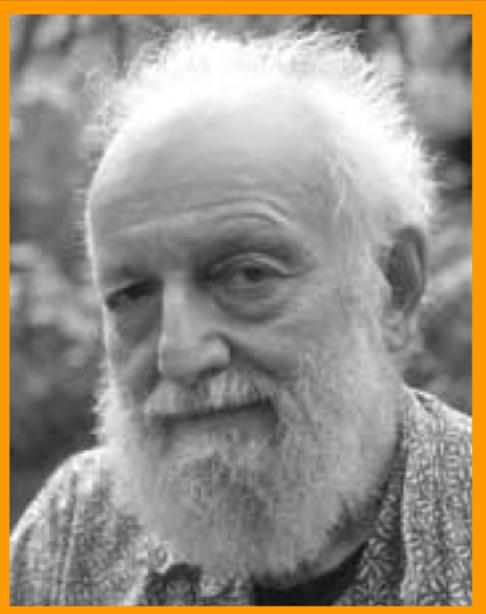
North-west Shelf (CSIRO)

Ningaloo (CSIRO/WAMSI)

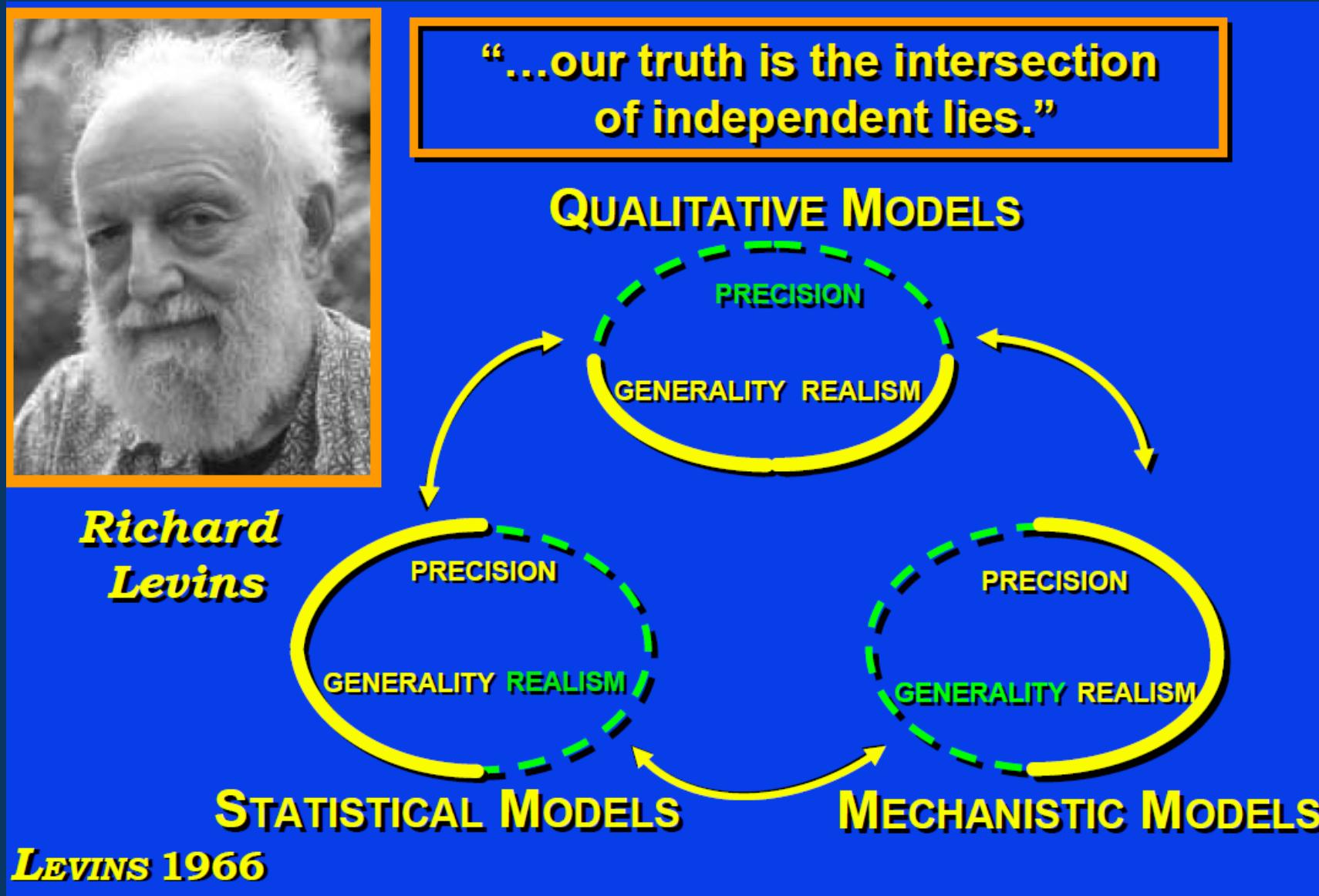
Jurien (CSIRO/Murdoch)

SW region (CSIRO)

Models
Precision
Generality
Realism



“...our truth is the intersection
of independent lies.”



Building system understanding and models

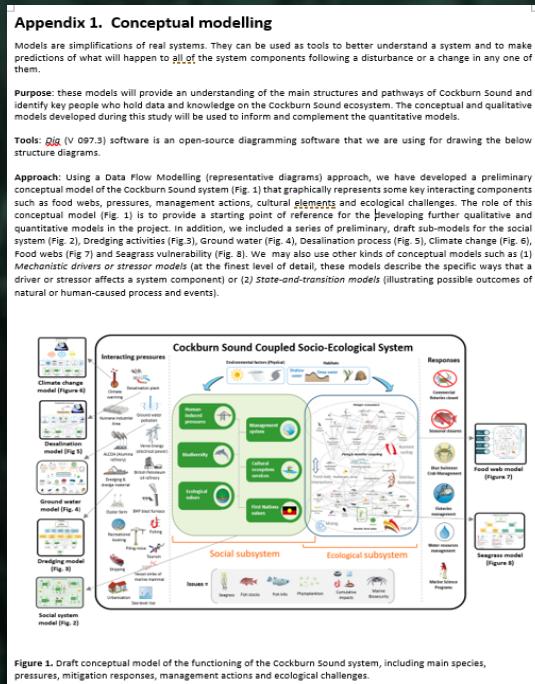
What we need

- diverse group of people, key people and organisations
- knowledge and data of the system
 - historical
 - current state
- major factors influencing the system (historical, current, future)
 - environmental, climatic
 - anthropogenic
- Key species and groups of species

Task

Project 1.3 Conceptual understanding and ecosystem models of Cockburn Sound (*Derbal Nara)

Appendix 1 Conceptual models



Appendix 2 Qualitative models

Task 1: What other qualitative scenarios would you consider relevant to explore with network analysis? (Figure 8 shows the main elements of the qualitative model)

Scenario	Scope of scenario
Species involved	Yes / No?
○ Seagrass?	<input type="checkbox"/> Explore the relationships <input type="checkbox"/> List of drivers <input type="checkbox"/> Expert consultation <input type="checkbox"/> Selection of key drivers of change for EwE (Quantitative model)
○ Blue Swimmer Crab?	
○ Little Penguin?	
○ Apex predators?	
○ Nekton?	
○ Seagrass?	
○ Pink Snapper?	
○ Blue Swimmer Crab?	
○ Little Penguin?	
○ Apex predators?	
○ Nekton?	
○ Other?	
Pressures / Drivers	
○ Climate change on Apex predators, iconic species, key commercial species, key recreational species?	<input type="checkbox"/> Explore the relationships <input type="checkbox"/> List of drivers <input type="checkbox"/> Expert consultation <input type="checkbox"/> Selection of key drivers of change for EwE (Quantitative model)
○ Dredging?	
○ Fishing?	
○ Desalination?	
○ Piling noise?	
○ Tourism?	
○ Urbanisation?	
○ Shipping?	
○ Ground water pollution?	
*Others	

*See Fig. 8 for the list of the social and ecological elements included in the [qualitative_model](#)

Appendix 3 Quantitative model

Table 1. Proposed functional groups for the Ecopath Cockburn Sound model

Category	# Workgroup	Proposed functional group	Remarks
High commercial species	1	Pink Snapper - Abundance	Commercial fishing
	2	Blue Swimmer Crab	Commercial fishing
	3	Southern Codfish	Commercial fishing
	4	Prickly	Seabed impact, fisheries
	5	Nudibranch (White bink)	Commercial fishing
	6	Regale (Southern Codfish)	Commercial fishing
	7	Western Australian Common Gurnard	Commercial fishing
	8	Black murex	Aquaculture
	9	Australian Hermit	Recreational fisheries
	10	Hermit crab (white)	Recreational fisheries
	11	King George Whiting	Recreational fisheries
	12	Bluegill (Yellowtail)	Recreational fisheries
	13	Marine invertebrates (non-Rainbow smelt)	Recreational fisheries
	14	Woollybats	Abundance (seabirds), seabirds (fisheries), seabirds (commercial fisheries)
	15	Blue Spotted	Spawning (fisher)
	16	Cownose (Bonyhead) (Abundance, spawning, abundance, fishing, fishing pressure)	Recreational fisheries
	17	Flockable and fathoms	Recreationally important (flockable seabirds), flocks (fisher), flocks (commercial fisheries), flocks (abundance), flocks (commercial fisheries)
	18	Australian Salmon	Recreational fisheries
	19	Mulloway	Recreational fisheries
	20	Western Australia flathead	Recreational fisheries
	21	Western King Prawn	Recreational fisheries
	22	Green sea urchin	Recreational fisheries

* Derbal Nara means Estuary of the Salmon, which is the Nyungar name for Cockburn Sound.

Task 1: What other qualitative scenarios would you consider relevant to explore with network analysis?

Scenario		Scope of scenario
Species involved	Yes / No?	
<input type="radio"/> Seagrass?		<input type="radio"/> Explore the relationships <input type="radio"/> List of drivers <input type="radio"/> Expert consultation <input type="radio"/> Selection of key drivers of change for EwE (Quantitative model)
<input type="radio"/> Blue Swimmer Crab?		
<input type="radio"/> Little Penguin?		
<input type="radio"/> Apex predators?		
<input type="radio"/> Nekton?		
<input type="radio"/> Pink Snapper?		
<input type="radio"/> Blue Swimmer Crab?		
<input type="radio"/> Little Penguin?		
<input type="radio"/> Apex predators?		
<input type="radio"/> Nekton?		
<input type="radio"/> Other?		
Pressures / Drivers		
<input type="radio"/> Climate change on Apex predators, iconic species, key commercial species, key recreational species?	<input type="radio"/>	<input type="radio"/> Explore the relationships <input type="radio"/> List of drivers <input type="radio"/> Expert consultation <input type="radio"/> Selection of key drivers of change for EwE (Quantitative model)
<input type="radio"/> Dredging?	<input type="radio"/>	<input type="radio"/>
<input type="radio"/> Fishing?	<input type="radio"/>	<input type="radio"/>
<input type="radio"/> Desalination?	<input type="radio"/>	<input type="radio"/>
<input type="radio"/> Piling noise	<input type="radio"/>	<input type="radio"/>
<input type="radio"/> Tourism?	<input type="radio"/>	<input type="radio"/>
<input type="radio"/> Urbanisation?	<input type="radio"/>	<input type="radio"/>
<input type="radio"/> Shipping?	<input type="radio"/>	<input type="radio"/>
<input type="radio"/> Ground water pollution?	<input type="radio"/>	<input type="radio"/>
*Others		

On break take a moment to write suggestions, species to include, processes to explore (Appendix 2)

CONCEPTUAL MODEL



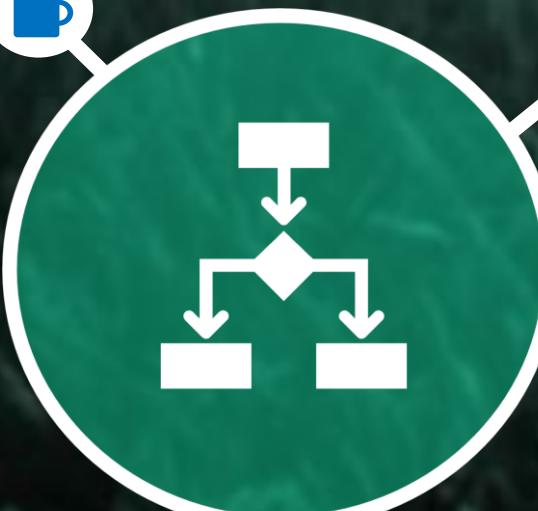
PLAN



Q&A



QUALITATIVE MODEL



Q&A

ECOPATH MODEL







Brent Wise *DPIRD*

Neil Loneragan *MU*

Stephanie Fourie *MU*

Hector Lozano *MU*



**Identify key links and process
for conceptual model**

**Define the structure of the functional
groups for EwE model**

**Identify key people who hold
data, knowledge or understanding
for the model development.**

KEY PEOPLE AND GROUPS FOR DATA / SUPPORT

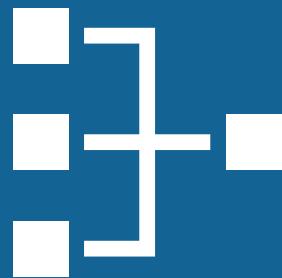
Area of expertise	Name	Institution
Seagrass	Gary Kendrick	UWA
	Kathryn McMahon	ECU
	Paul Lavery	ECU
Benthos general	James Tweedley	MU
Benthos general	Glenn Hyndes	ECU
Benthos general	John Keesing	CSIRO
Benthos general	Sorcha Cronin-O'Reilly	MU
Historical Prawns & crabs	James Penn	DPIRD
Squids & cuttlefish	Daniel Yeoh	DPIRD
Fish general	Daniel Gaughan	DPIRD
	Corey Wakefield	DPIRD
	Kurt Krispyn	MU
	Mitchell Haywood	MU
Fish-Pink Snapper	David Fairclough	DPIRD
Fish-Pink Snapper	Gary Jackson	DPIRD
Historical fish understanding	Rod Lenanton	DPIRD
Sharks	Matias Braccini	DPIRD
Australian Sea Lion	Chandra Salgado	ECU
	Kelly Waples	DBCA
Dolphins	Delphine Chabanne	MU
Seabirds (terns, gulls, cormorants)	Nic Dunlop	CCWA
	Claire Greenwell	CCWA

Area of expertise	Name	Institution
Little Penguin	Belinda Cannell	DBCA
	Erin Clitheroe	MU
Blue Swimmer Crab	Daniel Yeoh	DPIRD
	Danielle Johnston	DPIRD
Zooplankton & larval fishes	Lynnath Beckley	MU
	Joanna Strezleki	CSIRO
	David Holliday	MU
Micro-phyto-benthos	Mat Vanderklift	CSIRO
Phytoplankton	Rod Lukatelich	WAMSI Board
	Stuart Helleren	Dalcon Environmental
Ground water, nutrients, circulation, biogeochemistry	Matt Hipsey	UWA
	Chari Pattiaratchi	UWA
	Ming Feng	CSIRO

Expertise Groups

- WAMSI/Westport Science Group
- Cockburn Sound Management Council
- Recfishwest
- WAFIC - Matt Pember
- DPIRD researchers and managers
- DBCA researchers and managers
- Westport researchers and managers, all Theme Leaders

Approach



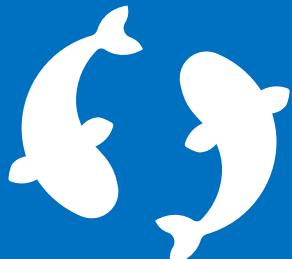
Marine
system
models

Use of
models

Integrated
information

Last decade

Marine system models



PLANKTON MODELS: increased resolution, additional processes, up to 15 phytoplankton groups.

FOOD WEB MODELS: added processes and resolution, some human interactions (i.e. fishing).

SOCIO-ECOLOGICAL MODELS “whole of ecosystem approach”:

- A) Very general, not deep in any particular process, very broad
- B) *MICE* (Model of Intermediate Complexity Ecosystem): focus on key players and processes

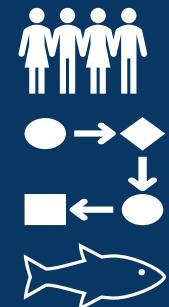
Use of models

**Conceptual & Qualitative
(understanding)**

**Tactical
(year to year)**



**Strategic:
understanding, forecast,
management support**



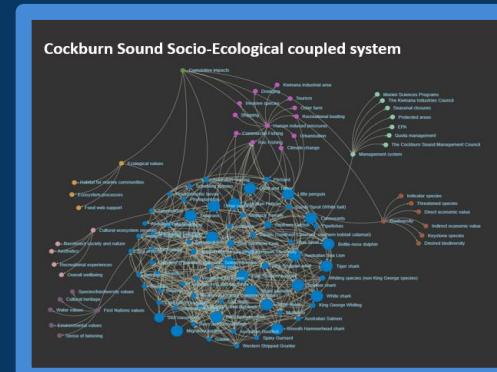
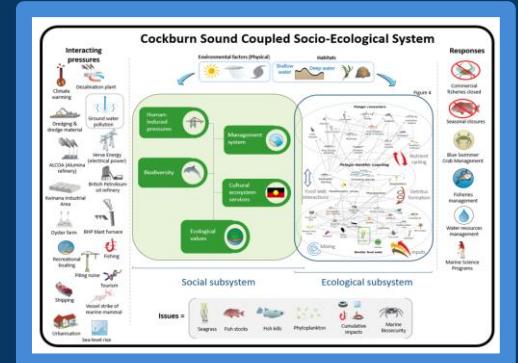
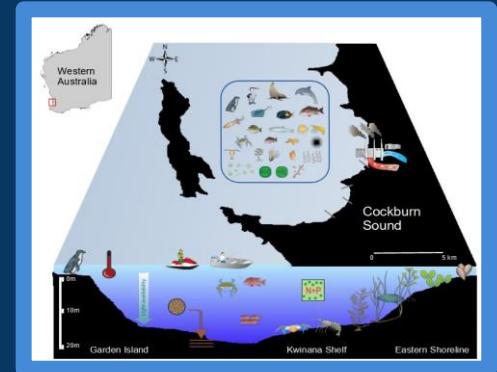
Integrated Information



Conceptual model

Qualitative model

Ecopath model



CONCEPTUAL MODEL



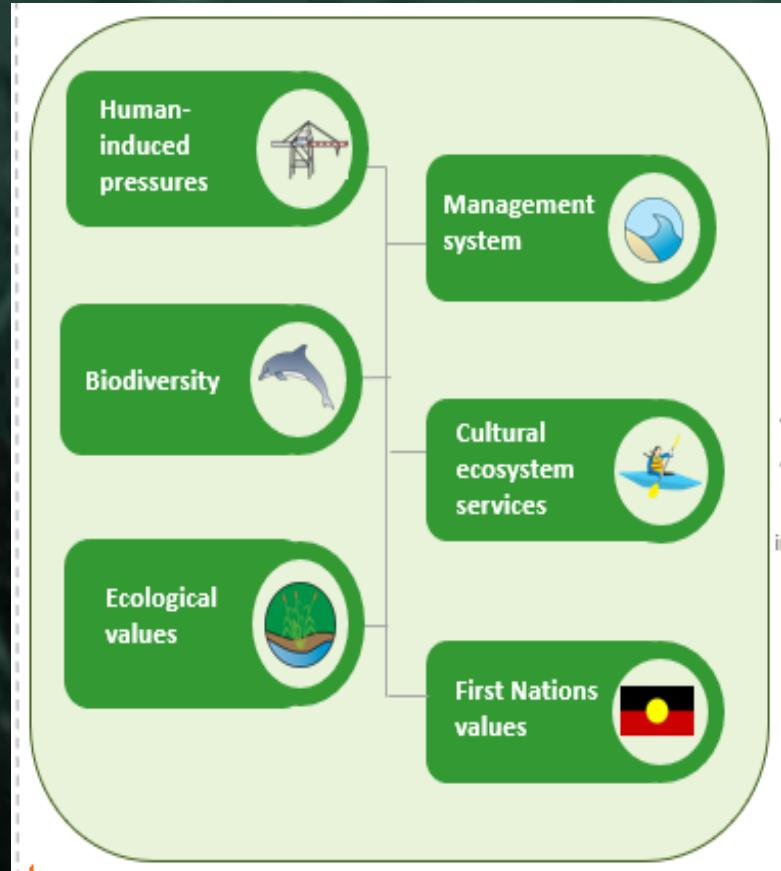
Model
entities

Functional
areas

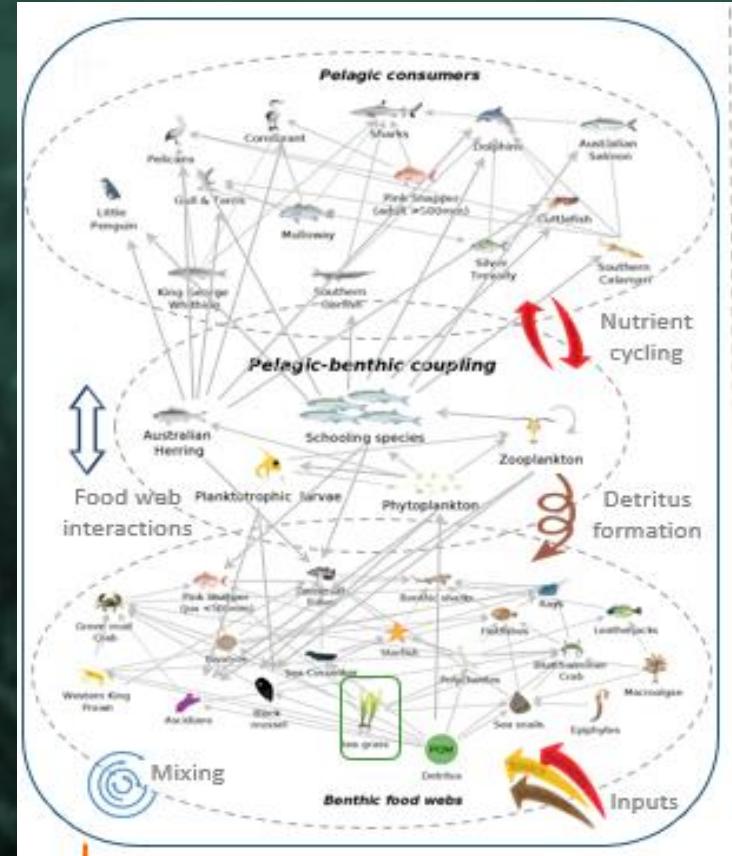
Influence
diagrams

Cockburn Sound

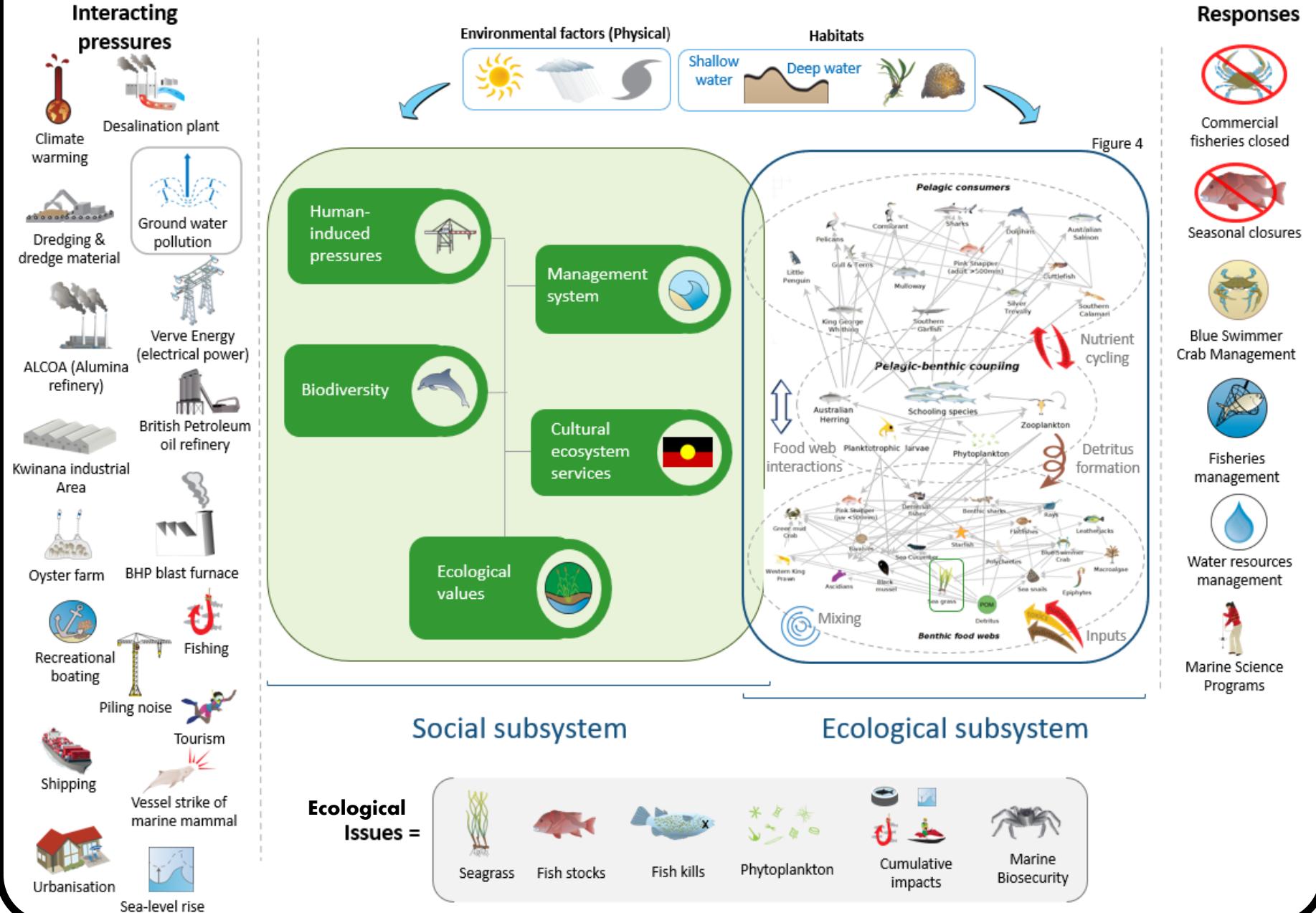
Social system



Ecological system

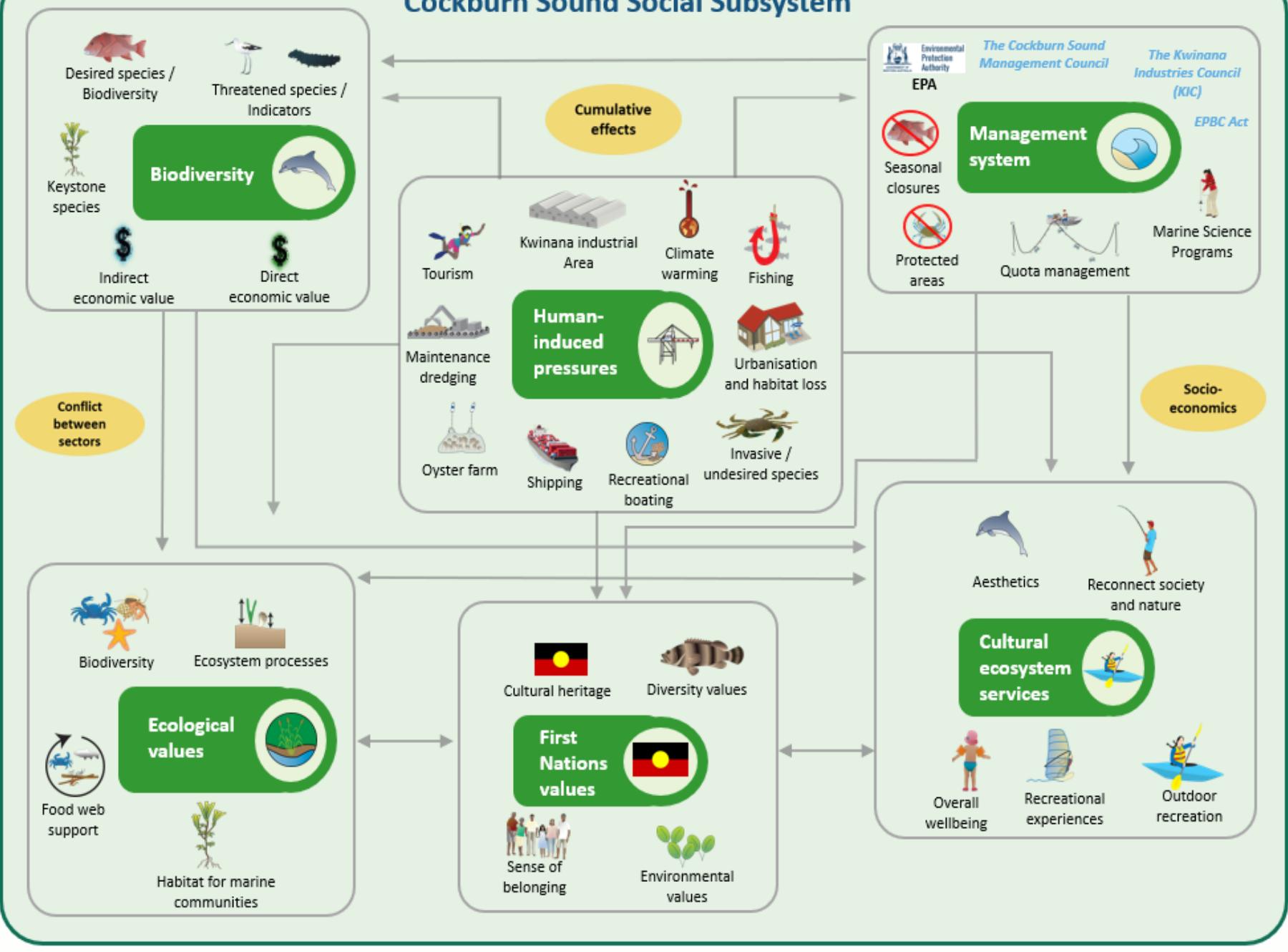


Cockburn Sound Coupled Socio-Ecological System

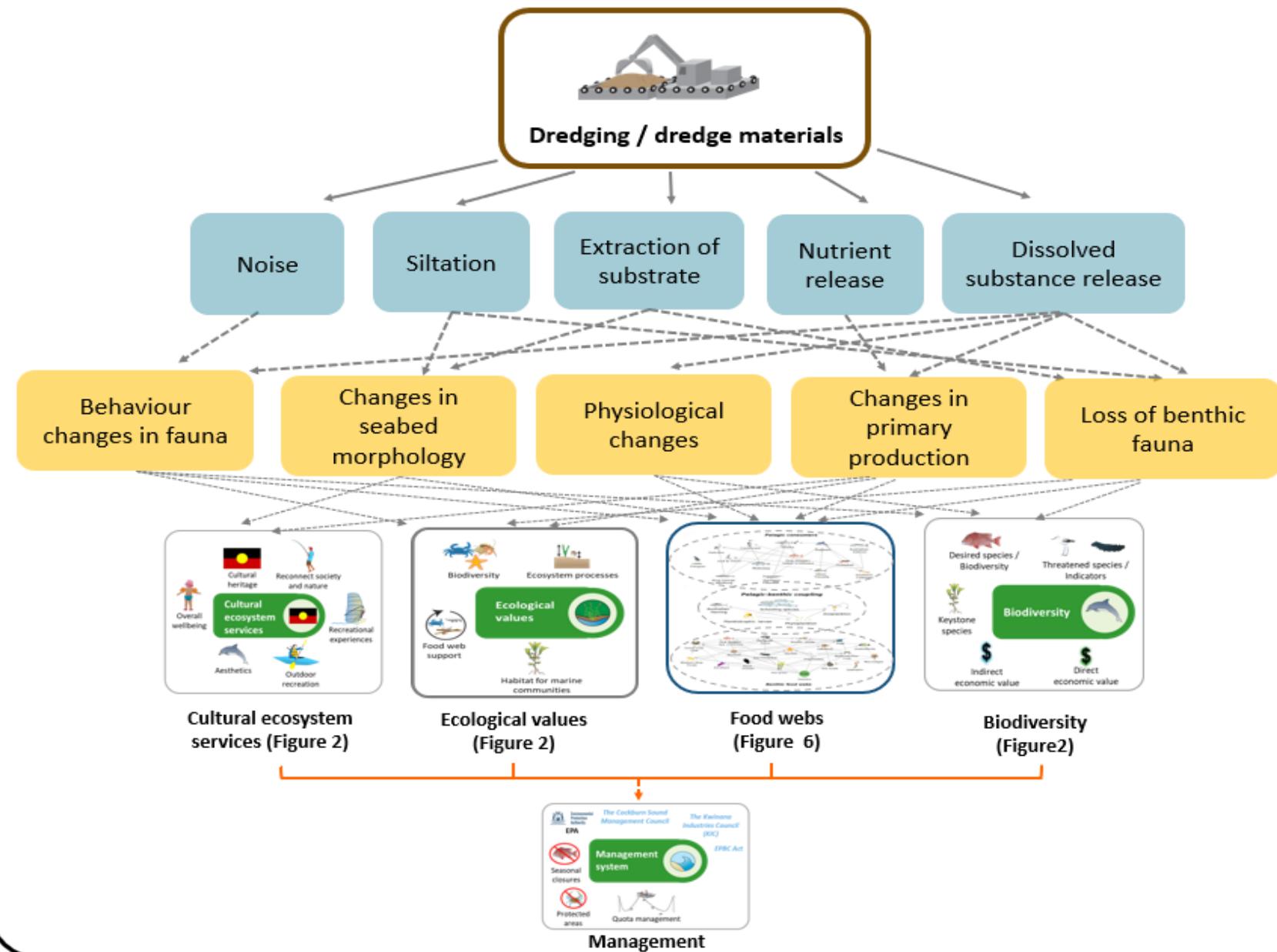




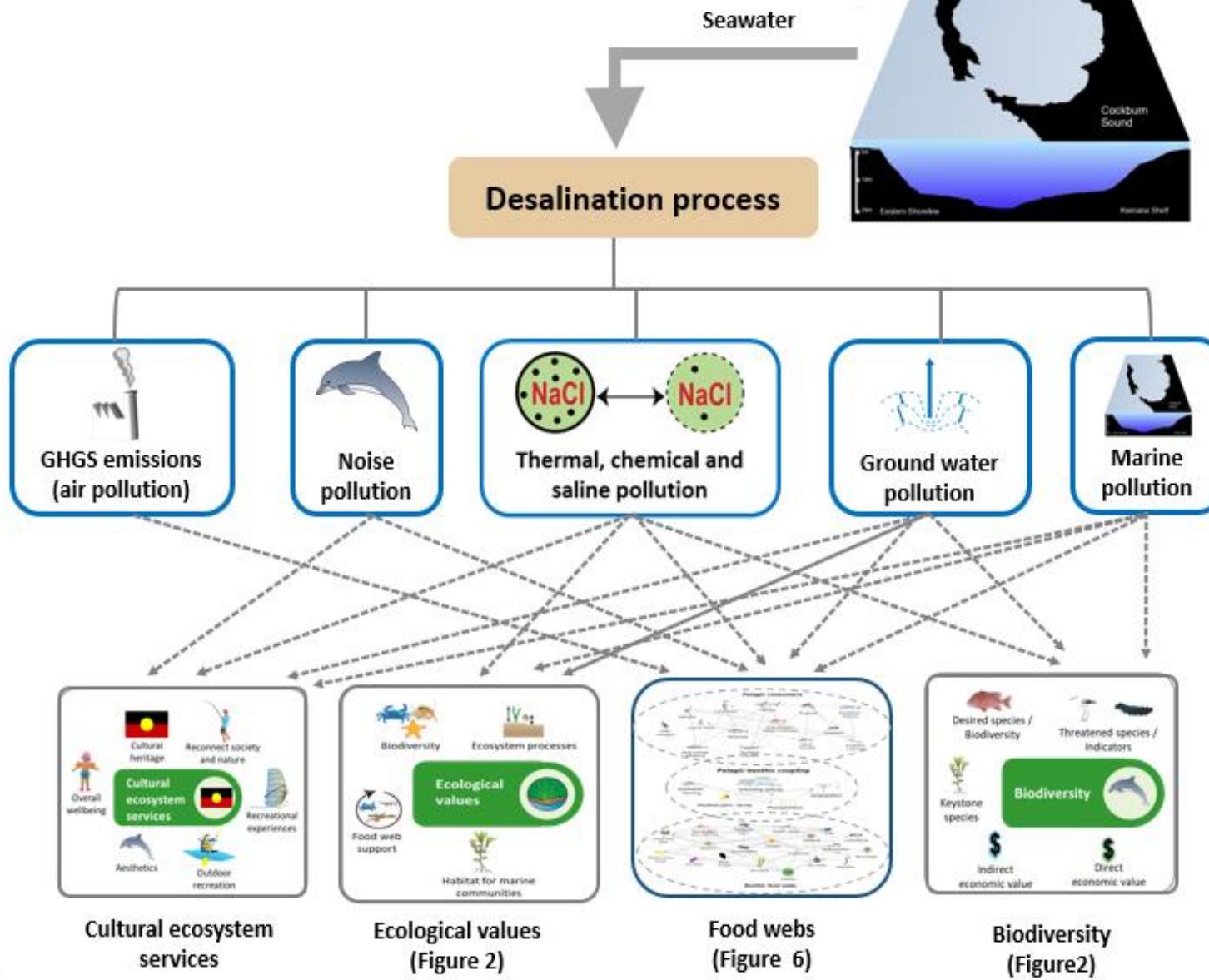
Cockburn Sound Social Subsystem



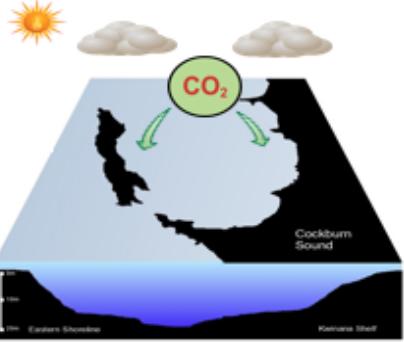
Dredging



Desalination process



Climate change



Warmer

Less O₂

More Acid



Desiccation



Mixing



Individuals,
Populations,
Food webs



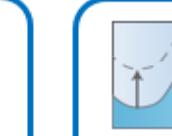
Fisheries



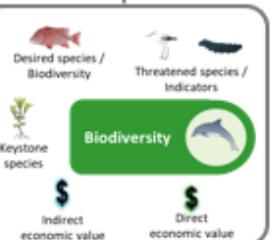
Habitats



Acidification



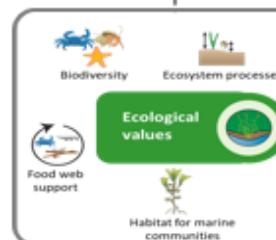
Sea level



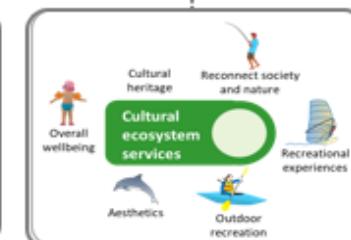
Biodiversity (Figure 2)



Management system
(Figure 2)

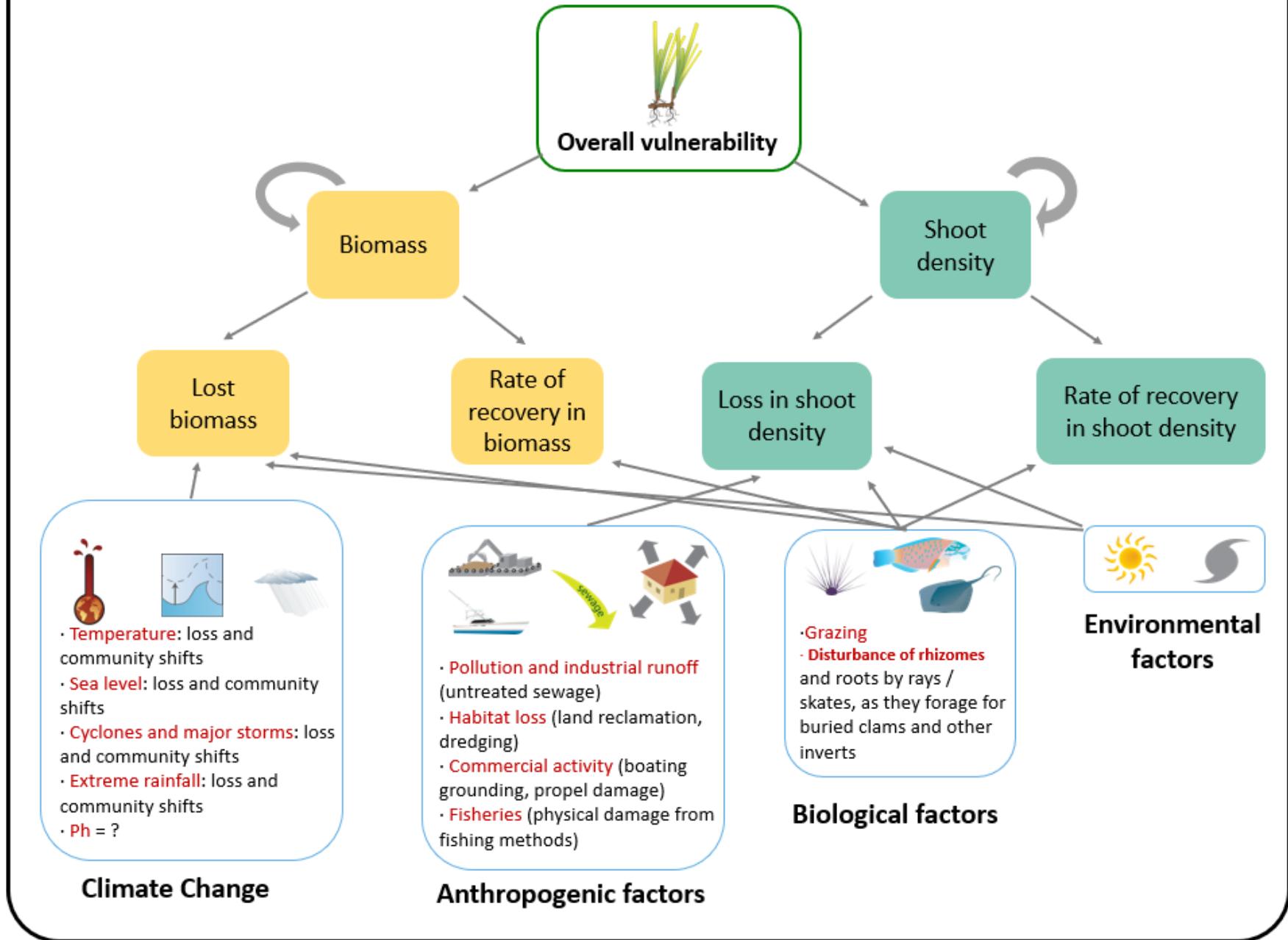


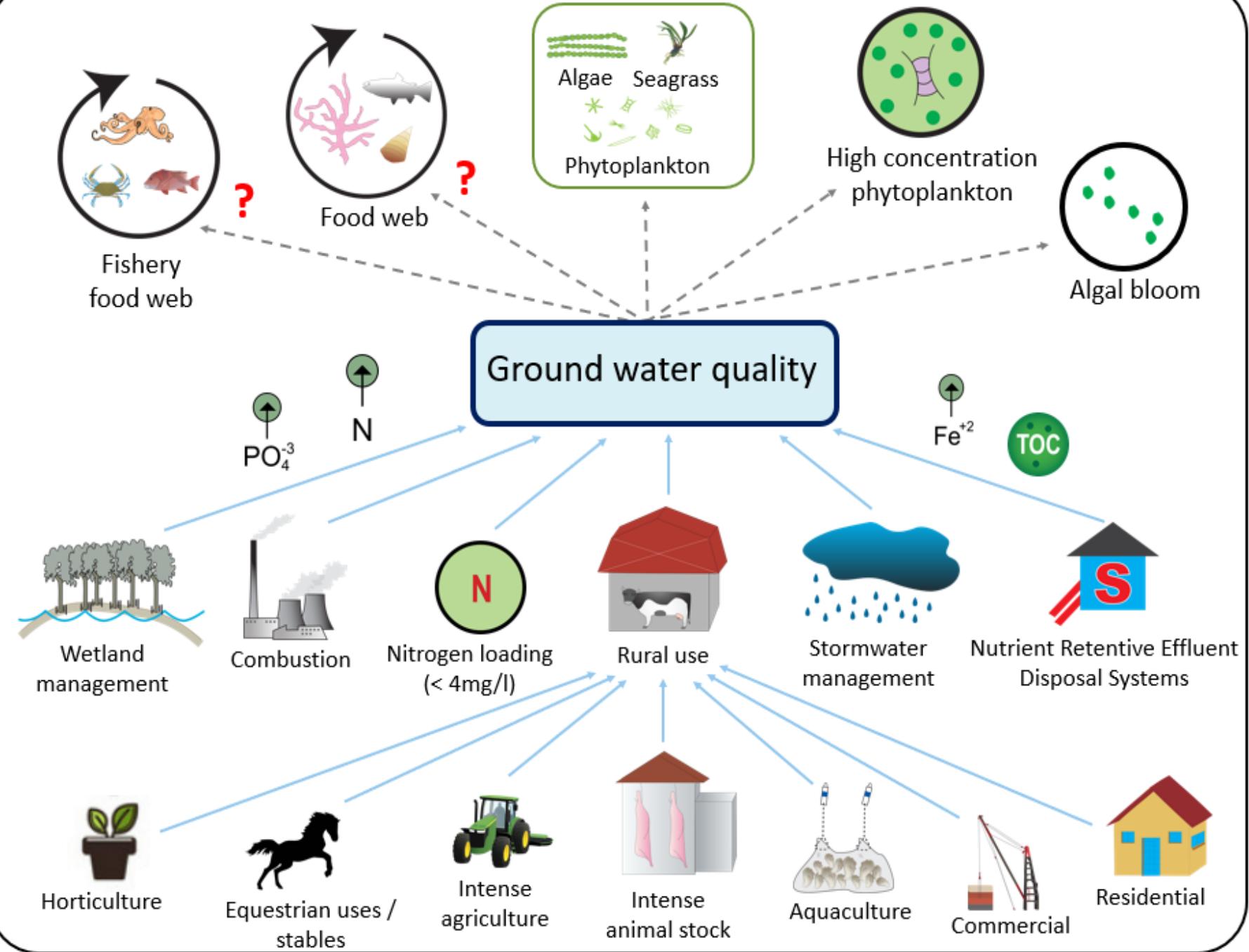
Ecological values
(Figure 2)



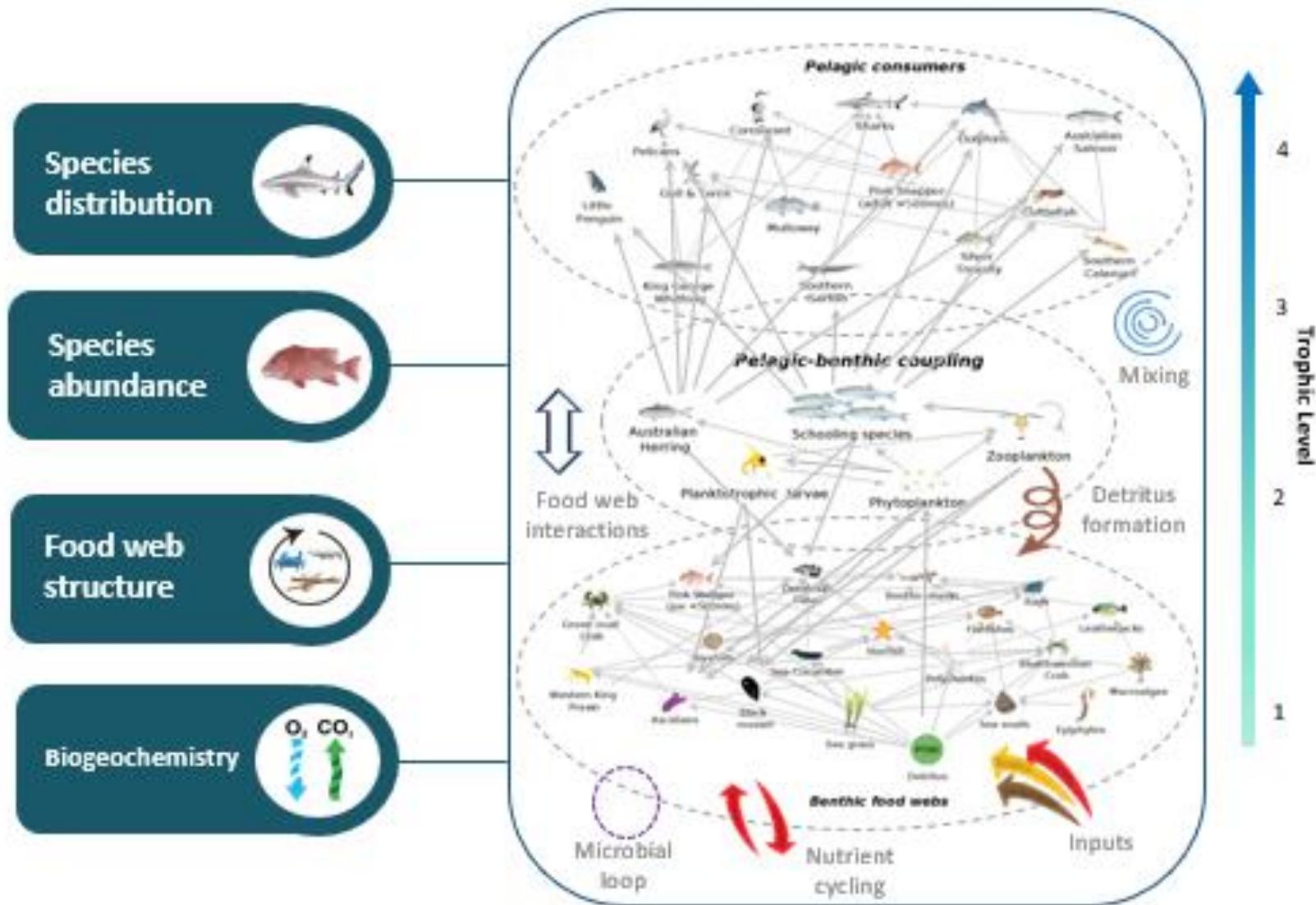
Cultural ecosystem services
(Figure 2)

Seagrass vulnerability





Cockburn Sound food web



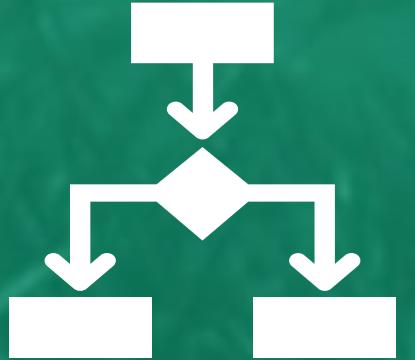
Ecological subsystem

Questions?

Q&A

A qualitative model
is a representation
of the relationships
between system
variables

QUALITATIVE MODELS



Purpose

Tool box

Signed
digraphs

Social
Network
Analysis

QUALITATIVE MODELS



Simplifying information to convey our understanding of ecosystem structure and function

Explore hypotheses and management alternatives for a disturbance

Inform and complement the EwE model

QUALITATIVE MODELS

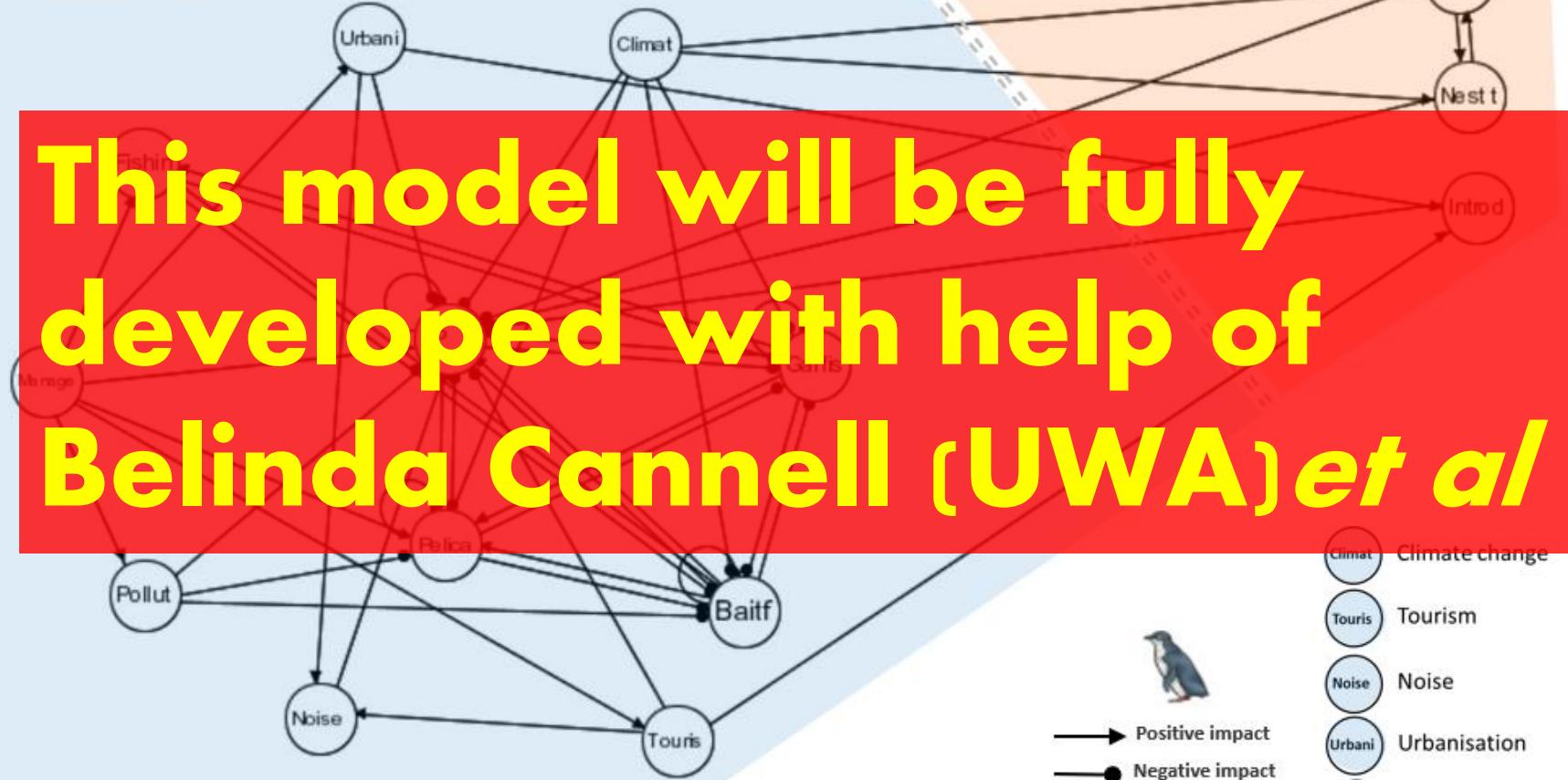


Diagrams that describe the relationship of community species based on sign of interactions, with positive effects (arrow) and negative effects (filled circle)

Using network and graph theory from social structure analysis, we will characterize key species, pressures and drivers (nodes) in Cockburn Sound to establish ties, edges or links (interactions) that connect them.

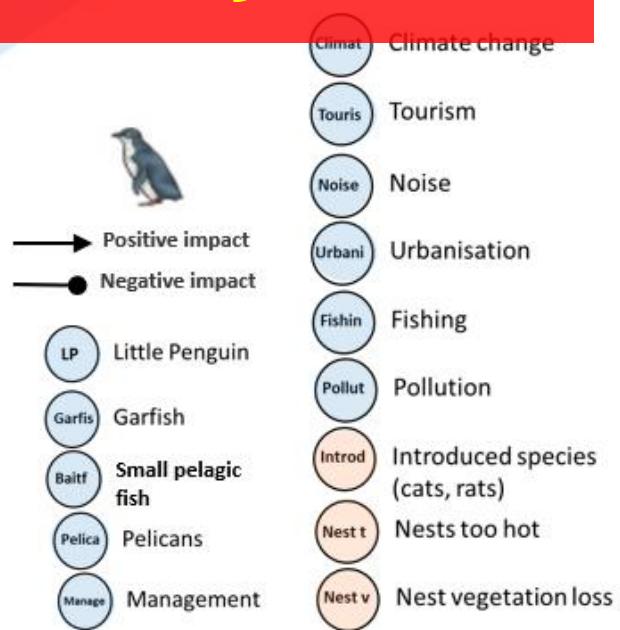
A sample model of Little Penguin

Cockburn Sound

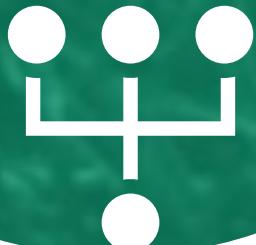


This model will be fully developed with help of Belinda Cannell (UWA) *et al*

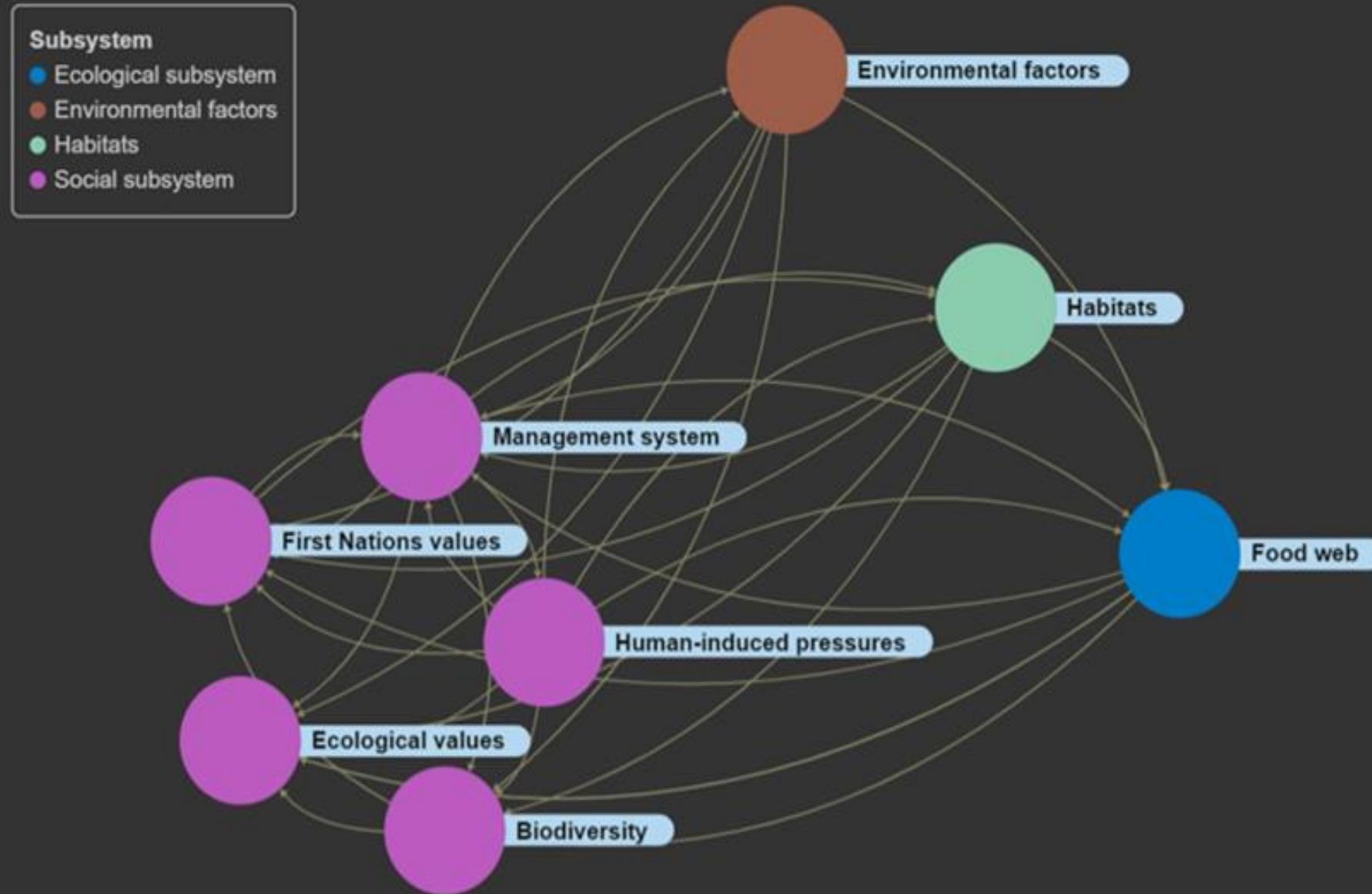
	LP	Penguin	Garfish	Bait	Fishing	Pelican	Urbanisation	Tourism	Noise polu.	Climate ch.	Management	Nest veget.	Nest too hot	Introduced	Pollution
LP	-1	1	1	0	-1	-1	-1	-1	-1	1	-1	-1	-1	-1	-1
Garfish	-1	-1	-1	-1	-1	0	0	0	0	0	0	0	0	0	0
Bait	-1	-1	-1	-1	-1	0	0	0	0	-1	0	0	0	0	-1
Fishing	0	1	1	0	0	0	0	0	0	1	0	0	0	0	0
Pelican	-1	1	1	0	-1	0	0	0	-1	1	0	0	0	0	-1
Urbanisation	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Tourism	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Noise polu.	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0
Climate ch.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Management	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nest veget.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nest too hot	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0
Introduced	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0
Pollution	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0

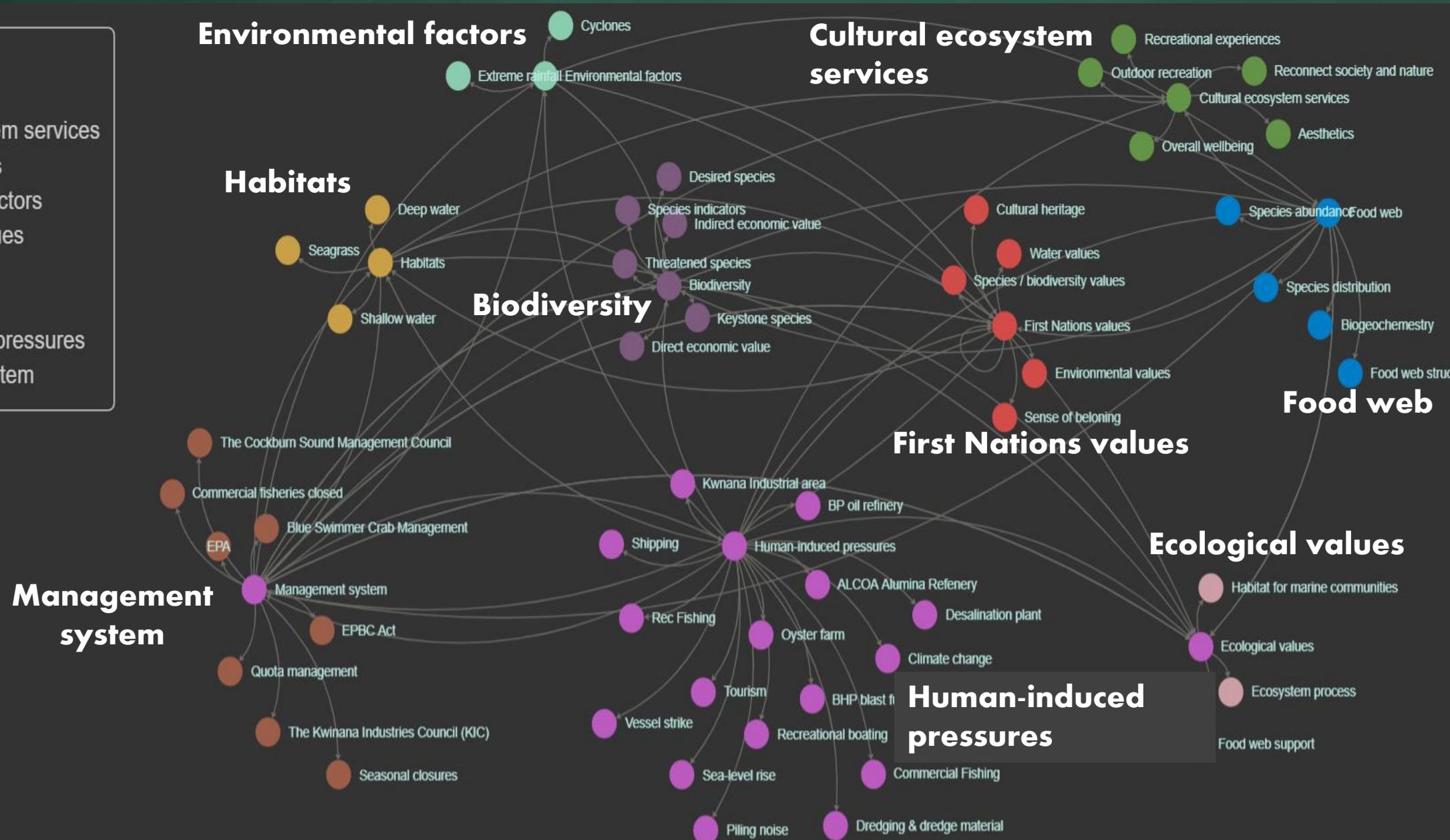


Social Network Diagrams

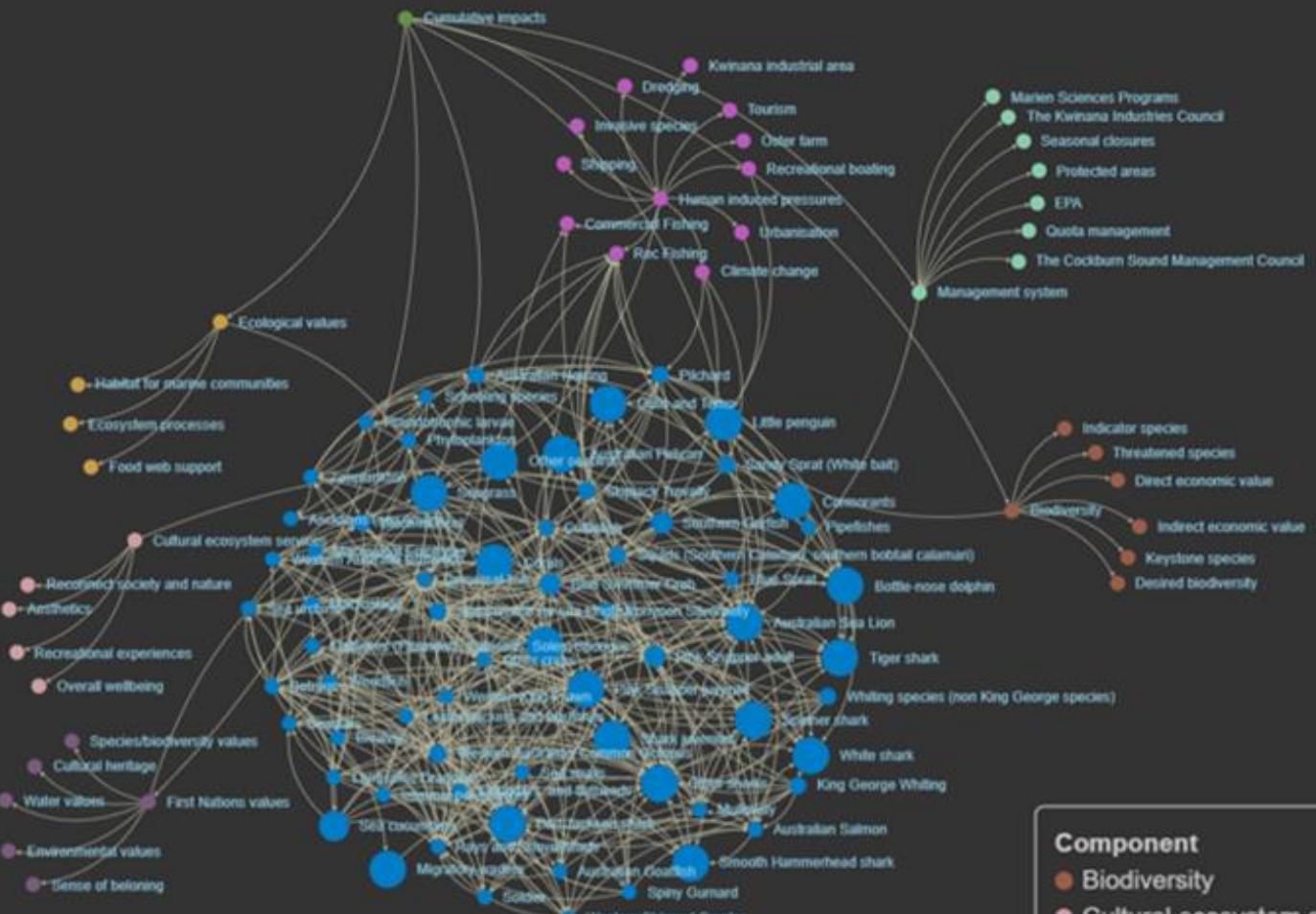


Cockburn Sound Socio-Ecological coupled system





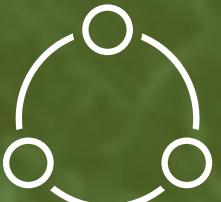
Cockburn Sound Socio-Ecological coupled system



Component

- Biodiversity
 - Cultural ecosystem services
 - Cumulative impacts
 - Ecological values
 - First Nations values
 - Food web
 - Human induced pressures
 - Management system

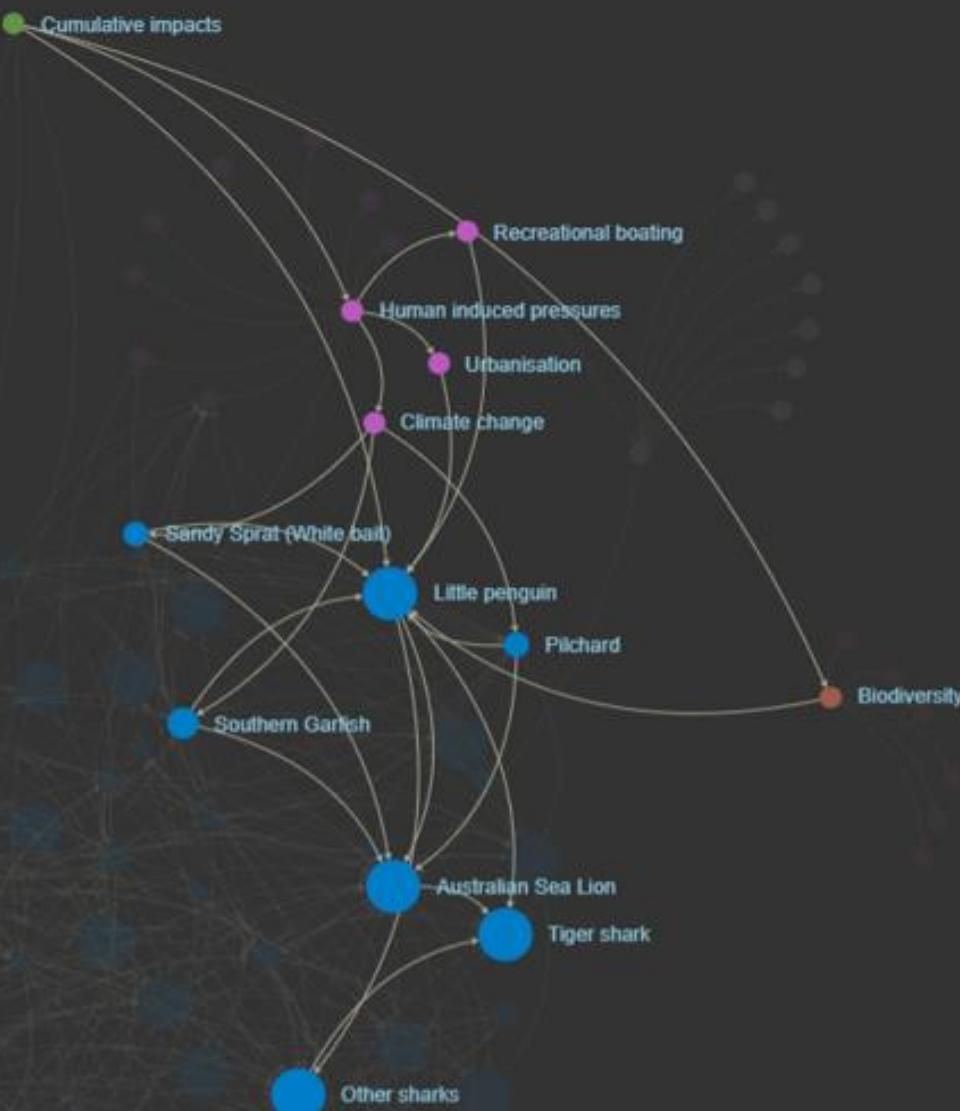
Influence
diagrams



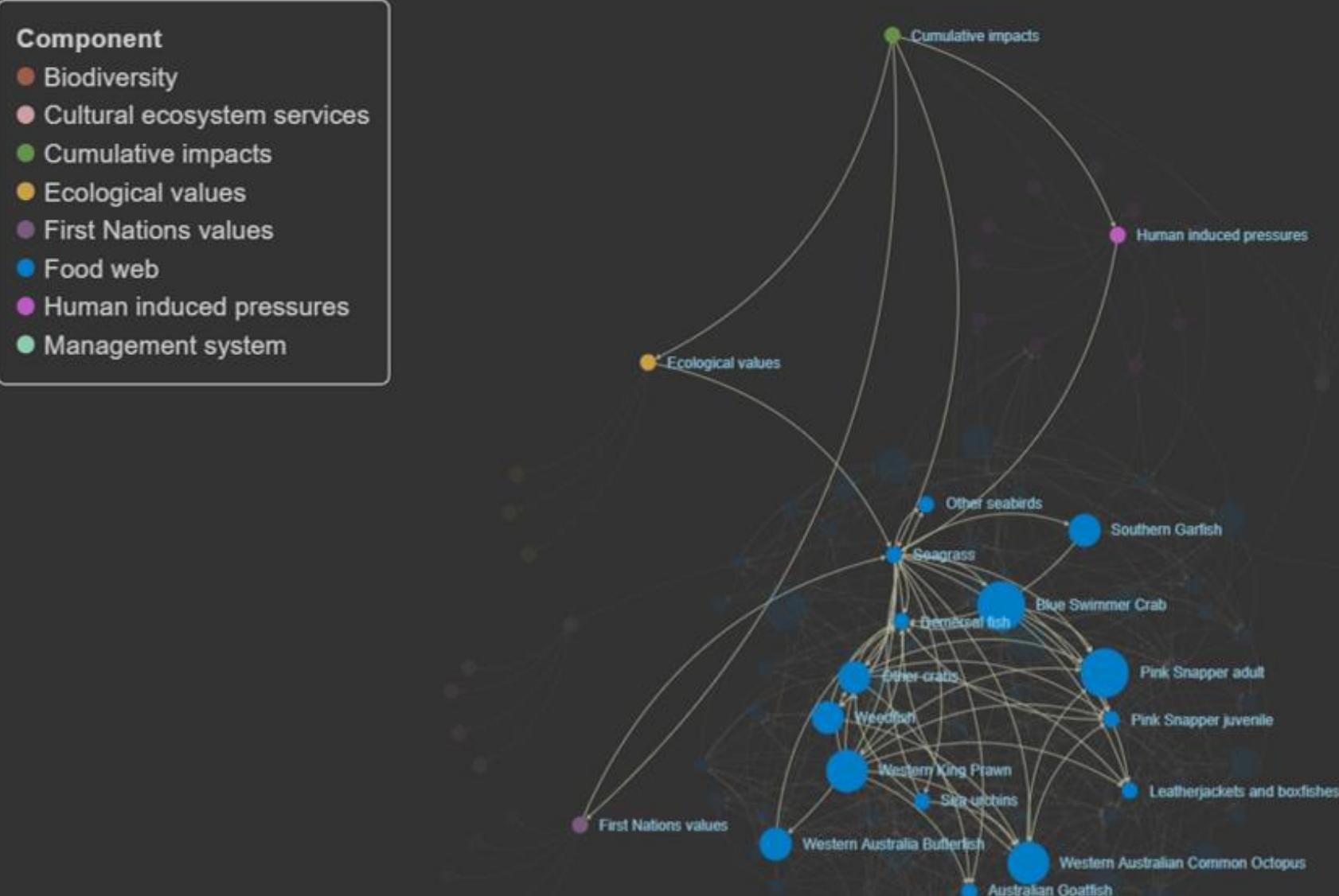
Little Penguin

Seagrass

Little Penguin interactions



Seagrass interactions



Questions?

Q&A

CONCEPTUAL MODEL



PLAN



QUALITATIVE MODEL

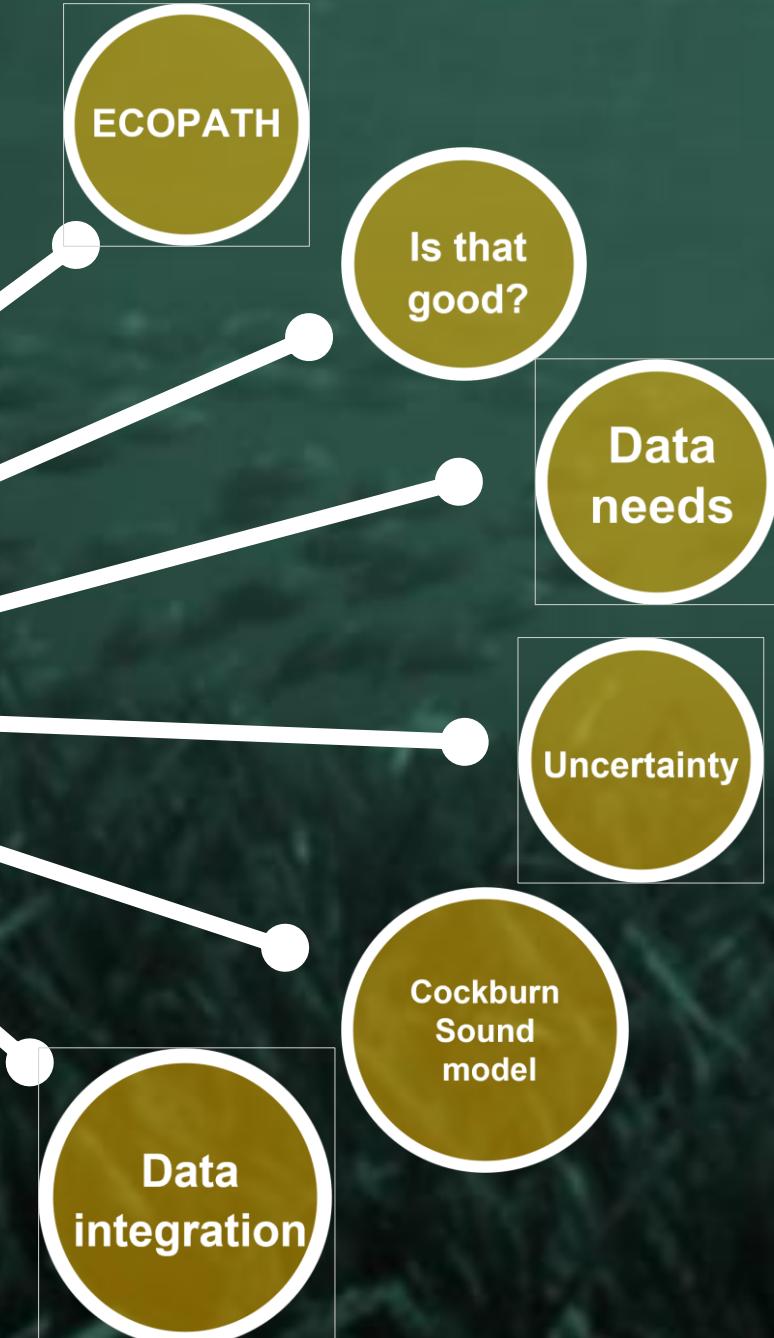
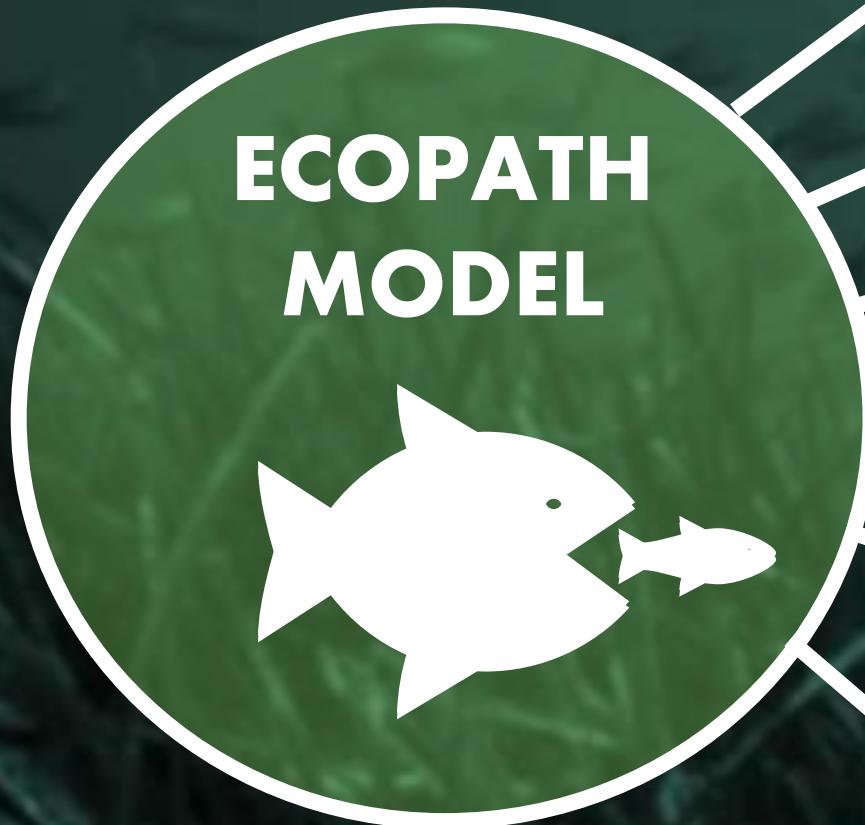


Q&A



**ECOPATH
MODEL**





Ecopath with Ecosim : A multispecies dynamic model

1) Mass-balance (within groups):

$$B_i \cdot (P/B)_i = Y_i + \sum_{j=1}^n B_j \cdot (Q/B)_j \cdot DC_{ji} + E_i + BA_i + B_i (P/B)_i \cdot (1 - EE_i)$$

Production = Yield + Predation + Biomass Acc. + Migration



Ecopath with Ecosim (EwE)

www.ecopath.org

2) Conservation of energy (between groups):

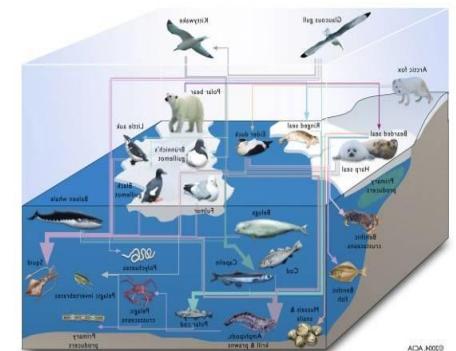
$$B \cdot (Q/B) = B \cdot (P/B) + (1 - GS) \cdot Q - (1 - TM) \cdot P + B \cdot (Q/B) \cdot GS$$

Consumption = Production + Unassimilated food

3) Biomass dynamics:

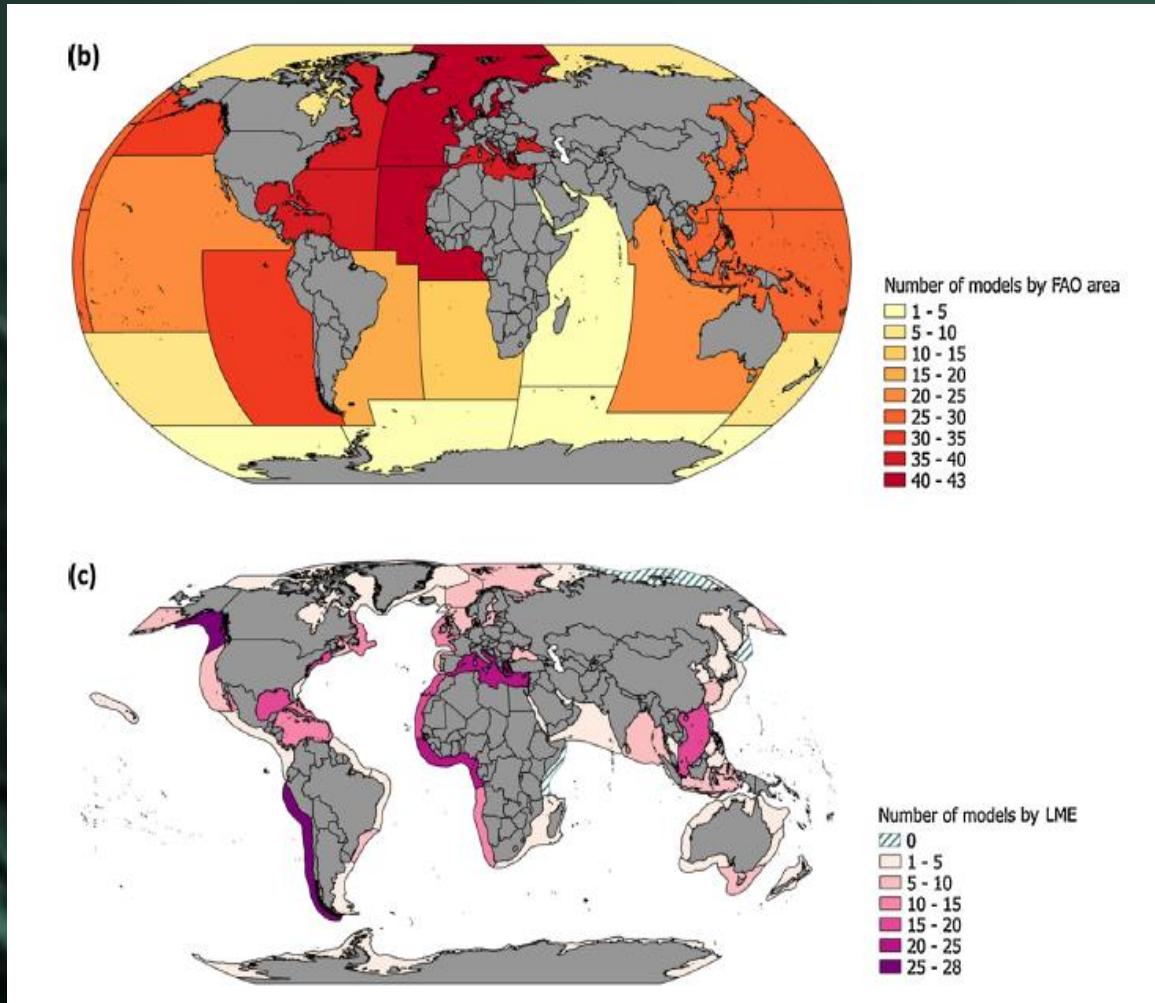
$$\frac{dB_i}{dt} = g_i \sum_j C_{ji} - \sum_j C_{ji} + I - (M_i + F_i + e_i) B_i$$

D Biomass = Growth + Immigration – Predation - Mortality



Used intelligently = EwE is a **VERY** good tool

- that's why its lasted for > 30 years (with >400 models published and 3000+ users)



Multi-stanza Groups

Each stanza (range of age) can be assigned distinctive:

1. Total mortality rate Z
2. Prey and Habitat preferences
3. Vulnerability to fishing
4. Responses to food availability via growth rates and predation risk

Pink Snapper
Adult > 500mm
Juvenile < 500mm

Ecopath data requirements

- **Biomass** (biological population density): population or organisms per unit of area or unit of volume.
- **Diets**
- **Habitat maps**: spatial distributions of flora and fauna
- **Growth rates** (year^{-1})
- **Biology data** (e.g. mortalities, recruitment, migration, movement rates, habitat use)
- **Fisheries data**: landings, effort, bycatch,

Addressing uncertainty in EwE

- Natural variability
- Observation error
- Structural complexity of the model
- Outcome uncertainty
- Bad communication among scientists and stakeholders



- Reducing the precision of parameter estimation
- Biases parameter estimation
- Inappropriate dynamics by omitting key processes



Approach to reducing uncertainty

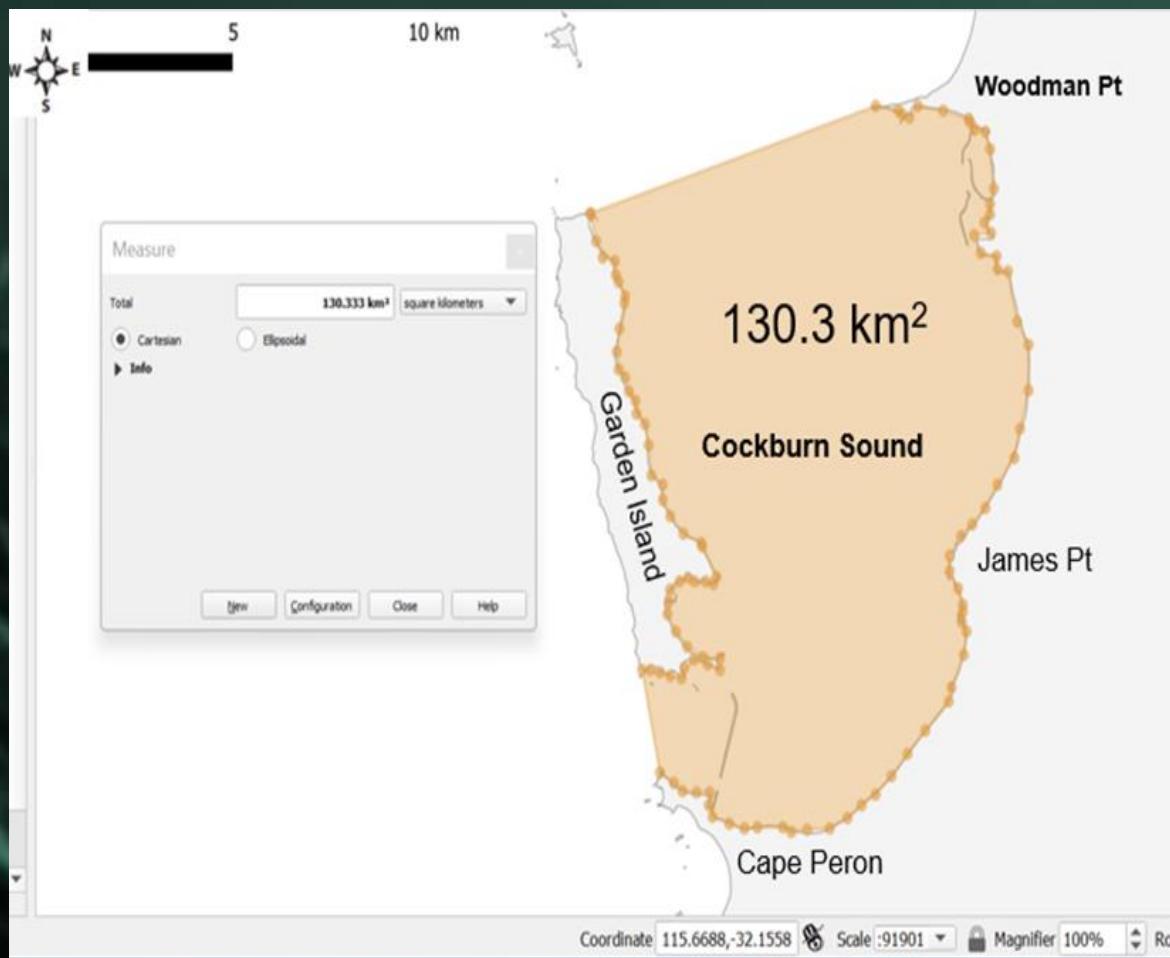
- Use of single species models for input parameters
 - Sensitivity analysis
 - “*Data Pedigree*”: categorizing data sources
- Monte Carlo re-sampling
- Calibration of the model
- MSE
- Communication: iterative with stakeholders



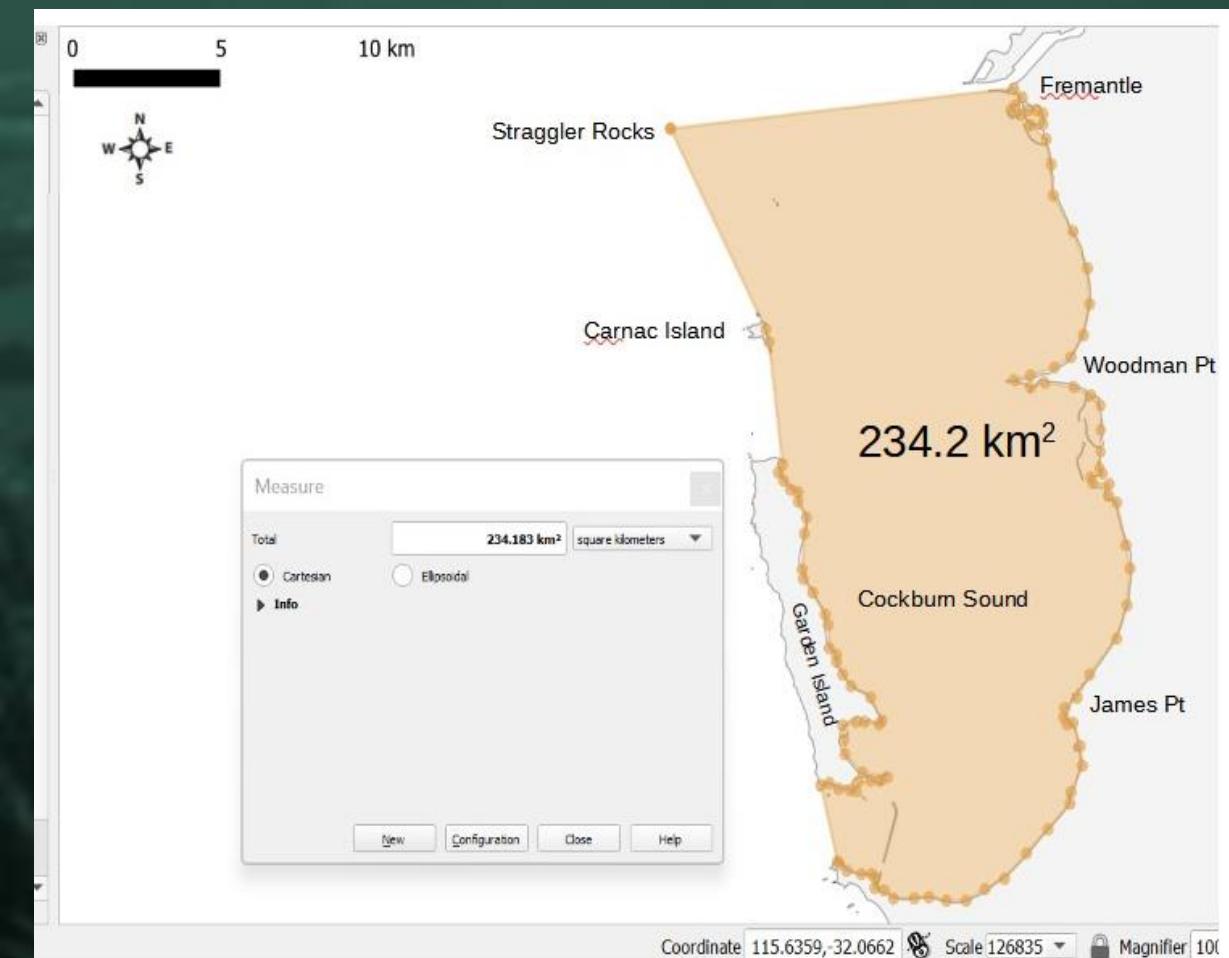
Model
domain

Functional
Groups

Option 1



Option 2



High Conservation Species (19)

Bottle-nose dolphin, White shark, smooth Hammerhead shark, Tiger shark, Spinner shark, Port Jackson shark, Other sharks, Shark juveniles, Little penguin, Cormorants, Australian pelican, Gulls and Terns, Migratory waders, other birds, Pink snapper juvenile (<500mm), Sea Cucumber, Corals, Seagrass



N = 64 groups (> 90 species)



High Recreational fishing species (14)

Australian Herring, Sea Kingfish, King George Whiting, Skipjack Trevally, Whiting species, Weedfish, Blue Sprat, Schooling species, Flounders, Australian Salmon, Mulloway, Western Australian Butterfish, Western King Prawn, Green mud crab

High Commercial fishing species (8)

Pink Snapper (>500mm), Blue Swimmer Crab, Southern Garfish, Pilchard, Sandy Sprat (White bait), Squids (Southern Calamari), Western Australian Common Octopus, Black mussel



Other invertebrates (6)

Bivalves, Cuttlefish, Starfish, Ascidians, Infaunal polychaetes, Sea snails



Primary producers (3)

Phytoplankton, Macroalgal Epiphytes, Macroalgae



Other fishes (12)

Rays and Shovelheads, Flatfishes, Western Stripped Grunter, Common Silverbelly, Soldier, Longspine Dragonet, Southern Crested Weedfish, Demersal fish, Pipefishes, Leatherjackets and boxfishes, Spinny Gunnard, Australian Goatfish

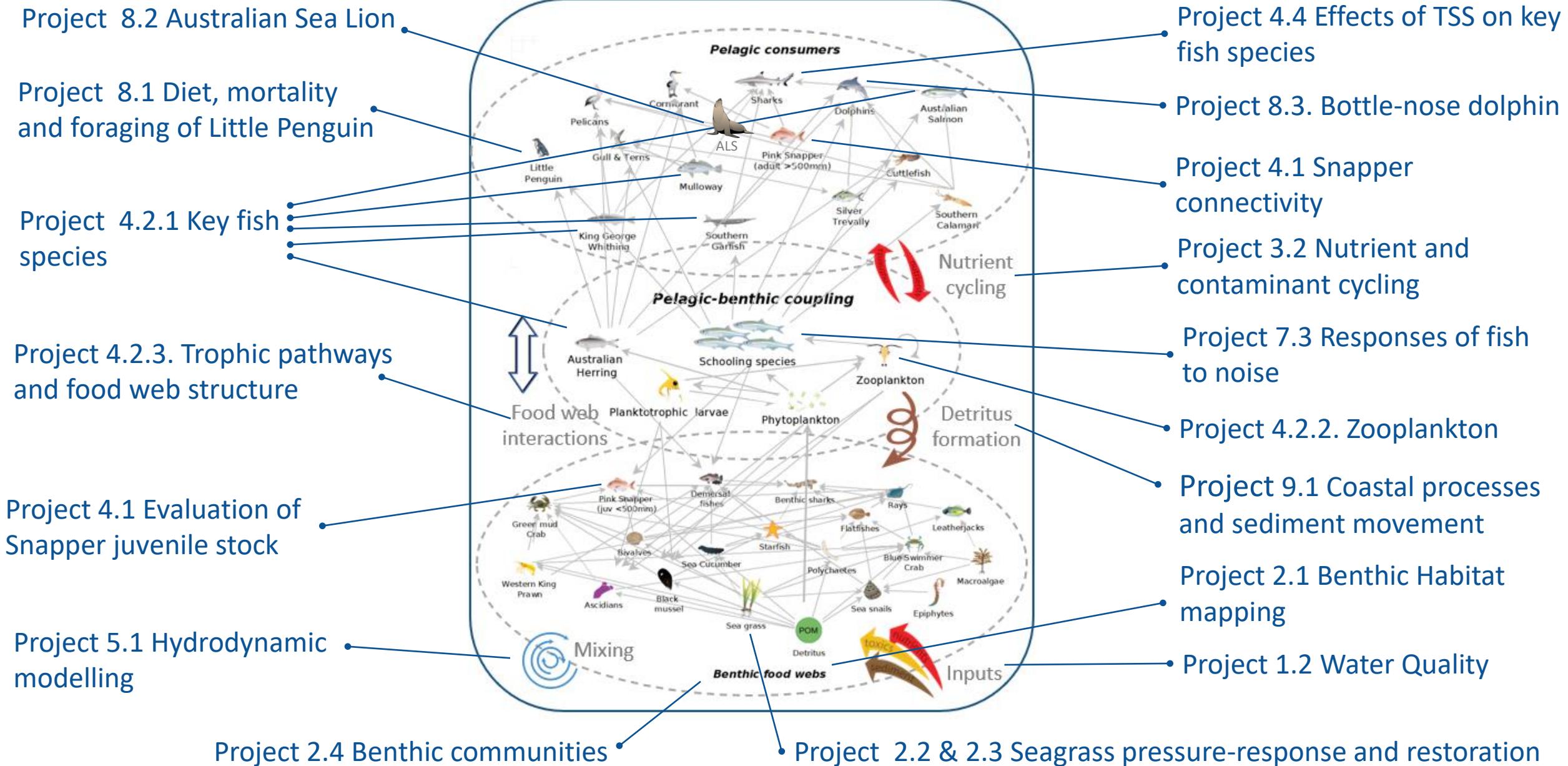


Nekton (2)

Zooplankton
Planktotrophic larvae



Cockburn Sound EwE model



Questions?

Q&A



THANK YOU