Introduction to EFlows for estuarine and marine environments: Concepts & methods

Lara van Niekerk

UNEP, Nairobi Convention

25th to 27th November 2019

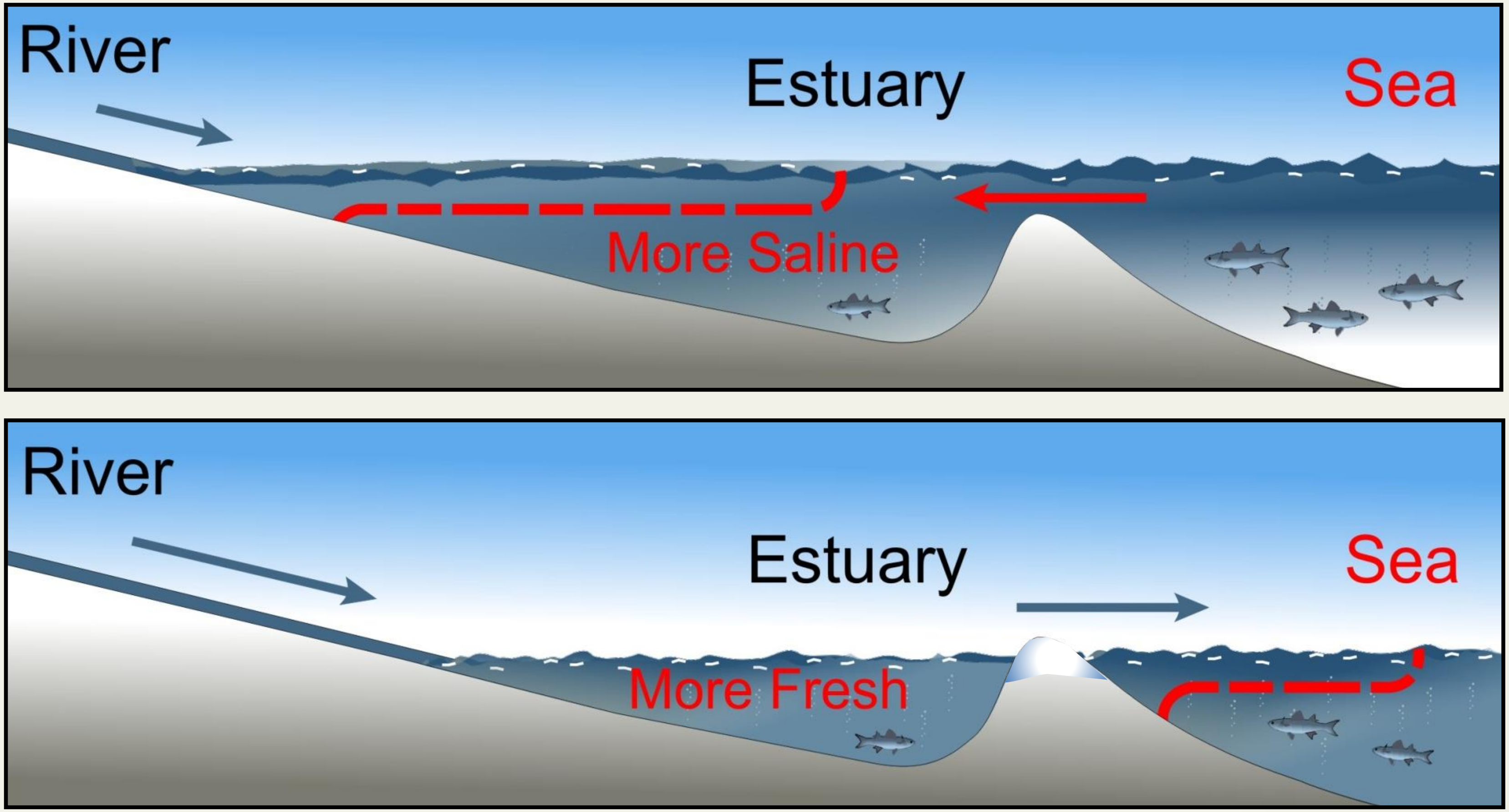
Cape Town

What are estuaries and nearshore?

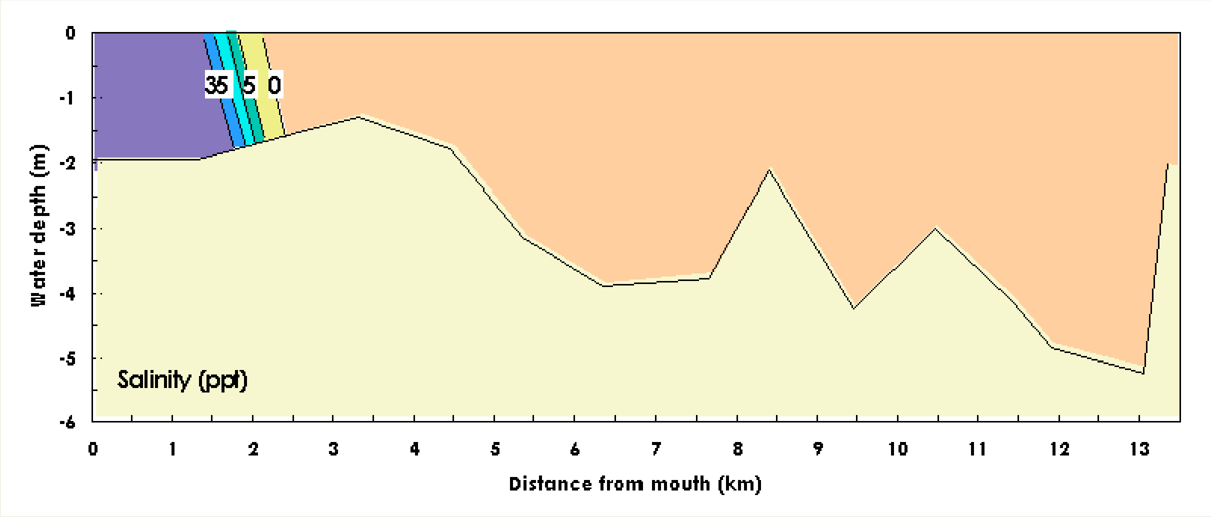
Important Biophysical Features

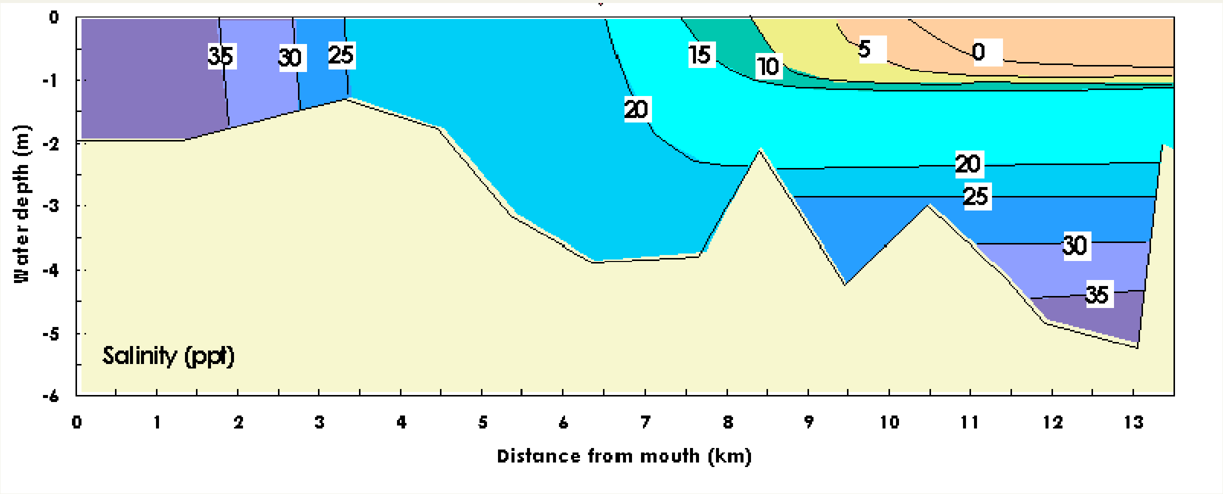
- Driven by both river runoff and seawater intrusion
- Longitudinal (and vertical) gradients in salinity & other physical and water quality parameters, influenced by the volume of river inflow and mouth state
- Marked differences between chemistry (or water quality) of river water and seawater, thus volume of river inflow also strongly influence water quality (i.e. not necessarily linked pollution)
- Physical characteristics and water quality usually not result of a single event, but rather that of flow patterns occurring over weeks or months

Important Biophysical Features…



Salinity regime





Key Biotic components…

IMPORTANT BIOTA

- Micro-algae
- Macrophytes
- Invertebrates
- Fish
- Birds

Importance of River Inflow…

- Regulates mouth status (open versus close):

  - link to marine environment

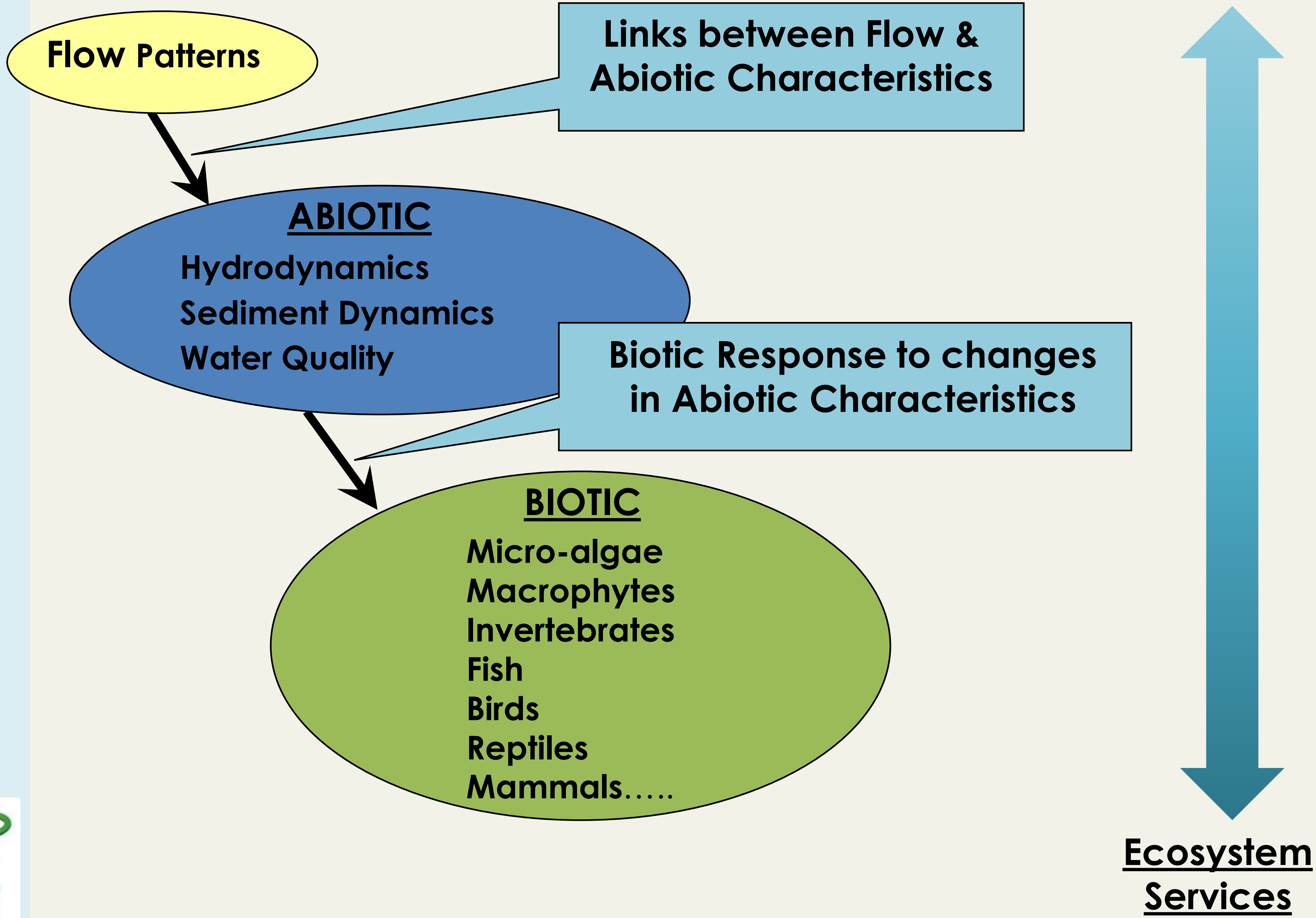
  - migratory route for estuarine dependent fish & invertebrates

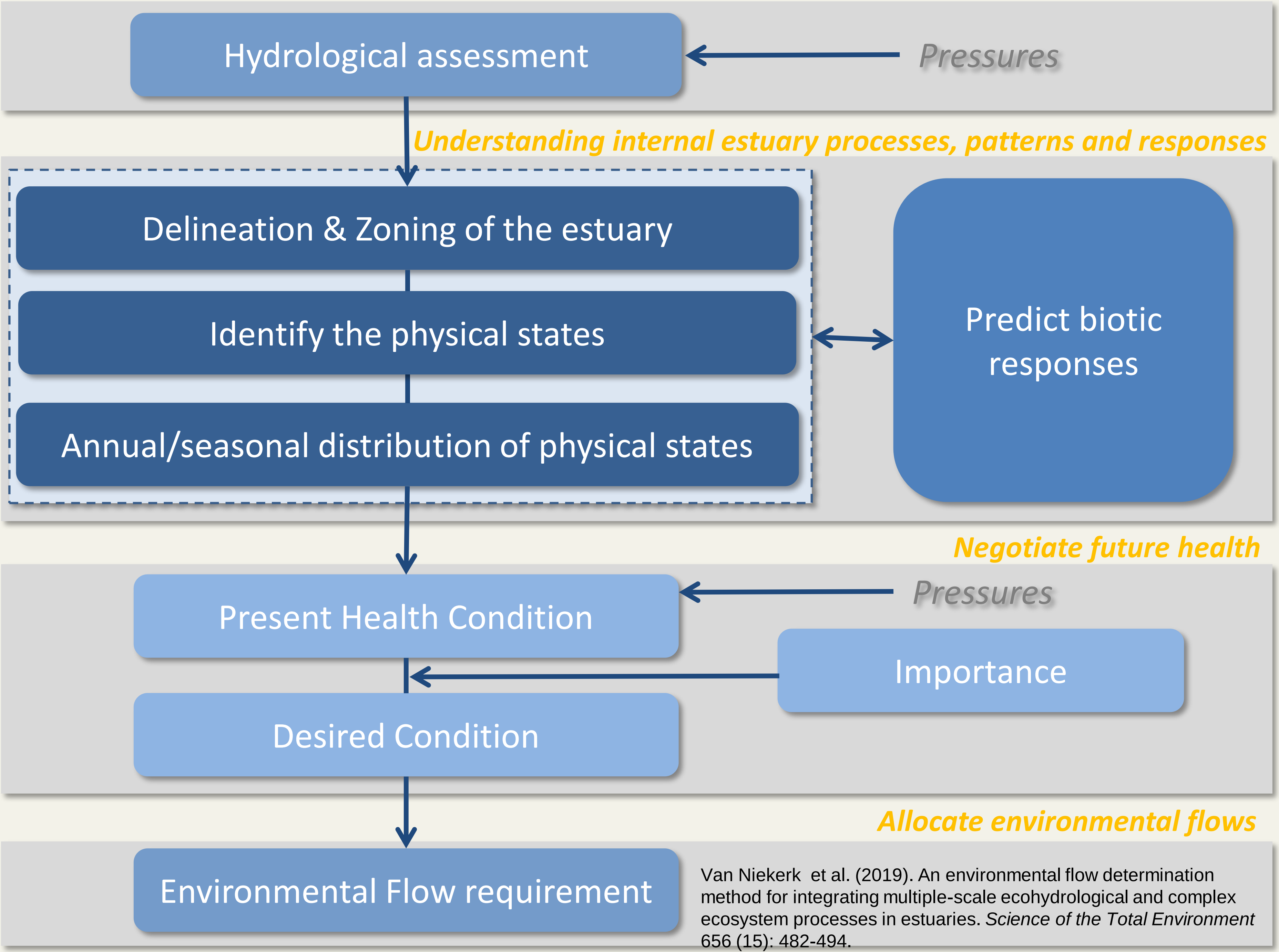
- Regulate salinity gradients require by estuarine biota

- Introduces nutrients to estuaries

- Scour accumulated sediments (floods), if not systems may gradually fill up

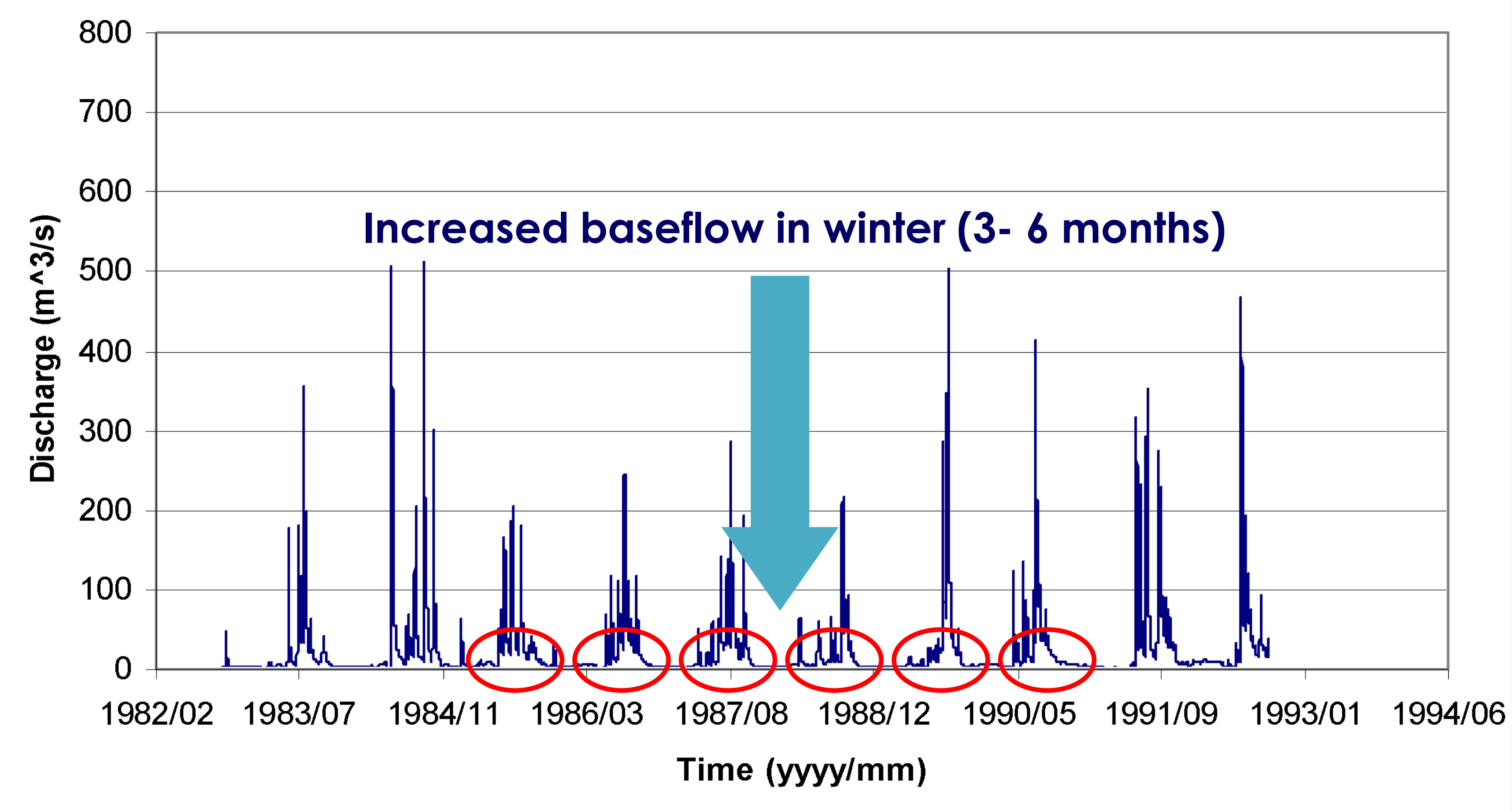
Overarching flow of information





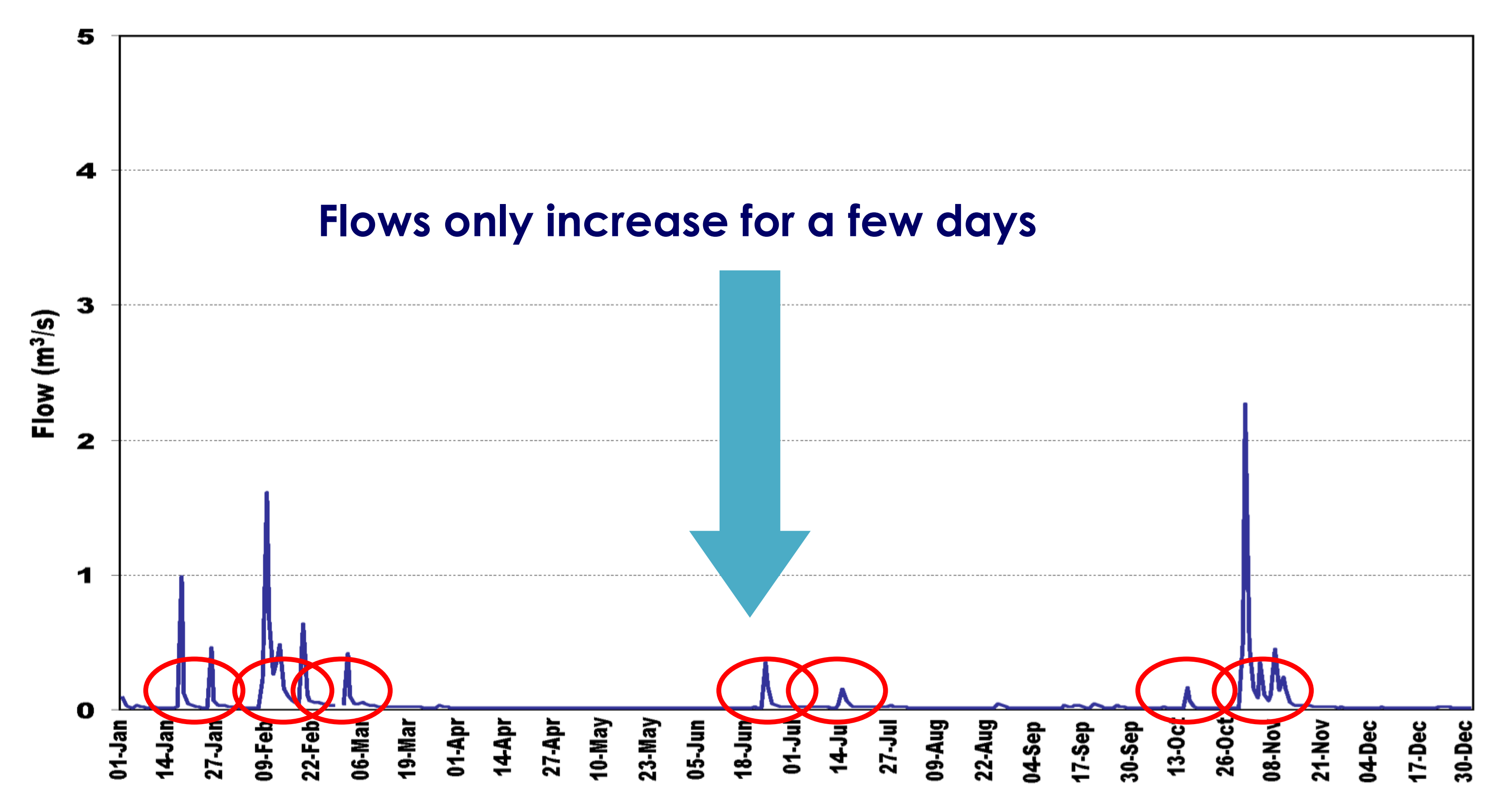
Van Niekerk et al. (2019). An environmental flow determination method for integrating multiple-scale ecohydrological and complex ecosystem processes in estuaries. *Science of the Total Environment* 656 (15): 482-494.

Runoff – Large catchment



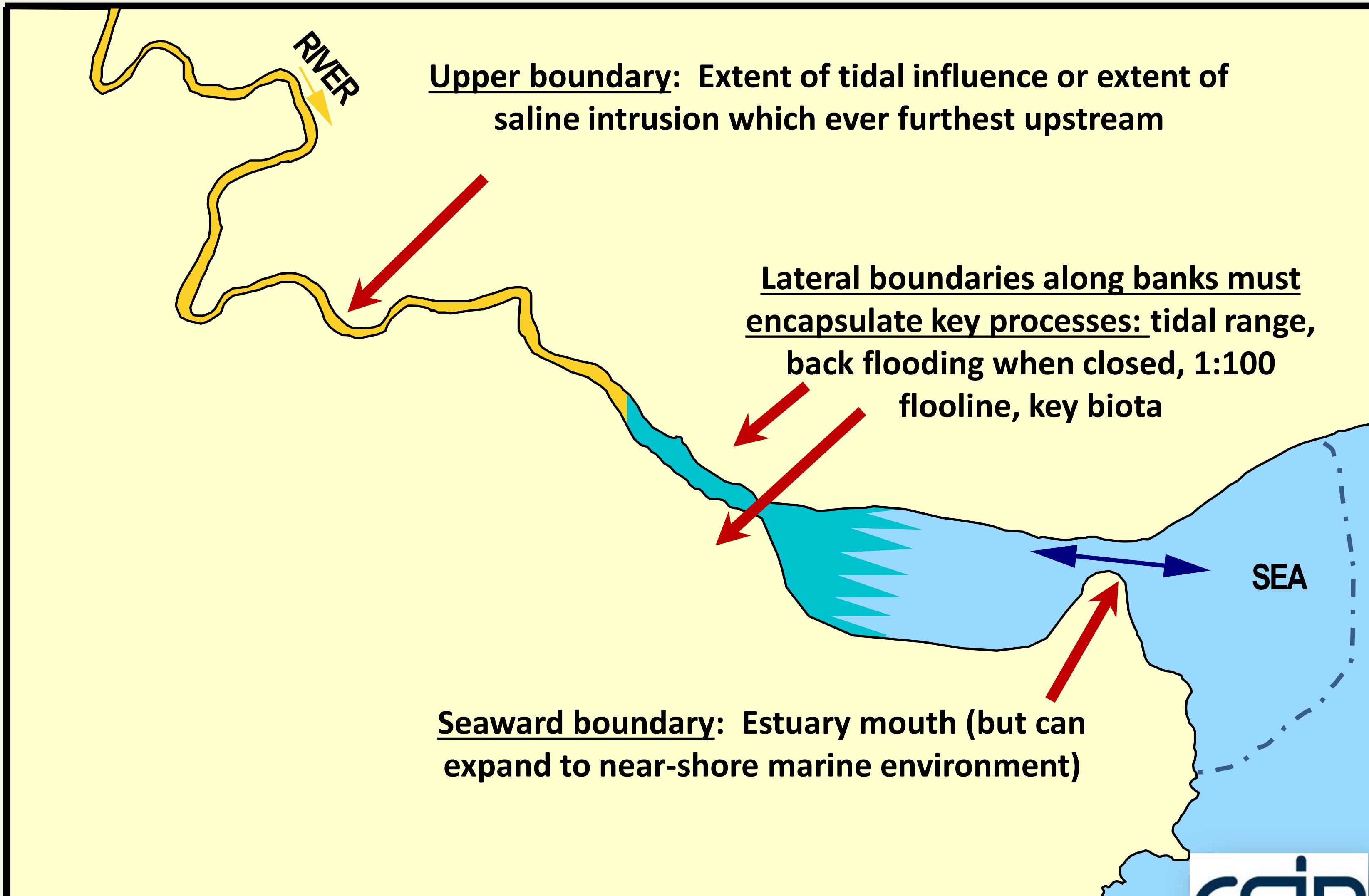
Olifants Estuary (Catchment = 49 000 km²)

Runoff – Small catchment

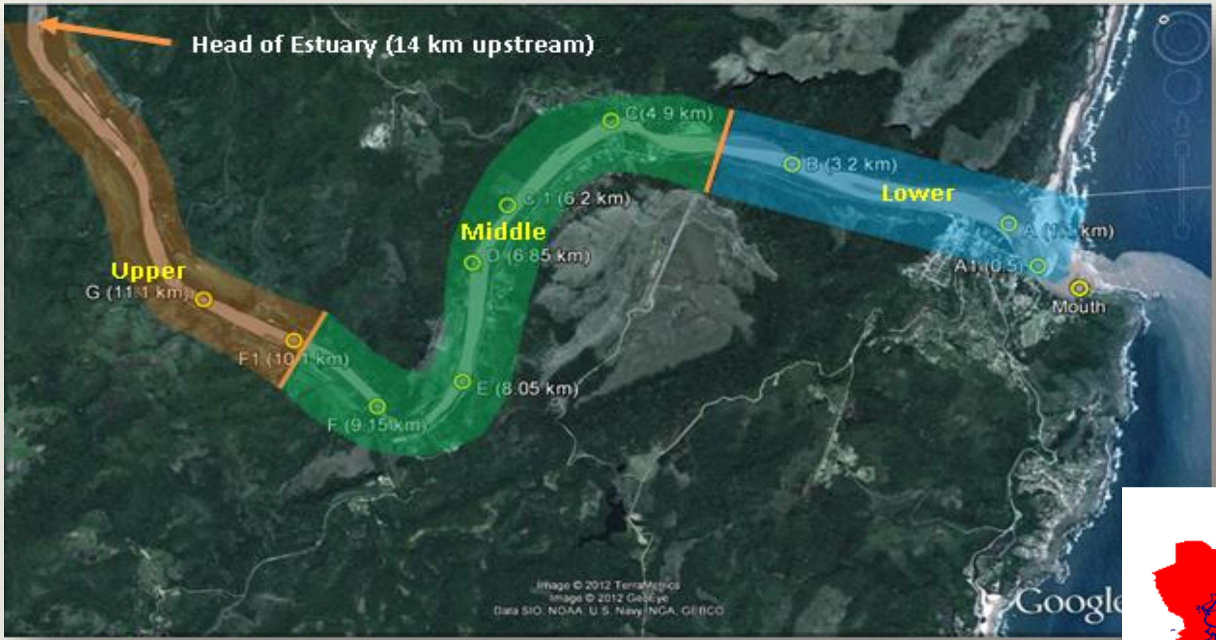


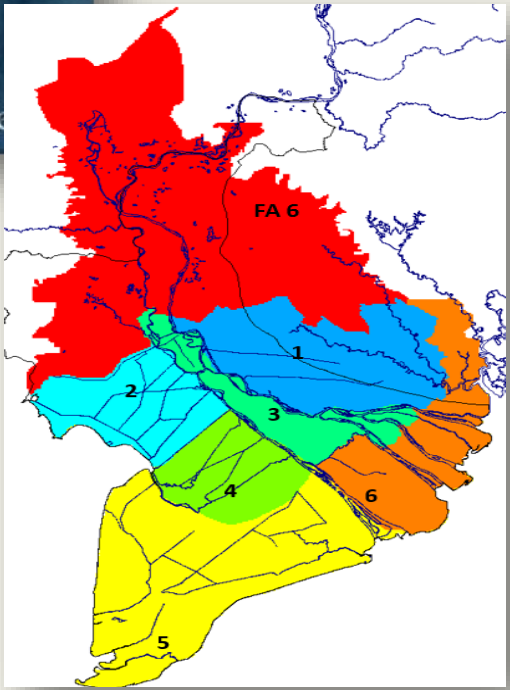
Siyaya Estuary (Catchment = 18 km^2)

Delineation & Zonation



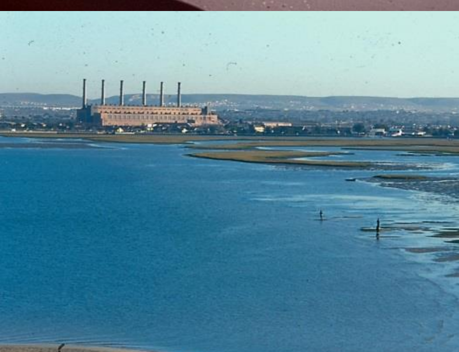
Delineation & Zonation





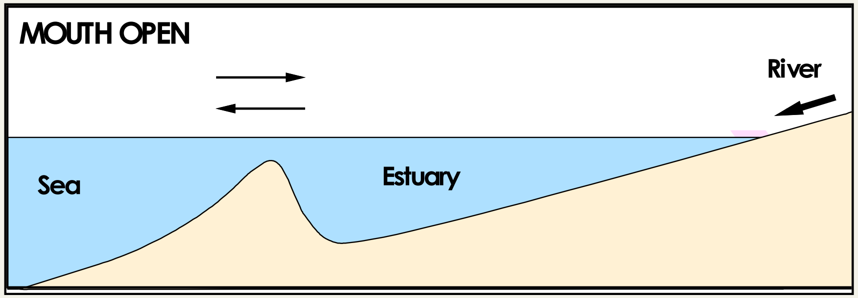
- Geomorphology/bathymetry
- Salinity regimes & responses to flow
- Retention of water (non-linear responses with delays)

Pressures

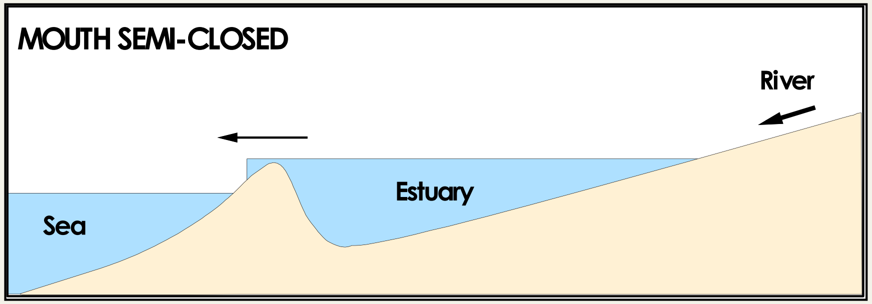


Water quality increasing concern ….

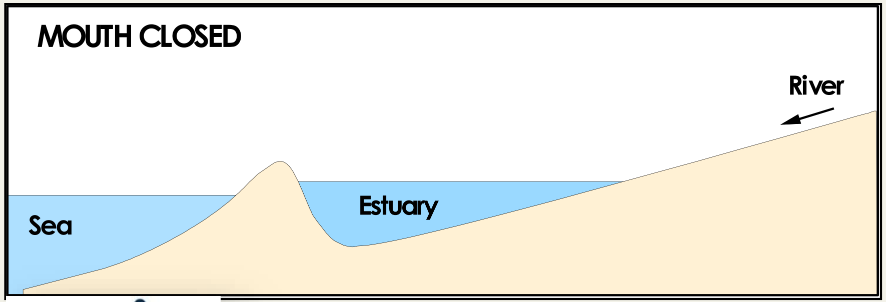
Abiotic States



STATE 1: The mouth of the estuary is open to the sea, allowing seawater intrusion during high tides, with river inflow introducing freshwater into the upper reaches.



STATE 2: The formation of a sand berm at the mouth prevents continuous seawater intrusion – seawater intrusion is limited to high tides. However, the berm is still not high enough to prevent water draining from the estuary into the sea.



STATE 3: The height of the sand berm at the mouth of the estuary prevents seawater from entering or water draining from the estuary into the sea. Although there may still be river water entering the estuary, the flow rate is too little to facilitate breaching.

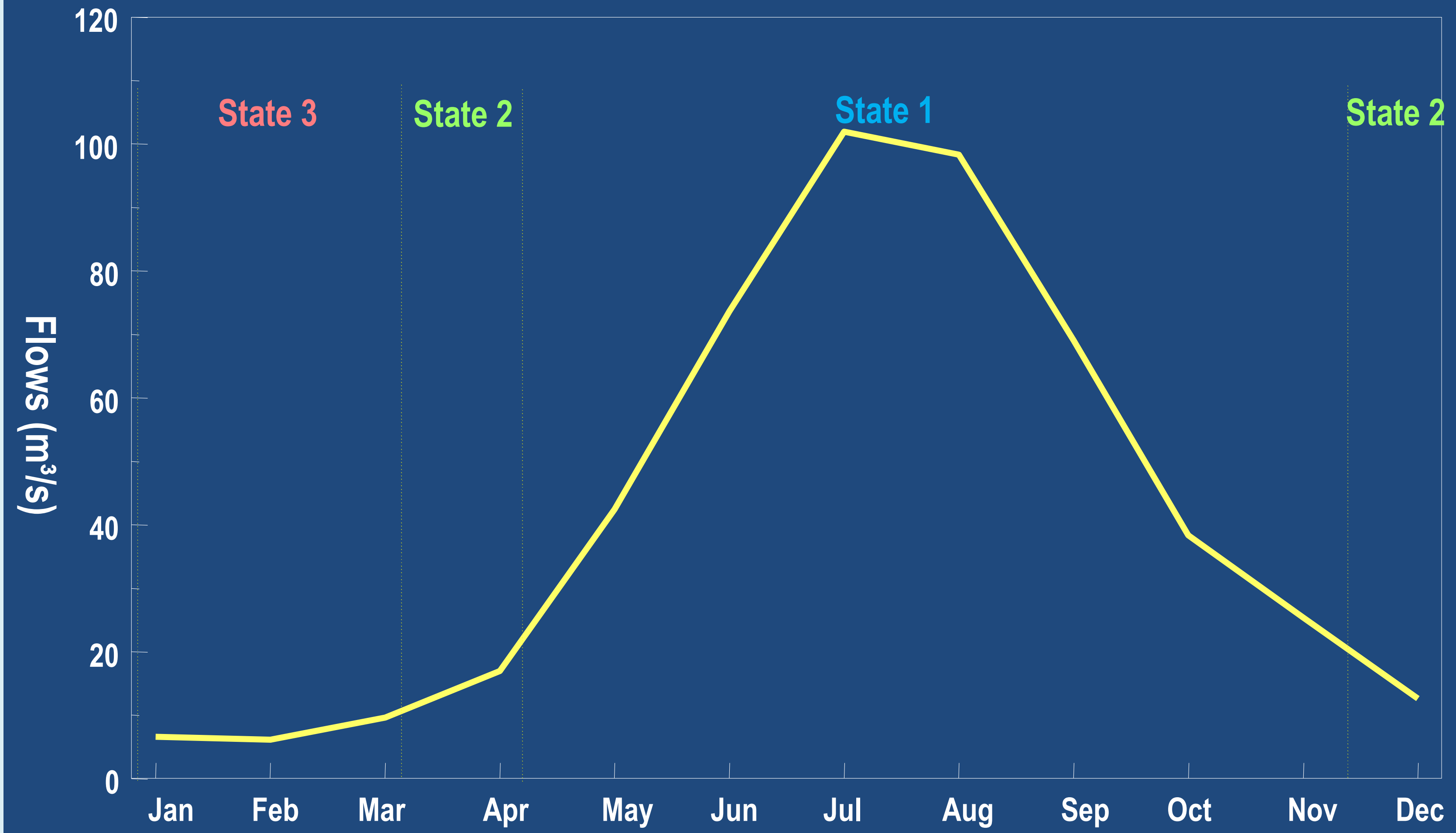
Abiotic States

Determine flow ranges associated with abiotic state:

- **Correlate observed mouth state with measured flow**
- **Extrapolate**
- **Model**

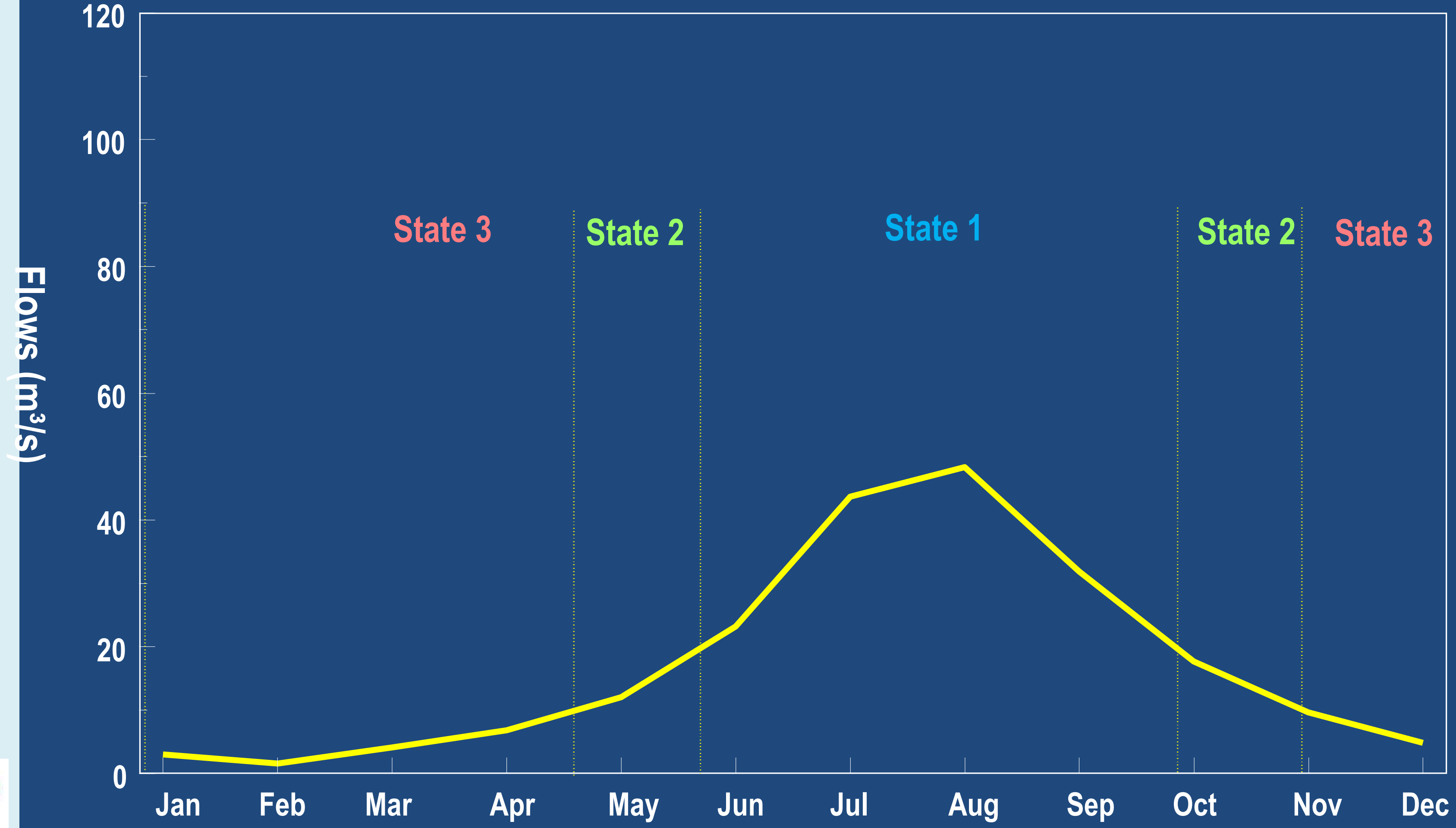
Mouth State	Flow Range ($m^3 . s^{-1}$)
State 1: Freshwater dominated - Open mouth	>10
State 2: Brackish - Open mouth	5 - 10
State 3: Closed mouth	< 5

Natural



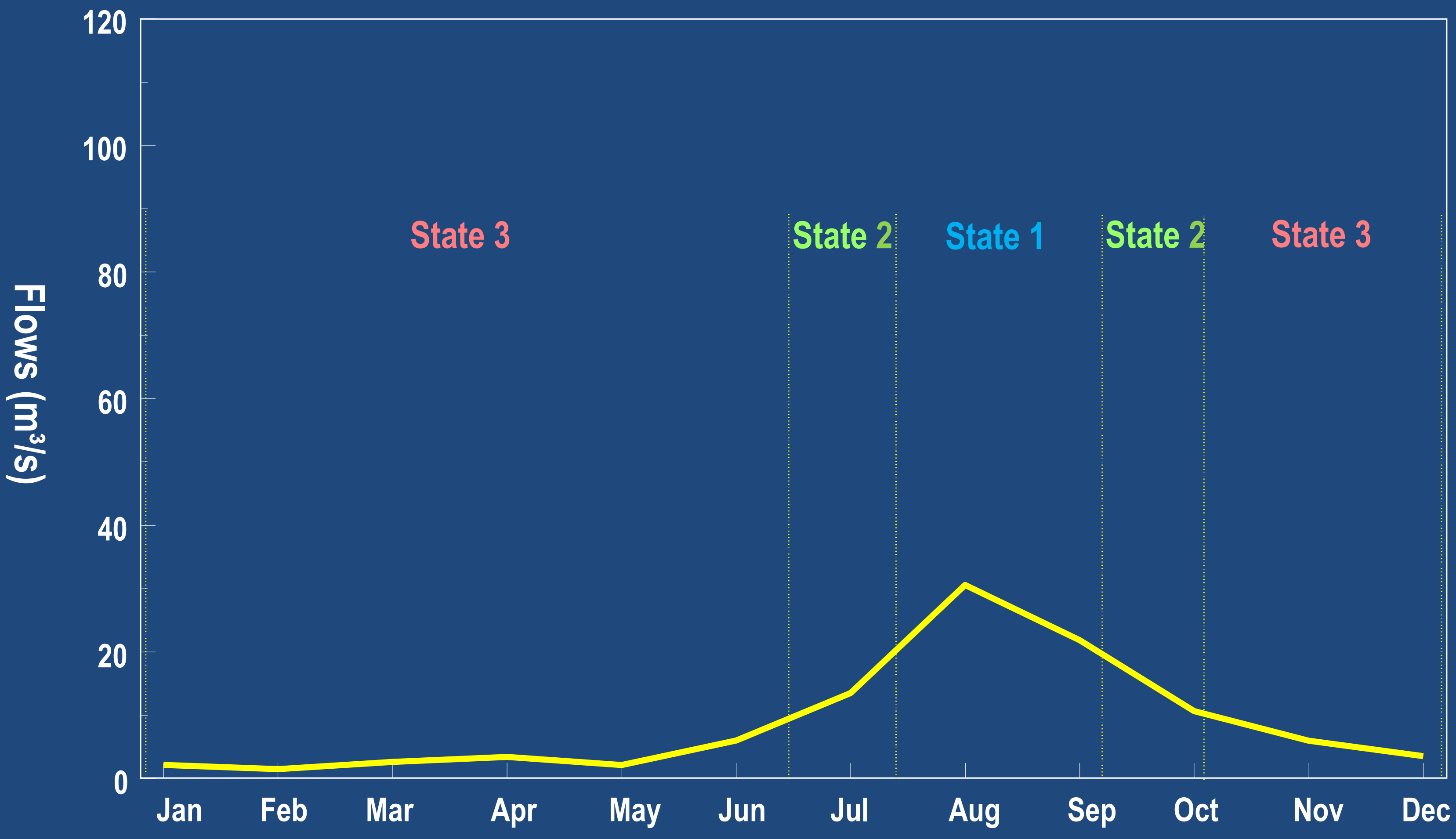
120
100
80
60
40
20
0
Flows (m³/s)
State 3
State 2
State 1
State 2
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

Present Day



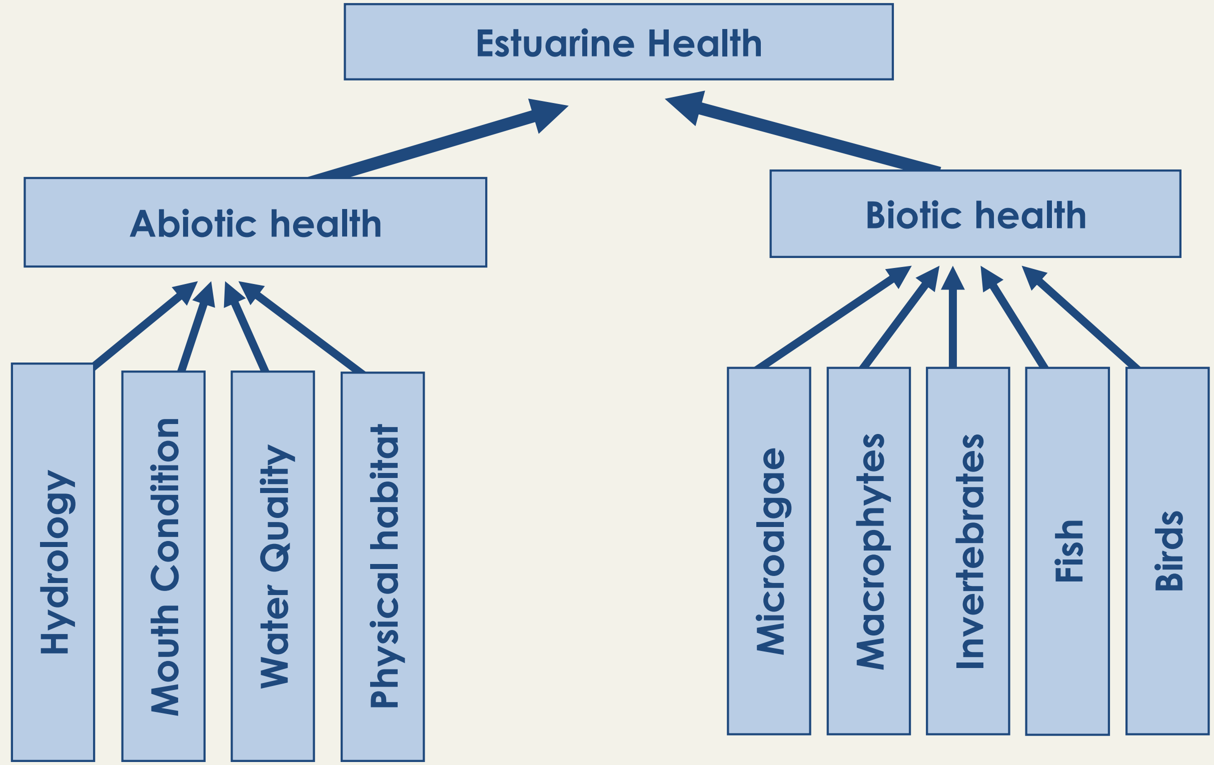
120
100
80
60
40
20
0
Flows (m³/s)
State 3
State 2
State 1
State 2
State 3
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

Development Scenarios



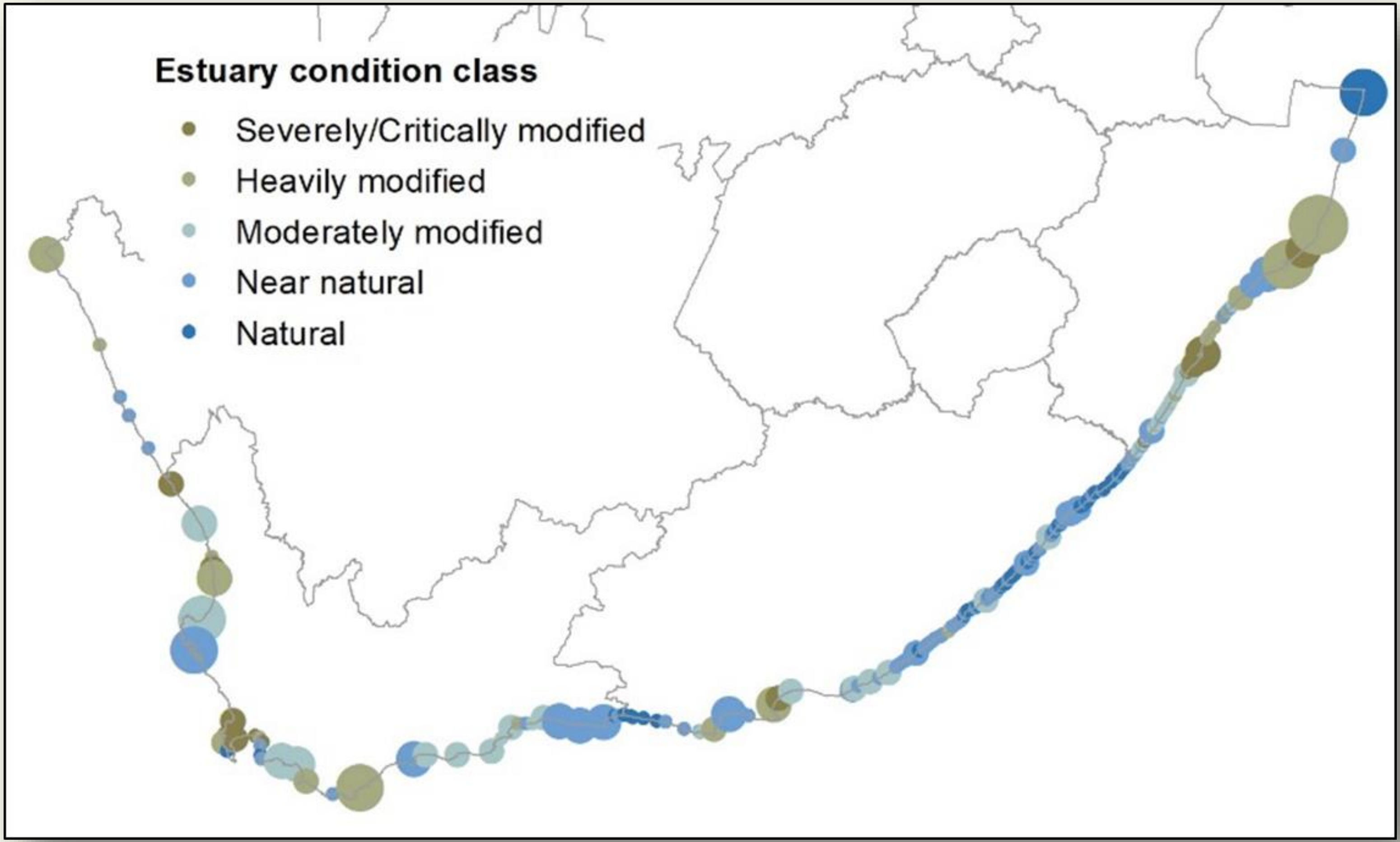
Estuary Condition

Estuarine Health Index (similarity to Reference/ Natural Condition)

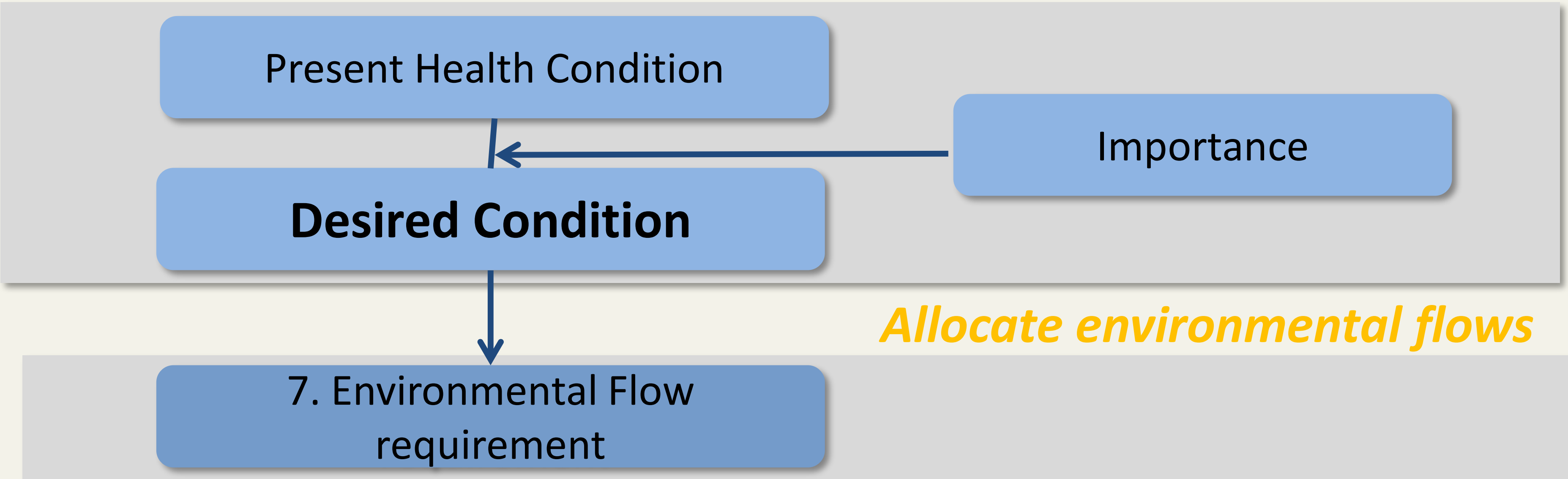


Condition	≥91%	90-75	75 - 61	60 - 41	40-21	≤ 20
Category	**A** Natural	**B** Largely natural / few changes	**C** Moderately modified	**D** Largely modified	**E** Highly degraded	**F** Extremely degraded
State	Excellent	Good	Fair		Poor	

Estuary Condition at country level

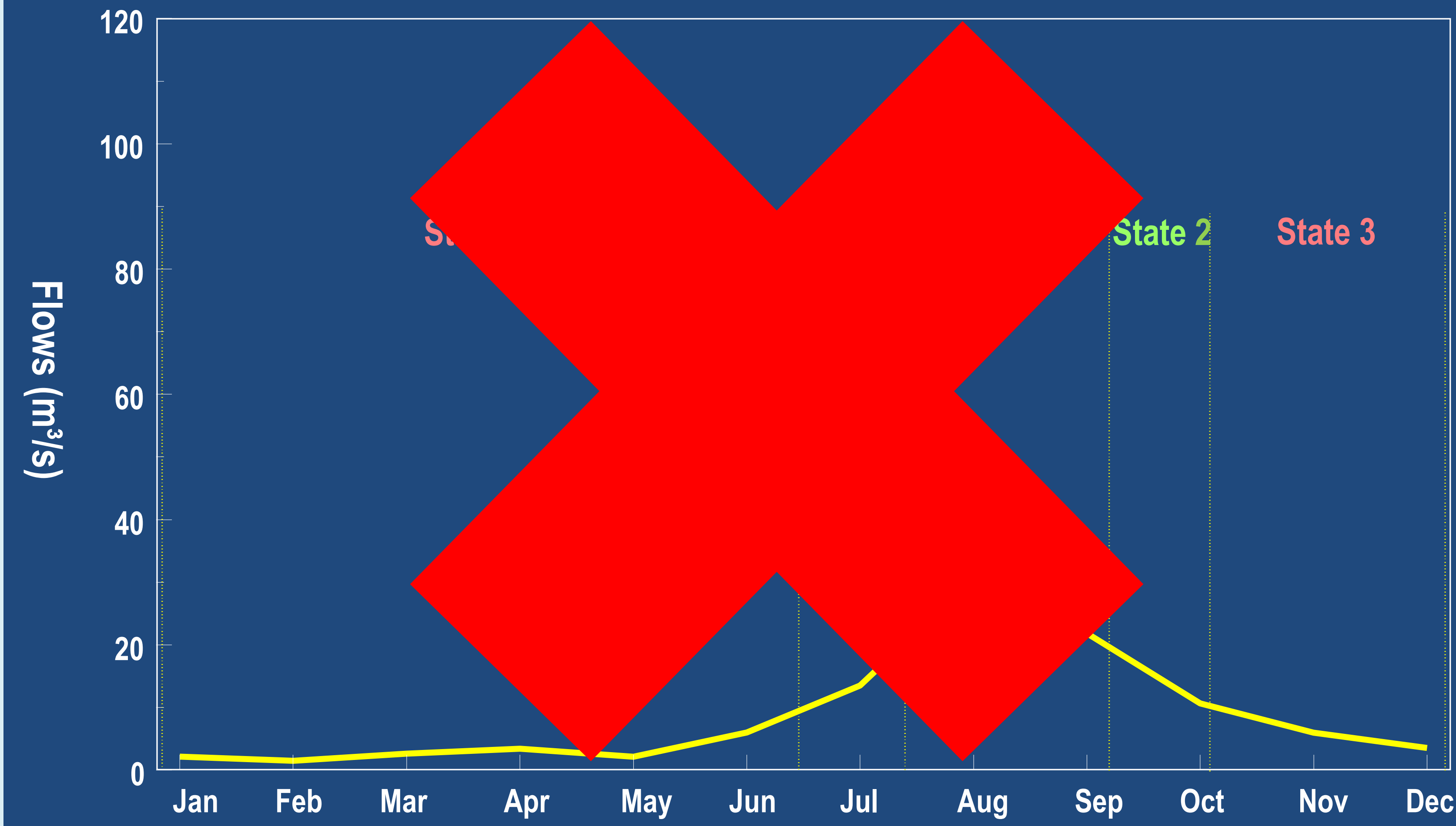


Recommended /desired condition



		Estuary Condition			
Estuary Importance		Good	Fair	Poor	Very degraded
	Very Important	Good	↑ Good	↑ Good/Fair	↑ BAS
	Important	-	Fair	↑ Fair	↑ BAS
	Low /ave importance	-	Fair	-	↑ BAS

Development Scenarios



Eflows allocation - Consultative process that allows stakeholders to negotiate the level of utilisation of water resources in a region

1. Delineate study area	Delineate the study area & individual resource units			
2. Develop future scenarios for a range of development options	Estuary scenarios	River scenarios	Wetlands scenarios	Scenarios
3. Level of resource use & degree of pressure	Estuary uses & pressures	River uses & pressures	Wetland uses & pressures	Macro economics & Ecosystem services
4. Determine resource health	Estuaries PES	Rivers PES	Wetlands PES	Current value of resource use
5. Determine resource importance and requirements	Estuary Importance	River Importance	Wetland Importance	Critically important uses
6. Define desired resource condition	Estuary REC	Rivers REC	Wetlands REC	Cost/Benefits of REC
7. Evaluate scenario consequences	Dams, River EWRs, WWTW	Dams, WWTW & Operational rules	Dams, WWTW & Operational rules	Cost/benefits of scenarios
8. Identify "Optimum Development Scenario Configuration"	Weighting scheme			
9. Set ecological condition targets, management objectives & future levels of resource use	Estuaries TECs, RQOs & use limits	River TECs, RQOs & use limits	Wetland TECs, RQOs & use limits	Socio-economic objectives

Resource Quality Objectives

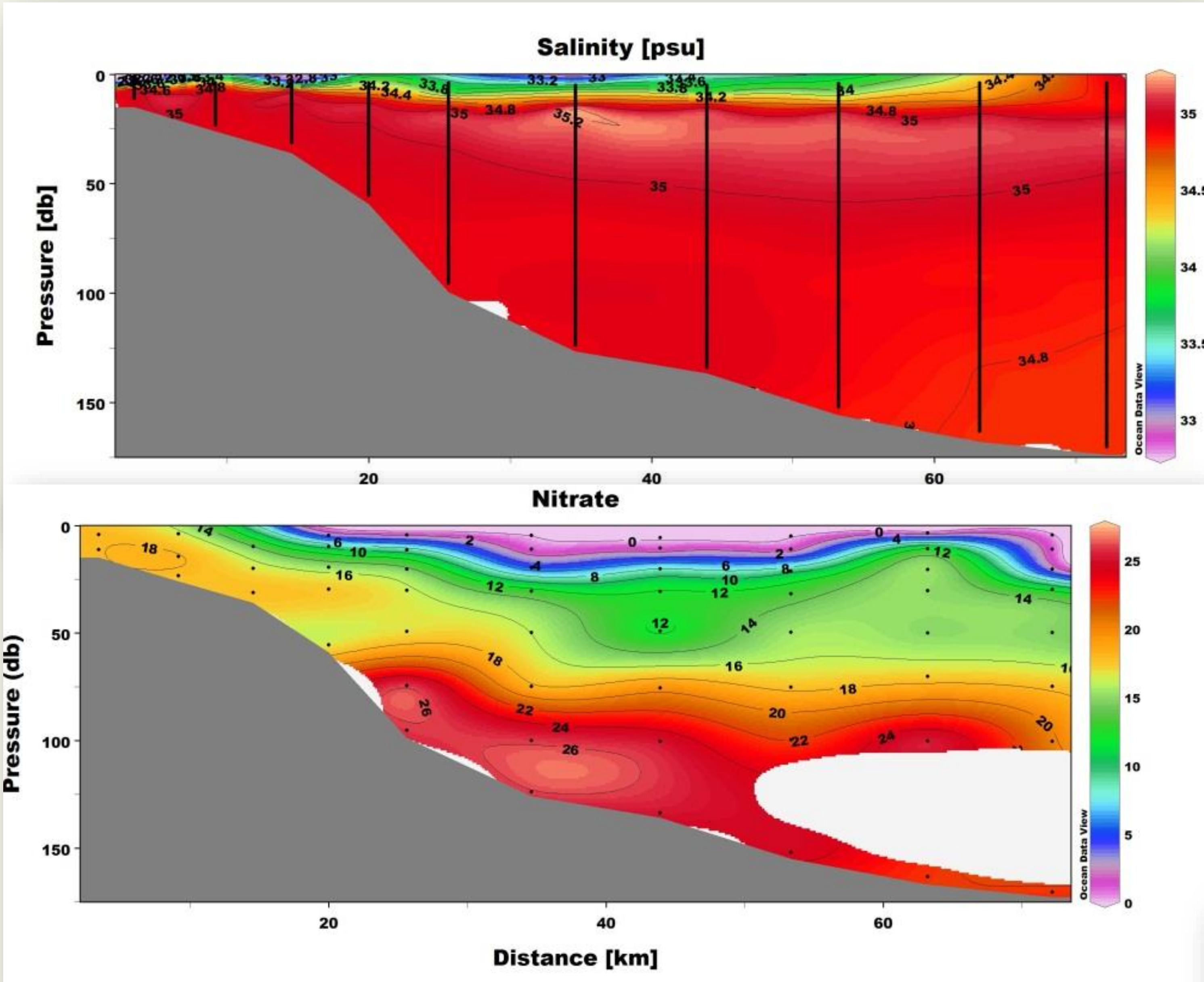
Component	Eco Specification	Threshold of Potential concern
…		
Salinity	Salinity intrusion should not impact on biota	• Salinity >20 for longer than 3 months at 7 km upstream from mouth • Salinity > 10 above 16 km upstream of the mouth
Fish	Retain fish assemblages (abundance): • Estuarine species (30-40%) • Estuarine associated marine species (60-70%) • Indigenous freshwater species (<1%)	• Estuary associated marine species drops <50% of total abundance • Estuarine species >50% of total abundance • Occurrence of alien freshwater species in the estuary
……		

Monitoring

Component	Action	Frequency	Location
…			
Salinity	Record longitudinal salinity and temperature profiles	Seasonally every year	Entire estuary at 10 stations
Fish	Record species and abundance of fish, based on seine net and gill net sampling.	Summer and winter survey every 3 years	Entire estuary at 5 stations
…			


Fluvially dependant coastal & nearshore environments
Mzimvubu plume Darren Hanner

What does a plume look like?



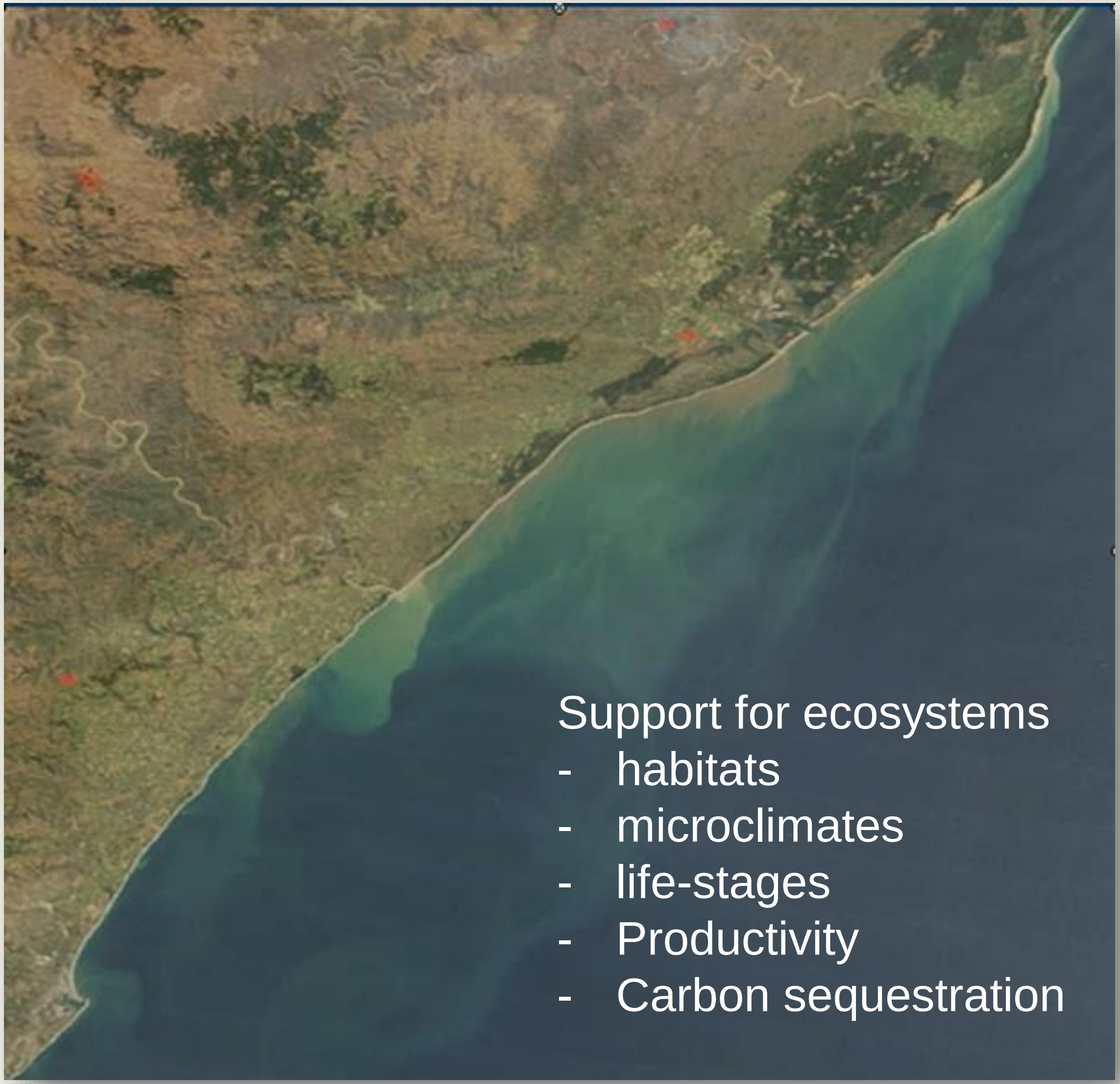
Orange Nearshore marine 4 & 5 Feb 2011 during 2010/11 flood (Source: DEA Hutchings & Lamont in press)

What does a fresh water flows do in the coastal and marine environment?

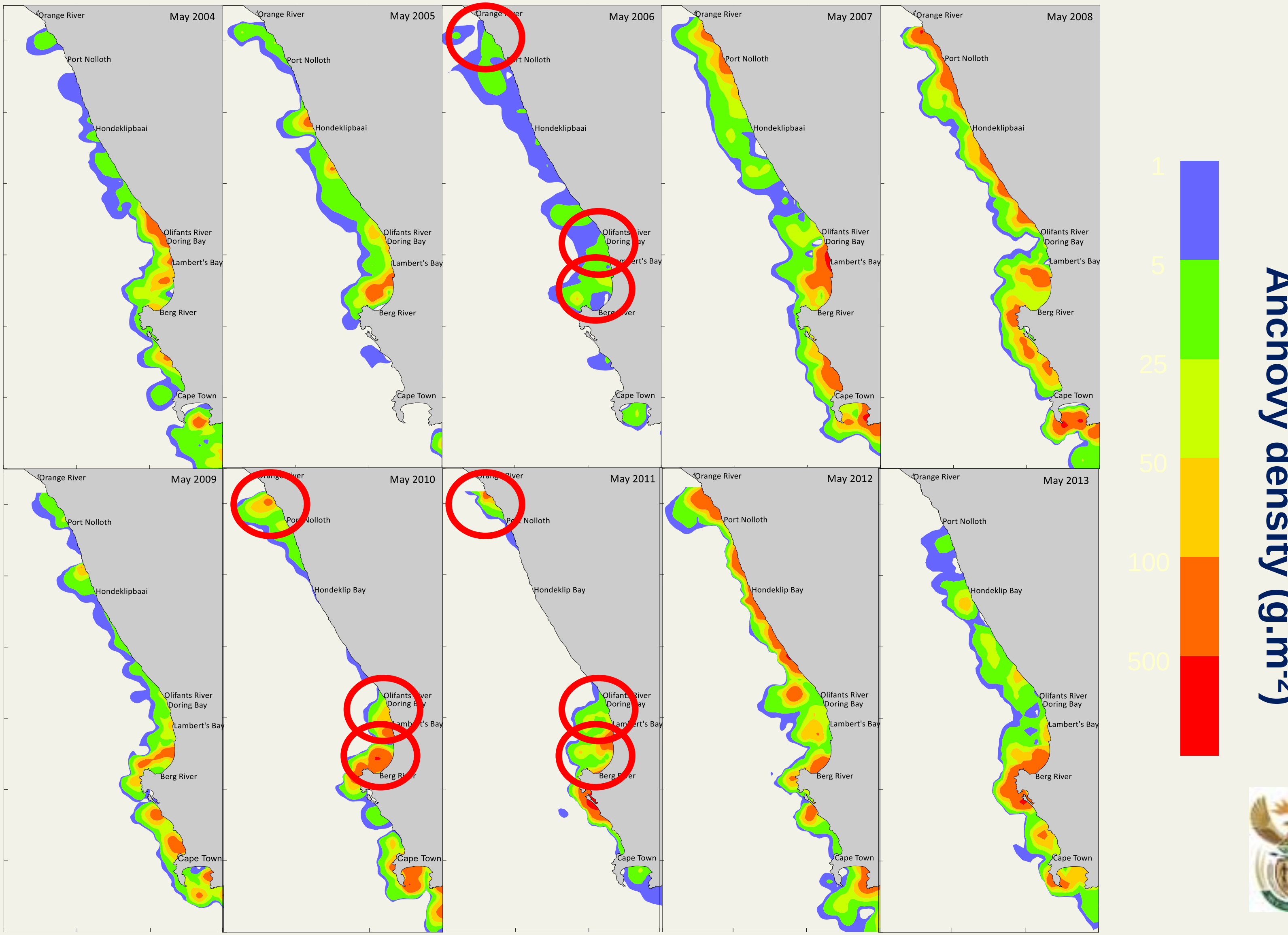
- ✓ Sediment supply to beaches
- ✓ Sustain nearshore marine habitat
- ✓ Turbidity fronts
- ✓ Salinity fronts
- ✓ Dissolved reactive silicate (DRS)
- ✓ Nutrient (N and P)

- ✗ Pollutants: Concerns in retention zones e.g. bays

Biological responses



Annual juvenile anchovy densities on the West Coast



Juvenile anchovy densities g.m^{-2} on the west coast of South Africa during May of each year from 2004 - 2013. Data and map source Dagmar Merkle, DAFF Small Pelagic Acoustic Survey. After Van Niekerk & Lamberth Eds. 2014.

Sediments

- Sediment delivery is a highly episodic process
- Wet years deliver much more sediment to estuaries and nearshore marine environment
- 33% more freshwater inflow under natural conditions
- Dams: relatively higher silt & clay fraction due to trapping of coarser fractions by dams

Marine eflows approach

STEP		ACTION

1	DEFINE ECOSYSTEM EXTENT AND RESOURCE USE	• Define legislative obligations (biodiversity protection, sustainable fisheries, coastal protection) including treaties & international agreements.
		  ○ Identify ecosystem extent (delineation).
		  ○ Identify key ecosystem functions & services.
		  ○ Identify ecosystem resource use.

2	DEFINE BIODIVERSITY & RESOURCE USE TARGETS	• Identify biodiversity and resource use targets (e.g. fish nurseries, fisheries production, MPAs, beach sediment requirement).

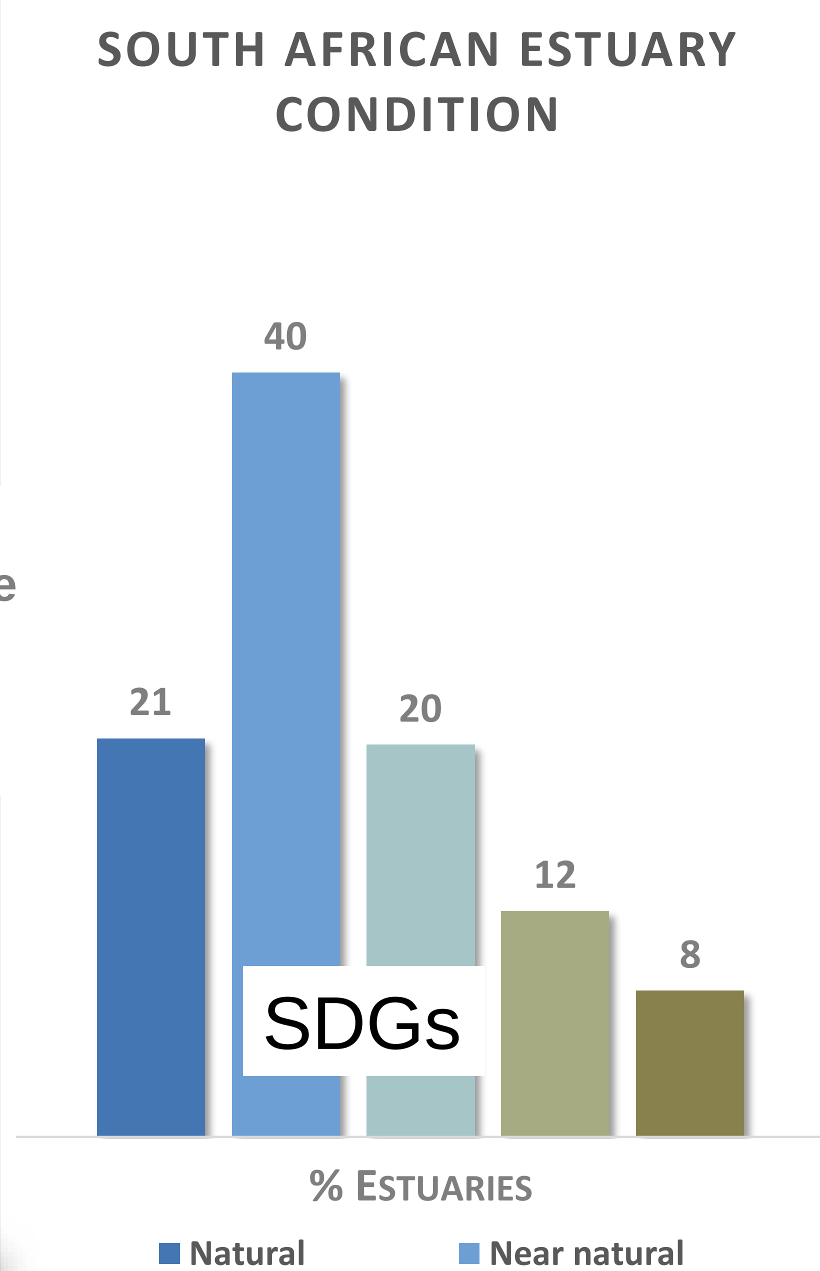
3	DETERMINE SENSITIVITY TO FLOW	• Determine ecosystem sensitivity to present flows:
		  ○ Key abiotic components (e.g. habitat) responses
		  ○ Implications of flow regime on biota (keystone/indicator species life-cycle & habitat requirements).

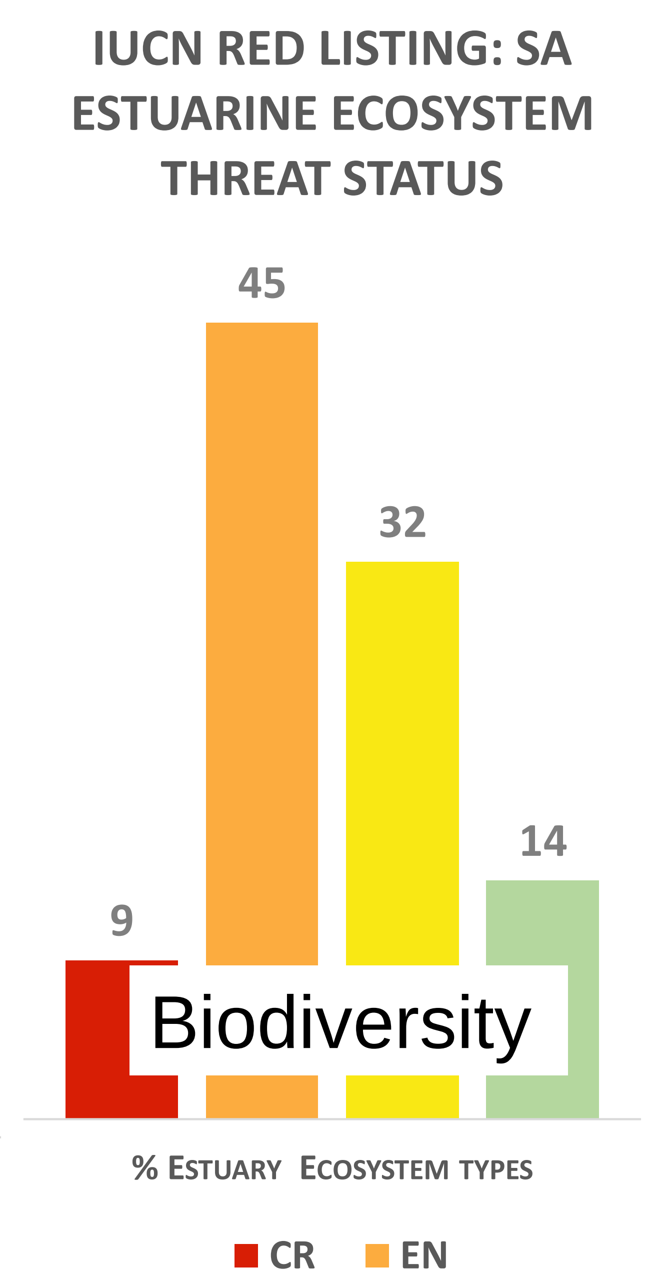
4	ASSES IMPACT OF FLOW SCENARIOS	• Assess hydrological scenarios - Predicted responses in abiotic drivers & biological components. • Implication for marine aquatic ecosystems & resource uses. • Recommend eflows.
5	SET RESOURCE TARGETS	• Set resource targets (e.g. freshwater flow, river water quality and sediment delivery) for nearshore marine environment

Link eflows to other processes

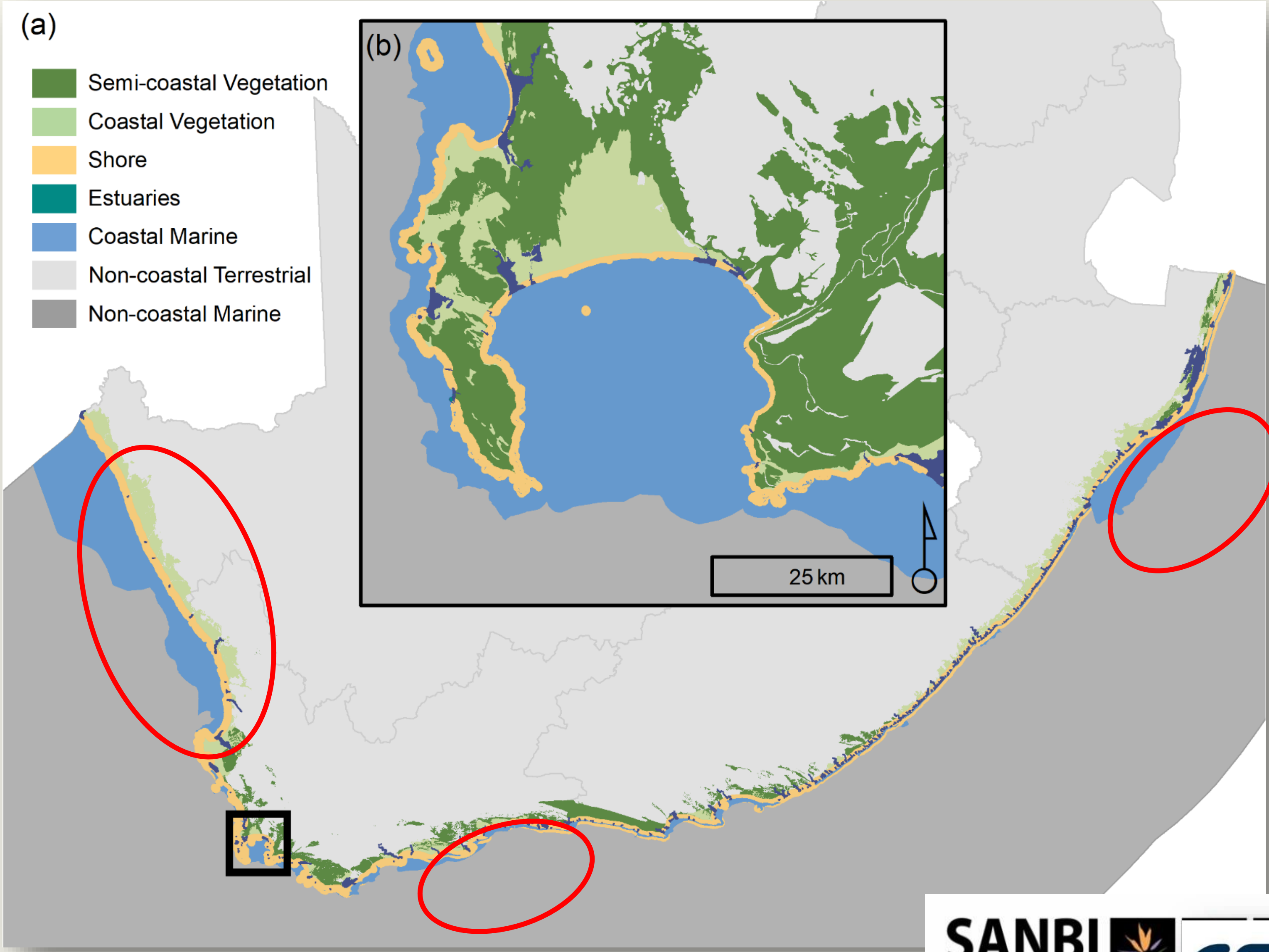
1. State of Environment reporting
2. SDGs
3. IUCN Redlisting of ecosystems
4. Restoration
5. Fisheries production (SA DEFF looking as squid, linefish, small pelagics (anchovy) & small scale fisheries).
6. Estuary Management processes.

Determine condition relative to natural for all estuaries using EFlows method





Delineate Coastal Ecosystem at the Country Level Scale



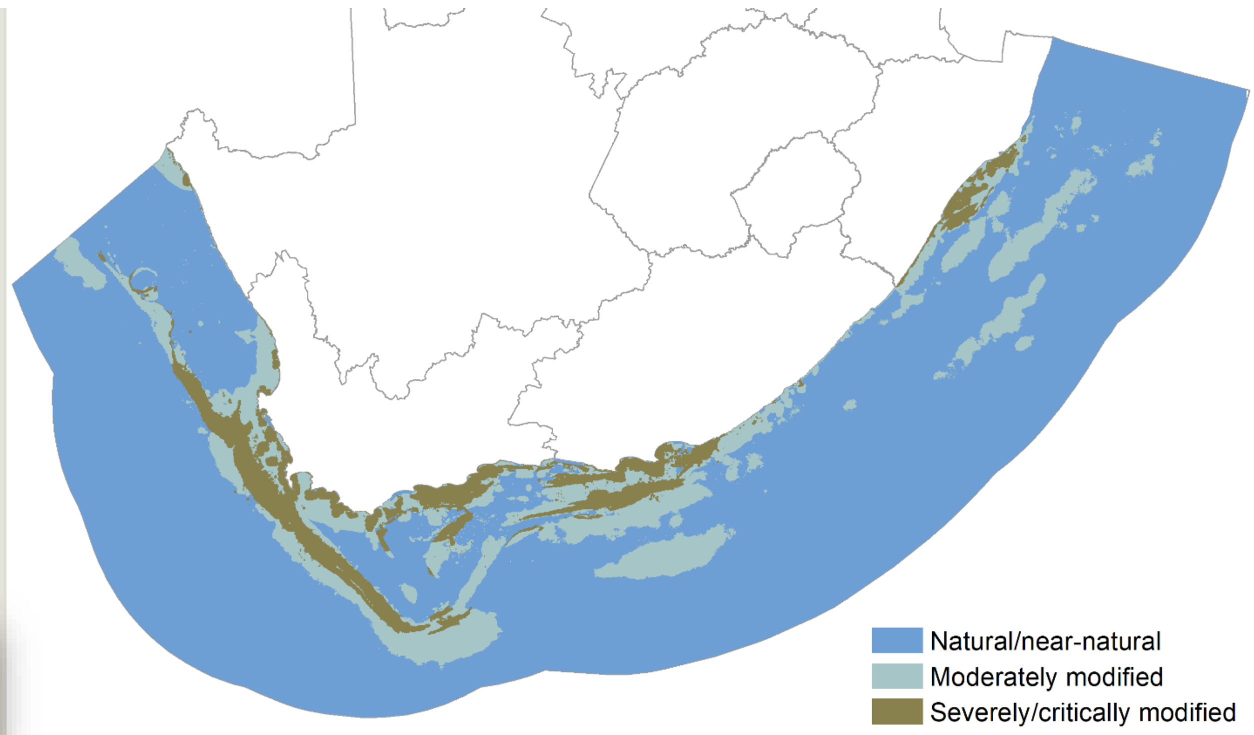
SANBI Biodiversity for Life South African National Biod

CSIR

	A	B	C	D	E	F
Department of Water and Sanitation (DWS) ecological condition	Natural	Largely natural	Moderately modified	Largely modified	Highly degraded	Extremely degraded
IUCN RLE ecosystem degradation categories	Natural or near natural (<50% degr.)		Moderately degraded (50–70% degr.)	Severely degraded (70–90% degr.)		Very severely degraded (>90% degr.)
NBA ecological condition categories	Natural	Near natural	Moderately modified	Heavily modified	Severely modified	Critically modified

Decreasing ecosystem function & increasing ecosystem restoration cost

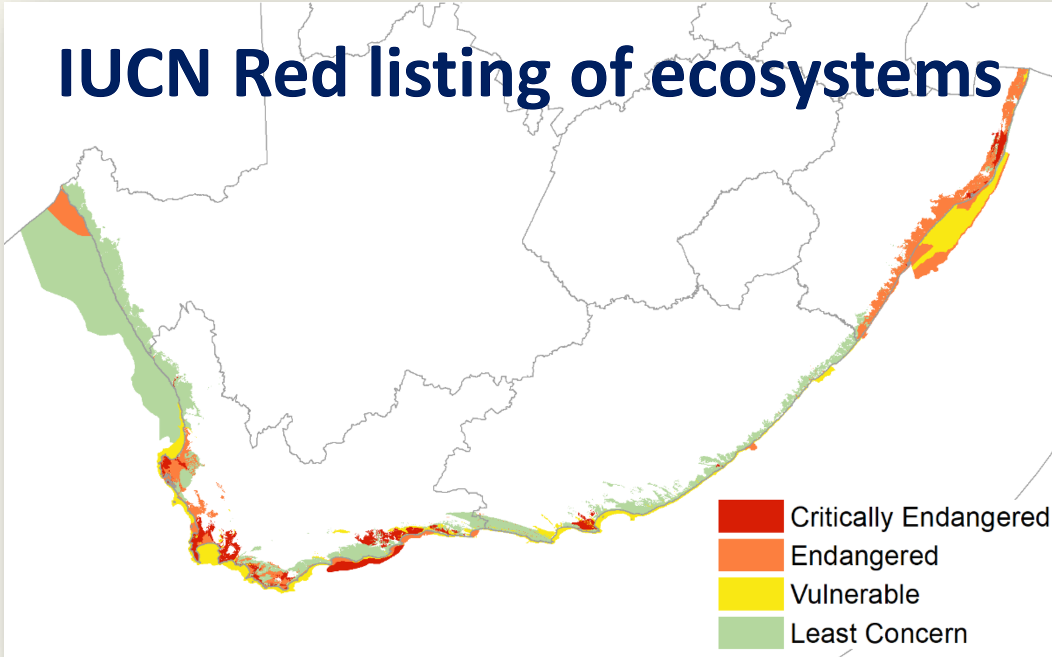
NBA 2018 Ecosystem condition



CSIR

SANBI
Biodiversity for Life
South African National Biodiversity Institute

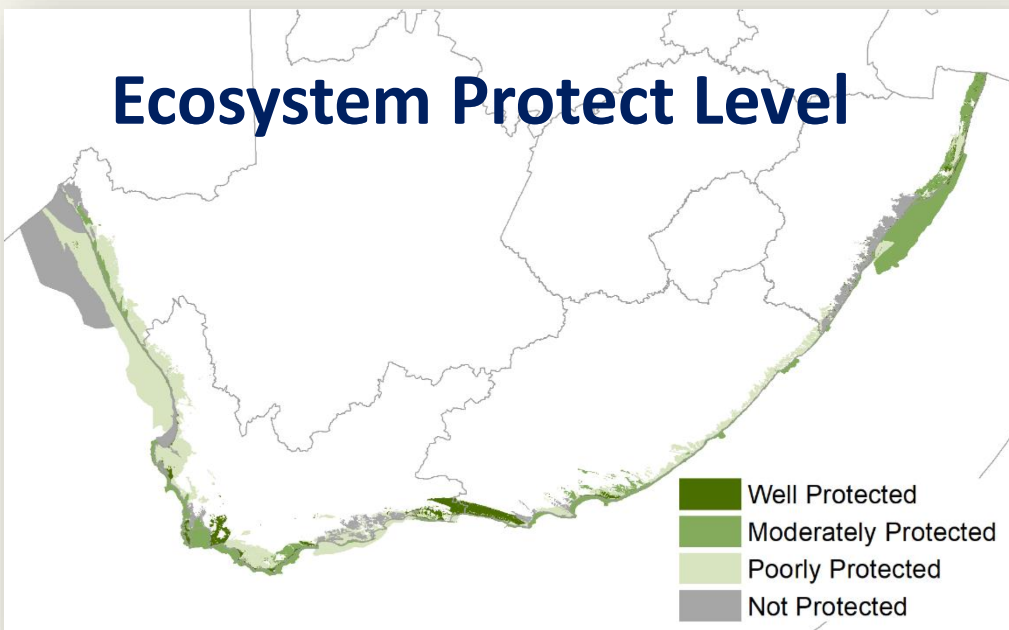
IUCN Red listing of ecosystems



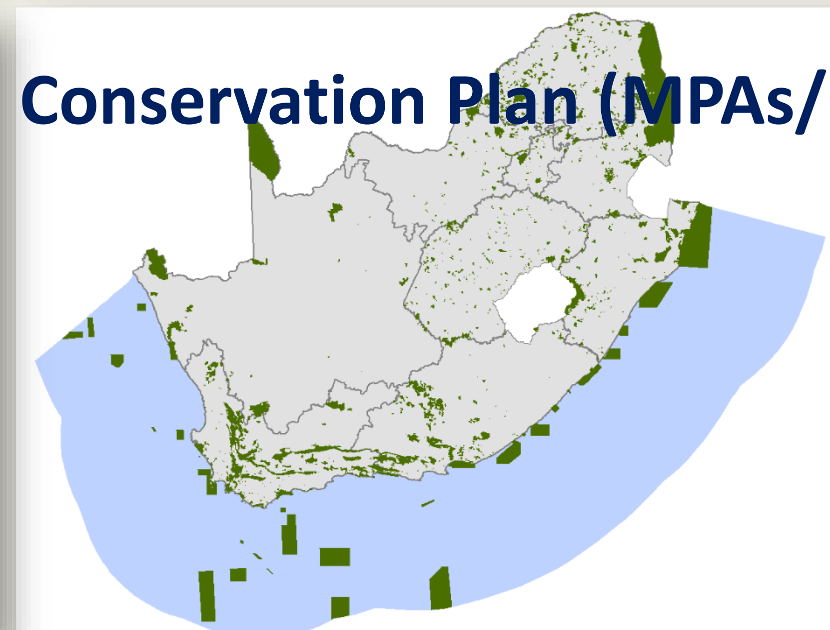
SANBI
Biodiversity for Life
South African National Biodiversity Institute

CSIR

Ecosystem Protect Level



Conservation Plan (MPAs/



Some thoughts…

1. Collate & simulate the best set of natural, present and future flow data possible (ToRs!!!). IN THE HYDROLOGY!!!
2. Delineation of Estuaries and Nearshore environment is critical. (DTM, remote sensing & expert opinion). These areas are larger than you think.
3. Type aquatic ecosystems to assist with determining sensitivity to flow upfront to guide TORs. Keep refining this as data comes in.
4. Determine all your uses and pressures (pollution, fishing development) - not just flow.
5. Estuarine and Nearshore marine processes should be modelled over long time scales (ToRs!!!).
6. Imbed in legislative frameworks.
7. Natural as reference state to link to other processes – State of Environment reporting, SDGs, IUCN Redlisting of ecosystems.

Literature

VAN NIEKERK L., TALJAARD S, ADAMS JB, LAMBERTH SJ, HUIZINGA P, TURPIE JK, WOOLDRIDGE TH (2019). An environmental flow determination method for integrating multiple-scale ecohydrological and complex ecosystem processes in estuaries. Science of the Total Environment 656 (15): 482-494.

VAN NIEKERK L, ADAMS JB, ALLEN D, TALJAARD S, WEERTS S, LOUW D, TALANDA, C, VAN ROOYEN P (2019). Assessing and planning future estuarine resource use: A scenario-based regional scale freshwater allocation approach. Science of the Total Environment 657 (20): 1000-1013.

VAN NIEKERK, L., ADAMS, J.B., BATE, G.C., FORBES, A.T., FORBES, N.T., HUIZINGA, P., LAMBERTH, S.J., MACKAY, C.F., PETERSEN, C., TALJAARD, S., WEERTS, S.P., WHITFIELD, A.K., WOOLDRIDGE, T.H. 2013. Country-wide assessment of estuary health: An approach for integrating pressures and ecosystem response in a data limited environment. Estuarine, Coastal and Shelf Science 130: 239-251.

Thank You