MSE and indicators for EBFM

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Motivation

- Focus globally (public and science) = ecosystems
- Legislation requires assessment of fisheries impacts on the environment (e.g. in Australia)
  - moving to ecosystem-based fisheries management (EBFM)

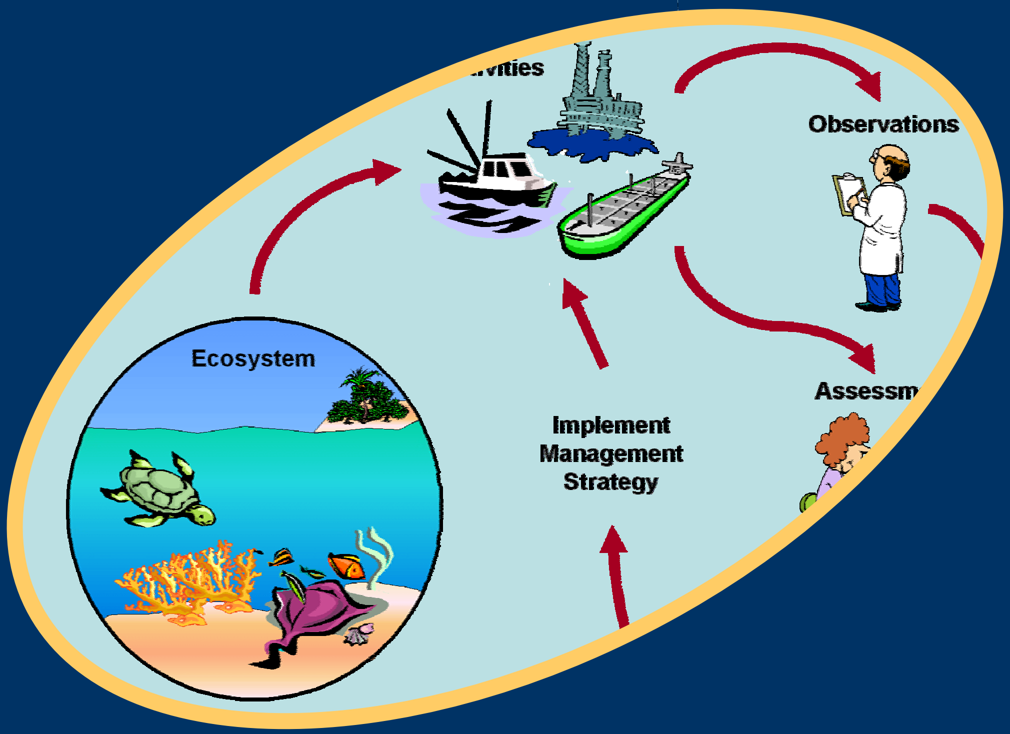
Basis of EBFM

- Not why and what, but how?
- Many documents but come down to 3 parts
  - set and operationalise objectives (hardest step)
  - assess current system status (indicators)
  - decision rules and implementation

Indicators

- Ecological indicators
  - many potential indicators, but do they work?
  - many framework/criteria documents, few tests (growing slowly now)
- Australia data poor
  - systematic field test impossible, thin first
  - simulate
  - targeted field check

Management Strategy Evaluation



Indicators Tested

- No operational EBFM objectives
  - — diagnostic indicators tested (ecological information content)
  - — robust = indicators that reliably and consistently predict trends in 1+ key attributes

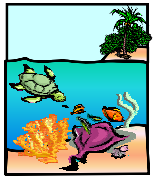
- Indicators tested cover
  - — populations, assemblages (communities), habitats, ecosystems
  - — empirical, model-dependent
  - — fisheries dependent and independent

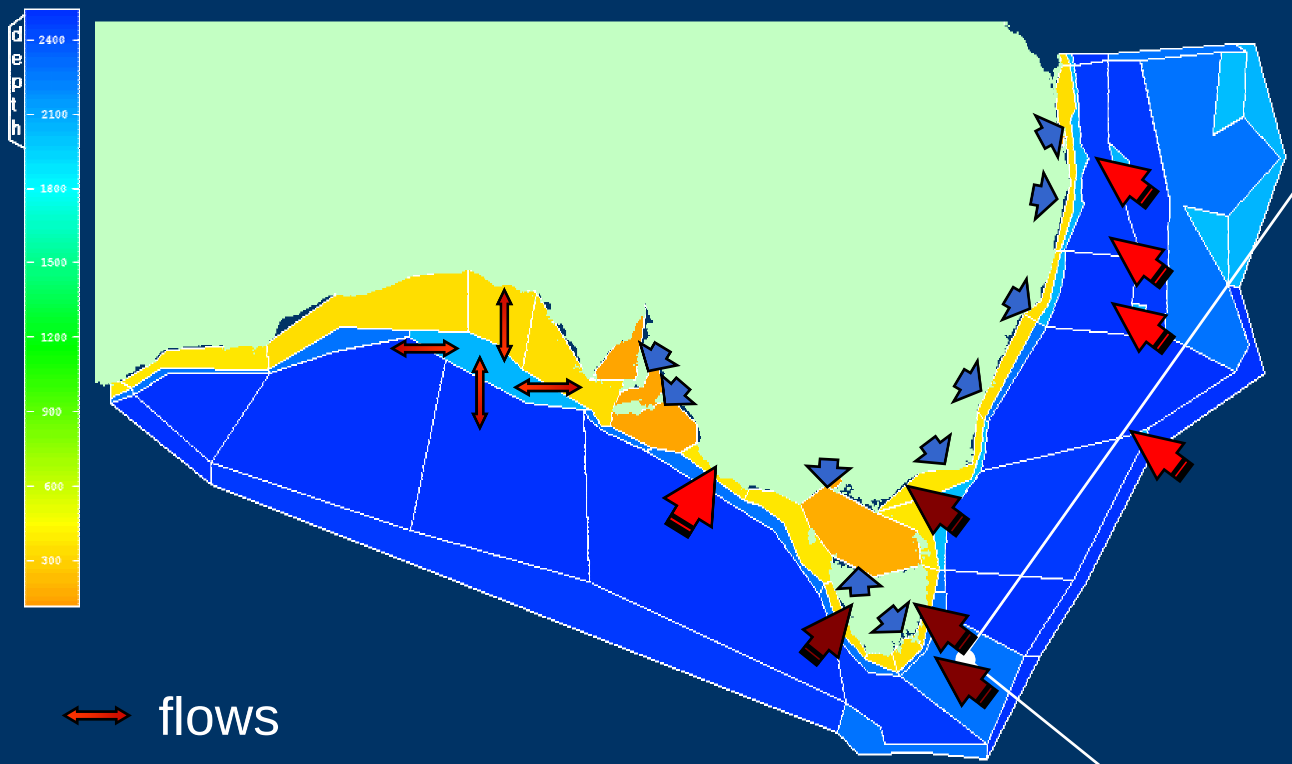
Attributes

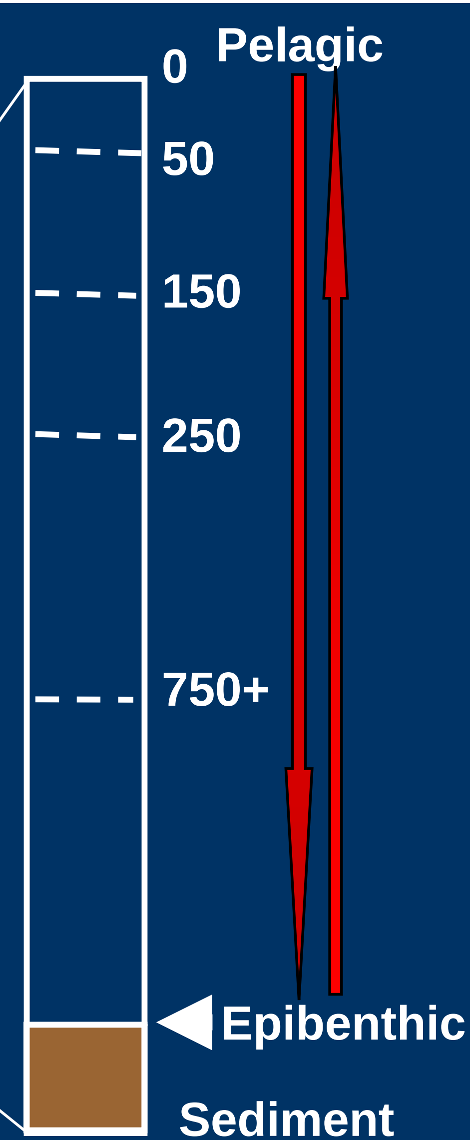
- Gross form of communities and ecosystem (+ key groups of concern)
  - biomass, size structure, spatial structure, number of groups to represent 80% of the biomass
  - species, guilds, communities
- Structure of communities and ecosystem
  - diversity, foodweb structure, trophic levels
- Ability to support current ecosystem state in the long-term
  - production, throughput, consumption, nutrient cycling
- System maturity
  - respiration

Simulation Model - Atlantis

Geography and Hydrodynamics



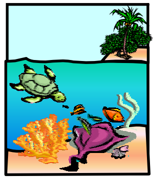




- flows
- upwelling (to surface or at depth)
- river or major inputs

- Physical properties per box (dynamic)

Ecology



- Biophysical
  - — sediment nutrient cycling
  - — growth limitation (nutrient, light, oxygen, space, substrate)
- Ecological
  - — main processes (feeding, reproduction, movement, mortality, waste, age)
  - — functional groups (by size and diet)
  - — invertebrate biomass pools, vertebrate age structured (+ condition)

Fisheries

- Harvest
  - multiple fleets
  - ports,
  - gears (catchability, availability, selectivity, escapement)
  - effort allocation (displacement, targeting)
  - impacts (including discarding, habitat modification etc)

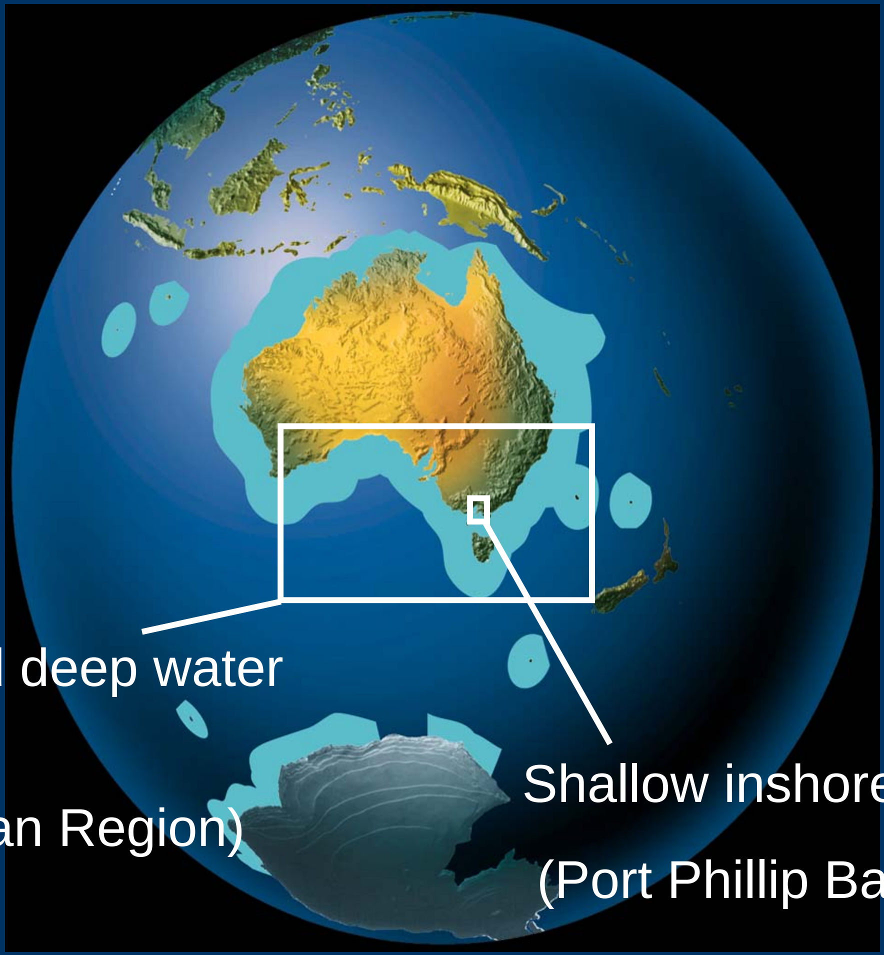
Observation Submodel

- Fisheries dependent data (with error)

- Fisheries independent data
  - observers
  - surveys (user defined sampling design)
  - with error
  - diet information can be at coarser resolution

- Additional processing (aging, aggregate data, models)

Simulated Ecosystems



Continental shelf and deep water system

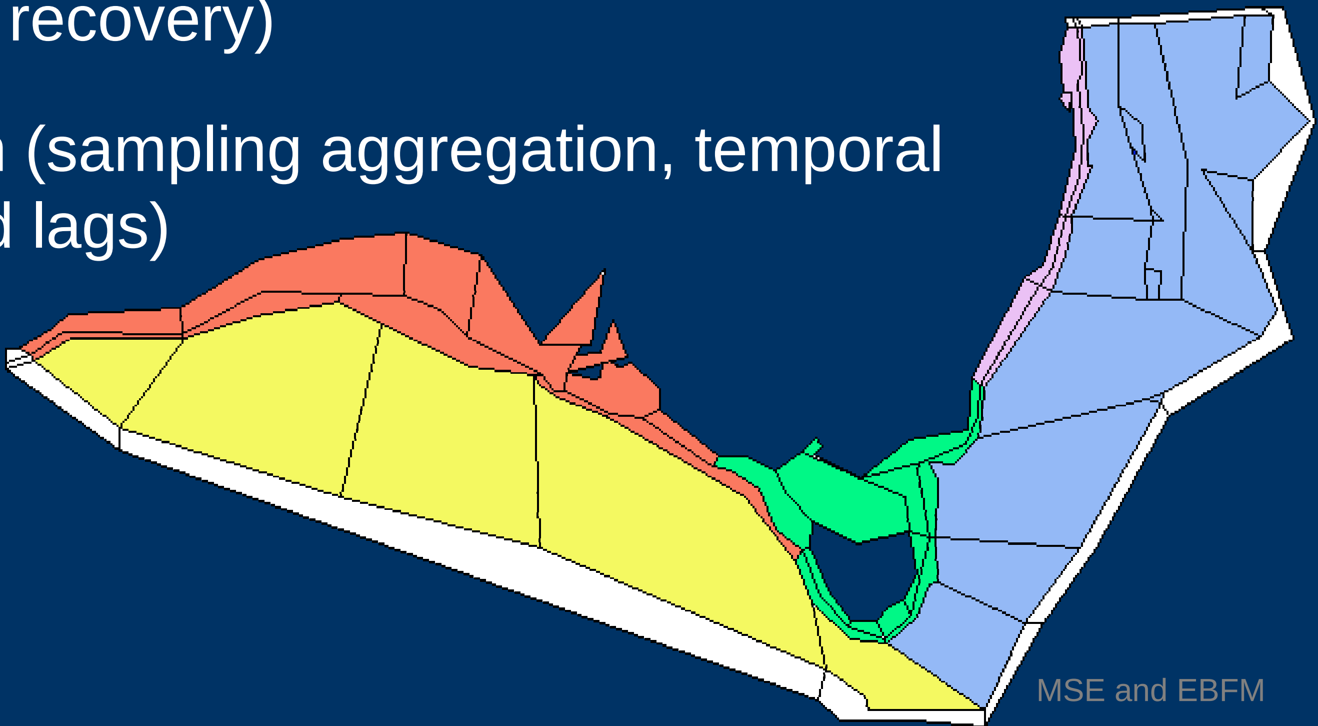
(South east Australian Region)

Shallow inshore system

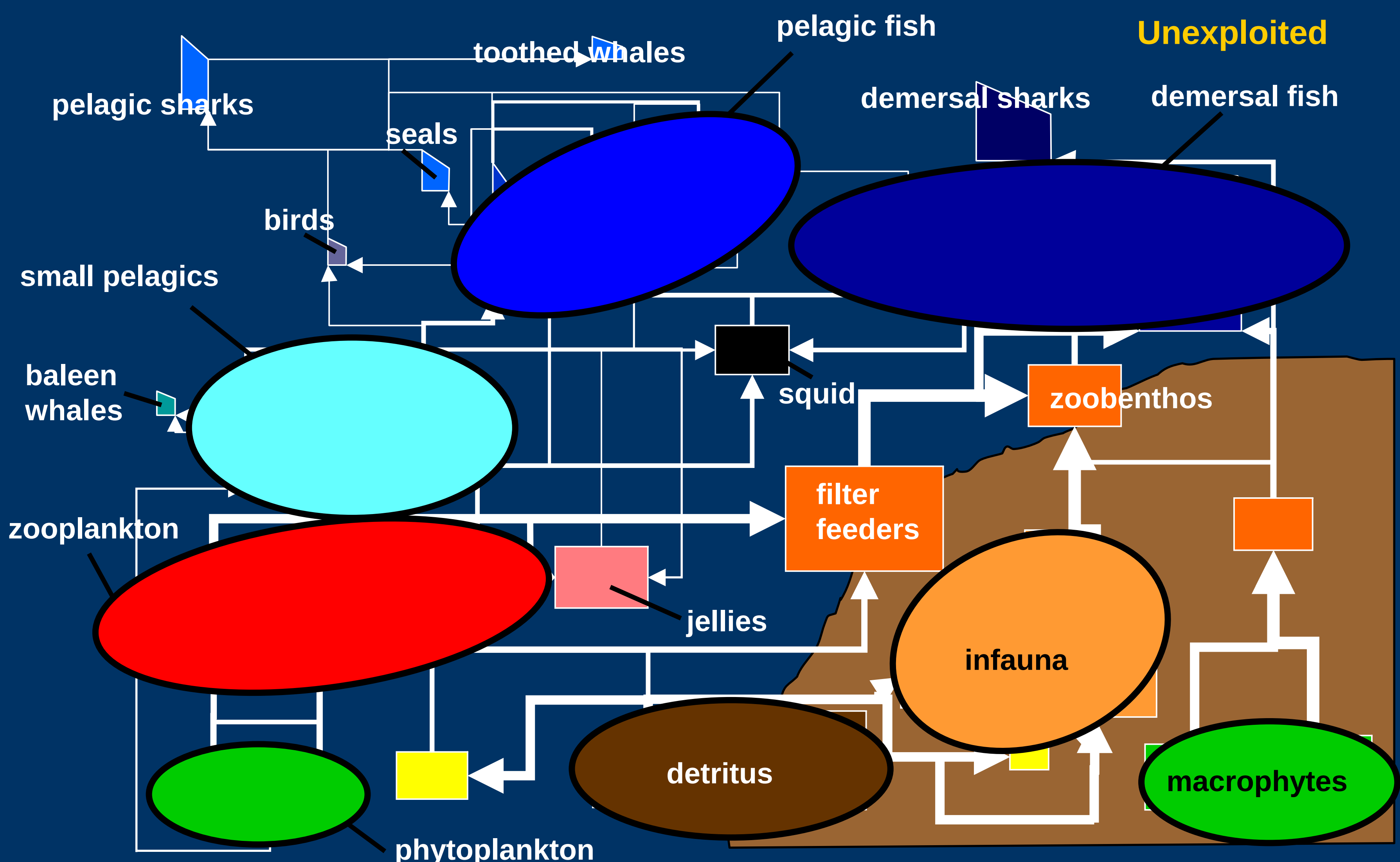
(Port Phillip Bay, Melbourne)

Scenarios and Sampling design

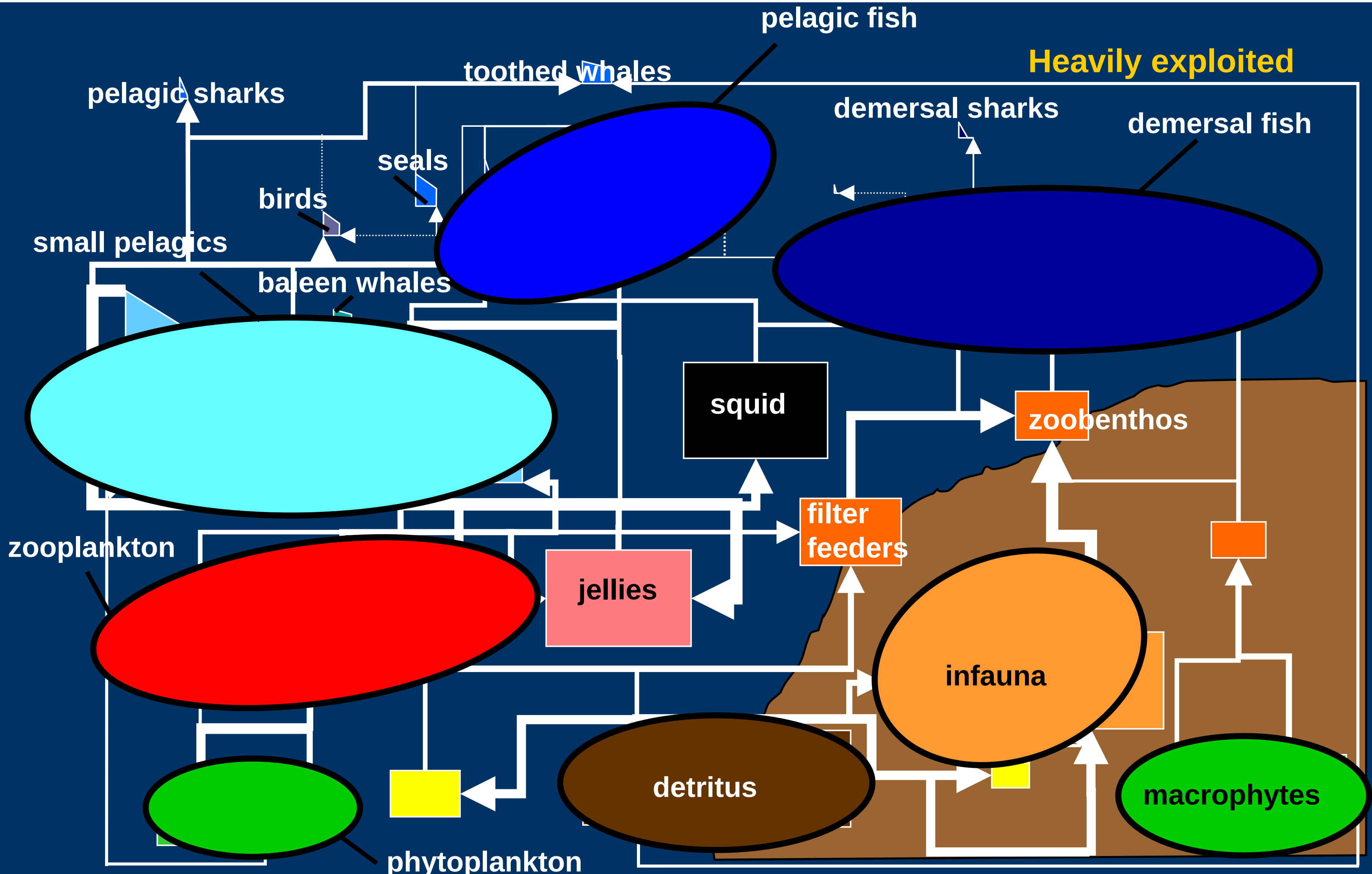
- Scenarios
  - anthropogenic (levels and types of impacts), fisheries and management structure (closures, effort control, quotas, mitigation, gear, compliance)
  - ecological (system closure, linkage strength, charismatic recovery)
- Sample design (sampling aggregation, temporal patchiness and lags)



Atlantis Model Behaviour



Atlantis Model Behaviour



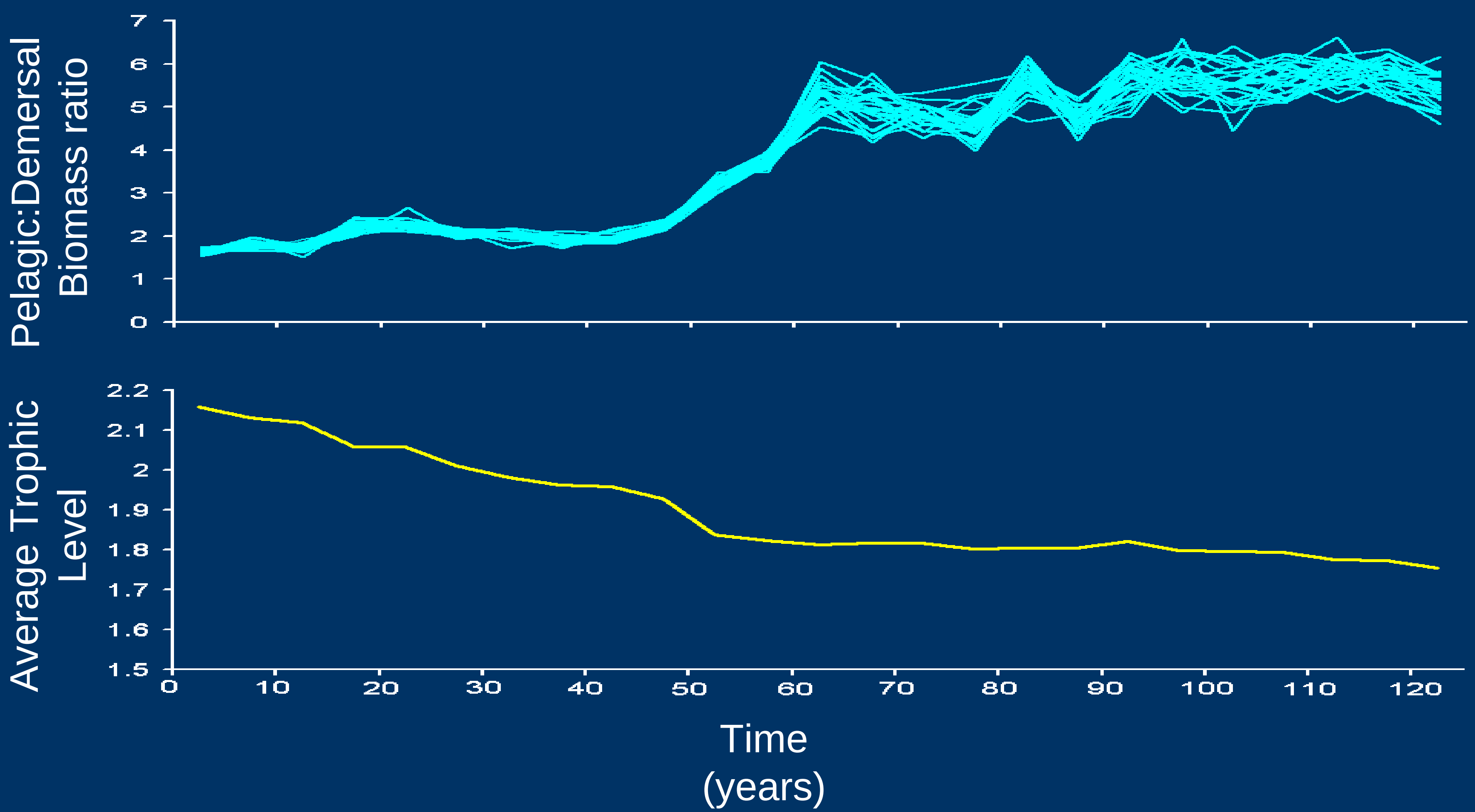
Attribute behaviour

- Attribute correlation
  - check for value of multiple correlations per indicator
  - check for "isolated" attributes
    - system structure
    - system productivity
    - migrants and what attracts them to the system
    - nutrient cycling (and productivity)
    - diversity (and productivity)

Analysis

- Correlation of indicators with attributes through time
  - — linear only (too hard to interpret and actually use if non-linear)
  - — Pearson and Spearman correlation
- Categories
  - — Consistent or Inconsistent
  - — Broad ($|r|>0.5$ for 40% attributes) or Restricted
  - — Very Clear ($|r| > 0.9$) or Strong ($0.9 \geq |r| > 0.7$) or Recognizable ($0.7 \geq |r| > 0.5$) or Uninformative ($|r| \leq 0.5$)
- Determine how robust indicators are to
  - — ecosystem conditions, levels and patterns of fishing pressure, sampling and processing error

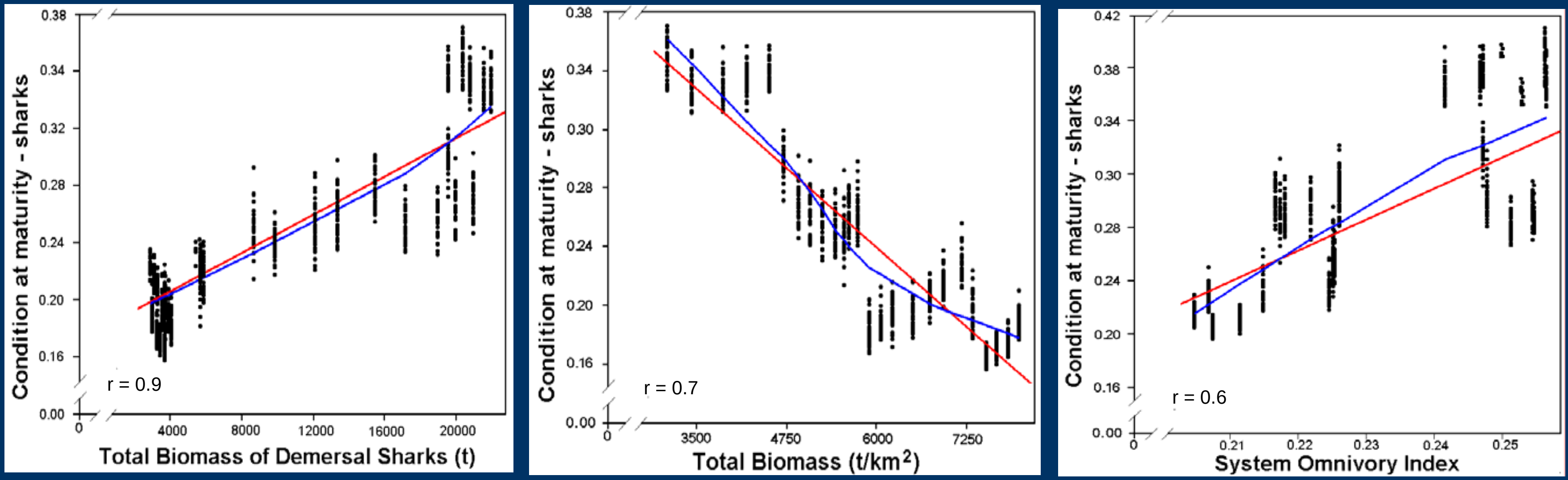
Indicator vs Attribute



Good performance

- Linear correlation with large r (easy to interpret and use)
- e.g. condition at maturity of sharks (size at maturity good too and easier to measure)

Indicator



Attribute

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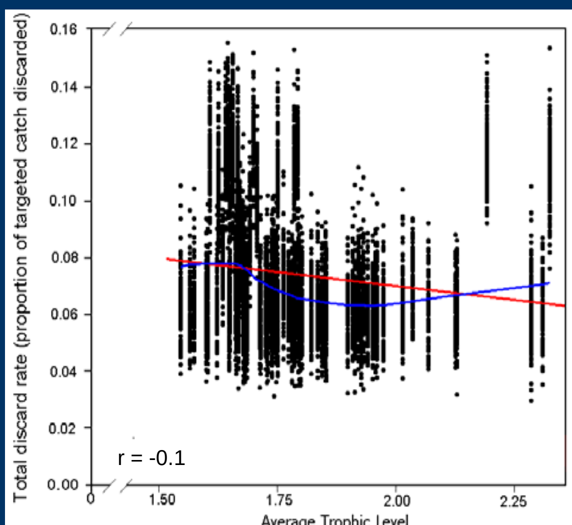
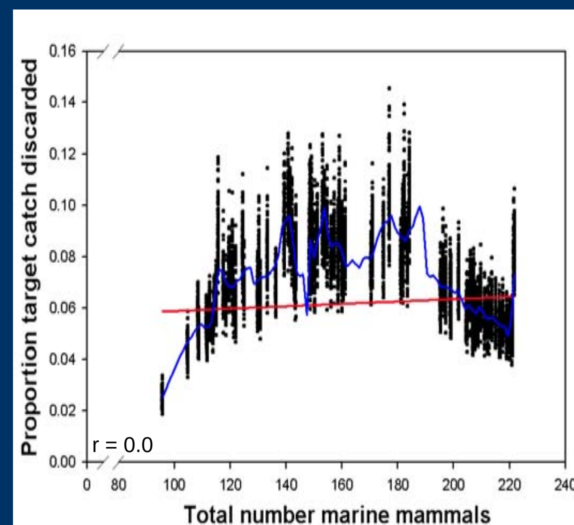
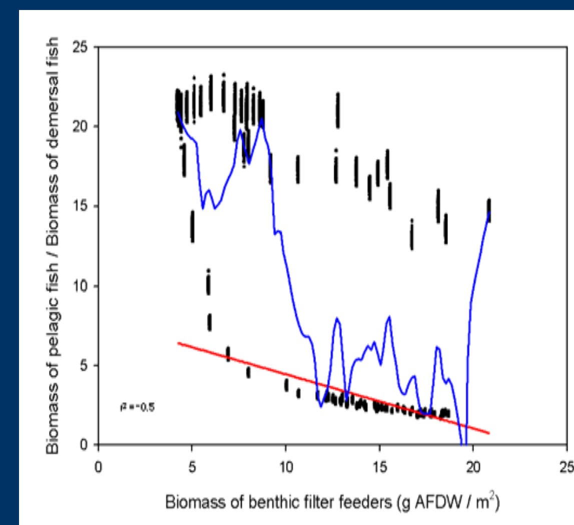
Poor performance

- No correlation (or linear with low r) or non-linear (hard to use!)

Indicator







Attribute

Simulation Results

Consistent (system independent)
Inconsistent (system dependent)
Broad (|r|>0.5 for 40+% attributes)
Restricted (|r|>0.5 for <40% attributes)
Very Clear (|r| > 0.9)
Strong (0.9 ≥ |r| > 0.7)
Recognizable (0.7 ≥ |r| > 0.5)
Uninformative (|r| ≤ 0.5)

- E+C versus P
- Ecosystem- and community-level indicators dominate
  - consistent, broad, |r| > 0.7

Best

	Consistent				Inconsistent			
	Broad		Restricted		Broad		Restricted	
Indicator type	E/C	P	E/C	P	E/C	P	E/C	P
Very clear		2		3		0		1
Strong		2		12		0		5
Recognizable		1		7		1	4	6
Uninformative	20*	9						

Useless

Worst

* mostly model dependent with p … ed errors, or misspecification

Simulation Results

- Reflected in skewed frequency of correlation

Model dependent (good data)

Condition or size at maturity

Biomass or biomass ratios

Size spectra

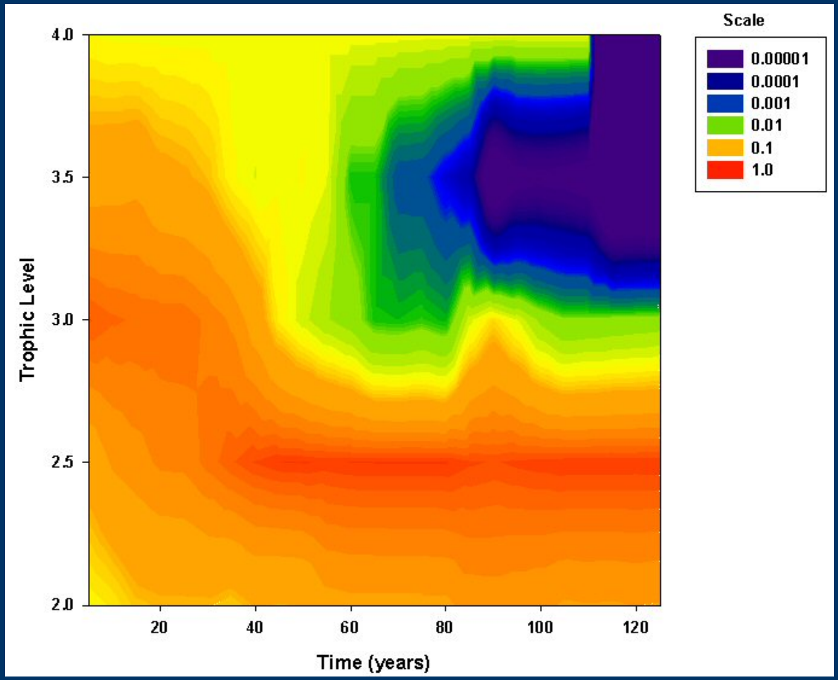
Indicator type	Consistent				Inconsistent			
	Broad		Restricted		Broad		Restricted	
	E/C	P	E/C	P	E/C	P	E/C	P
Very clear	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1
Strong	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	5
Recognizable	1	1	[illegible]	[illegible]	0	1	[illegible]	[illegible]
Uninformative	[illegible]	[illegible]						

Fisheries dependent (good data)

Model or catch dependent (poor data) or Population level

Simulation results

- Multidimensional indicators (size spectra, trophic spectra, ABC curves)
- Harder to summarise, but signal clear

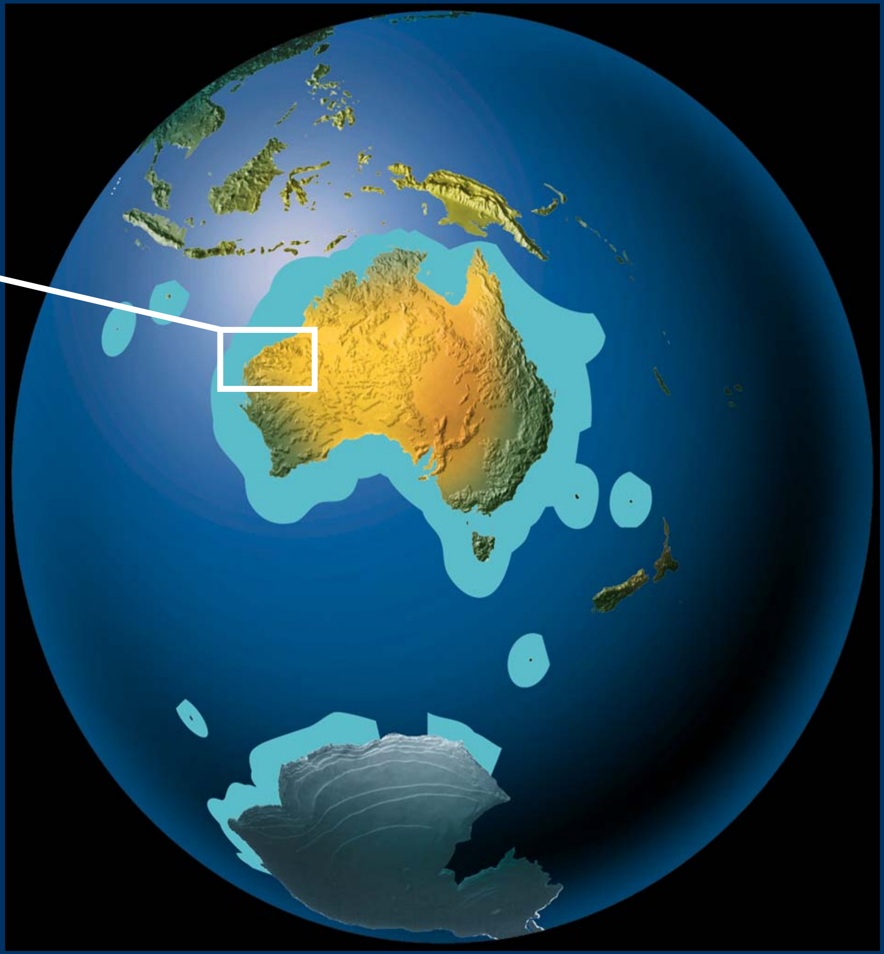


GIS Indicator study

- Trends in indicators through space and time

GIS test area

(North West Shelf)



Indicators Tested Using GIS

- Checked best performing from simulation tests
  - habitat cover
  - chlorophyll a
  - biomass ratios
  - average trophic levels

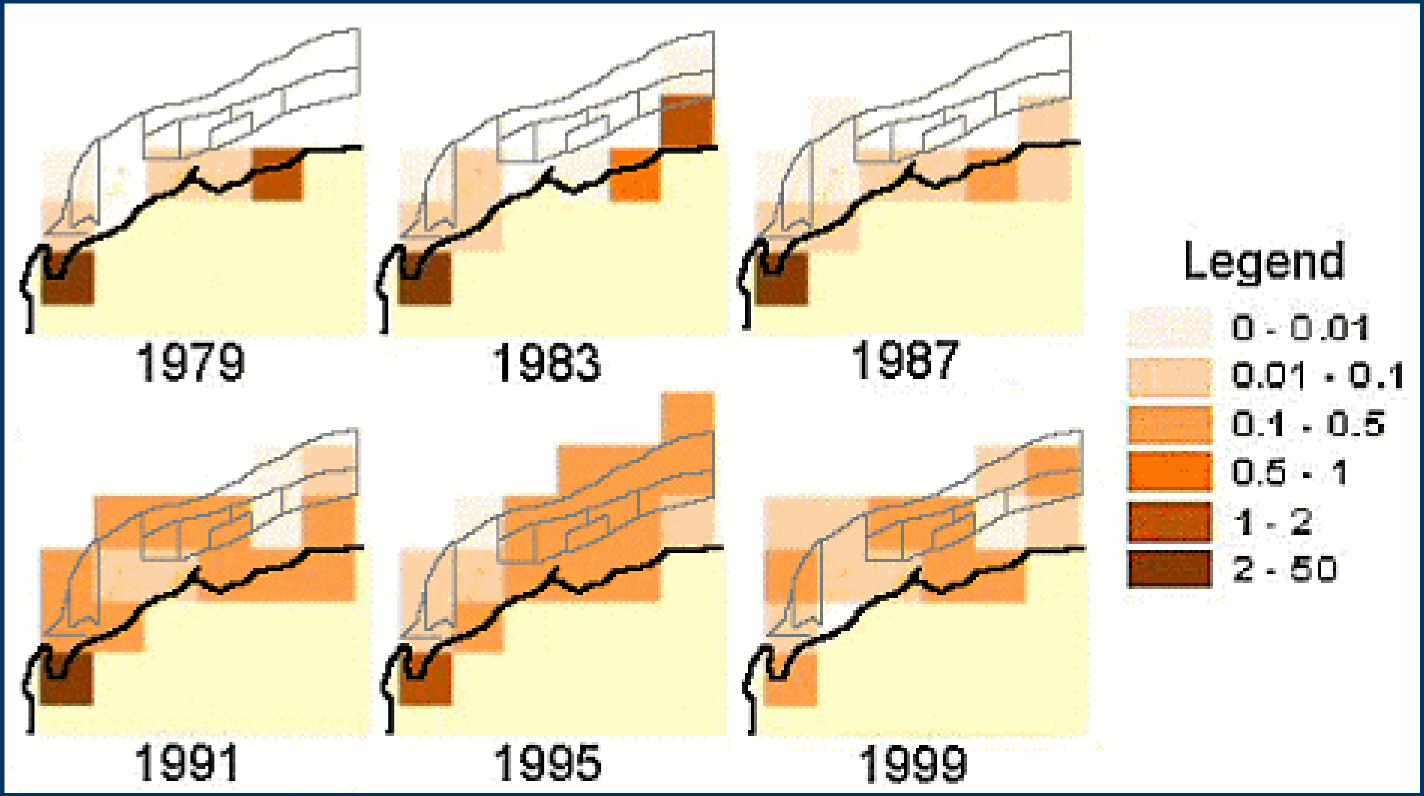
- Checked indicators that are most preferred “traditionally”
  - diversity (counts)
  - maximum length of catch
  - CPUE and catch trends

GIS results

- Performance consistent across simulations and GIS
- Spatial scale
  - data very poor single value maybe best can achieve
  - signal strength potentially stronger on slightly finer scale
  - different trends inshore vs offshore (different pressures)
- Traditional fisheries indicators contained weakest and least reliable signals
- Fisheries dependent data can still contain a signal
  - even using simple “rule of thumb” assumptions

GIS results - Example

- e.g. ratio small bodied : large bodied catch



General Findings – Indicators

- Good indicators
  - — easily measured (easy to sample, easy to calculate)
  - — cost effective
  - — easily understood (interpreted)
- Problems
  - — none perfect
  - — always some system dependency
  - — pragmatism required (even simple indicators hard to do in practice, simple assumptions maybe needed)

General Findings – No One Indicator

- Need a suite (no single indicator) as indicator performance may differ with
  - ecosystem
  - history of exploitation
  - other pressures (e.g. pollution, environmental change)
  - quality of sample collection

General Findings – Suite Needs

- Suite needs to contain indicators associated with
  - groups with fast turnover rates (potential early warning)
  - groups targeted by fisheries (state of exploited section of the ecosystem)
  - habitat defining groups
  - sensitive or key groups (often have “slow dynamics”)
  - multiple spatial and temporal scales
  - range of processes (with different rates), biological groups and indicator types (tactical and strategic, early warning and integrated system state)

► best combination of signal detection + system state

Recommended Indicator Groups

- Indicator functional groups found to be useful
  - gelatinous zooplankton
  - cephalopods
  - seagrass
  - planktivores
  - demersal fish
  - top predators (large sharks, mammals)

Recommended Indicators

Undesirable reference direction

Indicator	Direction	Indicator	Direction
Relative Biomass		**Biomass ratios**	
Gelatinous zooplankton	↑	Piscivore : Planktivore	↓
Cephalopods	↑	Pelagic : Demersal	↑
Planktivores	↑	Infauna : Epifauna	↑
Scavengers	↑	Size at maturity	↓
Demersal fish	↓*	Maximum length of catch	↓
Habitat forming epifauna (cover)	↓		
Seagrass (cover)	↓	Trophic spectra (slope)	Steeper
Piscivores	↓	Size spectra (slope)	Steeper
Top predators	↓	ABC curves (W)	↓
Diversity (counts)	↓*		
Chlorophyll a (or nutrients)	↑*	Temperature	

Reference points – Link 2005

- Link 2005 (ICES) provides warning / limit reference points
  - mean length of catch
  - slope of size spectrum
  - biomass of pelagics, flatfish, piscivores, top predators, scavengers, jelly fish
  - diversity (counts)
  - habitat cover
  - catch
  - number of cycles
  - mean number of interactions per species

Indicator Guidelines

- Performance: for ecosystem-level concerns use ecosystem- or community-level indicators
  - — population-level often too sensitive to “noise” or species-specific factors
- Responsiveness: Community-level (or population) for early warning and management
  - — ecosystem level too slow to respond (due to rate of system change and sampling frequency)
- Complexity: The fewer steps in calculation the better
  - — simple indicators (relative biomass of indicator groups, biomass ratios, size spectra and condition or size at maturity) are preferred
  - — catch and model based indicators should NOT be used alone (VERY sensitive to data quality)

Ecological indicators in EBFM

- Within EBFM indicators will be used
  - for performance reporting vs management objectives
  - in feedback decision rules (tactical population-level indicators + strategic community-level indicators)
  - reference-level framework needs more attention (reference directions, Link *et al* PCA-like approach, “best practice”)

- EBFM use of indicators (signal detection) benefits from
  - unfished reference areas (provide reference values)
  - fisheries independent data collection (provide broader understanding)
  - easier on shelf/slope than pelagic (require more data, but signal stronger)

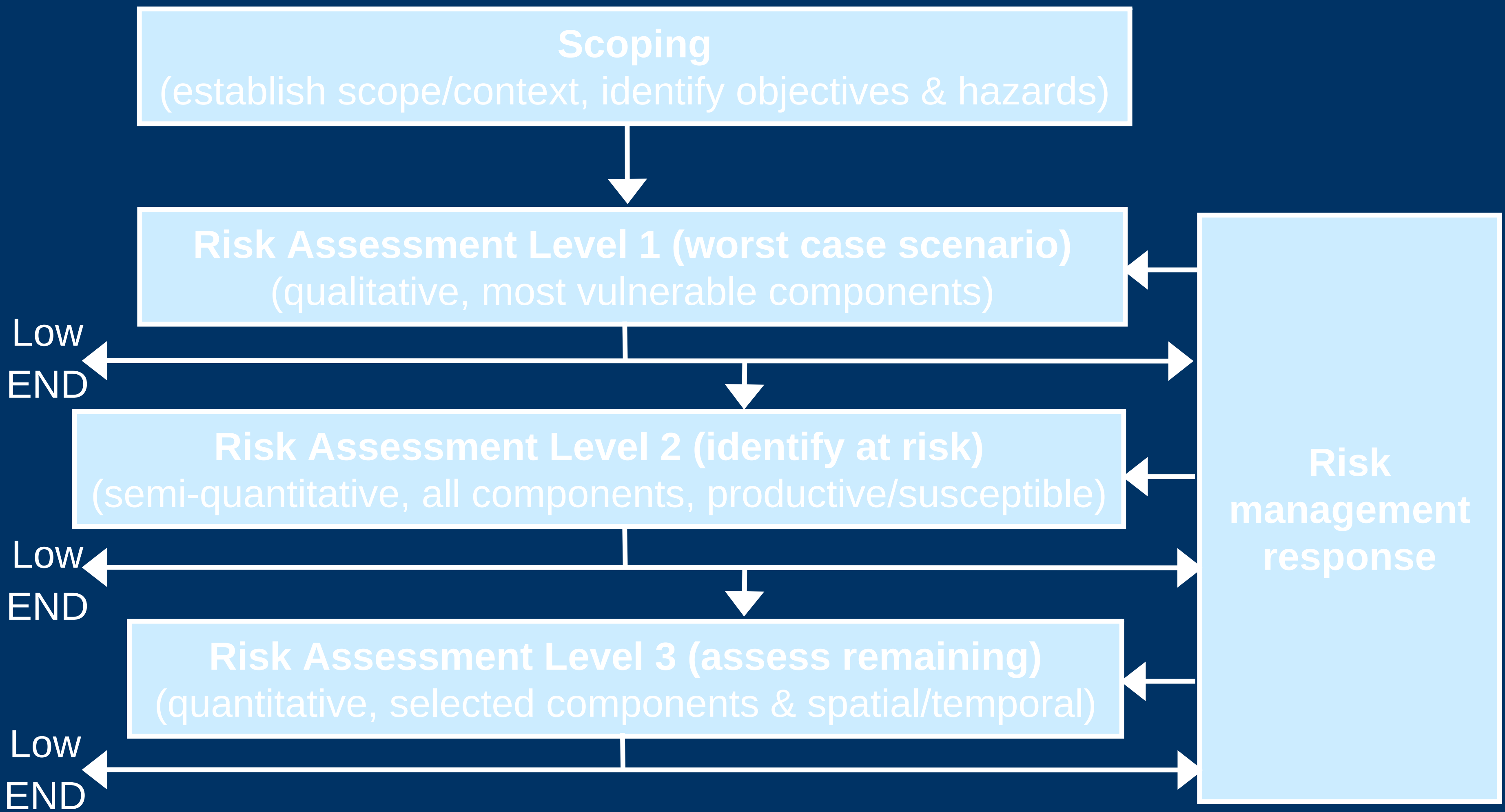
Ongoing work

- Fisheries independent surveys initiated (early days in Australia)
- MSE studies (qualitative and quantitative phases)
  - 10+ ecosystem-level MSE underway in Australia
  - multi-sector not just fisheries (also social & economic objectives not just ecological)
- New tools under development
  - tiered harvest strategies (still primarily single species)
  - Ecological Risk Assessment

Ecological Risk Assessment

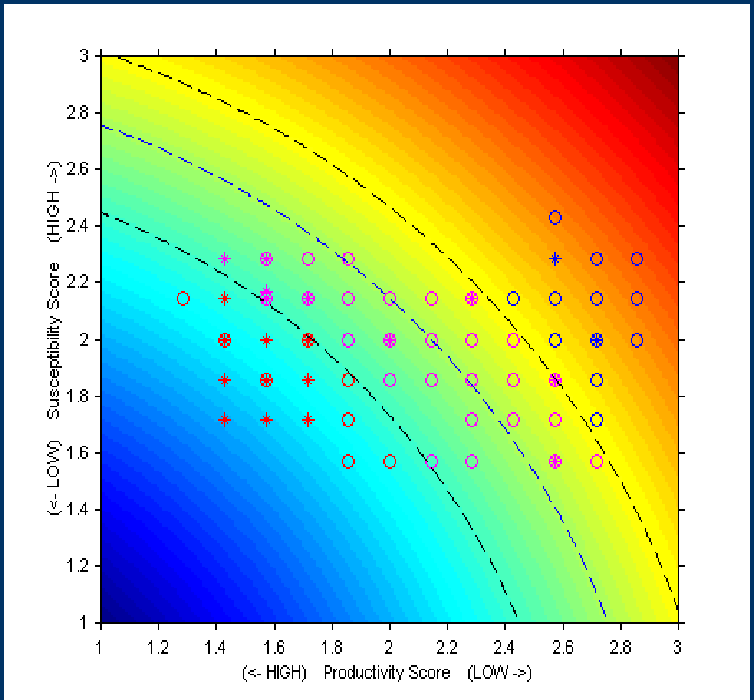
- Hobday *et al* (2004)
  - — use existing data (& expert knowledge) to identify main hazards target, by-product, bycatch, PET species, habitats, communities
  - — consider probability property of the system changes beyond acceptable limits
  - — precautionary in absence of data (can be big penalty, so provide direction on future research)
  - — hierarchical (3 levels, qualitative – quantitative) and document screening decisions at each level
  - — each level includes uncertainty analysis & screens out low consequence activities / low risk components

Ecological Risk Assessment



Ecological Risk Assessment

- End results
  - — identify research gaps and major threats (allows consideration across fisheries & under different management schemes)
  - — susceptibility plots under alternative management strategies



Final Word

- Tactical management at ecosystem level unlikely (due to time lags)
  - haven't abandoned single species assessments
- Use indicators to put tactical management in context (check for wider unanticipated effects)
- Simple, high-level indicators are the most useful
- New (potentially less quantitative) tools under development
  - interestingly in Australia interest in ecosystem-level concerns have lead to consideration of less quantitative methods