Methods for assessing species sensitivity or vulnerability to climate change

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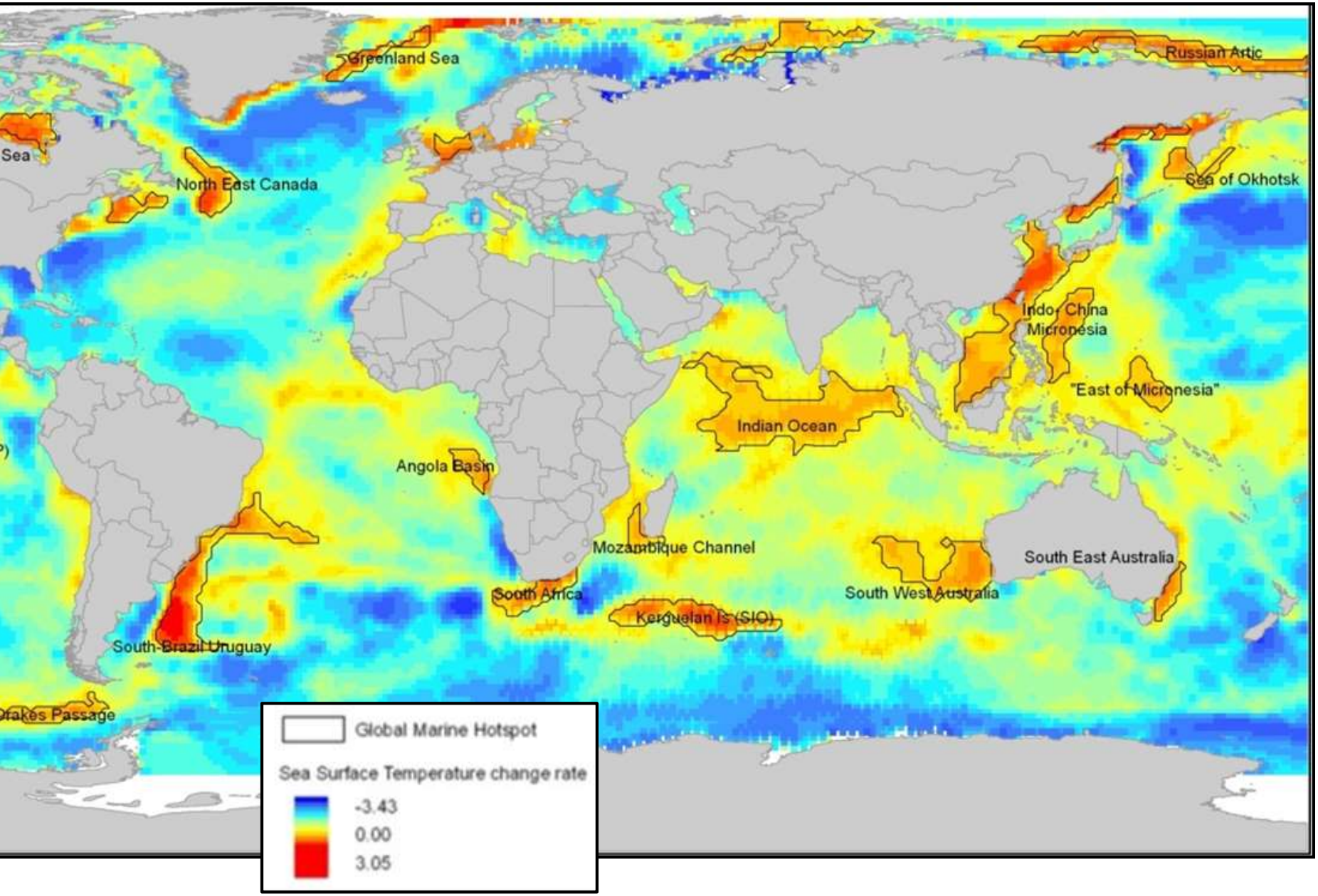


Hobday & Pecl 2014, 50 year time series of SST, change rate per century

Marine climate change in Madagascar

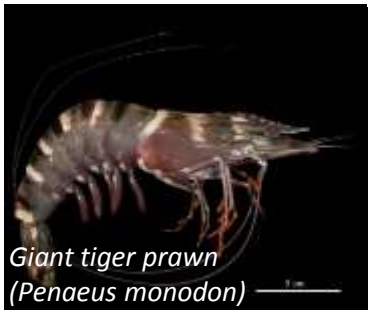
Previous reports have done an excellent job of examining vulnerability of :

- Habitats
- Regions
- Fisheries

Identified gaps/priorities:

- Effects of climate change on main target species
- Sustainable fishing levels for targeted resources
- Projected climate change impacts on important species


Stichopodidae
(Stichopus herrmanni)


Giant tiger prawn
(Penaeus monodon)


Candelamoa parrotfish
(Hipposcarus harid)


Blacktail reef shark
(Carcharhinus amblyrhynchos)


Tiger shark
(Galeocerdo

* Many species fished in Madagascar

* Impractical to address gaps with all of these

* Would it be a useful compliment to existing BV/WWF reports to identify most sensitive species?


Pink ear emp
(Lethrinus le


Sculptured mitten lobster
(Parribacus antarticus)

Leatherback turtle
(Dermochelys coriacea)


Ornate spiny lobster
(Panulirus ornatus)


Indo-Pacific swamp crab
(Scylla serrata)

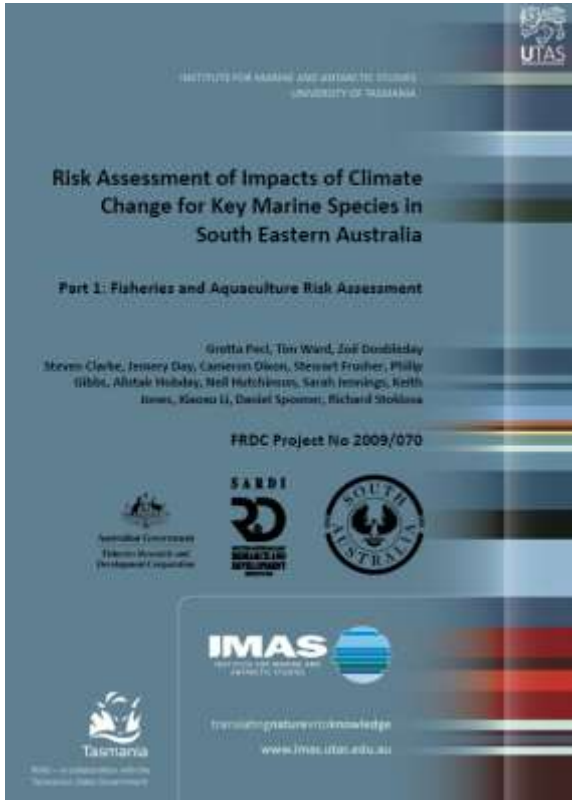
Species Sensitivity Assessment

- Purpose
  - Regions with greatest concentration of sensitive species
  - Most sensitive species within a particular region
  - Priorities for ….monitoring, management action, further assessment etc

- Approach
  - Correlative
    - projecting future distributions based on niche models etc
  - Mechanistic
    - laboratory and field observations, detailed & data intensive models
  - Trait-based
    - use biological characteristics as predictors of risk

- Diversity:
  - Data requirements
  - Spatial and temporal scales of application
  - Modelling methods
  - Uncertainty/limitations

Trait-based approach for assessing relative species sensitivity within regions

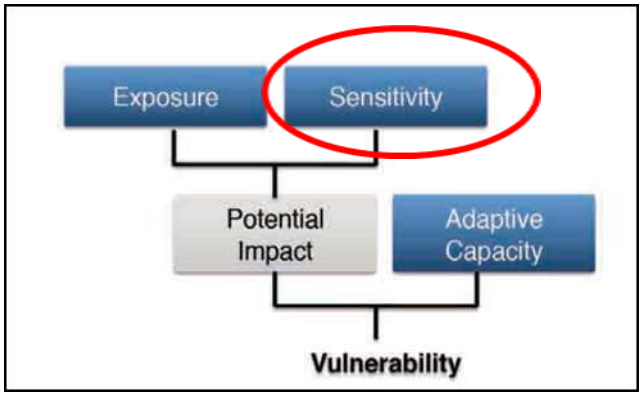


- Conducted for South East Australia, but repeated in northern Australia and West Australia (total of approx 120 species)
- Built on Ecological Risk Assessment for fisheries approach
- Adapted and applied by NOAA and Canada
- Adapted/adopted in Brazil, India and South Africa

Available as Pecl et al 2014
(Aquaculture section – Doubleday et al 2013)

Trait-based approach for assessing species sensitivity

- Estimate sensitivity of species to climate change drivers based on:
  - ABUNDANCE - measures of potential for biological productivity
    - Egg production?
    - Age at maturity?
  - DISTRIBUTION – measures of capacity to shift
    - Capacity for larval dispersal?
    - Thermal tolerance?
  - PHENOLOGY – measures of potential impact on timing of life cycle events
    - Temperature as a cue for spawning or moulting?



In context of ecological vulnerability only

Estimate sensitivity of species to climate drivers based on ABUNDANCE, DISTRIBUTION and PHENOLOGY

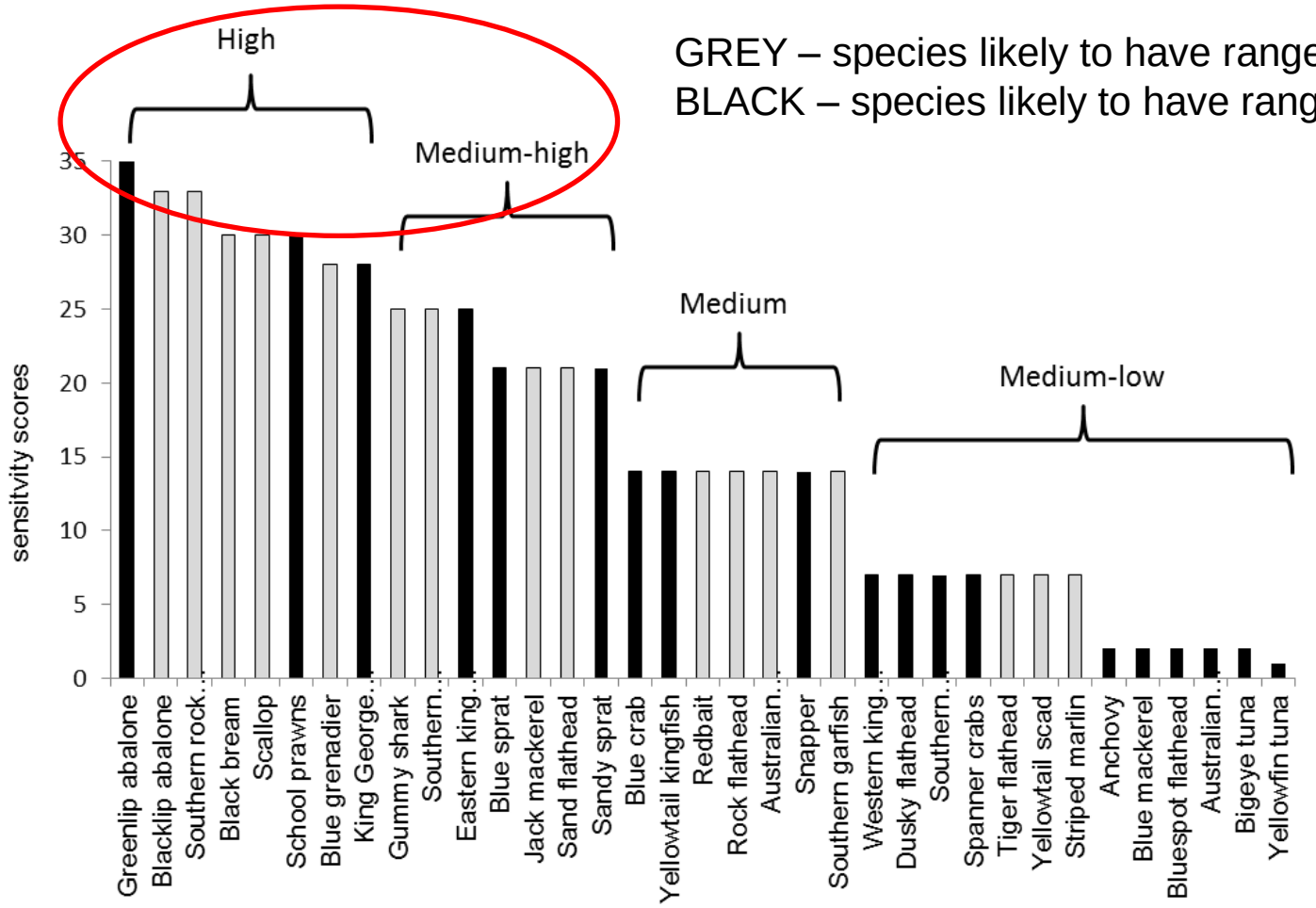
e.g. Distribution attribute – southern rock lobster

Sensitivity attribute		Risk category (sensitivity and capacity to respond to change)		
		High sensitivity (3), low capacity to respond (higher risk)	**Medium (2)**	**Low sensitivity (1), high capacity to respond (lower risk)**
Distribution	Capacity for larval dispersal or larval duration – hatching to settlement (benthic species), hatching to yolk sac re-adsorption (pelagic species).	<2 weeks or no larval stage	2–8 weeks	>2 months ★
	Capacity for adult/juvenile movement – lifetime range post-larval stage.	<10 km ★	10–1000 km	>1000 km
	Physiological tolerance – latitudinal coverage of adult species as a proxy of environmental tolerance.	<10° latitude ★	10–20° latitude	>20° latitude
	Spatial availability of unoccupied habitat for most critical life stage – ability to shift distributional range.	No unoccupied habitat; 0 – 2° latitude or longitude ★	Limited unoccupied habitat; 2–6° latitude or longitude	Substantial unoccupied habitat; >6° latitude or longitude

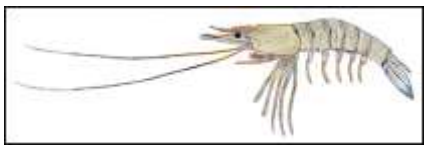
Average score 2.5 (scores for each attribute added and totals ranked)

Sensitivity attribute		Risk category (sensitivity and capacity to respond to change)		
		High sensitivity (3), low capacity to respond (higher risk)	**Medium (2)**	**Low sensitivity (1), high capacity to respond (lower risk)**
Abundance	Fecundity – egg production	<100 eggs per year	100–20,000 eggs per year	>20,000 eggs per year
	Recruitment period – successful recruitment event that sustains the abundance of the fishery.	Highly episodic recruitment event	Occasional and variable recruitment period	Consistent recruitment events every 1–2 years
	Average age at maturity	>10 years	2–10 years	≤2 years
	Generalist vs. specialist – food and habitat	Reliance on both habitat and prey	Reliance on either habitat or prey	Reliance on neither habitat or prey

Relative sensitivity rankings – South East Australia



GREY – species likely to have range contraction
BLACK – species likely to have range extension

Weaknesses?

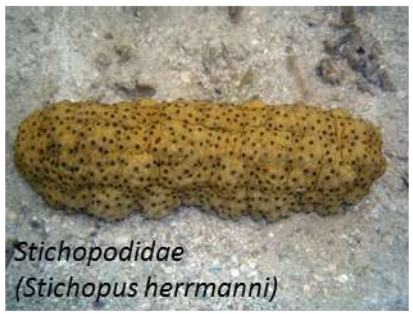
- Precise sensitivity thresholds with each trait unknown
- Traits are weighted equally
- Choice of traits
- Needs expert review!
- Not made with all potential species in mind (eg turtles)

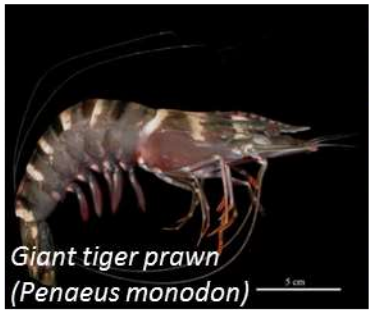
Strengths?

- Transparent
- Repeatable
- Can work with data poor and expert opinion
- Rapid assessment
- Prioritise

Questions for us

- Is a species sensitivity assessment a useful compliment for Madagascar?
- If so, how would we adapt the approach to best fit?
- Started a sensitivity assessment for Madagascar – Hajanirina Razafindrainibe and Nicola Breedt worked with local/regional experts putting a list together





Improvements/adaptations on Australian method

PLOS ONE

RESEARCH ARTICLE

A Vulnerability Assessment of Fish and Invertebrates to Climate Change on the Northeast U.S. Continental Shelf

Jonathan A. Hare[1]*, Wendy E. Morrison[2], Mark W. Nelson[3], Megan M. Stachura[3¤a], Eric J. Teeters[2], Roger B. Griffis[4], Michael A. Alexander[5], James D. Scott[6], Larry Alade[6], Richard J. Bell[1¤b], Antonie S. Chute[6], Kiersten L. Curti[6], Tobey H. Curtis[7], Daniel Kircheis[8], John F. Kocik[8], Sean M. Lucey[9], Camilla T. McCandless[1], Lisa M. Milke[8], David E. Richardson[1], Eric Robillard[6], Harvey J. Walsh[1], M. Conor McManus[10¤c], Katrin E. Marancik[10], Carolyn A. Griswold[1]

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OPEN ACCESS

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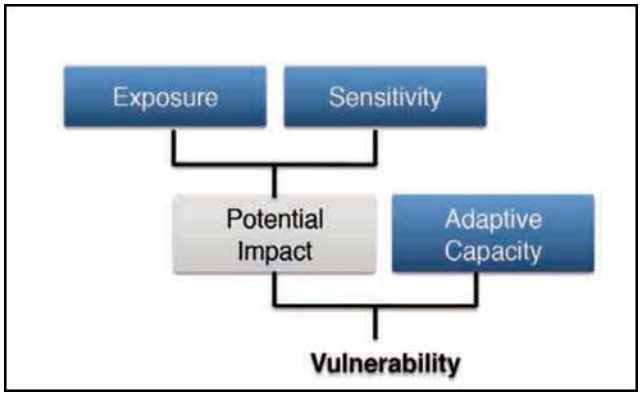


Looked at EXPOSURE and SENSITIVITY

Table 3. Logic rules for determining each species' sensitivity and exposure component scores.

Component Score	Scoring Criteria
Very High	3 or more mean attribute or factor scores ≥ 3.5
High	2 or more mean attribute or factor scores ≥ 3.0
Moderate	2 or more mean attribute or factor scores ≥ 2.5
Low	Less than 2 or more mean attribute or factor scores ≥ 2.5

- Rather than averaging fields within 'distribution', abundance' and 'phenology' - use 'logistic' model
- Incorporate 'exposure' elements as well as 'sensitivity'

SENSITIVITY	Low	Moderate	High	Very High
Very High	***Moderate***	***High***	***Very High***	***Very High***
High	***Low***	***Moderate***	***High***	***Very High***
Moderate	***Low***	***Moderate***	***Moderate***	***High***
Low	***Low***	***Low***	***Low***	***Moderate***

EXPOSURE

Matrix for combining 'exposure' and 'sensitivity' and arriving at final species designation

Data quality score?

Data Quality Score	Description
3	**Adequate Data.** The score is based on data which have been observed, modeled or empirically measured for the species in question and comes from a reputable source.
2	**Limited Data.** The score is based on data which has a higher degree of uncertainty. The data used to score the attribute may be based on related or similar species, come from outside the study area, or the reliability of the source may be limited.
1	**Expert Judgment.** The attribute score reflects the expert judgment of the reviewer and is based on their general knowledge of the species, or other related species, and their relative role in the ecosystem.
0	**No Data.** No information to base an attribute score on. Very little is known about the species or related species and there is no basis for forming an expert opinion.

Other Potential Improvements

- Incorporating uncertainty
  - Scored by multiple experts
  - Experts use ‘tallies’ per attribute
- Consider level of other stressors
- Check for general agreement b/w rapid approach and modelling outcomes

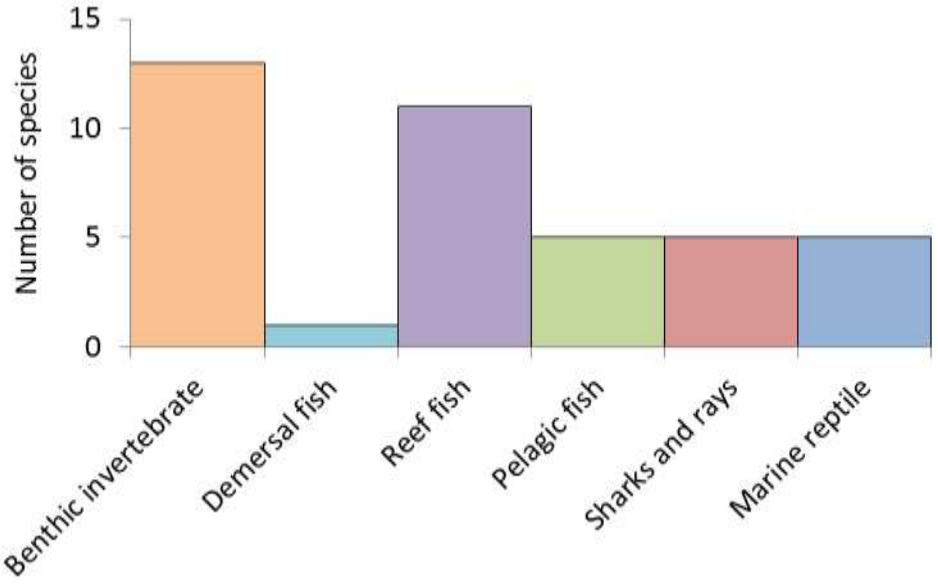

Mangrove red snapper
(Lutjanus argentimaculatus)


Pink ear emperor fish
(Lethrinus lentjan)


Yellowfin tuna
(Thunnus albacares)

Madagascan species sensitivity assessment

- List compiled by Nicola, Charlie, Haja, Melita, Warwick in consultation with local/regional experts
- Species selected – commercial, subsistence, small-scale, or recreational importance
- 40 species on final list
- 36 species enough data to progress (≥2 fields per category)
- Scored by 9 people literature searching **NOT regional experts**
    - Data quality – first tried data 1/ local species-specific, 2/ species elsewhere, 3/ similar species
- 13 attributes – several 100 references

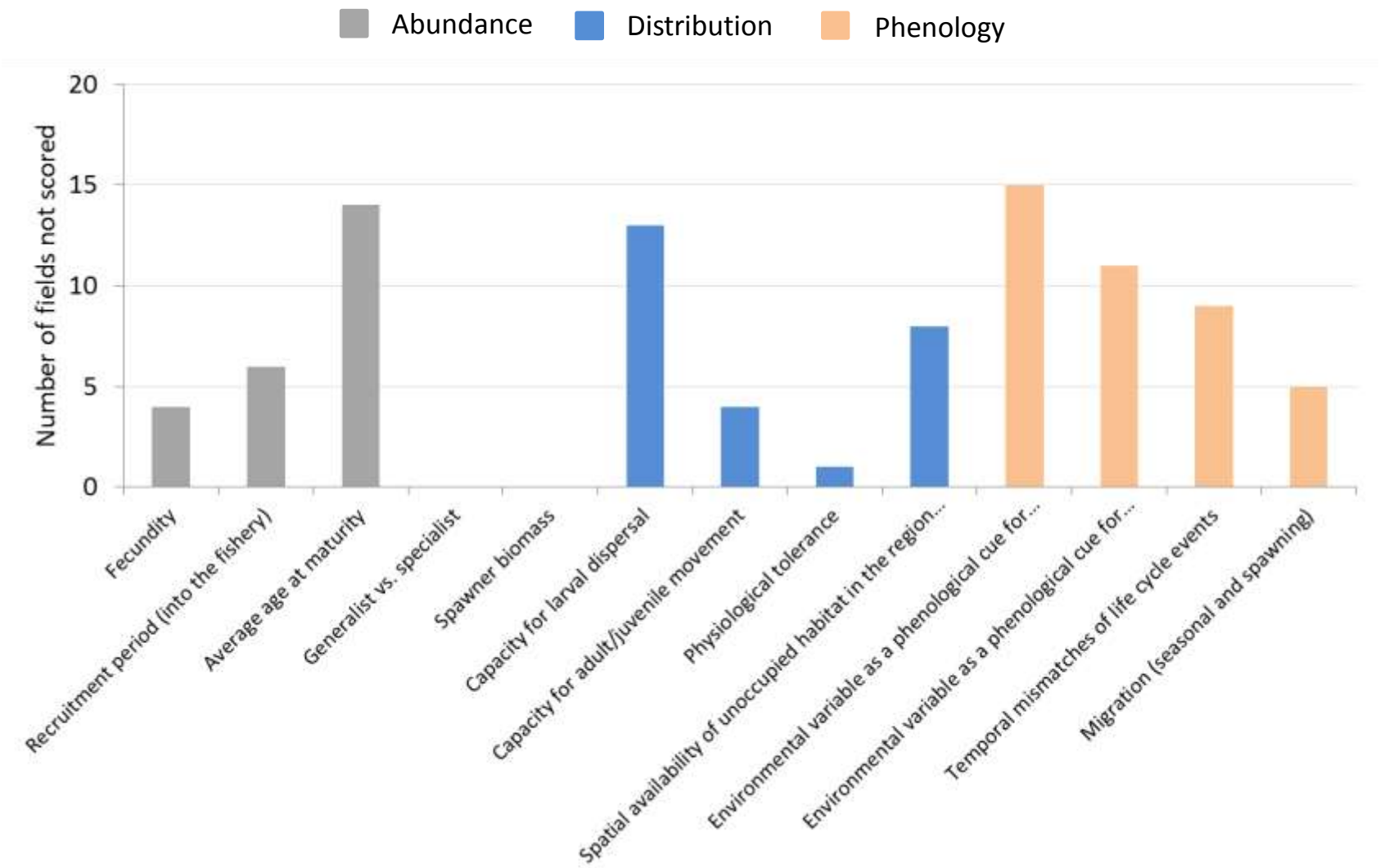


Attribute		Category		
		Low sensitivity (1), high capacity to respond (lower risk)	**Medium (2)**	**High sensitivity (3), low capacity to respond (higher risk)**
Abundance	Fecundity – egg production	>20,000 eggs per year	100–20,000 eggs per year	<100 eggs per year
	Recruitment period – successful recruitment event that sustains the abundance of the fishery.	Consistent recruitment events every 1–2 years	Occasional and variable recruitment period	Highly episodic recruitment event
	Average age at maturity	≤2 years	2–10 years	>10 years
	Spawner biomass	robust	uncertain/vulnerable	threatened
	Generalist vs. specialist – food and habitat	Reliance on neither habitat or prey	Reliance on either habitat or prey	Reliance on both habitat and prey
Distribution	Capacity for larval dispersal or larval duration – hatching to settlement (benthic species), hatching to yolk sac re-adsorption (pelagic species).	>2 months	2–8 weeks	<2 weeks or no larval stage
	Capacity for adult/juvenile movement – lifetime range post-larval stage.	>1000 km	10–1000 km	<10 km
	Physiological tolerance – latitudinal coverage of adult species as a proxy of environmental tolerance.	>20º latitude	10–20º latitude	<10º latitude
	Spatial availability of unoccupied habitat for most critical life stage – ability to shift distributional range.	Substantial unoccupied habitat; >6º latitude or longitude	Limited unoccupied habitat; 2–6º latitude or longitude	No unoccupied habitat; 0 – 2º latitude or longitude
Phenology	Environmental variable as a phenological cue for spawning or breeding – cues include salinity, temperature, currents, & freshwater flows.	No apparent correlation of spawning to environmental variable	Weak correlation of spawning to environmental variable	Strong correlation of spawning to environmental variable
	Environmental variable as a phenological cue for settlement or metamorphosis	No apparent correlation to environmental variable	Weak correlation to environmental variable	Strong correlation to environmental variable
	Temporal mismatches of life-cycle events – duration of spawning, breeding or moulting season.	Continuous duration; >4 months	Wide duration; 2–4 months	Brief duration; <2 months
	Migration (seasonal and spawning)	No migration	Migration is common for some of the population	Migration is common for the whole population

Madagascar

- Spawner biomass field added
- Obtained largely from IUCN list

Data obtained/missing



Results of sensitivity assessment

Figure removed as draft only - needs checking

Species list being revised with help from Luc Randriamarolaza

Concerns

General:

- Precise vulnerability thresholds with each trait unknown
- Traits are weighted equally
- Choice of traits
- Needs expert review!

Specific to Madagascar:

- Attribute suitability?
  - 'Consistent recruitment to the fishery' = 1 except tiger sharks=2
  - 'spawner biomass' –resorted to IUCN list BUT really needs to be assessed in region in question and at regional scale
- Not designed with species like turtles in mind

Range shift specific assessment?

- 27 species with room to shift south (based on Fishbase maps)

- From Sunday et al 2015 study we know that species with certain traits more likely to shift:
    - High adult mobility (benthic or swimming)
    - Generalist diet & lower trophic level – greater rate extension
    - Greater initial latitudinal range size- greater extension rates


Sculptured mitten lobster (Parribacus antarticus)

Leatherback turtle (Dermochelys coriacea)


Ornate spiny lobster (Panulirus ornatus)


Indo-Pacific swamp crab (Scylla serrata)

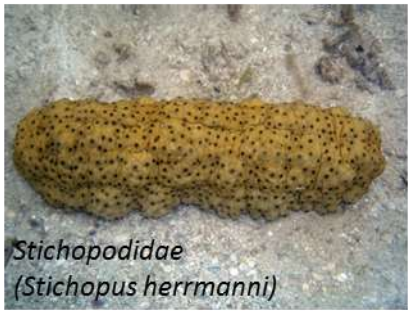
Back to the questions for us

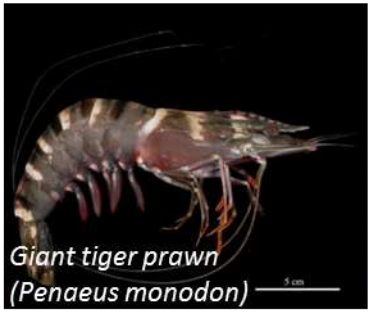
- Is a species sensitivity assessment a useful compliment for Madagascar?

  and/or

- BV/WWF assessment – climate modelling useful for ‘Exposure’?

- If so, how would we adapt the approaches to best fit?





Thanks






Fewer marine vulnerability assessments

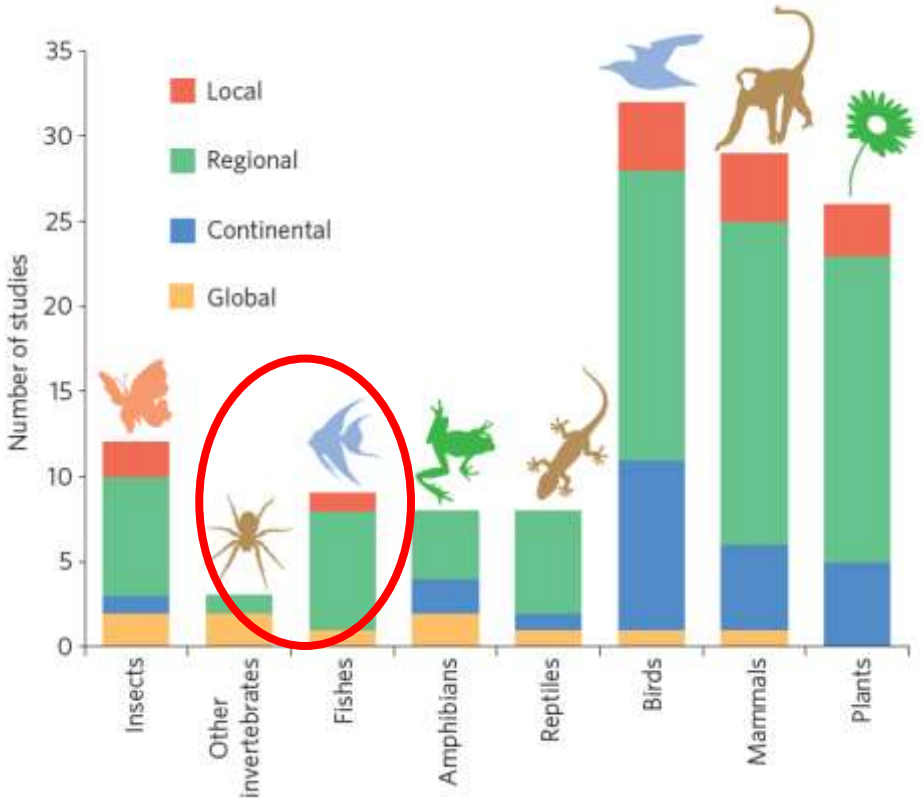
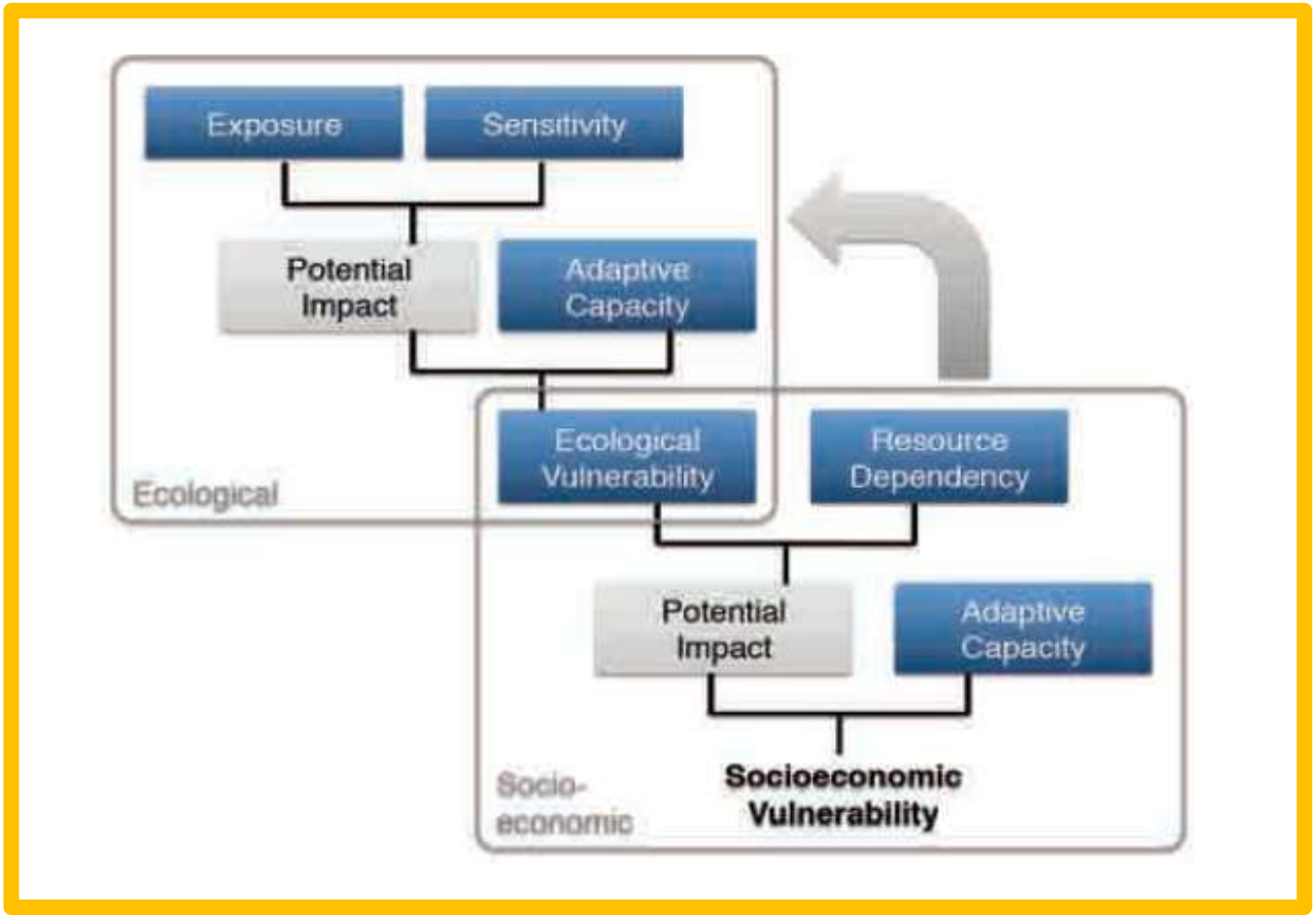


Figure 1 | Taxonomic focus of vulnerability assessments in the analysed papers. Birds are the most analysed taxon, followed by mammals and plants, while invertebrates other than insects have seldom been assessed. Colours represent the spatial scale of the assessments. Regional scale is defined as describing the range of 10^4–10^7 km^2, while scales smaller than 10^4 km^2 are referred to as local scales. (from Pacifici et al 2015)



Vulnerability Assessment model