

Assessing the Vulnerability of Marine Fish and Invertebrates to Climate Change

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William Cheung

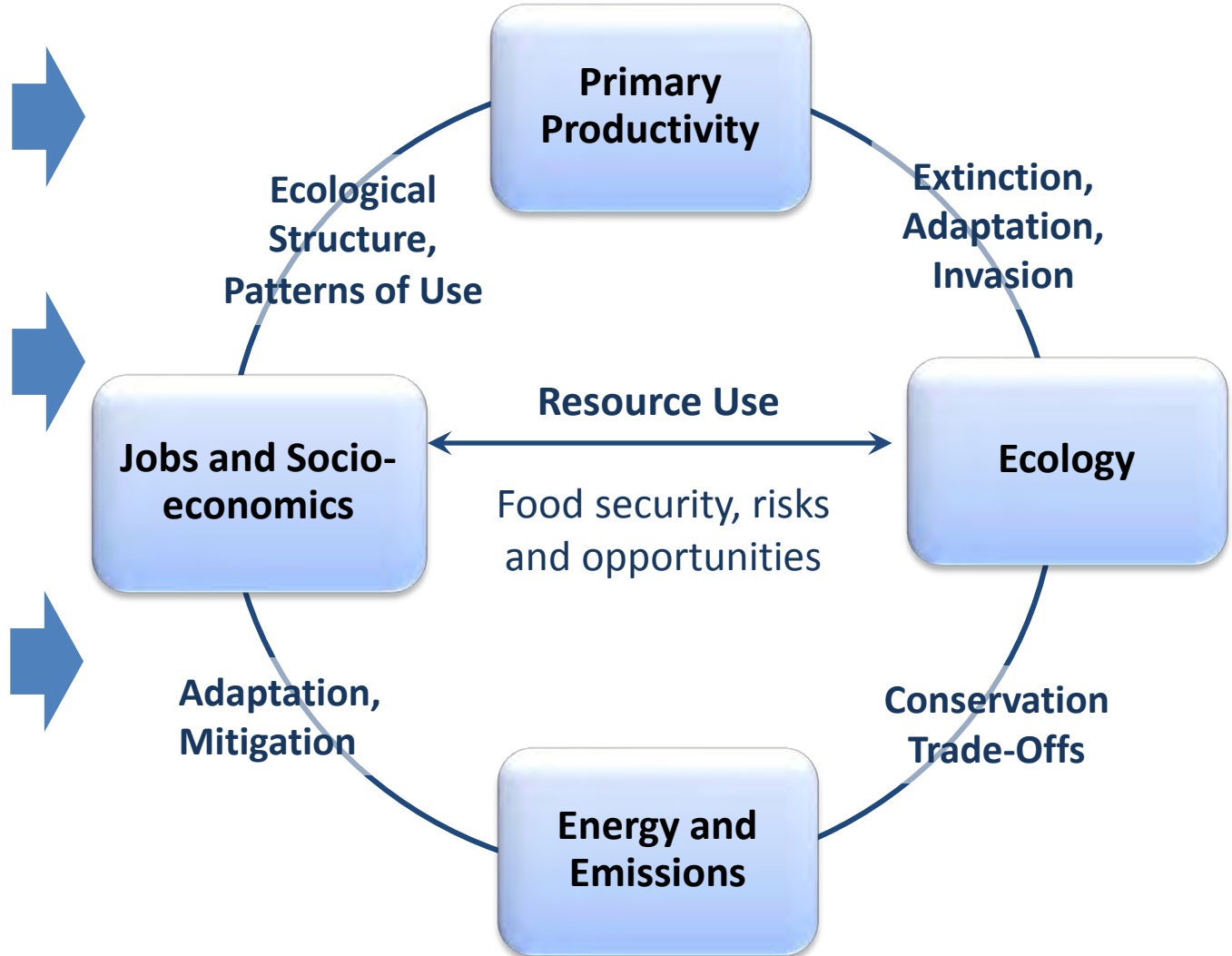
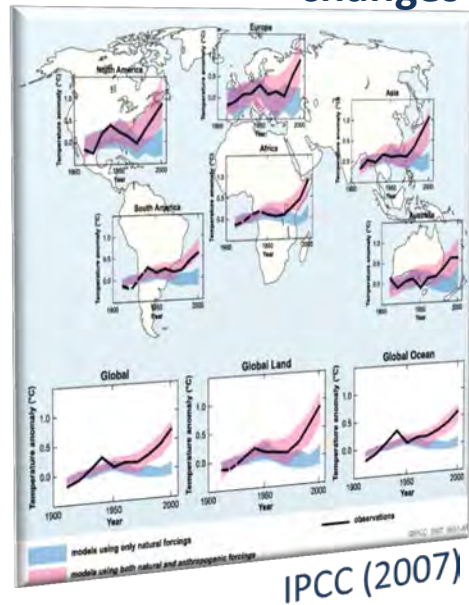
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Santos, 2015

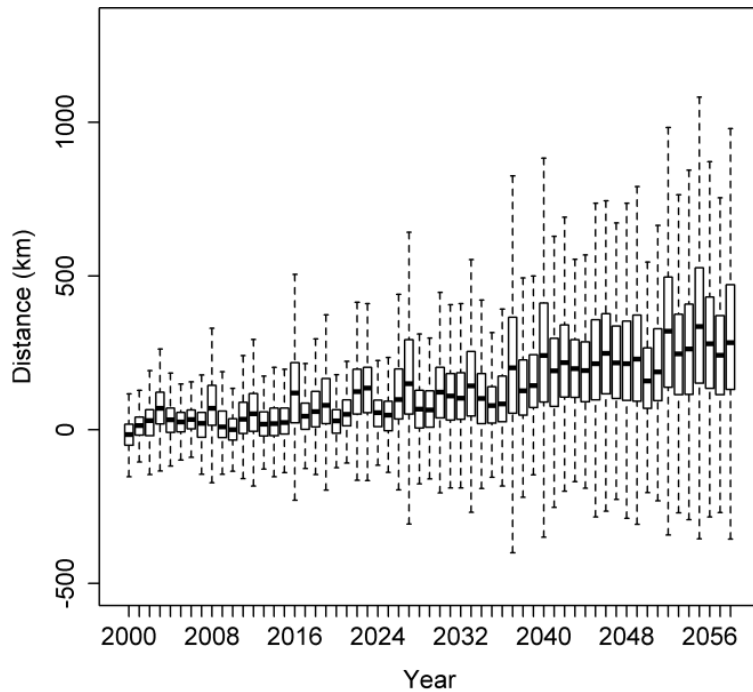
Effects of Climate Change on the World's Oceans

Changing Ocean Conditions

Ocean
Atmosphere
changes

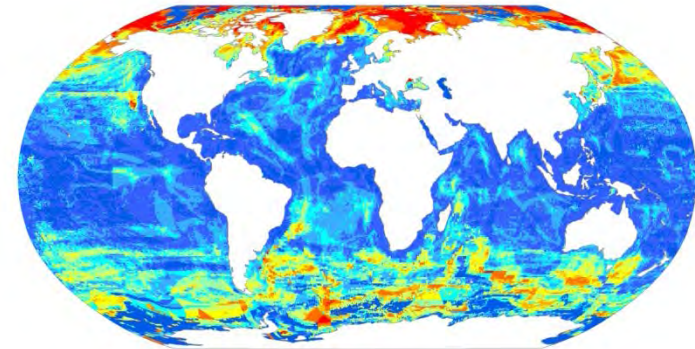


Predicted Distribution Shifts

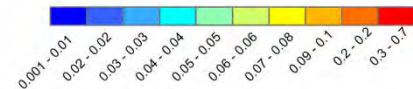
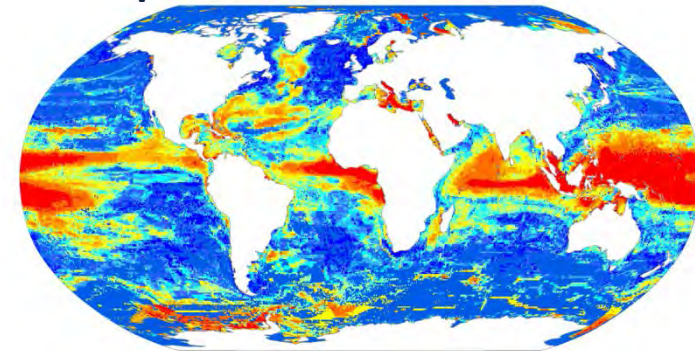


Projected median latitudinal range shifts (km decade⁻¹).

Species invasion

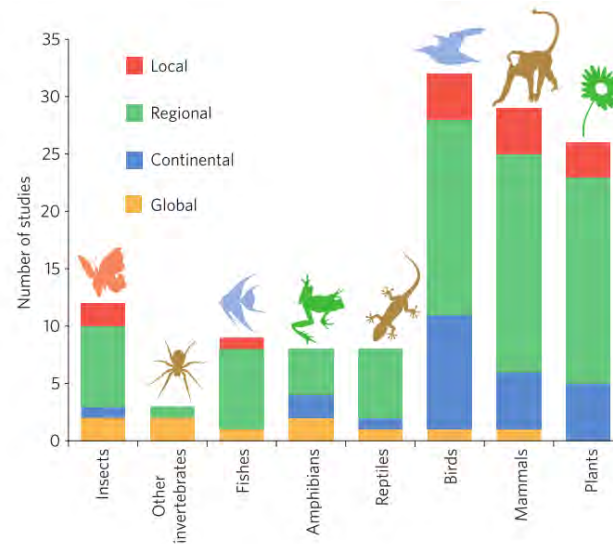


Species local extinction



Hotspots of (a) local invasion and (b) invasion between 2000 and 2050 averaged across AquaMaps, Maxent, and the DBEM under scenario RCP 8.5

Climate Change Vulnerability

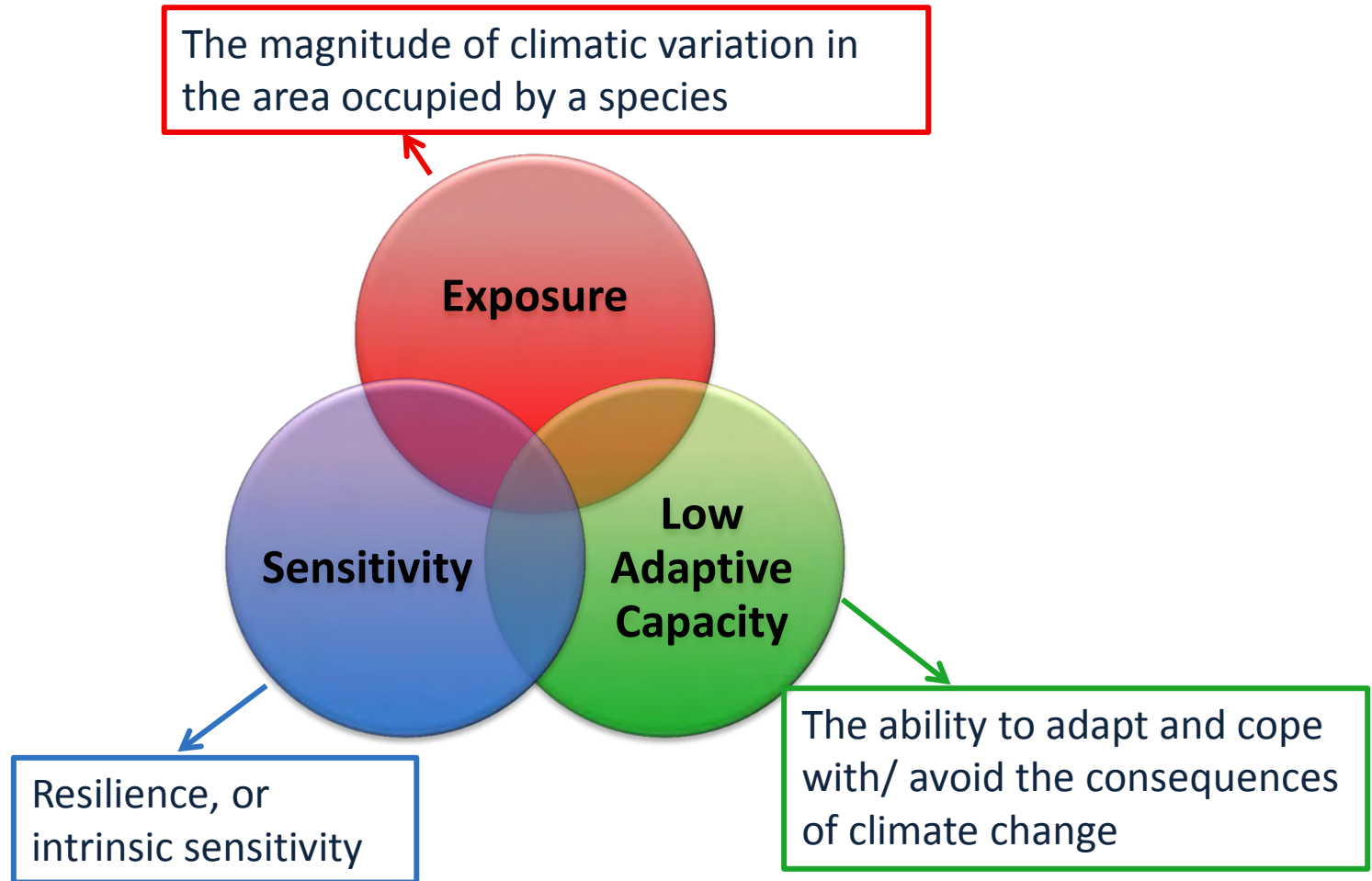


Pacifici *et al.* (2014) *Nature Climate Change*

- Large scale assessment of vulnerability to climate change.
- Combine species distribution modelling with fuzzy logic
- Compare vulnerability to climate change and fisheries

Integrated Climate Change Vulnerability

- 'The predisposition to be adversely affected' (IPCC)

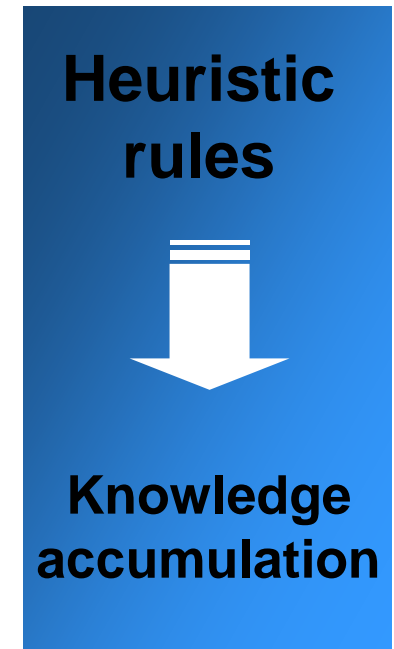
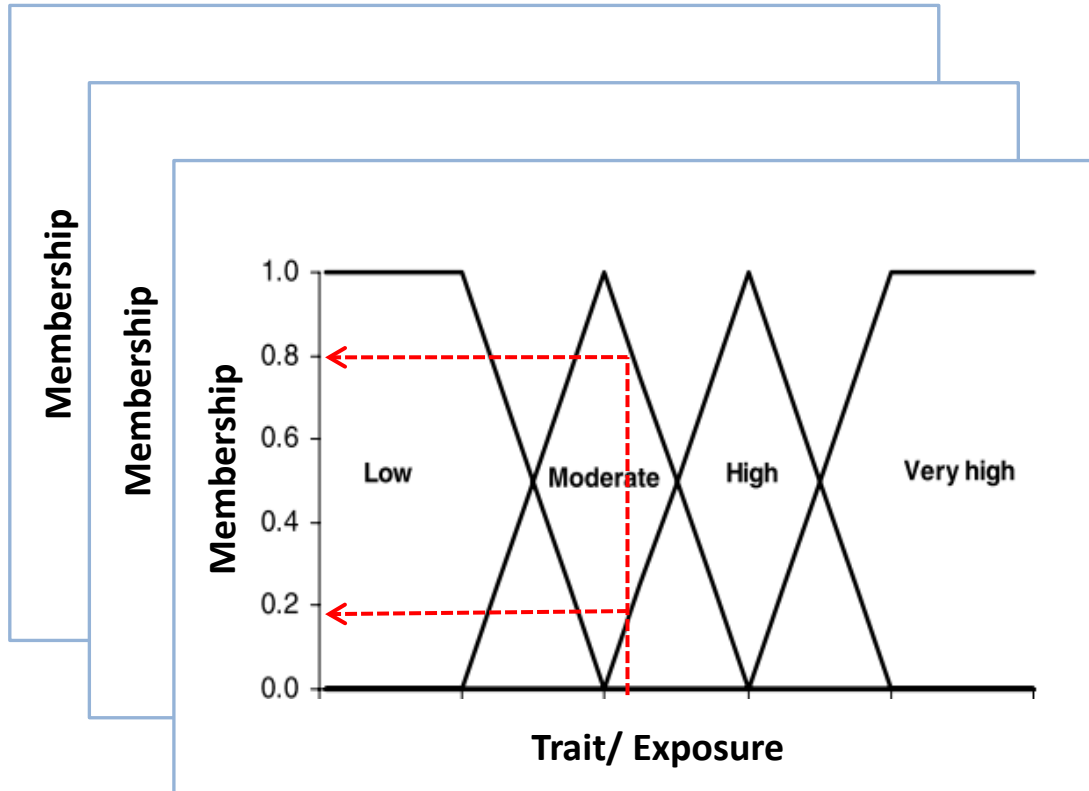


Fuzzy Logic

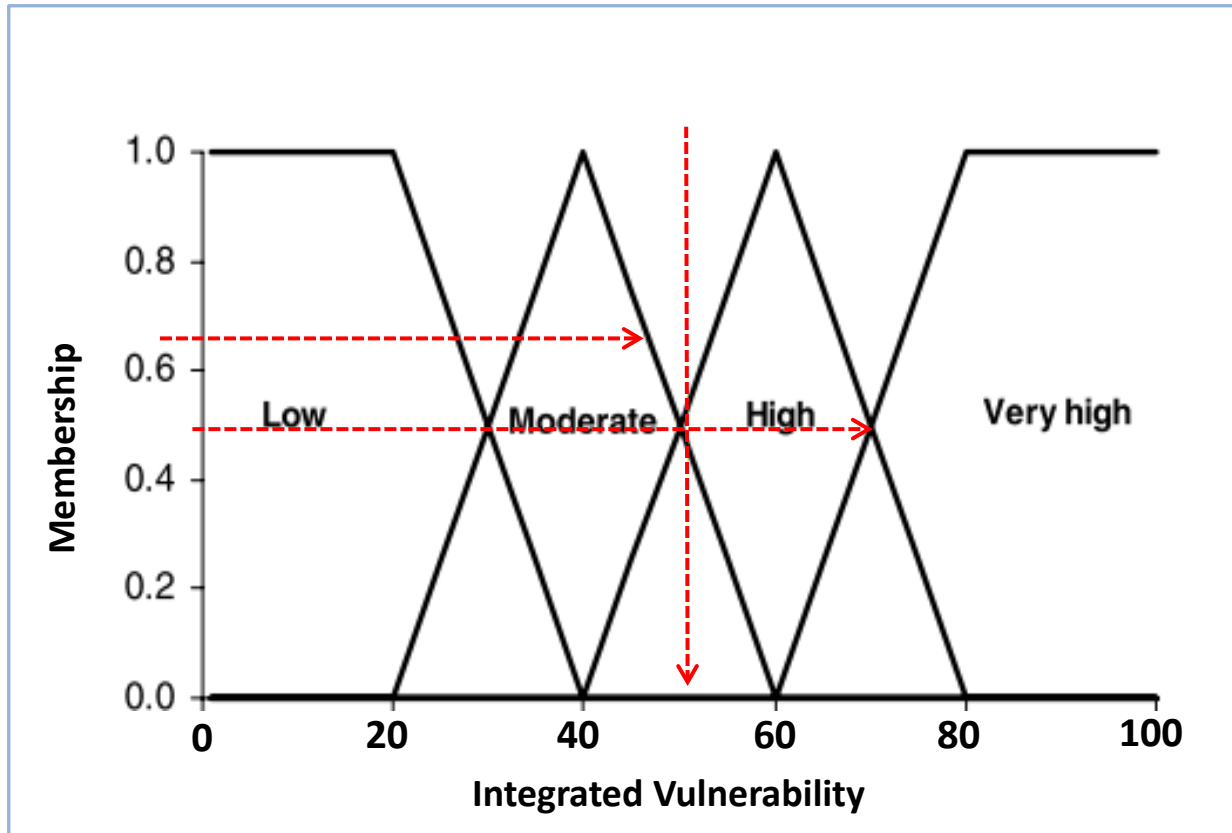
- Heuristic rules defined for input life history and ecological characteristics, and exposure levels.

| Attribute | Rule | Condition (A) | | | Conclusion (B) | |
|-----------|------|---------------|---|------|--------------------------------------|--|
| 1 | 1 | IF | Temperature tolerance is <i>very restricted</i> | THEN | Sensitivity is <i>very high</i> | |
| 1 | 2 | IF | Temperature tolerance is <i>restricted</i> | THEN | Sensitivity is <i>high</i> | |
| 1 | 3 | IF | Temperature tolerance is <i>moderate</i> | THEN | Sensitivity is <i>moderate</i> | |
| 1 | 4 | IF | Temperature tolerance is <i>wide</i> | THEN | Sensitivity is <i>low</i> | |
| 2 | 1 | IF | Fecundity is <i>low</i> | THEN | Adaptive Capacity is <i>very low</i> | |
| 2 | 2 | IF | Fecundity is <i>moderate</i> | THEN | Adaptive Capacity is <i>low</i> | |
| 2 | 3 | IF | Fecundity is <i>high</i> | THEN | Adaptive Capacity is <i>moderate</i> | |
| 2 | 4 | IF | Fecundity is <i>very high</i> | THEN | Adaptive Capacity is <i>high</i> | |

Fuzzy Sets



Integrated Vulnerability Output



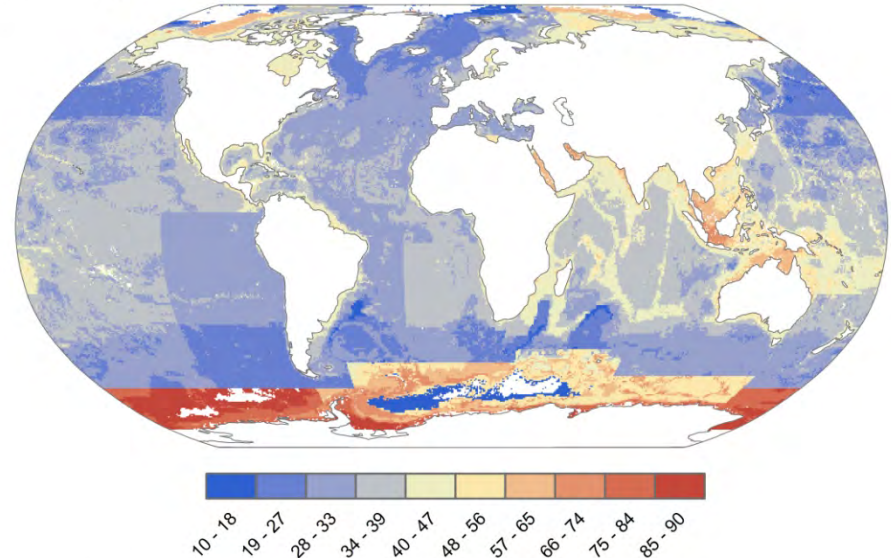
$$\begin{aligned} \text{Integrated vulnerability} &= \text{moderate} - \text{high} \\ &= 47 \end{aligned}$$

Sensitivity and Adaptive Capacity

Sensitivity

- Temperature tolerance
- Habitat association
 - Estuaries
 - Coral
 - Seagrass
 - Seamount

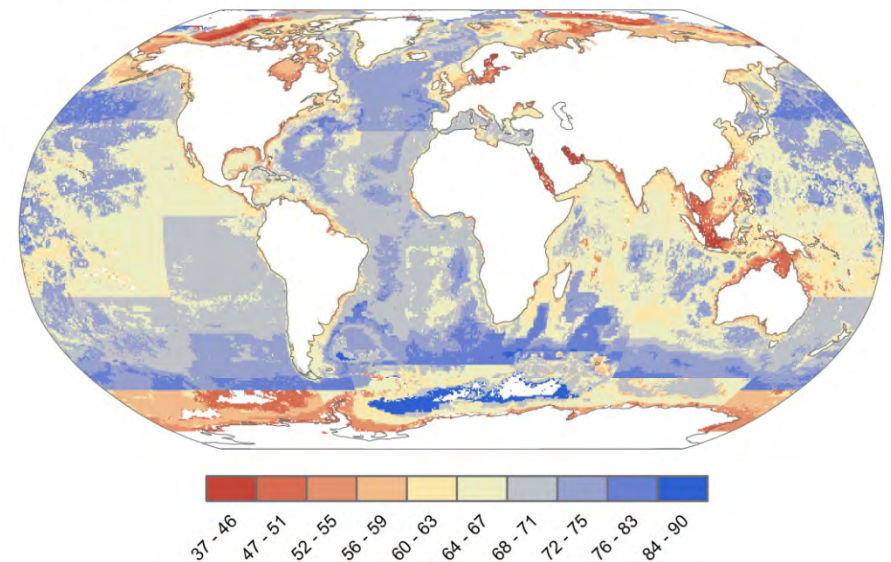
Average Sensitivity Index



Adaptive Capacity

- Latitudinal breadth
- Depth range
- Fecundity

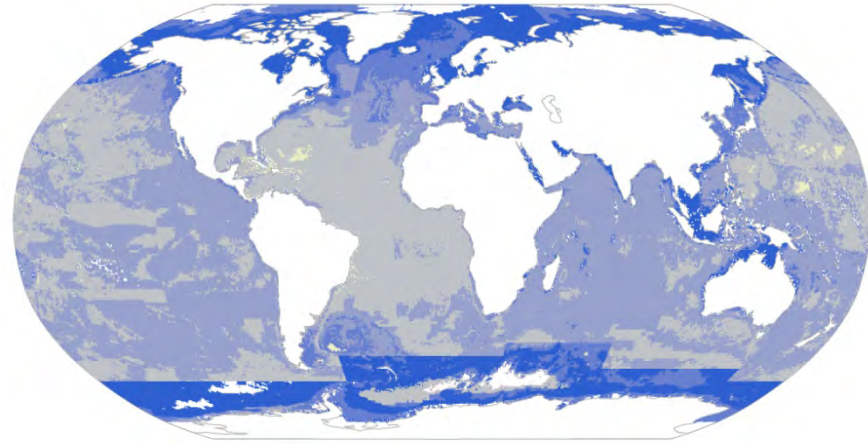
Average Adaptive Capacity Index



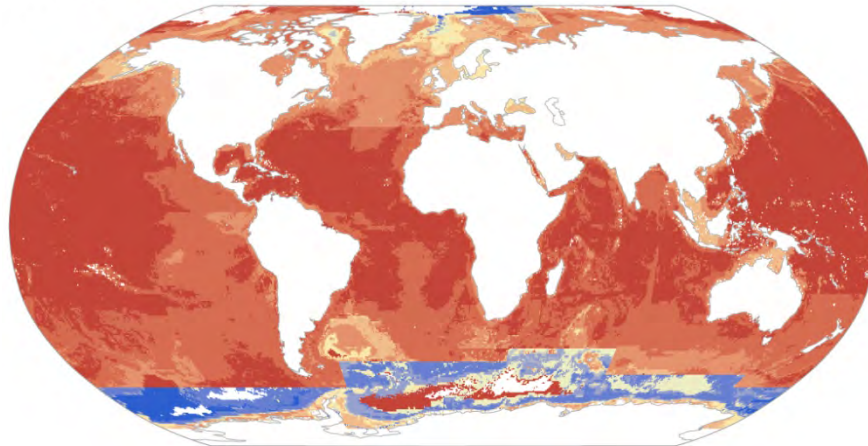
Exposure

- Measure the changes in ocean properties within species' ranges.
- Average species distributions (1991 – 2010)
 - AquaMaps (Kaschner *et al.* 2006; 2008)
 - Maxent (Phillips *et al.* 2004; 2006)
 - Dynamic Bioclimate Envelope Model (DBEM) (Cheung *et al.* 2008; 2011)

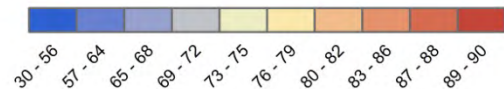
Average Exposure Index, RCP 2.6



Average Exposure Index, RCP 8.5

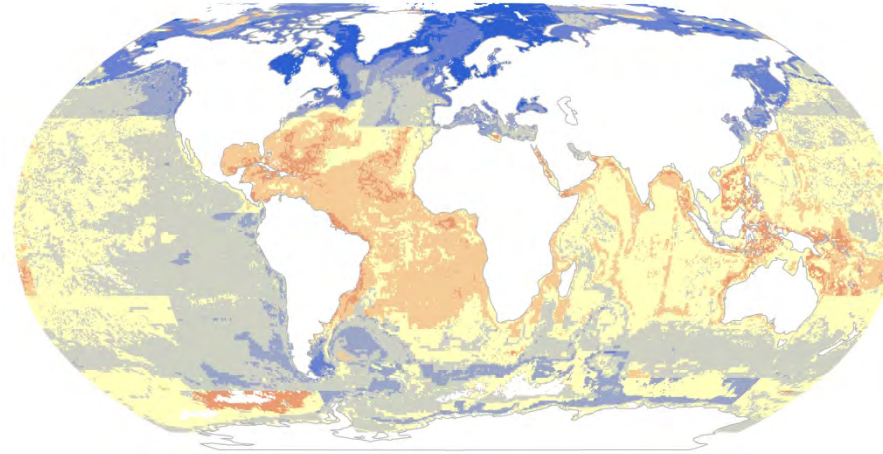


$$Exposure = \frac{\Delta V (2000 - 2050)}{Standard\ Deviation\ V(1951 - 2000)}$$

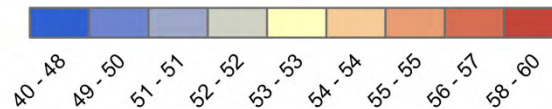
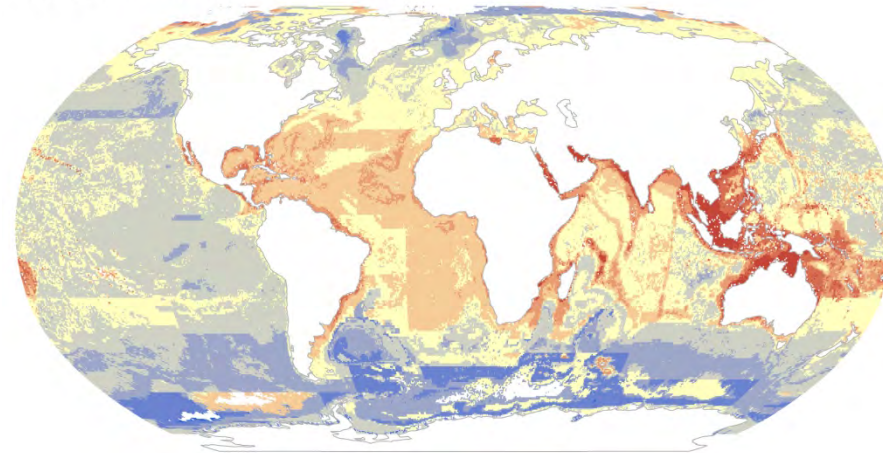


Integrated Vulnerability

Average Vulnerability Index, RCP 2.6



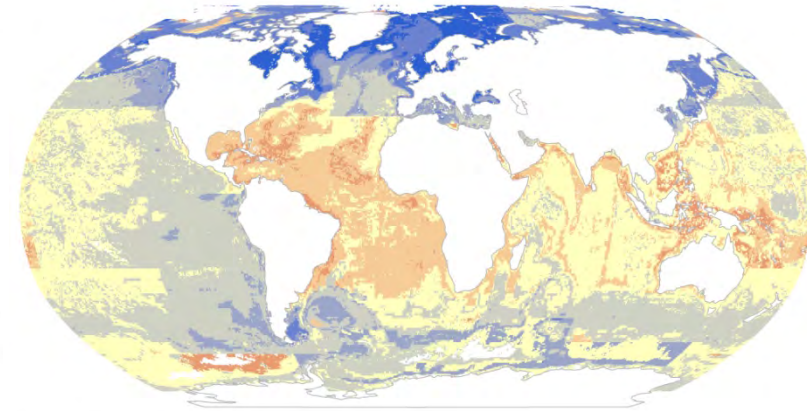
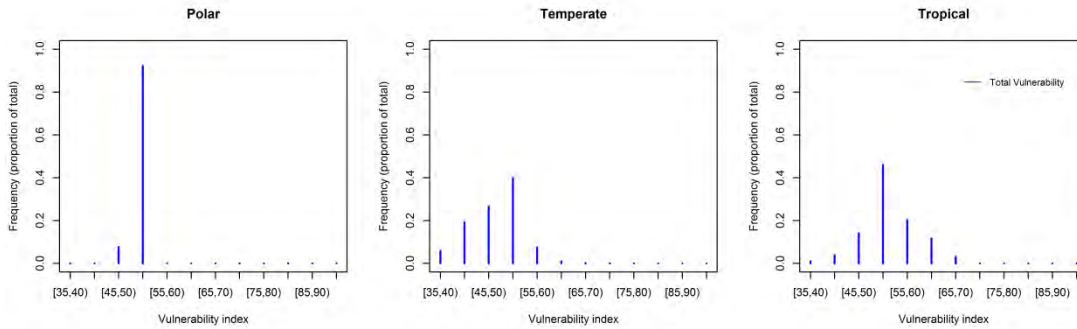
Average Vulnerability Index, RCP 8.5



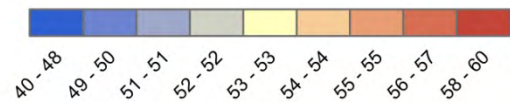
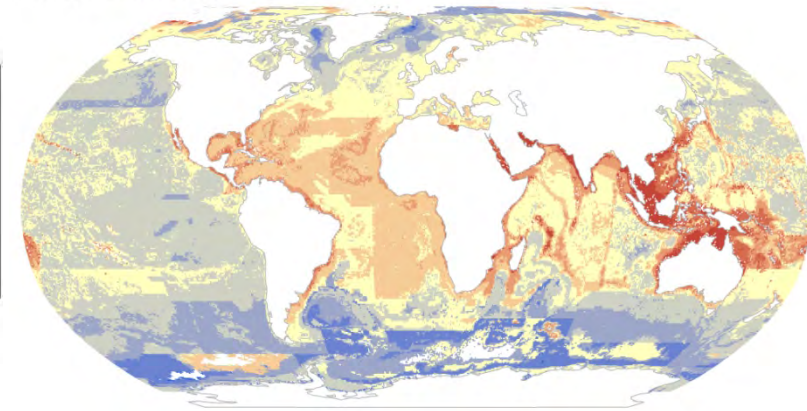
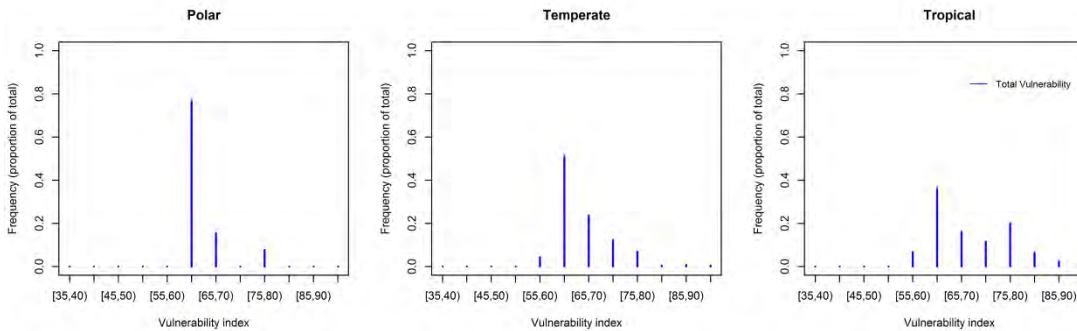
Average vulnerability index, by emissions scenario

Integrated Vulnerability

Average Vulnerability Index, RCP 2.6



Average Vulnerability Index, RCP 8.5



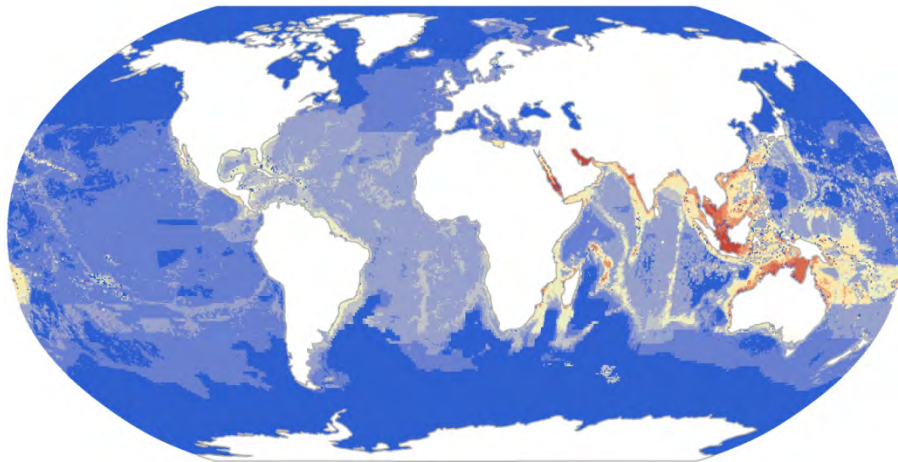
Average vulnerability index, by emissions scenario

Frequency distribution of integrated vulnerability index values, by climatic zone.

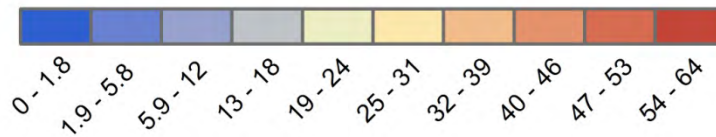
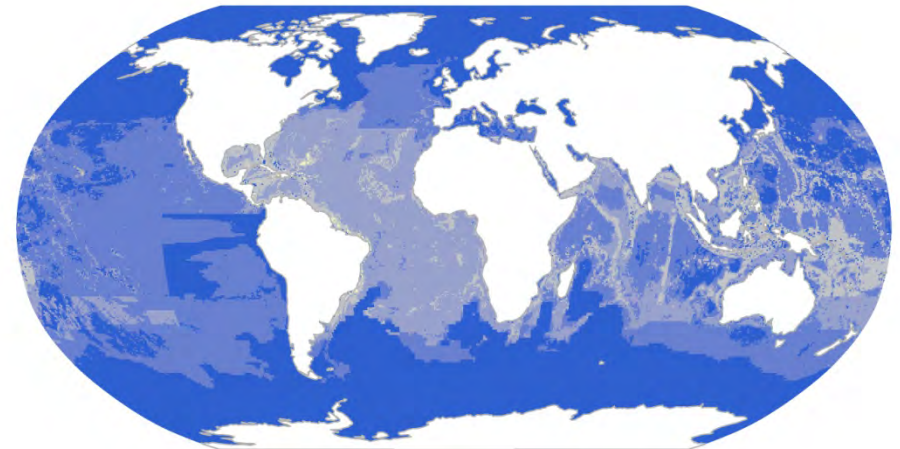
Benefit of Emissions reductions

- Proportion of species with a 'high' integrated vulnerability score

RCP 8.5

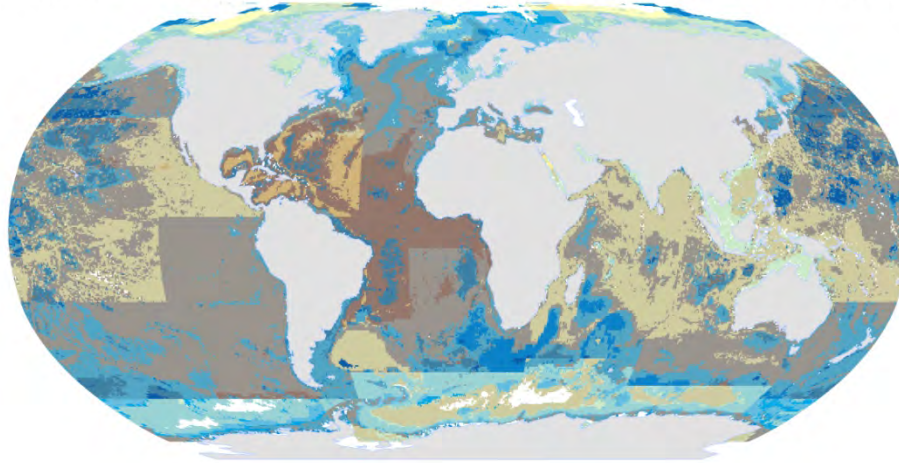


RCP 2.6

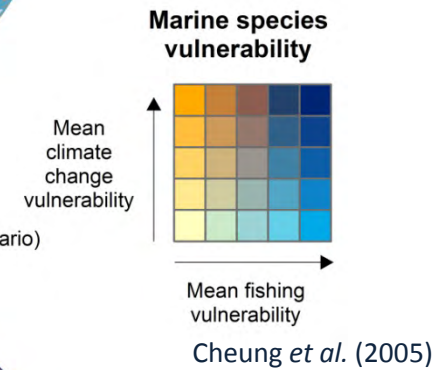
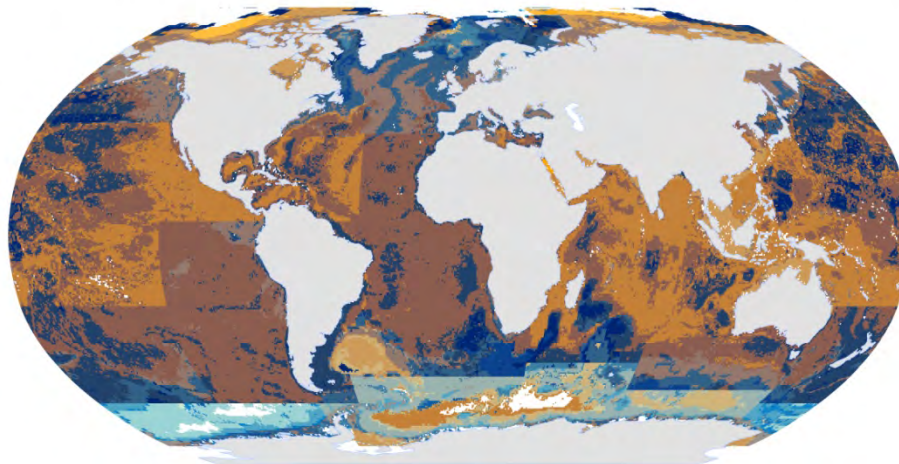


Climate Change & Fishing Vulnerability

Marine species vulnerability to fishing and climate change (based on RCP 2.6 emissions scenario)



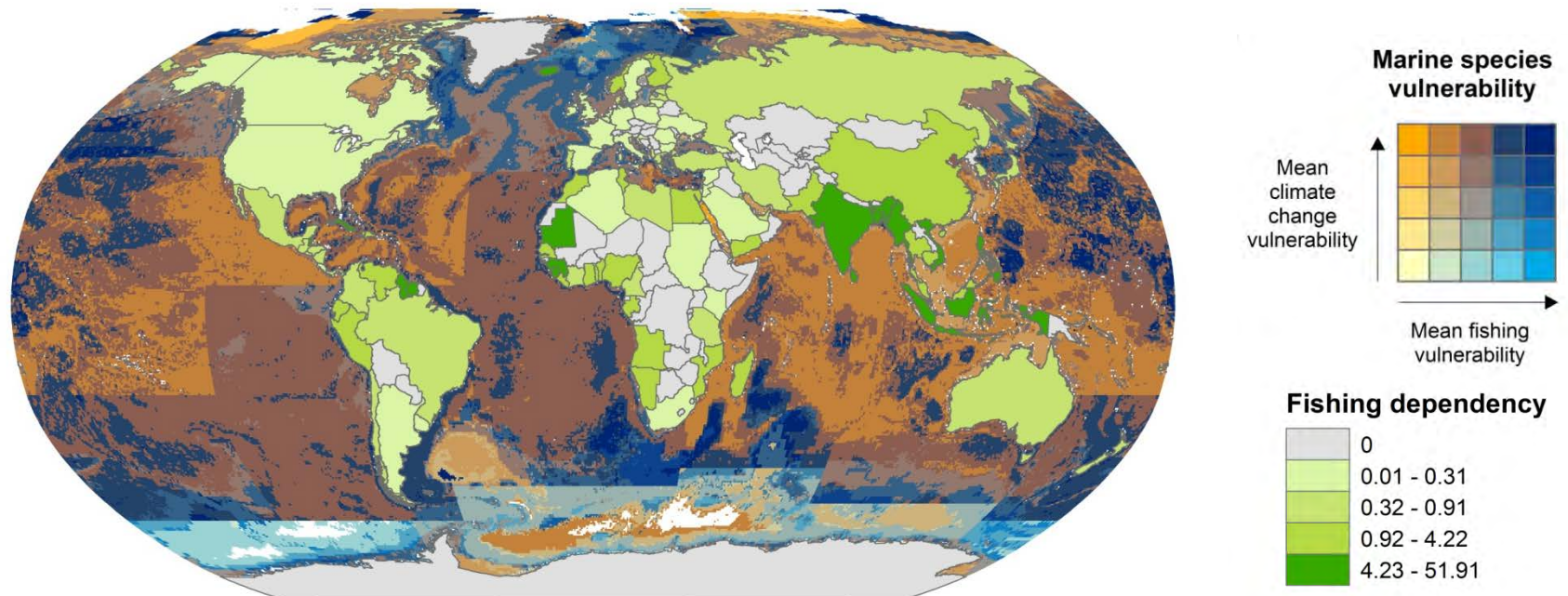
Marine species vulnerability to fishing and climate change (based on RCP 8.5 emissions scenario)



Climate Change & Fishing Vulnerability

Fisheries dependency index

- Average of employment, economy and food security metrics.
- Data obtained from publicly available databases held by the FAO (available at <http://faostat3.fao.org/>), the World Bank (<http://data.worldbank.org/>) and a recent compilation of fisheries employment data (Teh & Sumaila, 2013).



Next steps and conclusions

- Addressing uncertainties and sensitivities
 - Availability of catch data
 - Sensitivities to the traits incorporated
- Geographic pattern of vulnerability highlights regions of vulnerability in addition to those assessed using methods that don't incorporate trait data.
- Vulnerability to climate change and vulnerability to fishing may interact to increase the risk faced by nations with high dependencies on fish as a source of income and food.



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