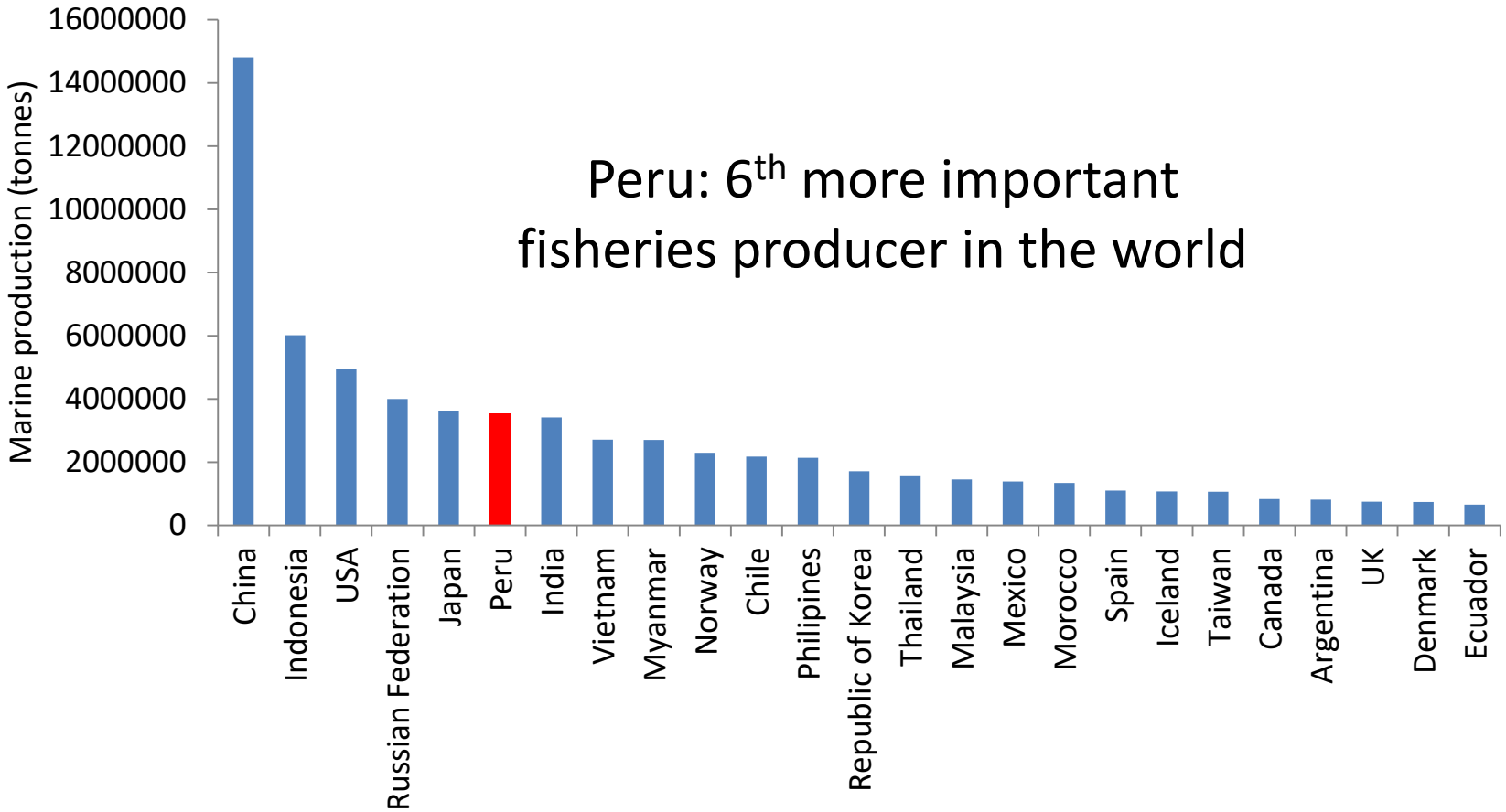
Vulnerability of key Peruvian fishery species to Climate Change

Jorge E. Ramos[1], Jorge Tam[2], Gretta T. Pecl[1,3], Dimitri Gutierrez[2]

jeramos@utas.edu.au

1. Institute for Marine and Antarctic Studies, University of Tasmania; Hobart, Australia.
2. Instituto del Mar del Peru; Lima, Peru.
3. Centre for Marine Socioecology; Hobart, Australia.

Peru fisheries statistics

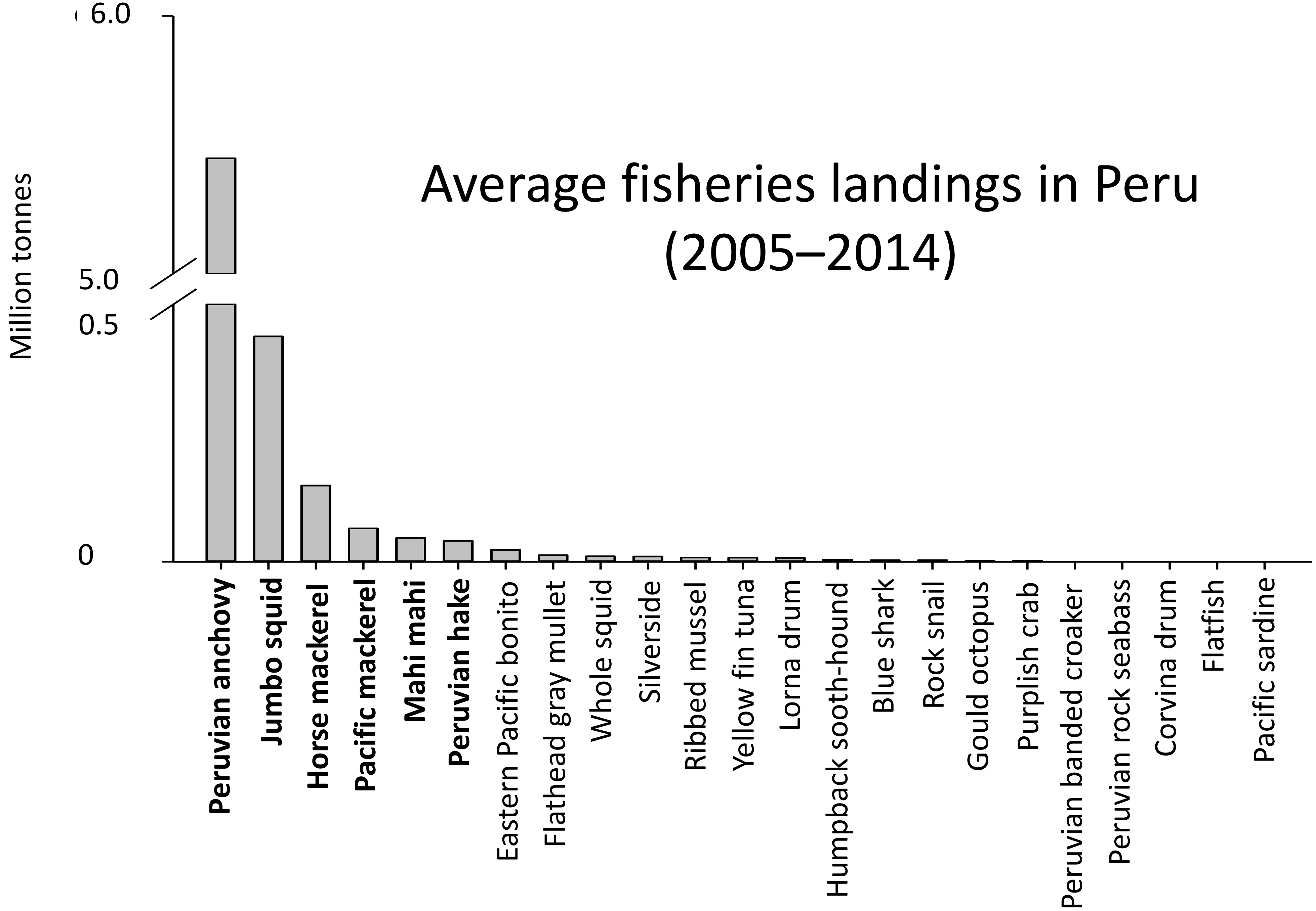


Peru: 6th more important fisheries producer in the world

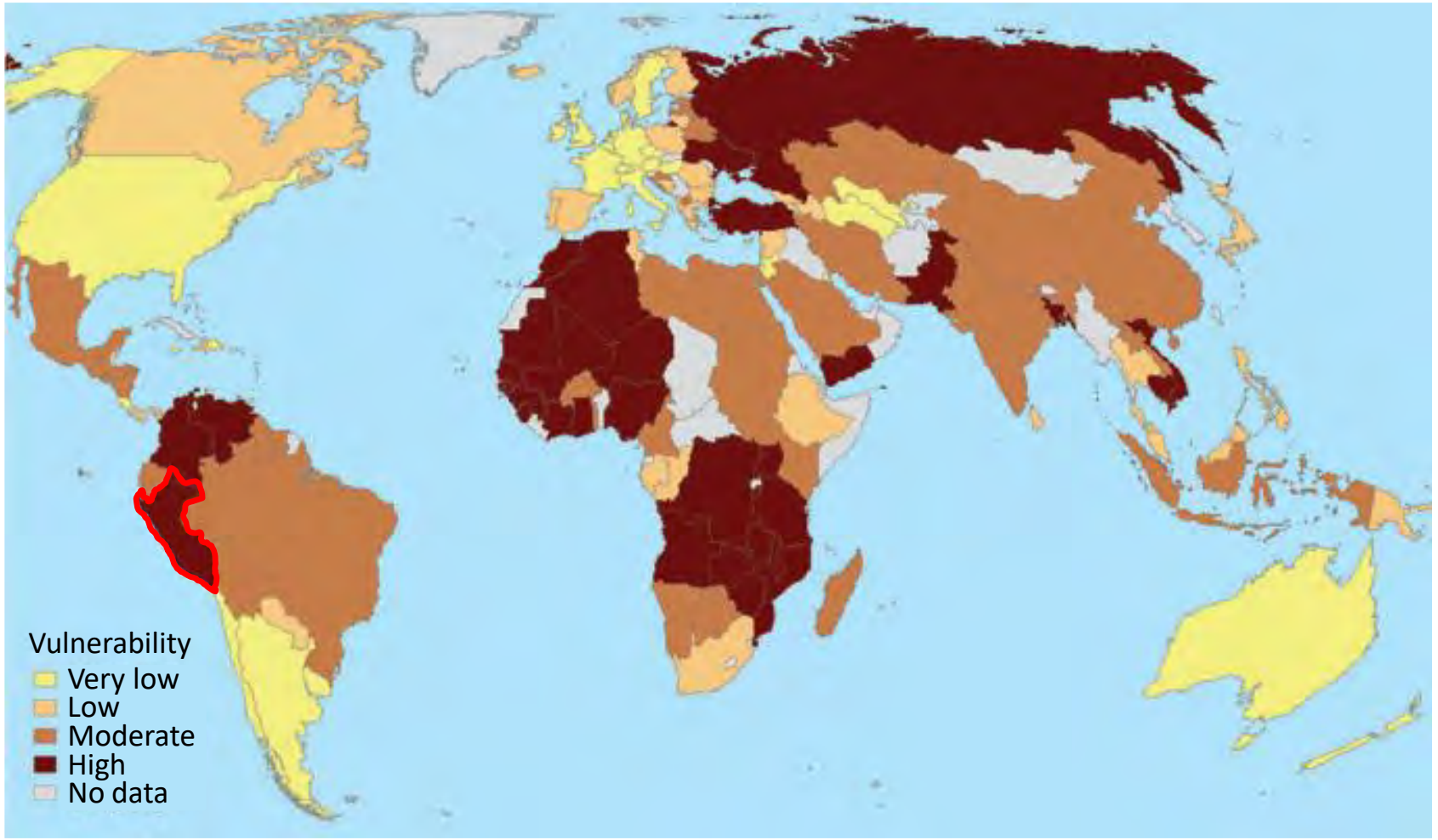
~10% of the world's fish catch!

http://www.fao.org/fishery/facp/PER/en; FAO, 2016

Average fisheries landings in Peru (2005–2014)



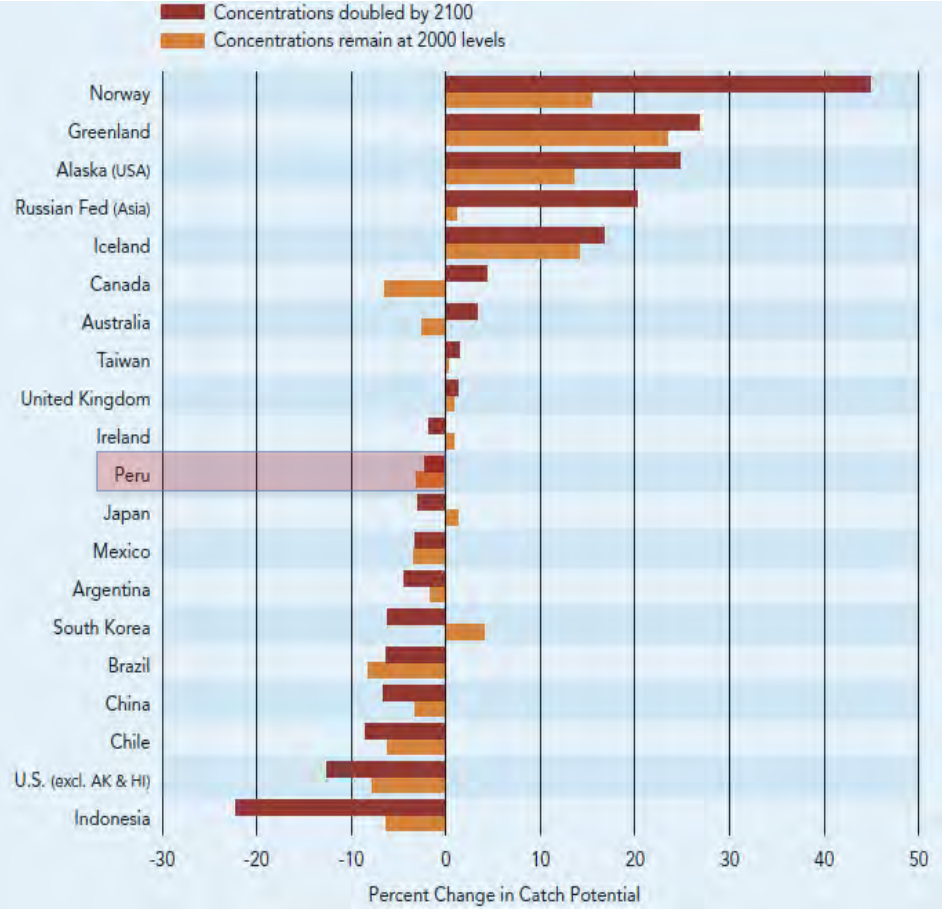
Peru's vulnerability to Climate Change



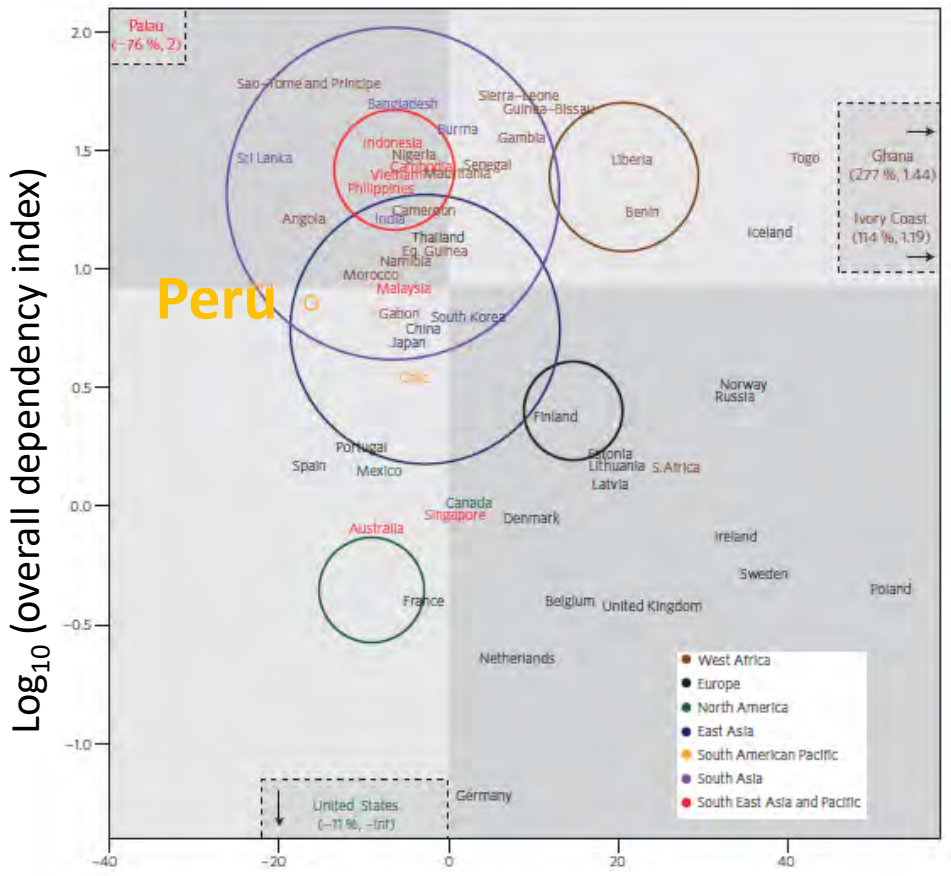
Vulnerability of national economies of potential climate change impacts on fisheries

Allison et al., 2009

Change in catch potential



Projected changes in 10-year averaged maximum catch potential from 2005 to 2055.



Percentage of potential catch change

Cheung et al., 2010; Barange et al., 2014

Aims

1. Estimate the **Exposure** of fishery species to climate factors and identify the climate factors of greater impact.

2. Estimate the **Sensitivity** of fishery species to the impacts of Climate Change.

3. Prioritize fishery species based on their **Vulnerability** to Climate Change.

4. Identify **data gaps** on the impacts of Climate Change on fishery species to pinpoint future research needs.

Vulnerability assessment framework

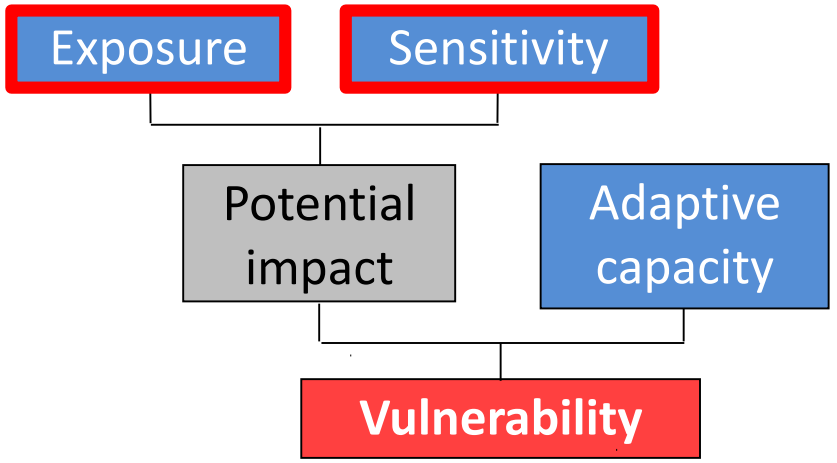
Exposure: Stimuli that have an impact on species, e.g. climatic conditions.

x

Sensitivity: Degree to which a species is affected by the climate stimuli.

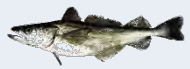
↓

Vulnerability: Degree to which a species is susceptible to damage (the detrimental part of sensitivity).



http://www.ipcc.ch/ipccreports/tar/wg2/index.php?idp=650

Species selected

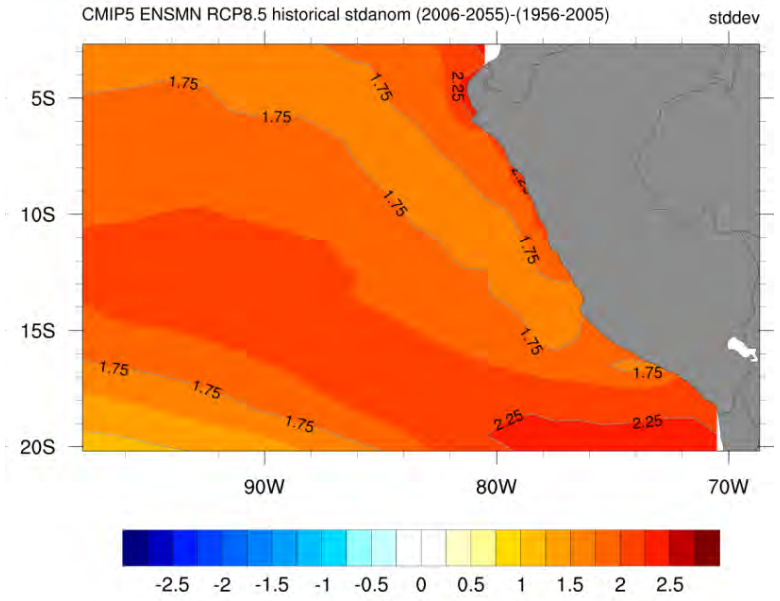
Pelagics (10)	Demersals (11)	Invertebrates (8)
Peruvian anchovy (*Engraulis ringens*) 	Catfish (*Galeichtys peruvianus*) 	Whole squid (*Loligo gahi*) 
Yellow fin tuna (*Thunnus albacares*) 	Peruvian rock seabass (*Paralabrax humeralis*) 	Purplish crab (*Platyxanthus orbignyi*) 
Eastern Pacific bonito (*Sarda chiliensis chiliensis*) 	Peruvian weakfish (*Cynoscion analis*) 	Rock snail (*Thais chocolata*) 
Pacific mackerel (*Scomber japonicus peruvianus*) 	Mote sculpin (*Normanichthys crockeri*) 	Ribbed mussel (*Aulacomya atra*) 
Horse mackerel (*Trachurus murphyi*) 	Peruvian banded croaker (*Paralonchurus peruanus*) 	Scallop (*Argopecten purpuratus*) 
Flathead gray mullet (*Mugil cephalus*) 	Corvina drum (*Sciaena gilberti*) 	Black ark (*Anadara tuberculosa*) 
Silverside (*Odonthestes regia*) 	Lumptail searobin (*Prionotus stephanophrys*) 	**Jumbo squid** (*Dosidicus gigas*) 
Mahi mahi (*Coryphaena hippurus*) 	Flatfish (*Paralichthys adspersus*) 	Gould octopus (*Octopus mimus*) 
Pacific sardine (*Sardinops sagax*) 	Lorna drum (*Sciaena deliciosa*) 	
Blue shark (*Prionace glauca*) 	**Peruvian hake** (*Merluccius gayi peruanus*) 	
	Humpback sooth-hound (*Mustelus whitneyi*) 	

Exposure

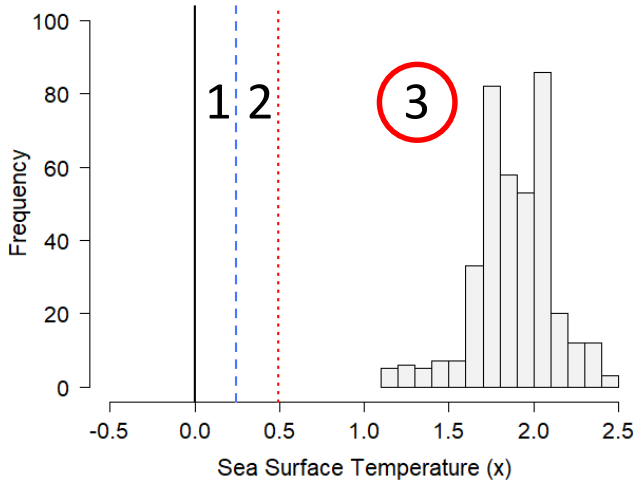
$$X = \frac{\text{Future (2006–2055) – past (1956–2005)}}{\text{SD of the past}}$$

Based on the **"business as usual"** Representative Concentration Pathway 8.5 (**RCP8.5**).

http://www.esrl.noaa.gov/psd/ipcc/ocn/



Exposure factors (X)
Sea Surface Temperature (SST)
Sea Surface Salinity (SSS)
pH
Sea Surface Chlorophyll
Primary productivity
Precipitation
Air Surface Temperature
Sea Bottom Temperature (SBT)
Sea Bottom Salinity (SBS)
Sea Level Rise



Magnitude of change	Thresholds
1) Low	x ≤ 1 SD
2) Medium	1 SD < x ≤ 2 SD
3) High	2 SD < X

Hare et al., 2016

Sensitivity Assessment

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

Pecl et al., 2014

Source of information

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.

Morrison et al., 2015

Sensitivity estimation based on: **ABUNDANCE**, DISTRIBUTION and PHENOLOGY

Sensitivity attribute		Risk category		
		Low sensitivity (1), high capacity to respond (lower risk)	**Medium sensitivity (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
	Average age at maturity	≤2 years	2–10 years ✓	>10 years
	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 period
	Generalist vs. specialist – Food and habitat	Reliance on neither hábitat or prey ✓	Reliance on either habitat or prey	Reliance on hábitat and prey
	Spawning biomass	Robust ✓	Vulnerable	Uncertain/threatened

Pecl et al., 2014

Sensitivity estimation based on: ABUNDANCE, **DISTRIBUTION** and PHENOLOGY

Sensitivity attribute		Risk category		
		Low sensitivity (1), high capacity to respond (lower risk)	**Medium sensitivity (2)**	**High sensitivity (3), low capacity to respond (higher risk)**
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	<10º latitude ✓	10–20º latitude	>20º latitude
	Spatial availability of unoccupied hábitat for most critical life stage – ability to shift distributional range.	Substantial unoccupied hábitat; >6º latitude or longitude ✓	Limited unoccupied hábitat; 2–6º latitude or longitude	No unoccupied habitat; 0 – 2º latitude or longitude

Pecl et al., 2014

Sensitivity estimation based on: ABUNDANCE, DISTRIBUTION and **PHENOLOGY**

Sensitivity attribute		Risk category		
		Low sensitivity (1), high capacity to respond (lower risk)	**Medium sensitivity (2)**	**High sensitivity (3), low capacity to respond (higher risk)**
Phenology	**Environmental variable as a phenological cue for spawning or breeding** – cues include salinity, temperatura, 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 & spawning)	No migration	Migration is common for some of the population	Migration is common for the whole population ✓

Pecl et al., 2014

Exposure/Sensitivity Scores and Components

Expert	Exposure factor/sensitivity attribute scores		
	Low (1)	**Medium (2)**	**High (3)**
1	0	1	3
2	0	1	3
3	0	1	3
4	0	0	4
Total	**0**	**3**	**13**

4 experts, 4 tallies

((Lx1)+(Mx2)+(Hx3))/(L+M+H) = Weighted Average Score

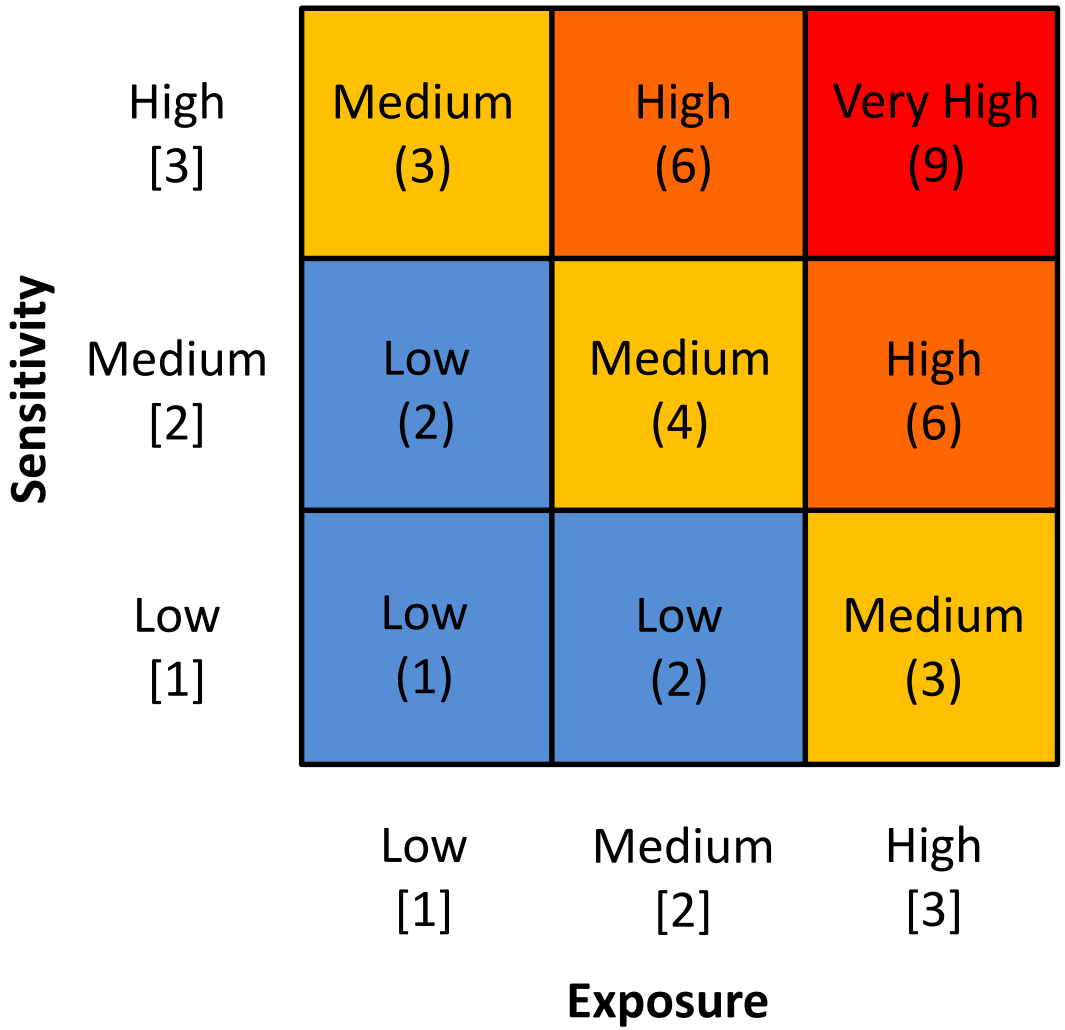
((0x1)+(3x2)+(13x3))/(0+3+13) = **2.81**

Logic rule	Overall Exposure/Sensitivity Component
2 or more attributes or factors mean ≥ 3	3) High
2 or more attributes or factors mean ≥ 2	2) Medium
All other scores	1) Low

Adapted from Hare et al., 2016

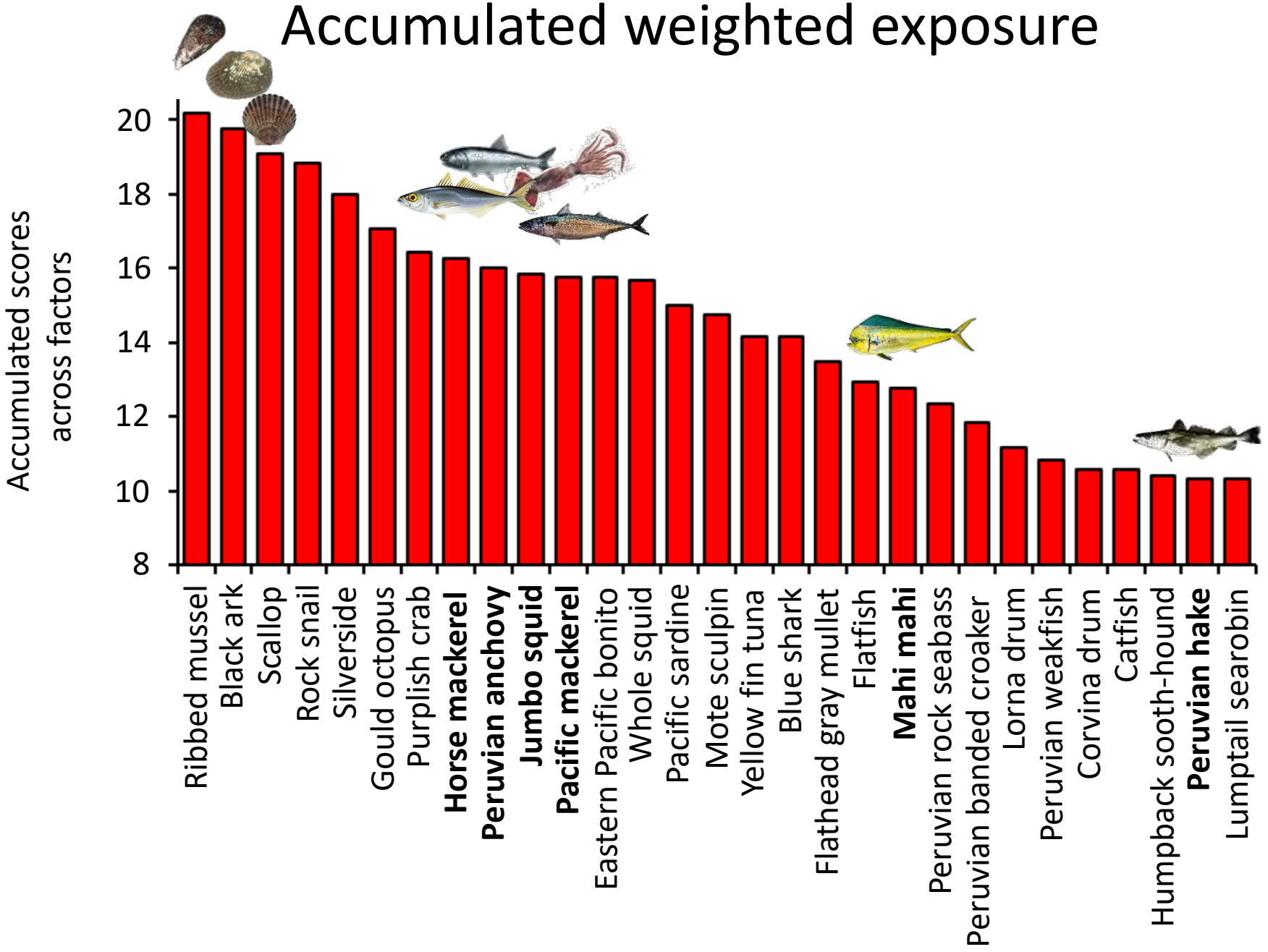
Vulnerability

Vulnerability = sensitivity x exposure

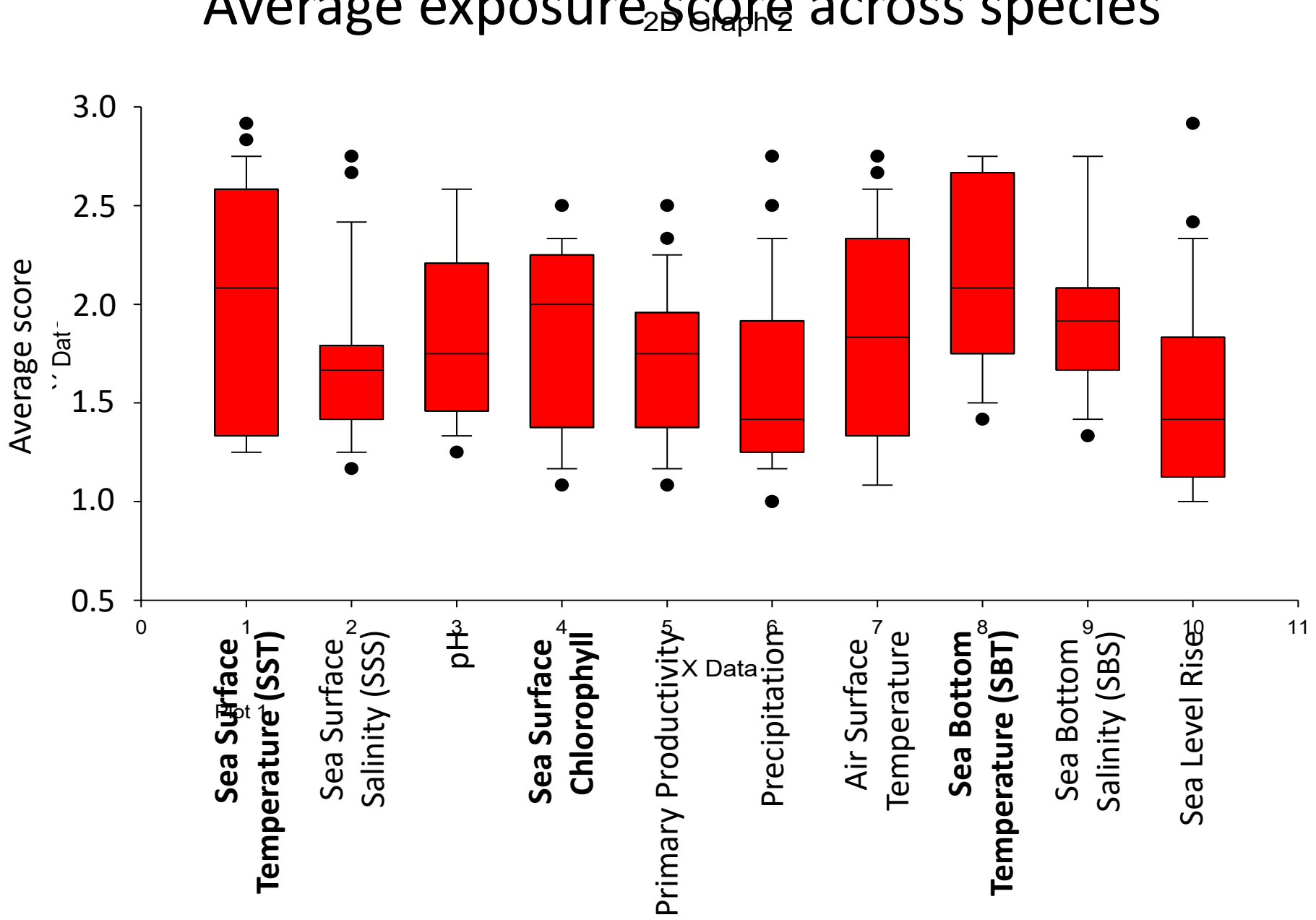


Morrison et al., 2015; Hare et al., 2016

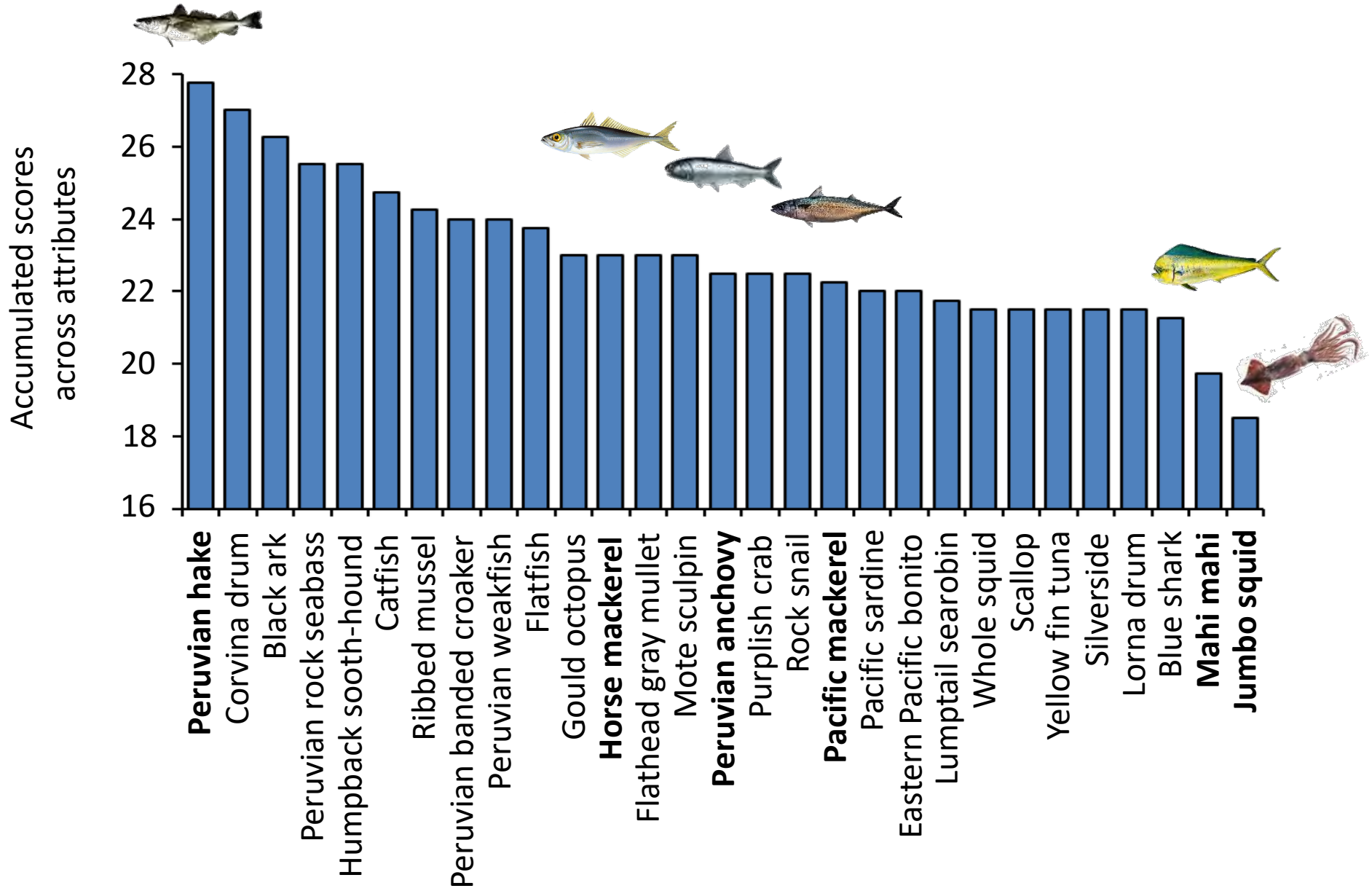
Accumulated weighted exposure



Average exposure score across species



Accumulated weighted sensitivity



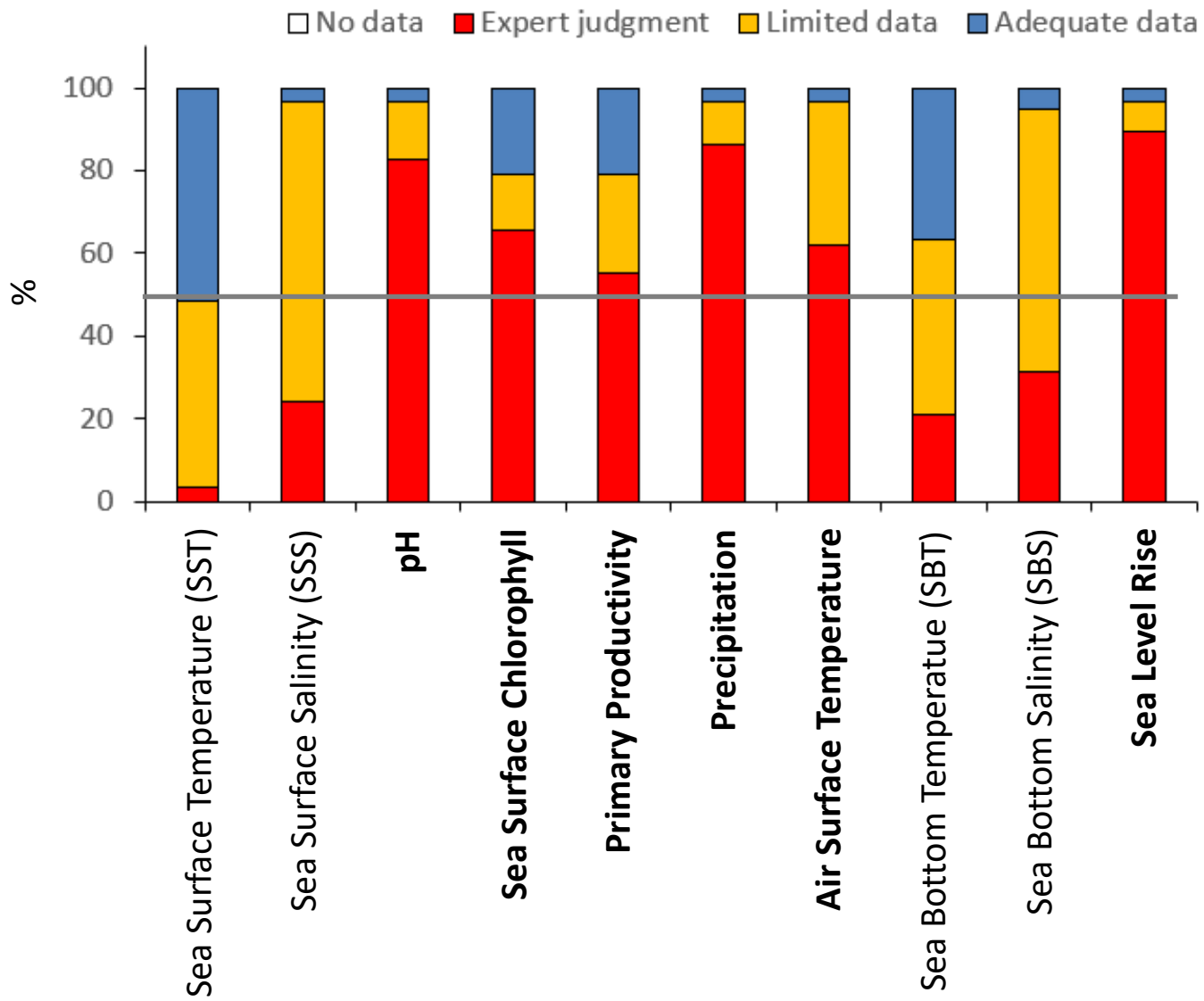
Vulnerability

Sensitivity \ Exposure	Low [1]	Medium [2]	High [3]
High [3]	**Medium (3)** **Peruvian hake** Humpback sooth-hound	**High (6)** **Horse mackerel** **Pacific mackerel** Pacific sardine Eastern Pacific bonito Yellow fin tuna	**Very High (9)** **Peruvian anchovy** Whole squid, Gould octopus, Purplish crab, Ribbed mussel, Scallop, Black ark
Medium [2]	**Low (2)**	**Medium (4)** Blue shark Silverside Peruvian banded croaker Mote sculpin **Jumbo squid**	**High (6)** **Mahi mahi** Flathead gray mullet Flatfish Peruvian rock seabass Rock snail
Low [1]	**Low (1)**	**Low (2)** Lumptail searobin Corvina drum Lorna drum	**Medium (3)** Catfish Peruvian weakfish

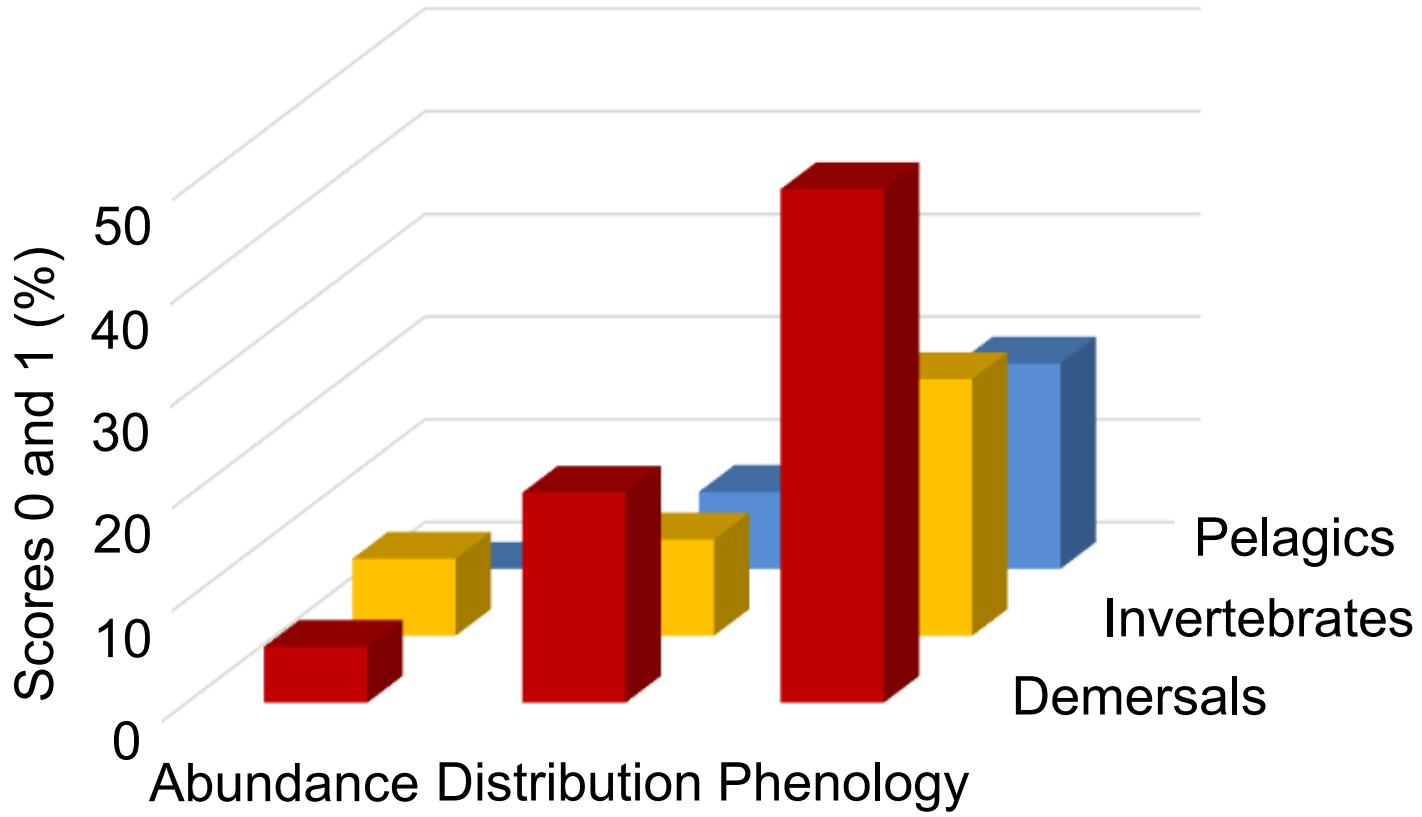




Relationship species-environment data gaps



Sensitivity data gaps



0) No data; 1) Expert judgement

Conclusions

1. Estimate the **Exposure** of fishery species to climate factors and identify the climate factors of greater impact.
    - **Invertebrates** (e.g. ribbed mussel, black ark, scallop, and rock snail) are highly exposed to the impacts of climatic factors.
    - Factors with greater impact: **Temperature** and **Sea Surface Chlorophyll**.

2. Estimate the **Sensitivity** of fishery species to the impacts of Climate Change.
    - **Fishes** had greater sensitivity, i.e. Peruvian hake, corvina drum, black ark, Peruvian rock seabass, Humpback sooth-hound.
    - **Peruvian anchovy, mackerels, and jumbo squid** had medium to medium-low sensitivity.

Conclusions

3. Prioritize fishery species based on their **Vulnerability** to Climate Change.
   - About **60%** of the species with **high to very high vulnerability**.
   - **The most important commercial species are the most vulnerable, e.g. Peruvian anchovy, mackerels.**

4. Identify **data gaps** on the impacts of Climate Change on fishery species to pinpoint future research needs.
   - pH, productivity, precipitation, temperature and sea level rise.
   - **Impact of exposure factors differ across species and life stages.**
   - **Phenology**, e.g. environmental effect on reproduction, spawning, metamorphosis and settling.

Next steps

- Mechanistic approaches.
  - Physiology
  - Migration patterns

- Modelling.
  - SDM
  - Biomass
  - Landings

Thank you

Felipe Briceño (NIVA Chile) · Mark Nelson (NOAA) · Rafael León (UTAS)· Betsy Buitrón (IMARPE) · Jorge Flores (IMARPE) · Antonio Cuba (IMARPE) · Jesús Rujel (IMARPE) · Emperatriz Gómez (IMARPE) · Martin Salazar (IMARPE) · Hans Jara (IMARPE) · Ricardo Bandin (IMARPE) · María Nelly Sanjinez (IMARPE) · Victor Aramayo (IMARPE) · Ernesto Fernández (IMARPE) · Carlos Romero (IMARPE)