Regional Marine Biodiversity & Climate Change in the Arabian Gulf

William W. L. Cheung

Nippon Foundation-Nereus Program and Changing Ocean Research Unit

Institute for the Oceans and Fisheries

The University of British Columbia, Canada

Regional Symposium on Climate Change
March 13 – 16, 2017 at the Environment Agency – Abu Dhabi

Project team

The Research team is comprised of 10 scientists from the Changing Ocean Research Unit and the Sea Around Us Project at the UBC:

PI: William Cheung, Co-PI: Daniel Pauly

Researchers: Dalal Al-Abdulrazzak, Myriam Khalfallah, Vicky W.Y. Lam, Deng Palomares, Gabriel Reygondeau, Lydia Teh, Colette Wabnitz, Dirk Zeller

Goal & Objectives

- **Goal:** Understand the vulnerability of Arabian Gulf marine biodiversity to climate change

✓ Evaluate the current status of marine biodiversity and fisheries in the Arabian Gulf;

✓ Assess the impacts and vulnerability of marine biodiversity and fisheries to climate change

This talk

- Global overview of climate impacts on marine biodiversity and ecosystem services;
- Arabian Gulf marine biodiversity and their vulnerability to climate change;
- Arabian Gulf marine fisheries and their vulnerability to climate change;
- Options for climate risk-reduction.

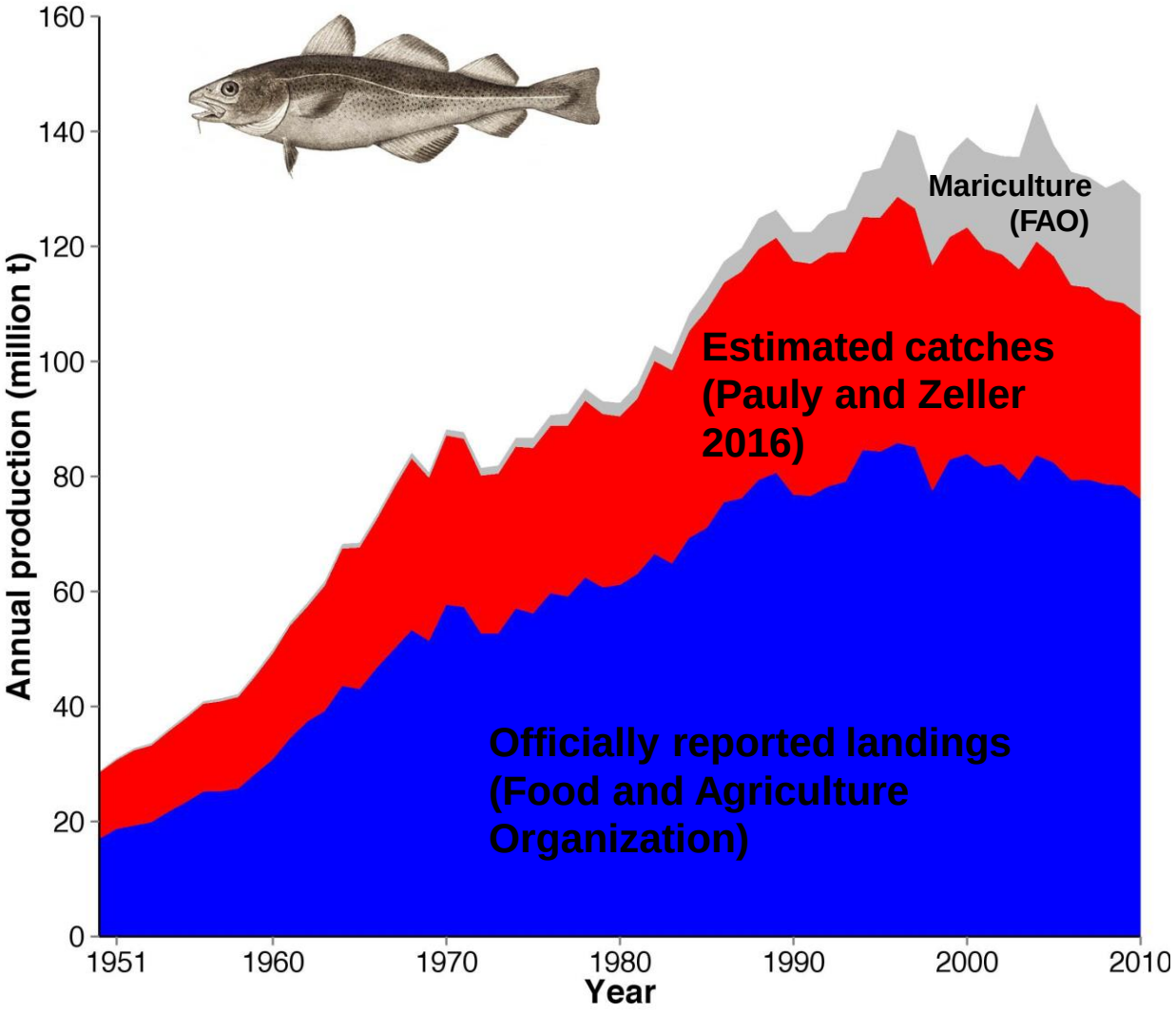
This talk

- Global overview of climate impacts on marine biodiversity and ecosystem services;
- Arabian Gulf marine biodiversity and their vulnerability to climate change;
- Arabian Gulf marine fisheries and their vulnerability to climate change;
- Options for climate risk-reduction.

Biodiversity in the oceans

- Home to 2,260,000 described eukaryotic species, including 35 animal phyla, 14 of which are exclusively marine;
- Contribute to vital ecosystem services.

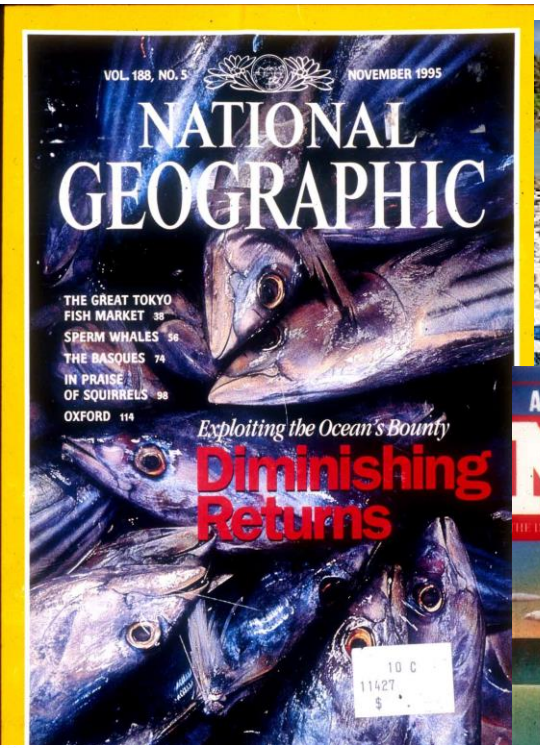
Importance of fisheries for human society

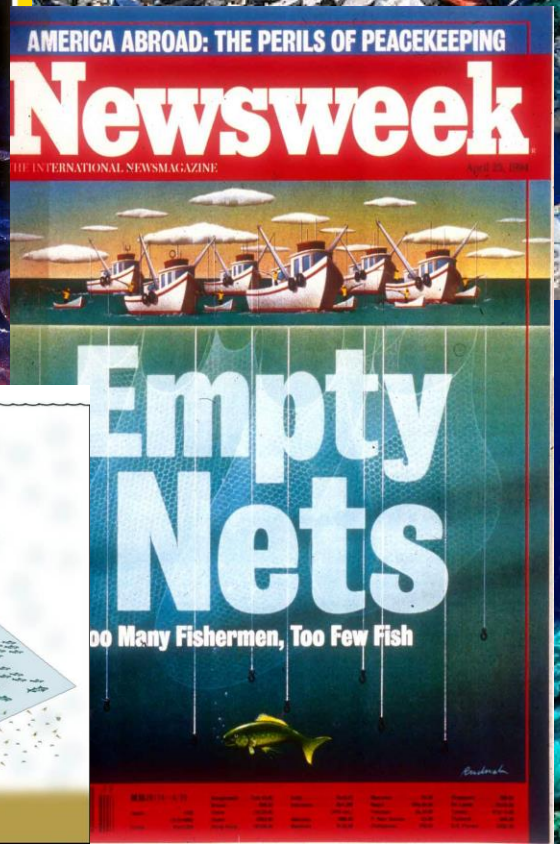


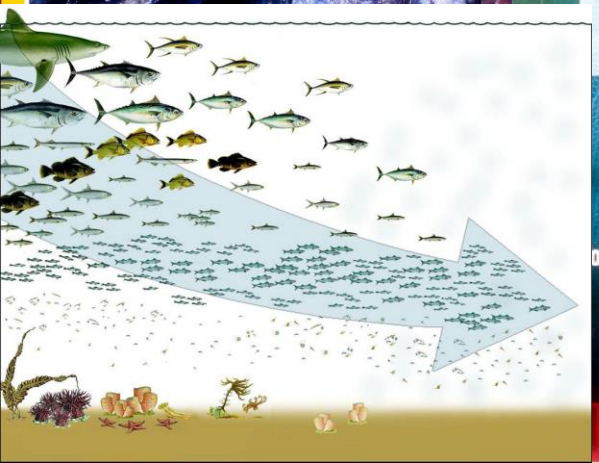
Fisheries landings generated around $100 billion USD per year, supporting livelihood of about 10 – 12% of the world's population directly or indirectly;

Provide 2.9 billion people with > 20% of their animal protein needs.

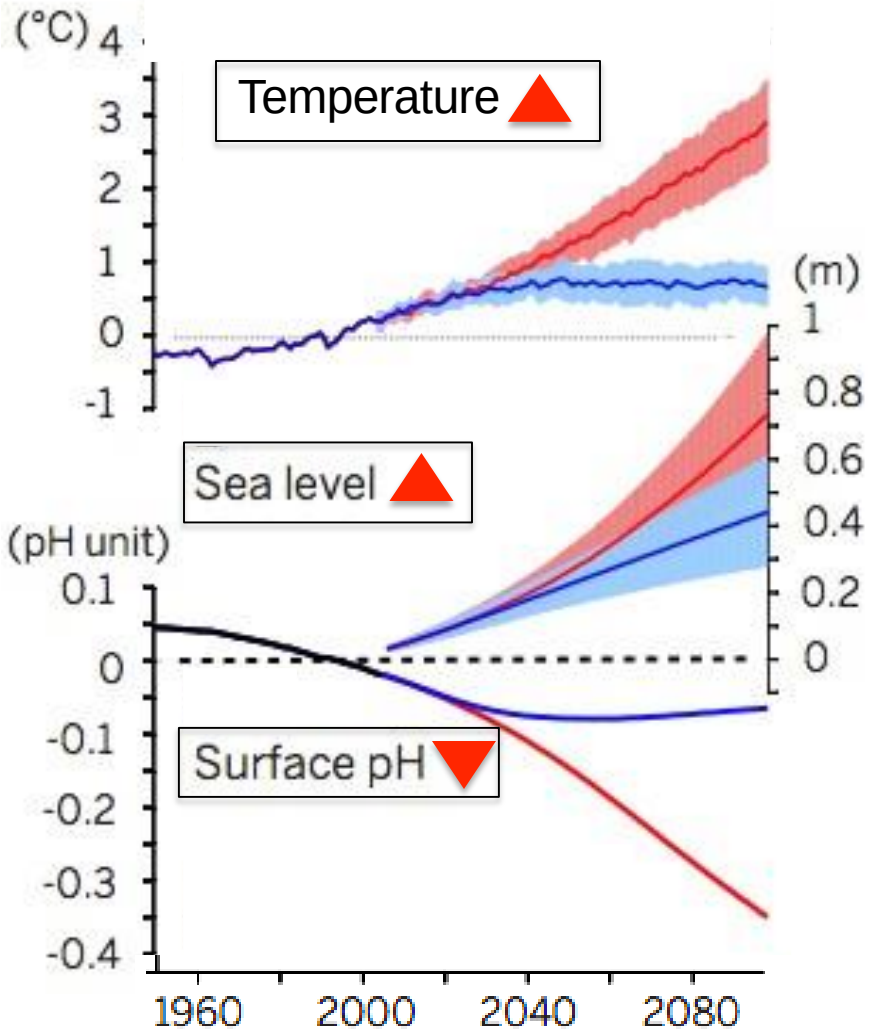
Human impacts on marine ecosystems

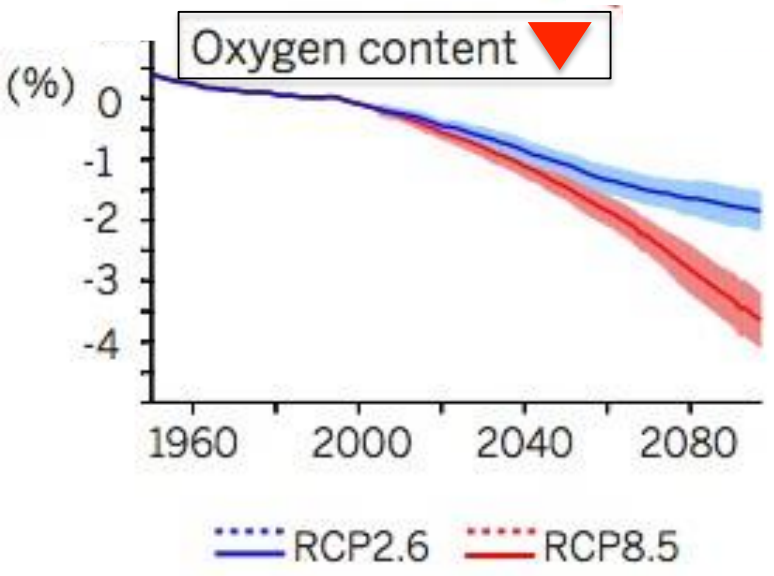






What does CO_2 emission do to the oceans?

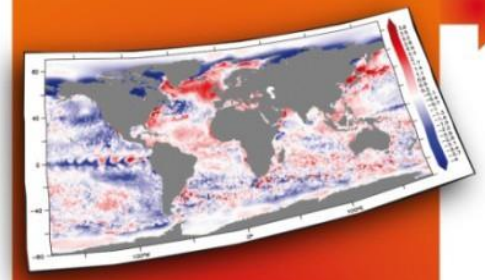




Gattuso, Magnan, Billé, Cheung, Howes, Joos, *et al*. 2015 Science.

Climate change impact on marine resources

Climate change

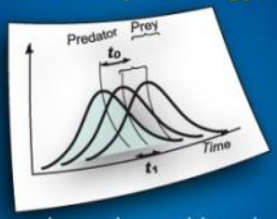


- Increasing global mean temperature
- Ocean acidification
- Change in frequency and severity of extreme event
- Change in biogeochemical structure (vertical stability, currents, physico-chemical composition...)

Effect on spatial distribution

- Habitat change (Poleward shift and deepening)
- Species invasion and local extinction

Effect on phenology

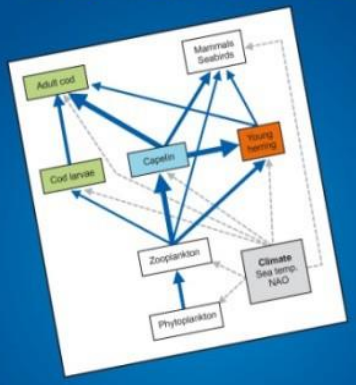


- Change in producers blooming
- Change in life cycle
- Change in predator prey interaction

Effect on physiology

- Change in photosynthesis activity, respiration
- Change in the biological key parameters (growth, reproduction, mortality, nutrition)

Effect on structure and dynamic of food webs

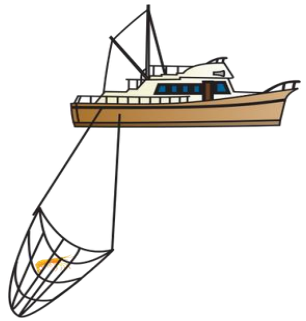


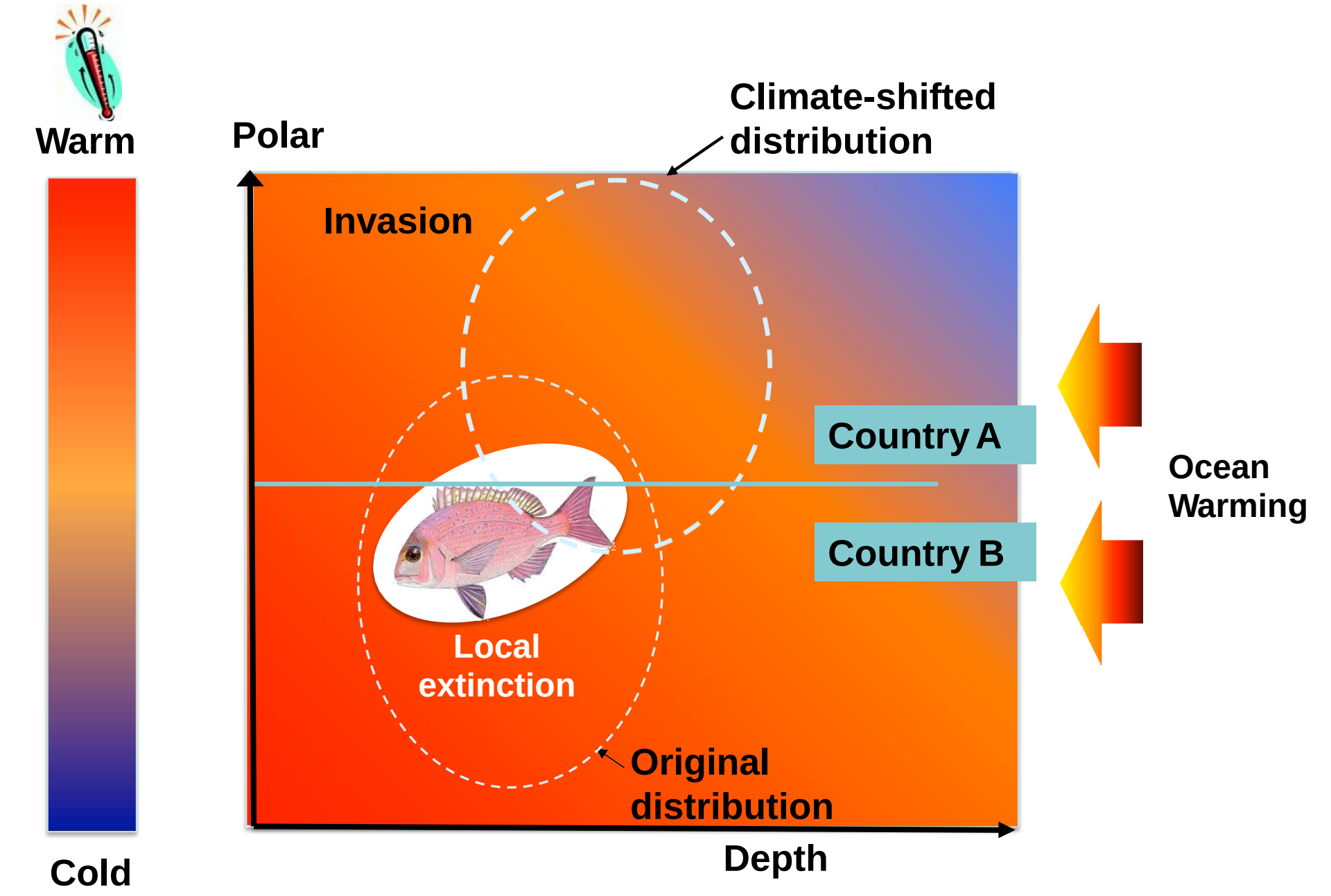
- Change in species assemblage
- Change in trophodynamics (productivity and catch potential)
- Change in resilience (regime shift)

Human impacts

- Overexploitation
- Pollution and habitat destruction Introduction of alien species

Effect on fisheries catch, landed value, food security and employment




Warm
Cold
Polar
Climate-shifted distribution
Invasion
Country A
Country B
Ocean Warming
Local extinction
Original distribution
Depth

Projecting climate impacts on marine biodiversity and fisheries

Earth System Model projections

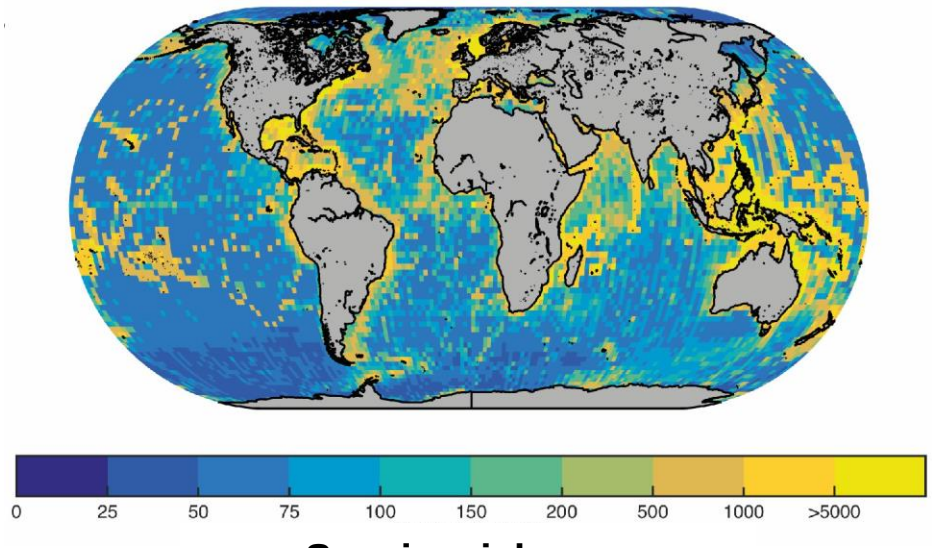
Biology and ecology of fish stocks

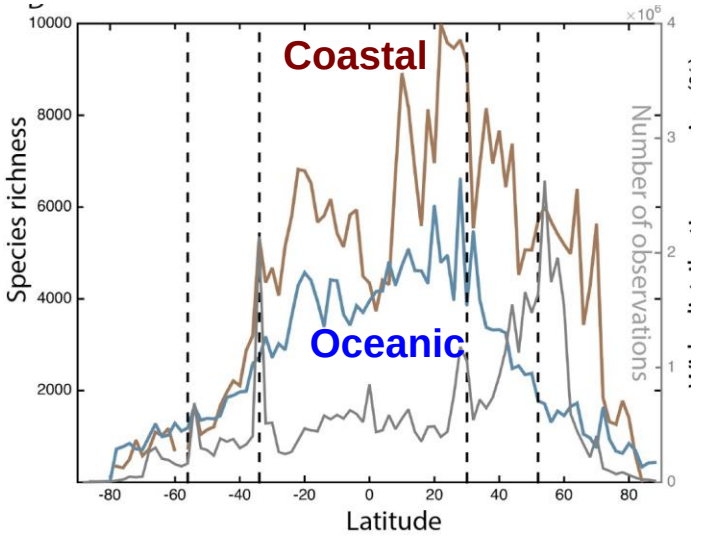
- **Occurrence records**
- **Fisheries data**
- **Habitat preferences and data**

Species distribution models

Predicted future distribution, species richness and catches

Marine biodiversity pattern explained by temperature and species' thermal strategies





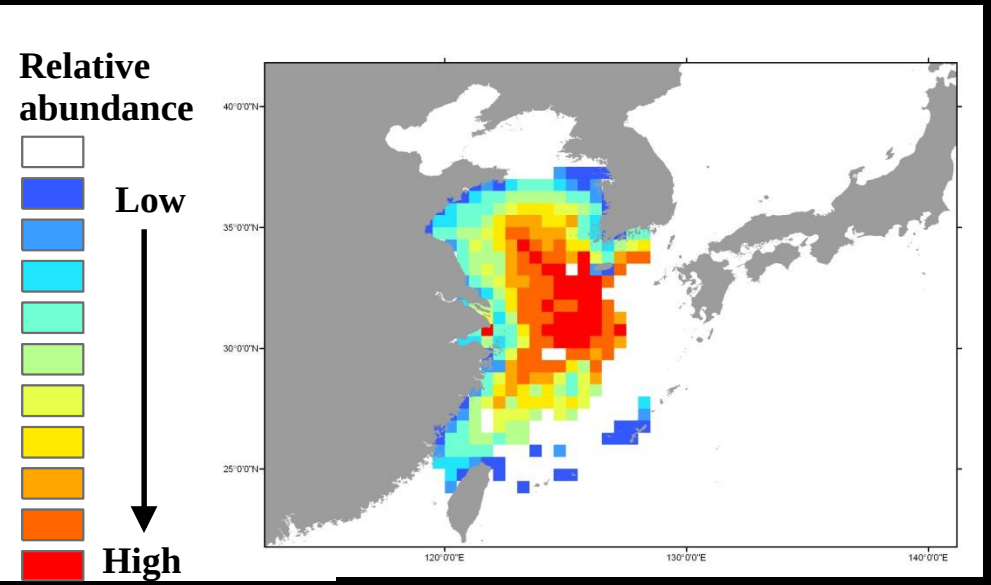
- > 103,000 extant species (> 100 million records) from phytoplanktons to marine mammals;
- Pattern of species richness is explained largely by:
  - Temperature
  - Species' thermal strategies – preferred temperature and breath of thermal niche.

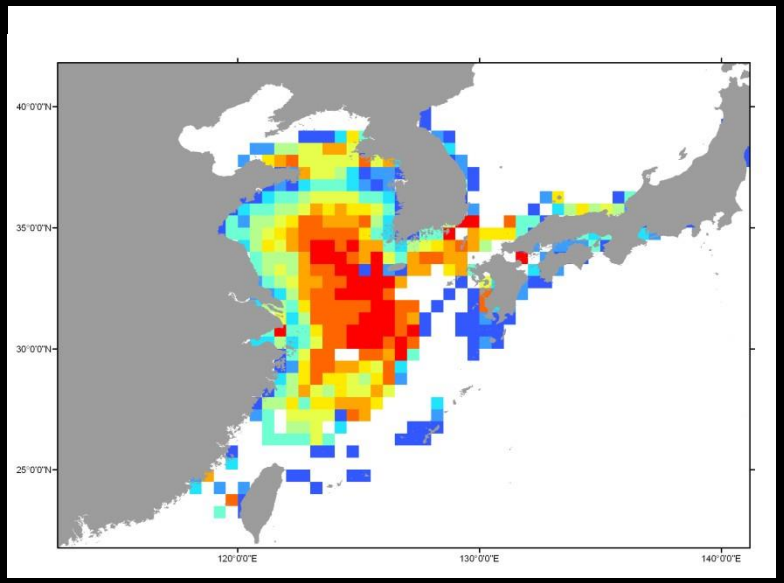
Reygondeau, Wabnitz & Cheung (in revision)

Example: Small yellow croaker (*Larimichthys polyactis*)

Original (static) distribution

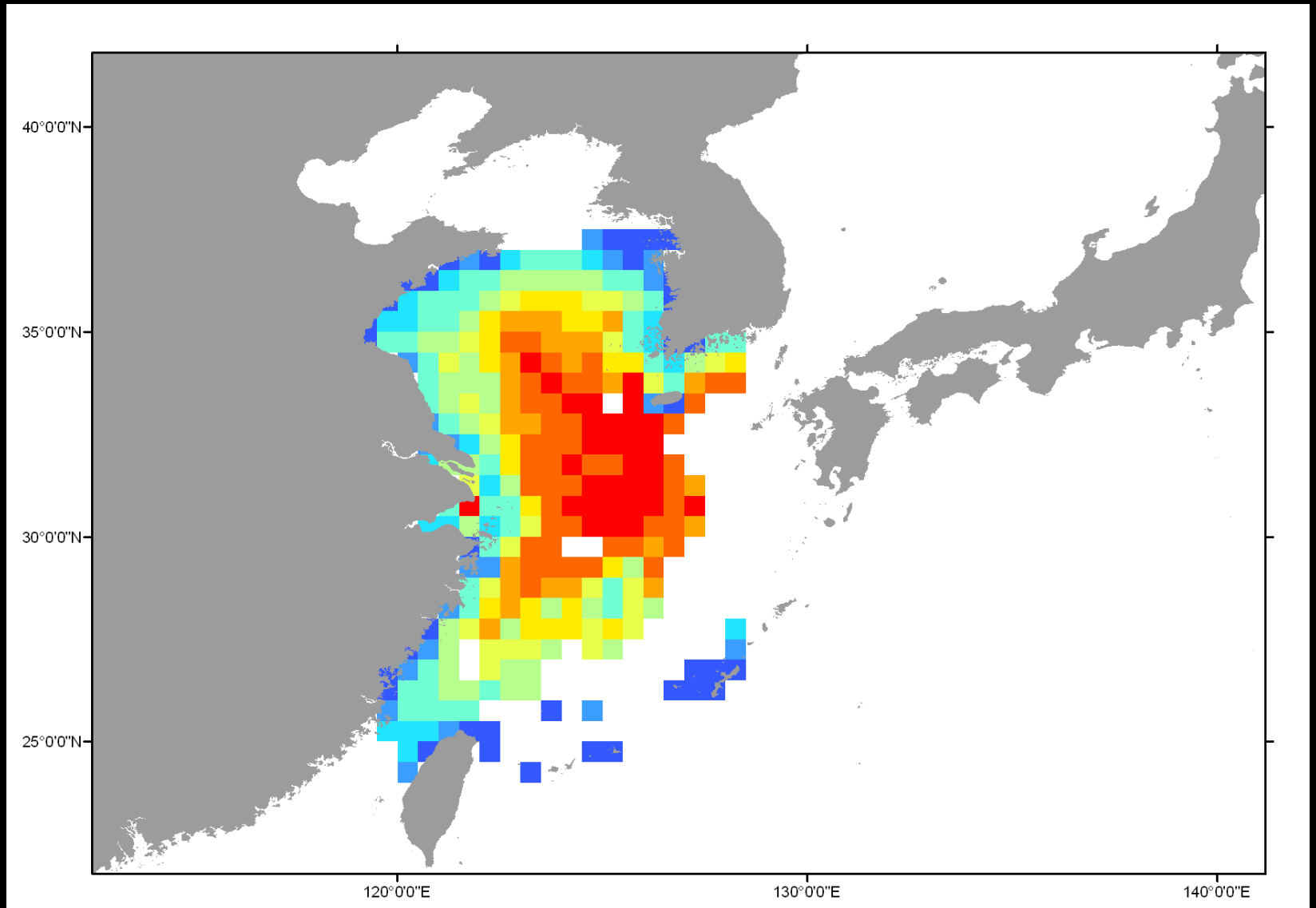
Distribution after 50 years
(Climate projection from NOAA/GFDL CM 2.1)





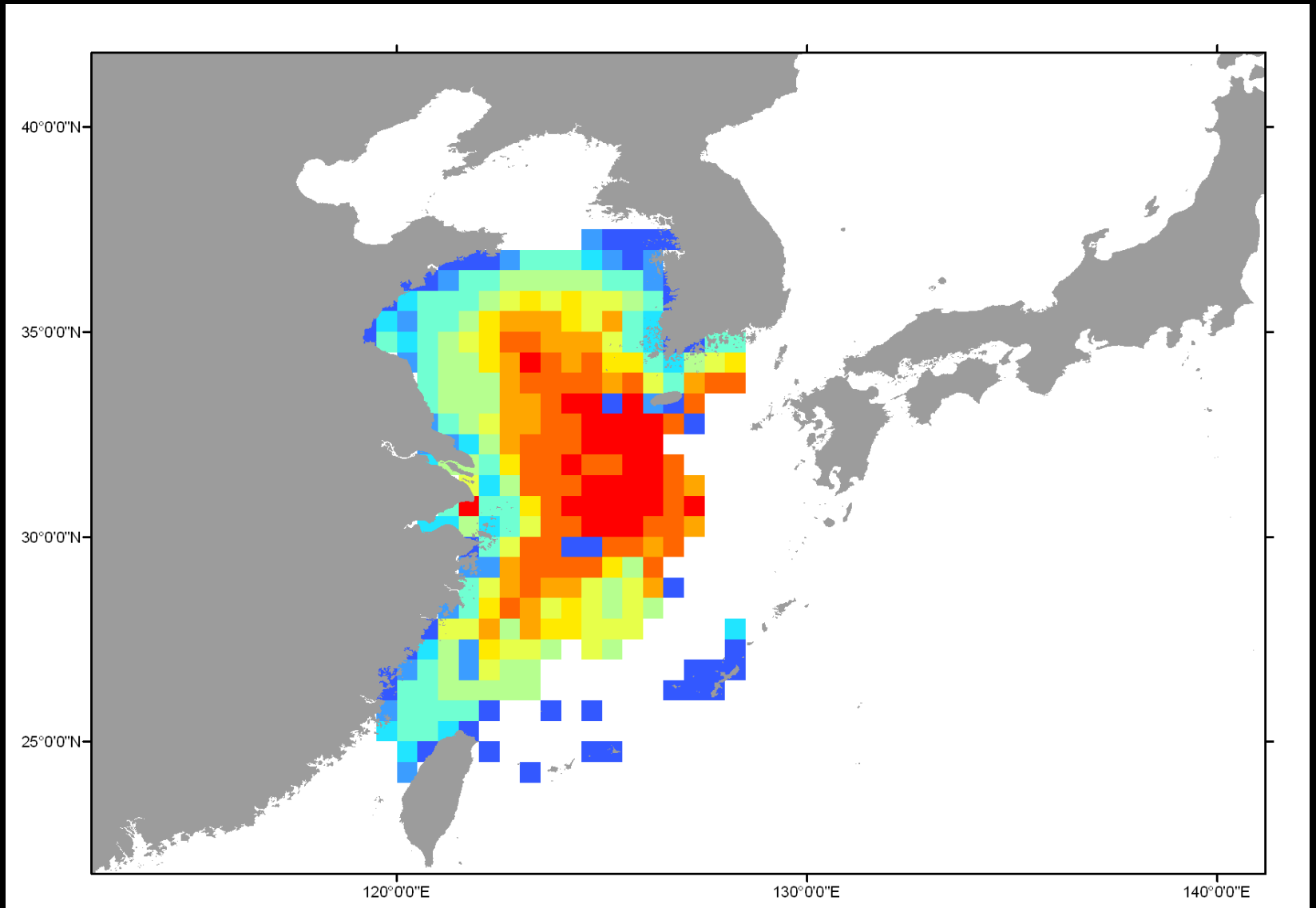
Small yellow croaker

Year 2001



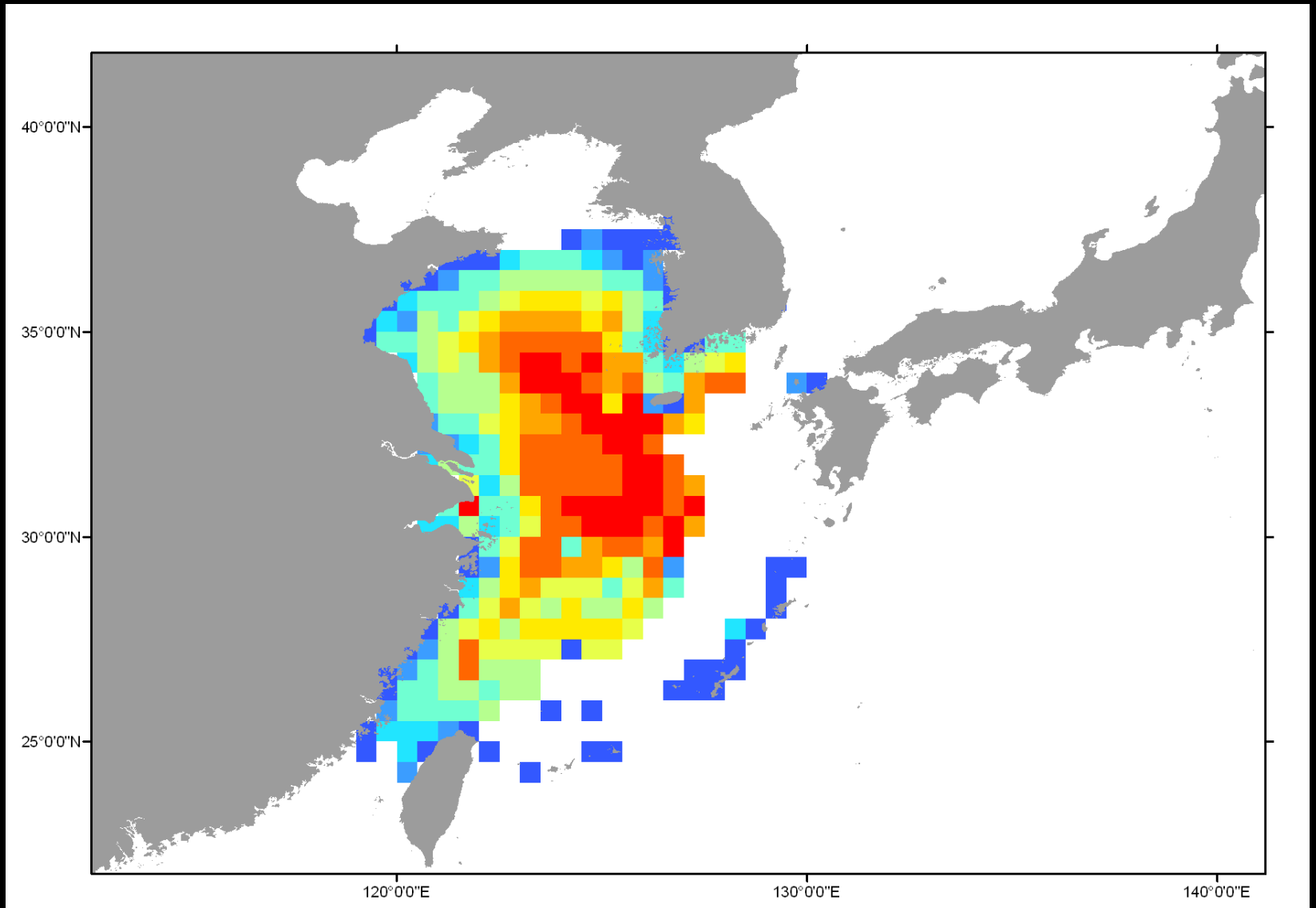
Small yellow croaker

Year 2006



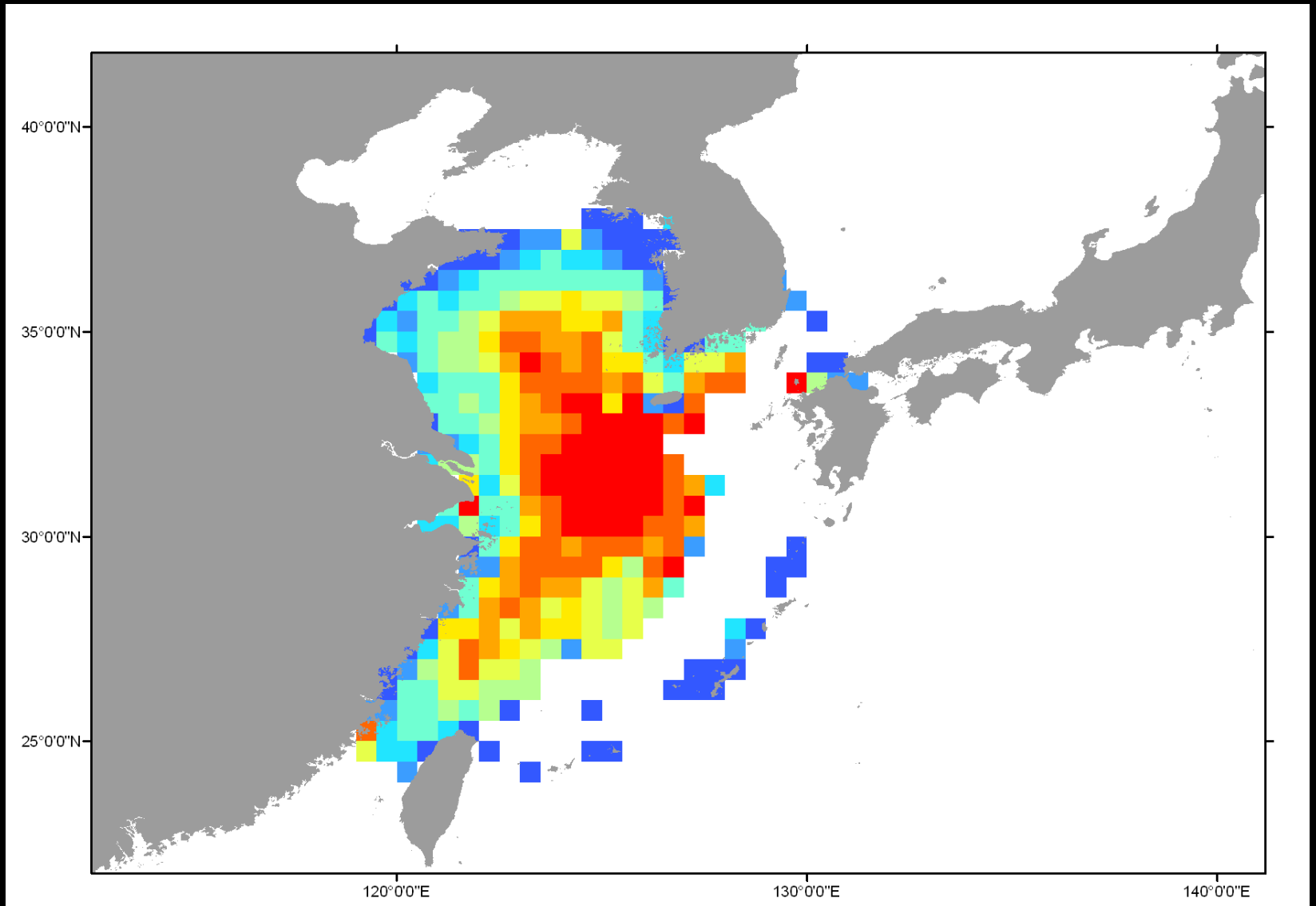
Small yellow croaker

Year 2011



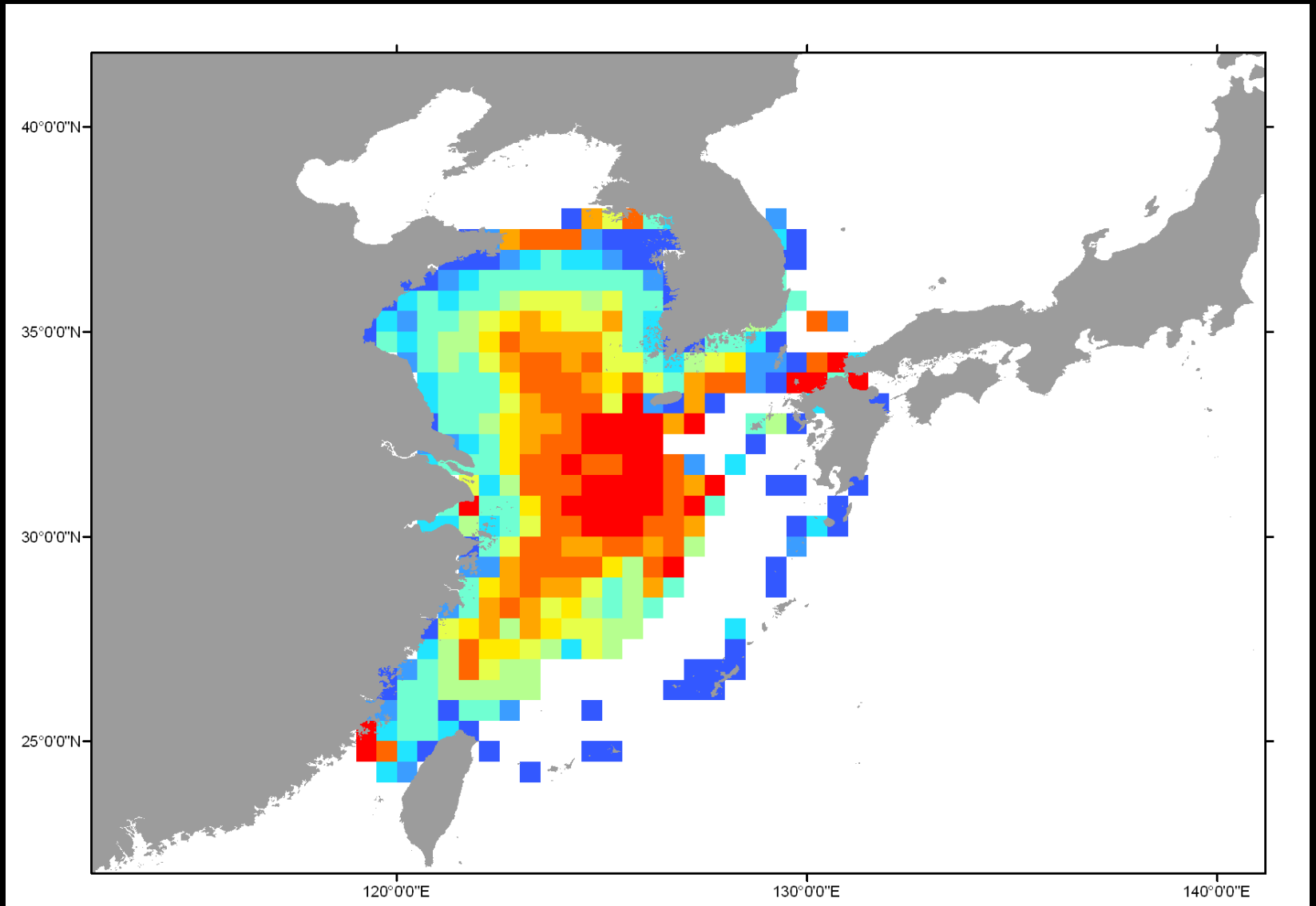
Small yellow croaker

Year 2016



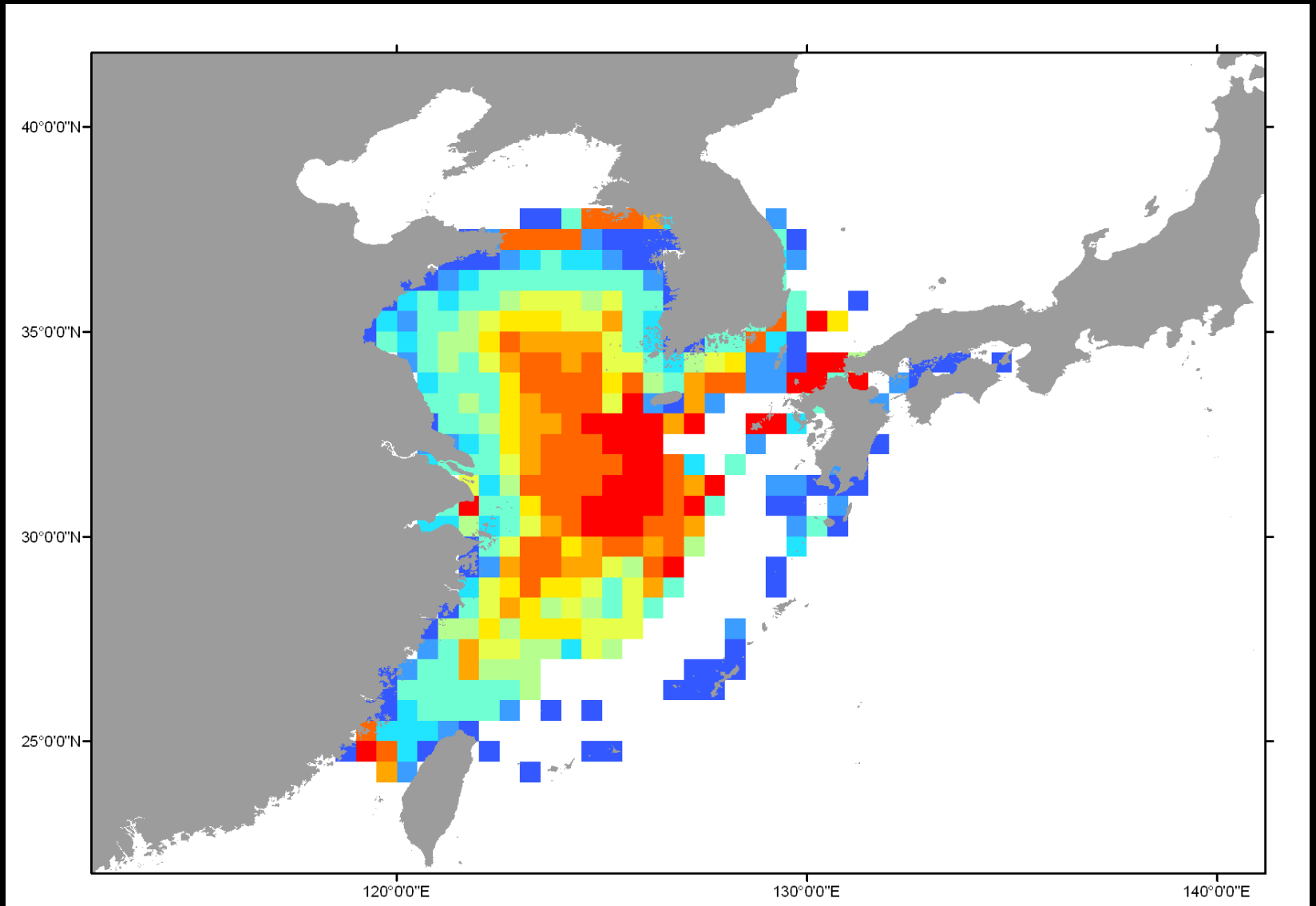
Small yellow croaker

Year 2021



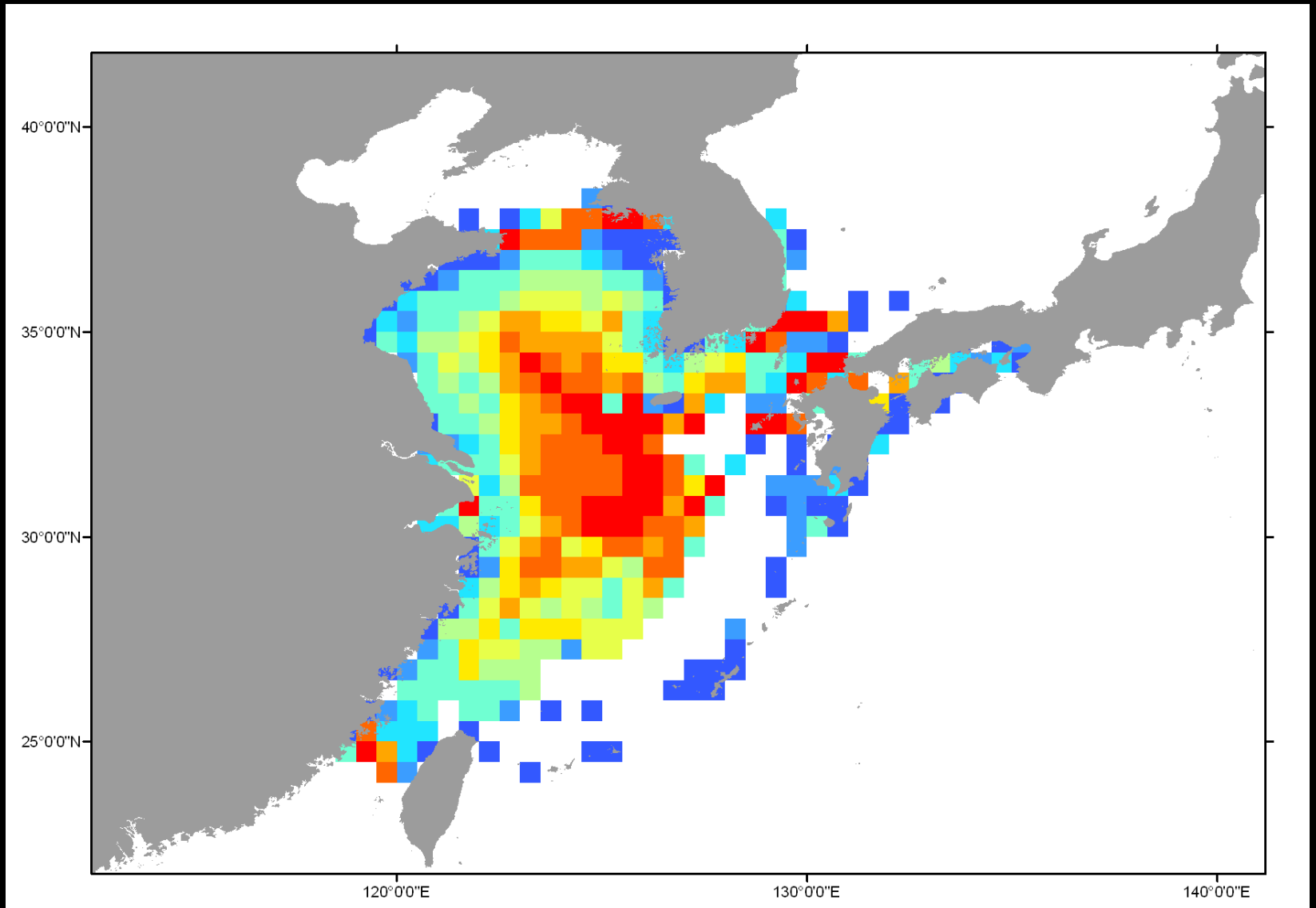
Small yellow croaker

Year 2026



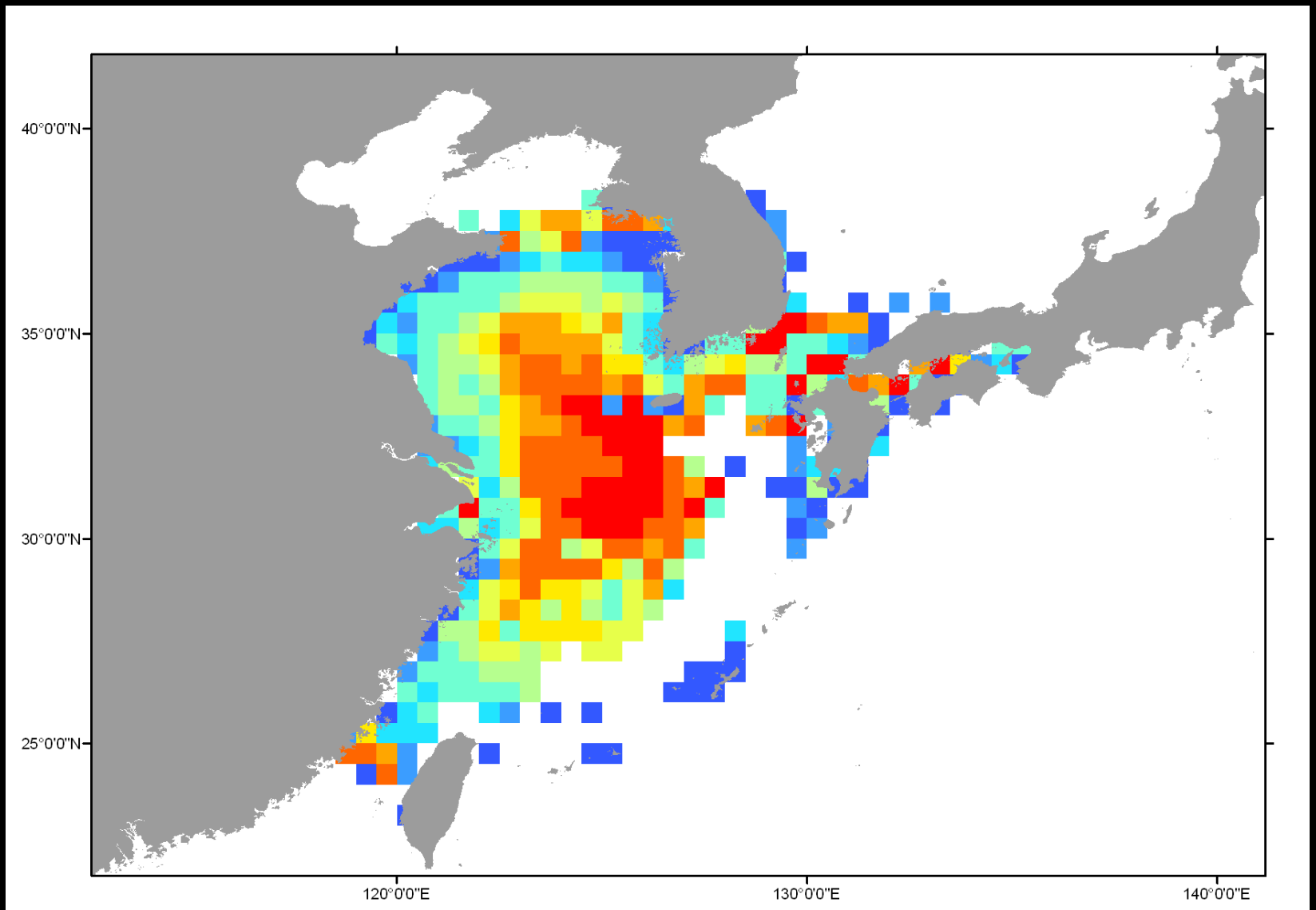
Small yellow croaker

Year 2031



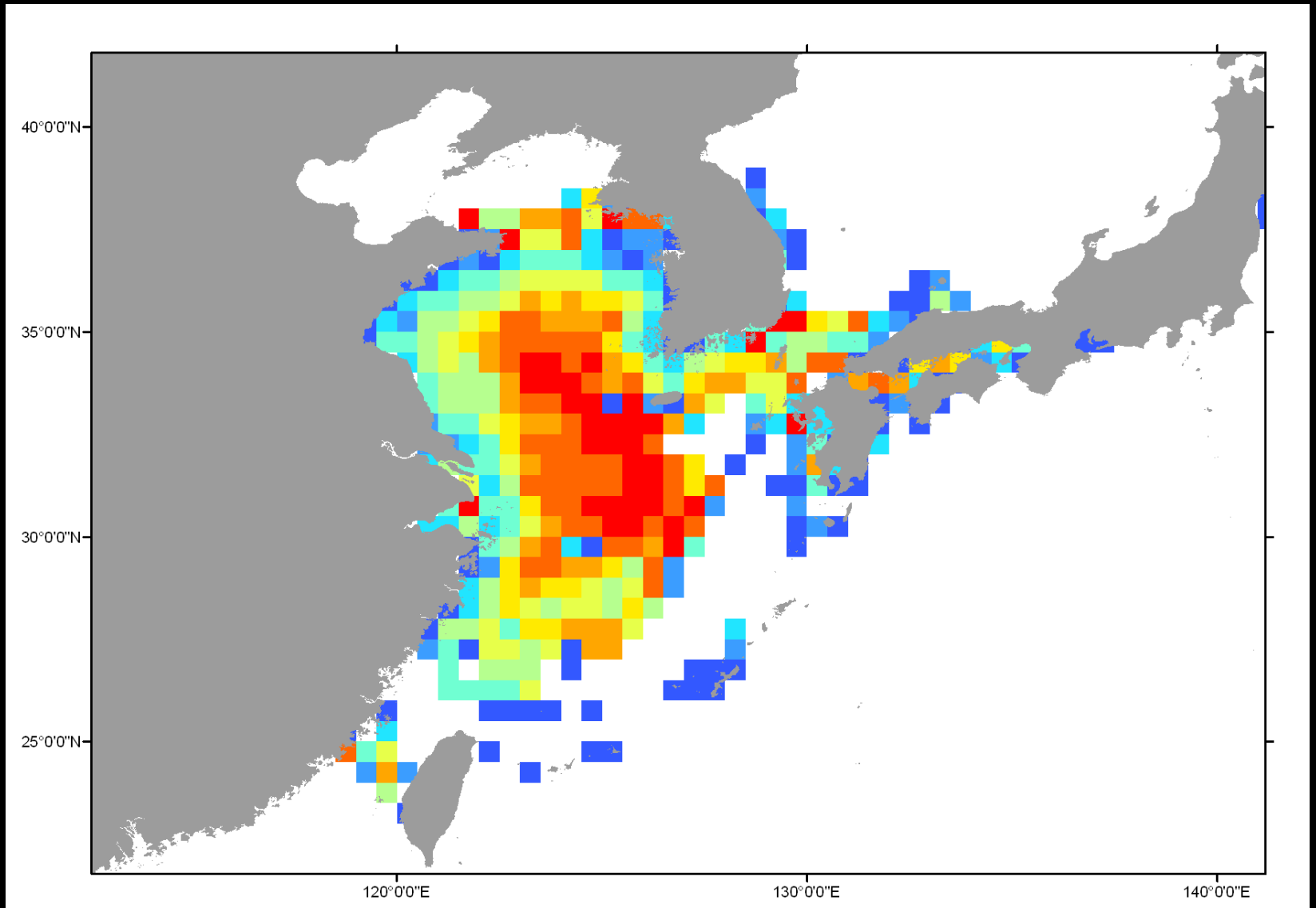
Small yellow croaker

Year 2036



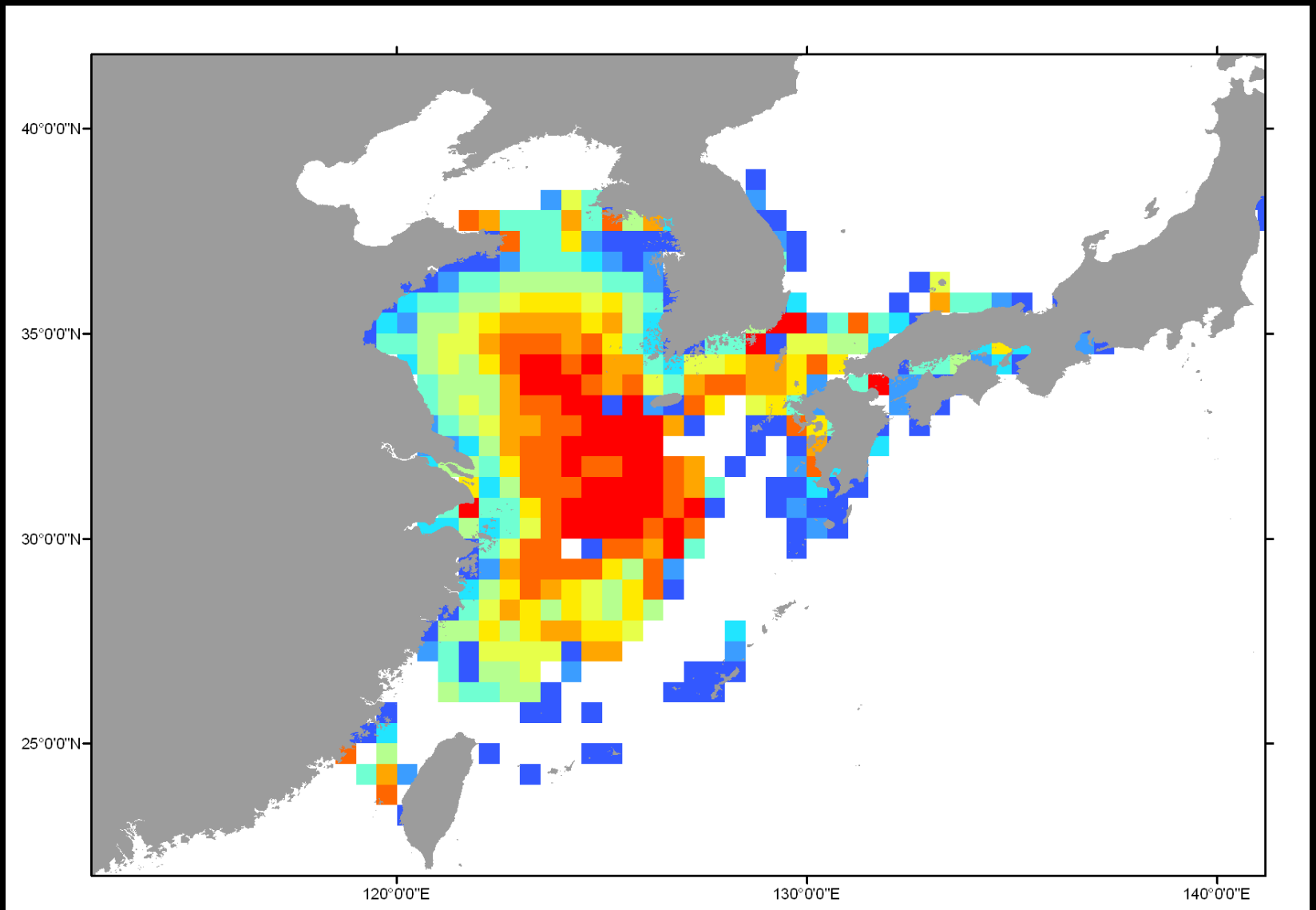
Small yellow croaker

Year 2041



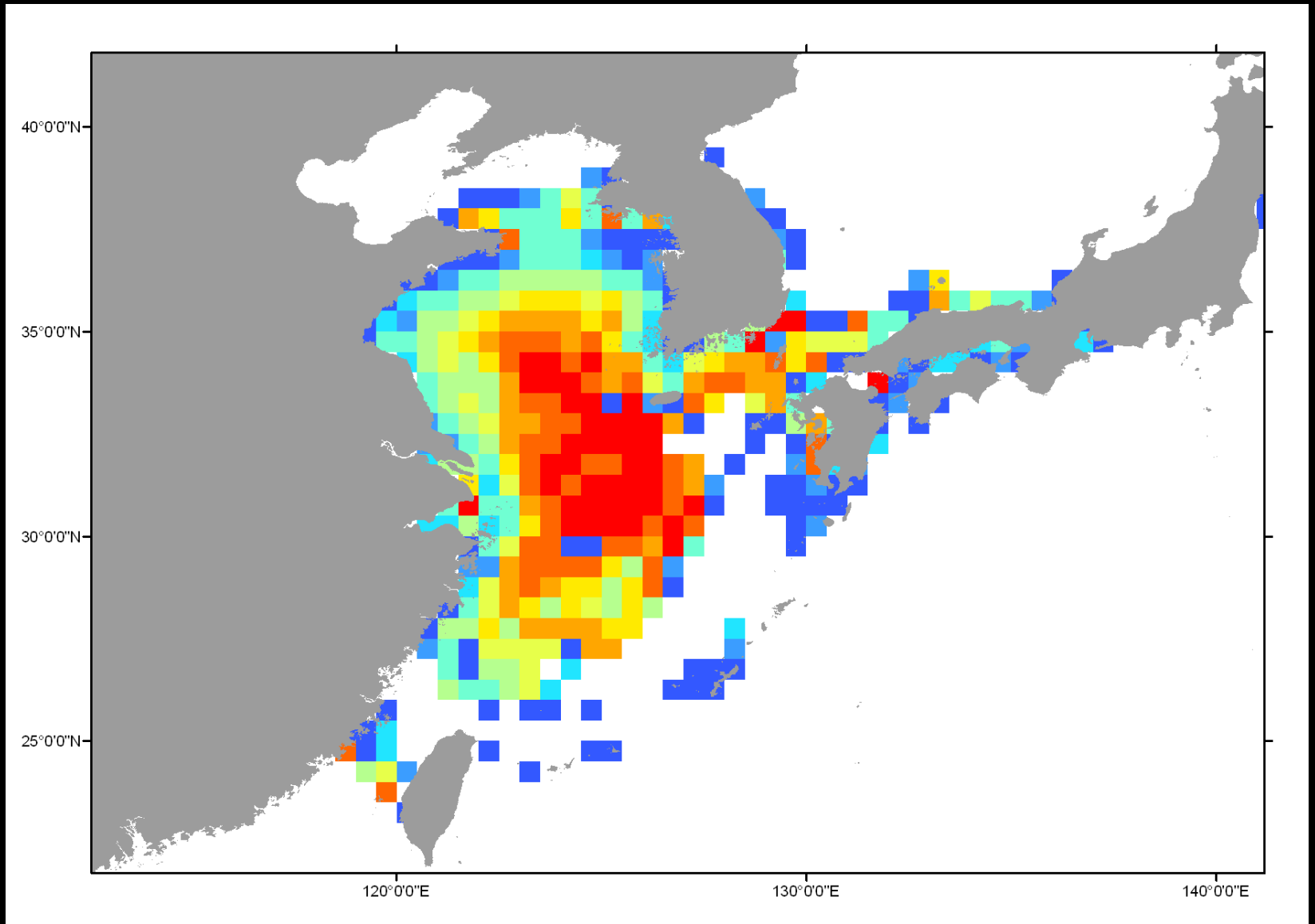
Small yellow croaker

Year 2046



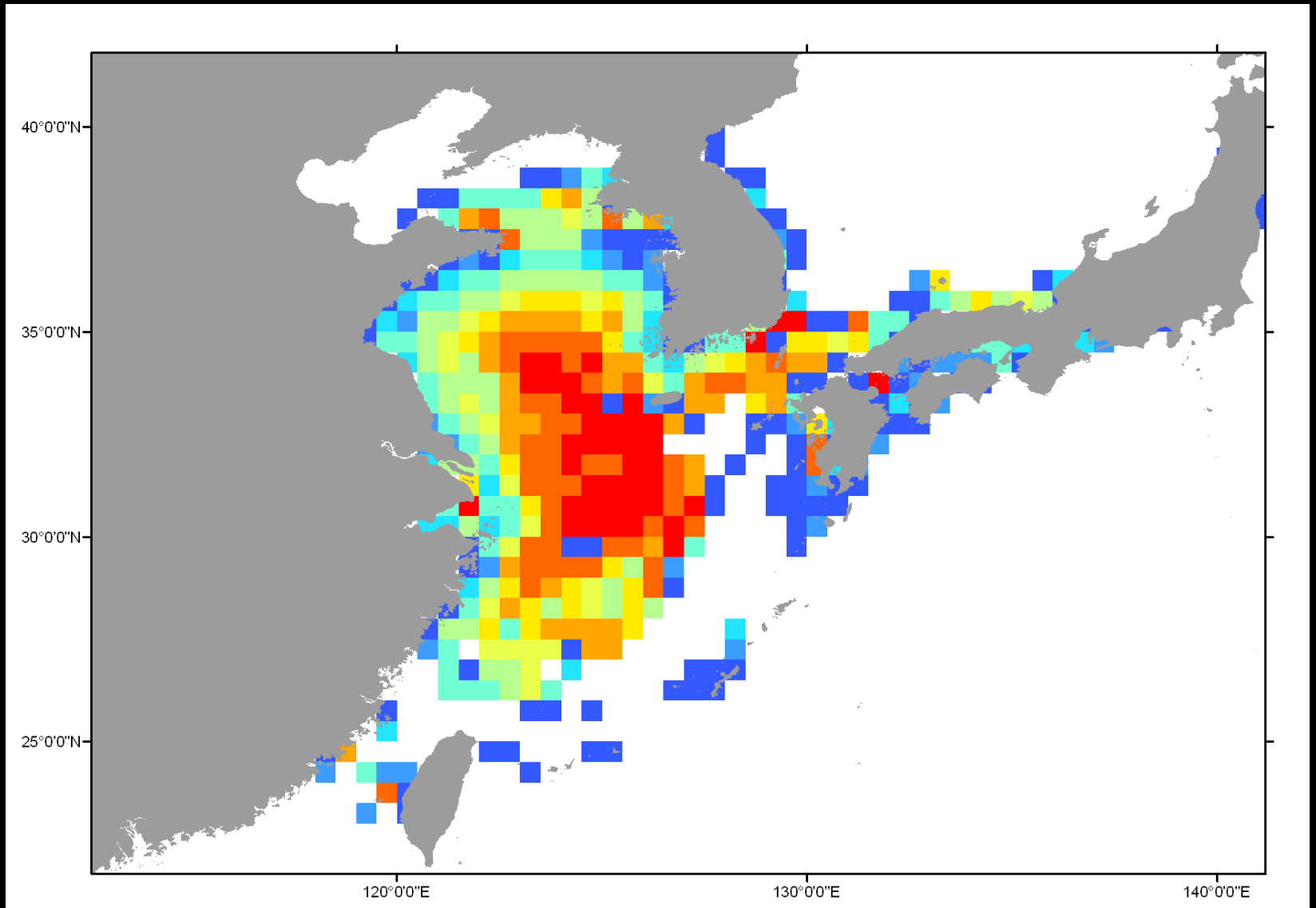
Small yellow croaker

Year 2051



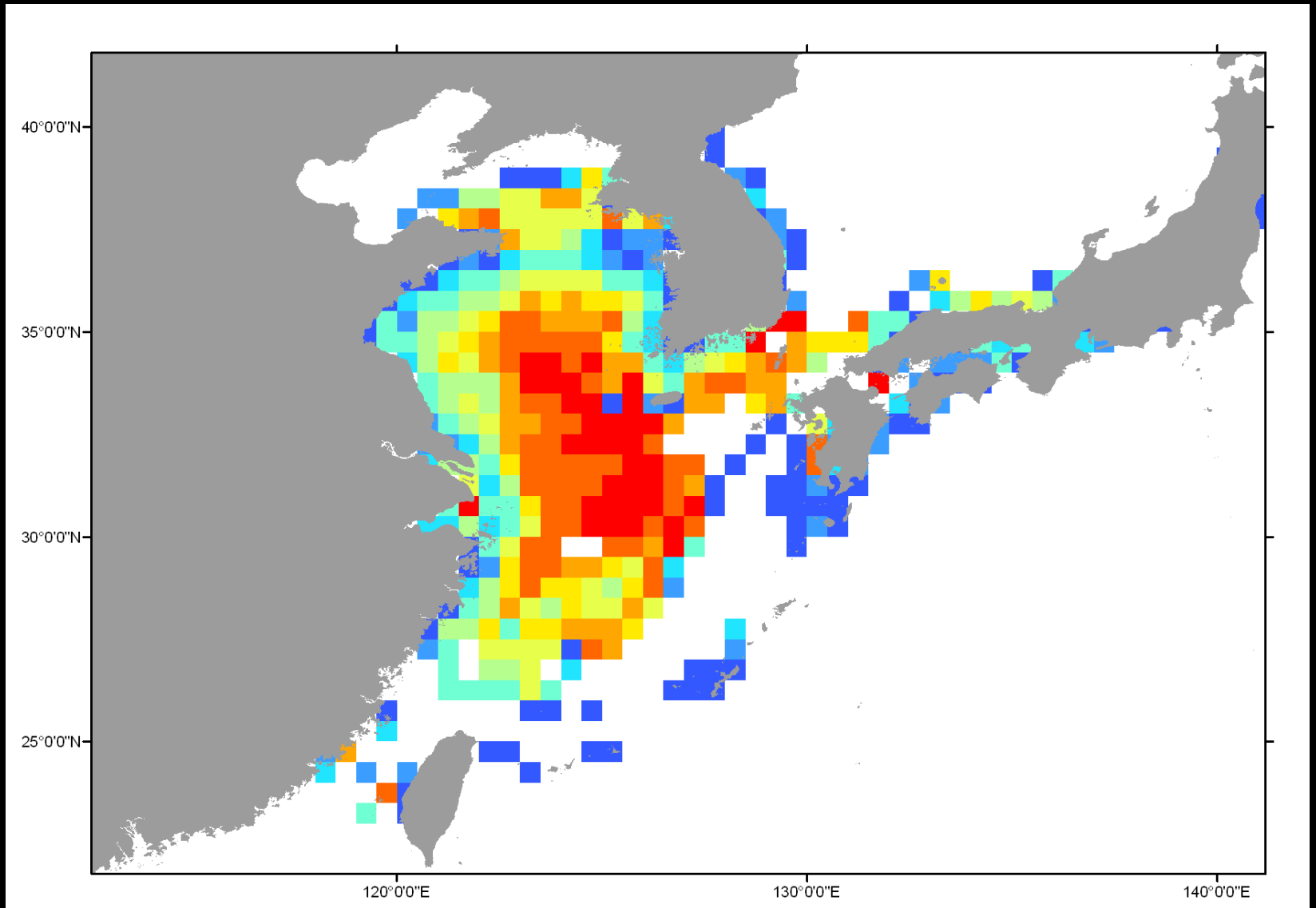
Small yellow croaker

Year 2056

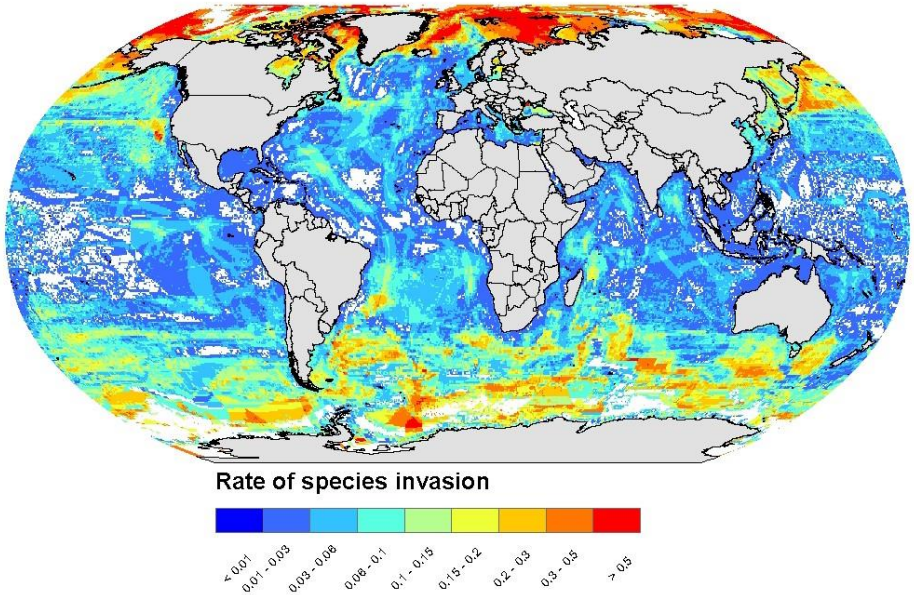


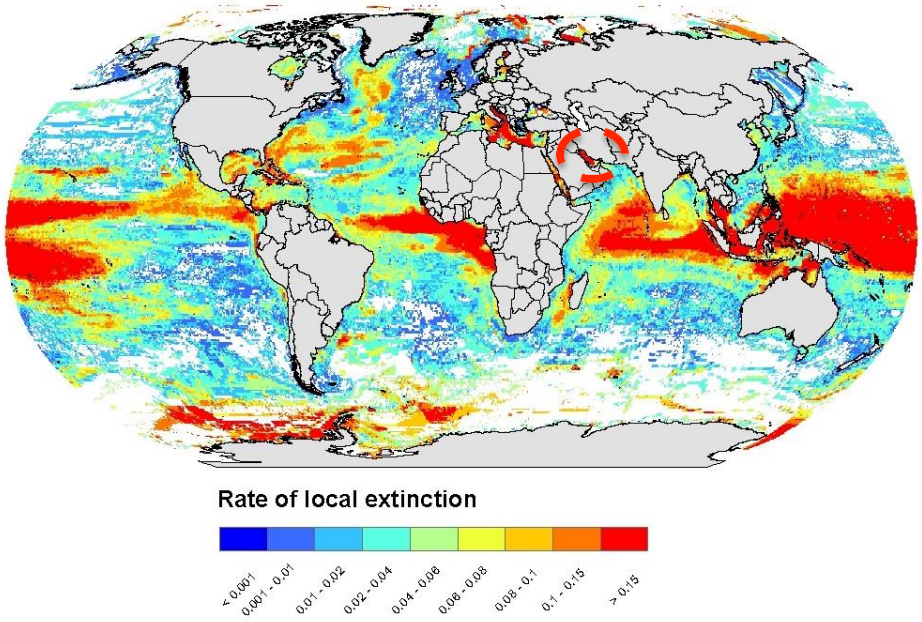
Small yellow croaker

Year 2060



Species invasion and local extinction

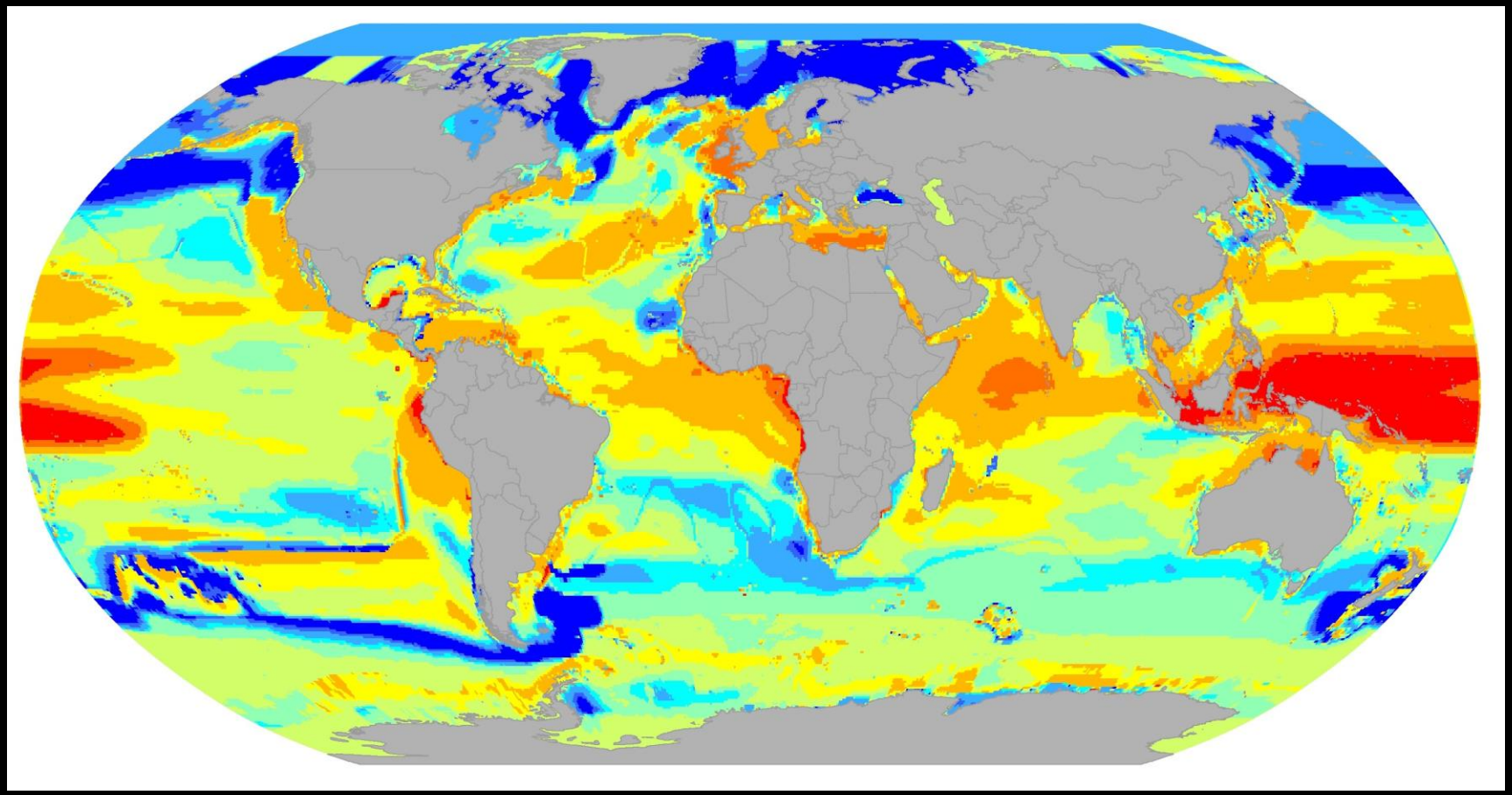




- >1000 spp of exploited marine invertebrates and fishes;
- Range shifts lead to species invasion and local extinction;
- 1000 species;
- 2050s relative to 2000s, RCP 8.5

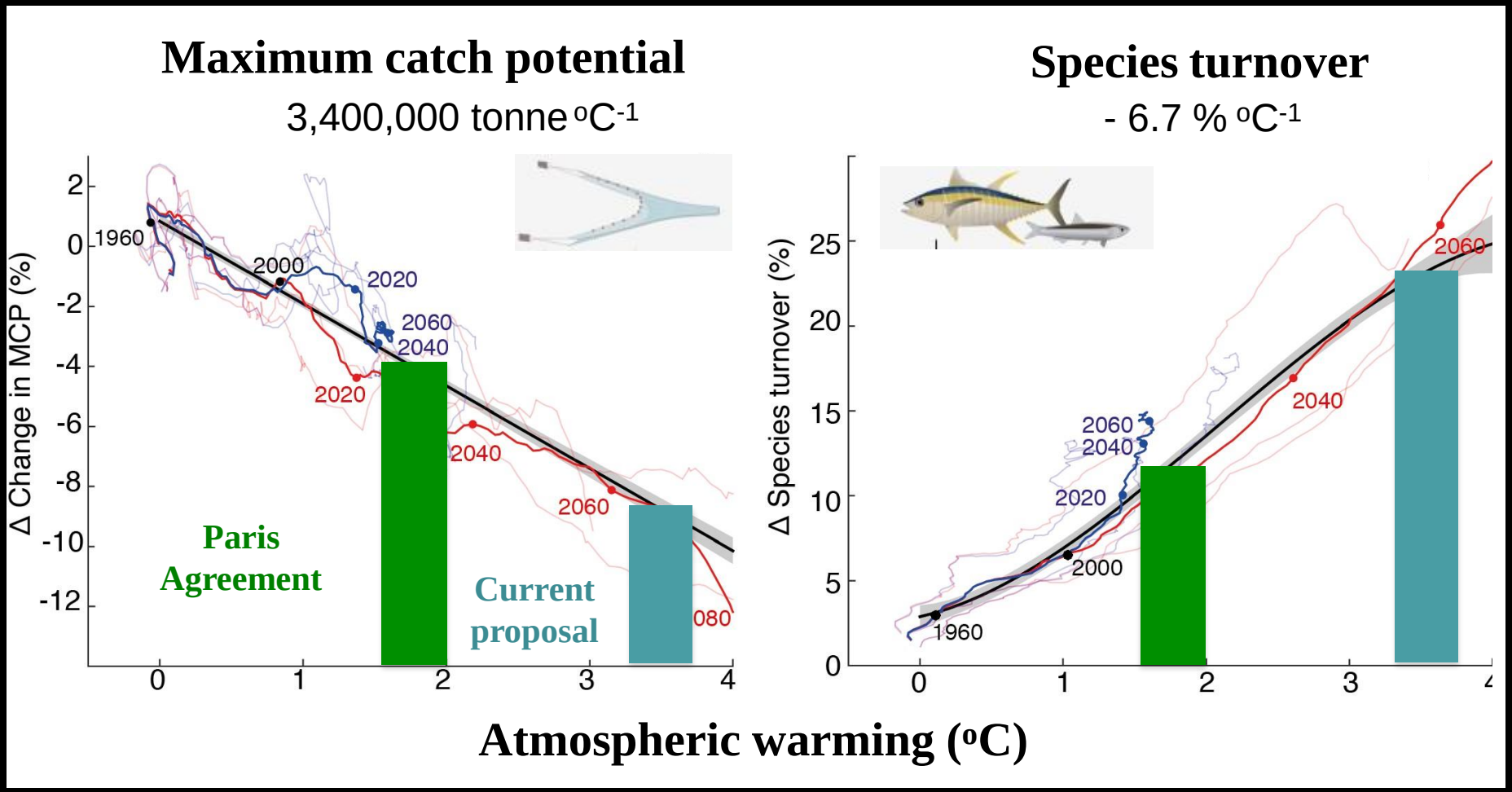
Cheung *et al*. (2009); Jones and Cheung (2015)

CHANGE IN MAXIMUM CATCH POTENTIAL (2041-2060 COMPARED TO 1971-2000, RCP 8.5)



Cheung et al. Update of IPCC (2014) AR5 WGII

Scaling between atmospheric warming and fisheries impacts



Cheung, Reygondeau, Frölicher (2016)

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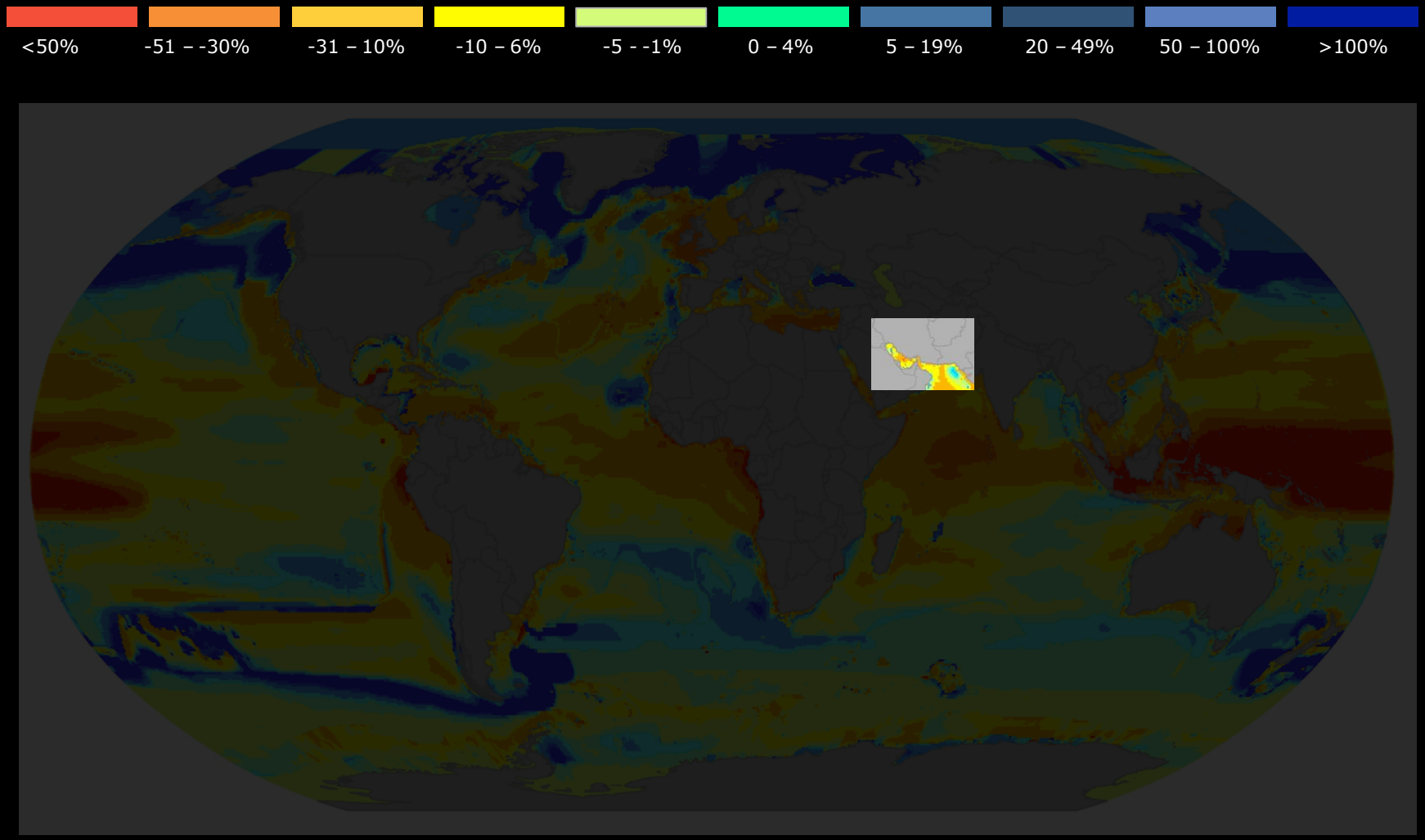


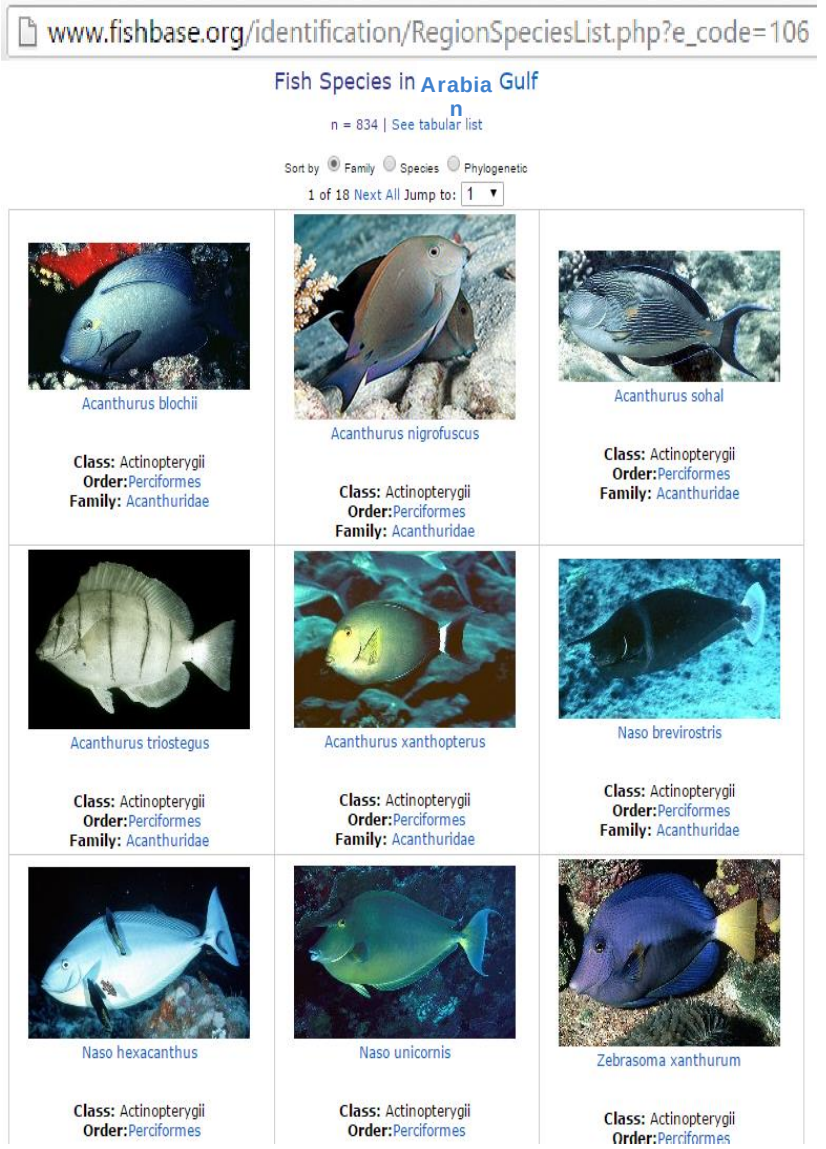
Cheung et al. Update of IPCC (2014) AR5 WGII

This talk

- Global overview of climate impacts on marine biodiversity and ecosystem services;
- Arabian Gulf marine biodiversity and their vulnerability to climate change;
- Arabian Gulf marine fisheries and their vulnerability to climate change;
- Options for climate risk-reduction.

Data collection – Fish species in Arabian Gulf

- We have characterized marine biodiversity for **834 fish species,** *based on initial discussions with stakeholders*, and have incorporated this information into an online database for easy access by stakeholders in the region.
- The database includes pictorial depictions, where possible;
- The database can be sorted by family, species, or phylogenetic tree;
- Selected 50 species with consultation with stakeholders for further study.



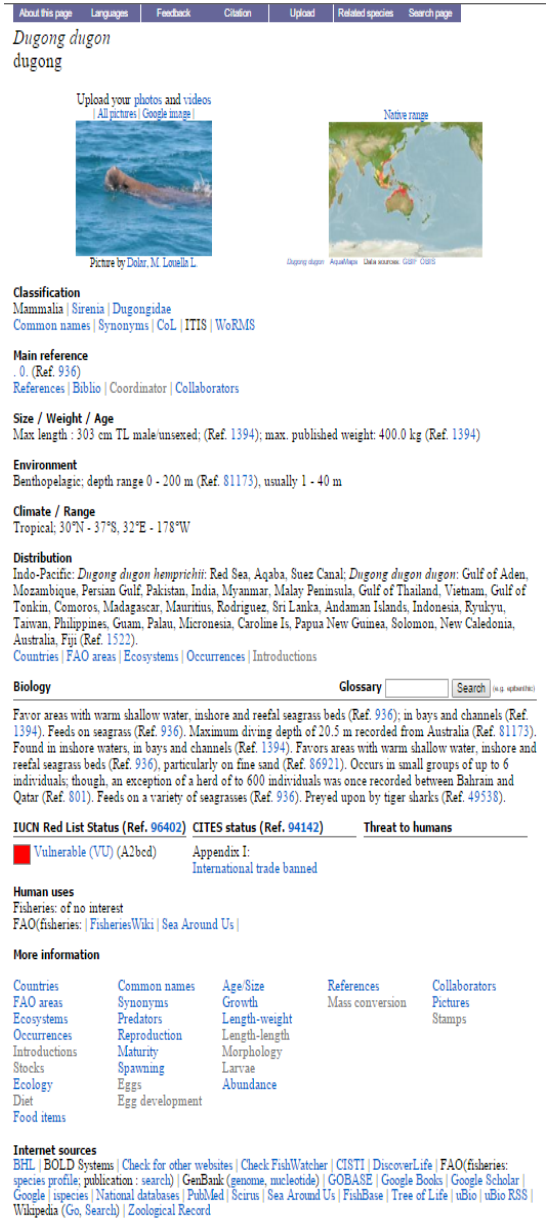
Data collection – Non-Fish species in Arabian Gulf

- We have also characterized marine biodiversity for **558 non-fish species,** *based on initial discussions with stakeholders*, and have incorporated this information into a separate online database for easy access by stakeholders in the region;

- The database includes pictorial depictions, where possible;

- Available at the following website: http://www.sealifebase.org/

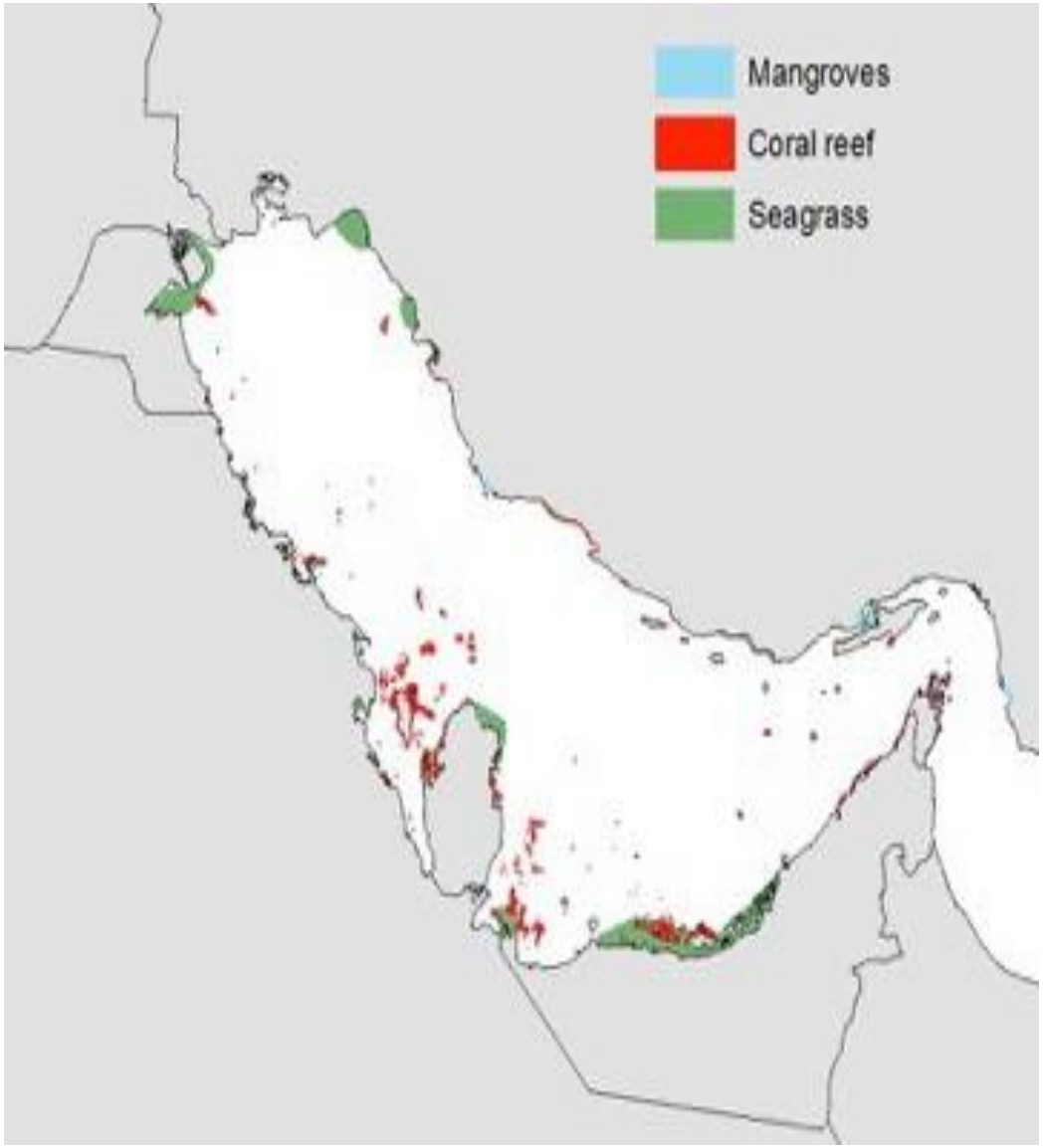
- Selected 7 non-fish species with consultation with stakeholders for further study.



Data collection – Habitats

- We have also focused on certain habitats, namely coral reefs, seagrasses, mangroves;
-
- We have developed a series of maps, based on publicly available sources and local data, that characterize the spatial distribution of these habitats;

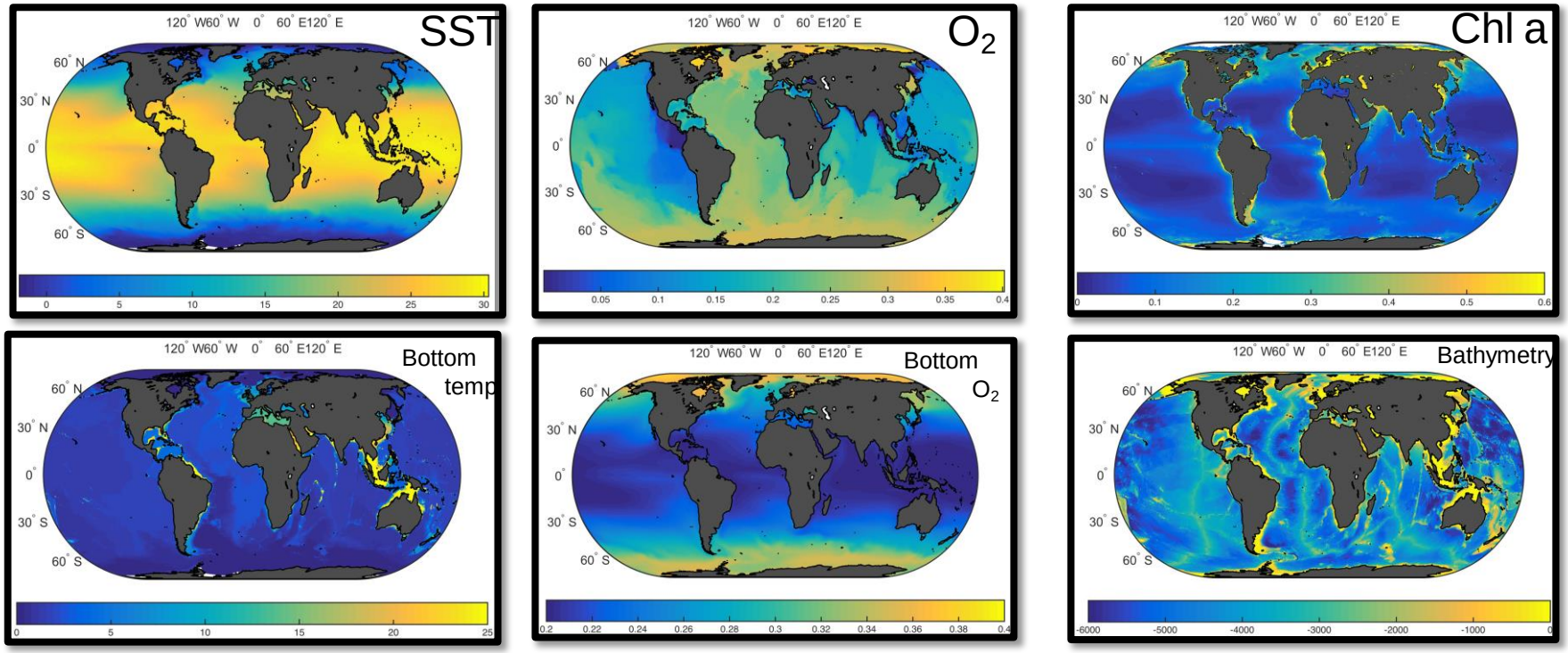
- These maps are used as inputs in modeling the distribution of “priority” fish and charismatic species.



Materials and Methods

Environmental datasets

Global coverage



Parameters: temperature, salinity, Chl *a*, POC, bathymetry, oxygen concentration, euphotic depth, nutrients concentration

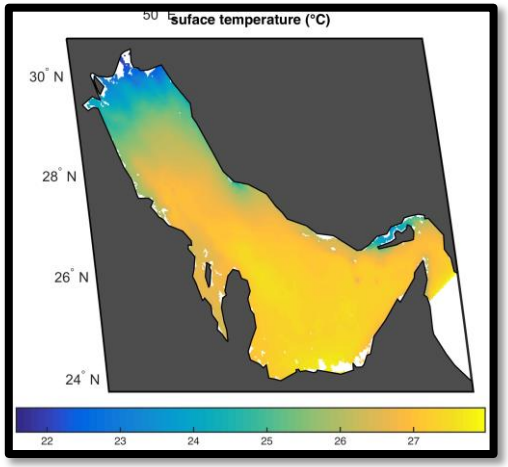
Resolution: annual average (1950-2010) for a grid of 0.25° of resolution. Vertical resolution: Surface and Seafloor (if available)

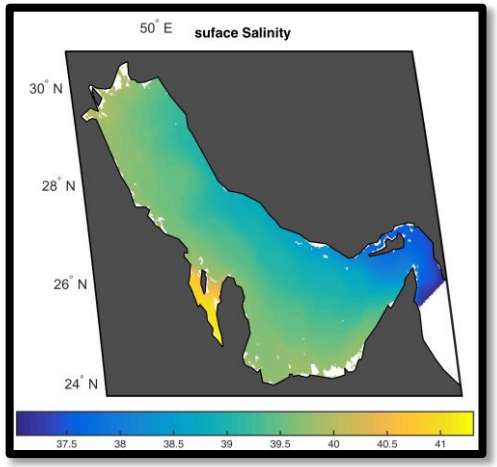
Source: GEBCO, NOAA (World Ocean Atlas 2013b), NASA

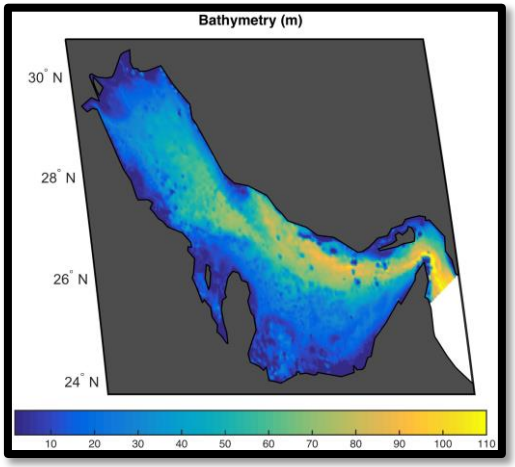
Materials and Methods

Environmental datasets

Regional coverage







Parameters: temperature, salinity, bathymetry from regional model (of spatial Resolution), Chl a, POC, oxygen concentration, euphotic depth, nutrients concentration

Regridded using a spline interpolation with regional model values

Resolution:

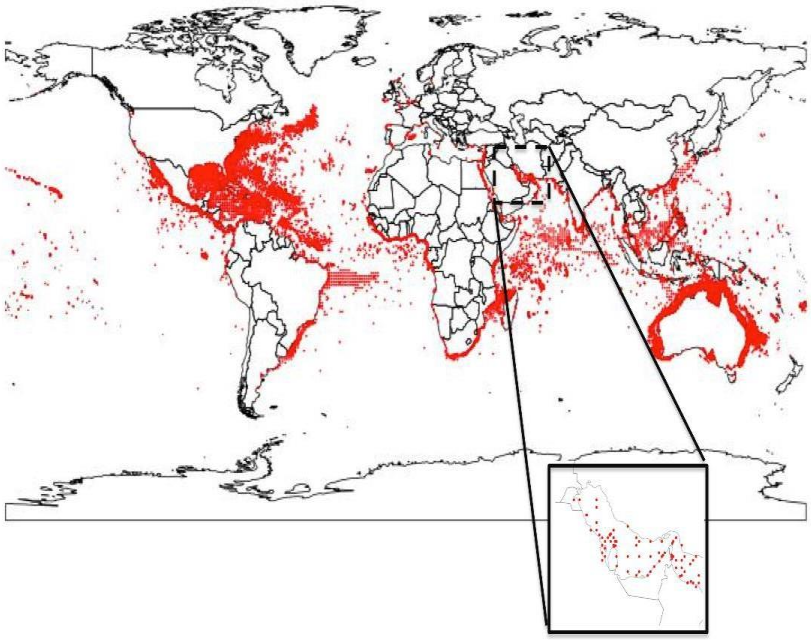
Space: 0.0275°

Time : mean values for 2000's, 2050's 2090's, and annual value (1950-2000)

Vertical resolution: surface and bottom (if available)

Materials and Methods

Biotic datasets



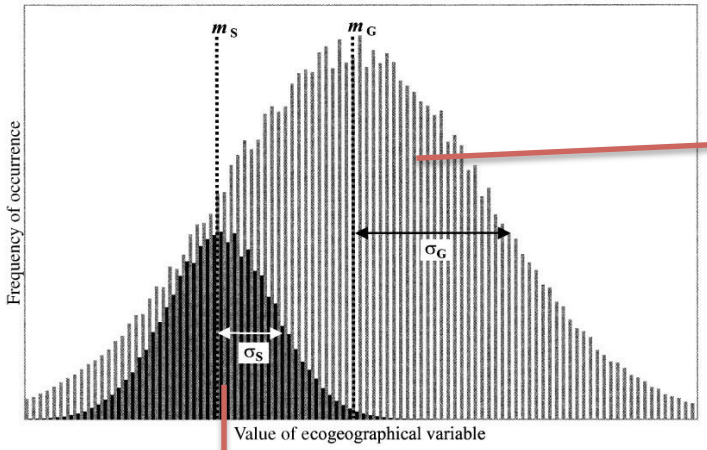
Source: Ocean Biogeographic information system, Global Biodiversity Information Facility and Fishbase

Type: Occurrence data

Metadata: For each species: Taxonomy, habitat, size, trophic level, IUCN index

Materials and Methods

Concept of the environmental niche: (Hutchinson, 1957)

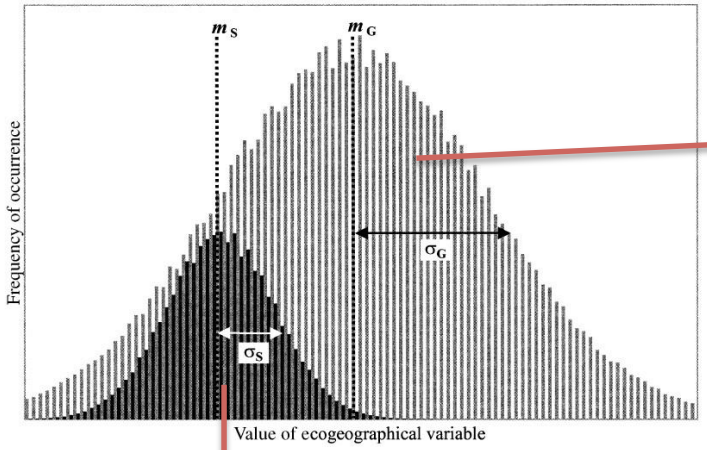


All the environmental possibilities offered by the biosphere

Environment experienced by the species

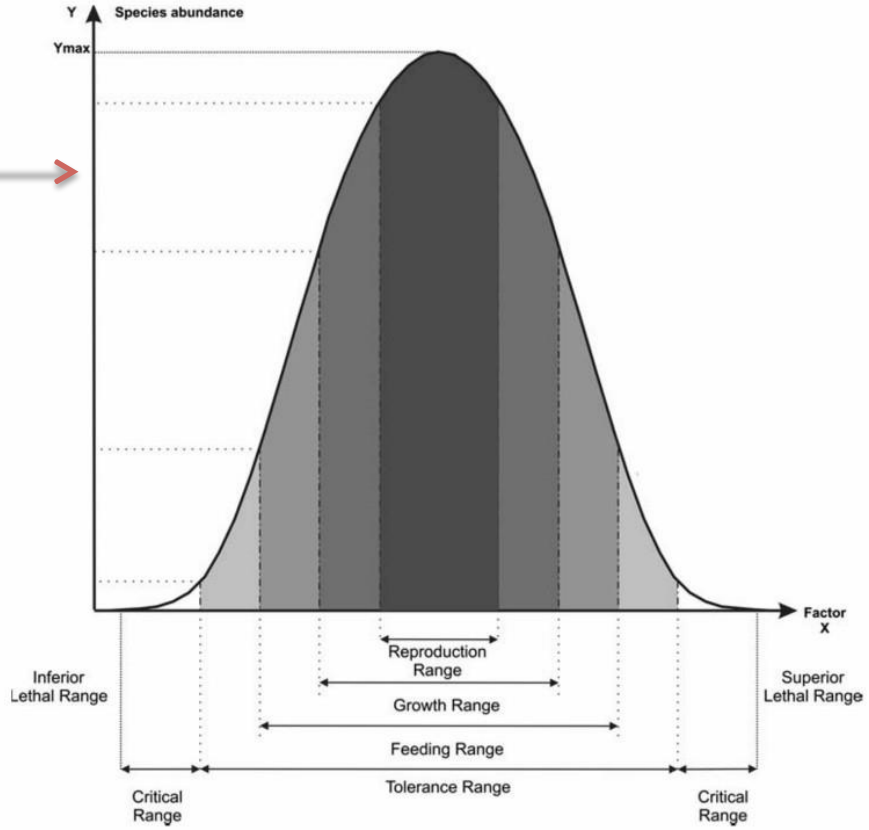
Materials and Methods

Concept of the environmental niche: (Hutchinson, 1957)



All the environmental possibilities offered by the biosphere

Environment experienced by the species

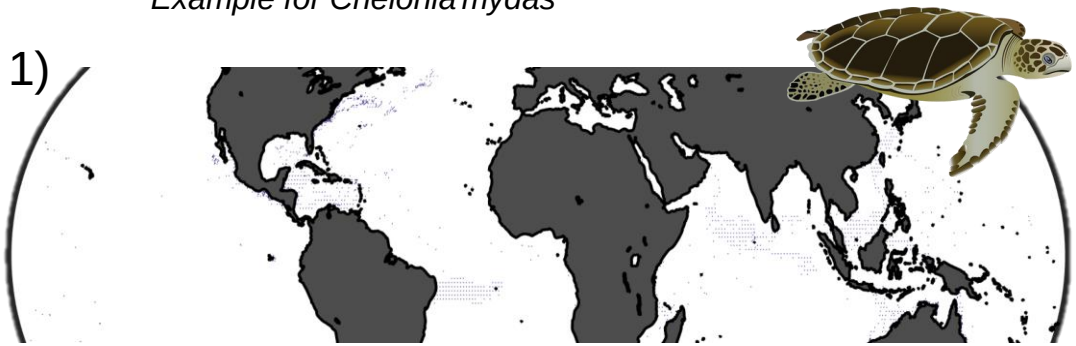


Materials and Methods

Environmental envelope models:

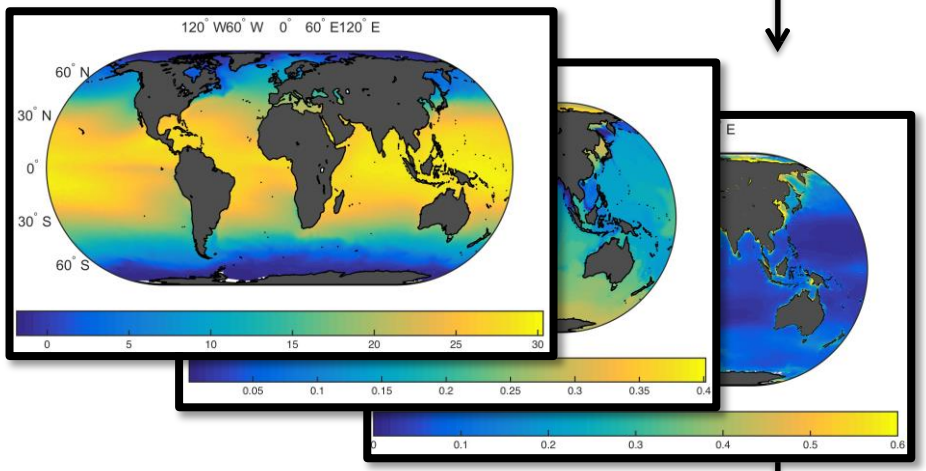
Example for Chelonia mydas

1)



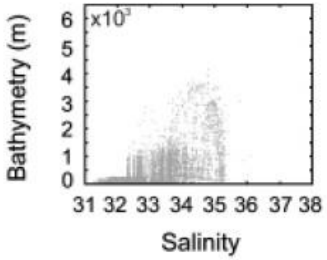
Observation of the species

2)



Characterisation for each observation of the most accurate environmental conditions influencing the distribution of the species

3)

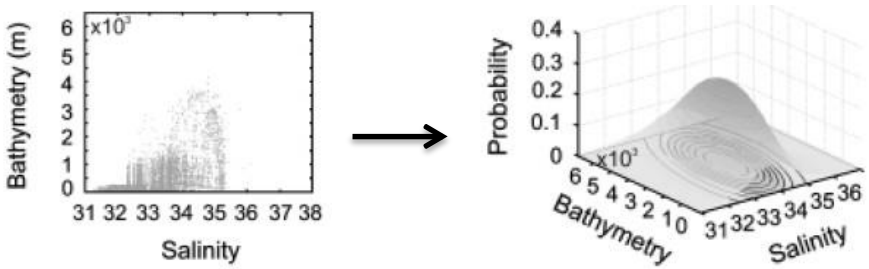


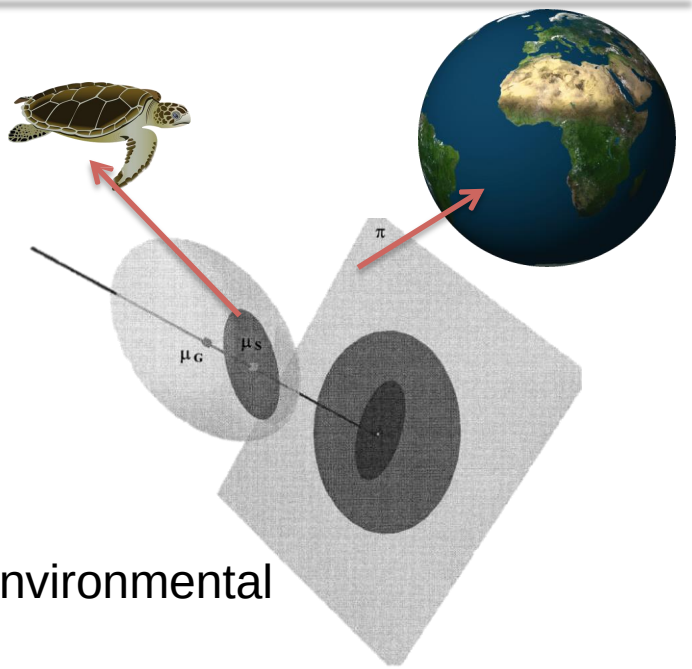
Quantification of the environmental range of the species for each parameters

Materials and Methods

Environmental envelope models:

4) Modelisation of the fundamental niche of the species:
Prob (occurrence)=f(Environmental condition)

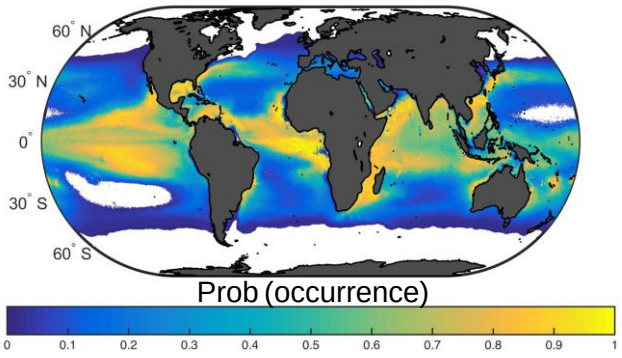


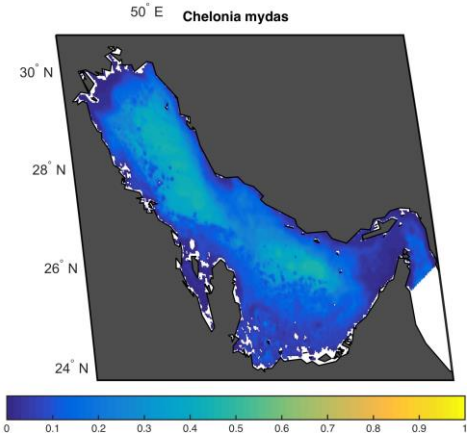


Model: NPPEN, ENFA, Bioclim

In a multivariate environmental dimension

5) Projection of the niche at a global scale to test and calibrate de model



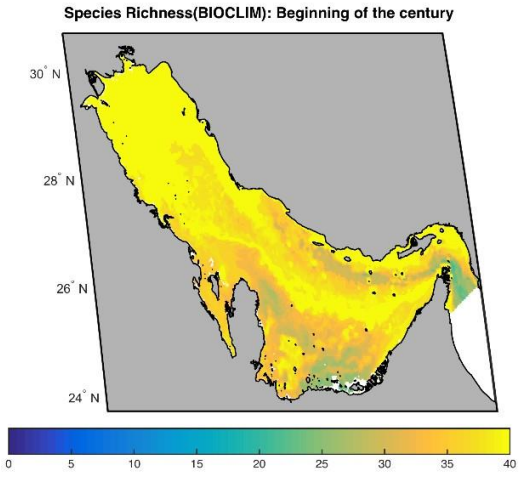


Rescale at a regional level for 2000's, 2050's and 2090's.

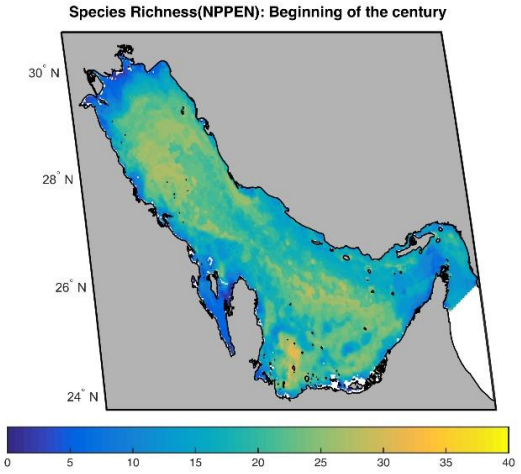
Modeling results - Current day species richness (early 21st Century)

Model simulations of current day species richness varies by model, with the NPPEN predicting the lowest level per area and ENFA the highest level.

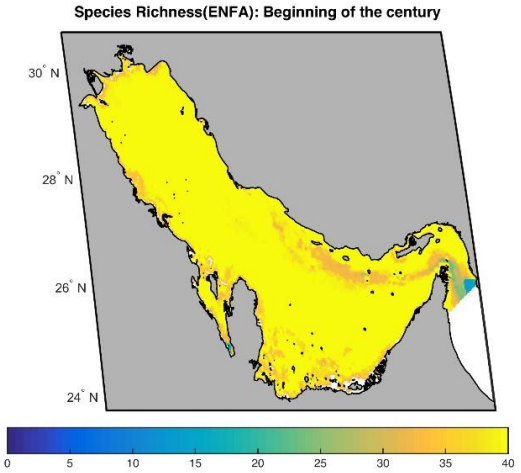
BIOCLIM



NPPEN



ENFA



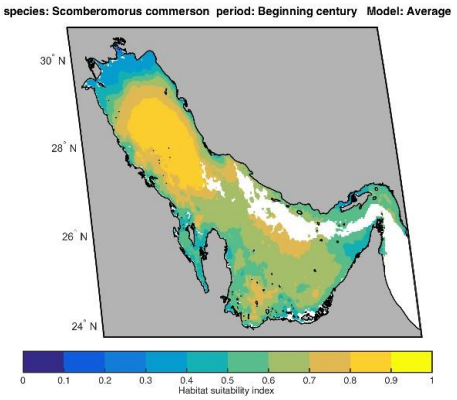
Species richness

Modeling results – Shifts in spatial distribution of priority fish species

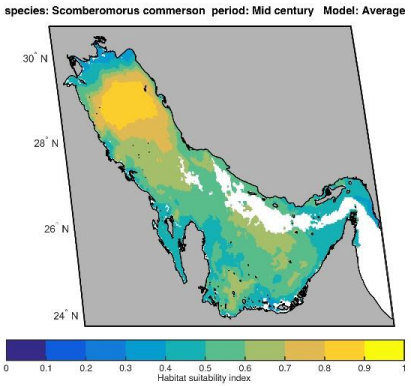
- Projected map of habitat suitability under current (2010) and future (2050 and 2090) distributions for each species under climate change (multi-model average);

- E.g., Spanish mackerel *Scomberomorous commerson* under the IPCC's Representative Concentration Pathway 8.5 (RCP8.5).

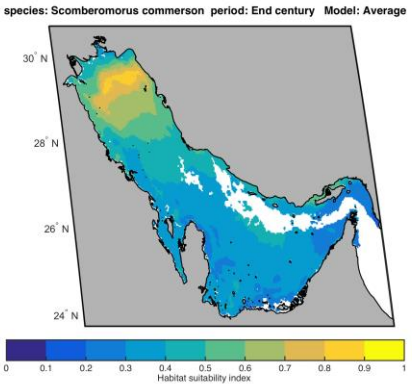
2000 (Current Day)



2050 (RCP8.5)



2090 (RCP8.5)

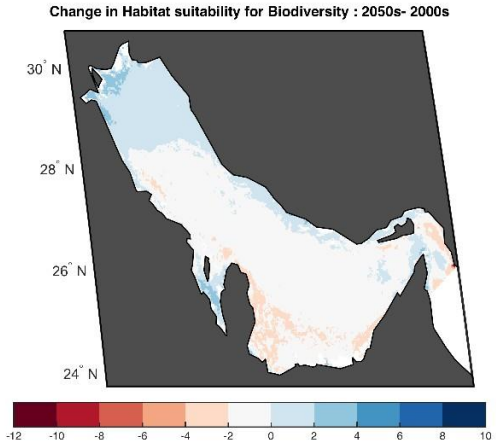


Habitat suitability

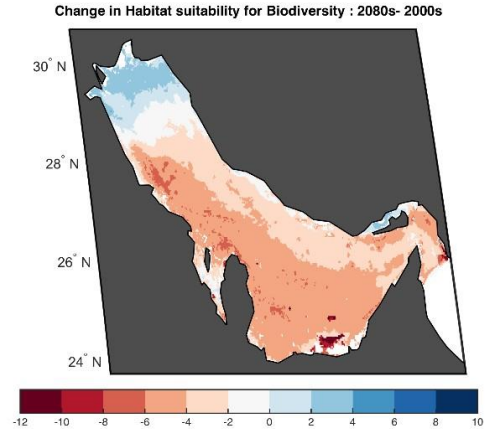
Modeling results - impacts to species' habitats

- Most of the Arabian Gulf is predicted to experience a **decrease** in habitat suitability for the priority species under climate change;
- Deteriorating habitats are particularly focused on the south and southwestern areas of the Gulf.

2050s



2090s



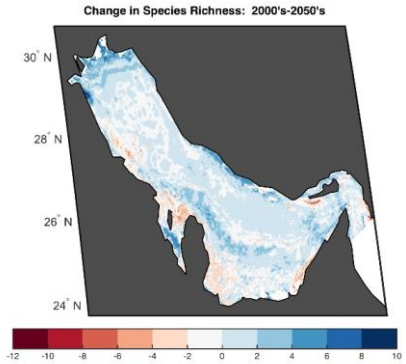
Loss **Habitat suitability** **Gain**

Modeling results – turnover of priority species by 2050 and 2090

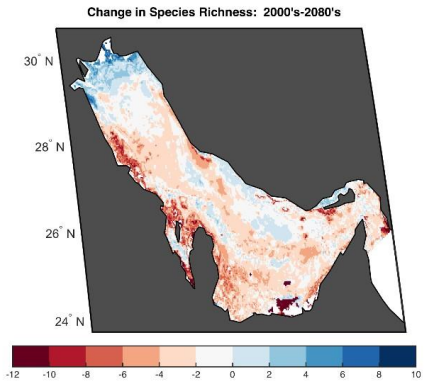
- The model outputs predicted high rates of local extinction in the Arabian Gulf due to climate change by the 2090s in the RCP8.5 scenario;

- By 2050, local extinction is concentrated along the southwest coast while species gains are predicted in the northern coast.

2050s



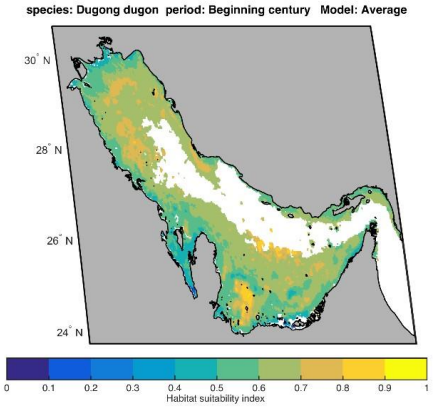
2090s



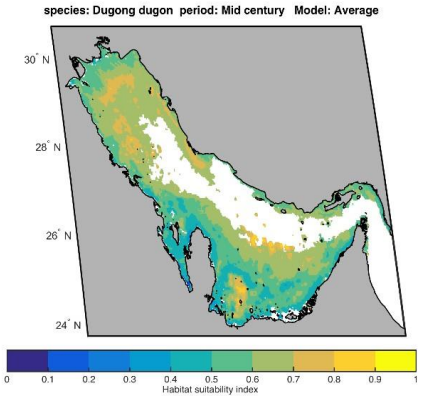
← ExNncNon Invasion →

Climate change impacts on Dugong habitats (RCP8.5)

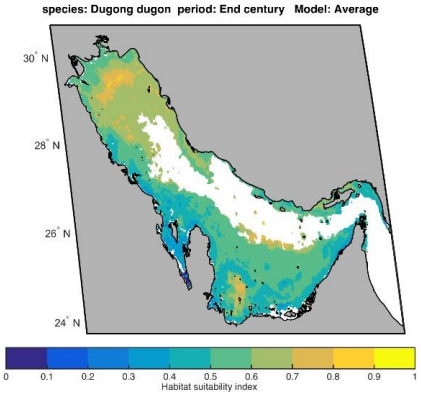
2000s



2050s



2090s

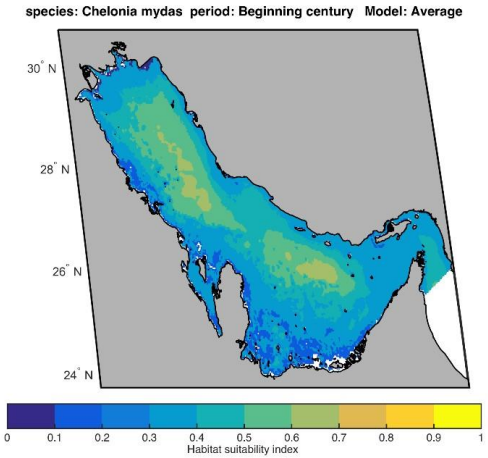


Habitat suitability

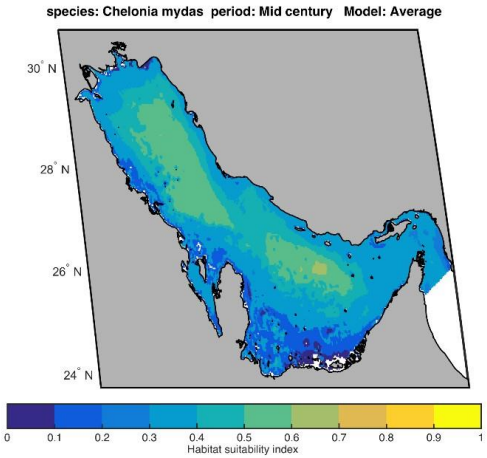
- Decrease in habitat suitability for dugong, particularly in southwestern part of its range.

Climate change impacts on green turtle habitats (RCP8.5)

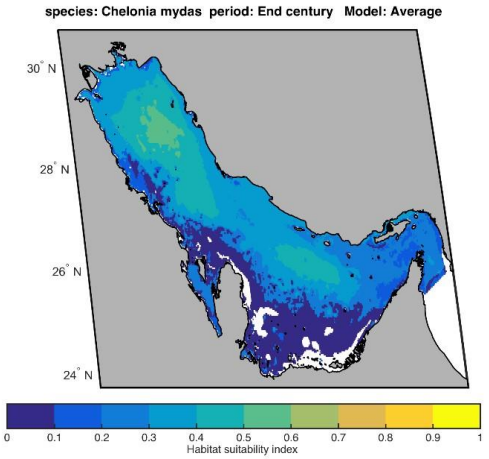
2000s



2050s



2090s

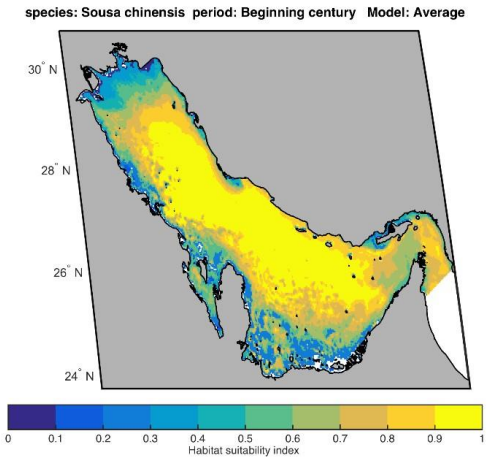


Habitat suitability

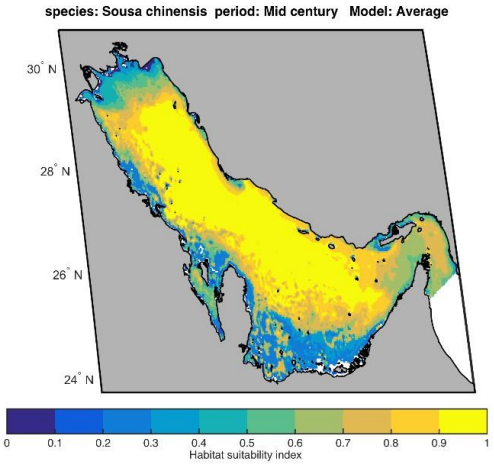
- Decrease in habitat suitability for green turtle, particularly in southwestern part of its range;
- However, these maps mainly represent the foraging habitat.

Climate change impacts on Indo-Pacific humpbacked dolphin habitats (RCP8.5)

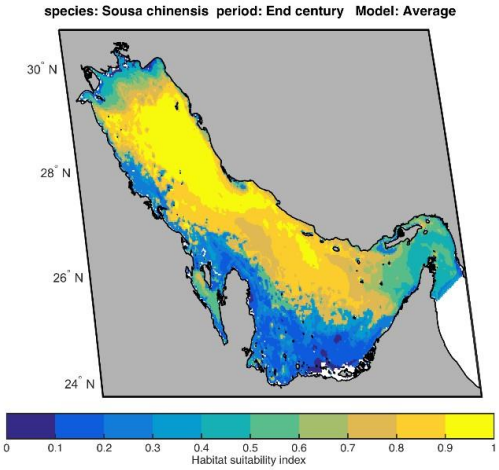
2000s



2050s



2090s

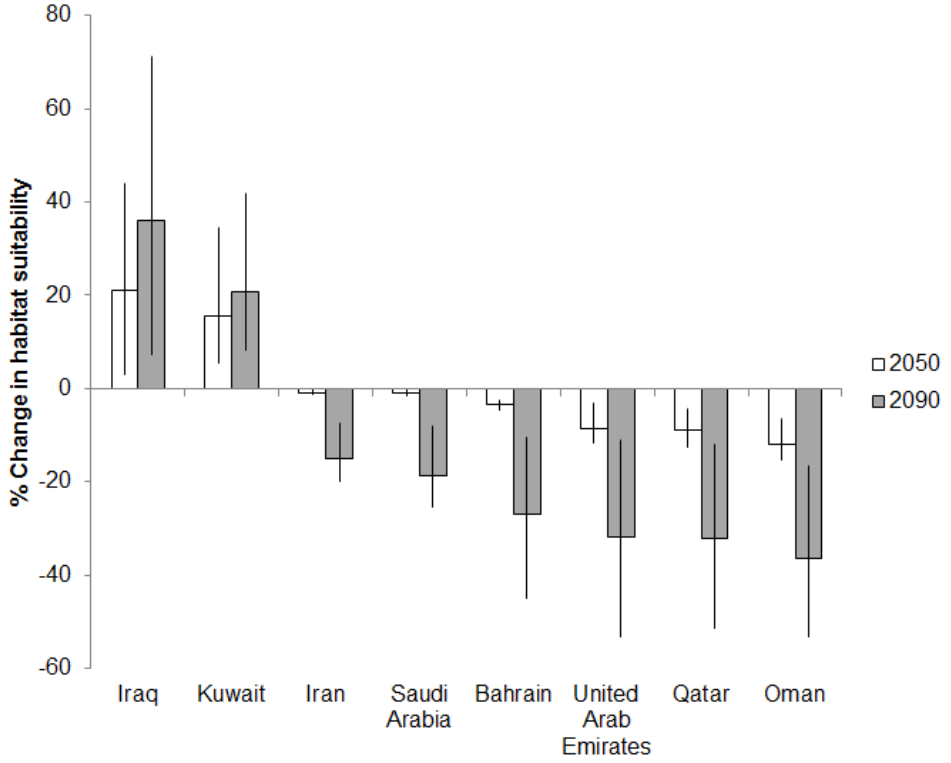


Habitat suitability

- Decrease in habitat suitability for Indo-Pacific humpbacked dolphin, particularly in southwestern part of its range.

Vulnerability of non-fish species to climate change

- Decrease in habitat suitability of all non-fish species considered in the 2050s and 2090s due to climate change for most countries, except Iraq and Kuwait.



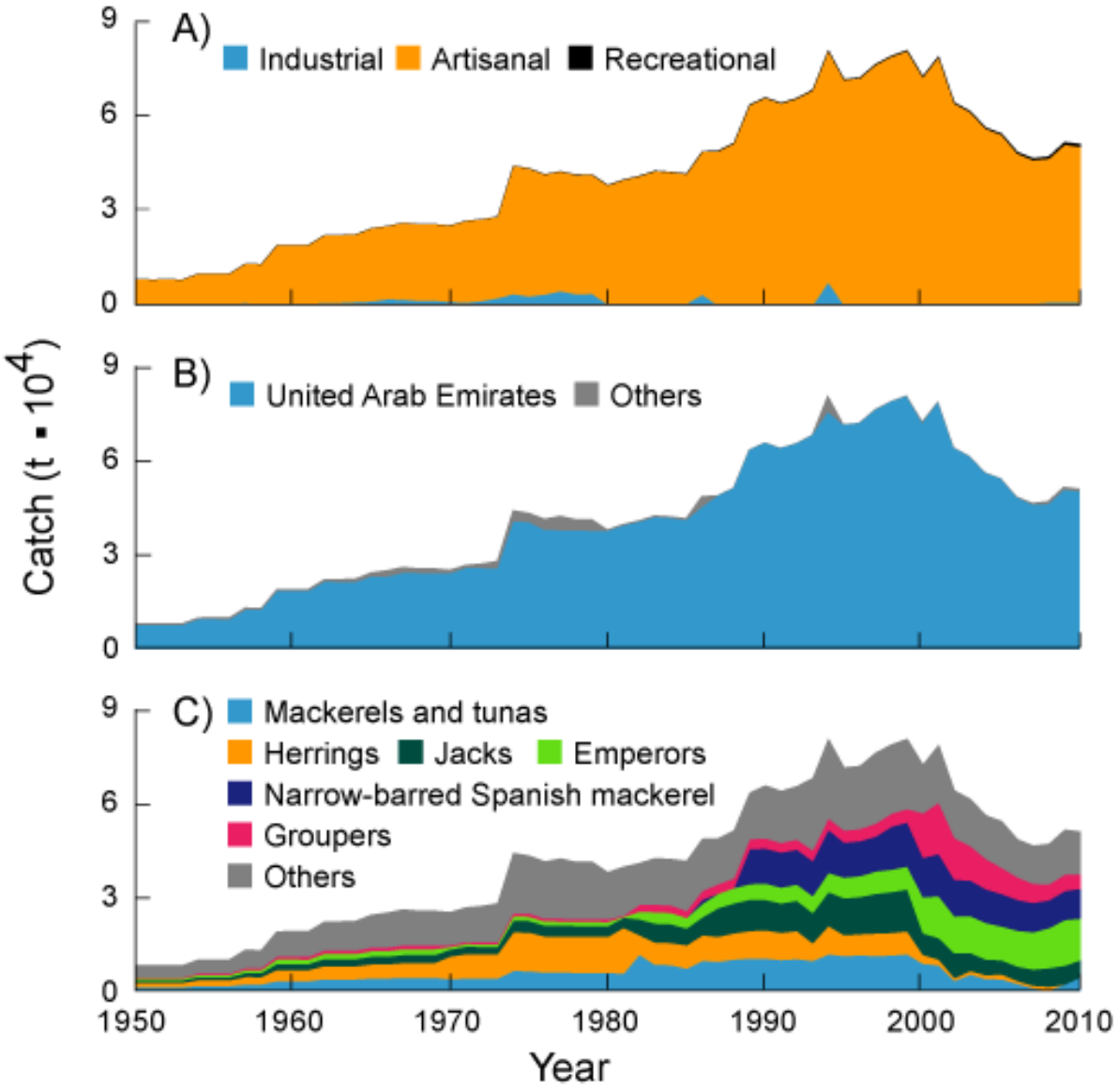
This talk

- Global overview of climate impacts on marine biodiversity and ecosystem services;
- Arabian Gulf marine biodiversity and their vulnerability to climate change;
- Arabian Gulf marine fisheries and their vulnerability to climate change;
- Options for climate risk-reduction.

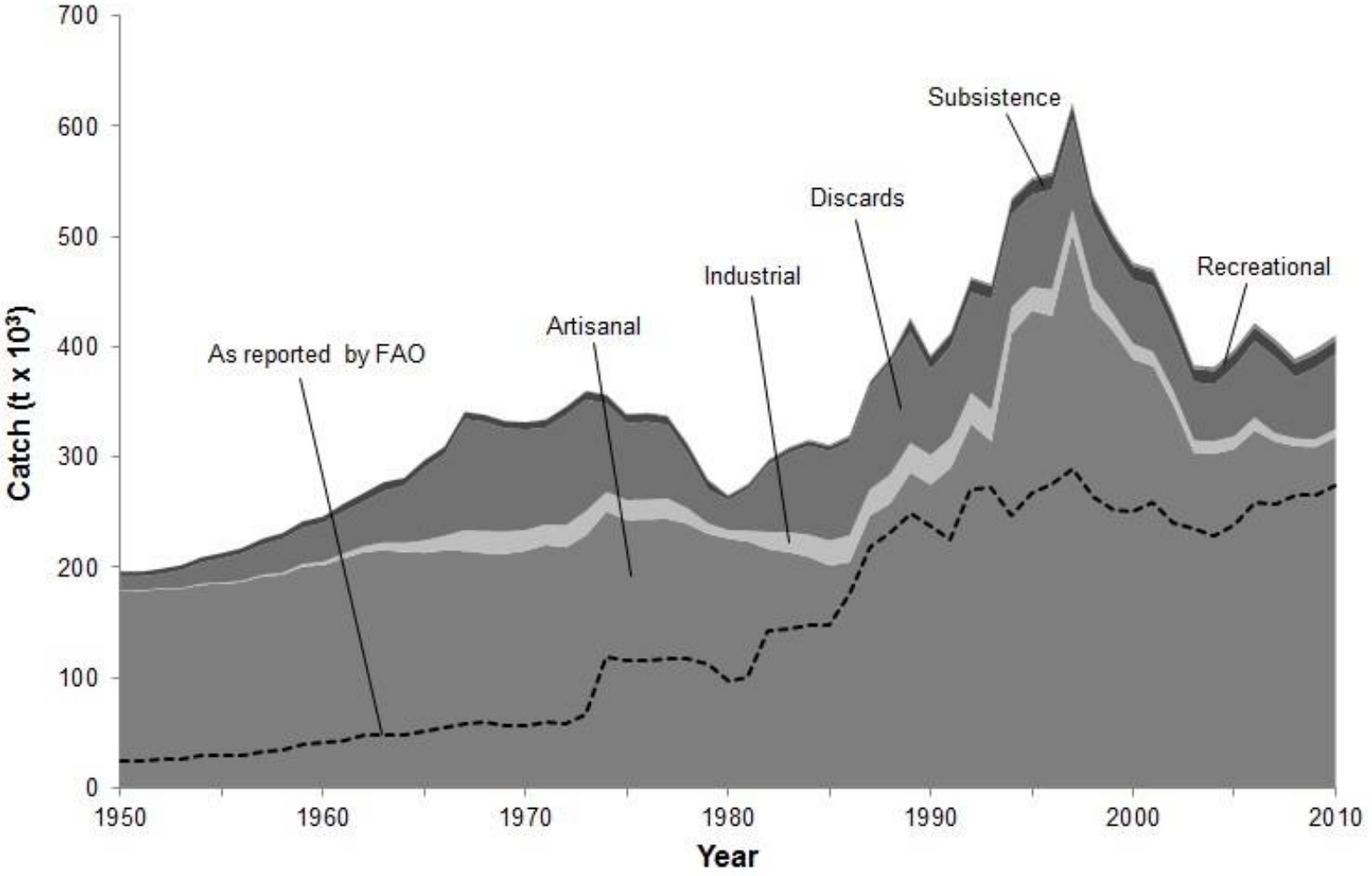
Fisheries catch reconstruction

- Identify and source existing, reported catch time series;
- Identify sectors, time periods, species, gears, etc., that are not covered in FAO or national data
- Acquire all available alternative information sources;
- Developed data anchor points in time for missing data items;
- Estimate final total catch time series estimates, combining reported catches from FAO or national data;
- Estimate catches that had been missed in these formal datasets.

United Arab Emirates



Arabia Gulf

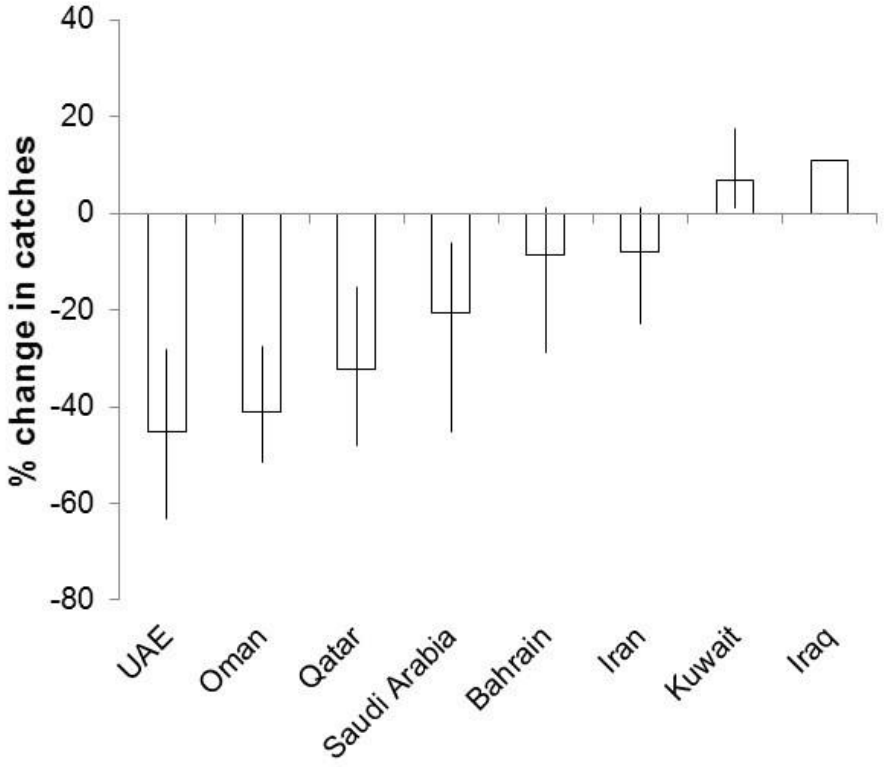

700
600
500
400
300
200
100
0
Catch (t x 10³)
1950
1960
1970
1980
1990
2000
2010
Year
As reported by FAO
Artisanal
Industrial
Discards
Subsistence
Recreational

Methodology to projected catch potential under climate change

- Divided into stocks (Exclusive Economic Zones and species);
- Based on reconstructed catches, assume carrying capacity (*K*) is dependent on relative habitat suitability;
- Apply three habitat suitability models (NPPEN, ENFA and Bioclim).

Climate change impacts on fish catch (RCP8.5)

- Catch potential is projected to decrease in most countries except the northern part of the Arabian Gulf.



Vulnerability assessment methodology - fisheries

- Vulnerability index composed of three components including exposure, sensitivity and adaptive capacity;
- The projected changes in species composition (species turnover) and catch potential represent the exposure of the marine ecosystems and fisheries to climate change ;
- Potential sensitivity of the region to these impacts will be indicated by the importance of fisheries to the national economies and food security;
- The adaptive capacity index is indicated by health, education, governance, fisheries management, size of economy and employment alternatives in each nation;
- Vulnerability for each country (v) is computed according to:

$$v = f(E,S,AC)$$

Sensitivity indicator: coastal protection dependence

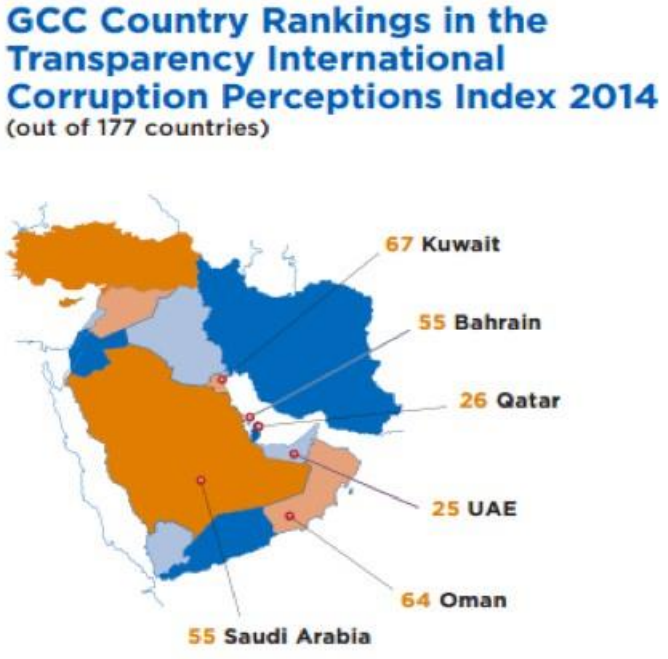
Definition: The level of dependence on marine ecosystems for coastal protection. This can be inferred from the degree of exposure to future impacts of climate change

Sensitivity Indicators:

- Percentage of land area at elevation <5m
- Percentage of population living at elevation <5m
- Percentage of children < 5 years who are below minus two standard deviations from median weight-for-age of the World Health Organization (WHO) Child Growth Standards
- Share of national Gross Domestic Product (GDP) derived from the commercial fishing industry in the Gulf
- Number of years a newborn infant would live if prevailing patterns of mortality at the time of its birth were to stay the same throughout its life.

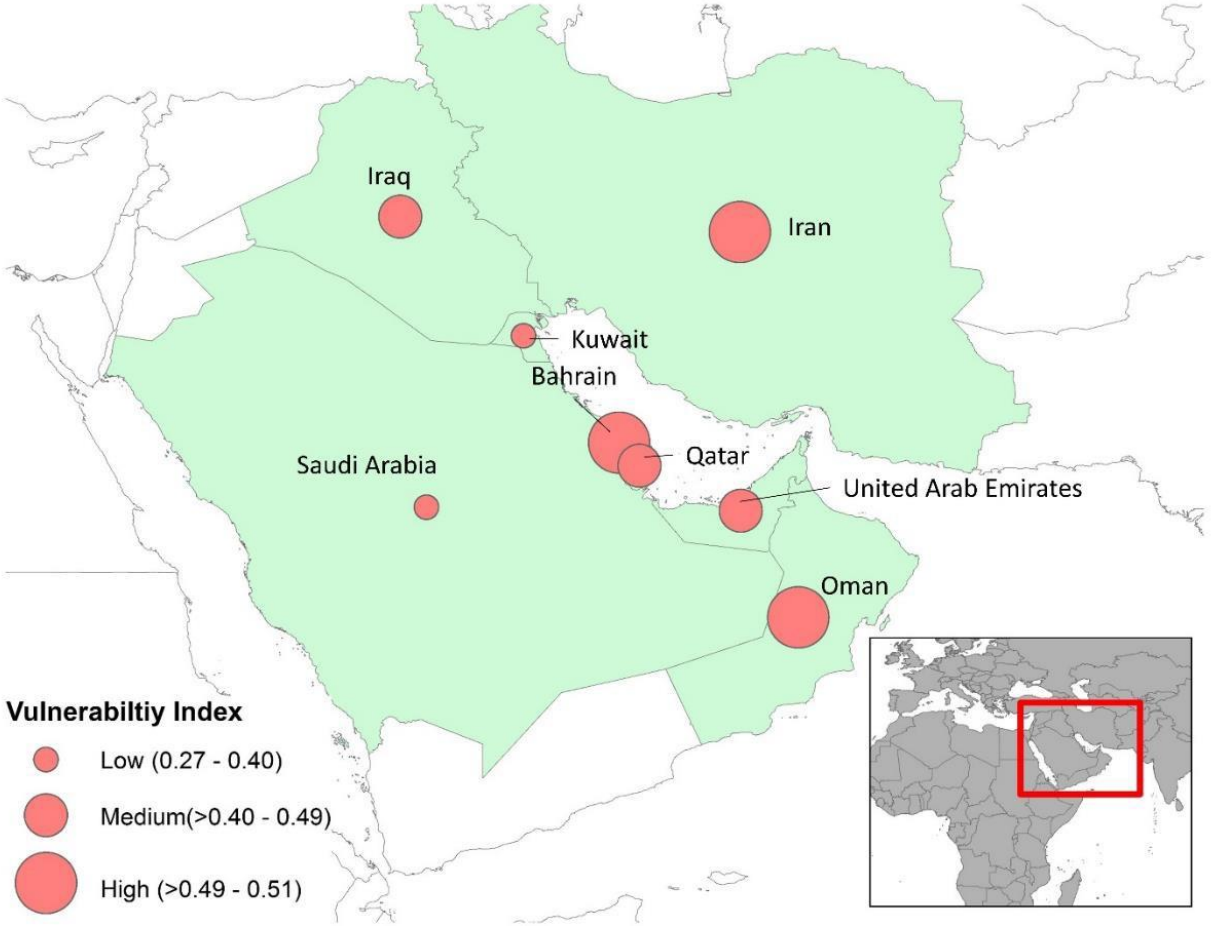
Adaptive capacity indicator: Governance

- Definition: Reports aggregate and individual governance indicators for six dimensions of governance:
  - ü Voice and Accountability
  - ✓ Political Stability and Absence of Violence
  - ✓ Government Effectiveness
  - ✓ Regulatory Quality
  - ✓ Rule of Law
  - ✓ Control of Corruption



Sources: Kaufmann, et al. (2010).
www.transparency.org/

Results – Fisheries Vulnerability Index



- Fisheries of Bahrain and Oman are most vulnerable; Qatar and UAE show medium vulnerability; Kuwait and Saudi Arabia show low vulnerability

Conclusions – Fisheries Vulnerability Assessment

- ✓ For countries on the western side of the Arabian Gulf, the fisheries of Bahrain and Oman are the most vulnerable to climate change. For Oman, vulnerability is mostly tied to its exposure (i.e., reduced future commercial fish catch); for the UAE, vulnerability is mostly tied to its sensitivity;
- ✓ Although the economy of United Arab Emirates is only slightly dependent on fisheries (~0.08% of GDP), UAE is highly exposed to climate change impacts. It still has relatively high vulnerability index (0.49);
- ✓ Iraq has very low adaptive capacity but its exposure to climate change is very low. So, it only has medium value of vulnerability index (0.45);
- ✓ Iran has the highest vulnerability index (0.51). It has high sensitivity and low adaptive capacity to climate change. It seems to be reasonable to have this result as Iran has the longest coastline in the Arabian Gulf, the highest catch amount in this area and the lowest employment alternatives in this region.

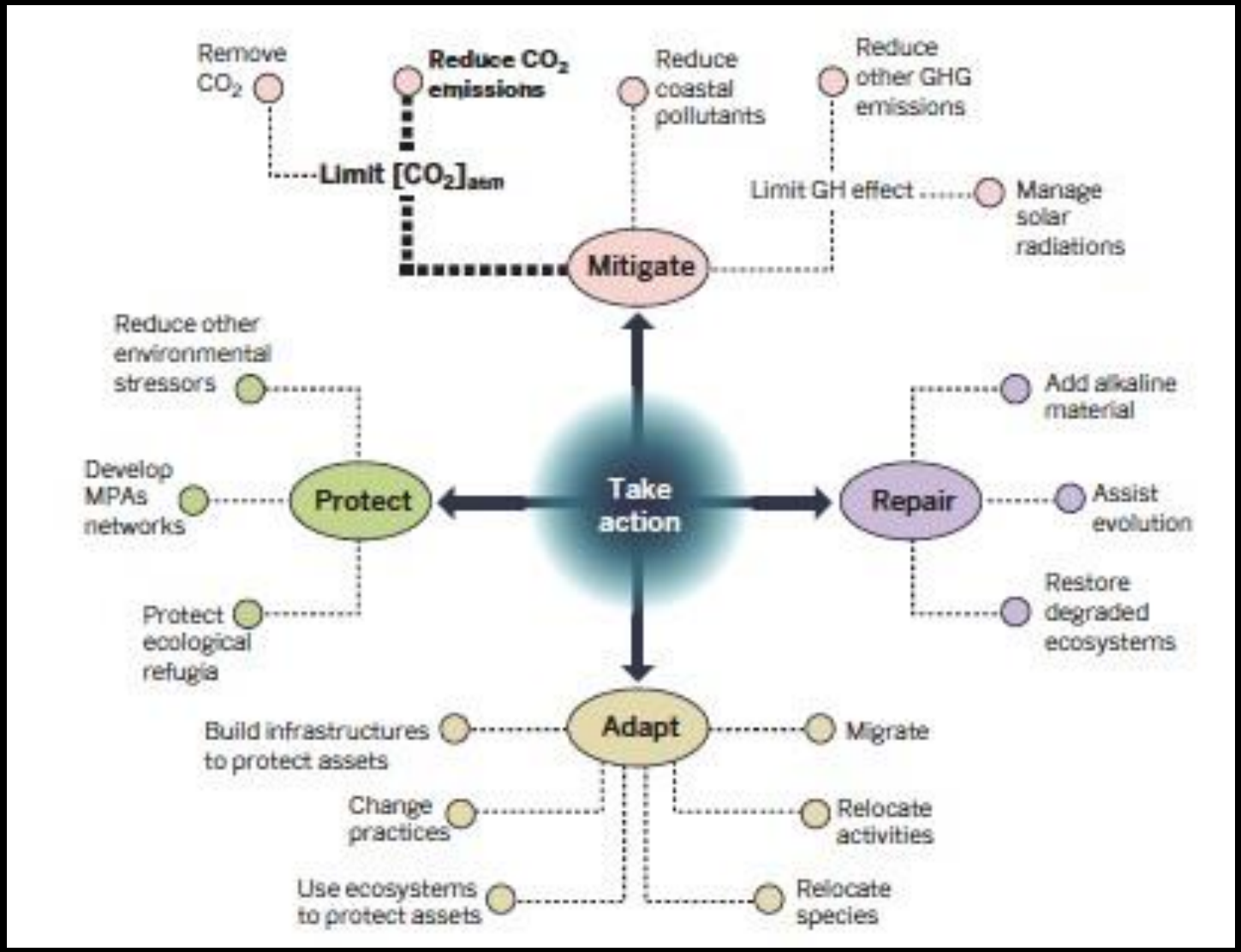
Uncertainties

- ✓ Impacts of climate change based on modelled species-specific preferred ranges and drove projections using predicted temperature and salinity shifts. .
- ✓ The accuracy of projections is also contingent on the outputs from regional oceanographic models;
- ✓ The environmental niche models applied in this study assume that species' traits do not evolve as environmental conditions change, but species may well adapt to warming through genetic or transgenerational adaptations;
- ✓ Confidence in the projections of habitat suitability loss for charismatic species, as a result of future climate-mediated changes in temperature and salinity, is lower than for other groups;
- ✓ We chose to give each indicator within a given dimension and each dimension within the overall vulnerability index equal weighting. Based on local settings, stakeholders may wish to give individual variables and/or indicators different weightings.

This talk

- Global overview of climate impacts on marine biodiversity and ecosystem services;
- Arabian Gulf marine biodiversity and their vulnerability to climate change;
- Arabian Gulf marine fisheries and their vulnerability to climate change;
- Options for climate risk-reduction.

Solutions to the CO_2 problems



Gattuso, Magnan, Billé, Cheung, Howes, Joos, *et al*. 2015 Science.

Overall conclusions

- ✓ Climate change is projected to have large impacts on marine biodiversity in the Arabian Gulf region, particularly high along the south and southwestern coasts, where high rates of local extinction are projected by the end of the 21st century.
- ✓ Under climate change, species' ranges would shift poleward, from the eastern part of the Gulf to the coast of Iraq and Iran ;
- ✓ Decline in species habitat suitability translated directly into a projected decrease in maximum fisheries catch potential, particularly along the southwestern parts of the Gulf;
- ✓ The results of this study suggest an increase in vulnerability of charismatic species to climate change in the Arabian Gulf;
- ✓ The nations most vulnerable to climate change impacts on fisheries were not confined to the southwestern coast, but also included Iran and Iraq.

Thank you!

شكـــرا

Bill Dougherty

Jane Glavan

Numerous colleagues and stakeholders who provided data and comments

Climate Change Research Group

AGEDI
مبادرة أبوظبي العالمية للبيانات البيئية
Abu Dhabi Global Environmental Data Initiative

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Environment Agency - ABU DHABI