Dynamic bioclimate envelope model to predict climate-induced changes in distributions of marine fishes and invertebrates

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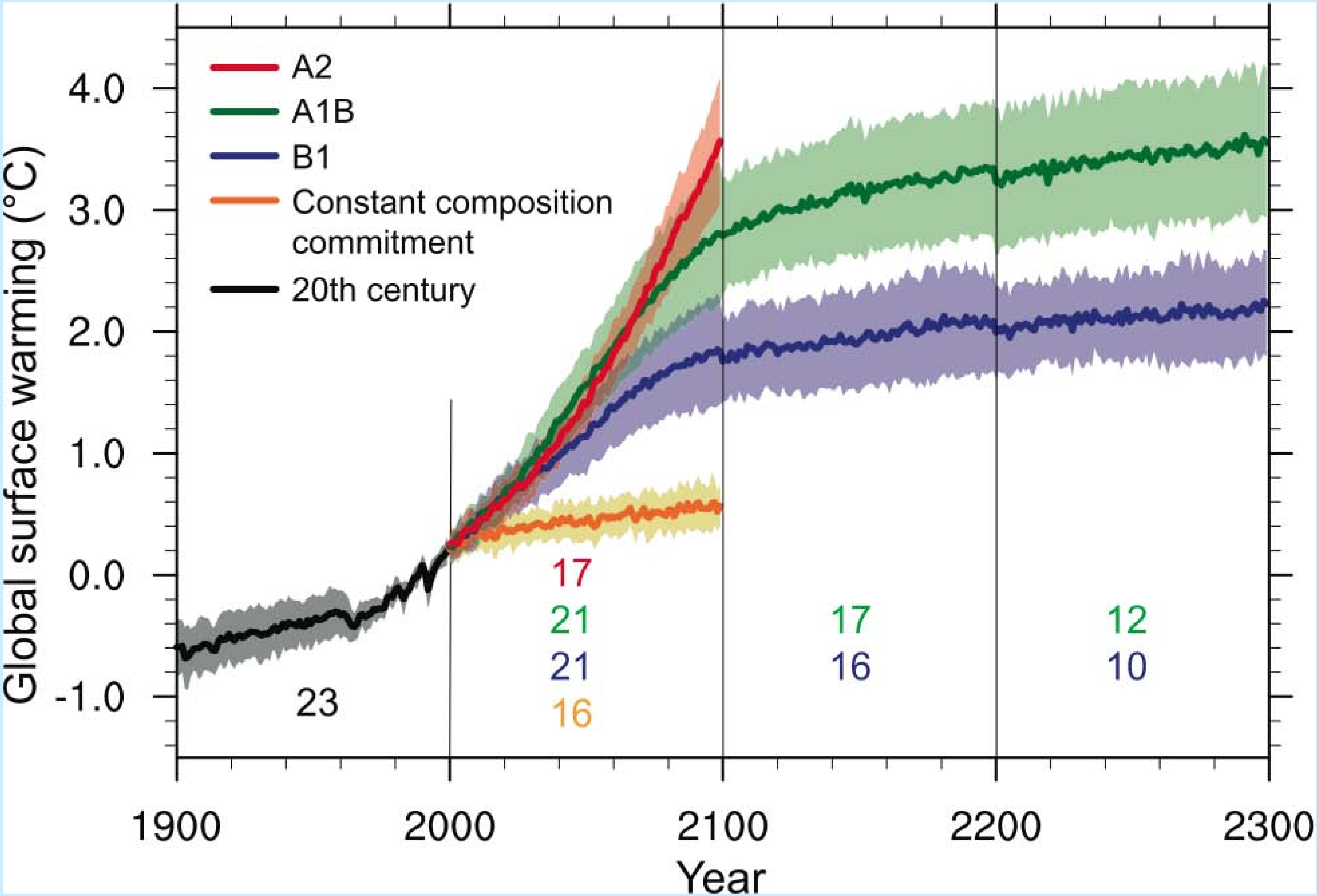
Effects of Climate Change on the World's Ocean, Gijon, Spain
May 18, 2008

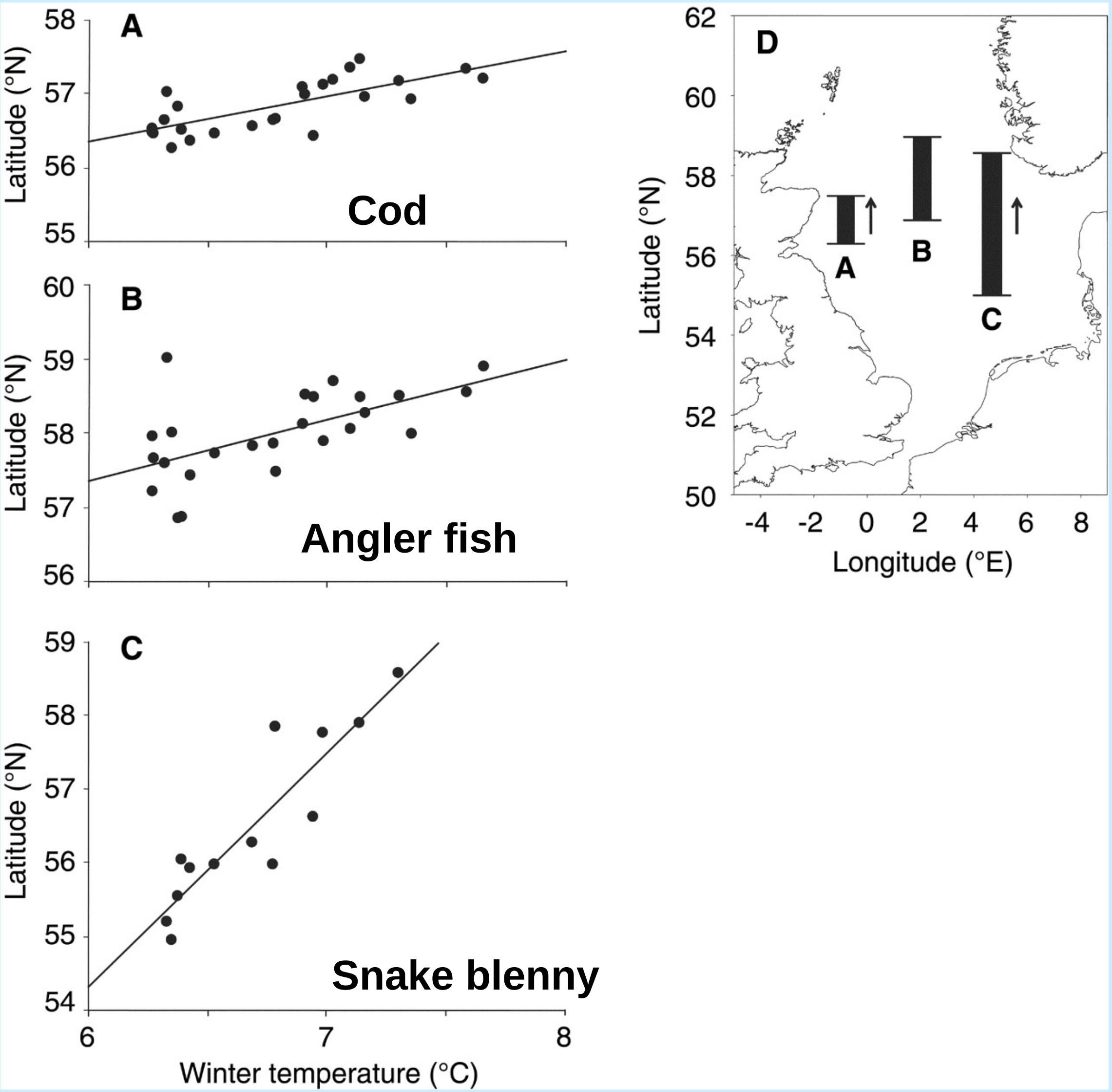
Cheung *et al*. (2008) Fisheries Centre Research Report 16(3)

Projected temperature changes in the next three centuries



Source: IPCC 2007

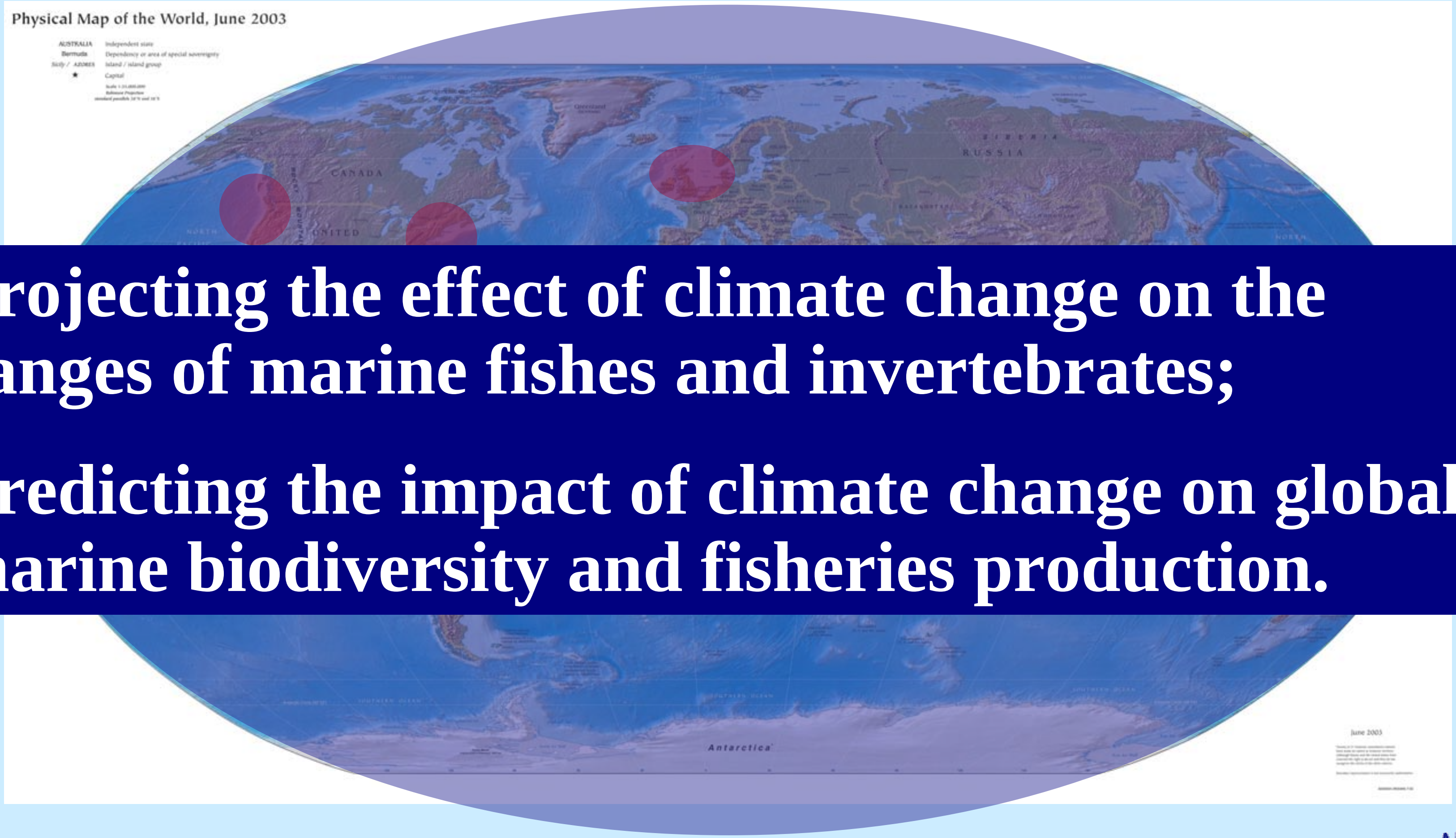
Observed climate-induced range-shifting



- Poleward shifts in distributional ranges of marine species;
- E.g. in the North Sea.

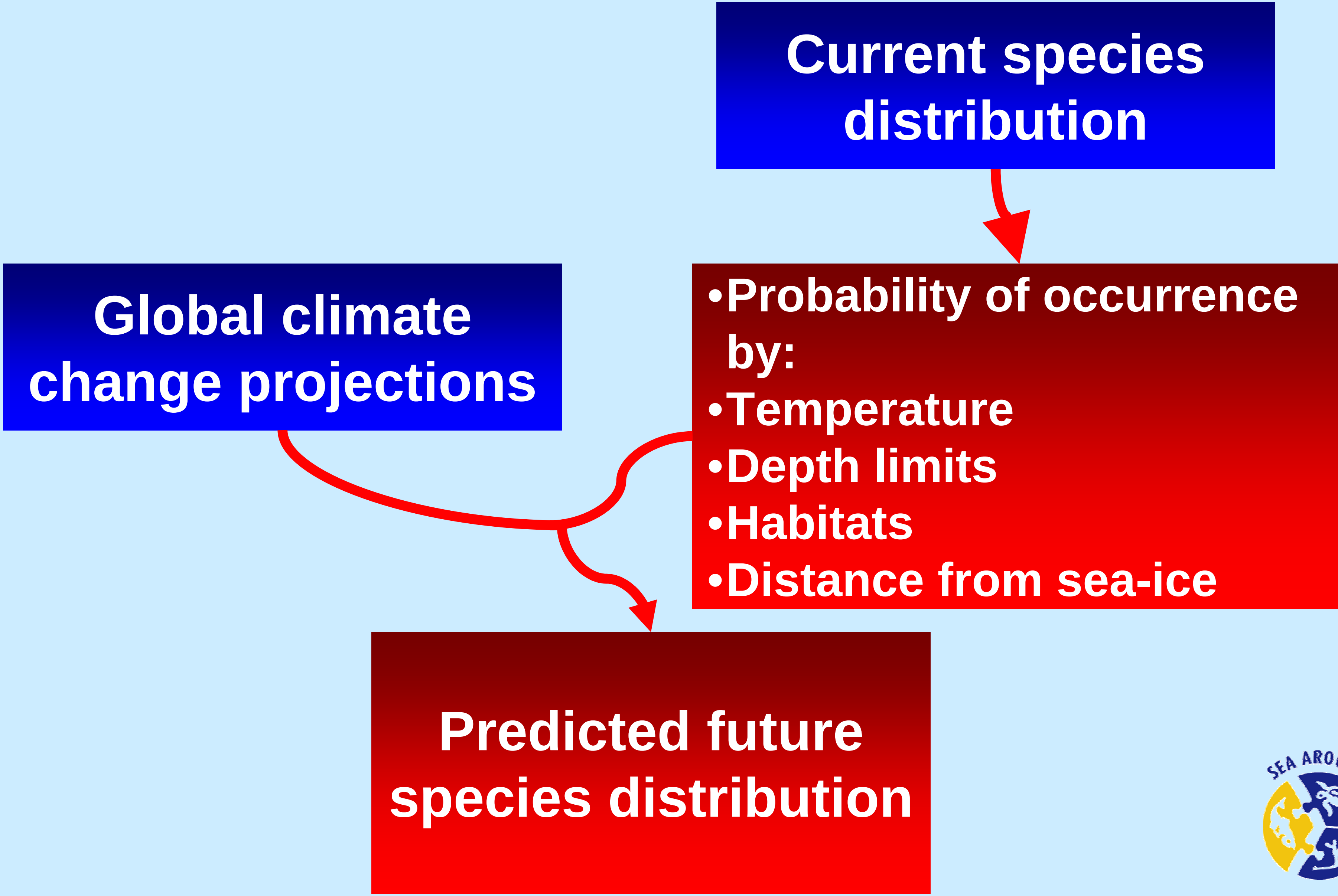
Source: Perry *et al*. (2005) *Science* 308

Research objective



- **Projecting the effect of climate change on the ranges of marine fishes and invertebrates;**
- **Predicting the impact of climate change on global marine biodiversity and fisheries production.**

Climate change-distribution prediction



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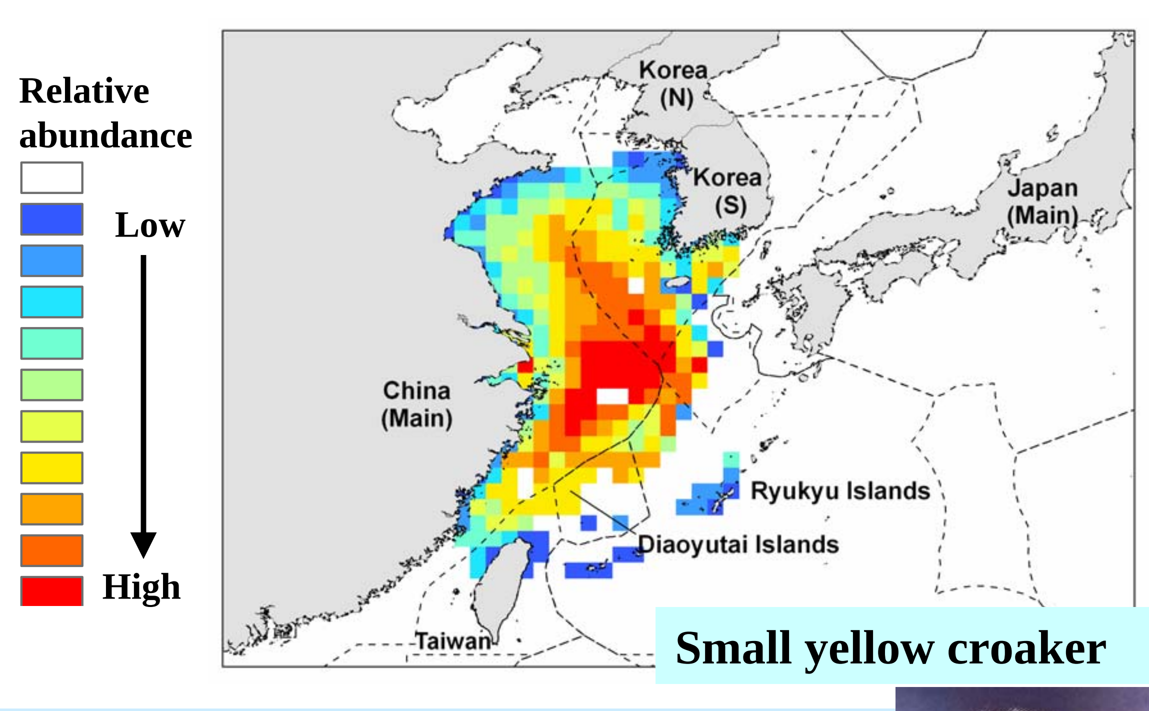
Predicting species distributions

- Current (1980-2000) distributional ranges of over 1,200 species of marine fishes and invertebrates are predicted from:

Attributes:

- Depth limits;
- Latitudinal limits;
- Associated habitats;
- Known range boundary.



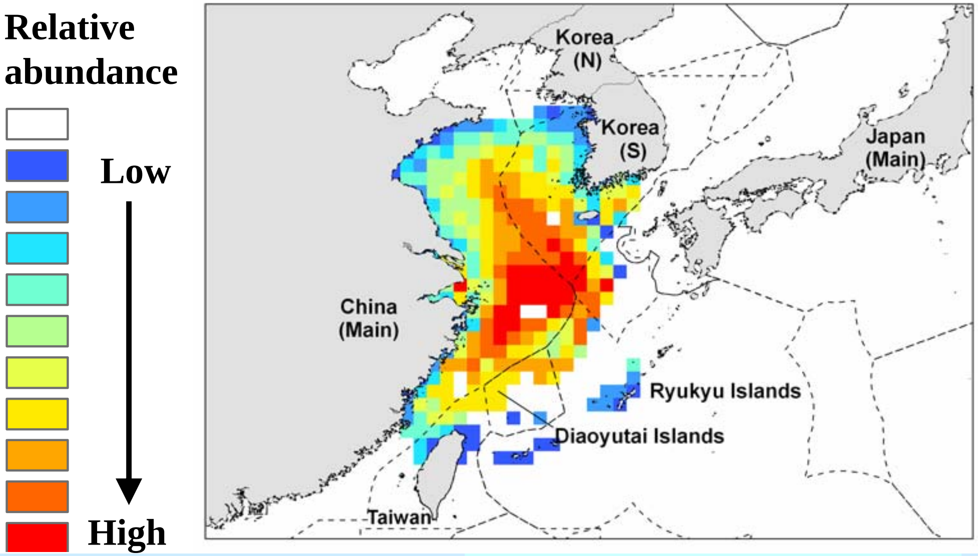
Small yellow croaker

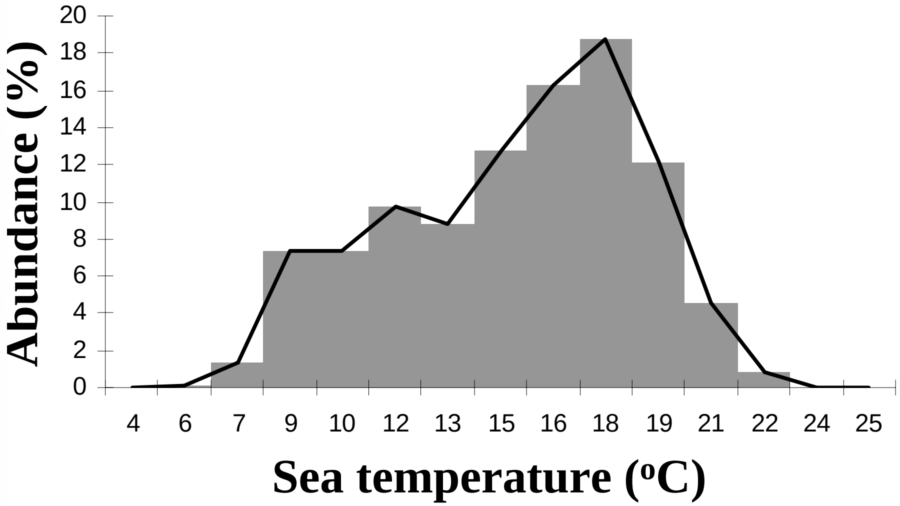
Close, Cheung, Hodgson, Lam, Watson, Pauly (2006) Fisheries Centre Research Report 14(4)

Temperature preference profile

Overlaying current ranges with sea temperature from 1980-2000

Probability of occurrence by water temperature

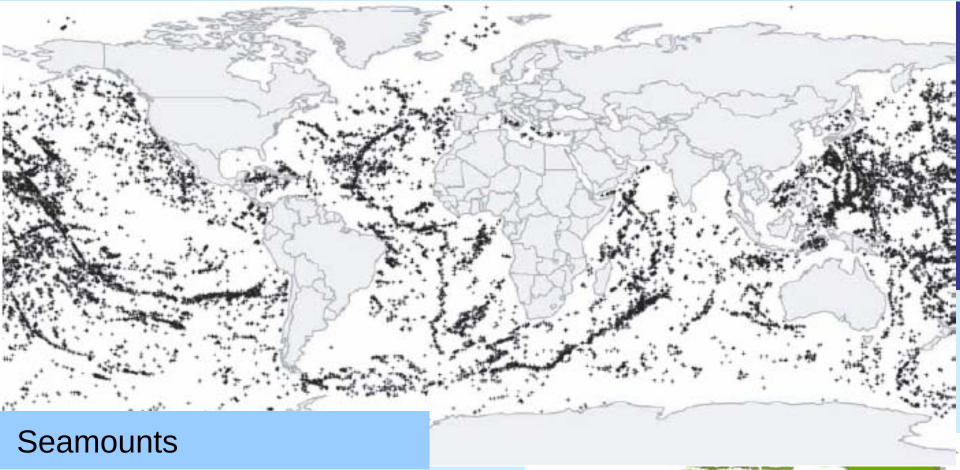




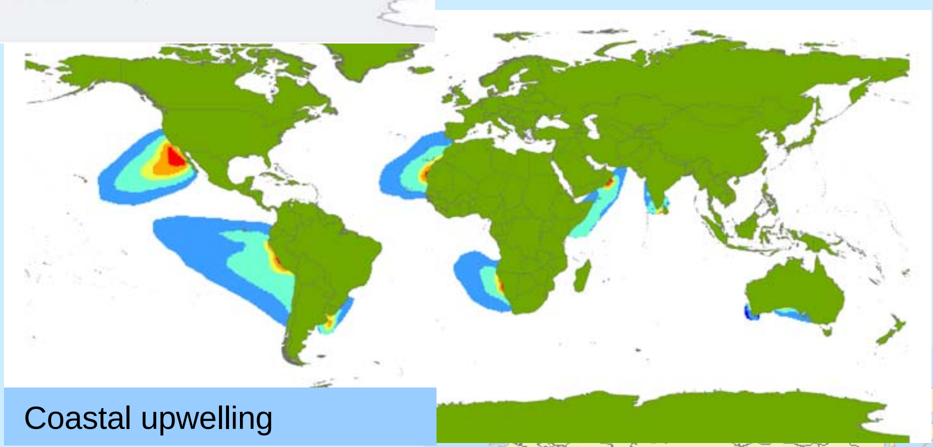
Small yellow croaker

Habitat preferences

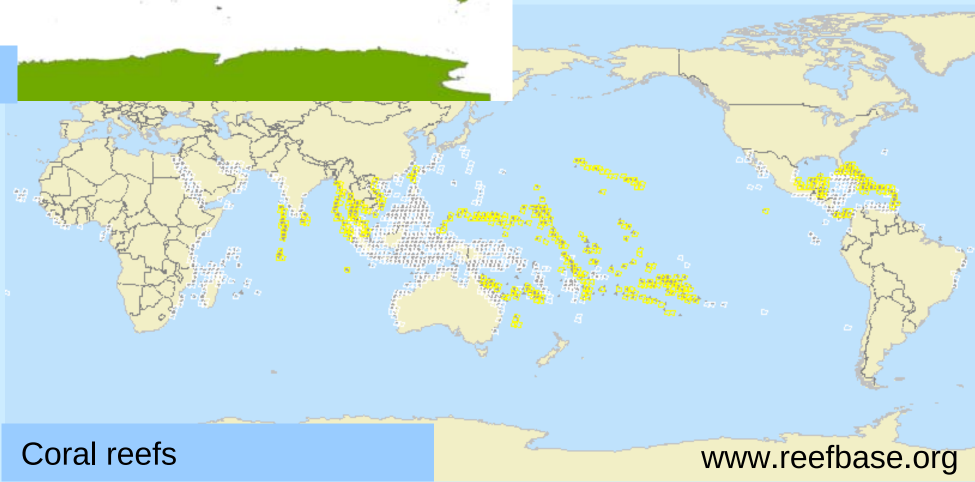
Coral reefs, estuaries, seamounts, salinity and coastal upwelling



Seamounts



Coastal upwelling



Coral reefs

www.reefbase.org

Population dynamics

- **Intrinsic growth (G): logistic model;**
- **Immigration (I): influx of pelagic larvae + movement of adults;**
- **Extirpation/emigration (E);**
- **Abundance change (each spatial cell, each time step) = G + I – E;**
- **Carrying capacity, net migration and extirpation rates depend on temperature-abundance profile and other environmental preferences.**

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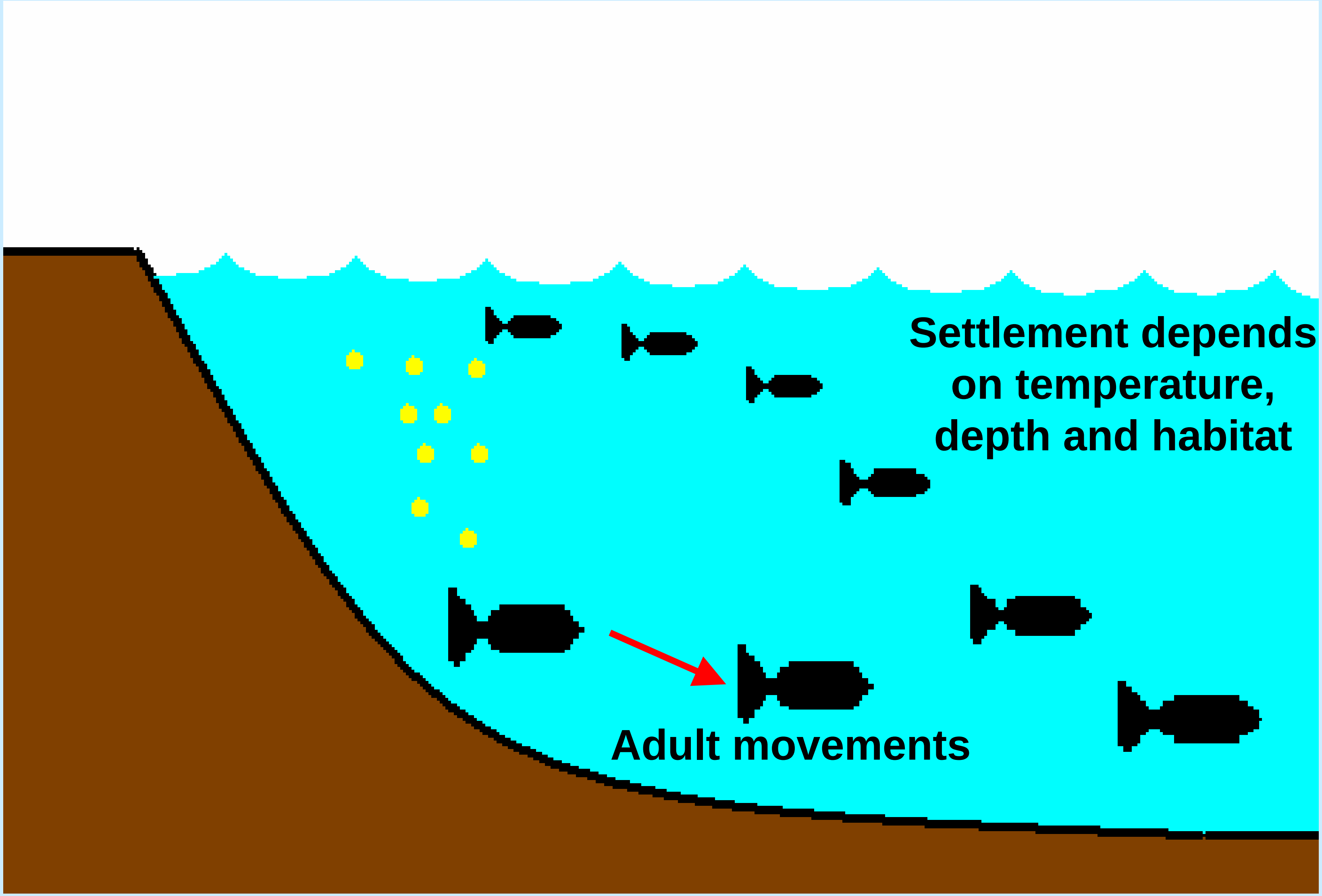
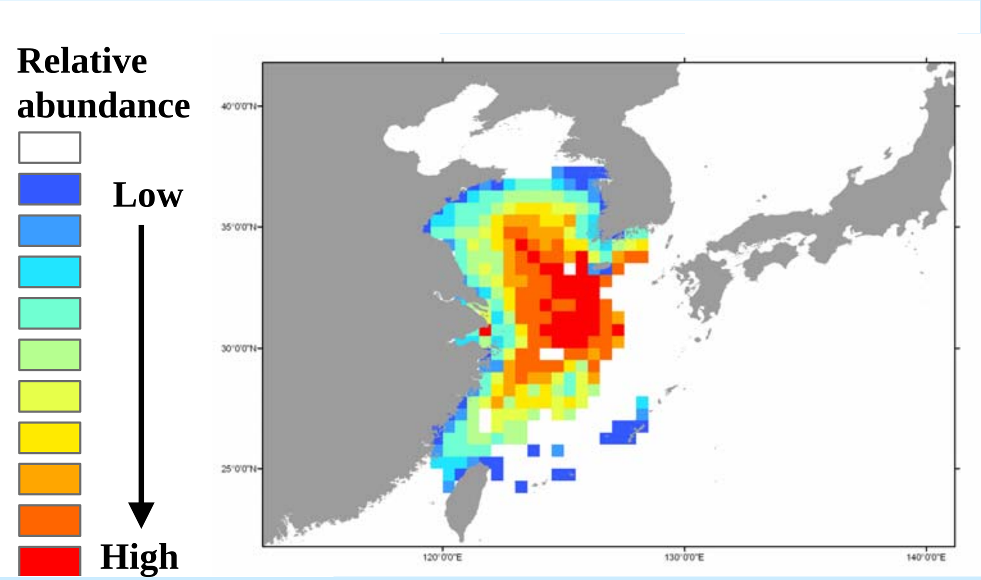
Dispersal by larvae and adults

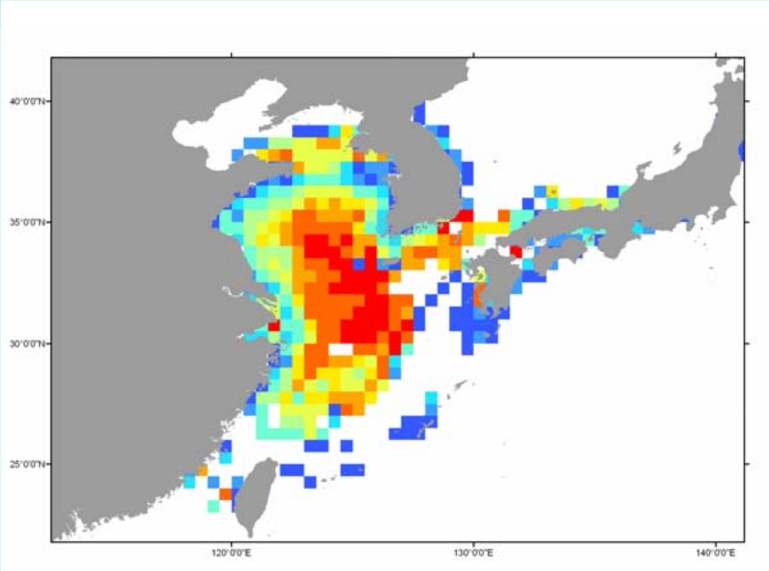


Example: Small yellow croaker (*Larimichthys polyactis*)

Original (static) distribution

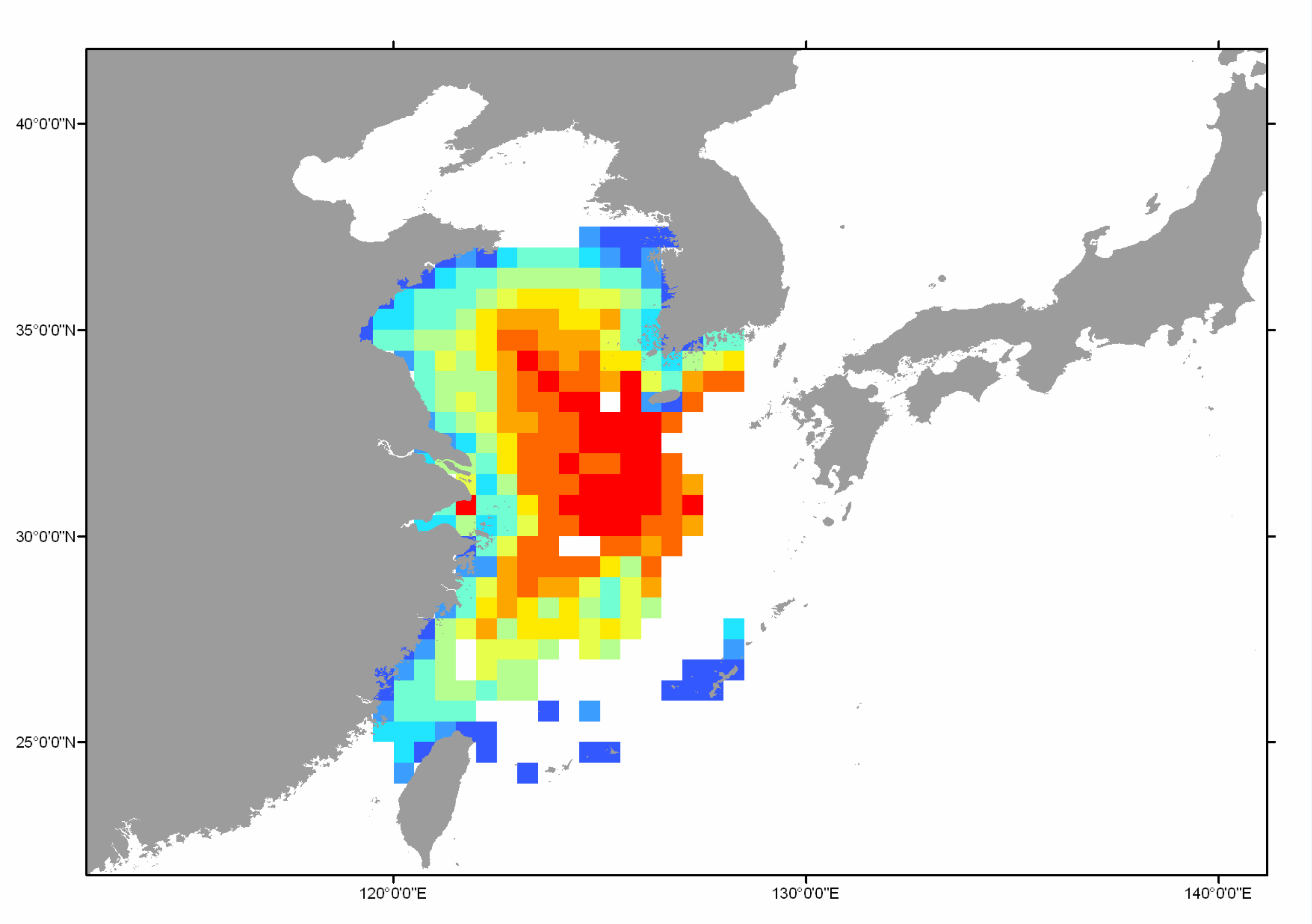


Distribution after 50 years
(Climate projection from NOAA/GFDL CM 2.1)



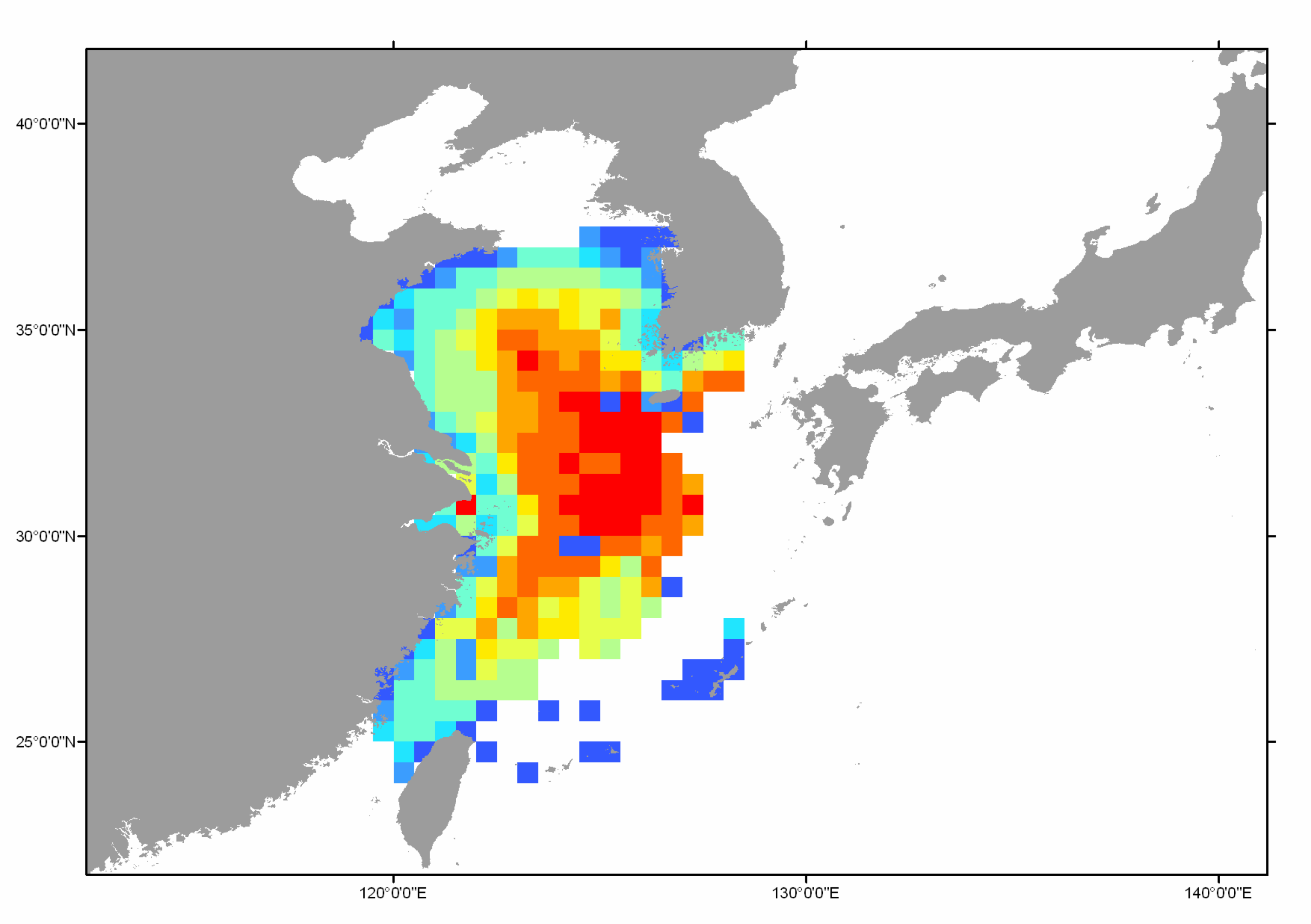
Small yellow croaker

Year 2001



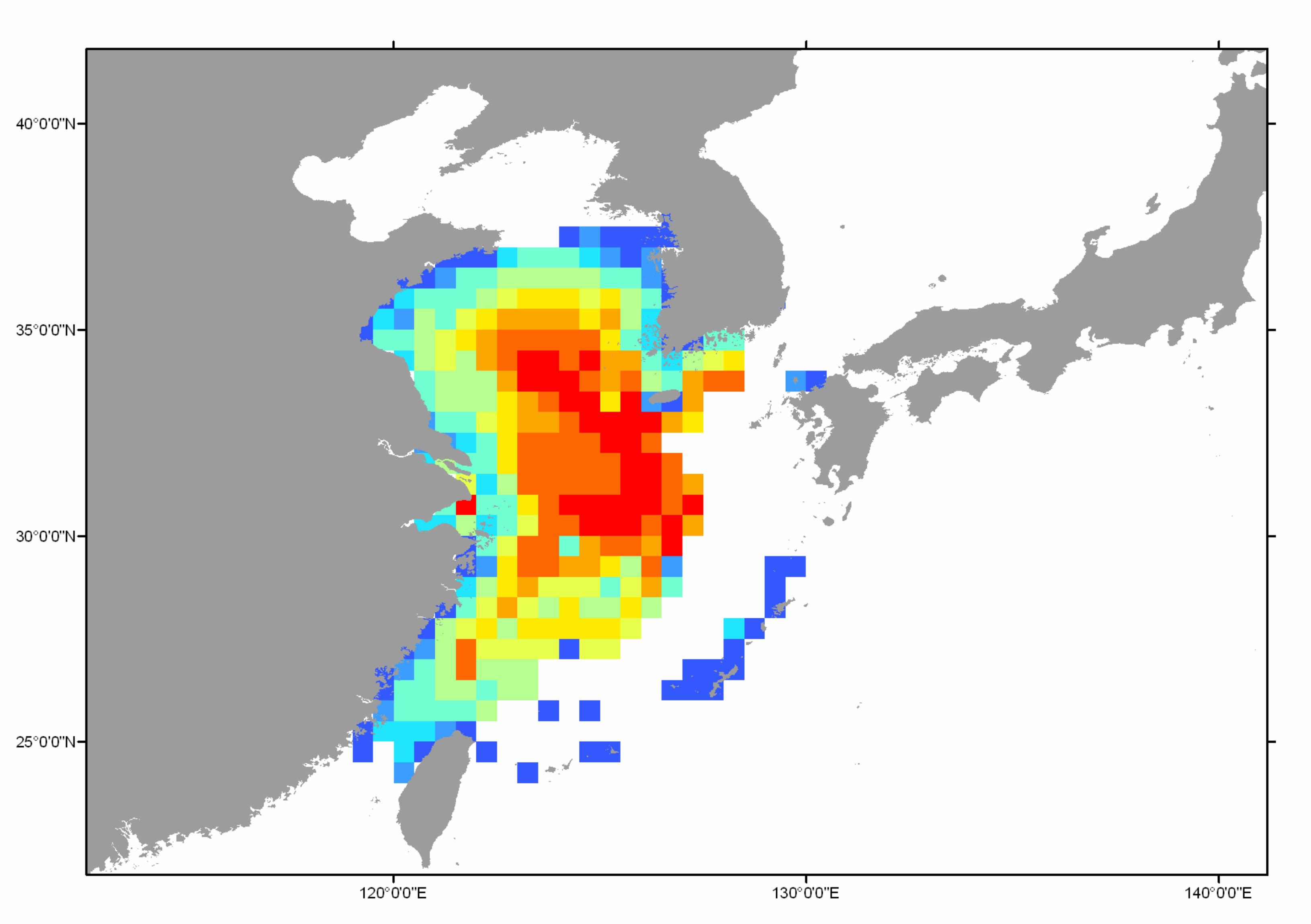
Small yellow croaker

Year 2006



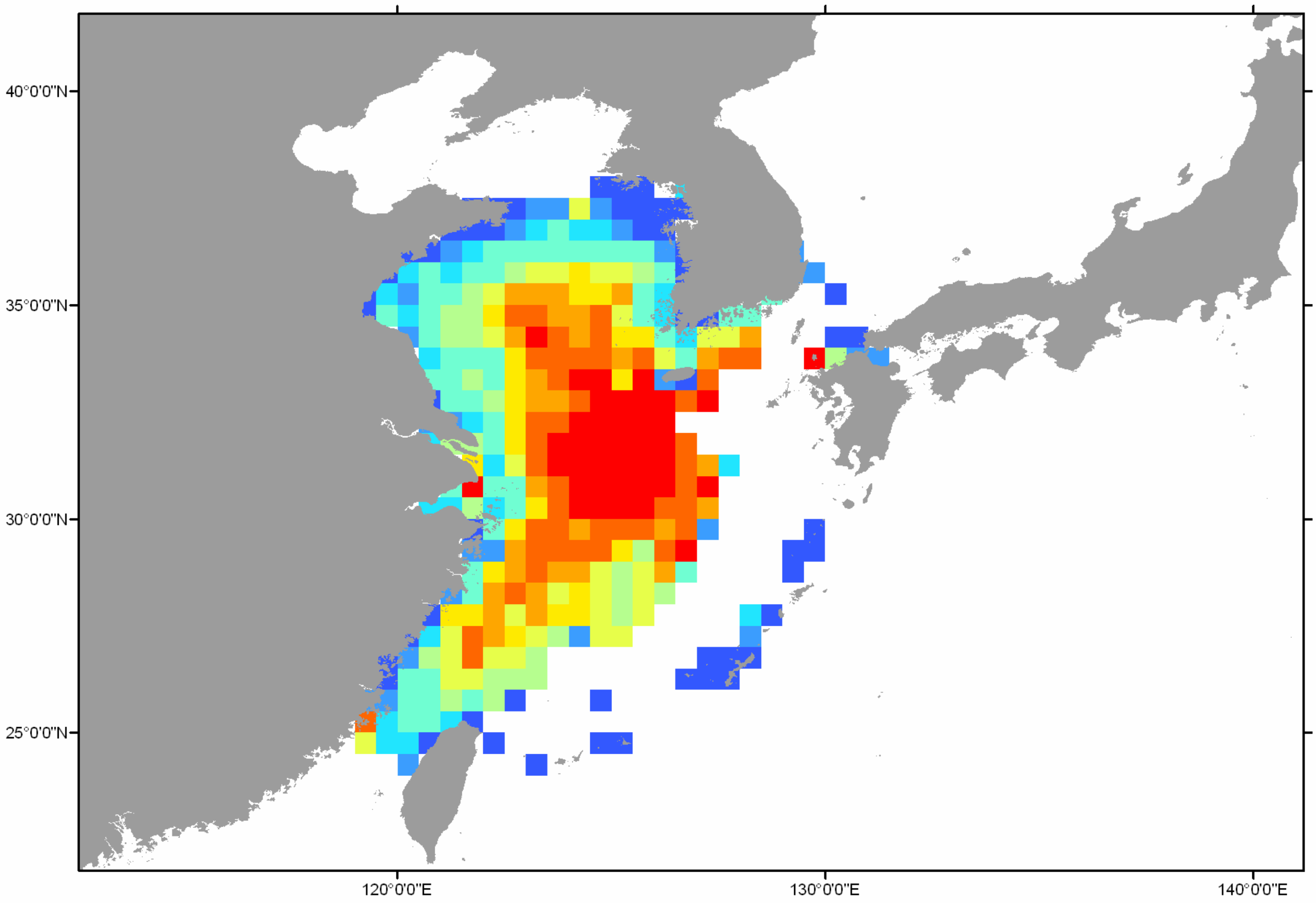
Small yellow croaker

Year 2011



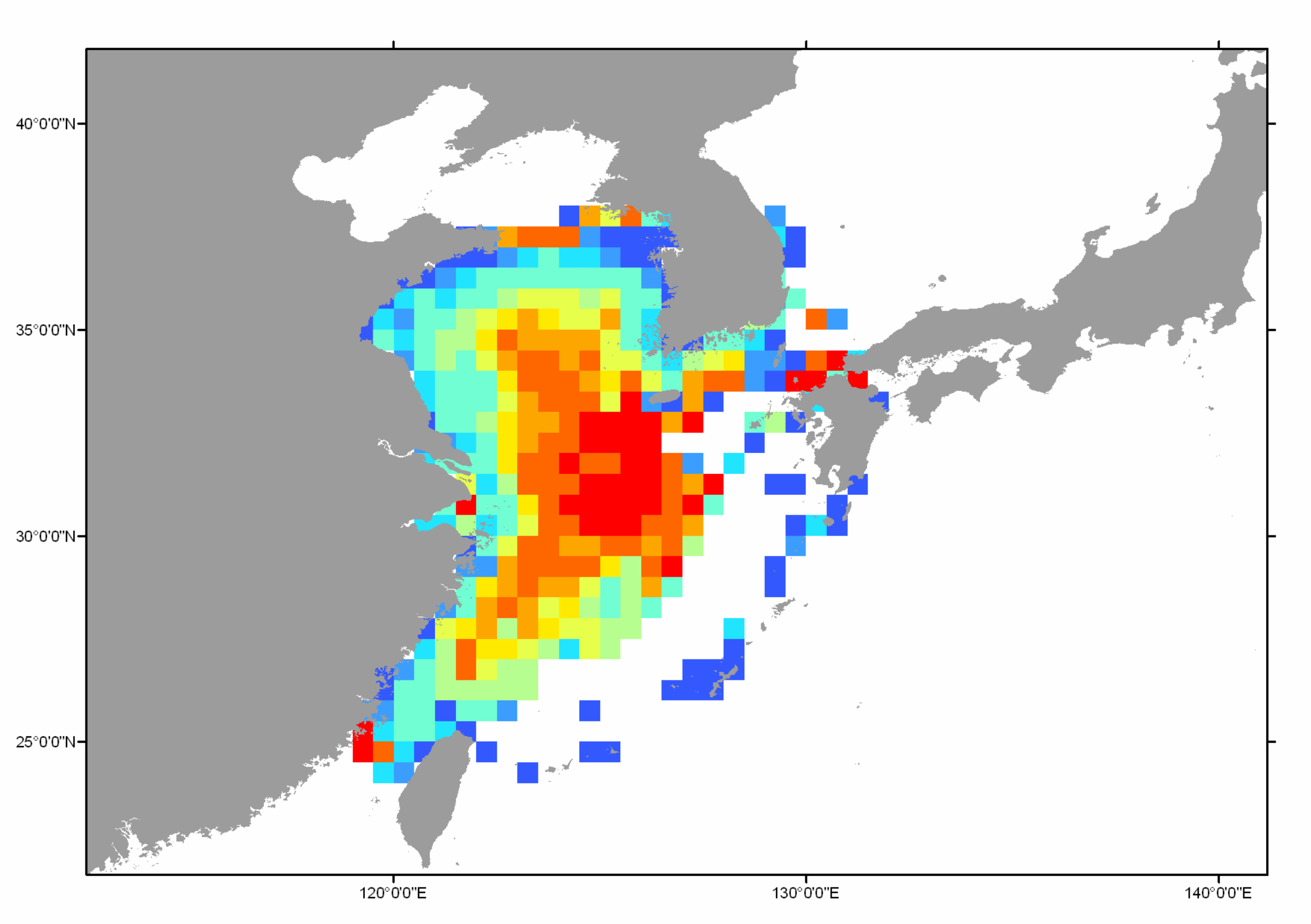
Small yellow croaker

Year 2016



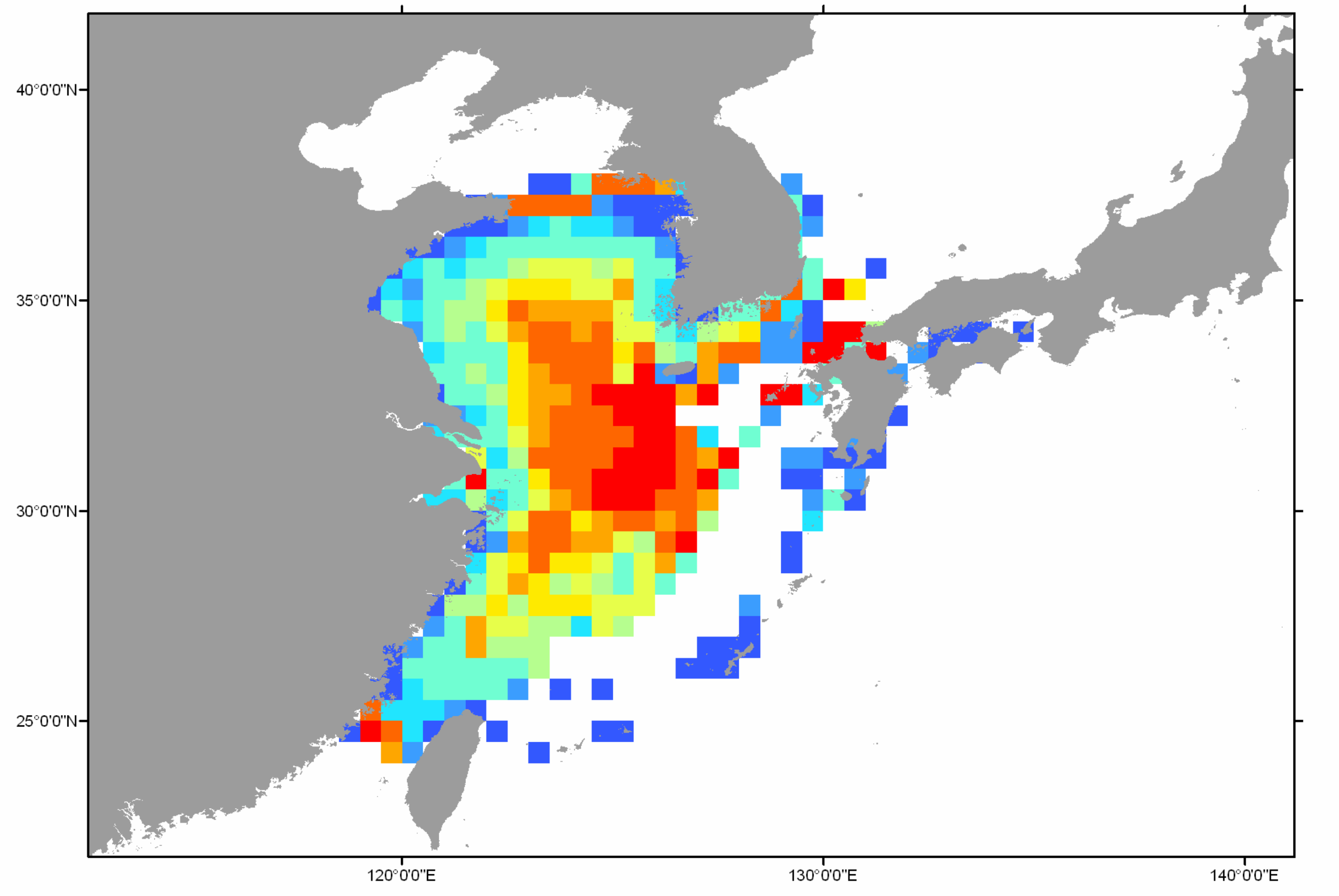
Small yellow croaker

Year 2021



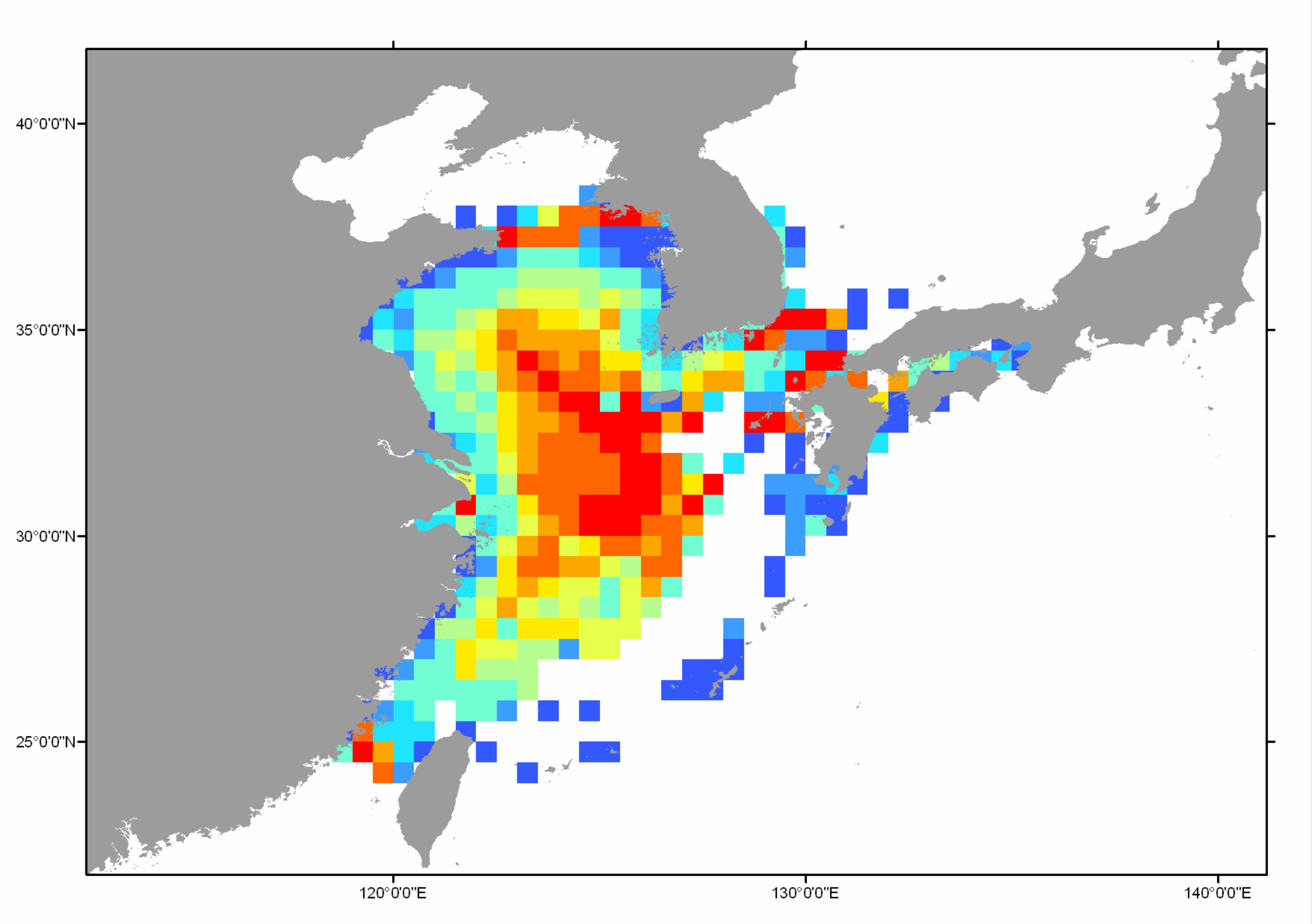
Small yellow croaker

Year 2026



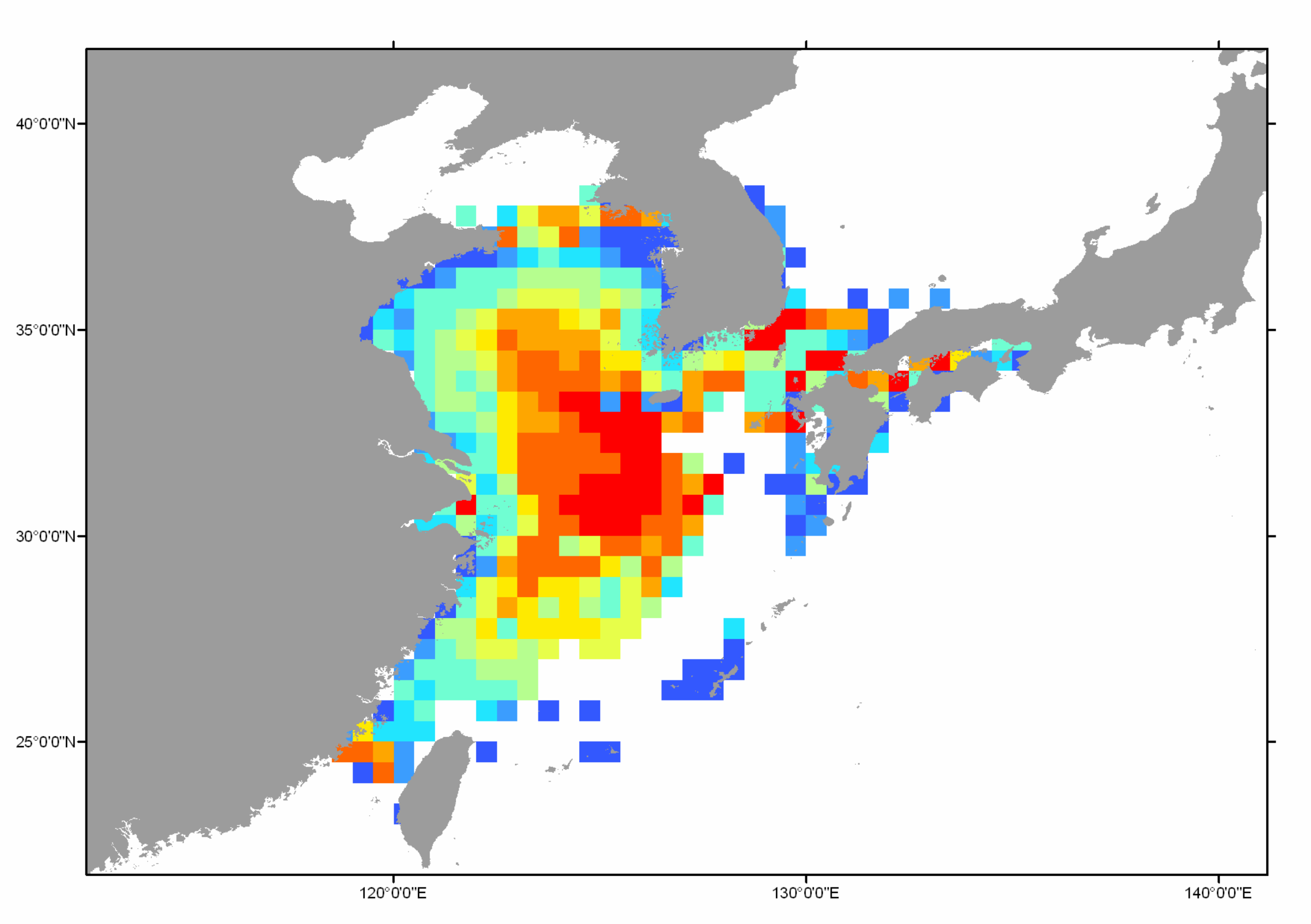
Small yellow croaker

Year 2031



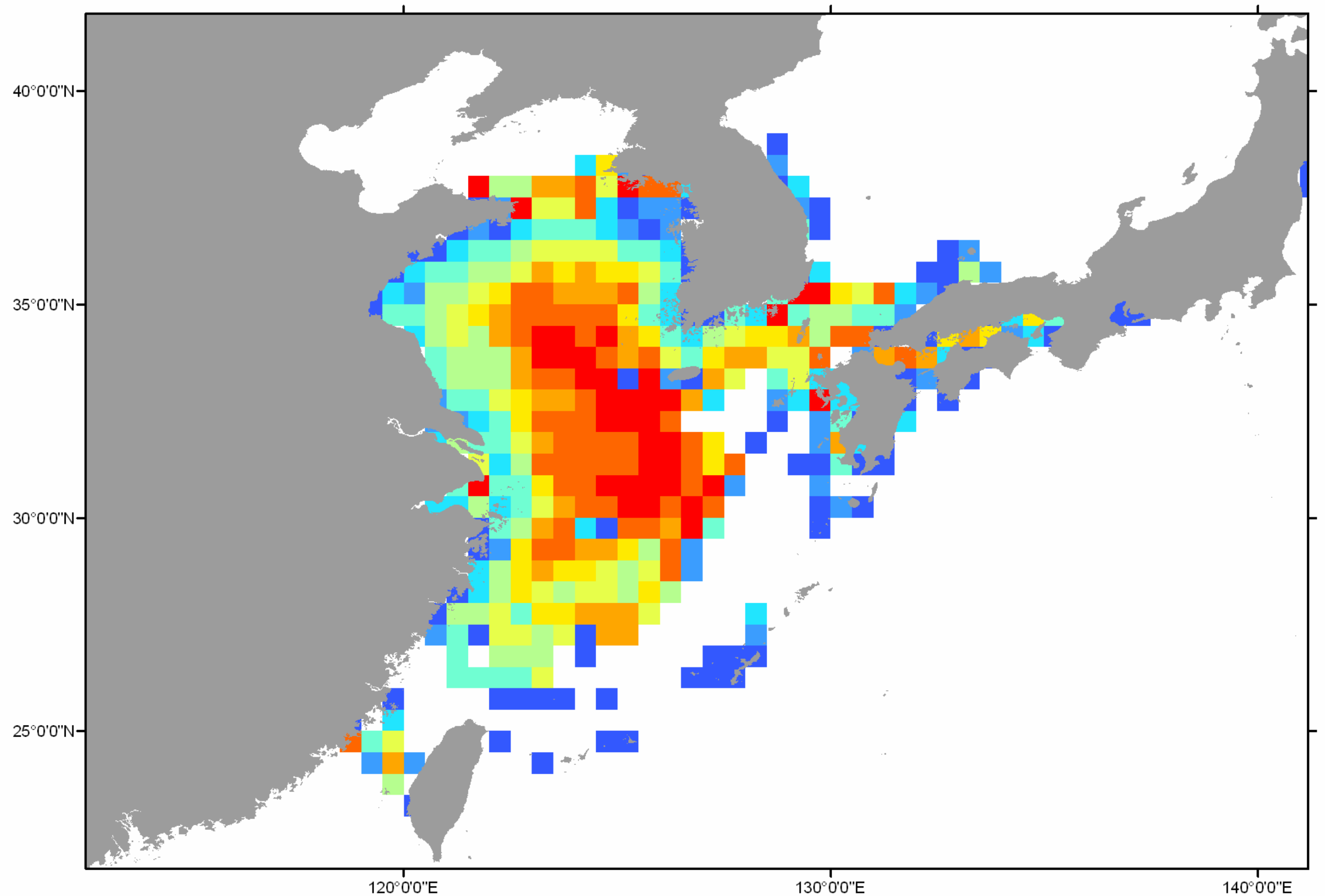
Small yellow croaker

Year 2036



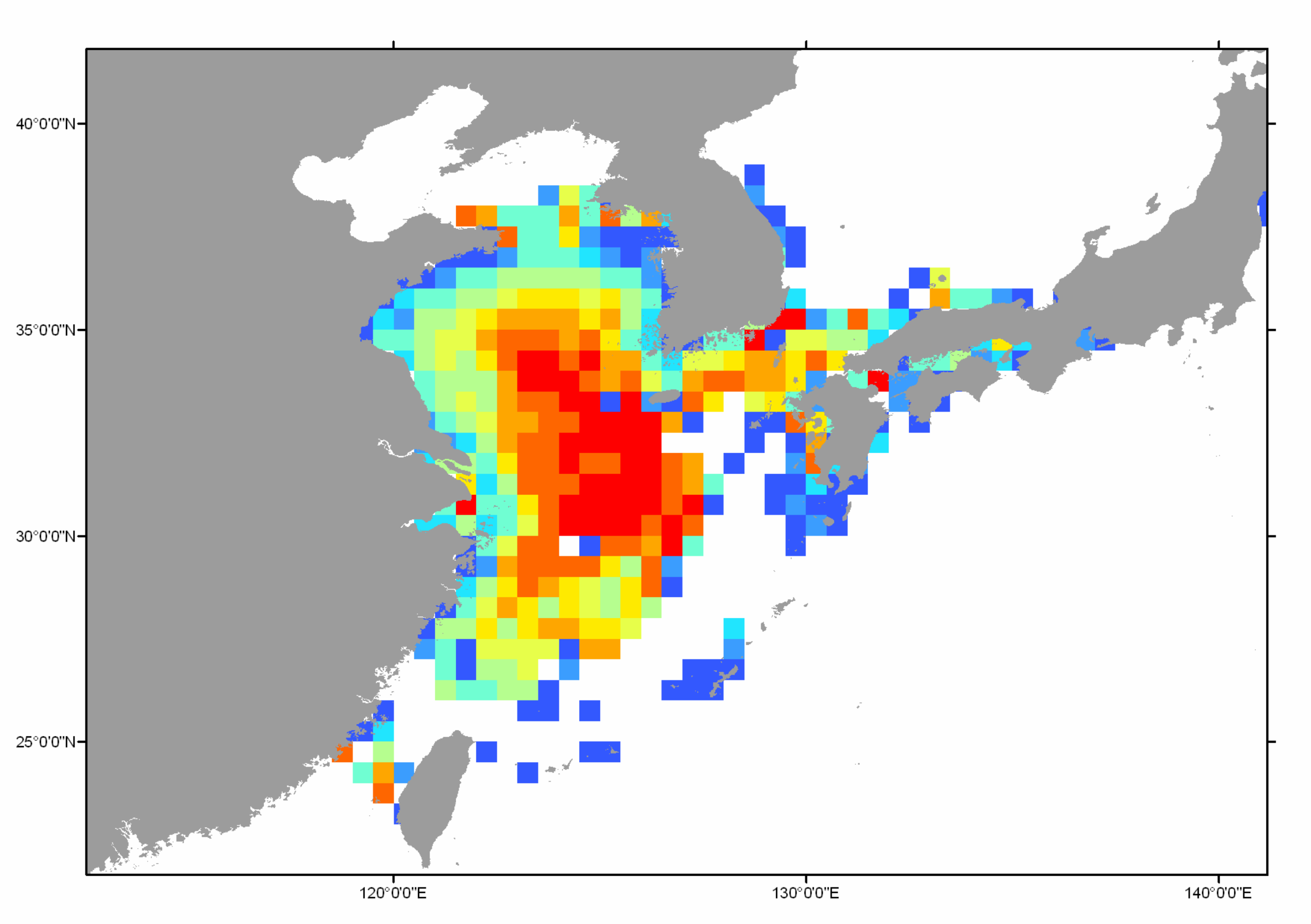
Small yellow croaker

Year 2041



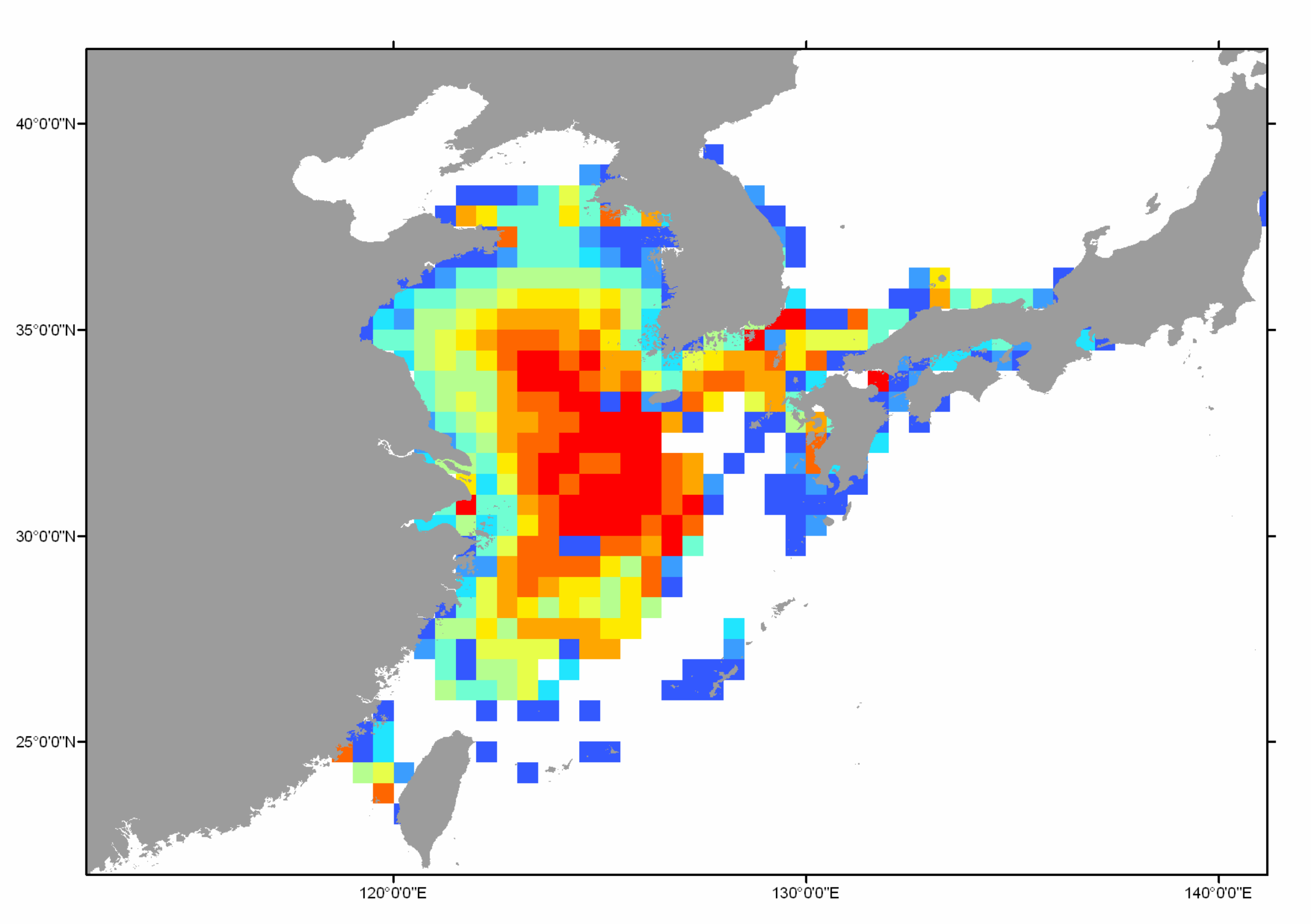
Small yellow croaker

Year 2046



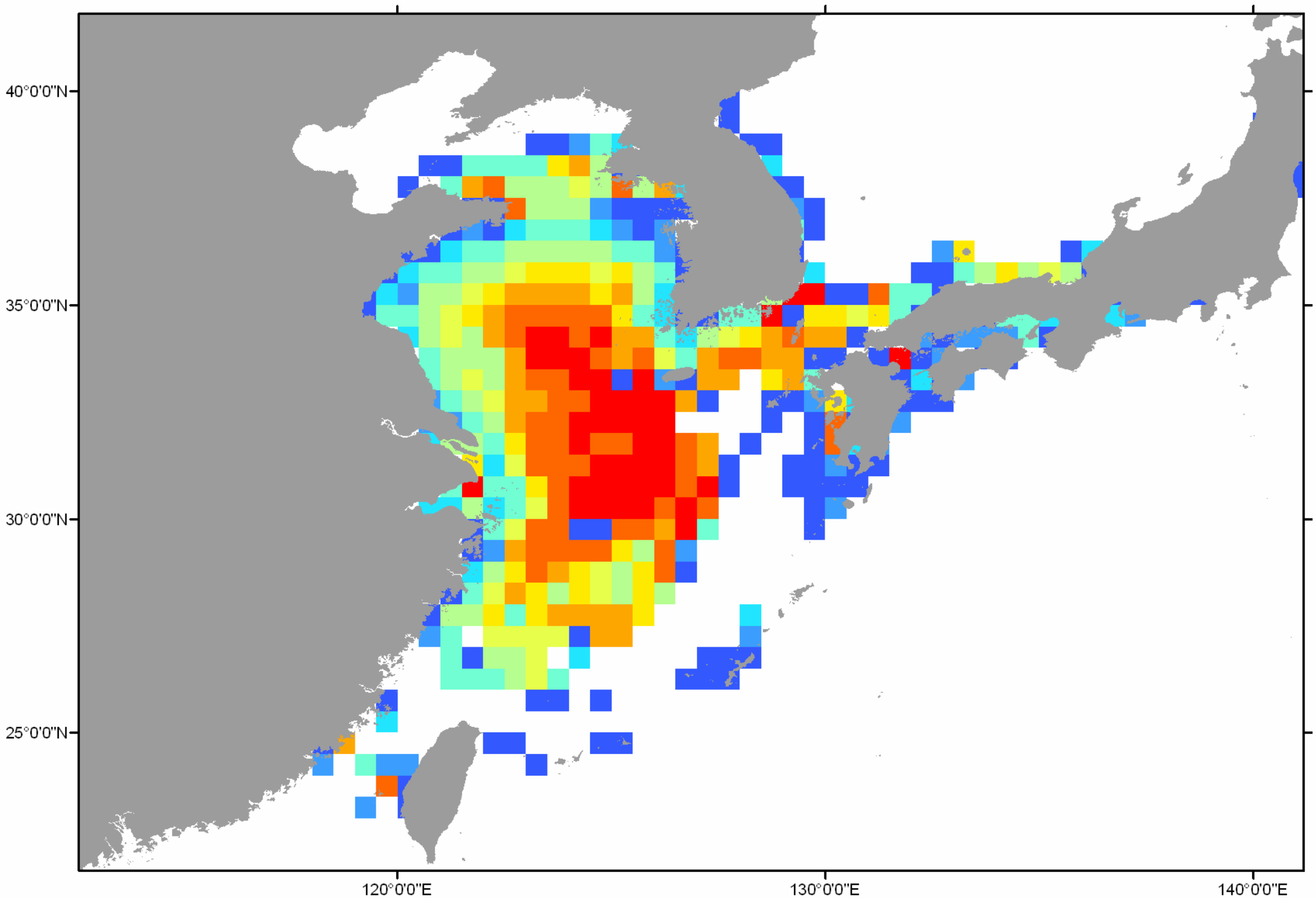
Small yellow croaker

Year 2051



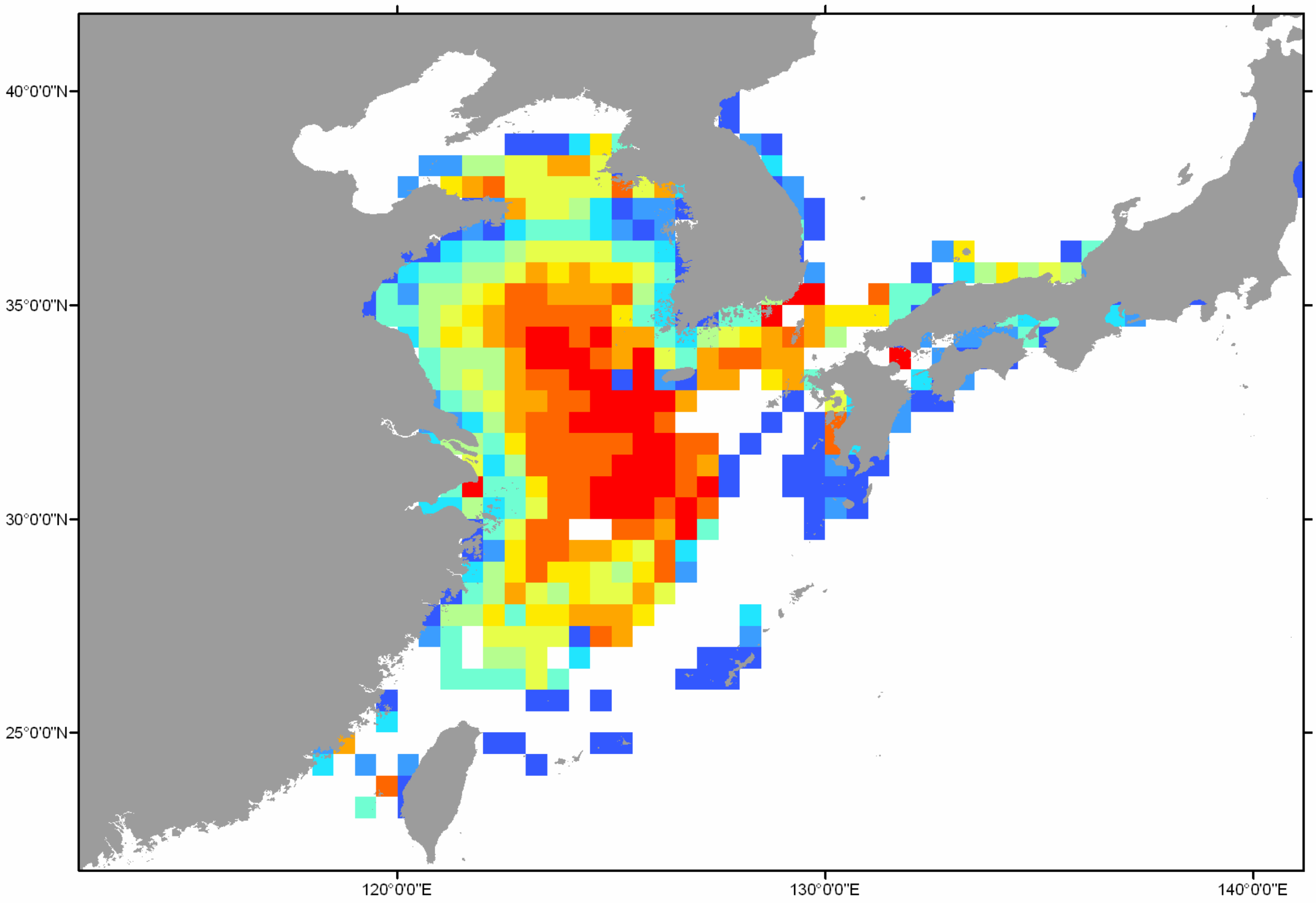
Small yellow croaker

Year 2056

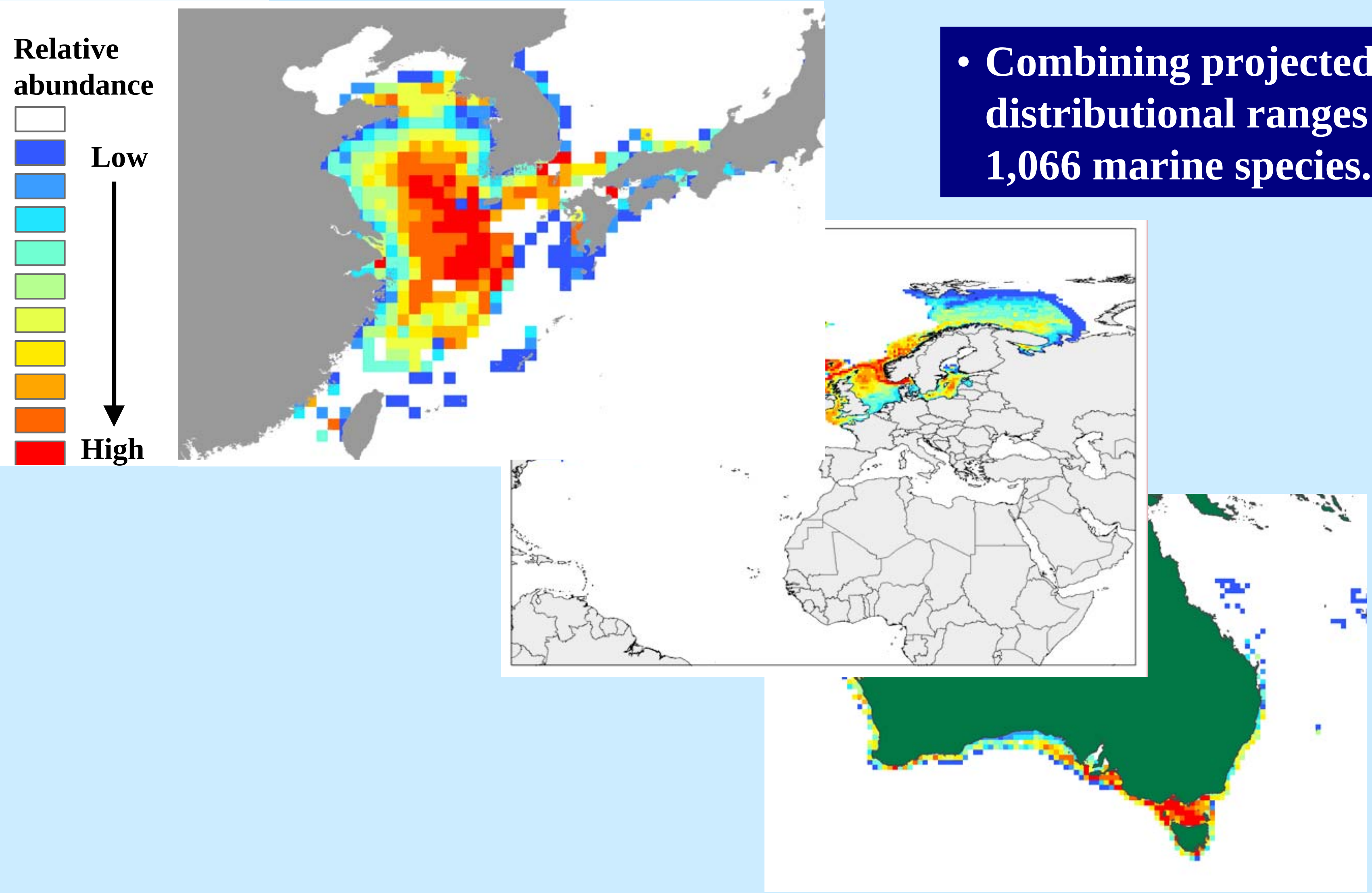


Small yellow croaker

Year 2060



Predicting climate change impacts on marine biodiversity



- **Combining projected distributional ranges of 1,066 marine species.**

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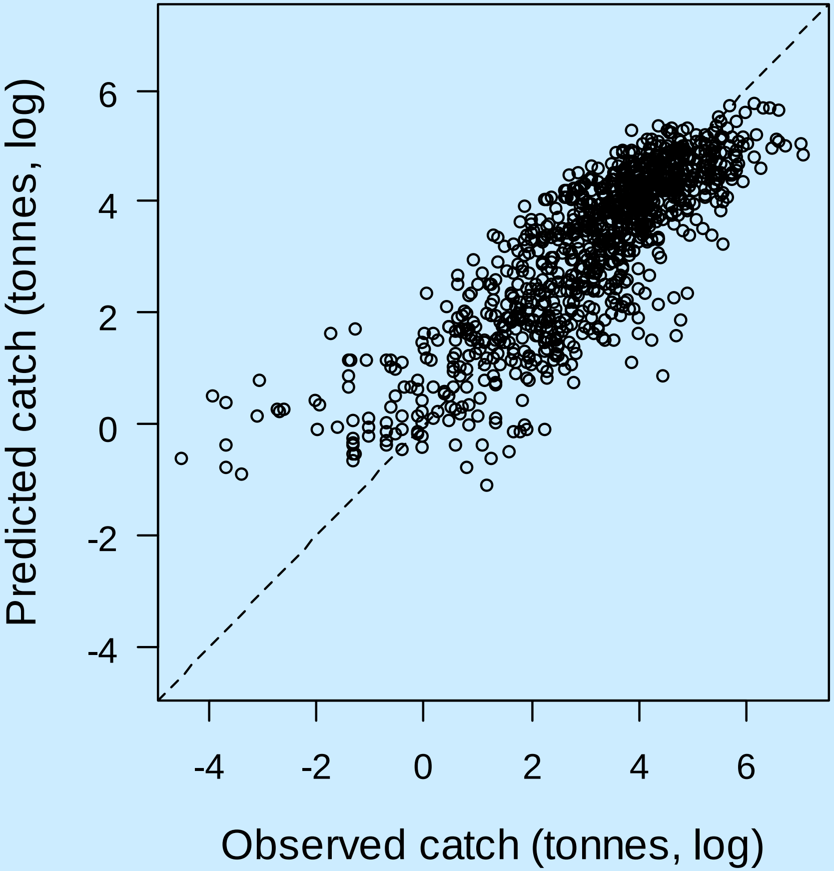
Fitting the model using GLM

N = 1,000, P < 0.001, R^2 = 0.70



- Fit the empirical model to observed maximum catch potential of 1,000 spp of marine fishes and invertebrates;
- Include species from krill to tuna and sharks;
- The model has high explanatory power and agrees with expectations from theory.

Cheung *et al*. (in press) Mar. Ecol. Prog. Ser.

Uncertainty

- **Recent distributional ranges can be uncertain;**
- **Accurate estimates of population and dispersal parameters are not available;**
- **Synergistic effects between species or non-climate anthropogenic factors are not captured;**
- **Effect of change in ocean chemistry (e.g. ocean acidification) is not considered;**
- **Species' genotypic or phenotypic adaptations to the changing climate are assumed to be negligible;**
- **However, sensitivity analysis demonstrates reasonable model robustness to some of these uncertainties.**

Summary

- The model appears to provide reasonable predictions of climate change-induced shift in distribution ranges;
- Sensitivity analysis indicates that model predictions are robust to major model assumptions and parameter uncertainties;
- Global impacts of climate change on marine biodiversity and fisheries production can be revealed by predicting the shifting of ranges of 1,066 species of marine fish and invertebrates.

SEA AROUND US PROJECT

Acknowledgements

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  - Pew Charitable Trusts through the *Sea Around Us* Project;
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- A. Gelchu, A. Kitchingman, D. Zeller, , J. Alder, J. Hui, R. Ahrens, S. Hodgson and many others.

Thank you