# Impacts of Fisheries and Global Warming on Marine Ecosystems: the Challenges for New Zealand

**Daniel Pauly**
***Sea Around Us***

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# Global fishery prospects under contrasting management regimes

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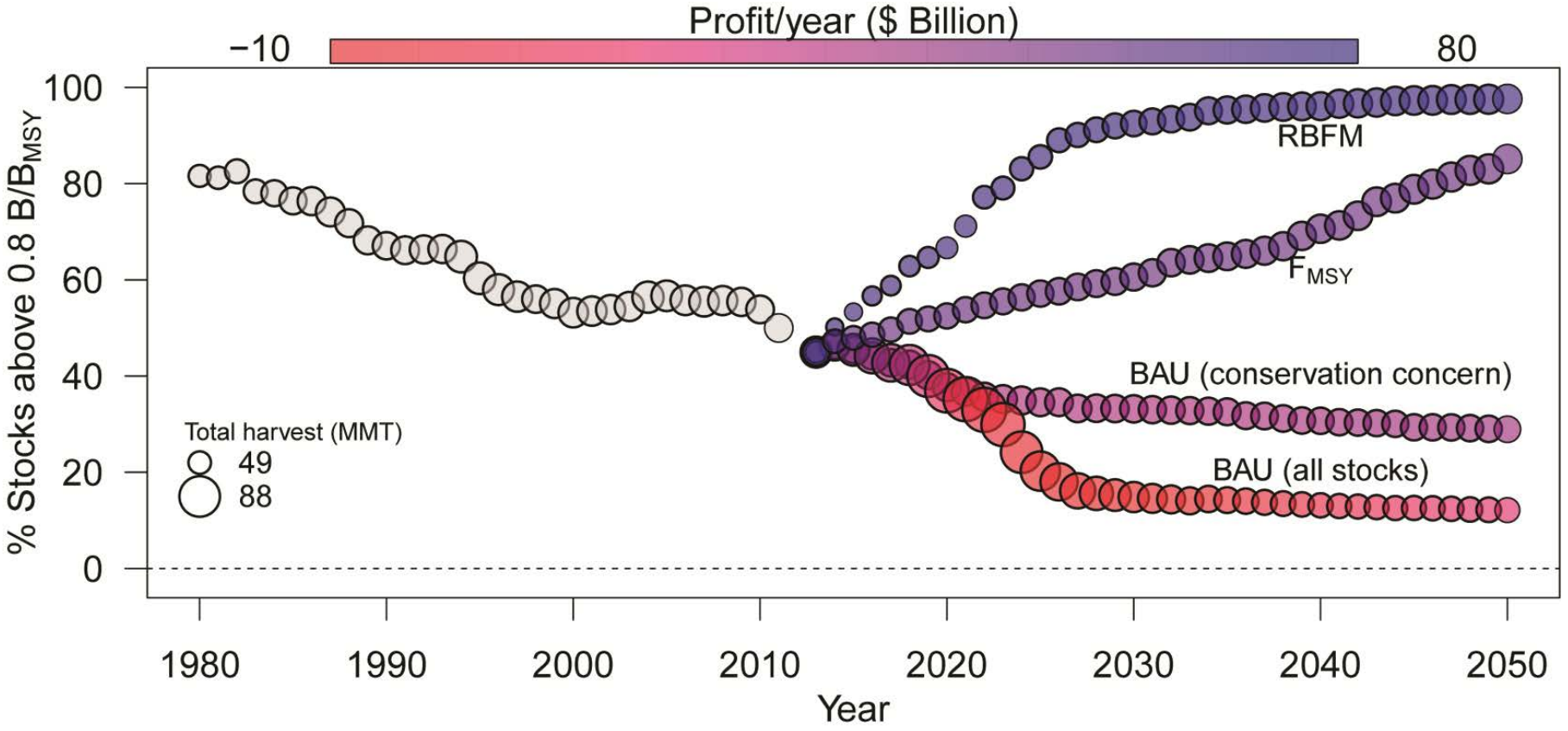
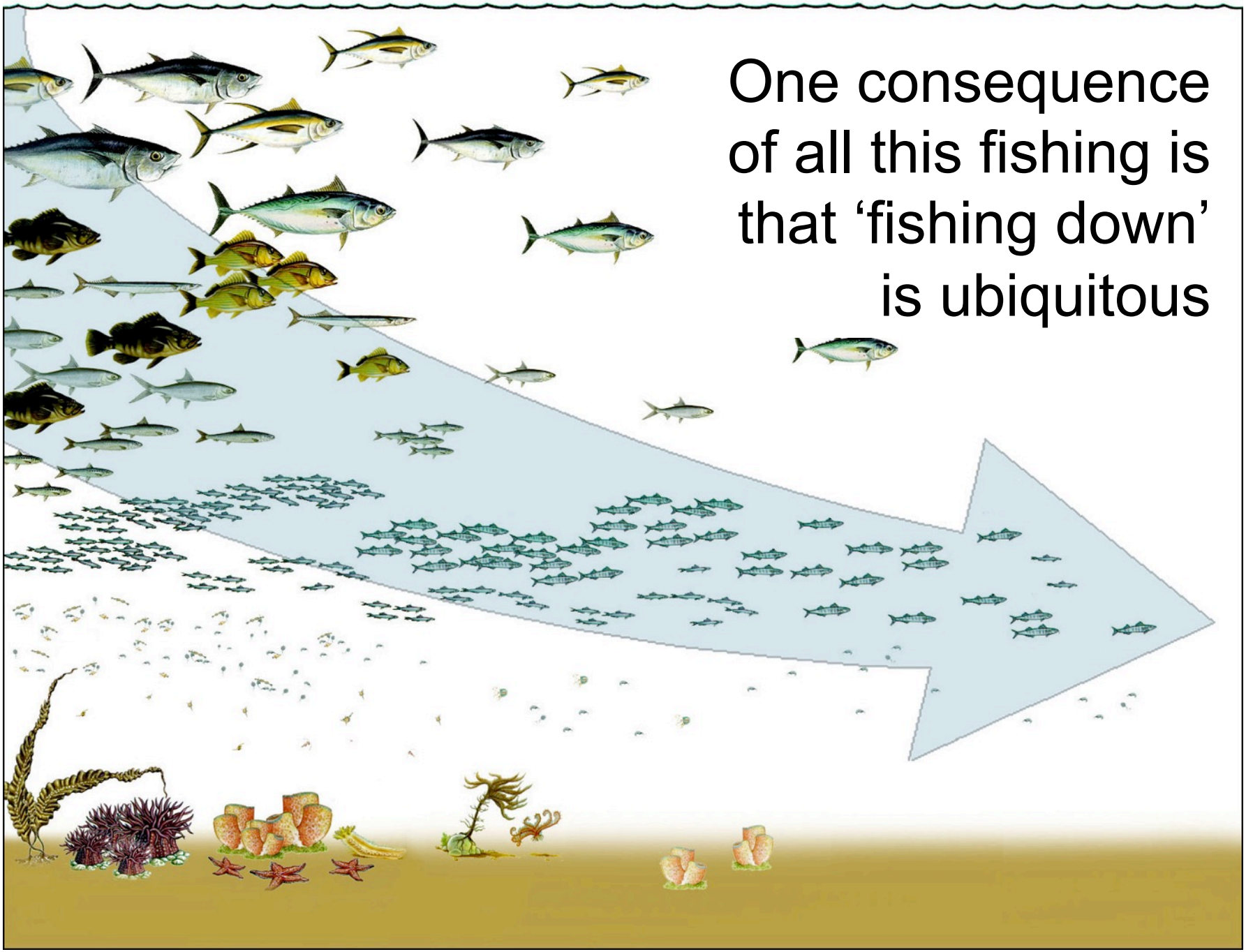
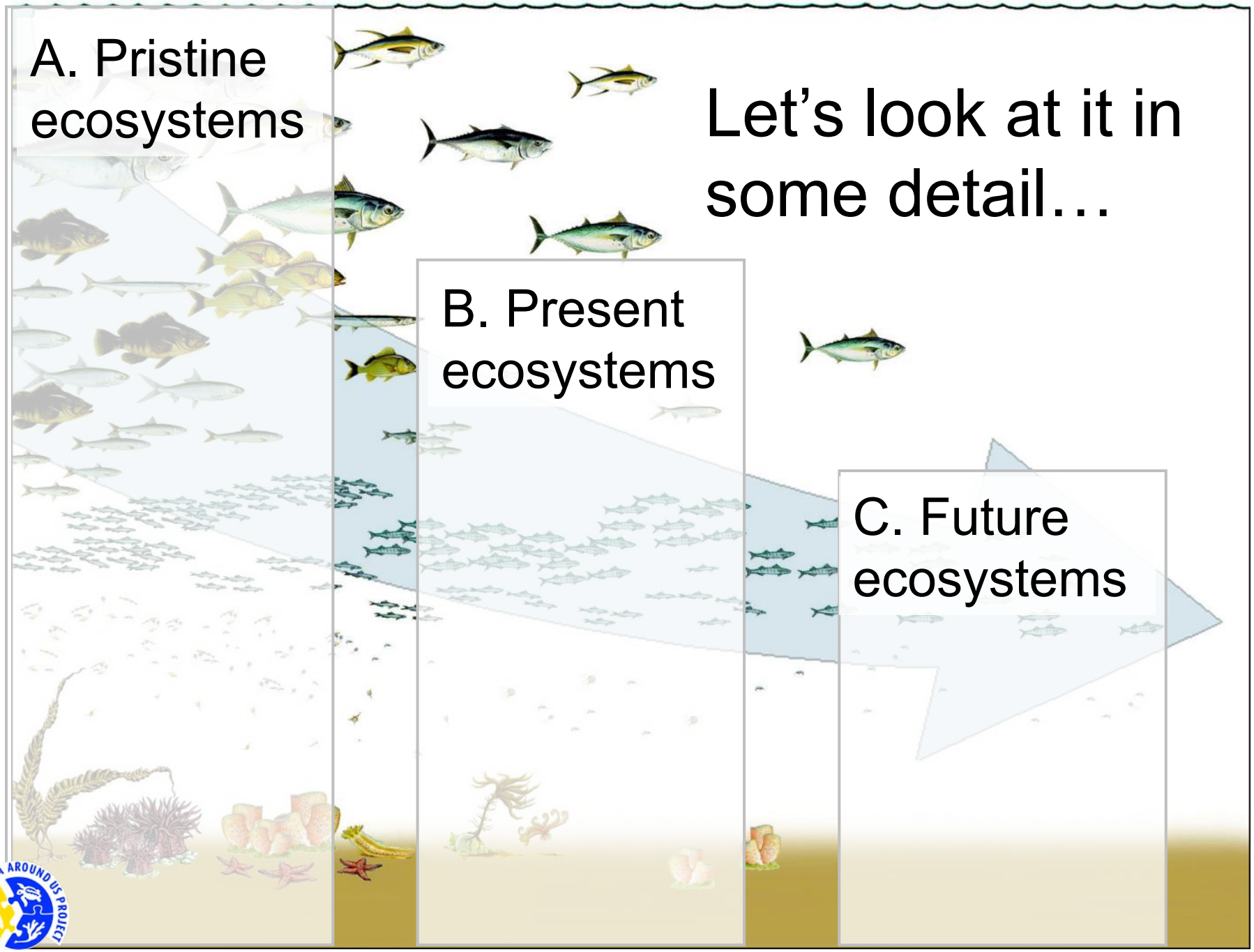
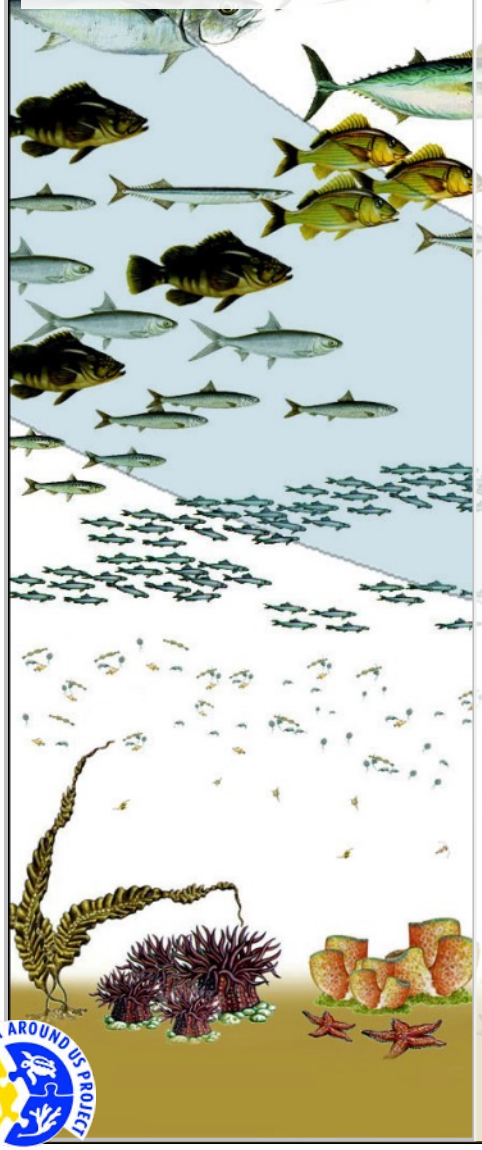



Which of the scenarios will be realized?


One consequence
of all this fishing is
that ‘fishing down’
is ubiquitous


A. Pristine ecosystems
Let's look at it in some detail…
B. Present ecosystems
C. Future ecosystems

# A. Pristine ecosystems



- Abundant large, long-lived, high trophic-level predators (incl. fish and turtles that eat jellies);
- Moderate populations of small pelagic fishes, and of opportunistic invertebrates (cephalopods, shrimps, jellyfish);
- Clear waters, due to (1) consumption of excess primary production by abundant bottom animals and (2) consolidation of bottom substrate by biogenic structures;
- Predation and competition by long-lived benthos challenge settling polyps.

For pristine ecosystems, see the National Geographic Channel*

*And note that they have to go father and farther to shoot their films…

- Decline of high trophic-level species;
- Initial increase of mid sized and mid trophic-level species, then subsequent decline of same;
- Increase of small, opportunistic species supporting valuable fisheries (shrimps, crabs, squids and now jellyfish).

# B. Present ecosystems

- Decline of benthos cover, which reduces predation on, and competition for polyps;
- Localized transition to eutrophic waters on top of the muddy areas generated by trawlers.

- Ecosystem dominated by small fishes and invertebrates, notably jellyfish;
- Re-suspension of sediments by storms and bottom trawling injects nutrients into water column;
- High primary production;
- Microbial process dominate, and system susceptible to invasions and harmful algal blooms and jellyfish;
- Benthic processes dominated by anoxic events, i.e., ‘dead zones’, and growth of polyp fields.

## C. Future ecosystems

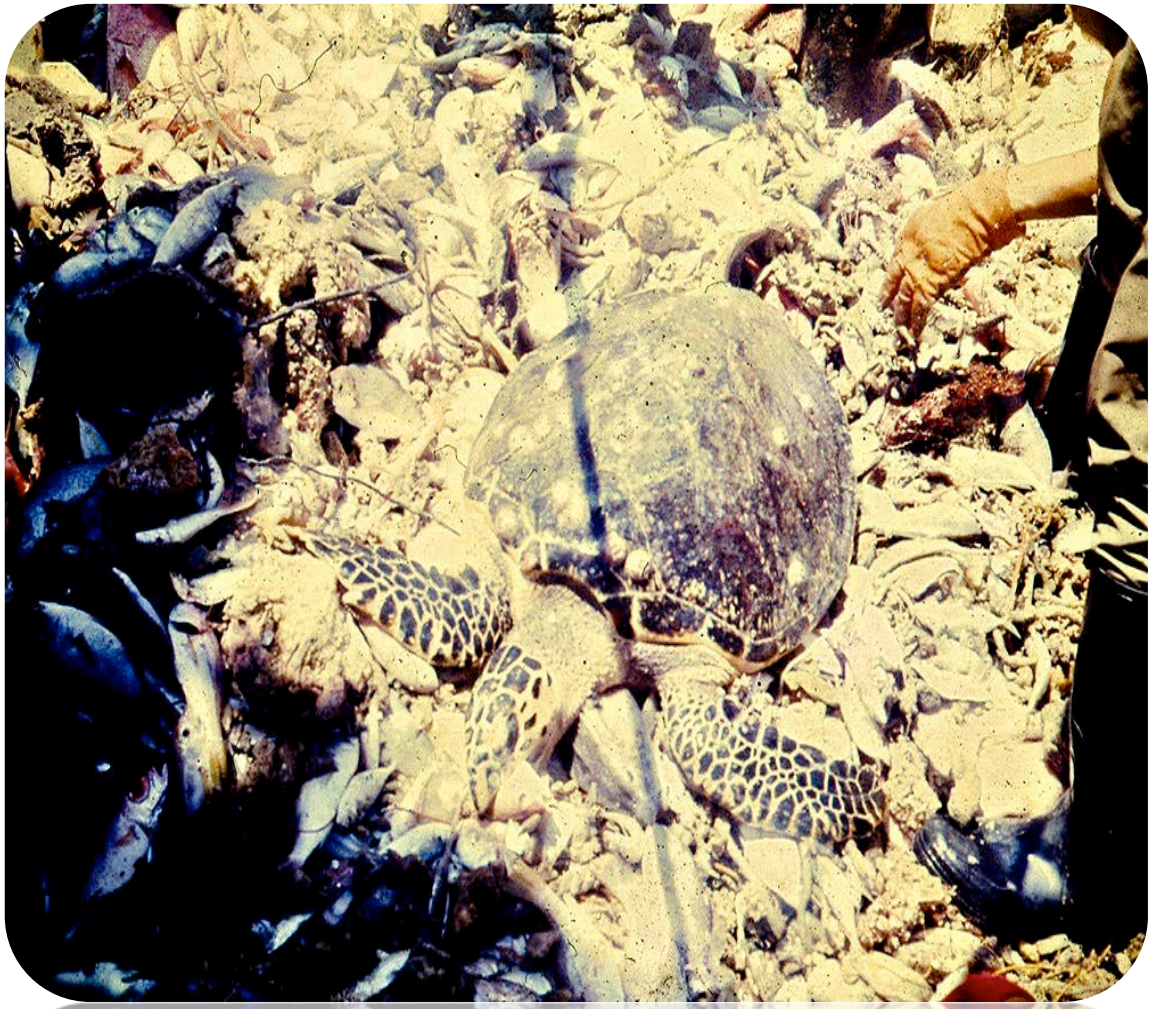
The Chinese coastal fisheries provide a good example of what ‘Fishing down’ leads to…

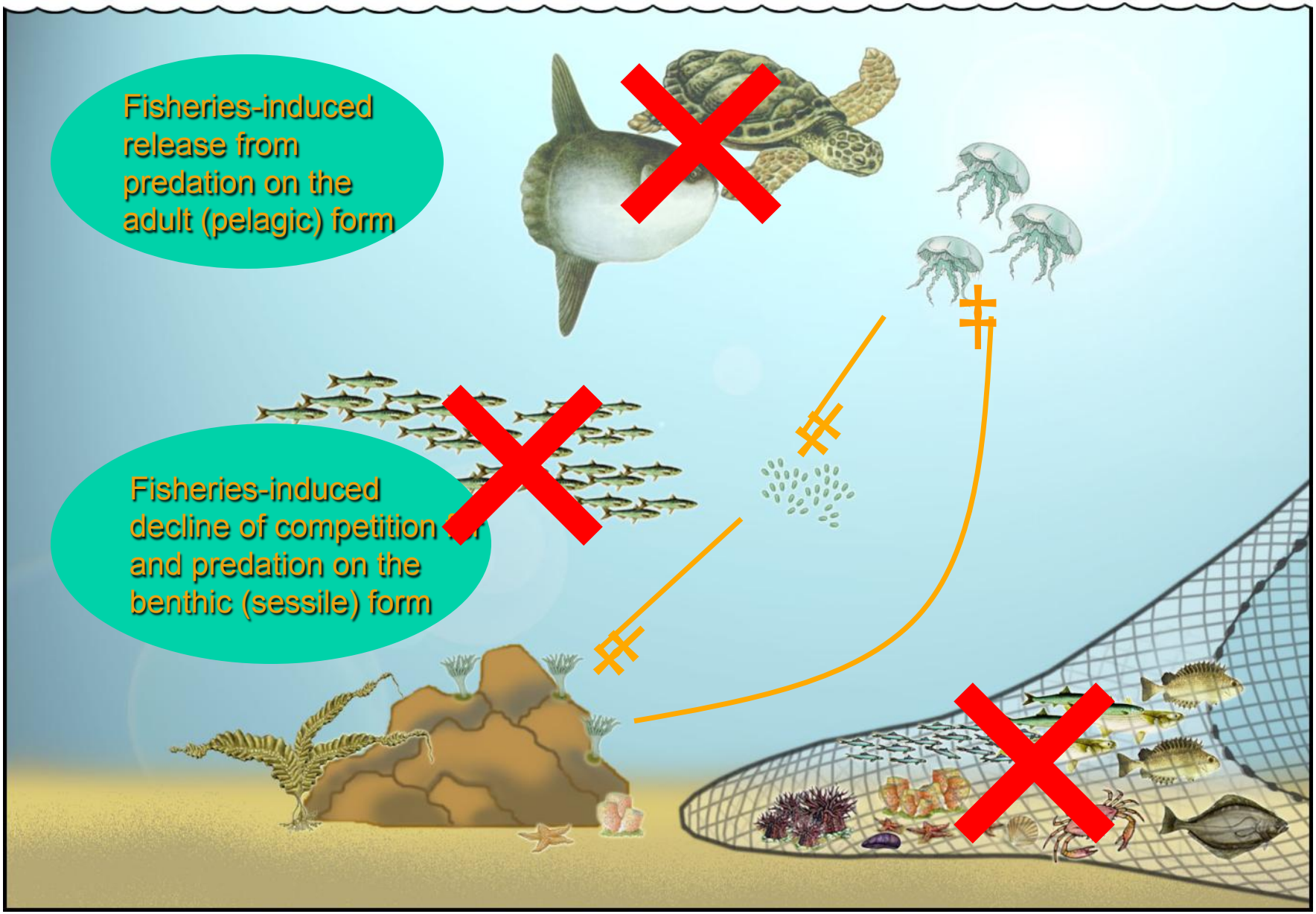
In the Java Sea, Western Indonesia, 1975

Removing the bottom animals as ‘fisheries development’…

and more…

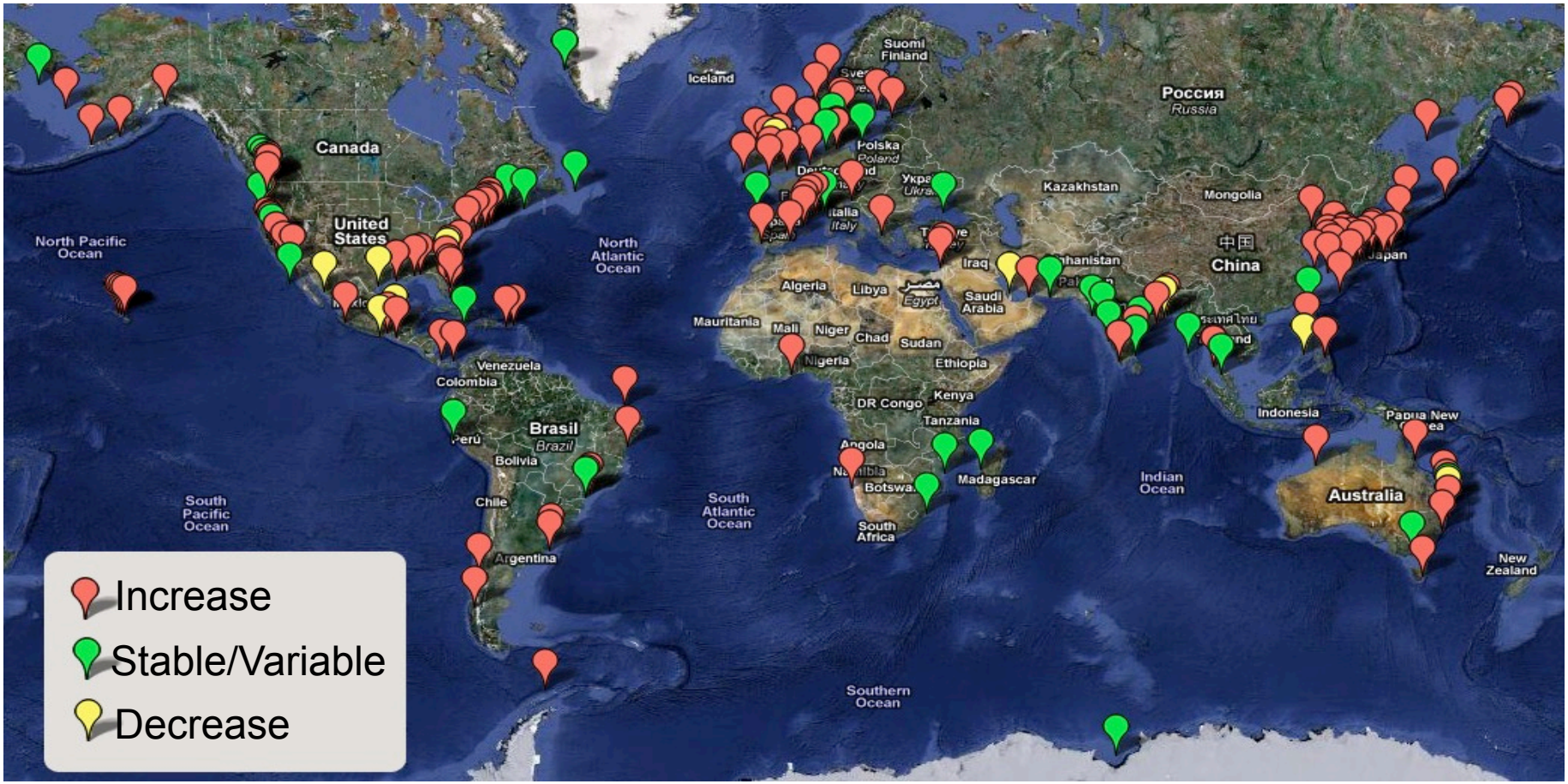
See the turtle?




Fisheries-induced release from predation on the adult (pelagic) form
Fisheries-induced decline of competition and predation on the benthic (sessile) form

The effect of all this is that jellyfish appear to increase almost everywhere...

To test this, a global analysis was conducted by my PhD student Lucas Brotz, of cases of increases, decreases or no changes on a global basis. His key result is:

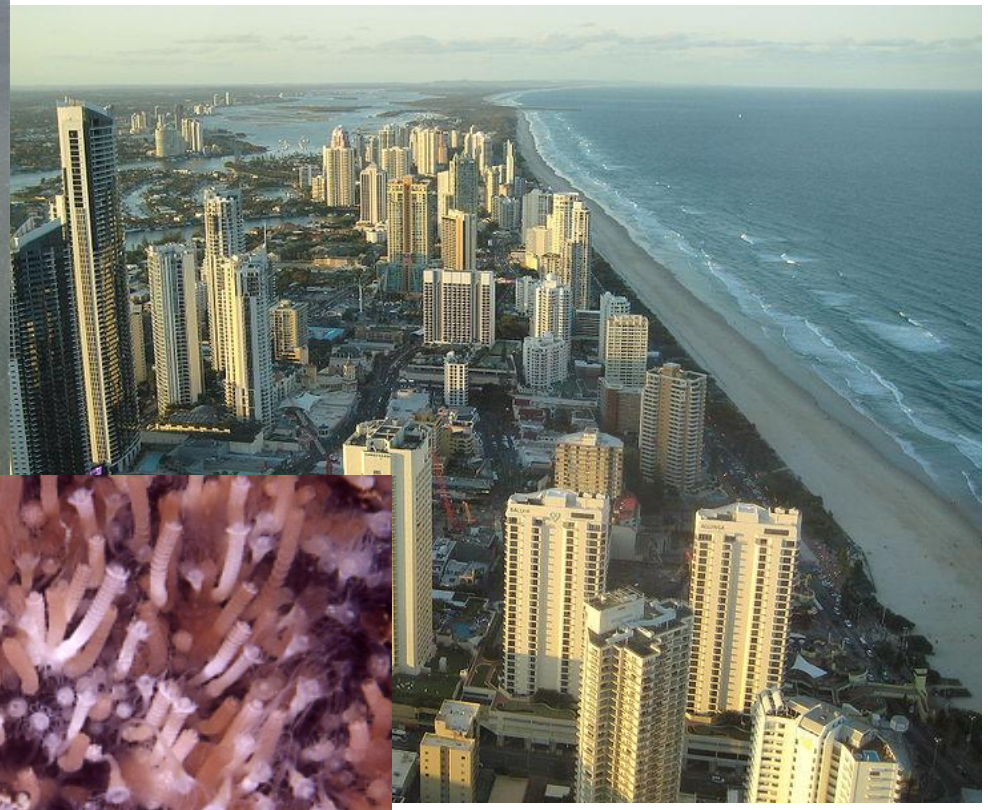


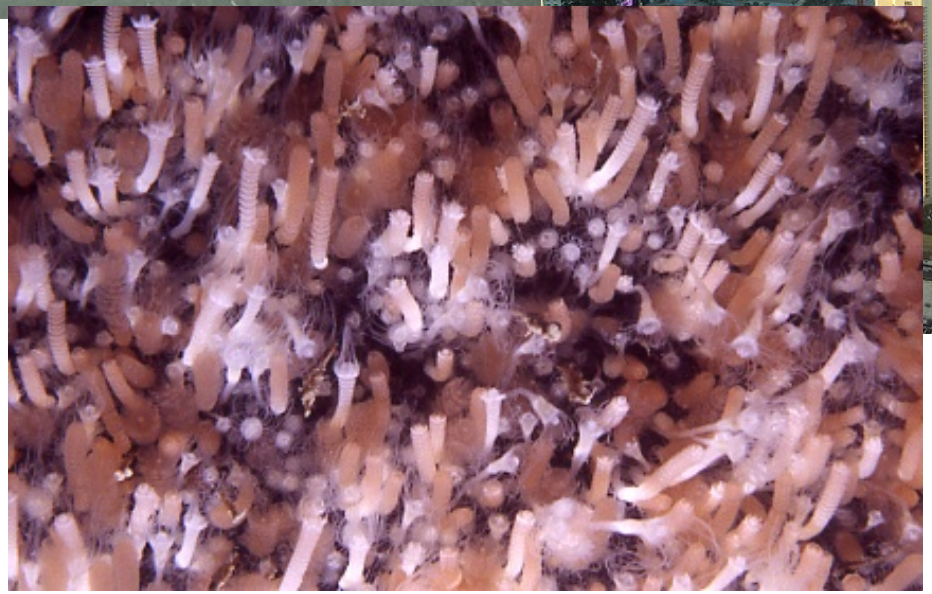

Brotz *et al.* (*Hydrobiologia,* 2012)




One factor are dead zones, which are increasing in size and number (now over 400 in the world). One of the better-known dead zone is in the northern Gulf of Mexico, whose extent broadly overlaps with sources of jellyfish outbreaks

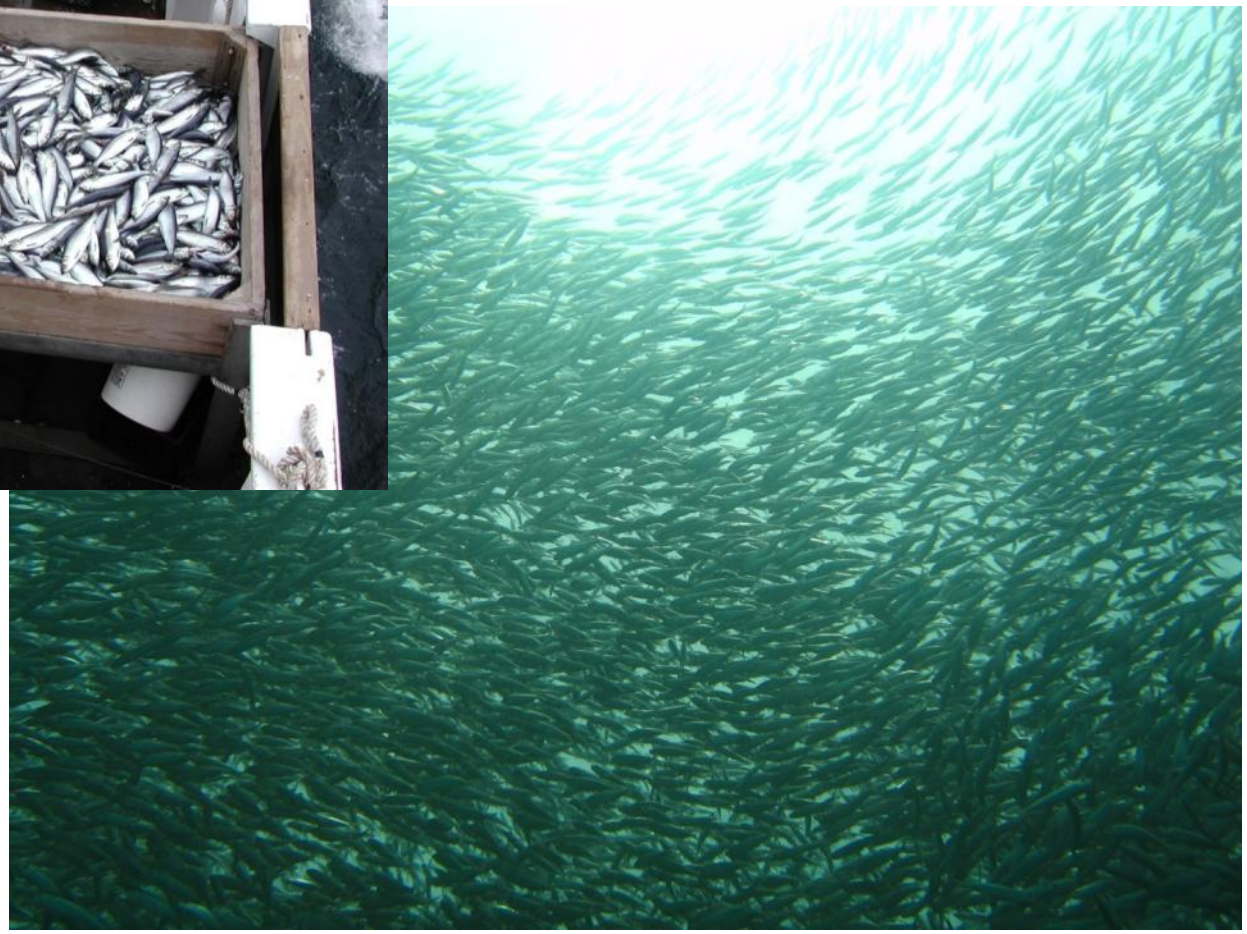
# Another possible cause is coastal development





Hoover & Purcell 2009

# Then there is fishing for small fishes



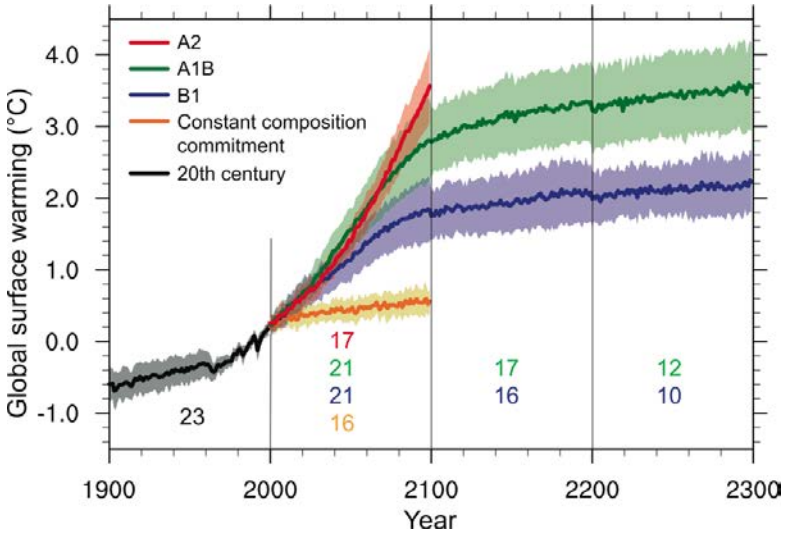
# Trawling and dredging


FK2-2137

… and since trawling and fishing down are likely to continue, enjoy your JBLT !

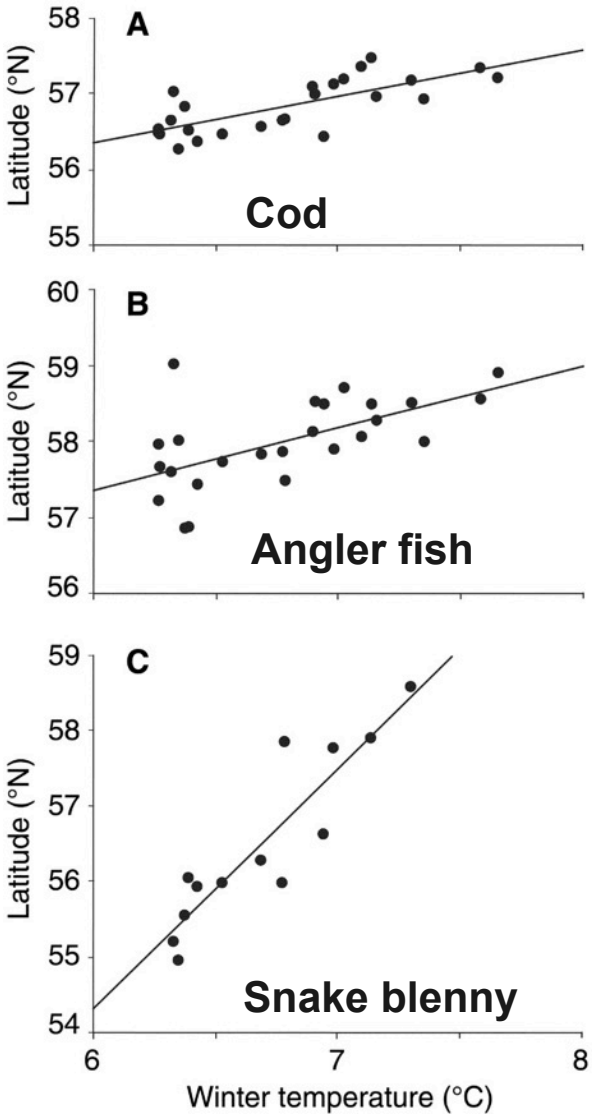
Design: Jennifer Jacquet

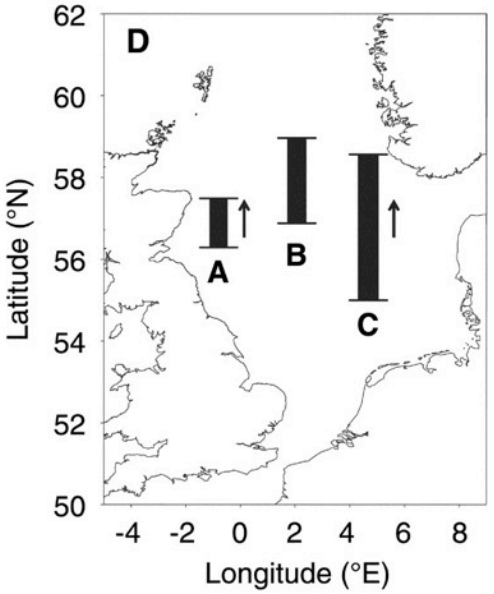
# Meanwhile, things are heating up…




# Observed climate-induced shifts in distribution ranges

Poleward shifts in distribution ranges of marine species, e.g., in the North Sea (Perry *et al. Science,* 2005).

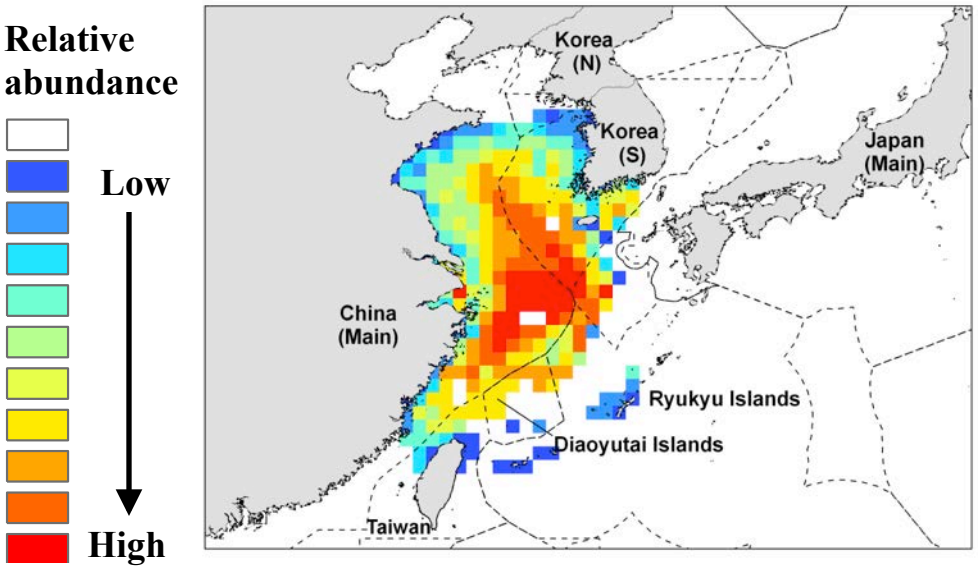


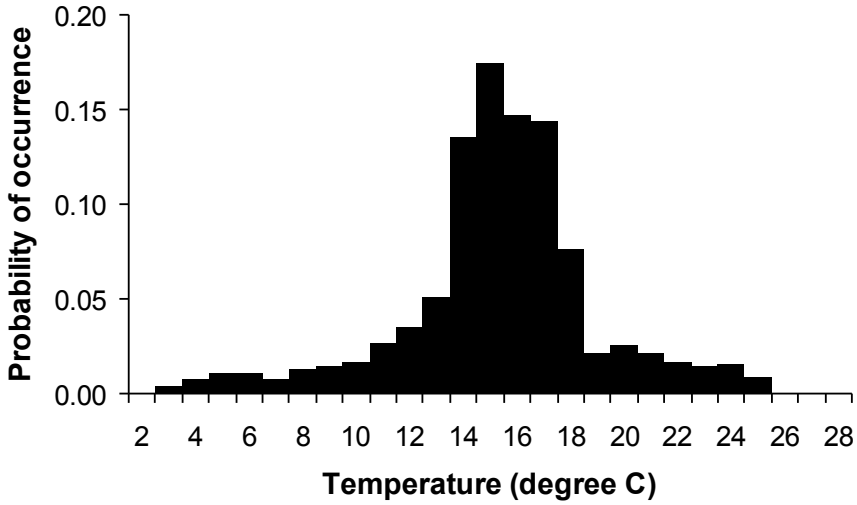



# Simulating poleward shifts using temperature-abundance profiles…

**Small yellow croaker (*Larimichthys polyactis*)**

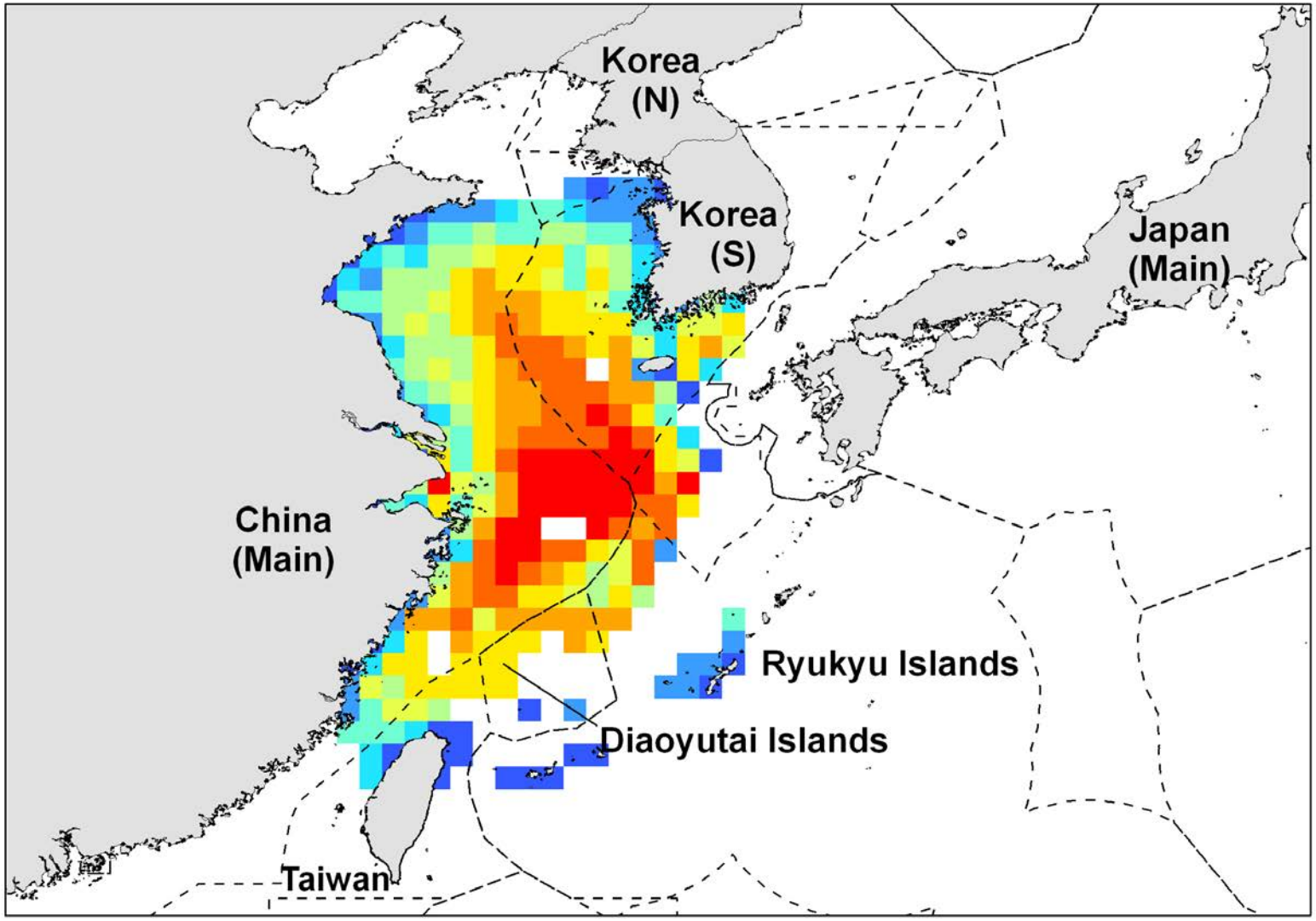
**Probability of occurrence by water temperature**



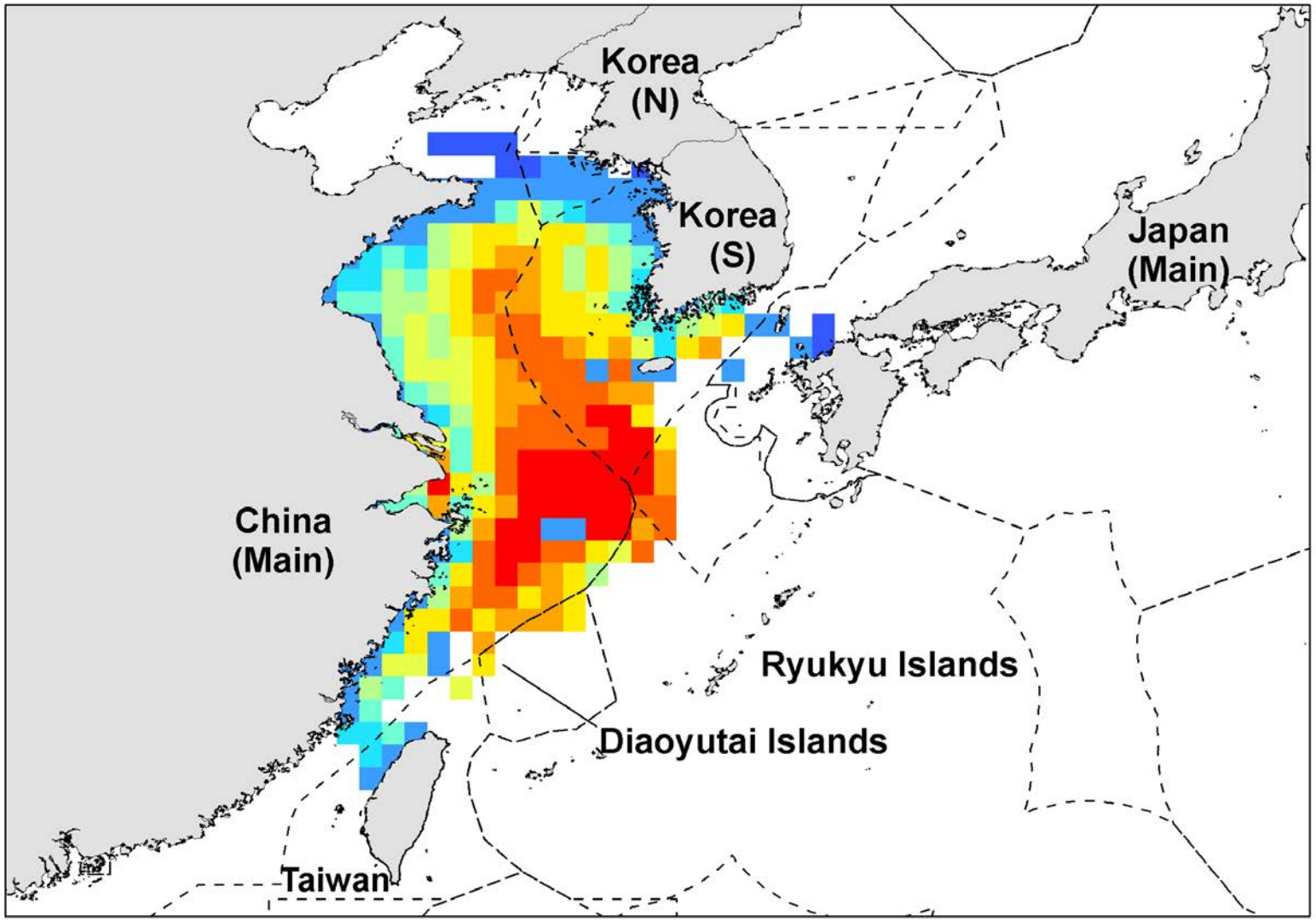
# Small yellow croaker

**Year 0**



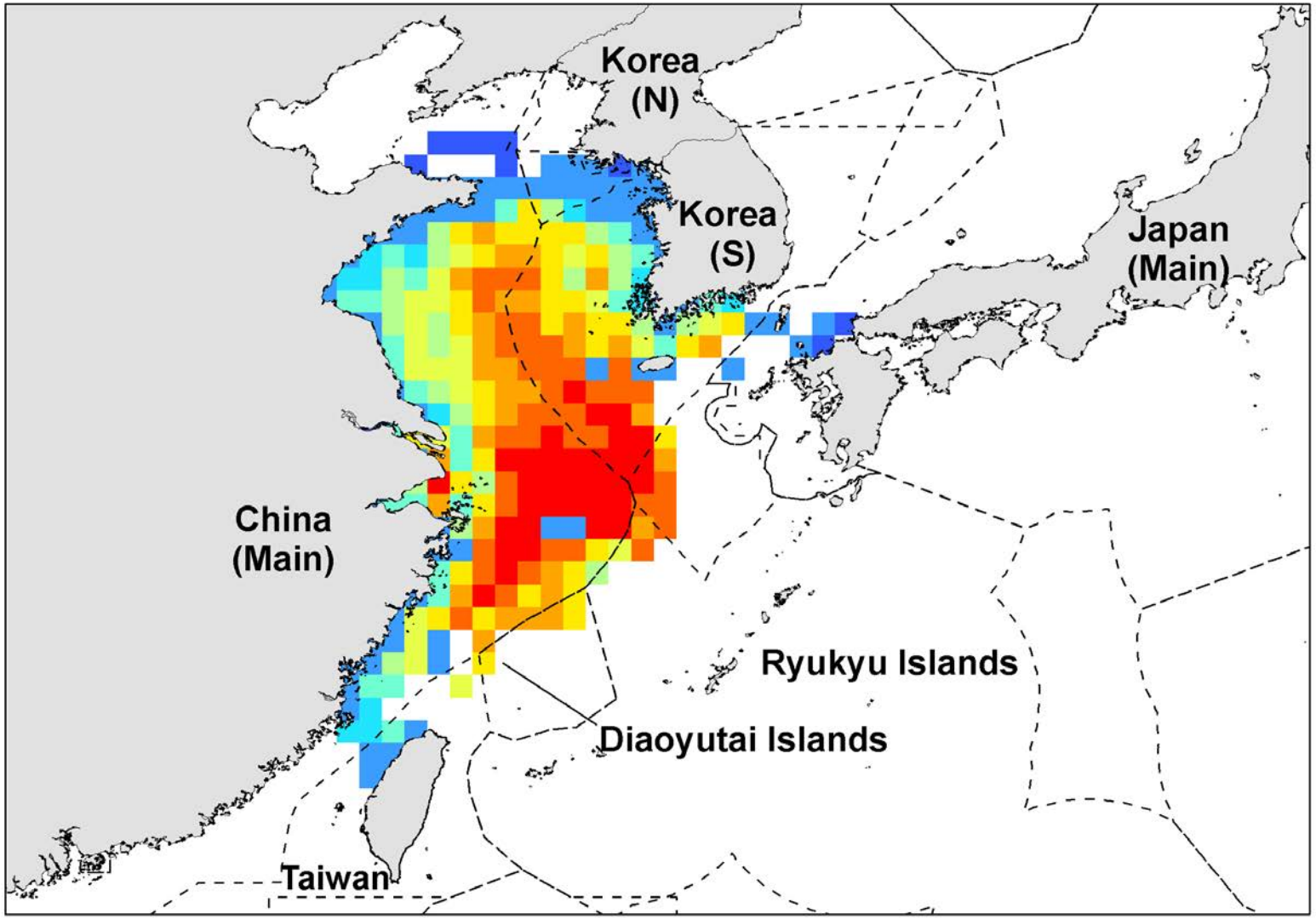
# Small yellow croaker

**Year 2**



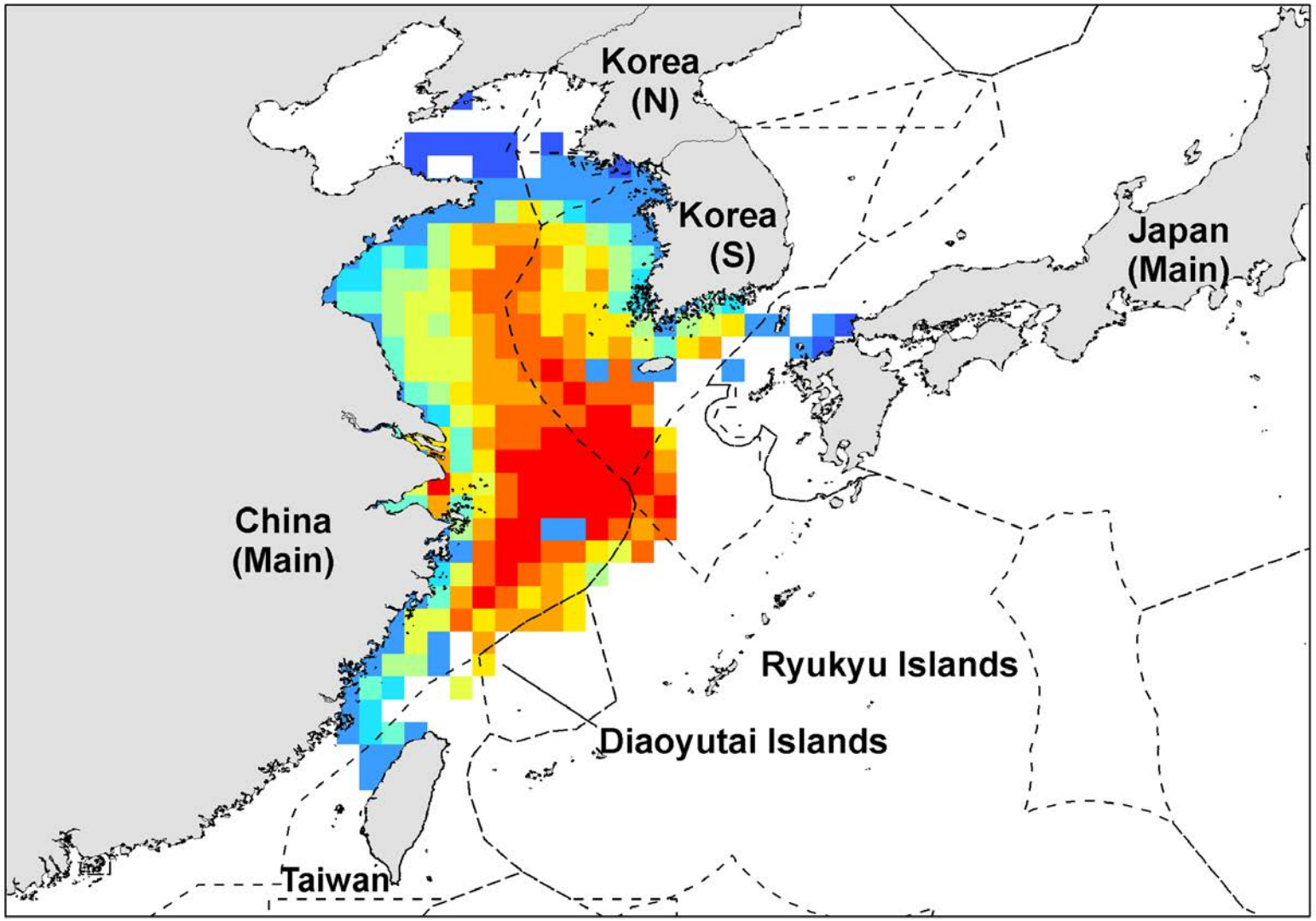
# Small yellow croaker

**Year 4**



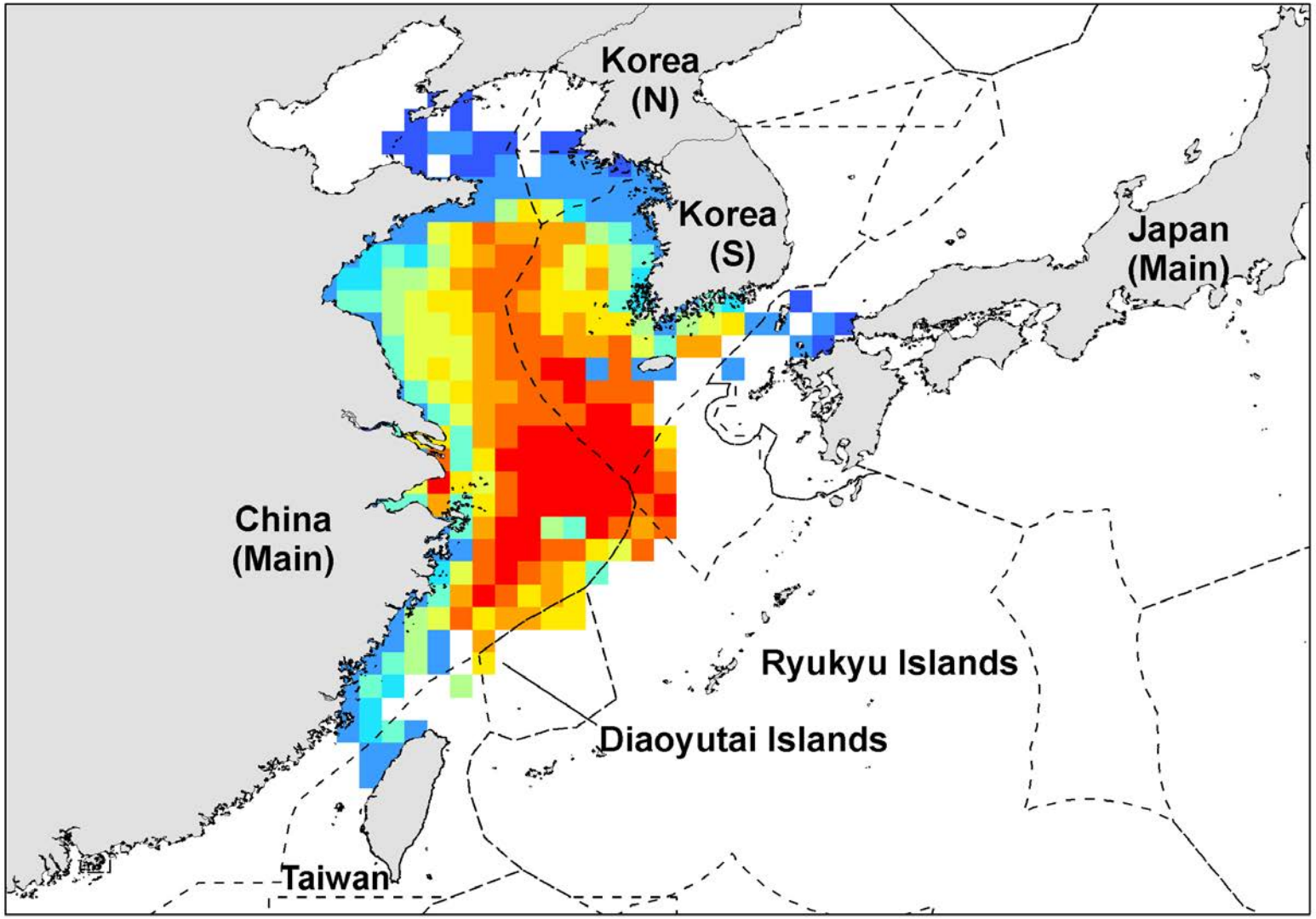
# Small yellow croaker

**Year 6**



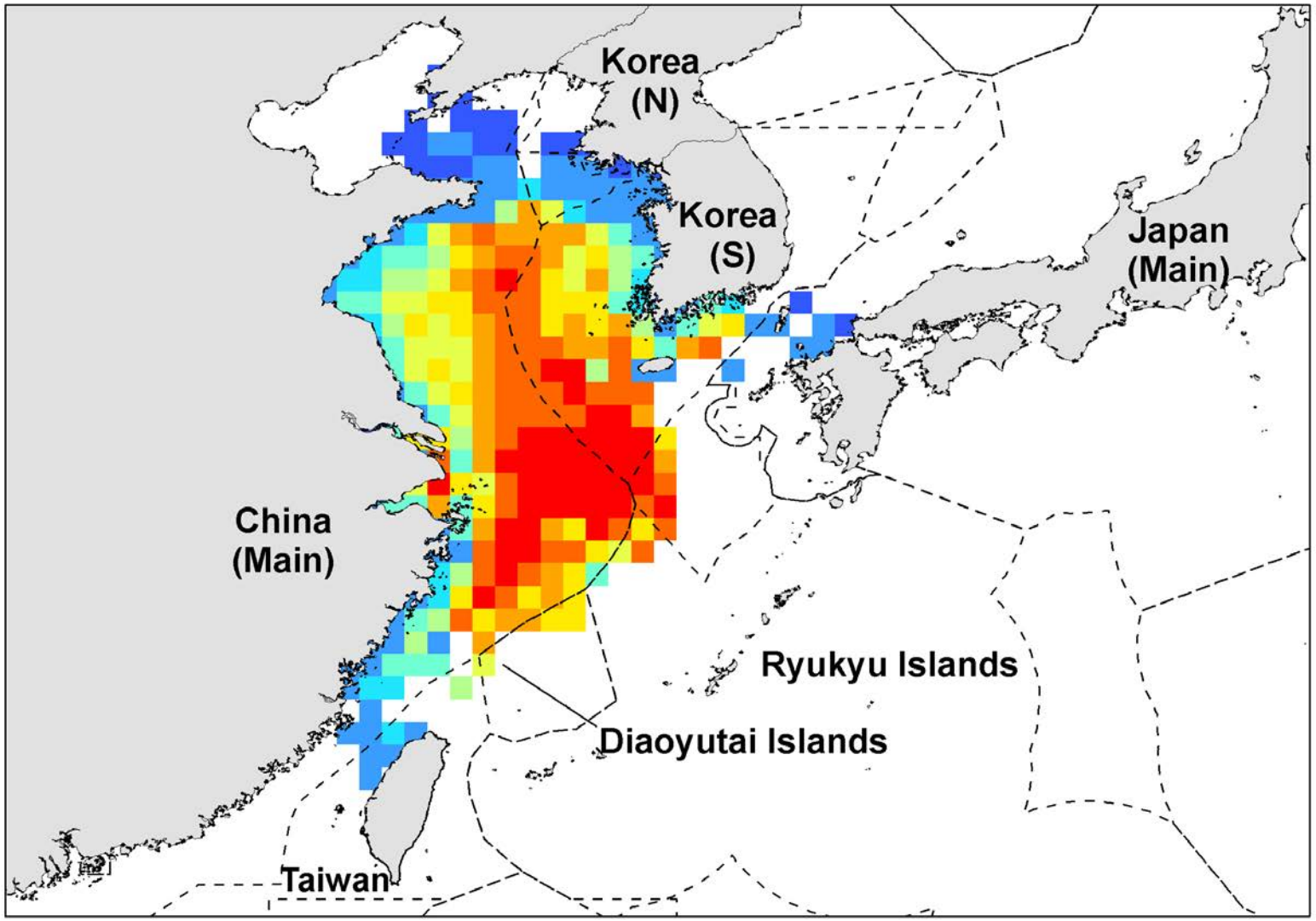
# Small yellow croaker

**Year 8**



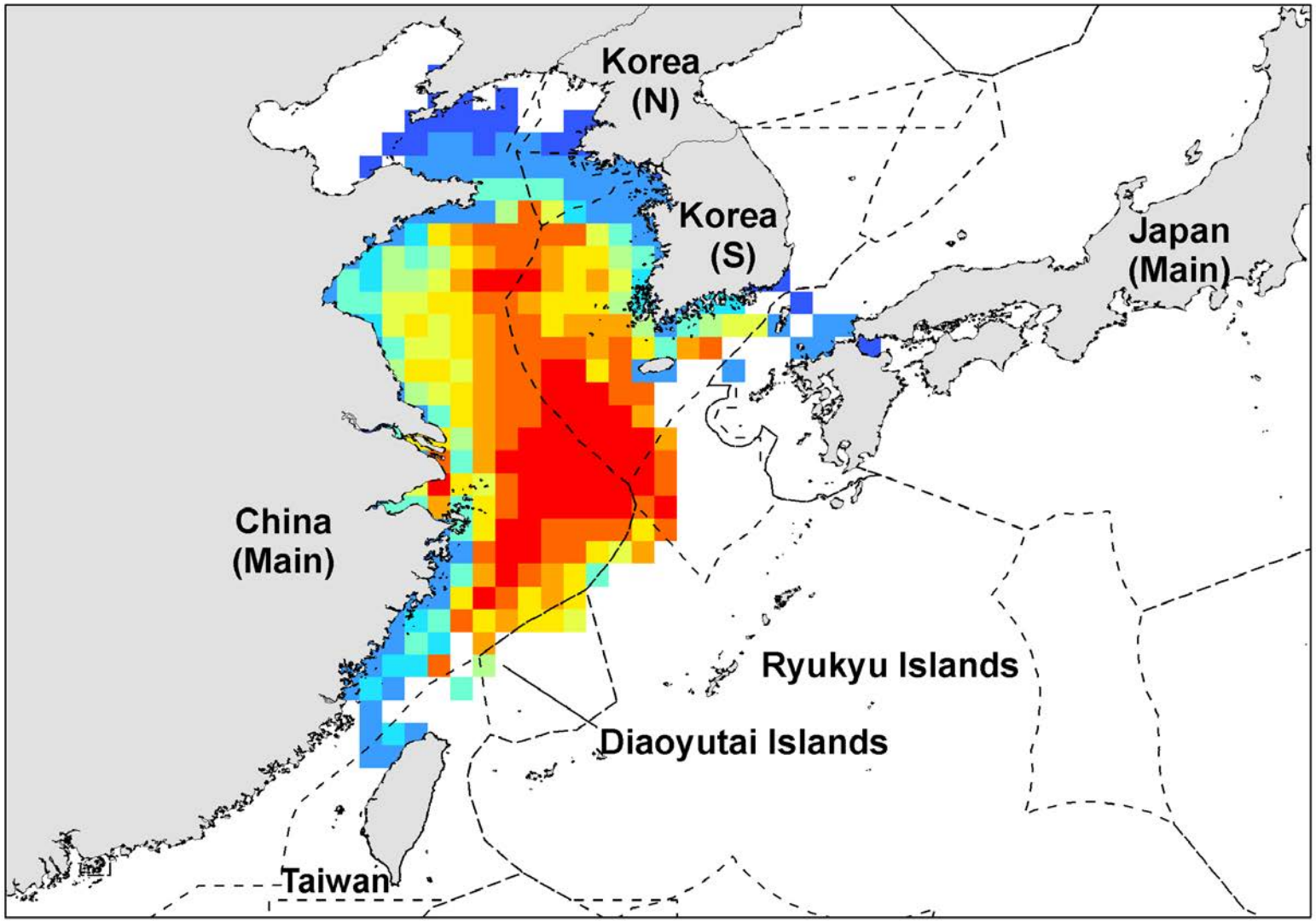
# Small yellow croaker

**Year 10**



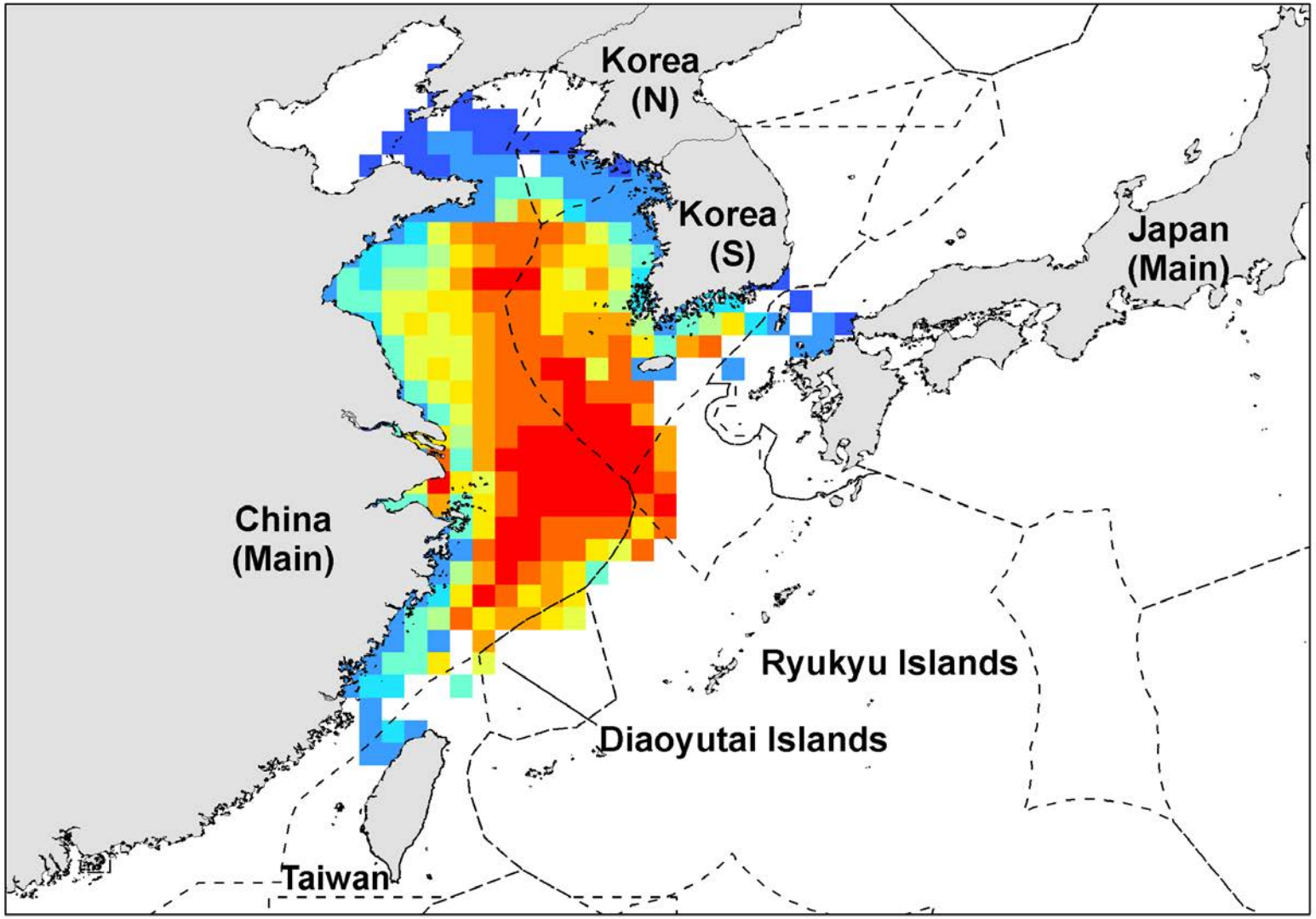
# Small yellow croaker

**Year 12**



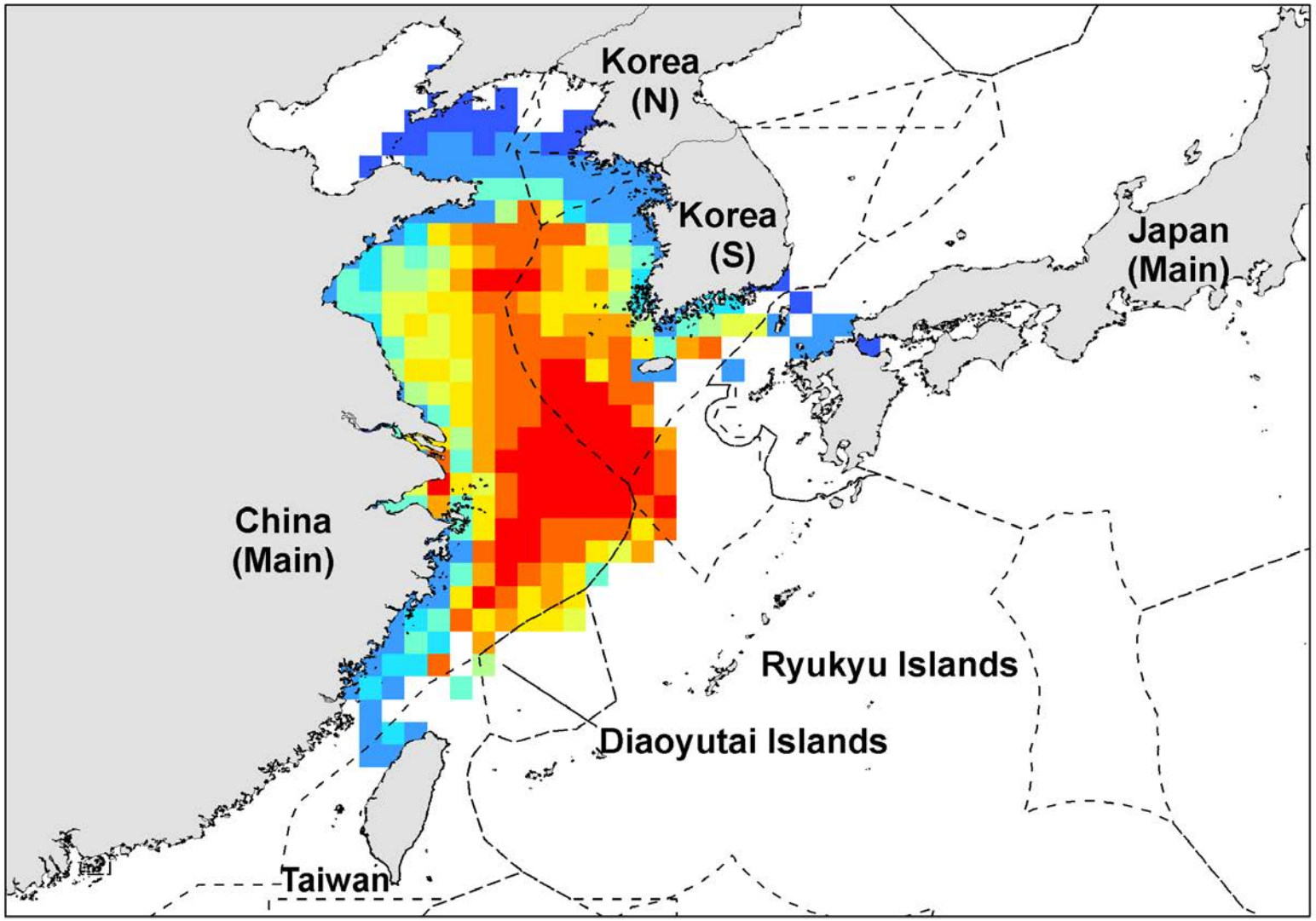
# Small yellow croaker

**Year 14**



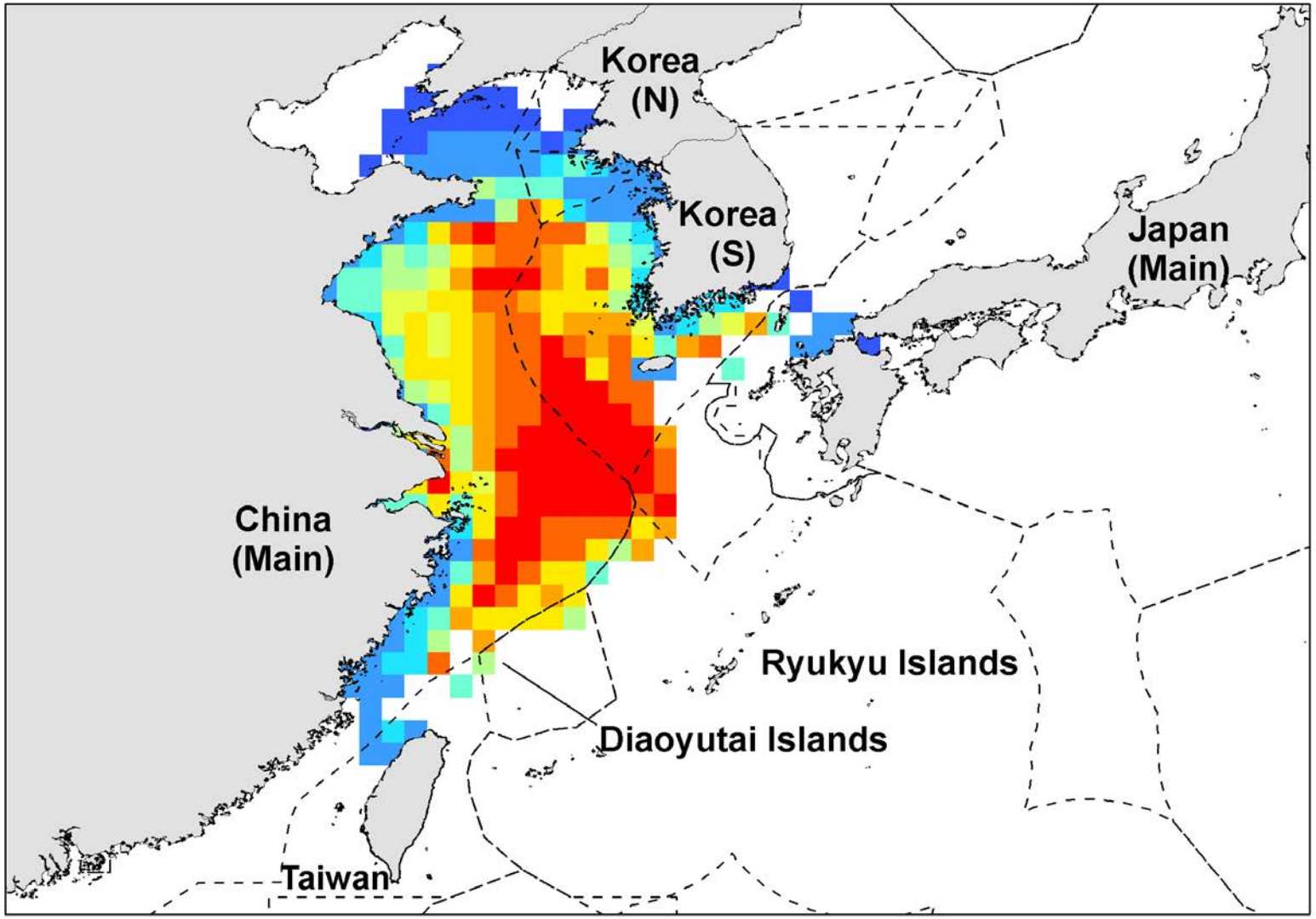
# Small yellow croaker

**Year 16**



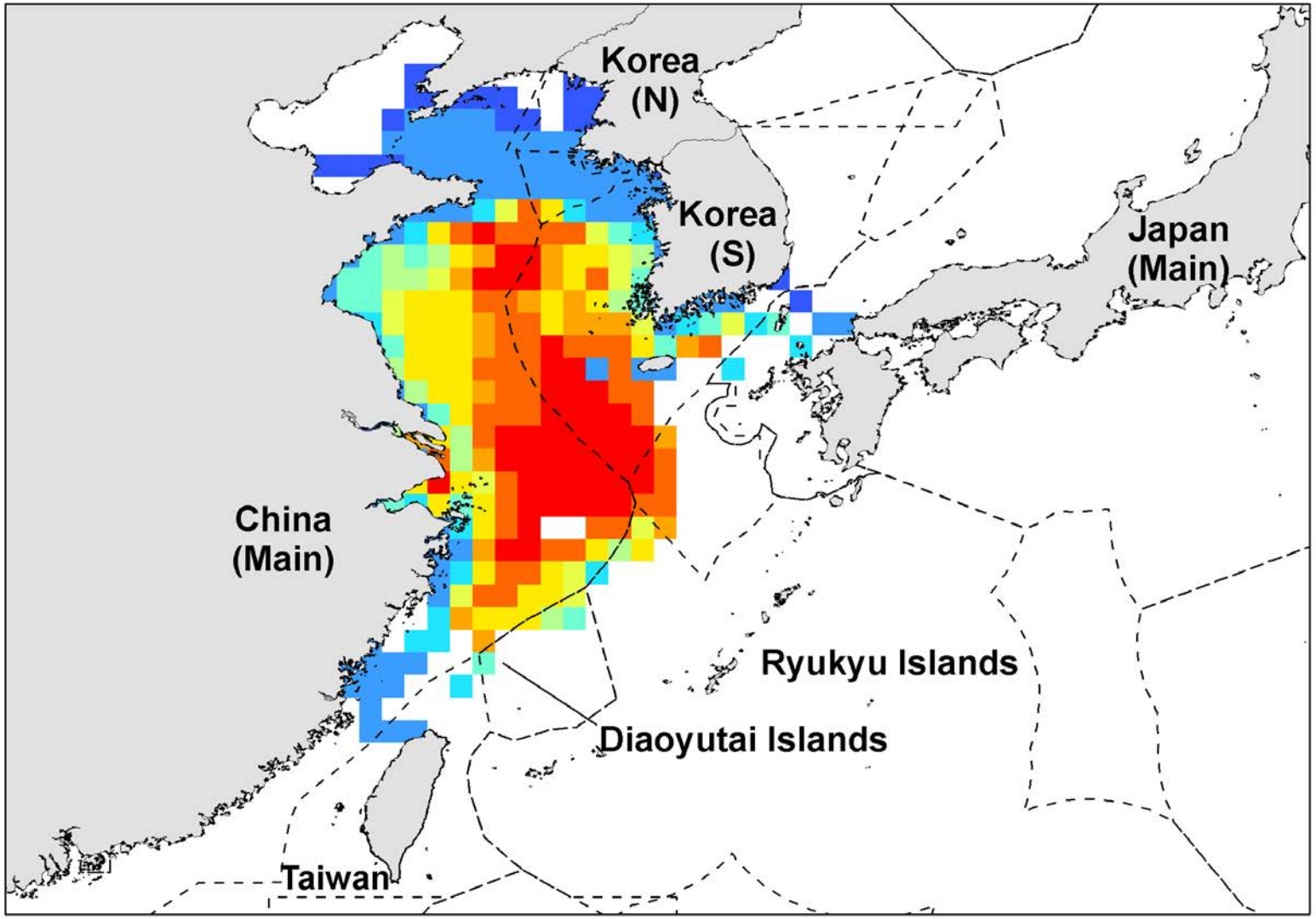
# Small yellow croaker

**Year 18**



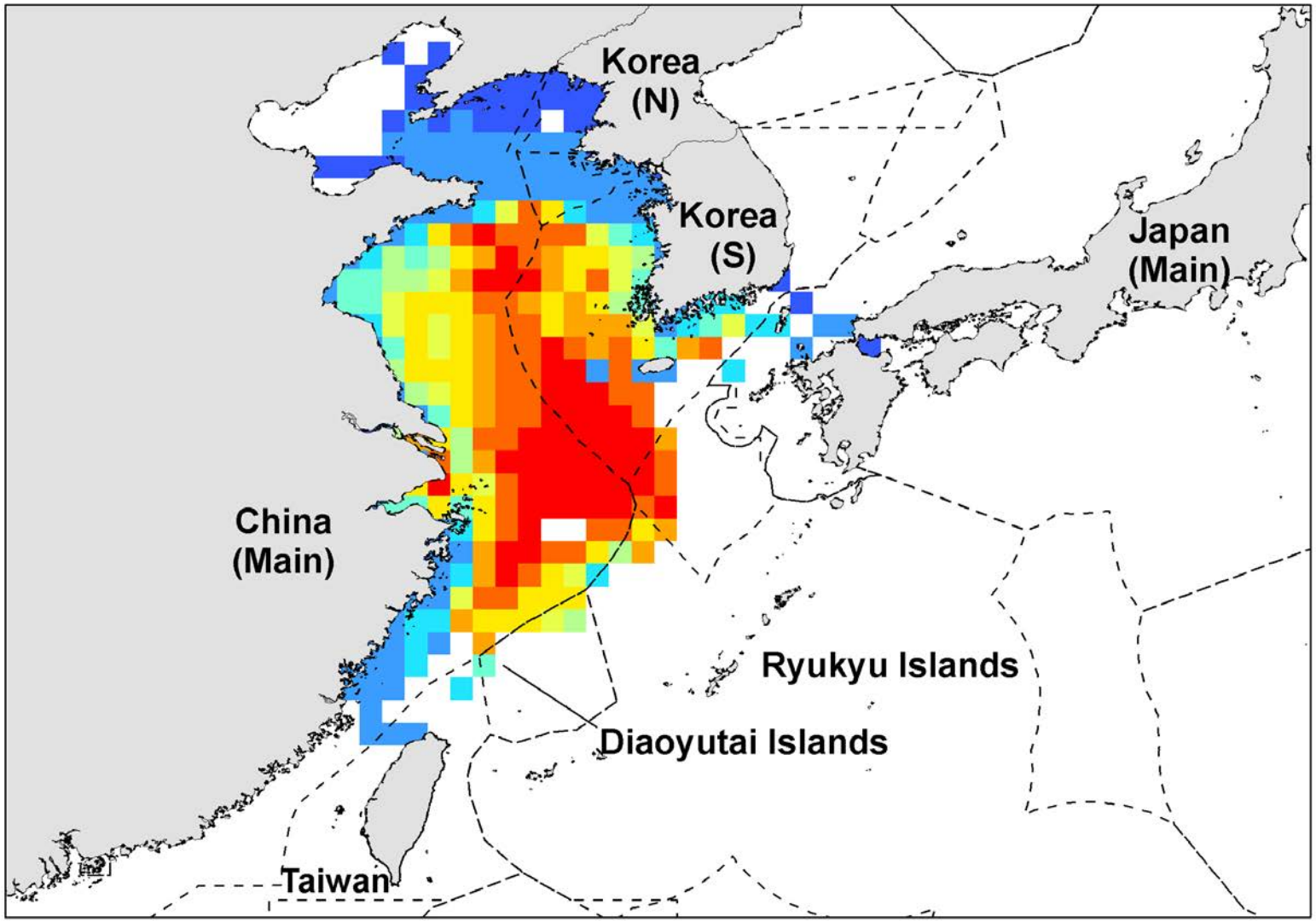
# Small yellow croaker

**Year 20**



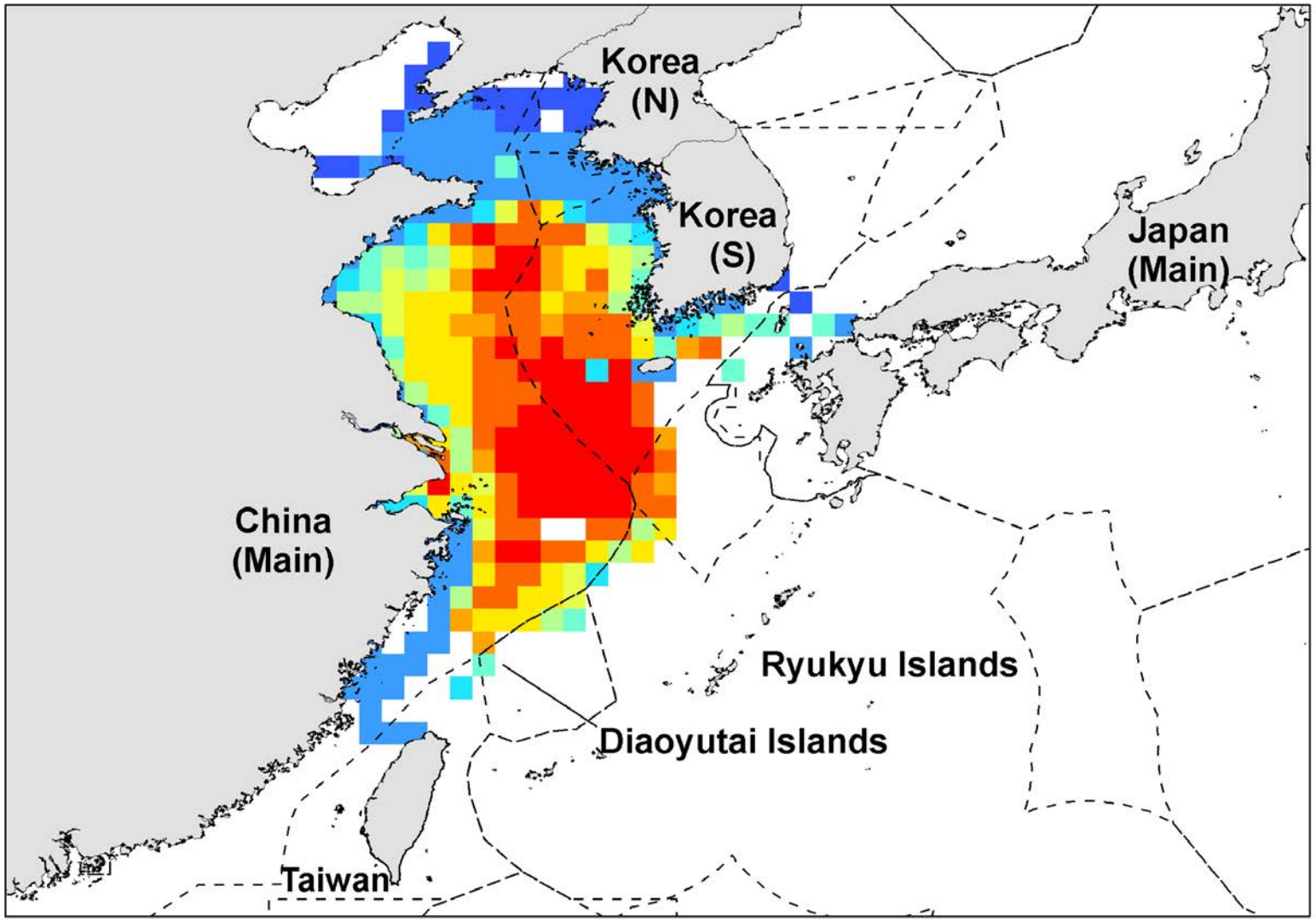
# Small yellow croaker

**Year 22**



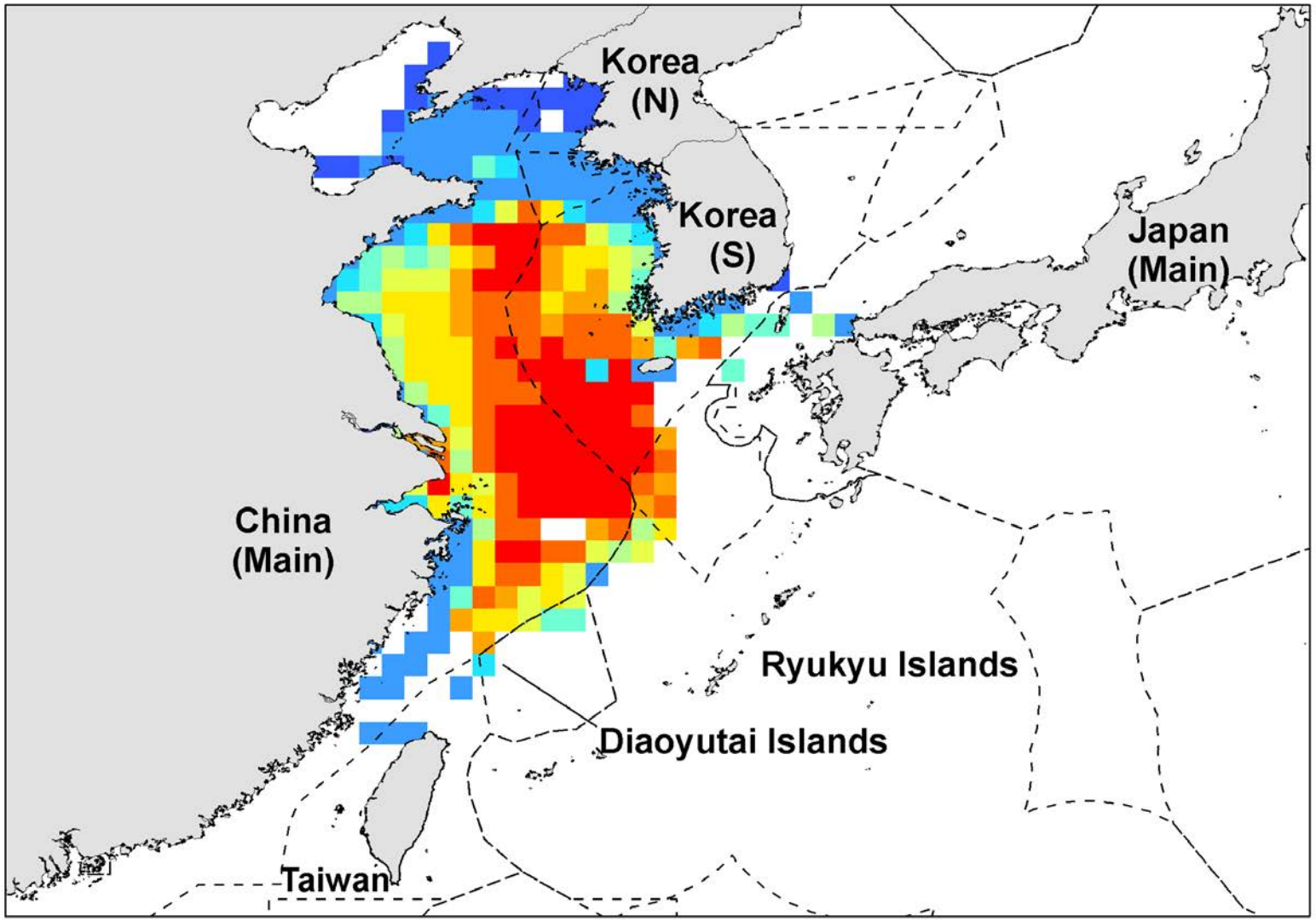
# Small yellow croaker

**Year 24**



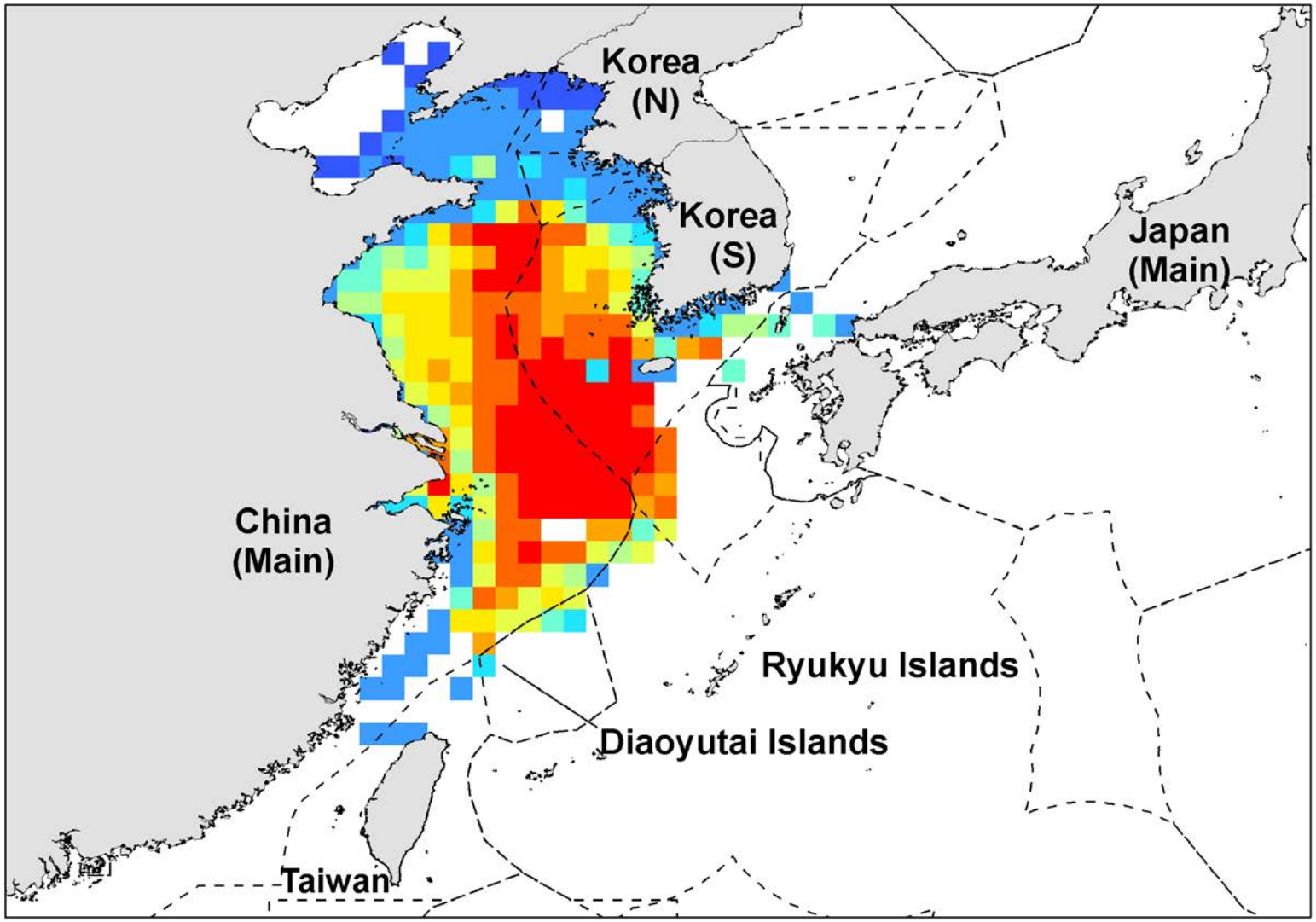
# Small yellow croaker

**Year 26**



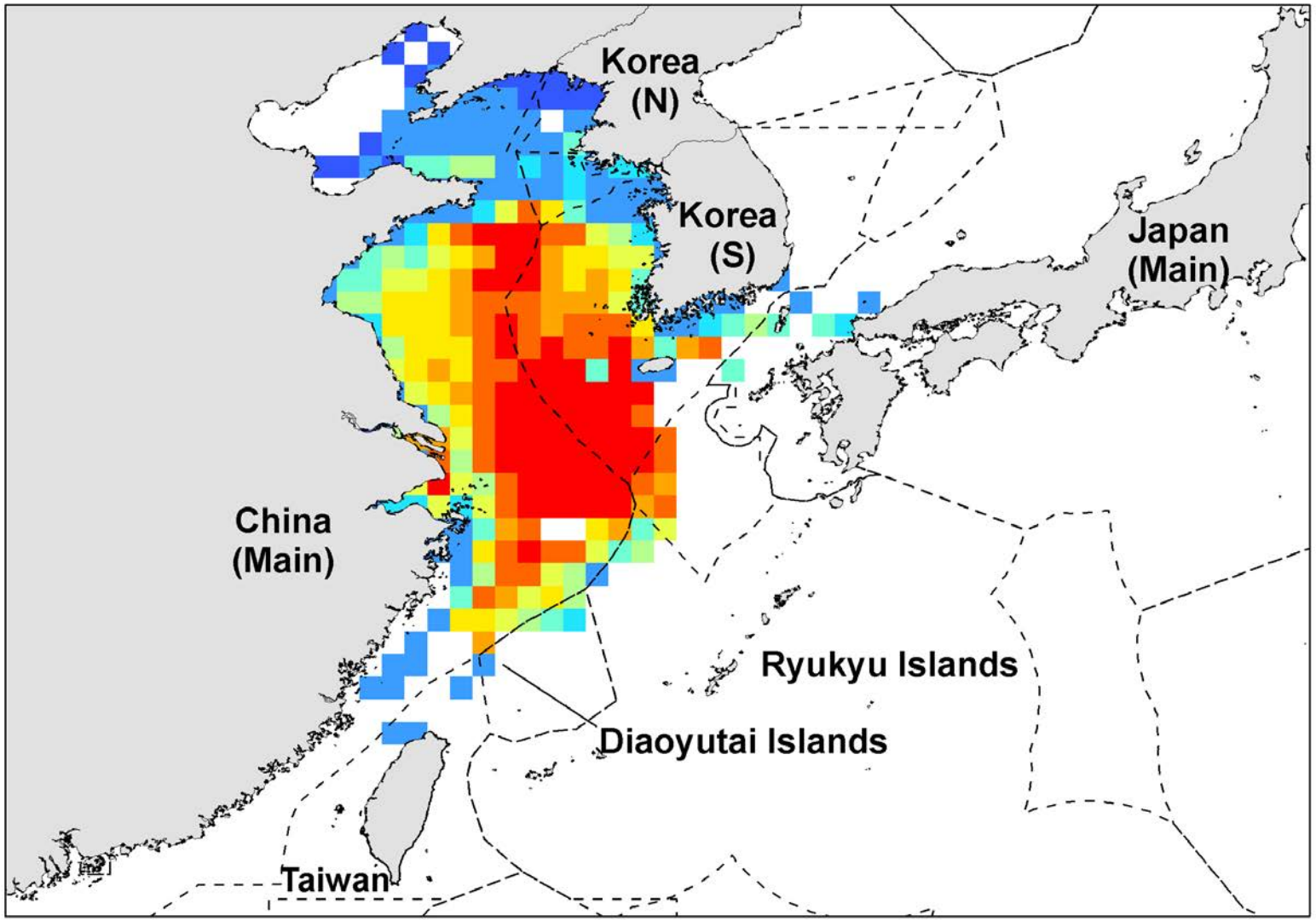
# Small yellow croaker

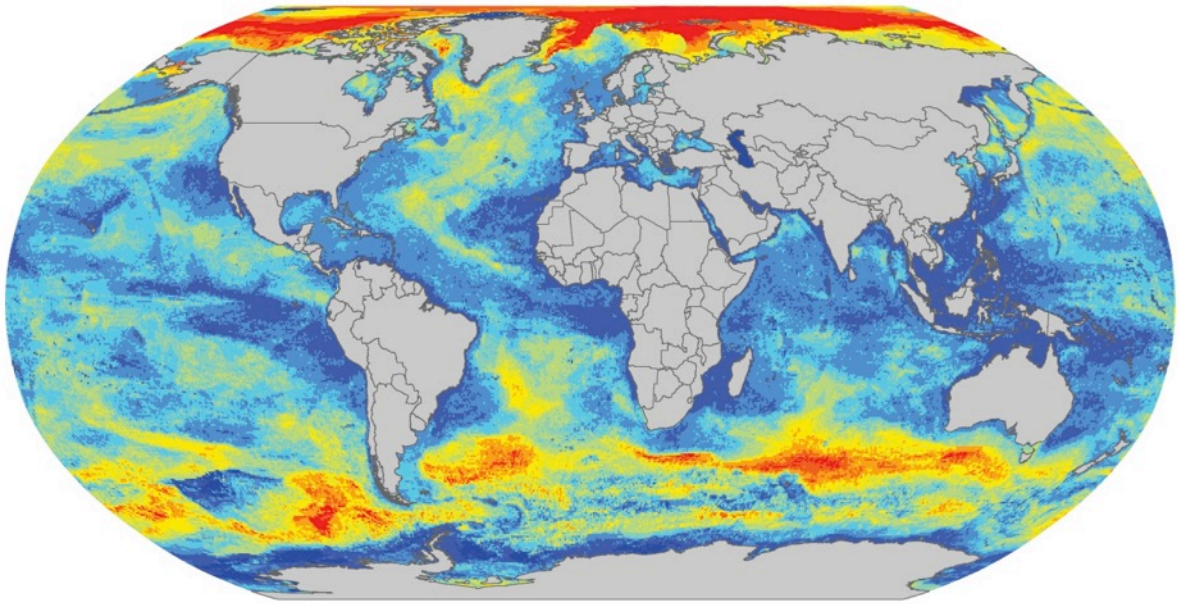
**Year 28**

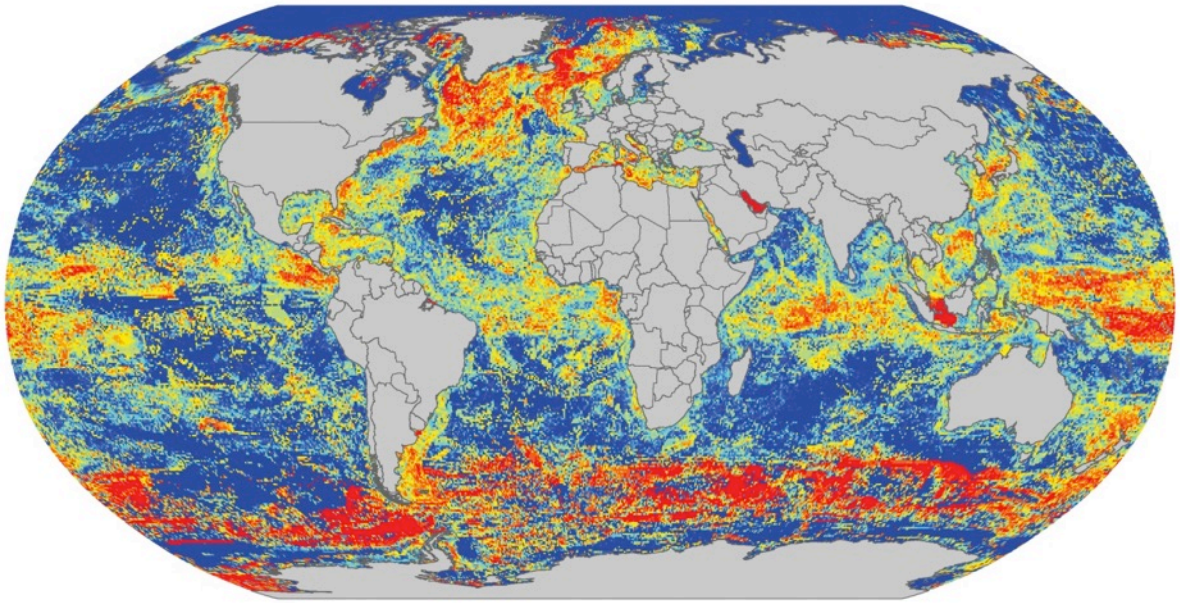


# Small yellow croaker

**Year 30**

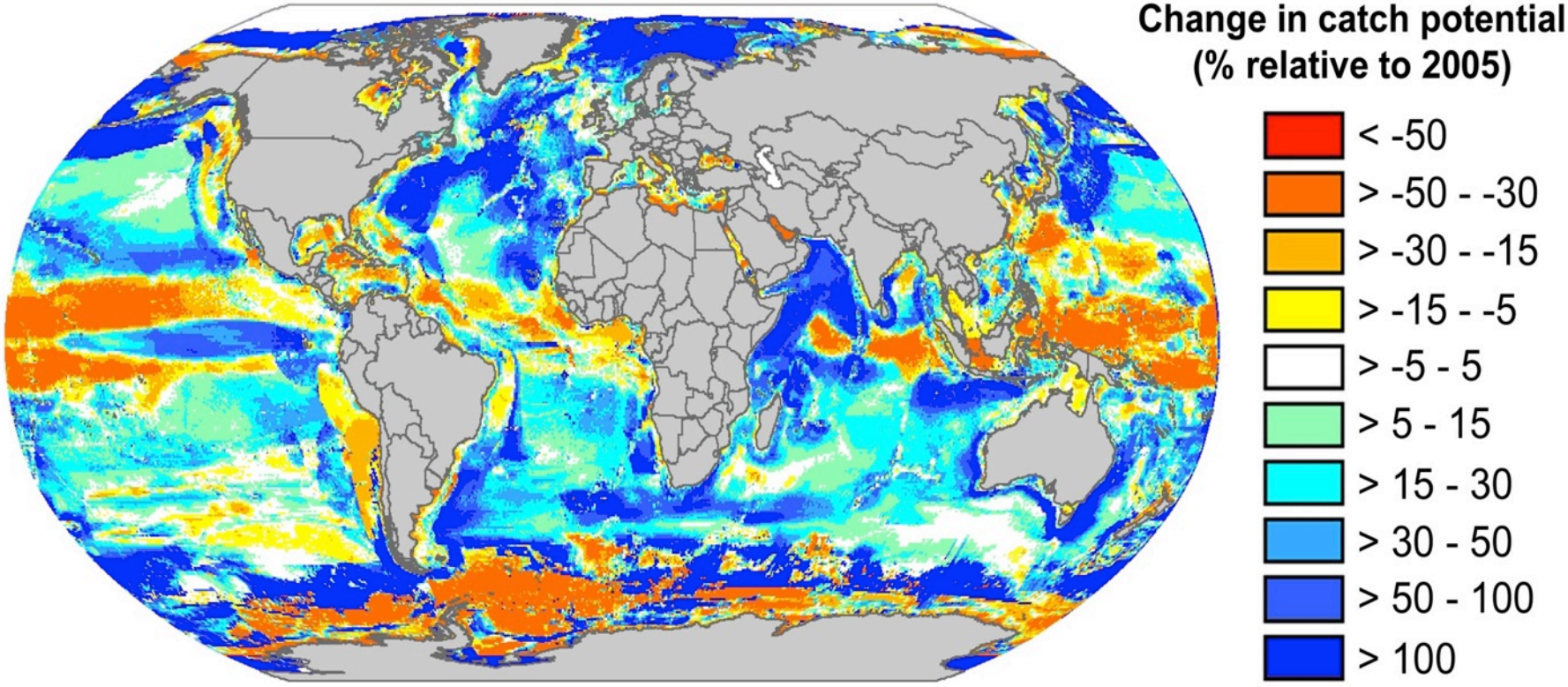




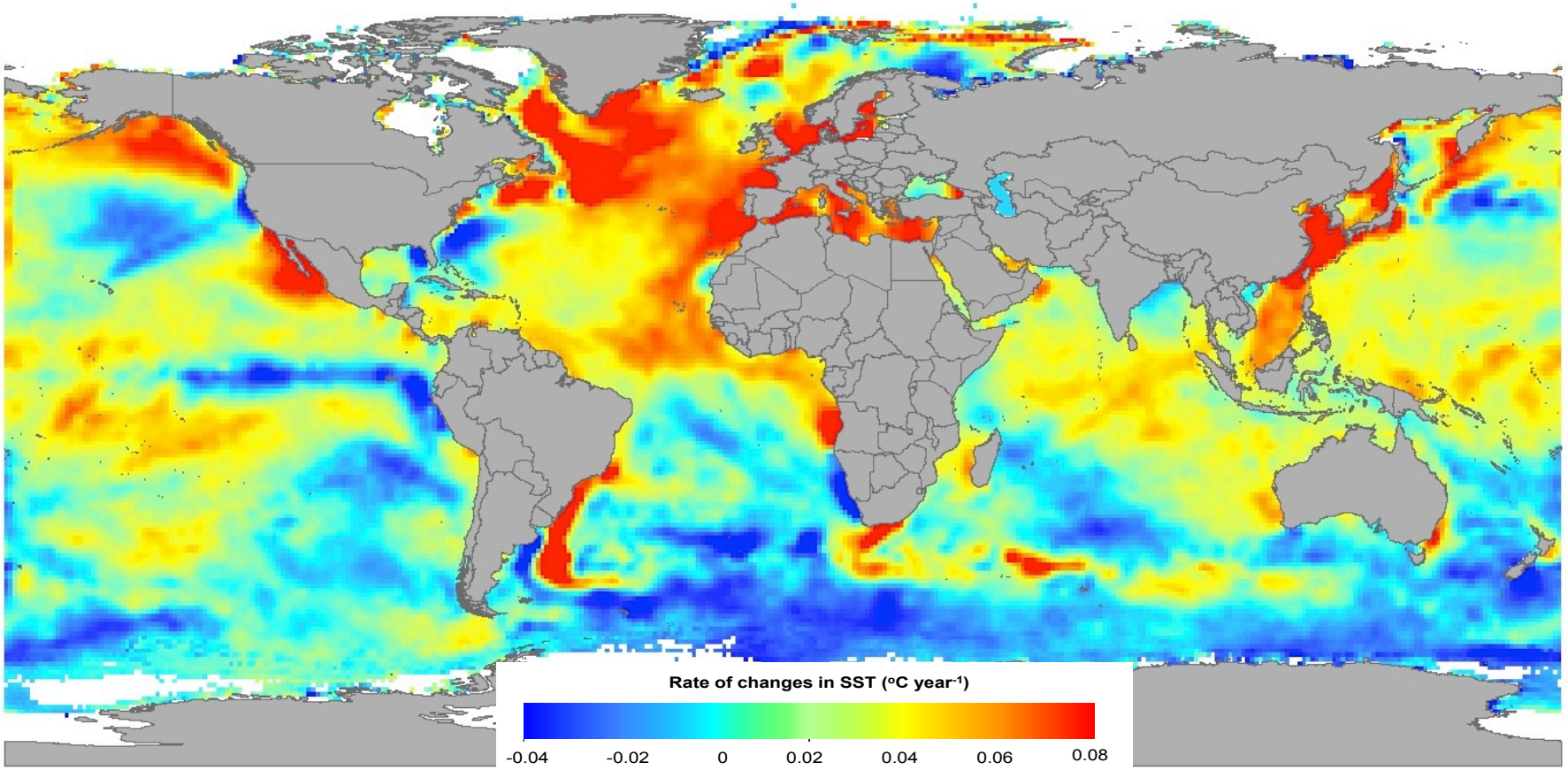

Cheung, Lam, Kearney, Sarmiento, Watson and Pauly (*Fish and Fisheries,* 2009)

# Projected change in catch potential in 50 years




Cheung, Lam, Kearney, Sarmiento, Watson, Zeller and Pauly (*Global Change Biology,* 2009)

# Moreover, we shouldn’t forget that global warming already began several decades ago…




Ocean warming in the 4 decades from 1970 to 2009 (from Hadley Centre)

And thus we did now what we could have done years ago…

LETTER

doi:10.1038/nature12156

# Signature of ocean warming in global fisheries catch

William W. L. Cheung[1], Reg Watson[2] & Daniel Pauly[3]

**Marine fishes and invertebrates respond to ocean warming through distribution shifts, generally to higher latitudes and deeper waters. Consequently, fisheries should be affected by 'tropicalization' of catch[1–4] (increasing dominance of warm-water species). However, a signature of such climate-change effects on global fisheries catch has so far not been detected. Here we report such an index, the mean temperature of the catch (MTC), that is calculated from the average inferred temperature preference of exploited species weighted by their annual catch. Our results show that, after accounting for the effects of fishing and large-scale oceanographic variability, global MTC increased at a rate of 0.19 degrees Celsius per decade between 1970 and 2006, and non-tropical MTC increased at a rate of 0.23 degrees Celsius per decade. In tropical areas, MTC increased initially because of the reduction in the proportion of subtropical species catches, but subsequently stabilized as scope for further tropicalization of communities became limited. Changes in MTC in 52 large**

and increased vulnerability of many coastal fisheries to climate change, particularly in the tropics[6]. Climate change effects on some fisheries have been detected[14,15]. For example, the rapid increase in catches of red mullet (*Mullus barbatus*), a warm-water species, around the UK is suggested to be related to ocean warming[15]. However, a signature of the effect of climate change on global fisheries has so far not been demonstrated. Because marine fisheries contribute to the economy and food security of many coastal communities, fisheries' responses to climate change need to be better understood to inform the development of effective management and adaptation policies[7].

Shifts in distributions of exploited stocks are expected to affect their availability to fisheries. Spatial distributions of marine fishes and invertebrates are strongly dependent on the relationship between physiological optima and limits under different temperatures, oxygen levels and other biotic and abiotic conditions[16,17]. Organisms living in temperatures outside their thermal optima experience reduced aerobic

# We invented a new indicator: the ‘Mean Temperature of Catch’ (MTC)

Median preferred temperature = 8 °C

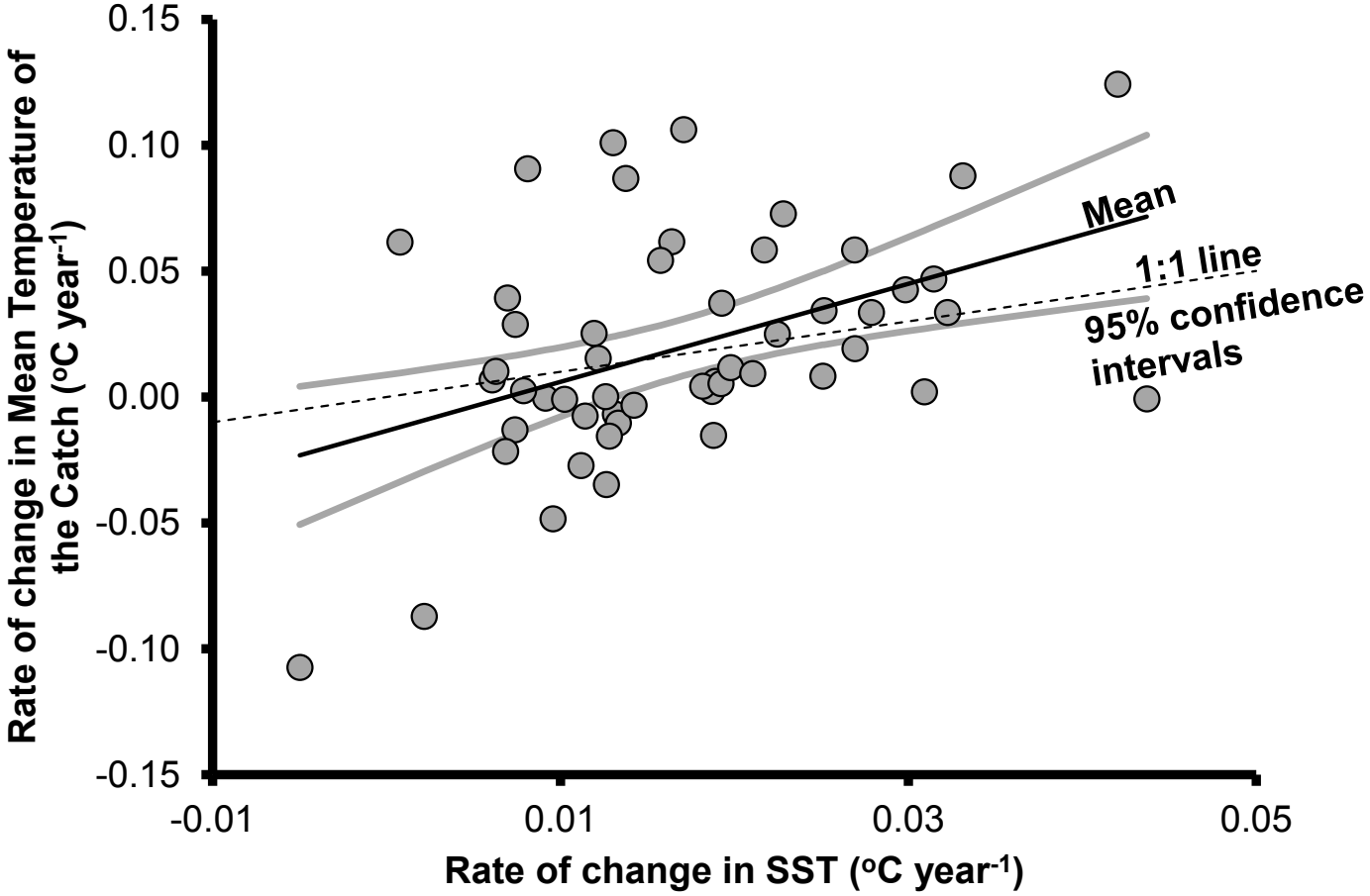
Median preferred temperature = 12 °C

Median preferred temperature = 10°C

Median preferred temperature = 6 °C

MTC = Average preferred temperature weighted by the catch

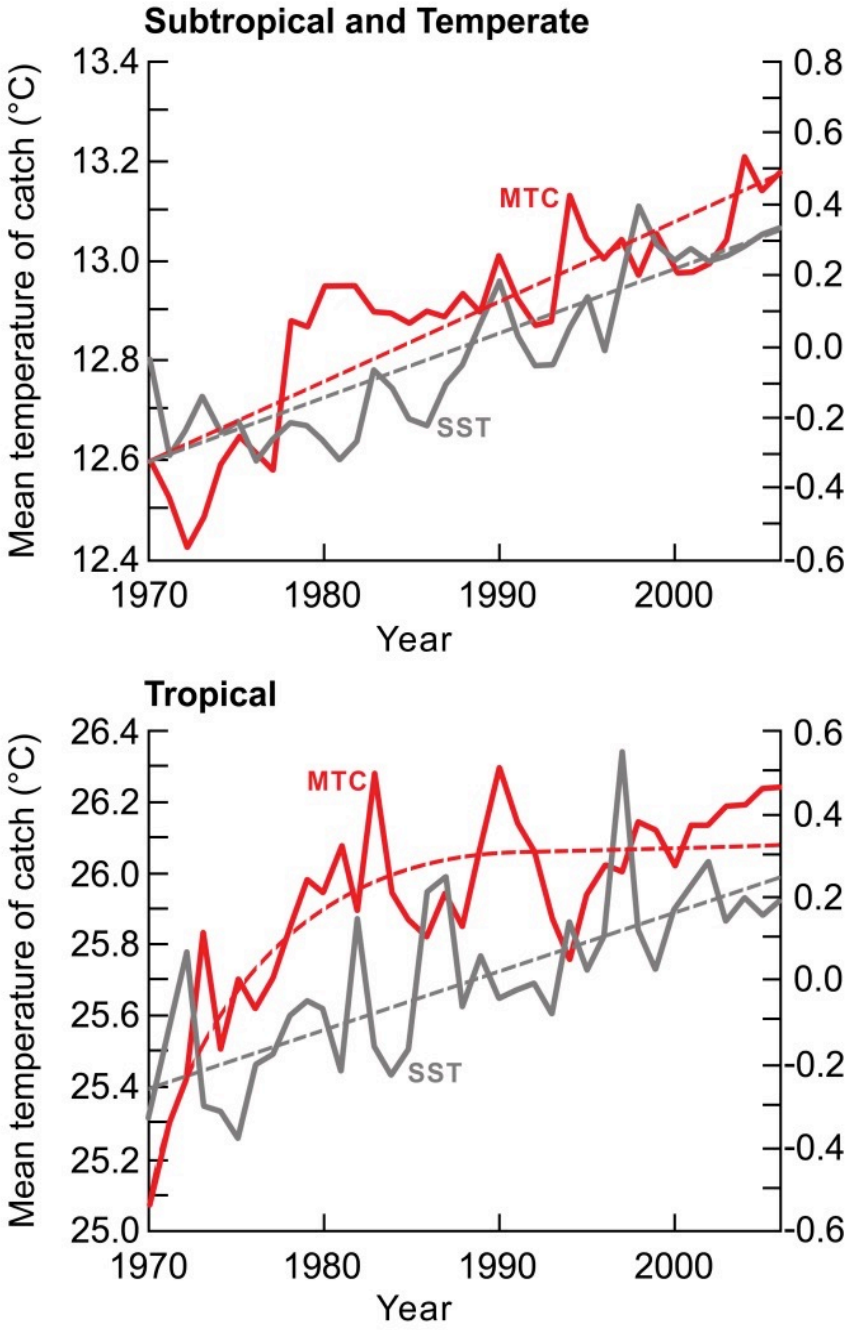
# Warming-induced changes in catch composition of LMEs



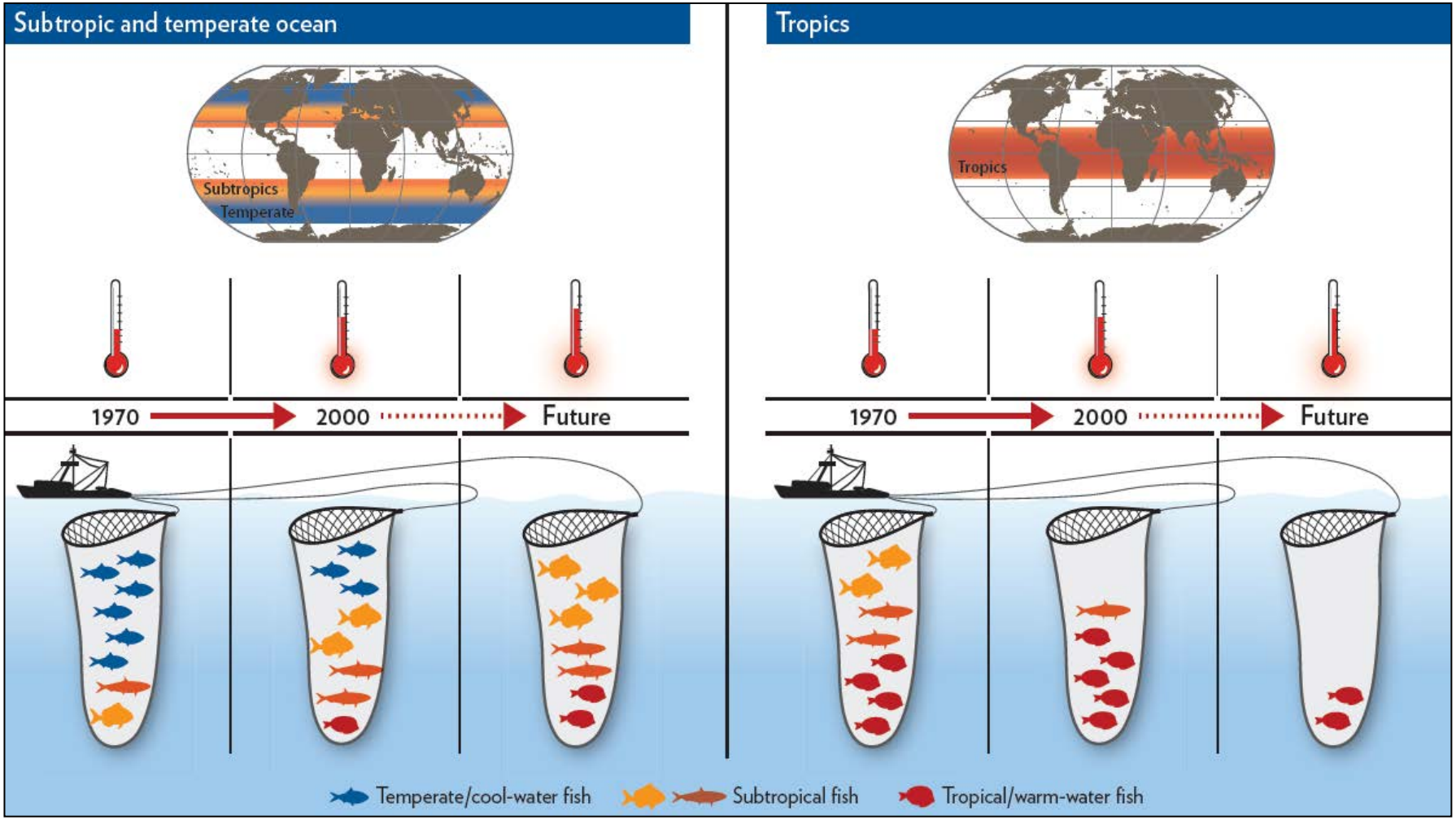

- MTC increased at a rate of 0.19 °C decade$^{-1}$;
- MTC is significantly related to changes in SST;
- MTC trends are robust to alternative species distributions, changes in fishing effort, misreporting of catch data, etc.

Cheung, Watson and Pauly (*Nature,* 2013)

Trends in the ‘Mean Temperature of the Catch’ in two climate types.



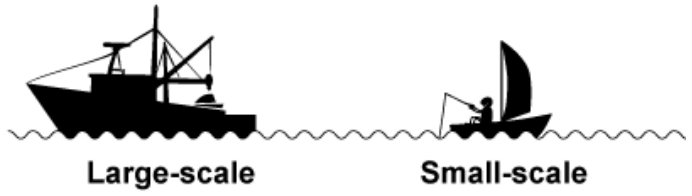
# In summary:


Subtropic and temperate ocean
Subtropics
Temperate
1970
2000
Future
Tropics
Tropics
1970
2000
Future
Temperate/cool-water fish
Subtropical fish
Tropical/warm-water fish

# Again:

Small-scale fisheries can help about the habitat degradation and ecosystem changes that are presently occurring.

Also note that an abundance of fish in the water can mitigate some of these changes.



| Fisheries benefits | Large-scale | Small-scale |
|---|---|---|
| Annual landings for human consumption | about 60 million tonnes | about 27 million tonnes |
| Annual catch discarded at sea | 10 million tonnes | Almost none |
| Annual catch for industrial reduction to fishmeal and oil, etc. | 26 million tonnes | Almost none |
| Fuel used per tonne of fish for human consumption | 5-20 tonnes | 2-5 tonnes |
| Number of fishers employed | about 1/2 million | about 12 million |
| Government subsidies (billions of USD) | $$$$$ 25-30 billion USD | $ 5-7 billion USD |

# Acknowledgements…


- Thanks to The Pew Charitable Trusts and the Paul G. Allen Family Foundation for support

THE PEW CHARITABLE TRUSTS

THE PAUL G. ALLEN FAMILY FOUNDATION

- Thanks to other funding sources: FAO, US Western Pacific Fisheries Management Council, EU-Parliament, UNEP, BOBLME, MAVA Foundation, Rockefeller Foundation, WWF
- Thanks to all members of the *Sea Around Us,* past and present…


… sorry, I ran out of pictures….


*and thanks to many other colleagues*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