Incorporating climate scenarios into fisheries research

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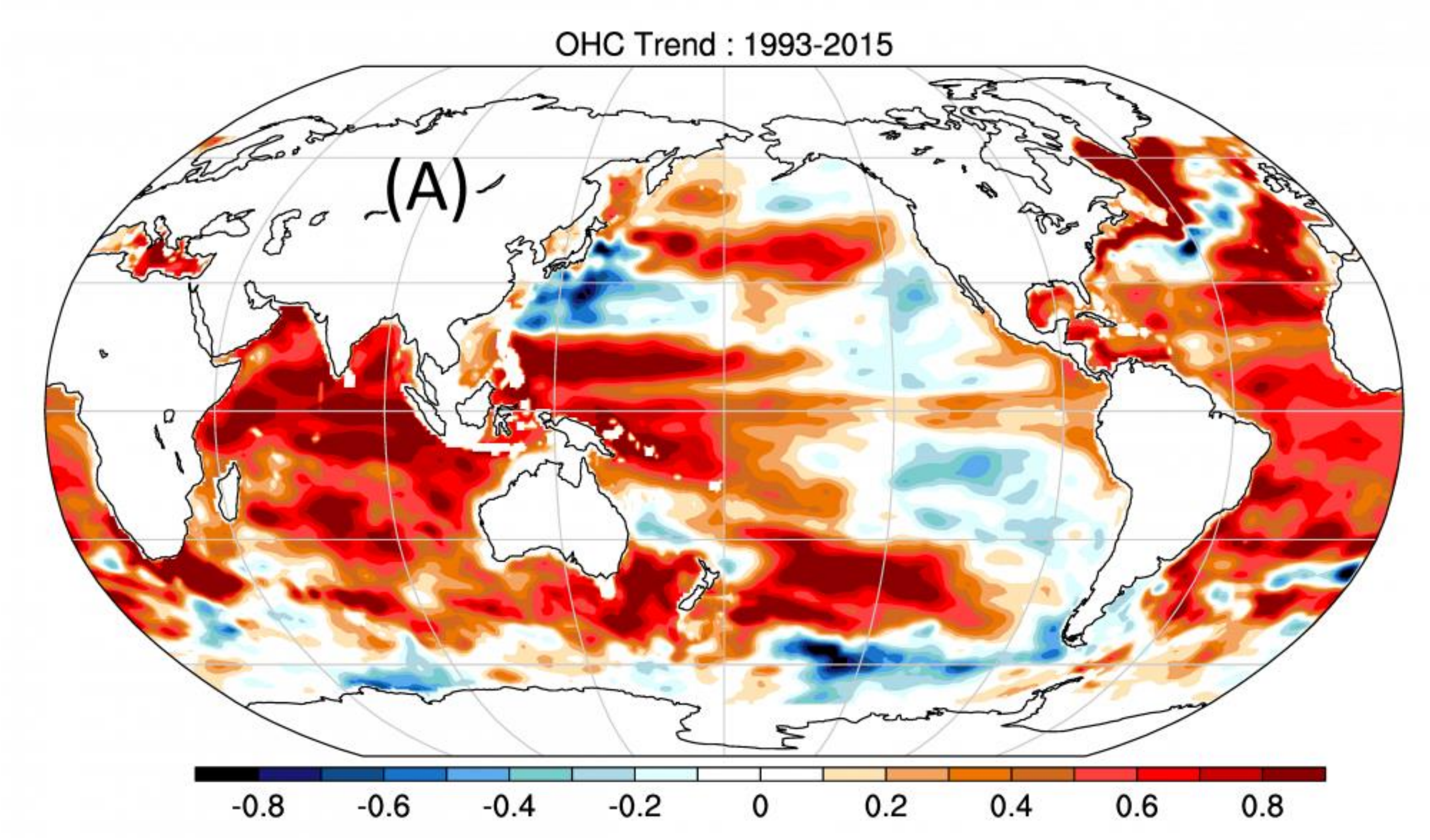
Our oceans are rapidly warming

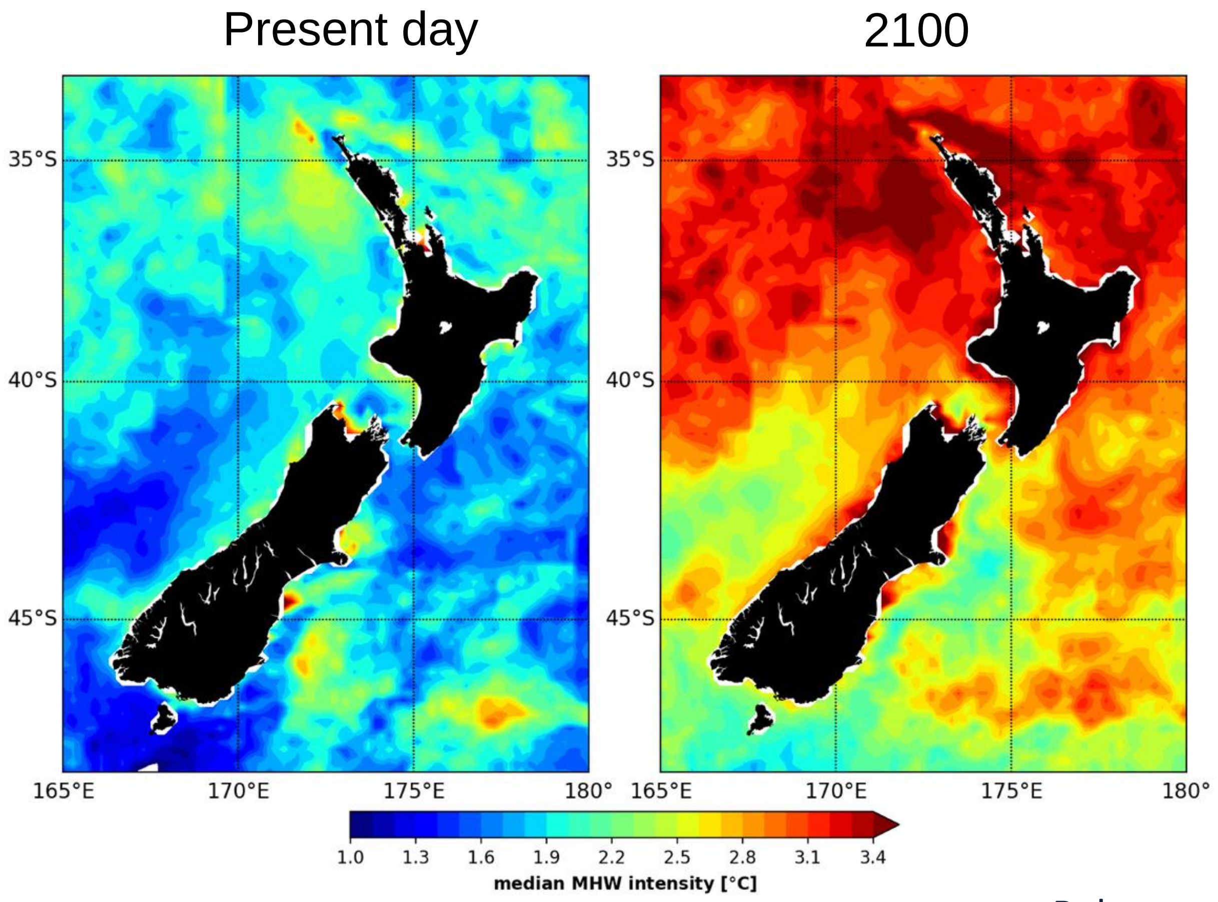


Cheng et al (2015) *Science Advances*

Increasing strength and frequency of extreme events

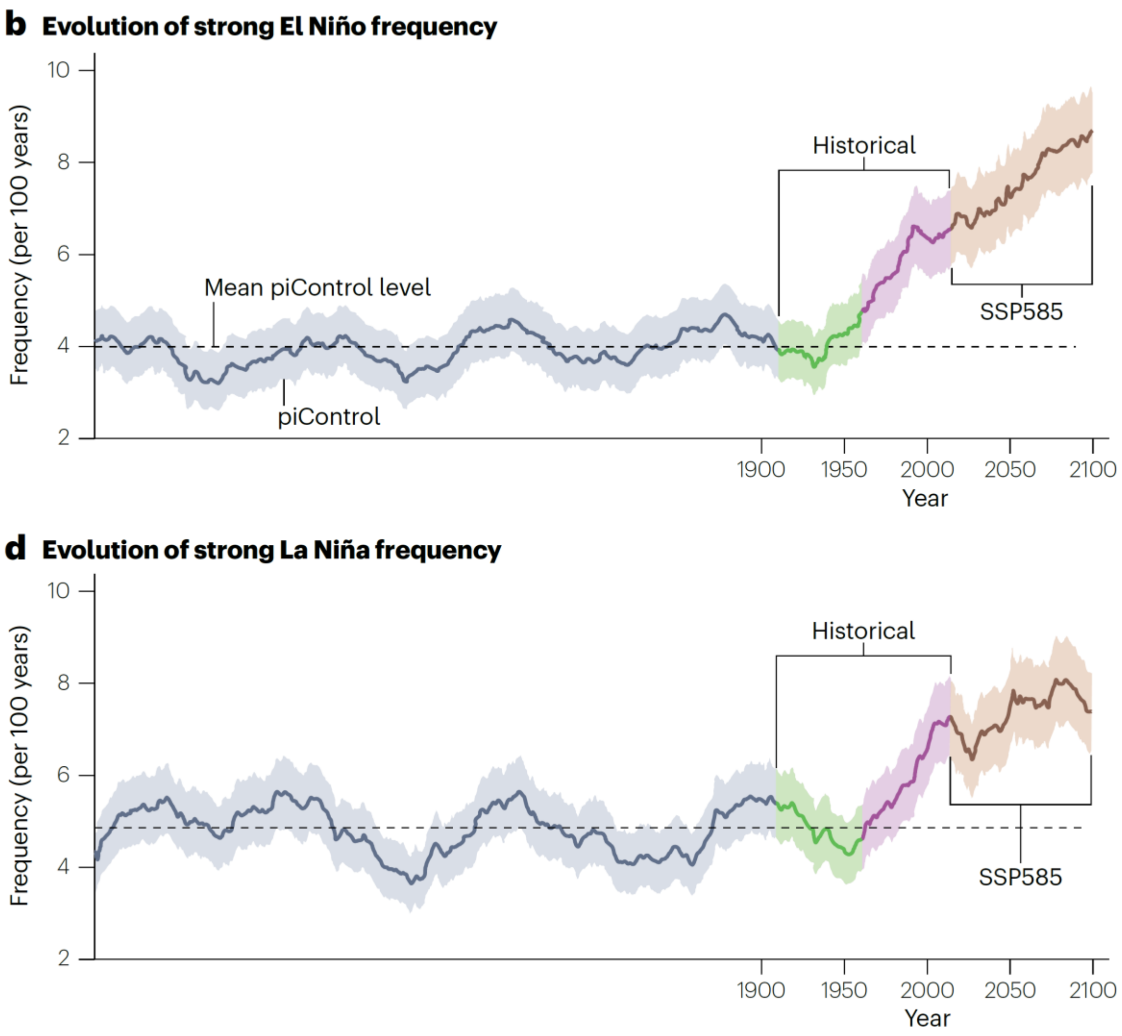
Marine heatwave intensities forecast to increase by 20-100%

Annual heatwave days could increase from 40 to 80-170 days



Behrens et al (2022) *Frontiers in Climate*

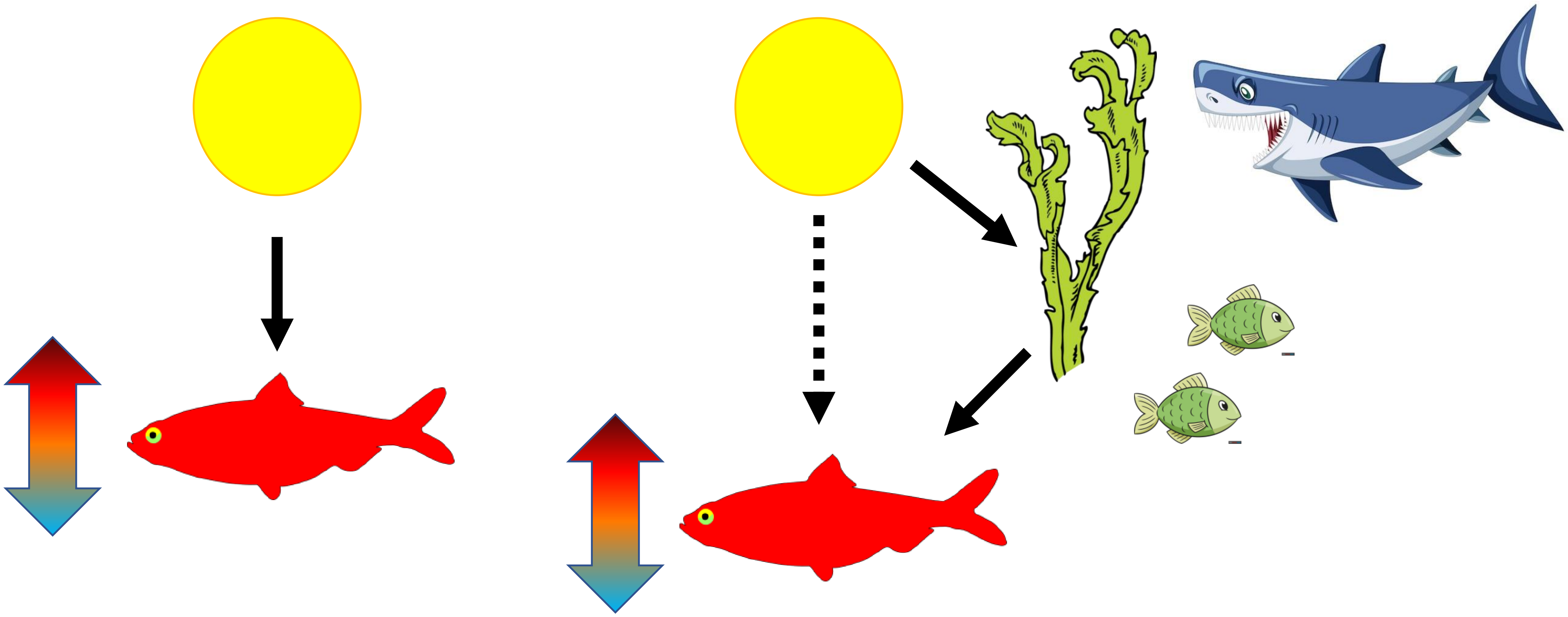
Increased climate variability



Cai et al (2023) *Nature Reviews Earth & Environment*

Ocean warming has caused significant biological change in our oceans

Temperature can have direct and indirect effects on fish



Three universal impacts of climate change

1) Shifts in species’ distributions

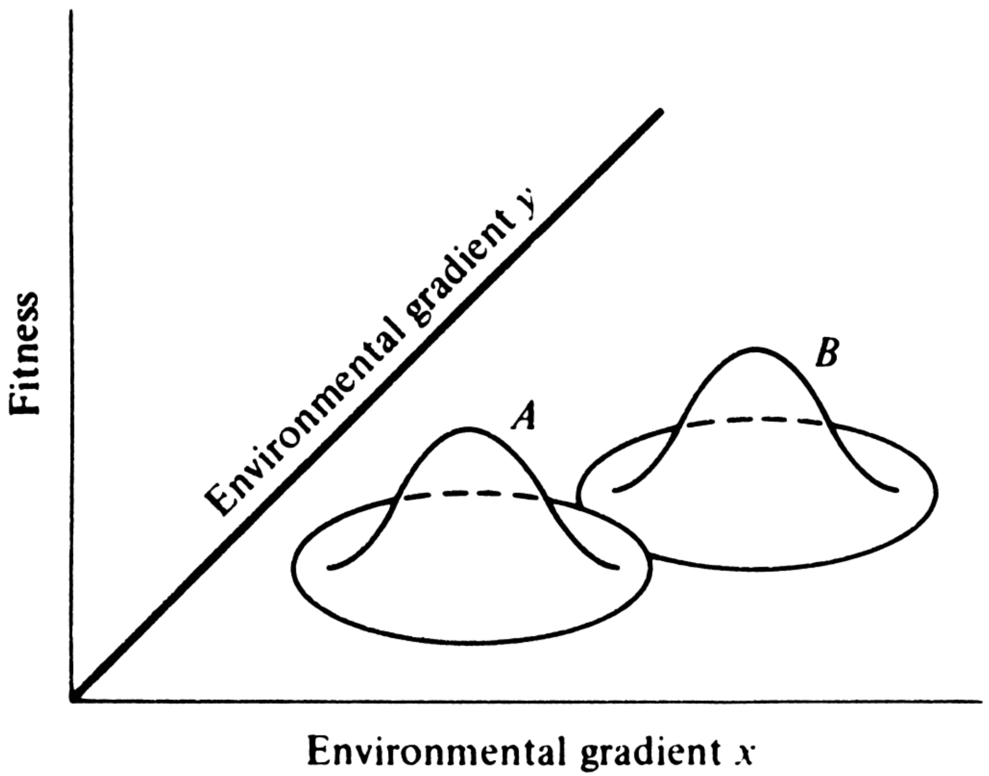
2) Reduced body size

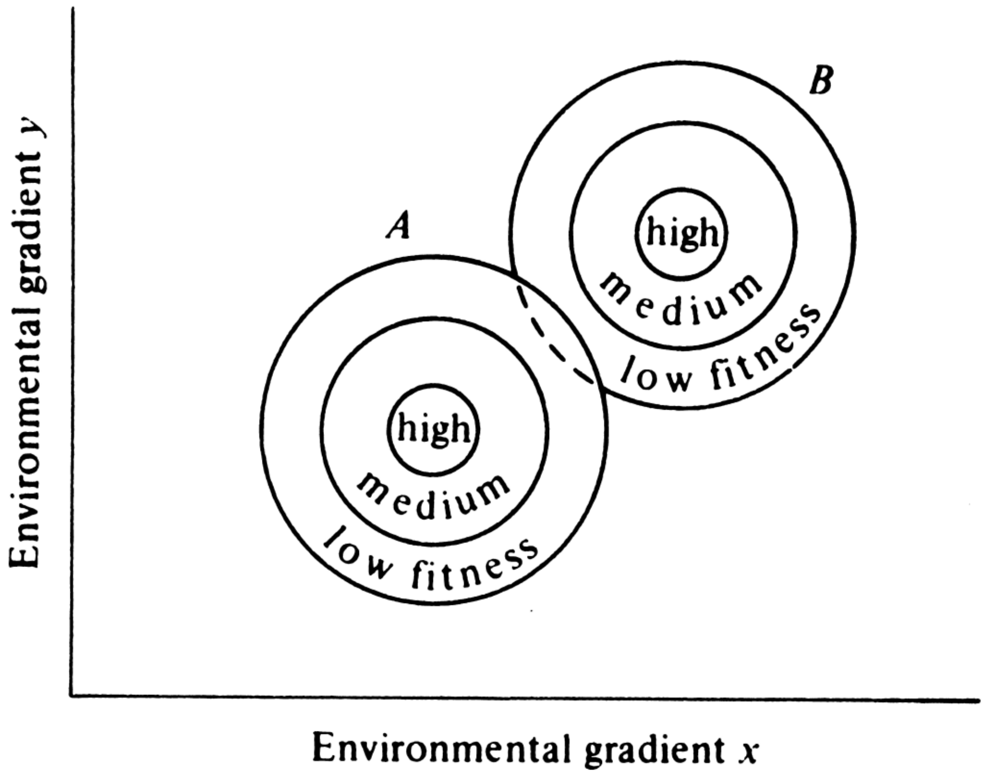
3) Seasonal shifts in the timing of life history events (their ‘phenology’)

All these climate-induced changes have significant impact on fisheries

The ecological niche plays a critical role in shaping a species' distribution

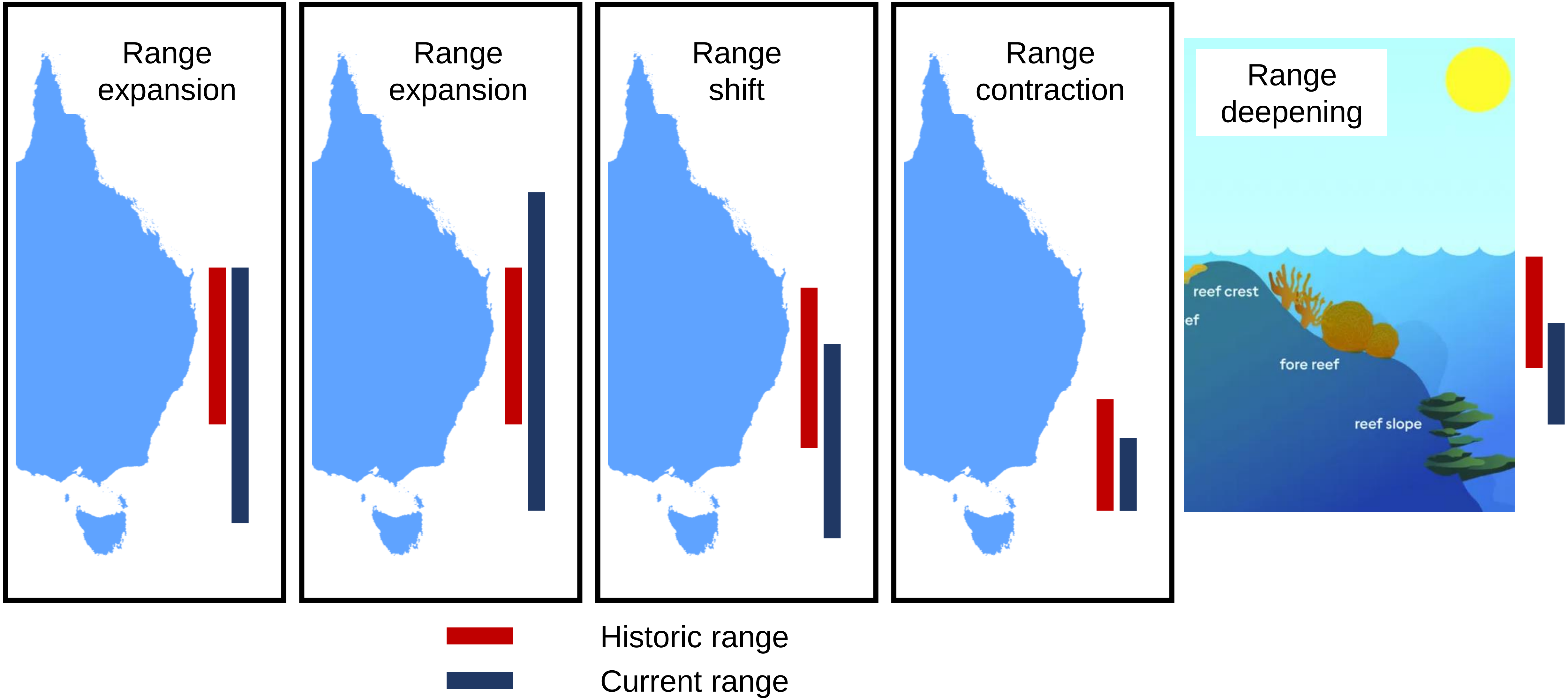
Niche: "total range of conditions under which the individual (or population) lives and replaces itself"





Hutchinson (1957)

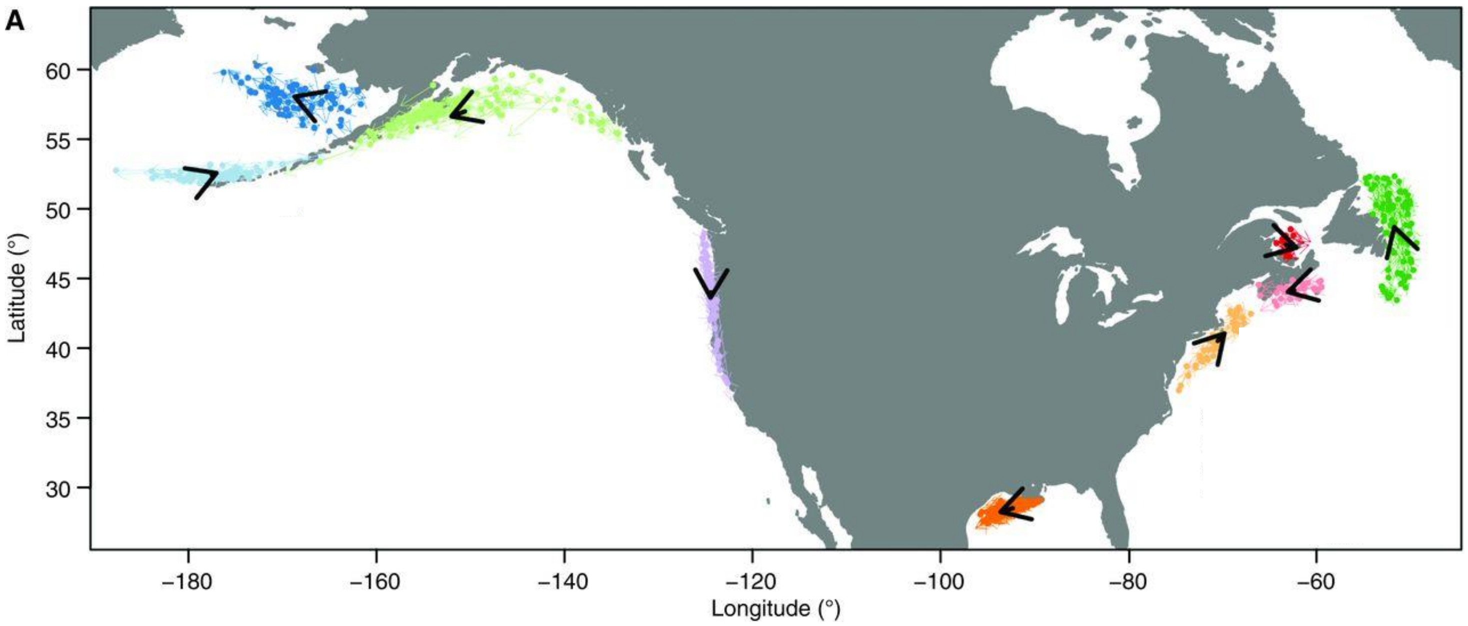
When the environment changes, the niche moves

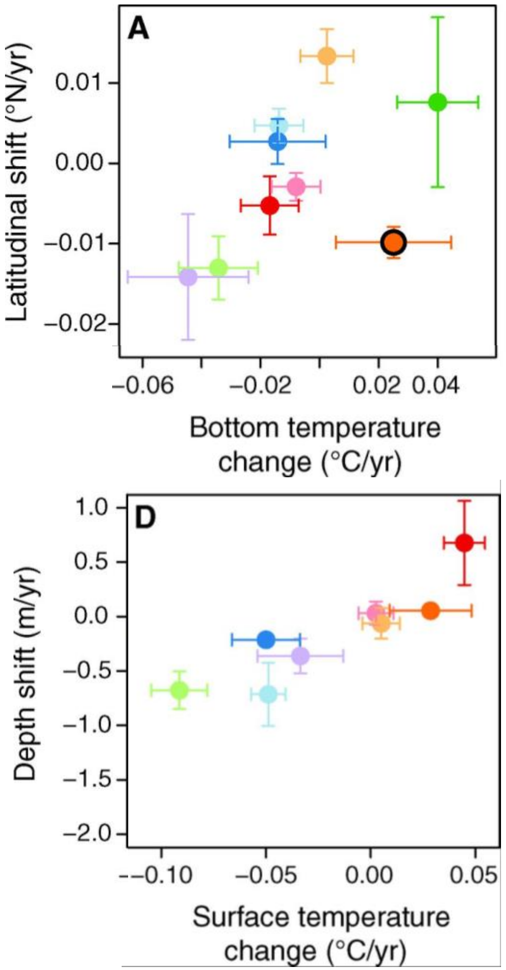


Warming drives distributional changes

Species are generally shifting to higher latitudes (or greater depths) as waters warm

Species inhabiting more rapidly warming areas are more likely to experience a range shift

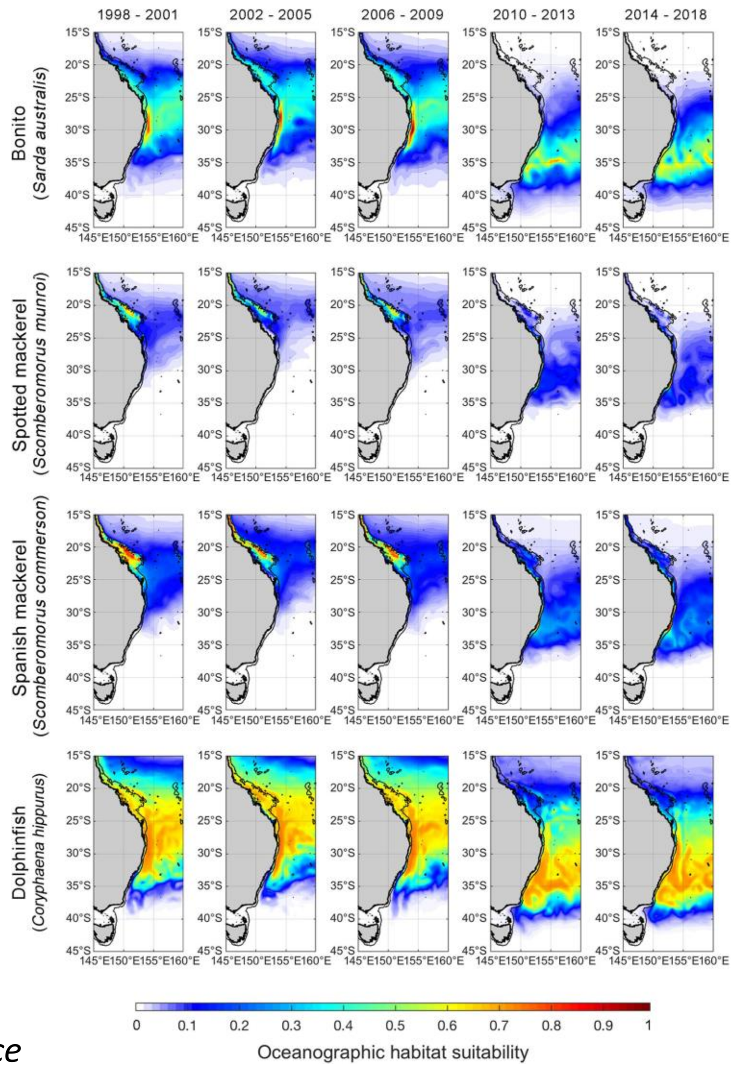




~50 years of distributional data from >350 species

Pinsky et al (2013) *Science*

Climate-driven range shifts can be rapid

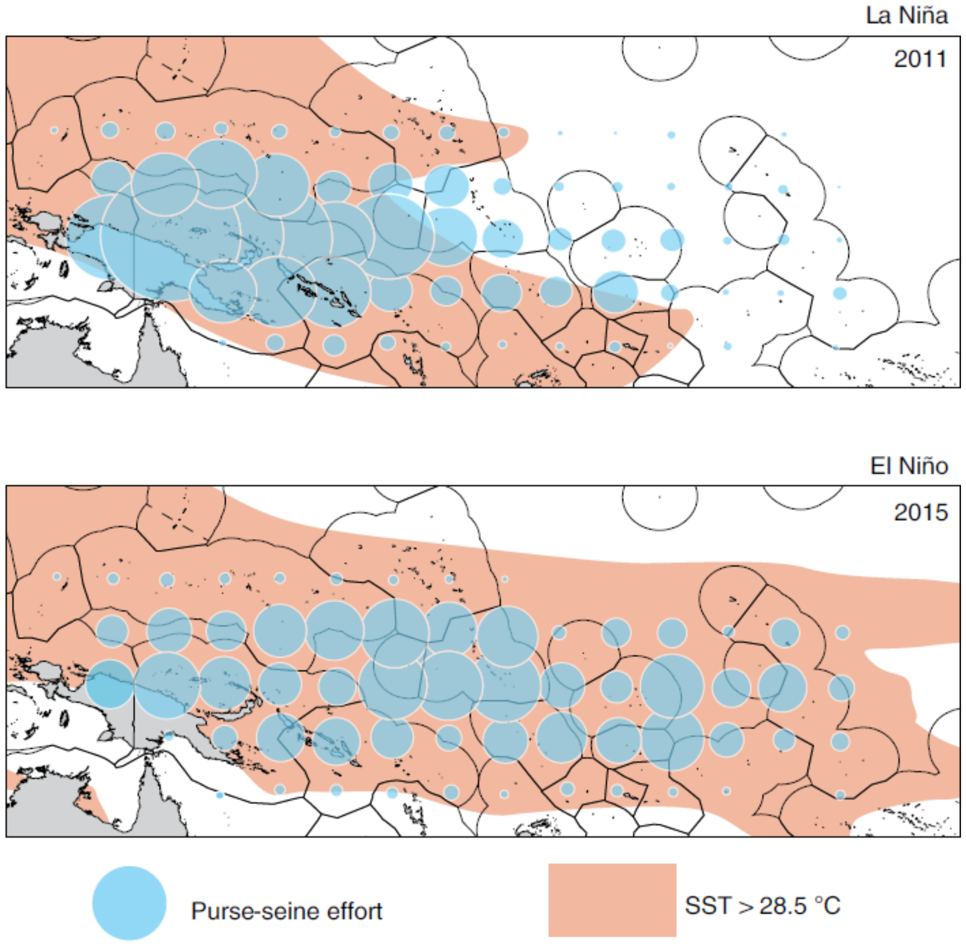


Four important coastal-pelagic fishery species moved south ~130km/ decade

Champion et al (2021) *Frontiers in Marine Science*

Shifting distributions of tuna in the western and central Pacific

Tuna distributions (skipjack, yellowfin, bigeye) are highly sensitive to SST, leading to large spatio-temporal variation in catch



Lehodey et al (1997) *Nature*; Bell et al (2021) *Nature Sustainability*

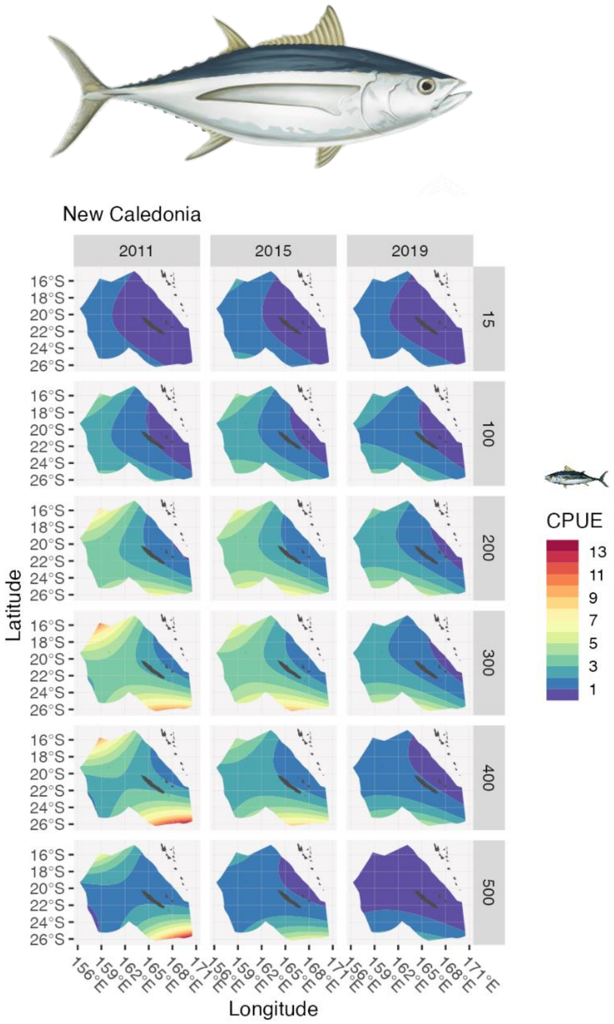
The impacts of El Niño–Southern Oscillation on Pacific fishes

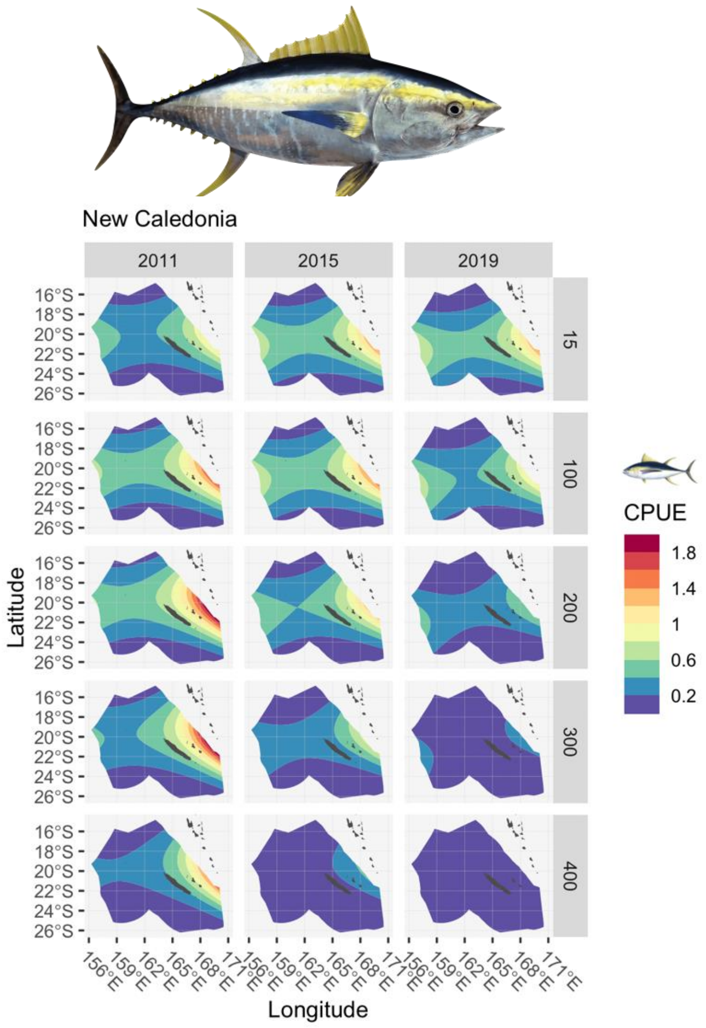
PhD candidate Juan Wang
Jed Macdonald, Steve Swearer

THE UNIVERSITY OF MELBOURNE
Pacific Community
Communauté du Pacifique

Recreated time series of catch-at-depth 2009-2021

Long-line data from New Caledonia (thank you Direction des Affaires Maritimes Nouvelle-Calédonie)

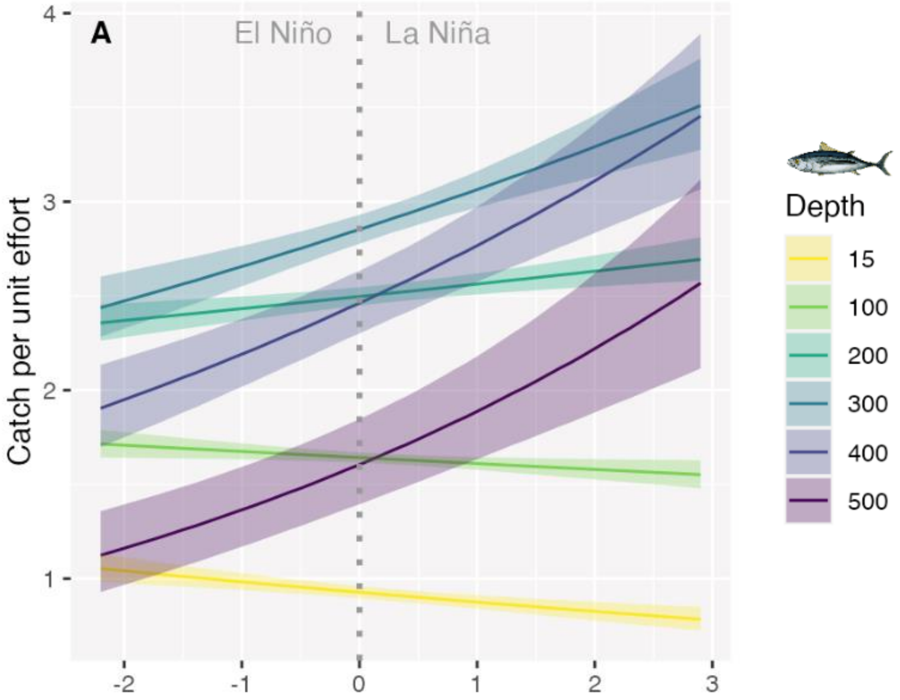


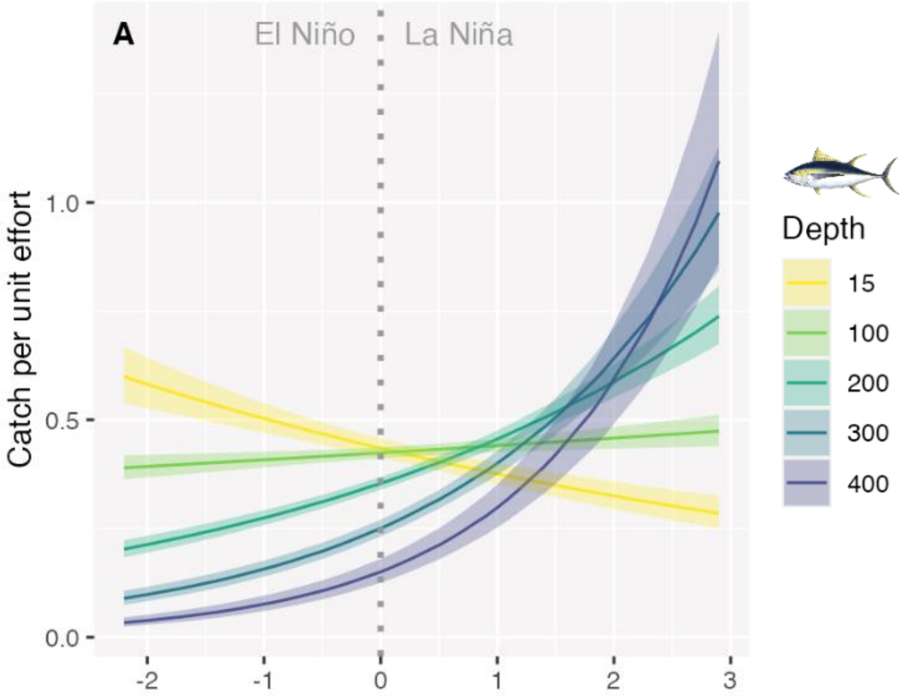


Wang et al (*unpublished*)

ENSO drives changes in vertical distribution of tuna

Both species deepen during La Niña and shoal during El Niño



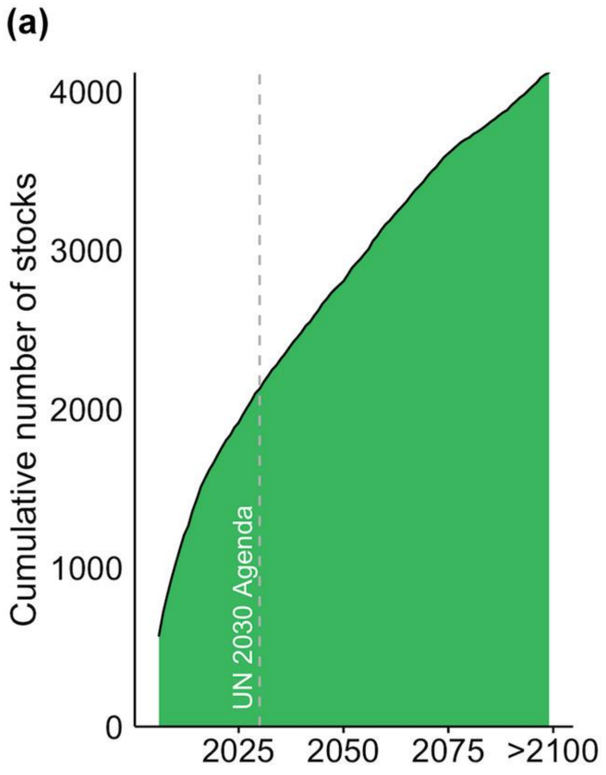


Wang et al (*unpublished*)

Projected shifts in distributions of fished species

Climate change is causing shifts in the distribution of shared stocks between neighboring EEZs

Implications for international fisheries governance



Palacios-Abrantes et al (2022) *Global Change Biology*

Shifting/ expanding/ contracting species

Distributional changes may offer new fishing opportunities, or could result in fishing declines

‘Winners’



‘Losers’



Management requirements when fish are redistributing

What should managers do to be both proactive and reactive?

FISH and FISHERIES

FISH and FISHERIES, 2011, **12**, 461–469

Guidelines for incorporating fish distribution shifts into a fisheries management context

Jason S Link[1], *Janet A Nye*[1] *& Jonathan A Hare*[2]

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Management requirements when fish are redistributing

Properly define stocks in the first place (tagging, genetics etc.)

Monitor spatial distribution of stocks (inc. depth!)

Be prepared to re-evaluate stock identification

Be prepared to re-evaluate stock area

Be prepared to update stock models

Warming is driving body size change in fishes

Warming-induced reductions in body size are greater in aquatic than terrestrial species

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Edited by James H. Brown, University of New Mexico, Albuquerque, NM, and approved October 2, 2012 (received for review June 22, 2012)

Warming temperatures and smaller body sizes: synchronous changes in growth of North Sea fishes

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LETTERS

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nature climate change

Shrinking of fishes exacerbates impacts of global ocean changes on marine ecosystems

William W. L. Cheung[1]*, Jorge L. Sarmiento[2], John Dunne[3], Thomas L. Frölicher[2], Vicky W. Y. Lam[1], M. L. Deng Palomares[1], Reg Watson[1] and Daniel Pauly[1]

Received: 14 December 2021 | Revised: 24 January 2022 | Accepted: 7 February 2022

DOI: 10.1111/ele.13989

LETTER

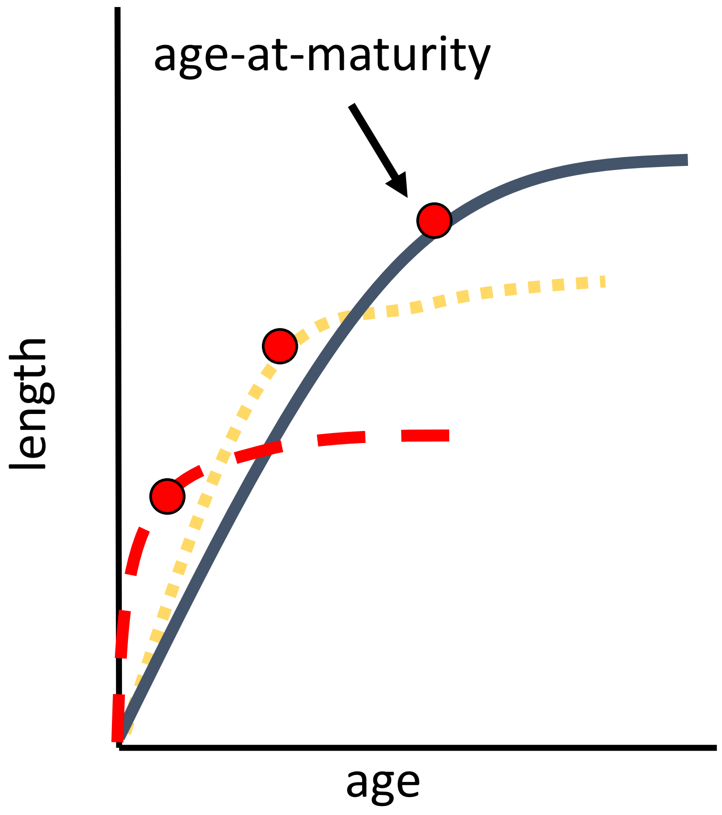
ECOLOGY LETTERS WILEY

Smaller adult fish size in warmer water is not explained by elevated metabolism

Henry F. Wootton[1] | John R. Morrongiello[1] | Thomas Schmitt[1] | Asta Audzijonyte[2,3]

Warming leads to reduced fish body size

Temperature size rule (TSR) describes the observed phenomena of increased juvenile growth, earlier maturation, reduced lifespan, smaller adult size at higher temperatures



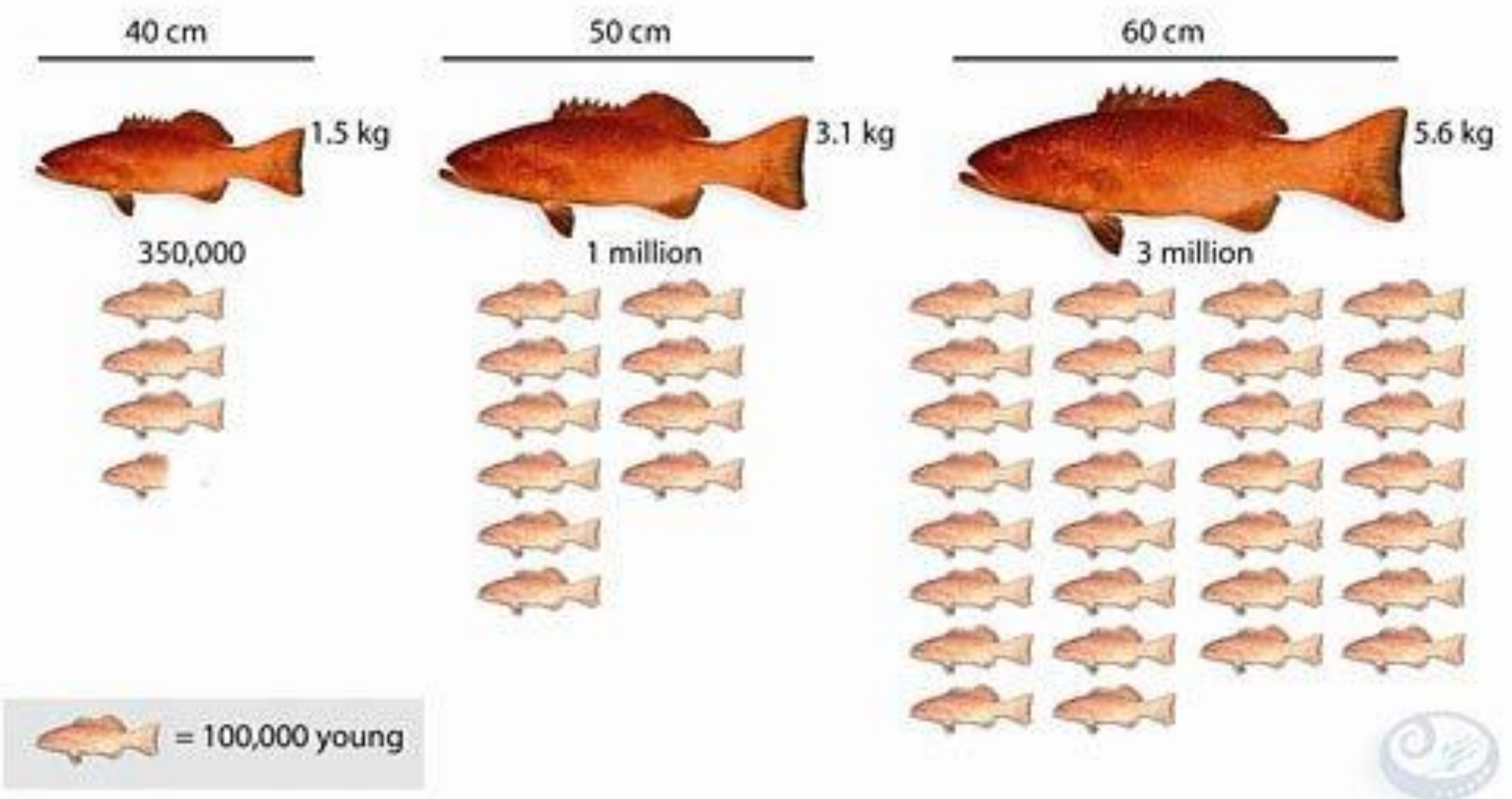
The mechanism driving ‘shrinking fish’ is hotly debated!

1. Larger body sizes have increased oxygen demand, but lower oxygen in warmer water means larger fish basically find it ‘hard to breath’?

2. Biological rates are faster at warmer temperatures, so fish develop into adults faster (and thus at smaller size)?

3. Warming-induced changes in reproductive allocation decisions? etc.

Bigger fish produce disproportionately more offspring

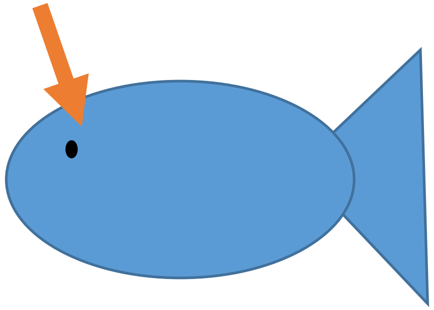


Average numbers of young produced by three different sizes of coral trout.
Data: Goeden (1978) Queensland Fisheries Service Research Bulletin

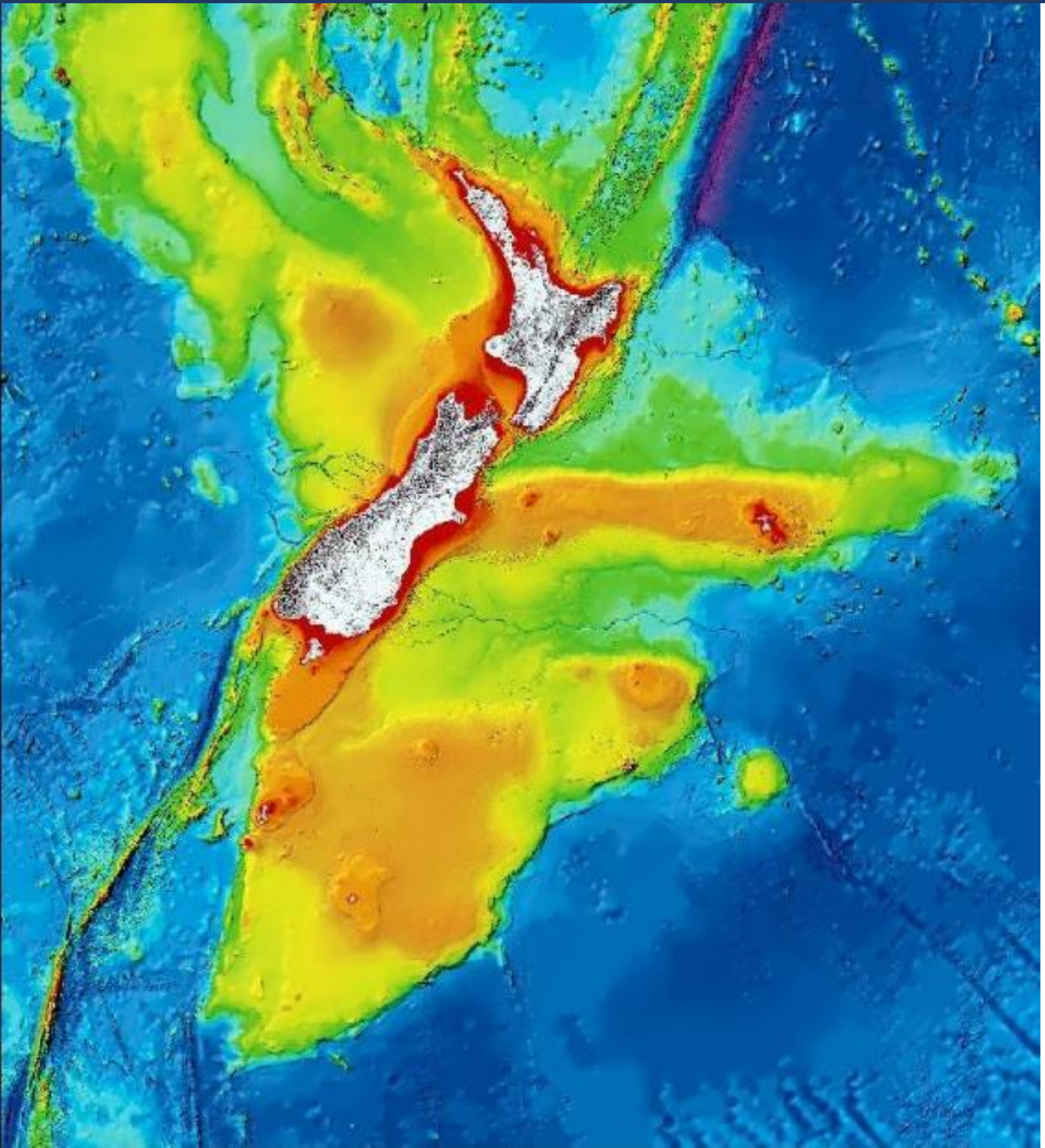
Smaller fish have higher mortality risk

What if you do not have a good understanding of body size changes through time?

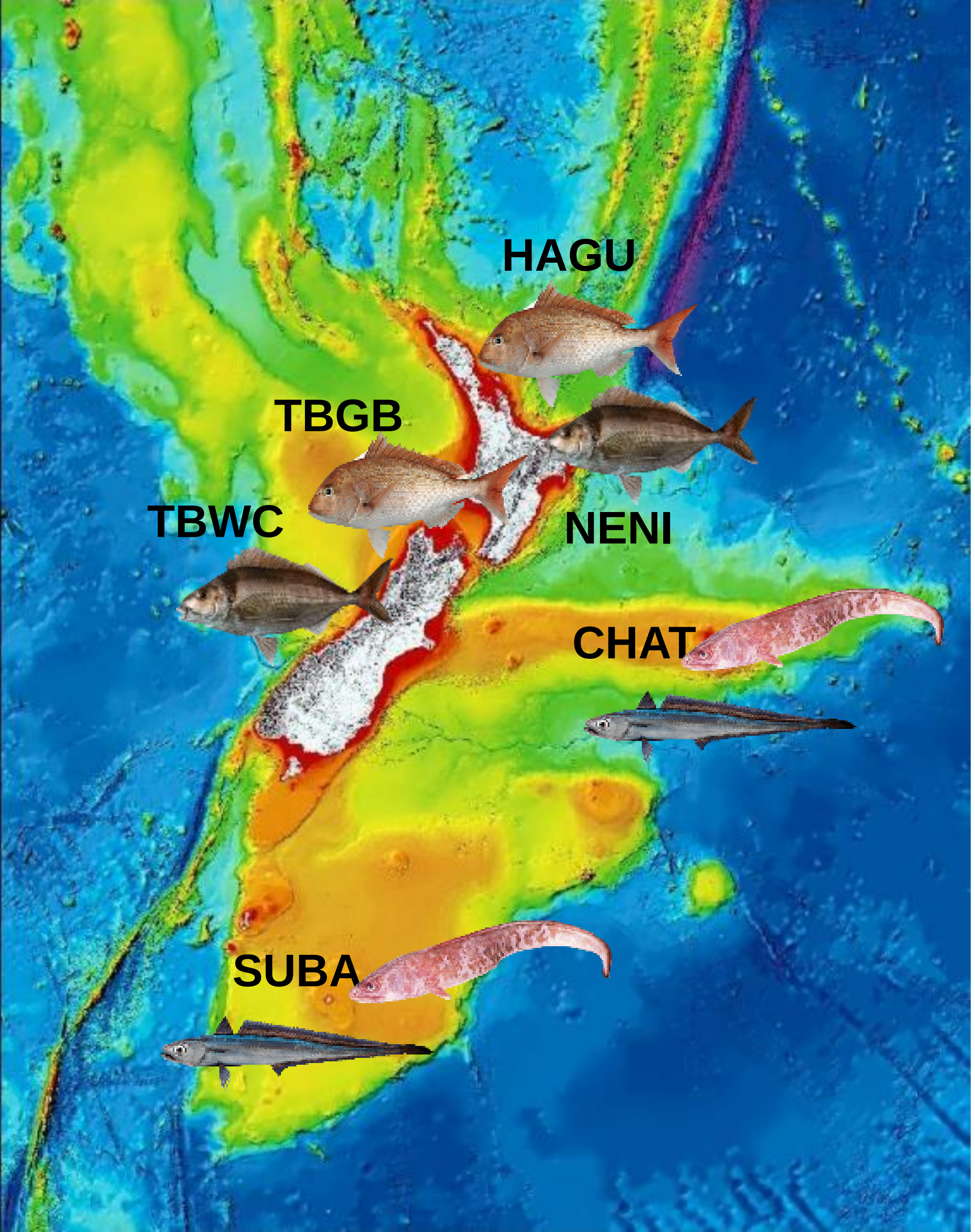
Measuring and analysing fish growth using otoliths

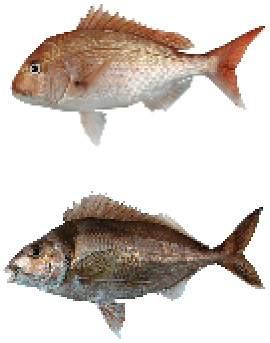


How does climate affect the growth of New Zealand fish?

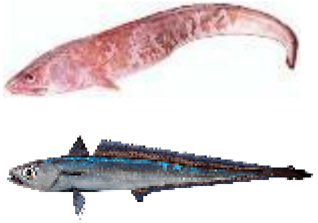


Morrongiello et al. (2021) *Global Change Biology*





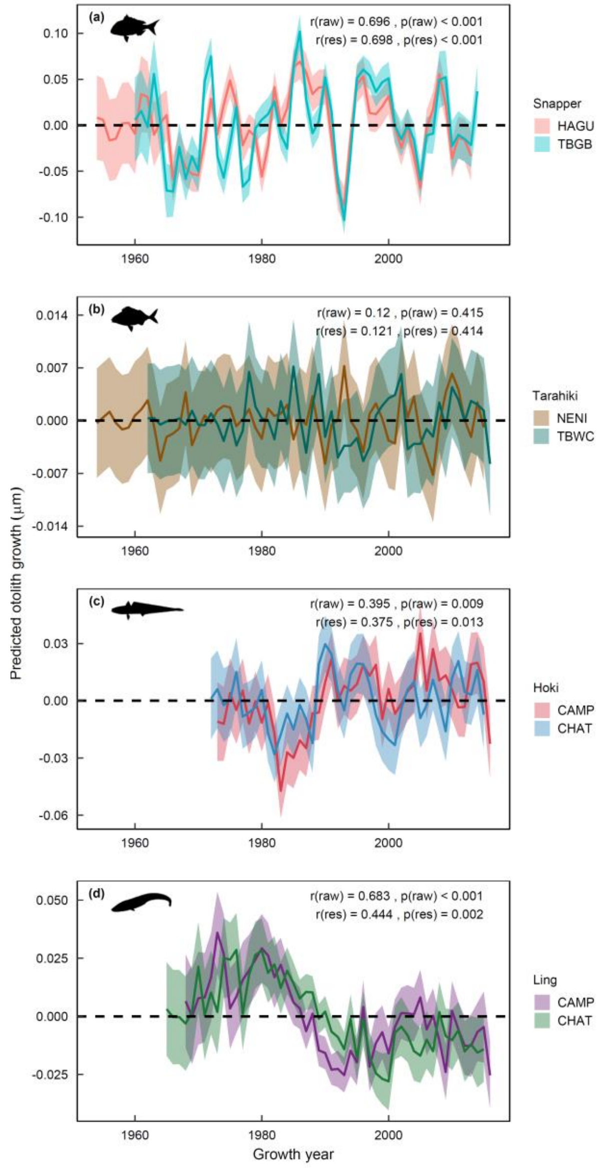
Near-shore **(<100m)**



Deep-water **(200-800m)**

Morrongiello et al. (2021) *Global Change Biology*

Considerable inter-annual growth variation in 3 of 4 species



Otoliths allowed us to recreate 40-60 years of growth variation

What is driving variation in growth?

Morrongiello et al. (2021) *Global Change Biology*

Drivers of annual growth variation

Near-shore species: regional climate

Deep-water species: basin-wide climate, modulated by fishing

All species: fishing activity

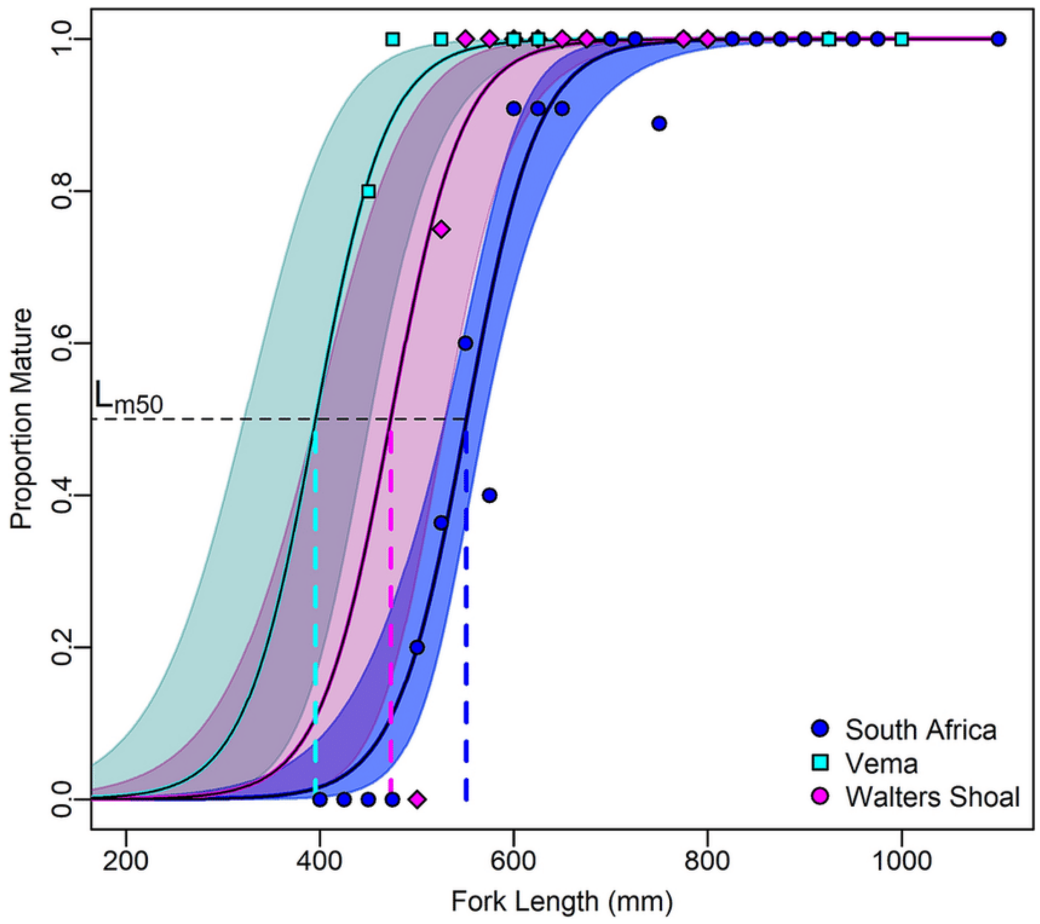
	Near-shore		**deep-water**	
				
	Snapper	tarakihi	hoki	ling
Interdecadal Pacific Oscillation (IPO)			IPO x SSB	IPO x SSB
SOI				
SST	+	+		
Wind	-	+		
Fishing activity	+	+	+	+

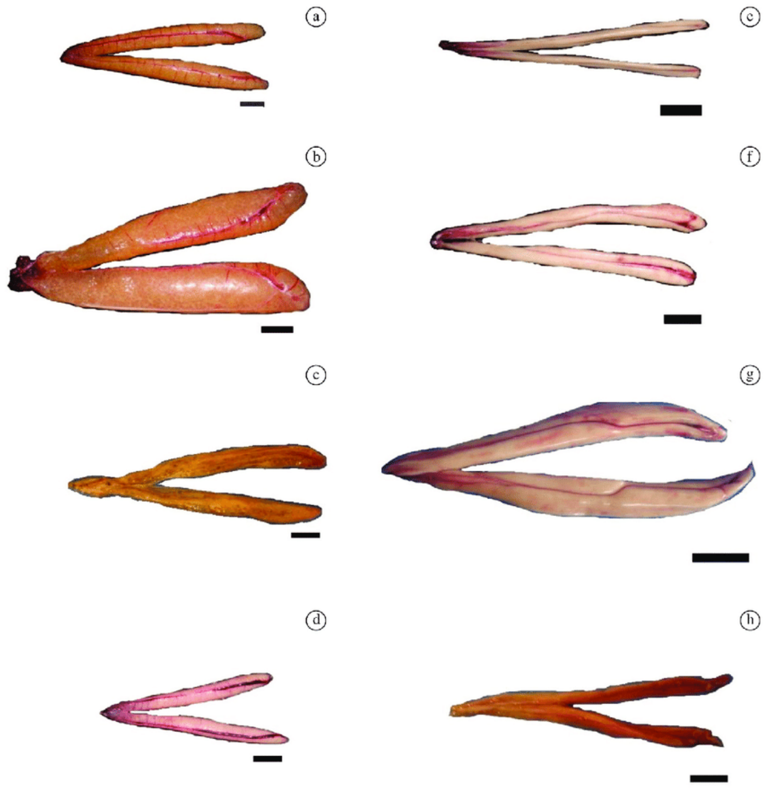
Morrongiello et al. (2021) *Global Change Biology*

We generally assume maturity schedules are fixed

We perform gonad analyses and characterise fish as immature/mature

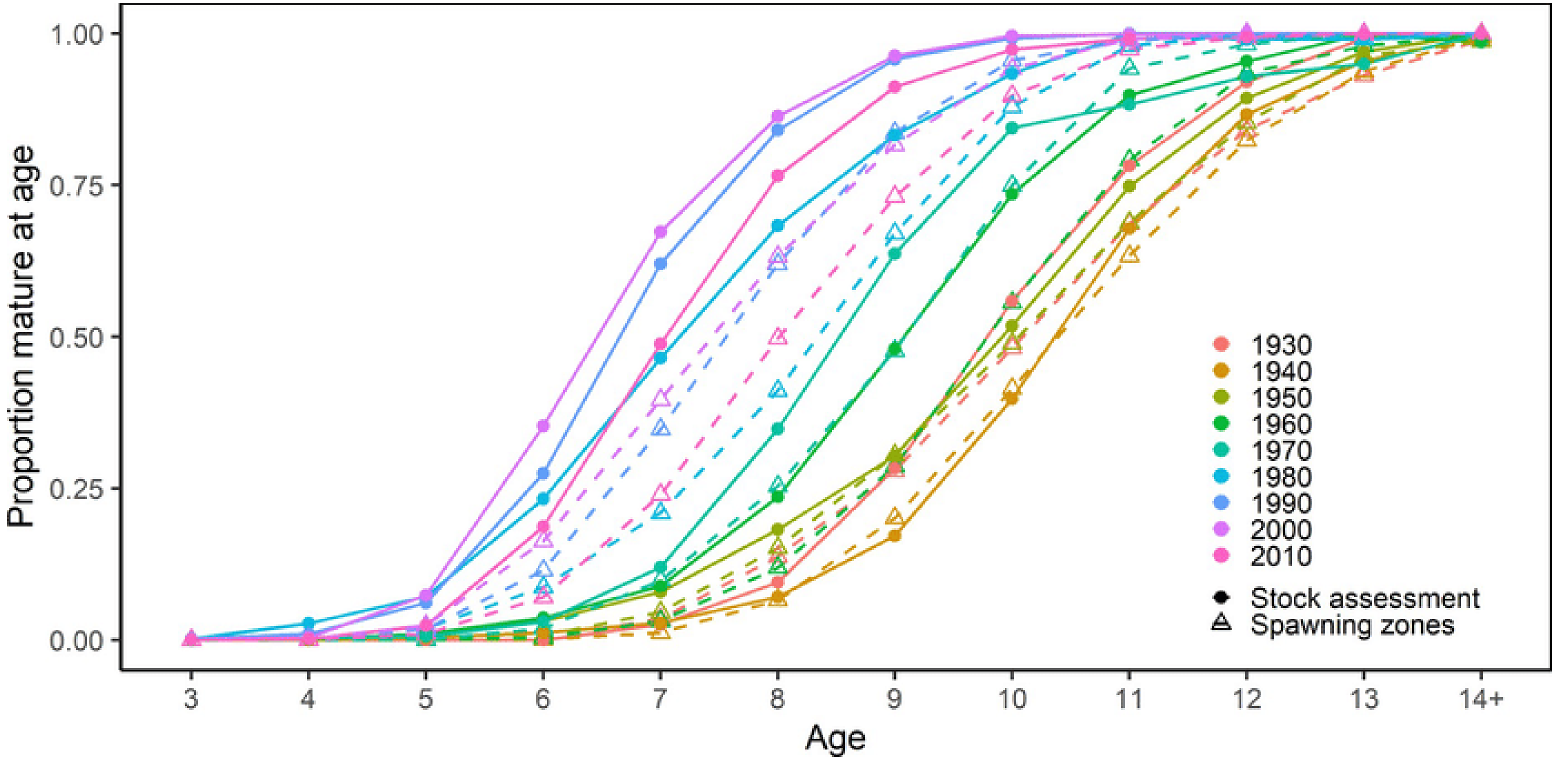
Use this, with size and age data, to produce ogive

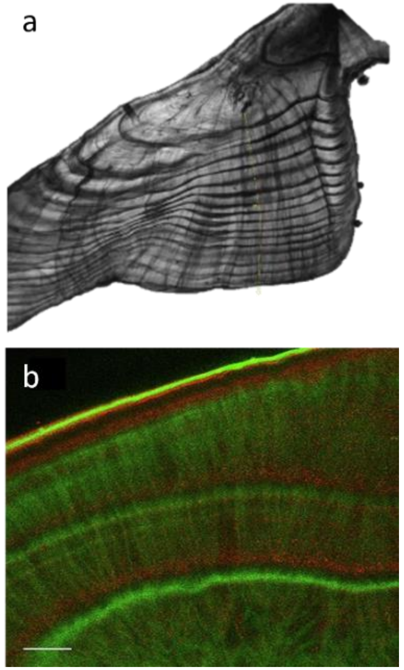




But maturity schedules can be driven by environmental change!

Need a lot of samples to detect these changes





What to do about fish size changes?

Monitor size and age structure of catch (through time and/or space)

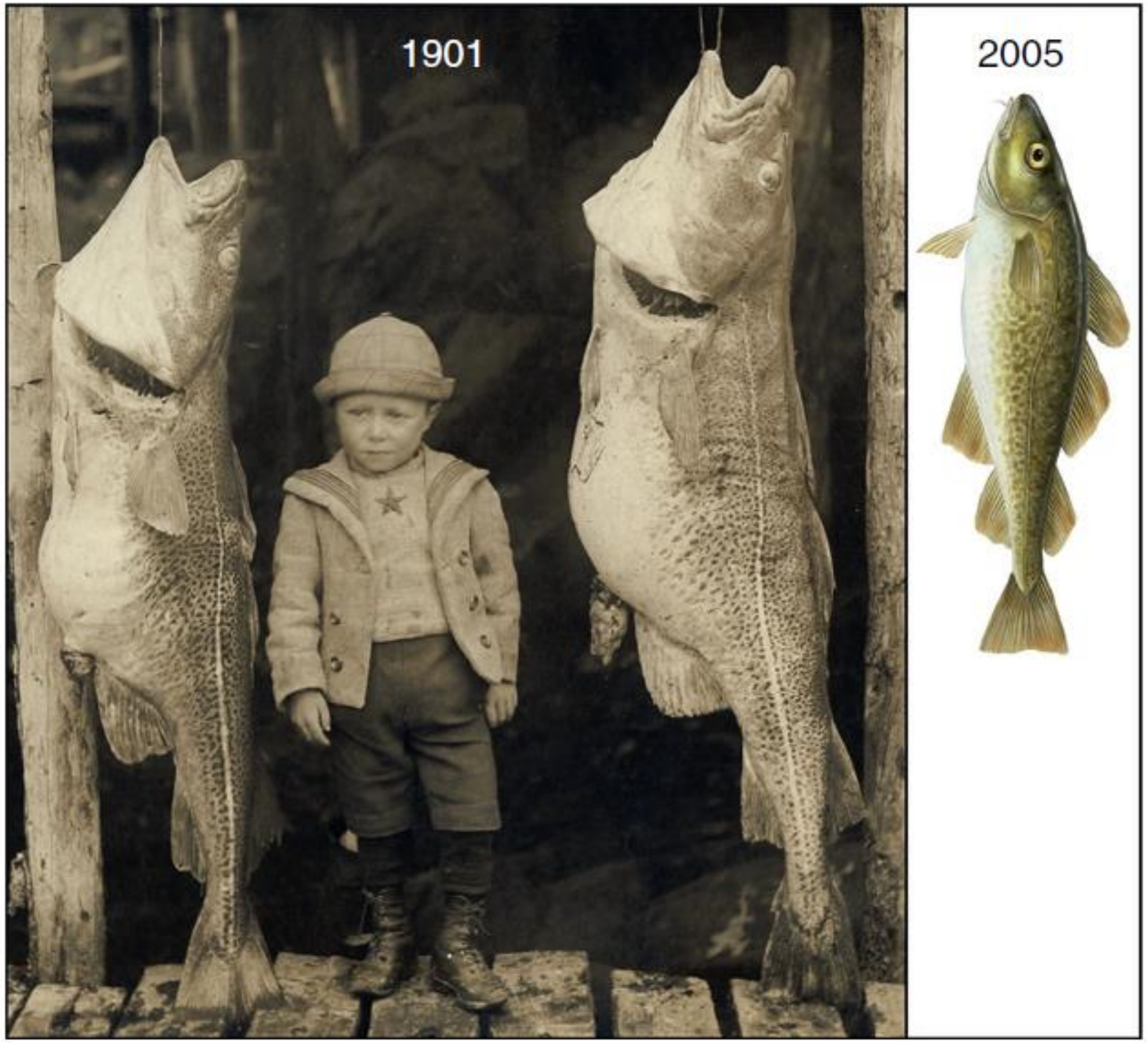
Consider targeted studies (e.g. otolith growth) to assess sensitivity of stock to current and future warming

Don’t assume that life history parameters (e.g. age or size at maturity) are stationary. Try to monitor these periodically (gonads or new maturity proxies)

Be prepared to update stock models with new knowledge

Promote preservation of big fish

Remember: fishing selects against large, old fish too



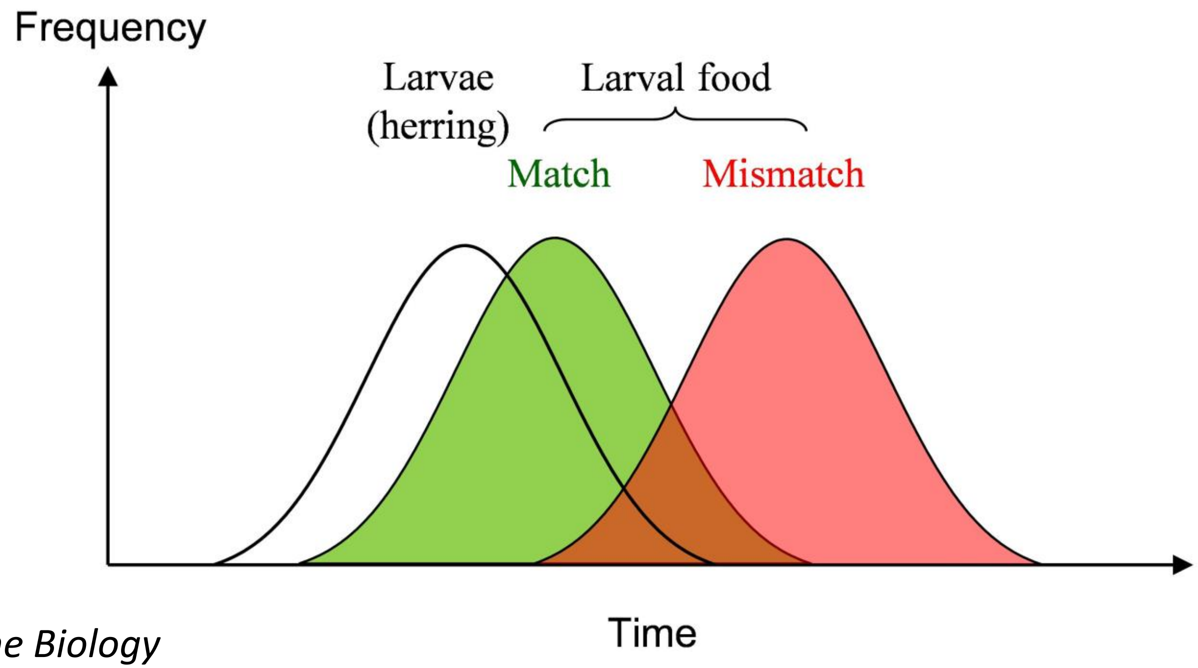
TRENDS in Ecology & Evolution

Altered phenology

Rapid warming can alter cues used by species to stimulate reproduction and developmental rates

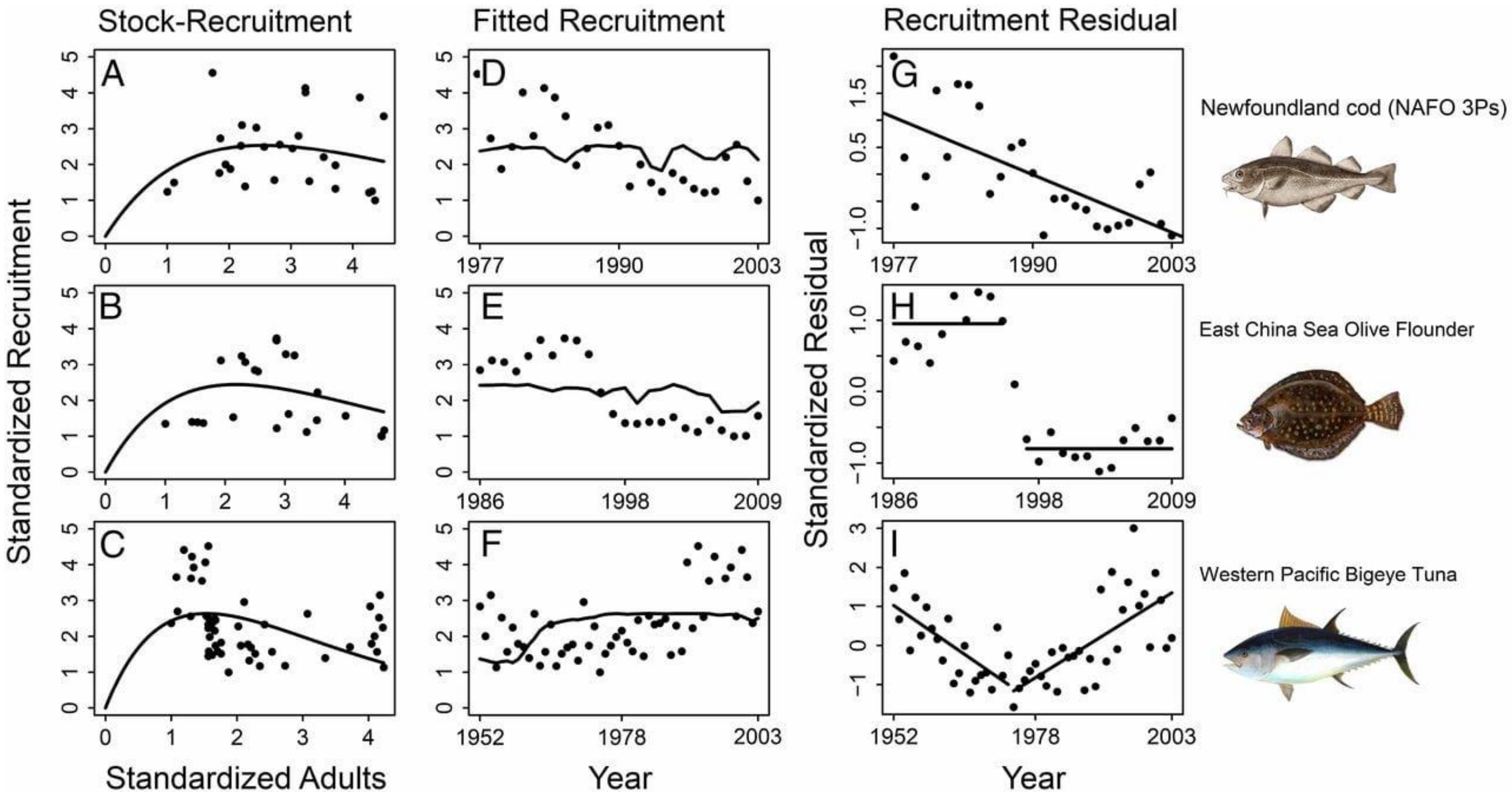
Match-mismatch hypothesis: recruitment greatest when newly hatched larvae encounter a food-rich environment

Advanced phenology can increase likelihood of mismatches and recruitment failure



Cushing (1990) *Advances in Marine Biology*

Recruitment can be really hard to predict!

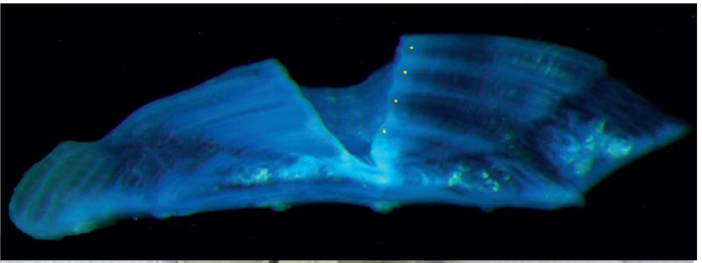


Britten et al (2015) *PNAS*

Barramundi- simple recruitment model

Crook et al (2022) *Ecological Applications*

Barramundi year class strength can be predicted by monsoon intensity



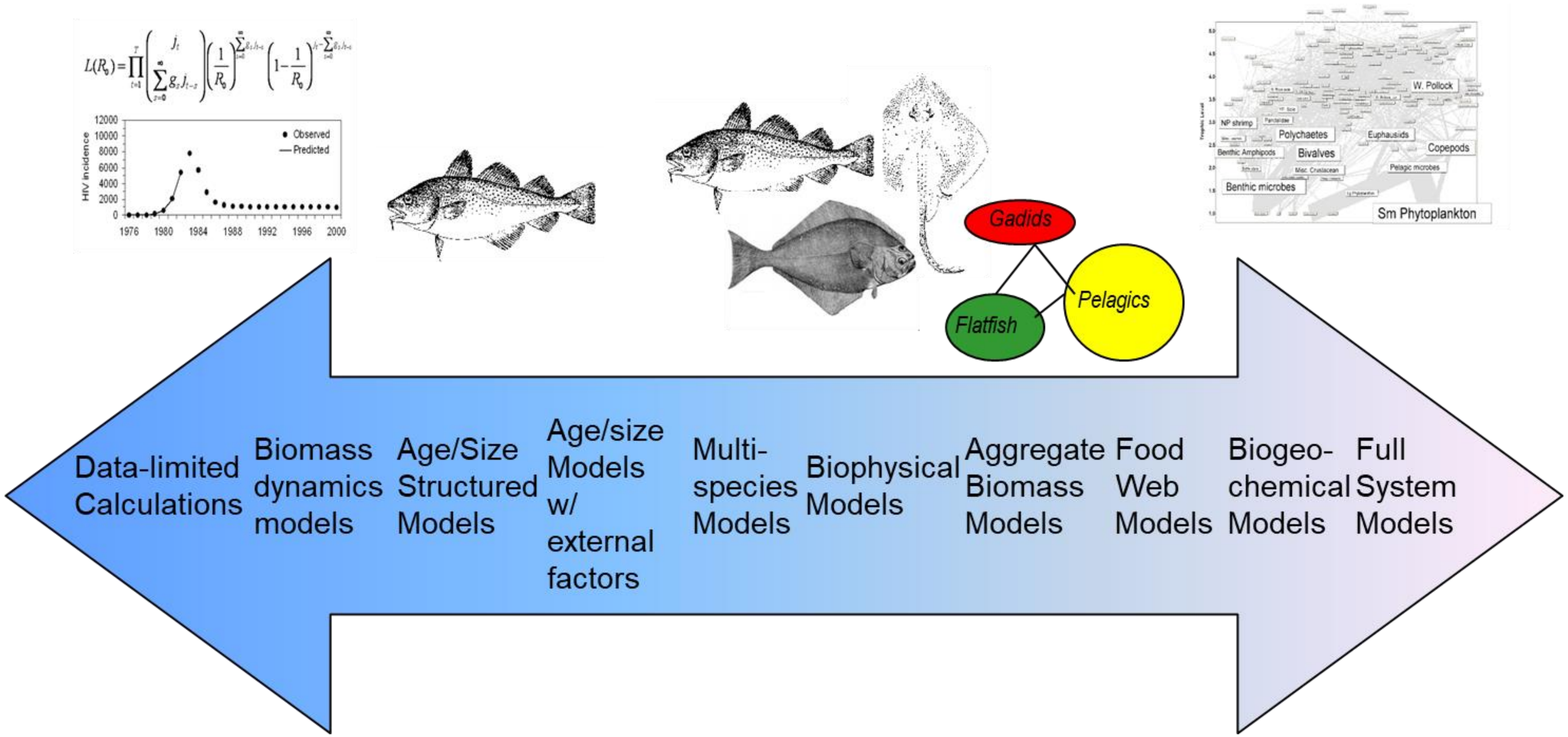
Valuable tool for Northern Territory Fisheries

Crook et al (2022) *Ecological Applications*

Fisheries models can be simple or complex

Fisheries models can be simple, such as describing relationship between fish and habitat

They can be complex, capturing ecosystem relationships and multiple users



Key messages

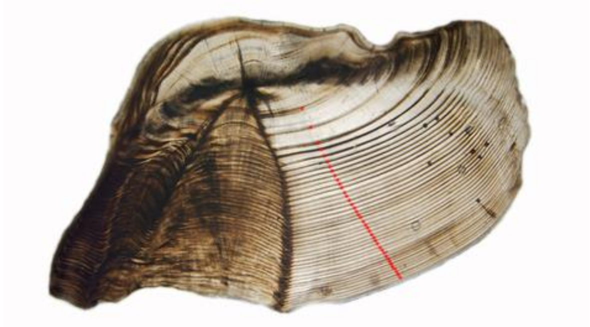
Monitor your stock and keep an eye out for changes!

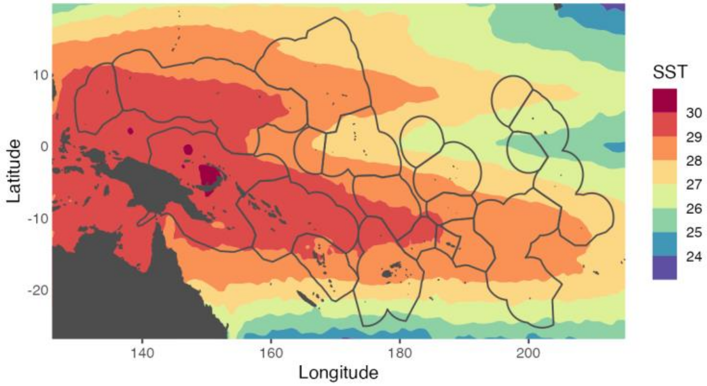
Distributional changes can have significant implications for fishery productivity and food security

Warming-induced declines in size can impact on stock productivity and viability

Climate change is impacting on recruitment patterns and phenology, but this is hard to assess

Understand how warming will affect your stock (be prepared). This could be an empirical assessment, or predictions based on existing knowledge





Thank you

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