Climate, Anchovy and Sardine

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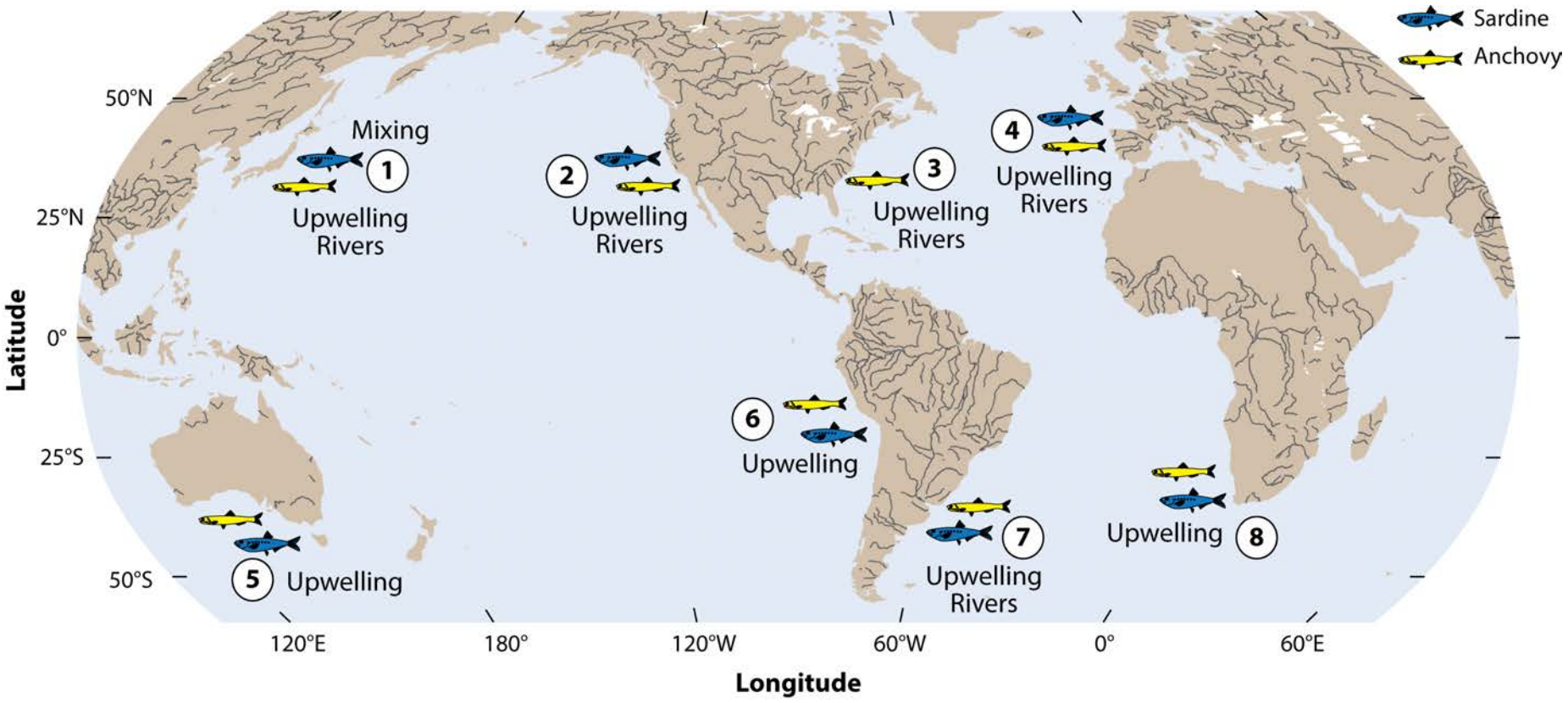
The past is a window to the future.

The environment is changing due to greenhouse gas (GHG) emissions.

How will stocks of anchovy and sardine react to future environmental change?

How can anchovy and sardine stocks be optimally managed?



1 Kuroshio-Oyashio **2** California Current **3** NW Atlantic **4** NE Atlantic

5 Australia-New Zealand **6** Humboldt Current **7** Argentina-Brazil **8** Southern Africa

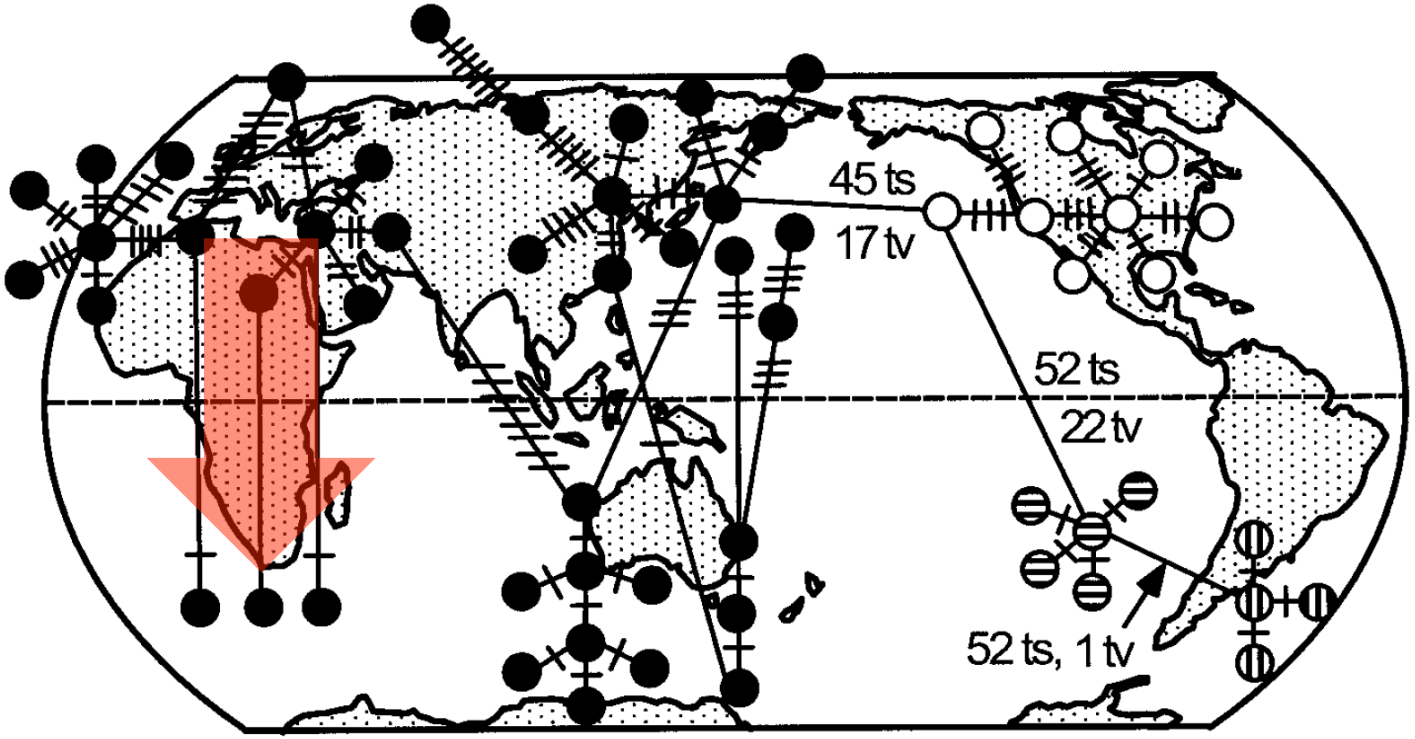
Genetics

Anchovy and sardine have “shallow life histories in deep evolutionary lineages”

Grant and Bowen 1998

- Evolved 10s of millions of years ago
- Populations established < 500,000 years ago
- Some populations extirpated and reestablished

Genetics – Cape anchovy – no refuge from warming



Parsimony network of 58 cytochrome *b* haplotypes in anchovies (*Engraulis*).
(Grant and Bowen 1998)

Anchovy and Sardine Evolved Traits

Share

- fast growth, life history, body form, behaviors

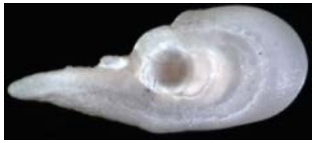
Differ

- feeding: anchovy feed on larger particles
- migration: sardine move faster and longer

Paleo Record – Anoxic Sediments

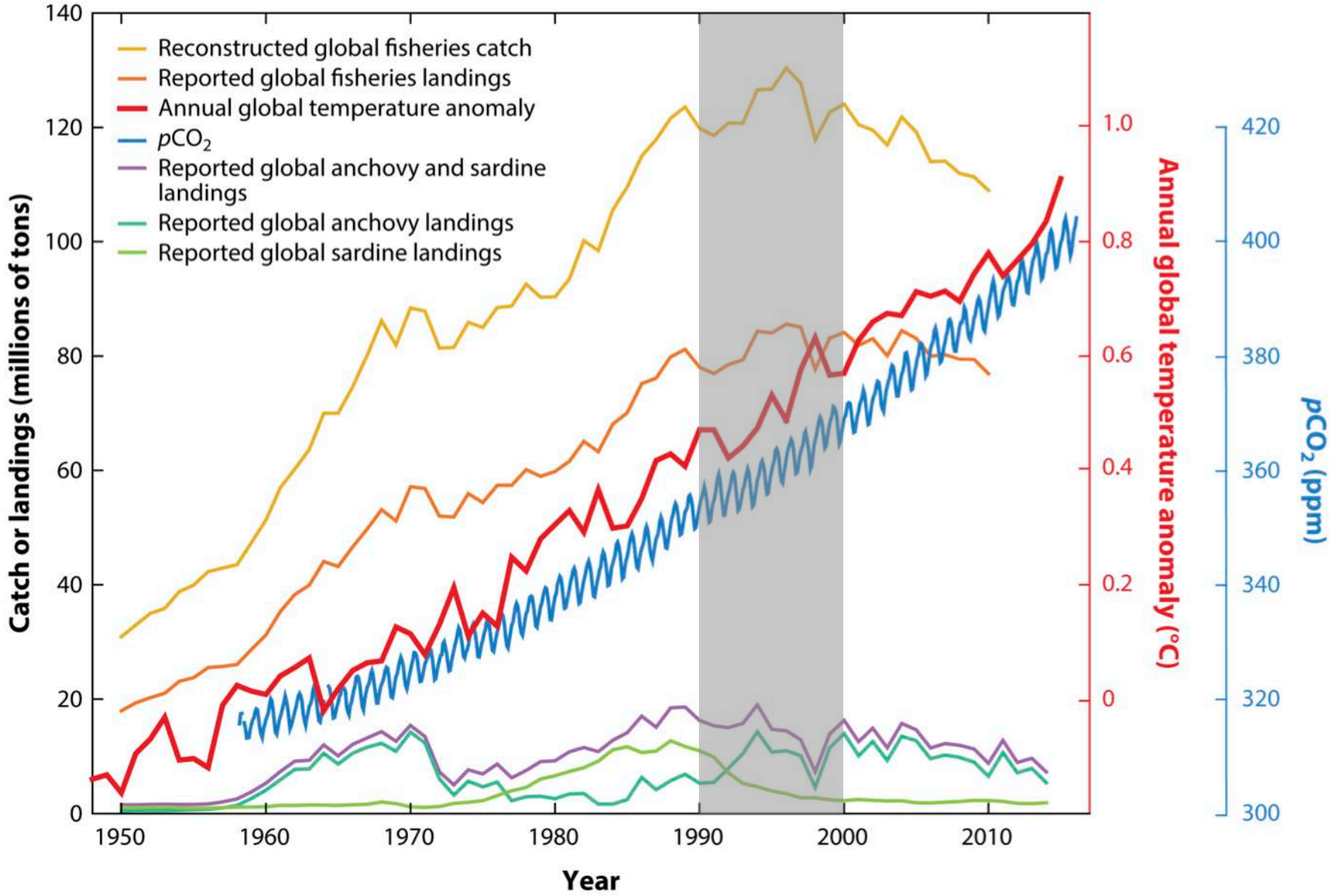
- Anchovy and sardine scale deposition rate varied over past two millennia, often with 50-70y period – Baumgartner et al. 1992; Guiñez et al. 2014

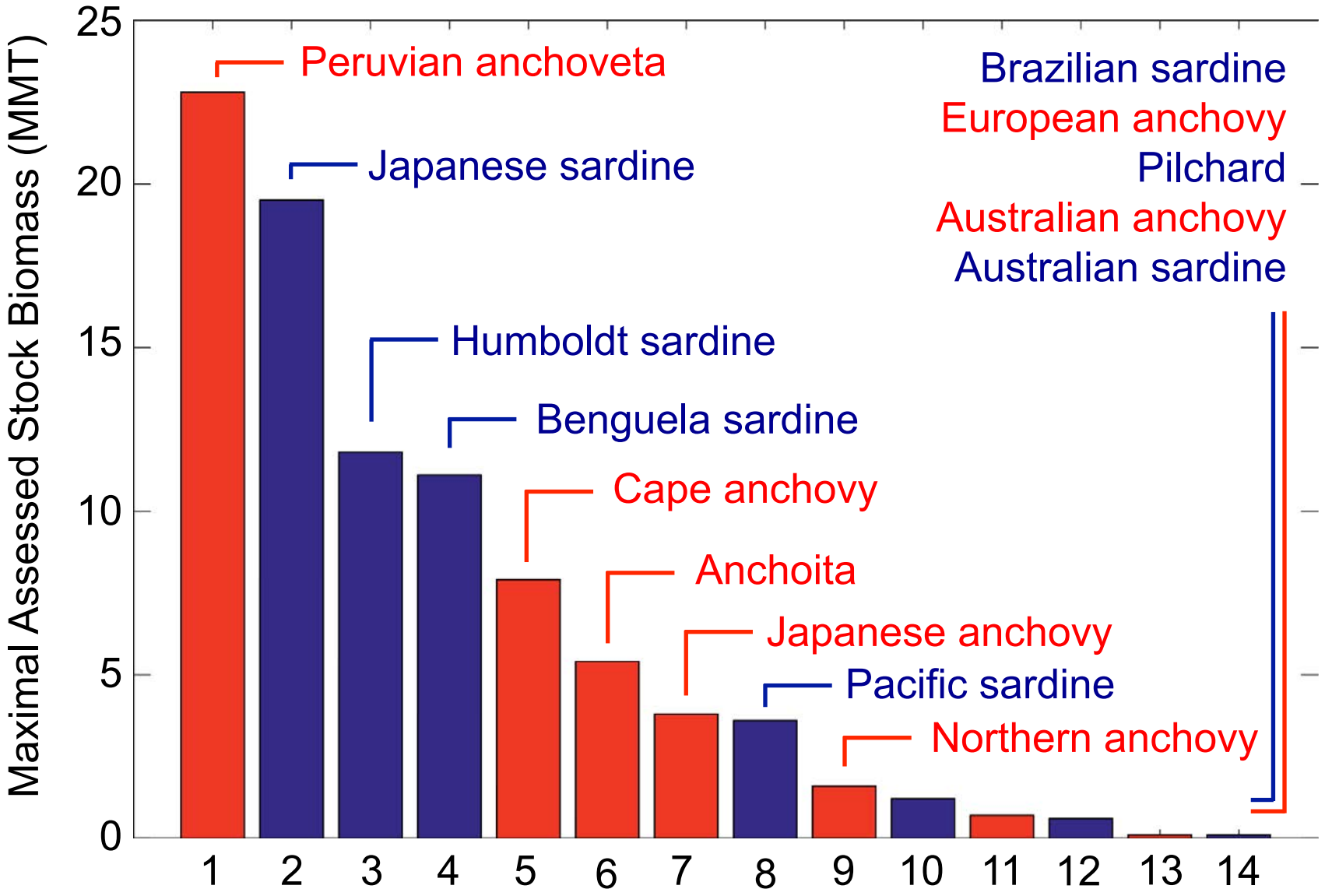
- Midwater fish, not small pelagic fish, dominate otoliths deposited in Santa Barbara Basin over past two millennia, with 50-250y periods – Jones 2016

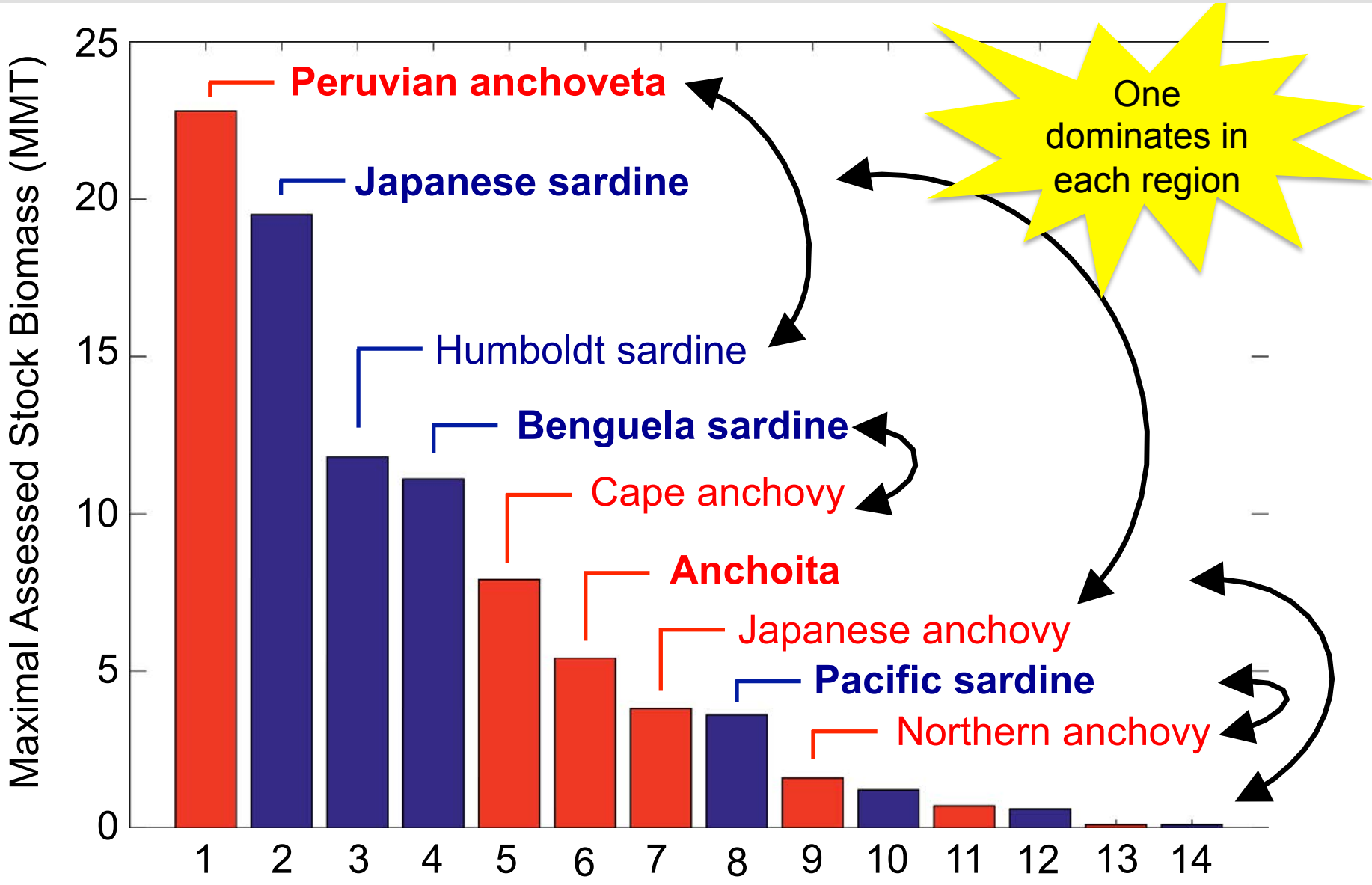


Conclusions

- Anchovy and sardine are old species
- Share and differ in key traits
- Populations are relatively young
- Populations vary naturally (before fishing) on scale of climate variation


Reconstructed global fisheries catch
Reported global fisheries landings
Annual global temperature anomaly
pCO_2
Reported global anchovy and sardine landings
Reported global anchovy landings
Reported global sardine landings
Catch or landings (millions of tons)
Annual global temperature anomaly (°C)
pCO_2 (ppm)
Year
0
20
40
60
80
100
120
140
0
0.2
0.4
0.6
0.8
1.0
300
320
340
360
380
400
420
1950
1960
1970
1980
1990
2000
2010


Maximal Assessed Stock Biomass (MMT)
25
20
15
10
5
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
Peruvian anchoveta
Japanese sardine
Humboldt sardine
Benguela sardine
Cape anchovy
Anchoita
Japanese anchovy
Pacific sardine
Northern anchovy
Brazilian sardine
European anchovy
Pilchard
Australian anchovy
Australian sardine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Peruvian anchoveta
Japanese sardine
Humboldt sardine
Benguela sardine
Cape anchovy
Anchoita
Japanese anchovy
Pacific sardine
Northern anchovy
One dominates in each region

New Production:

Primary production based on nitrogen from outside the euphotic zone

Dugdale and Goering 1967

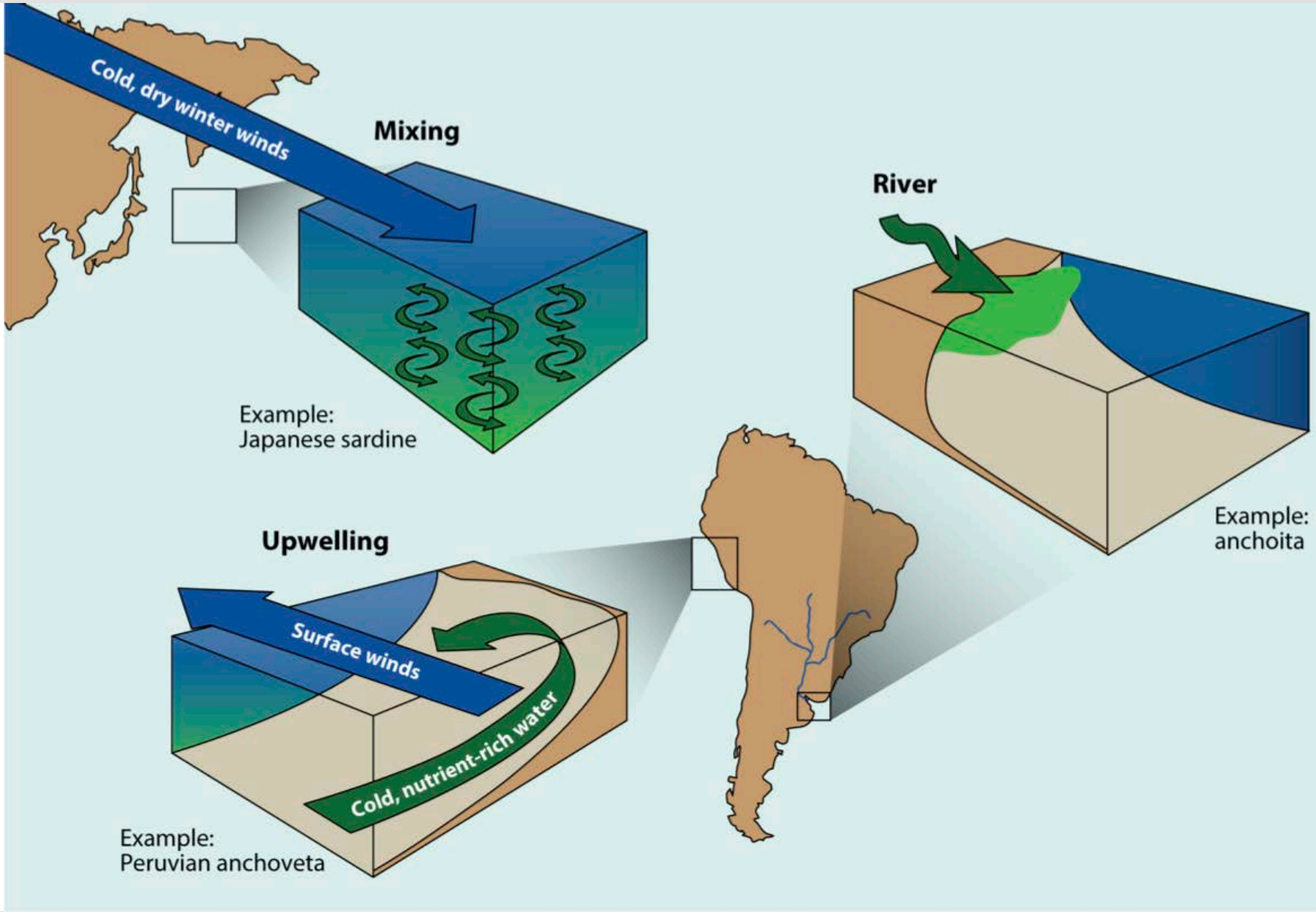
Classify stocks by new N source

Anchovy

- Coastal
- Coastal wind-driven upwelling
- Rivers

Sardine

- Offshore
- Wind-stress curl-driven upwelling
- Mixing


Cold, dry winter winds
Mixing
Example:
Japanese sardine
River
Example:
anchoita
Upwelling
Surface winds
Cold, nutrient-rich water
Example:
Peruvian anchoveta

Conclusions

- Anchovy or sardine is dominant in each region
- New nitrogen supply:

	Upwelling	Mixing	River
Anchovy	✓ ✓		✓
Sardine	✓ ✓	✓ ✓	

Climate Change Projections

- Distributional shifts
- Phenology (warming, river flow, prey timing)
- Quality of source water
- Ocean acidification
- Habitat compression
- Plankton composition and production
- Fishing – food security
- Acclimation and adaptation

Climate Change Challenges

- Attribution
- Projections on scales (time, space) relevant to decisions in management and policy
- Projections require mechanistic understanding; fisheries classically relies on empirical relations such as between stock and recruitment (S-R)
- Skill evaluation necessary to build trust by decision makers and public

Recommendations

- Time series of anchovy, sardine and environment – for models and attribution
- Mechanistic modeling on relevant scales
- Focus on bottom-up (new N), top-down (fishing) and traits
- Acidification, acclimation and adaptation in regions with extremes, e.g., Peru with anchoveta
- Evaluate forecast skill to enhance trust

The End

Checkley Jr DM, Asch RG, Rykaczewski RR. 2017. Climate, Anchovy, and Sardine. *Annual Review of Marine Science* 9: 469-93.

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