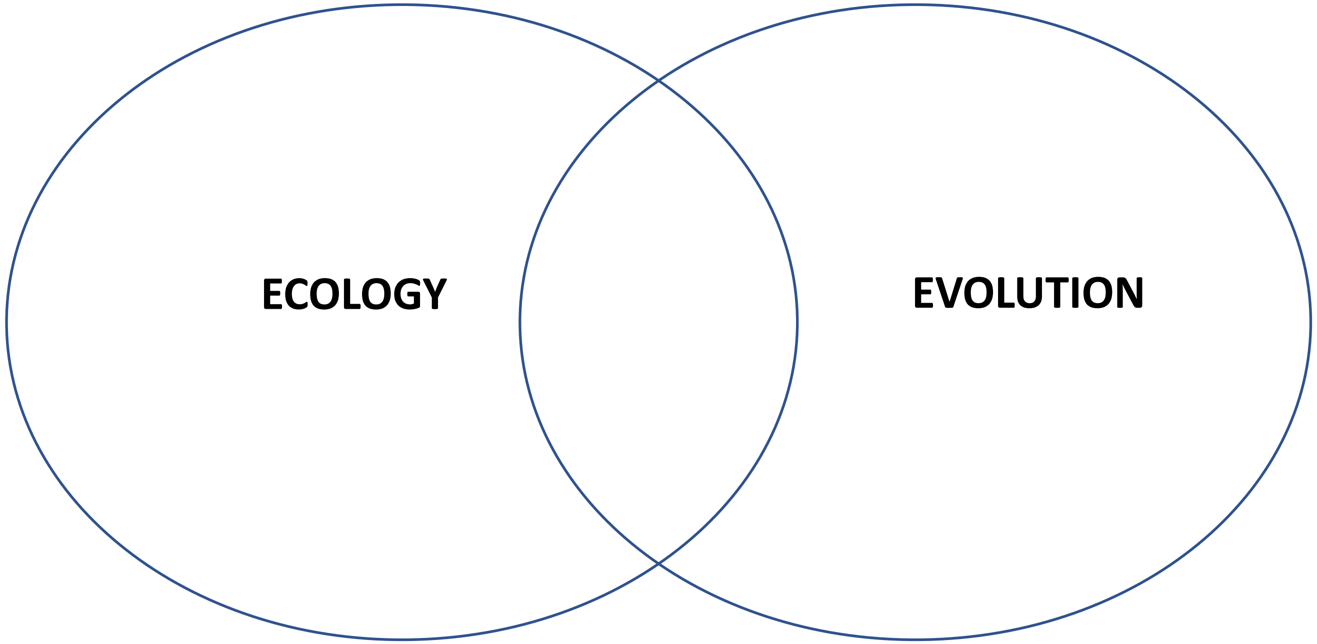
EVOLUTIONARY ECOLOGY

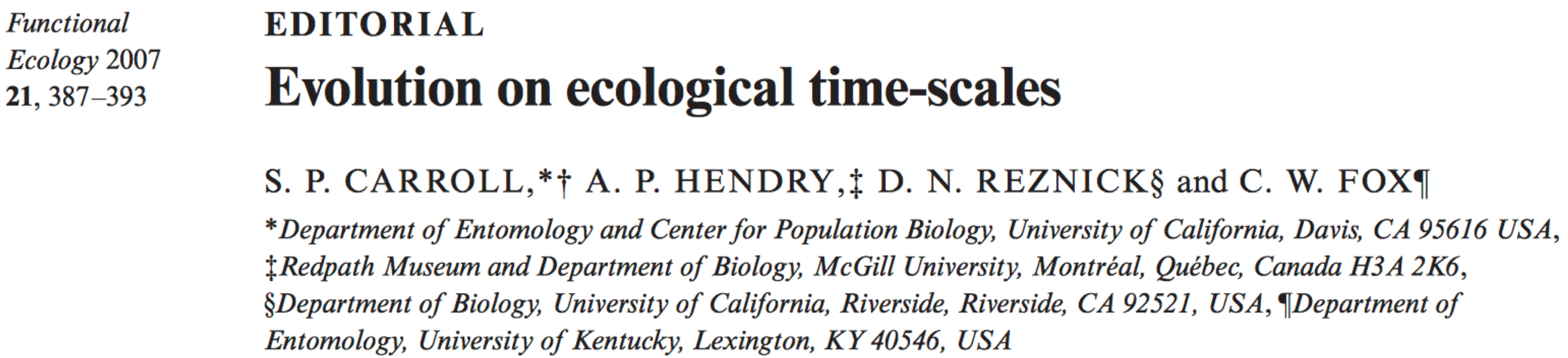


ECOLOGY

EVOLUTION

Eco-evolutionary dynamics – first use by Oloriz et al 1991,
modern use in 2007, special issue of Functional ecology

Eco-evo dynamics: interactions between ecology and evolution that play out on the contemporary time scales- years to centuries)



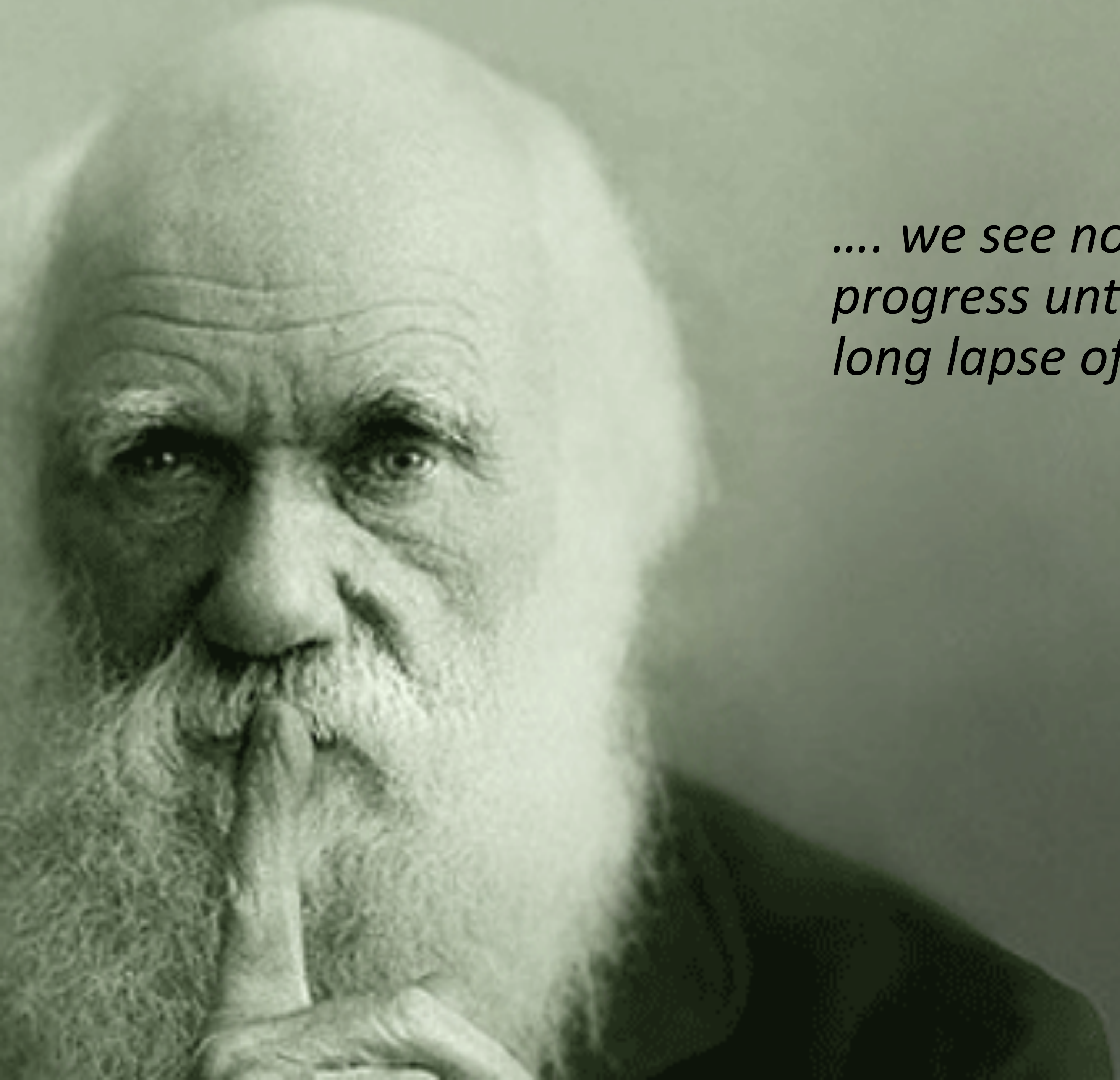
Functional Ecology 2007
21, 387–393

EDITORIAL

Evolution on ecological time-scales

S. P. CARROLL,*† A. P. HENDRY,‡ D. N. REZNICK§ and C. W. FOX¶

**Department of Entomology and Center for Population Biology, University of California, Davis, CA 95616 USA, ‡Redpath Museum and Department of Biology, McGill University, Montréal, Québec, Canada H3A 2K6, §Department of Biology, University of California, Riverside, Riverside, CA 92521, USA, ¶Department of Entomology, University of Kentucky, Lexington, KY 40546, USA*



…. we see nothing of these slow changes in progress until the hand of time has marked the long lapse of ages…

Darwin, 1859

ECO –EVO

- adaptation of populations to changing environment

EVO- ECO

- trait change in a focal population alters its population dynamics, influence the structure of its community or alters the ecosystem processes (contemporary evolution leading to ecological change)

- feedback ECO → EVO →ECO

EVOLUTION: Descent with modification; transformation of species through time, including both changes that occur within species, as well as the origin of new species.
Losos et al. Princenton guide to Evolution, 2014

ECOLOGY: Heckel: “the comprehensive science of the relationship of the organism to environment.”

EVOLUTIONARY FORCES:
Selection
Gene flow
Genetic drift
Mutation
Recombination

ECOLOGICAL VARIABLES:
Abiotic
Biotic (competitors, mutualists, predators, and pathogens…)

WHY ARE FISH GETTING SMALLER?

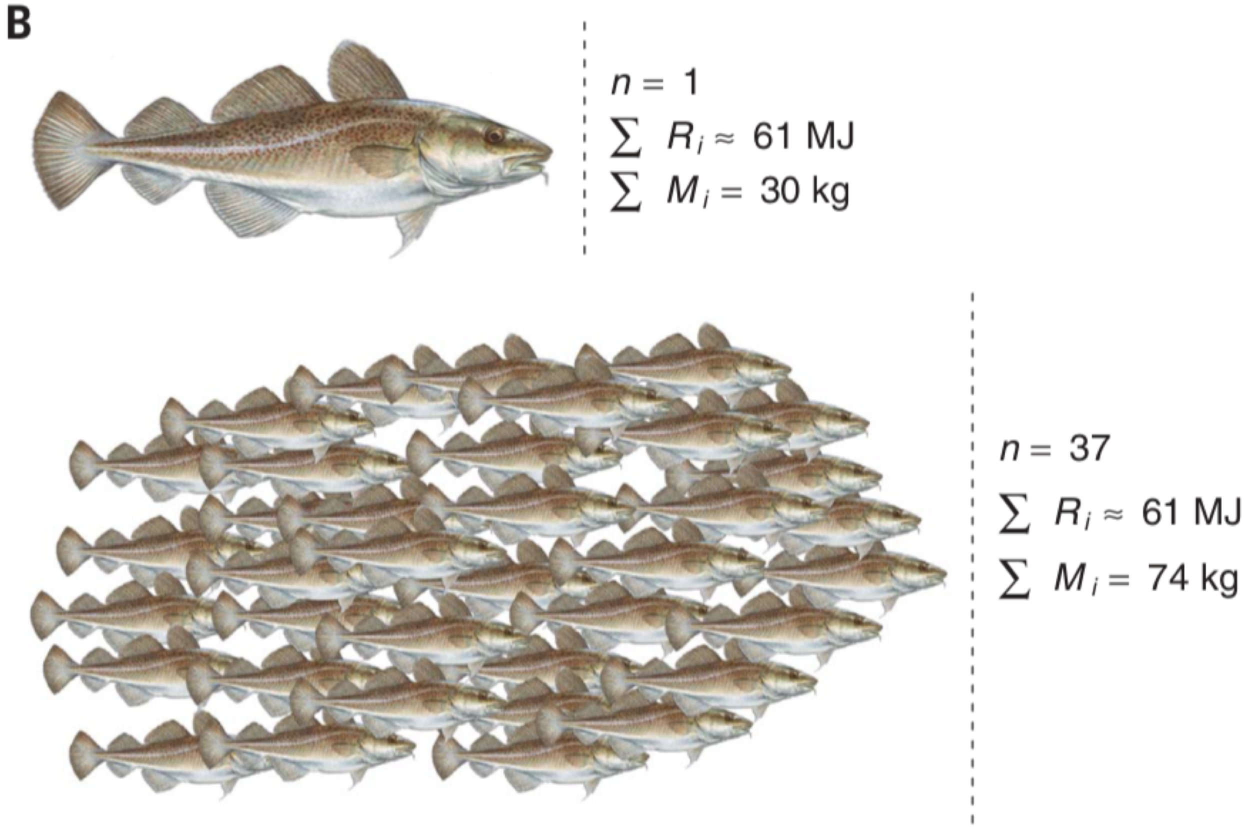
Photos courtesy of OSU/NOAA Fish ecology group

Different body weight of similar length juvenile Chinook salmon representing lower growth during warm ocean conditions (upper fish) and higher growth during cold ocean conditions (lower fish). Image courtesy Oregon State

Reproductive success


Photos courtesy of OSU/NOAA Fish ecology group

Smaller fish have less offspring!
- decrease of population productivity!



Gadus morhua (Norwegian cod) –30 kg ind. have more offspring than two 28 kg individuals

Trophic nets

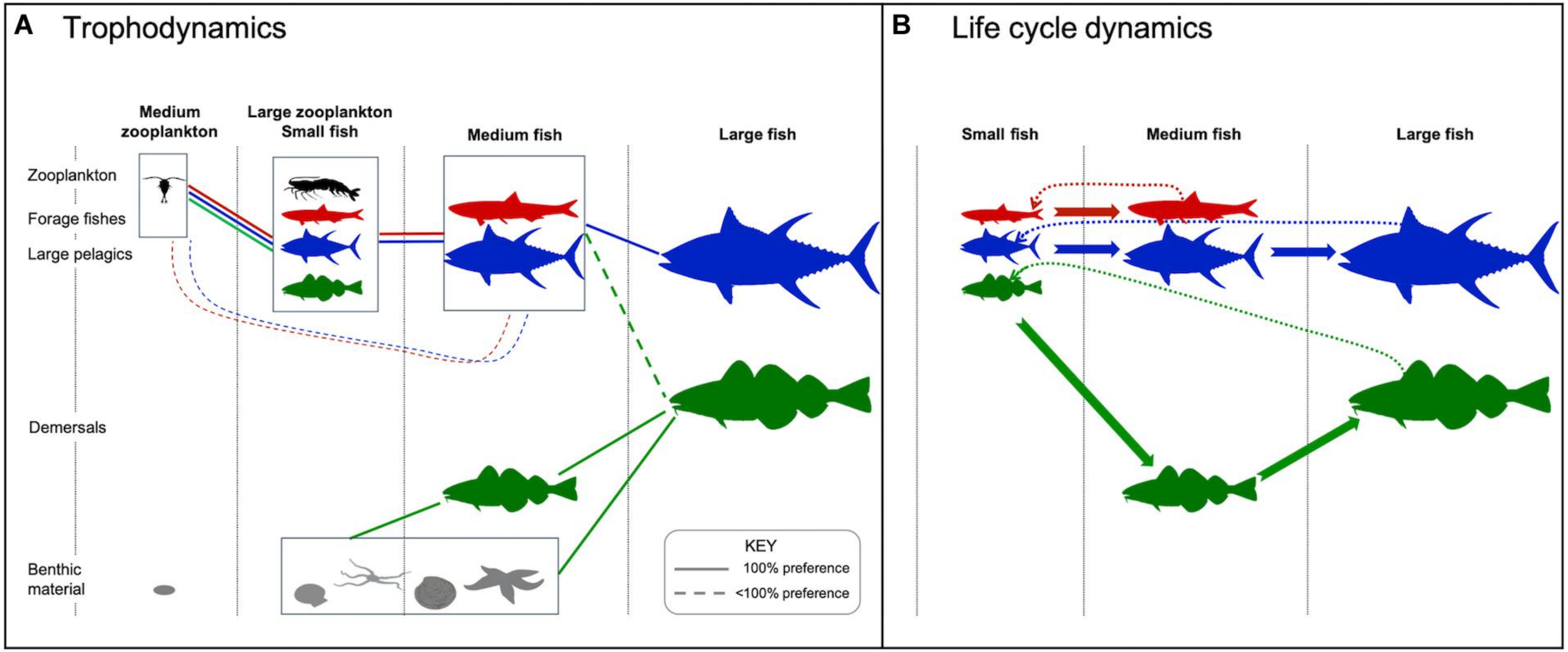

Photos courtesy of OSU/NOAA Fish ecology group

Different body weight of similar length juvenile Chinook salmon representing lower growth during warm ocean conditions (upper fish) and higher growth during cold ocean conditions (lower fish). Image courtesy Oregon State

body size determines **predator-prey relationships**, change of marine food webs
-bigger fish - bigger prey; have fewer predators

- reducing the global fish supply

.



Adult fish sizes have shrunk over 50 years of sea temperature rises

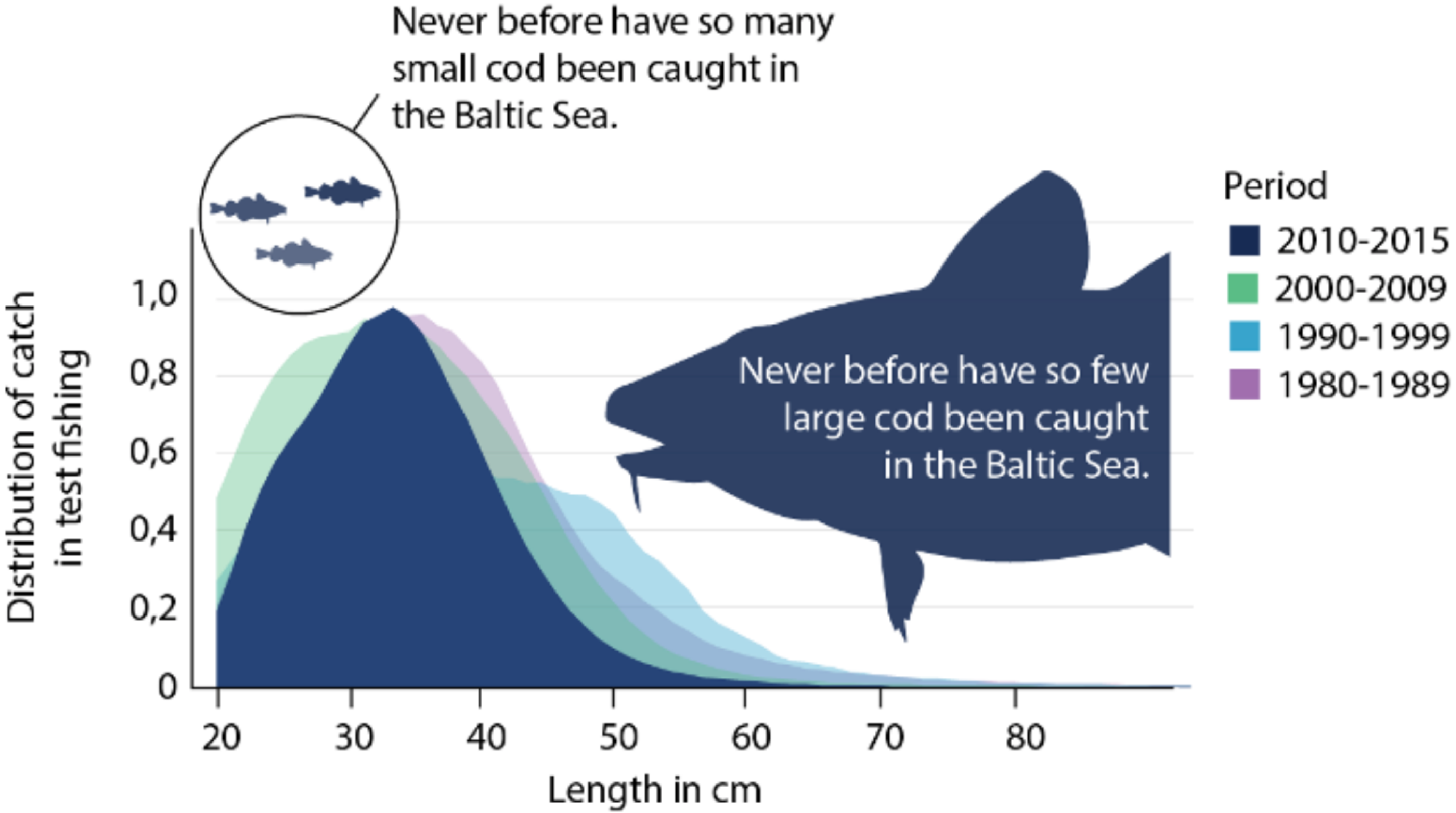
ENVIRONMENT 31 December 2020

By **Donna Lu**

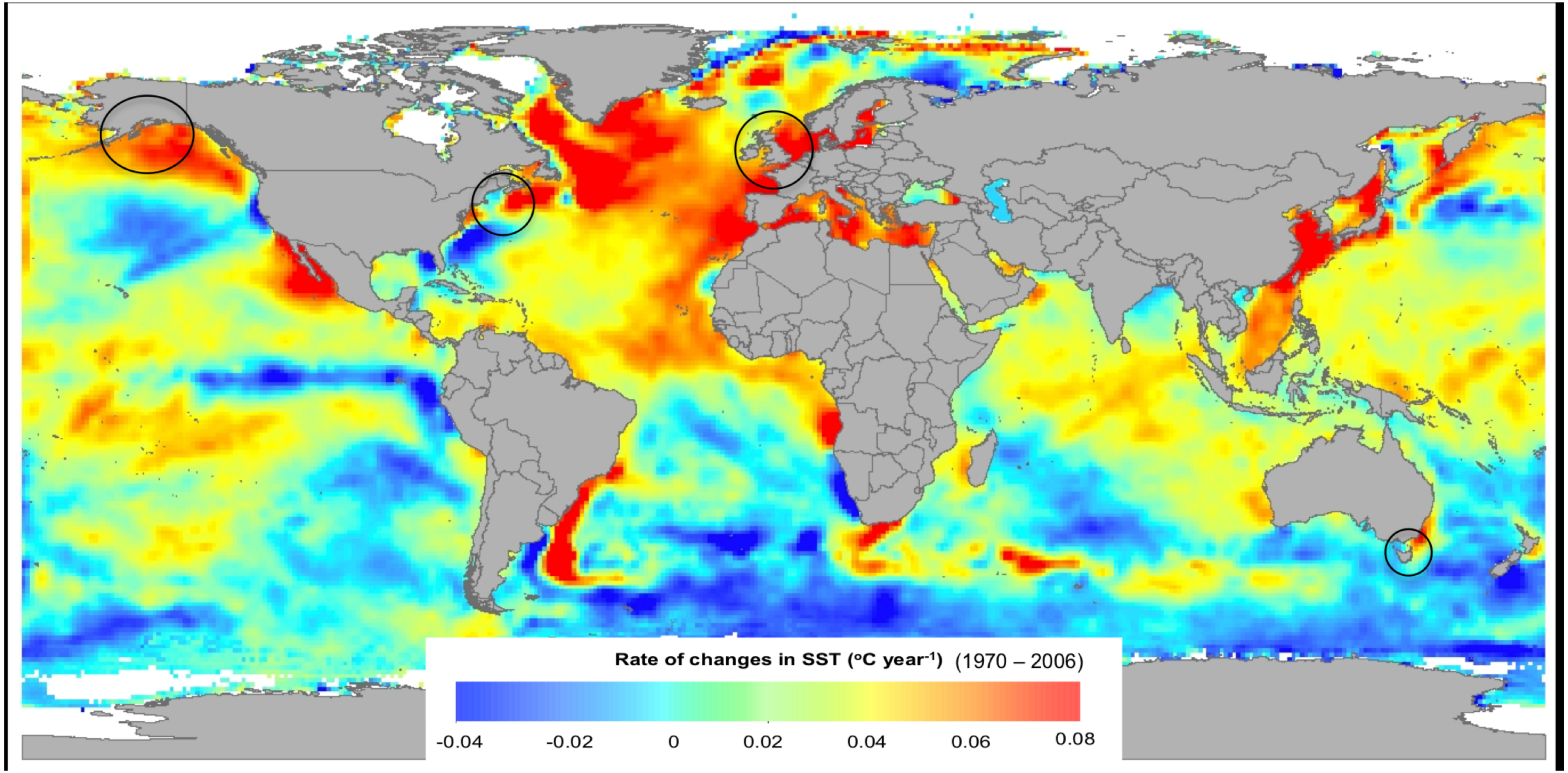
Cod in the North Sea are getting smaller

Alex Mustard / naturepl.com

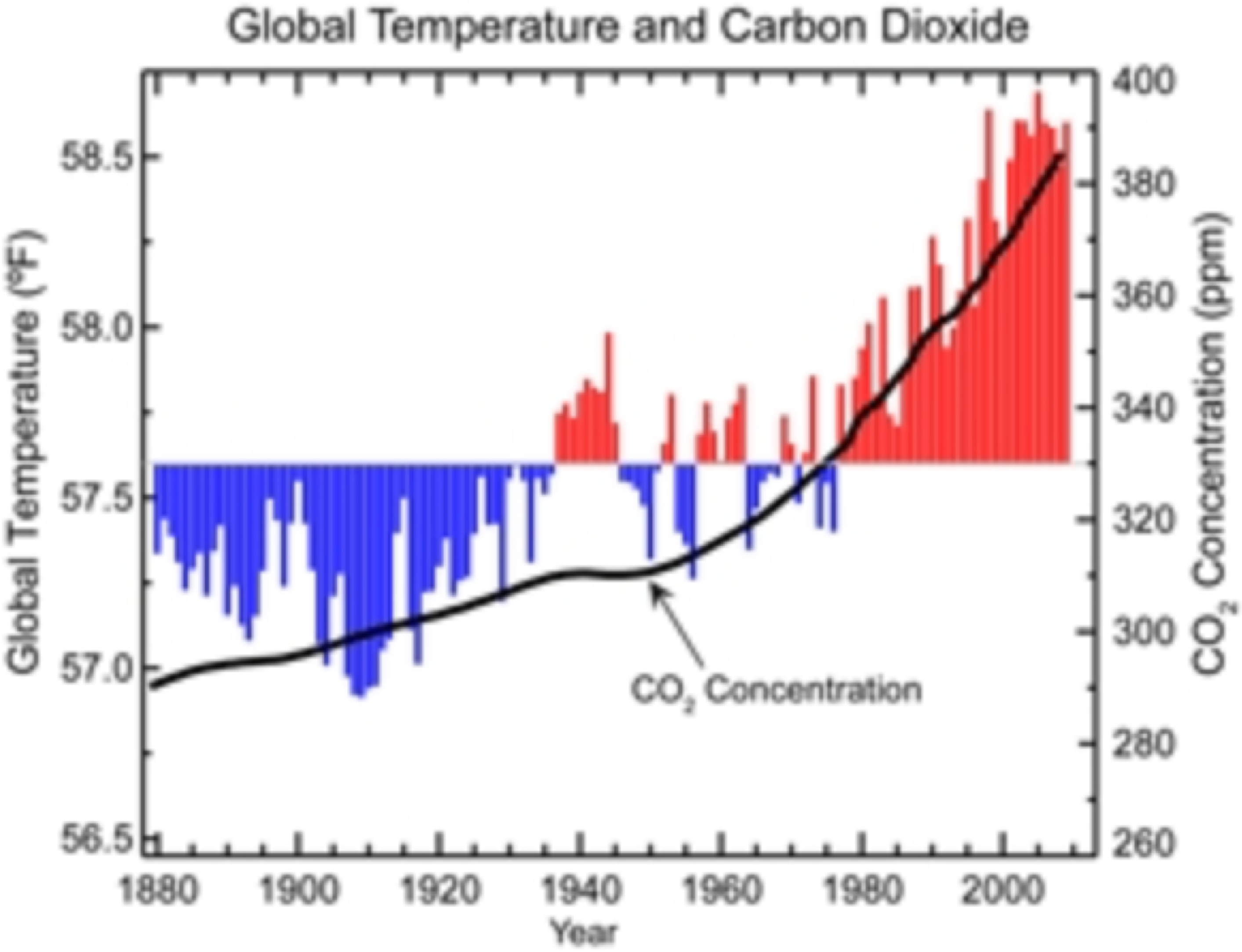
The shrinking Baltic Cod

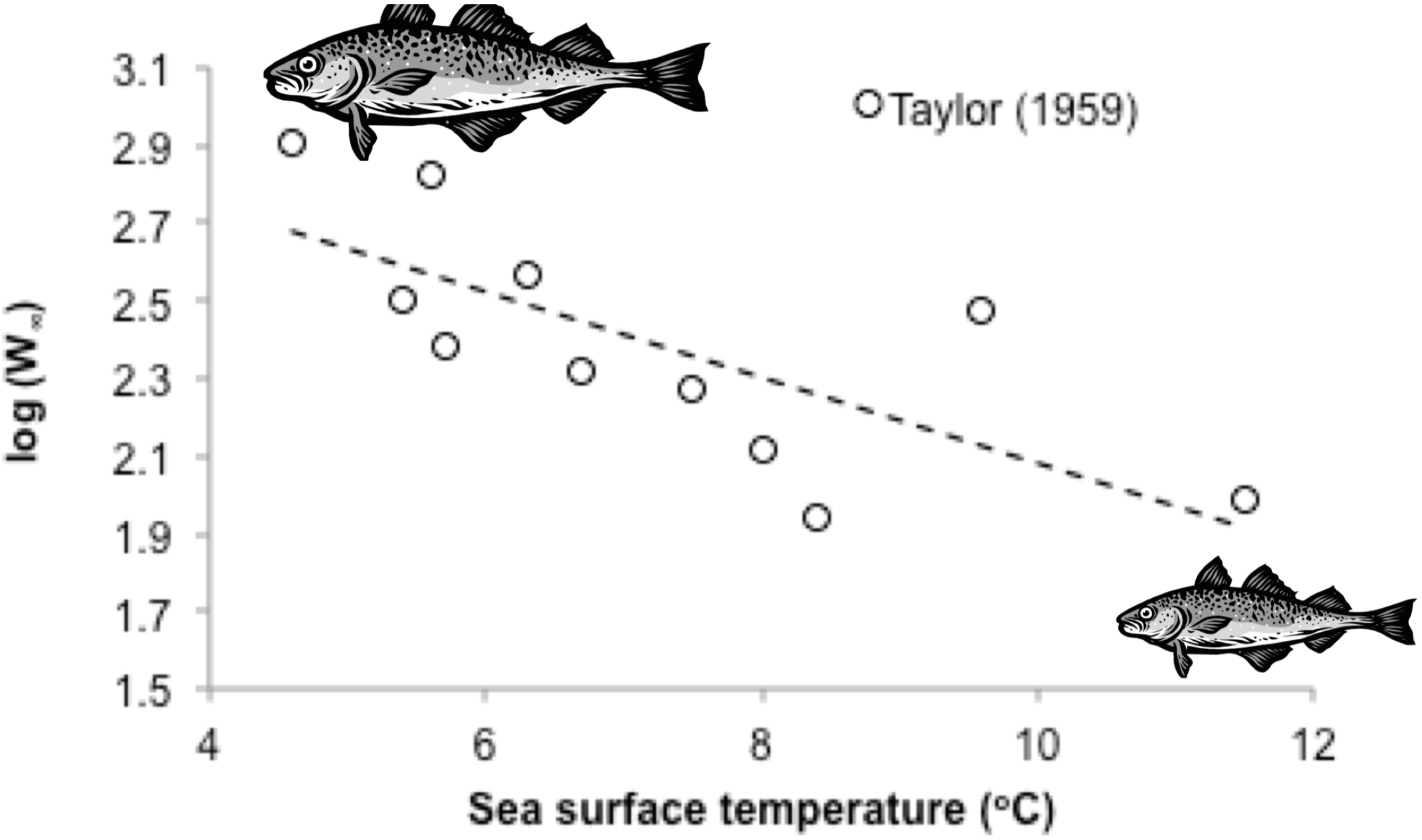
Never before have so many small cod been caught in the Baltic Sea.
Never before have so few large cod been caught in the Baltic Sea.
Period
2010-2015
2000-2009
1990-1999
1980-1989
Distribution of catch in test fishing
1,0
0,8
0,6
0,4
0,2
0
20
30
40
50
60
70
80
Length in cm

Global warming



-shift in species distribution and abundance
-changes in phenology


Global Temperature and Carbon Dioxide
Global Temperature (°F)
56.5
57.0
57.5
58.0
58.5
CO$_2$ Concentration (ppm)
260
280
300
320
340
360
380
400
1880
1900
1920
1940
1960
1980
2000
Year
CO$_2$ Concentration

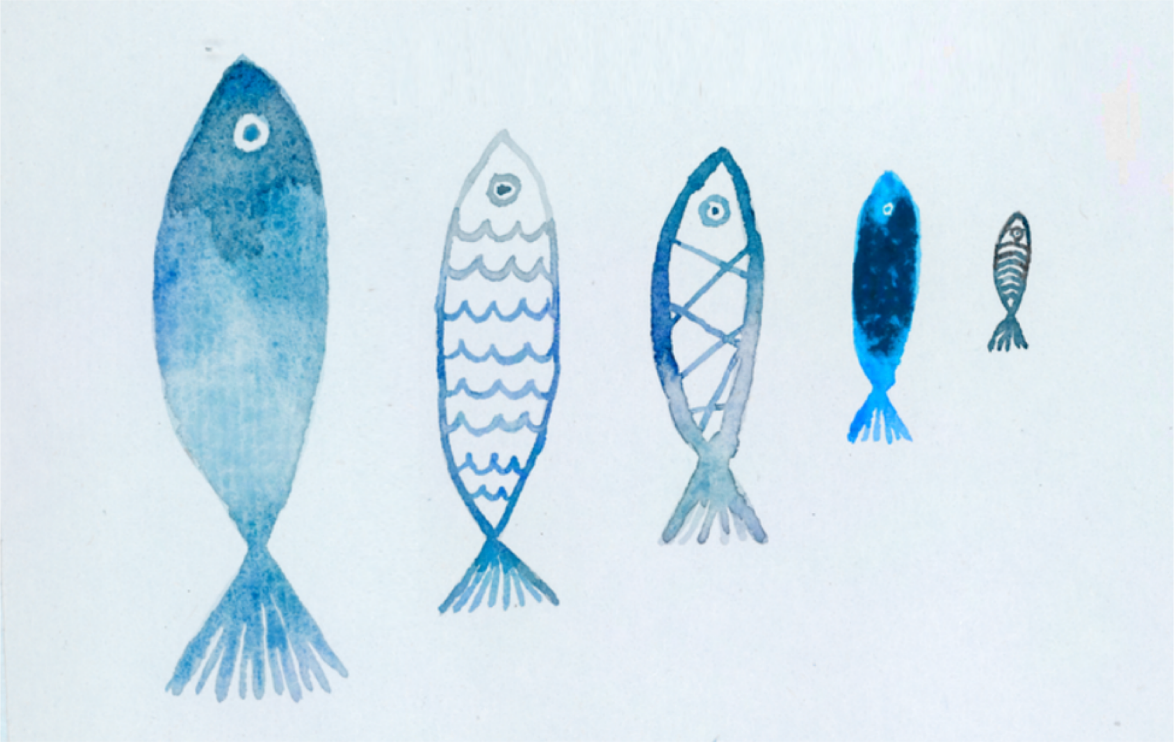


Why temperature increase drives decrease in fish body size?

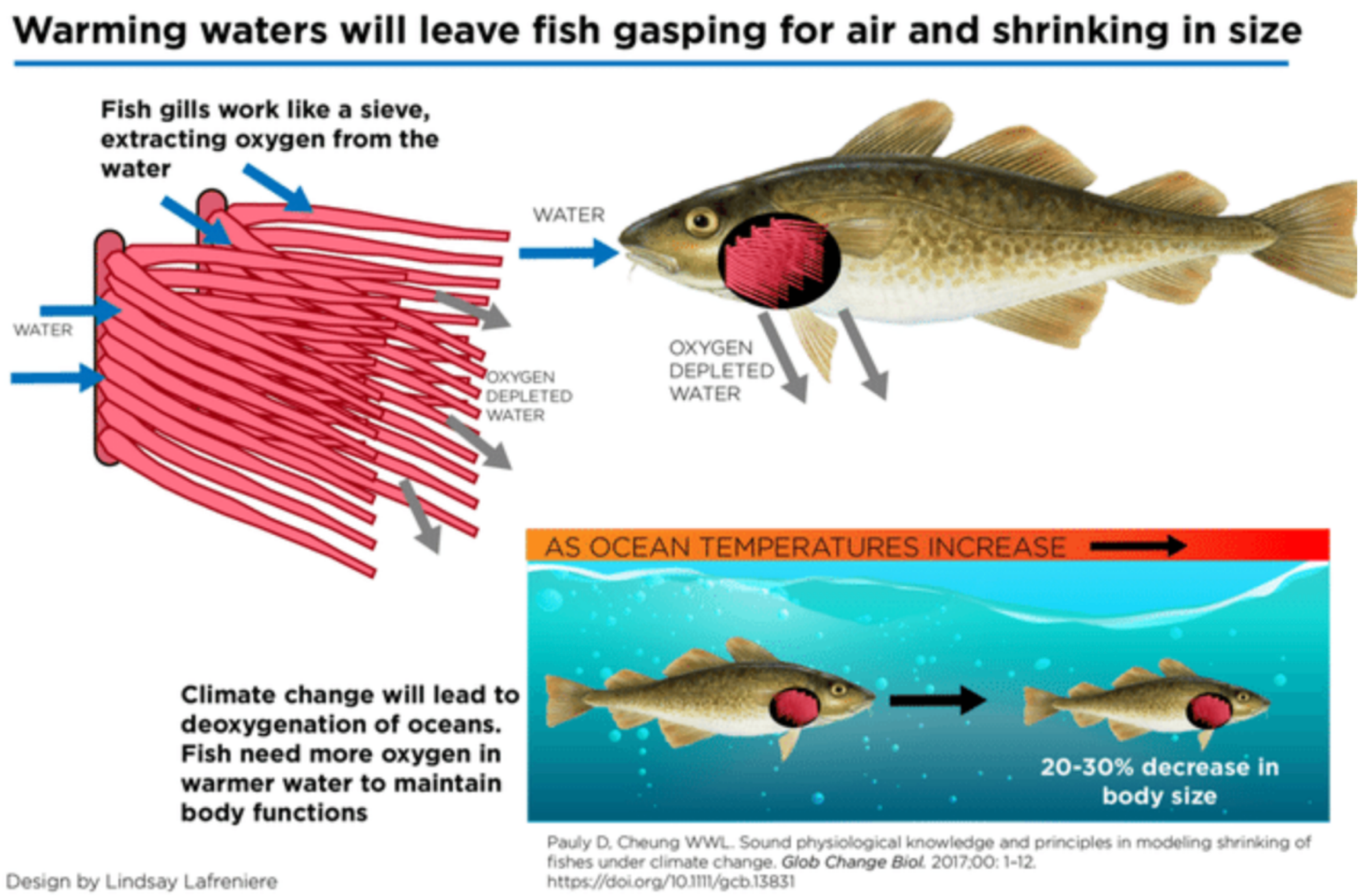
Climate change

Fish are poikiloterms
- higher temperatures- higher metabolism – higer oxygen demand
- higher water temperatures – less oxygen

gills canot keep up with the demand of big bodies



Climate change

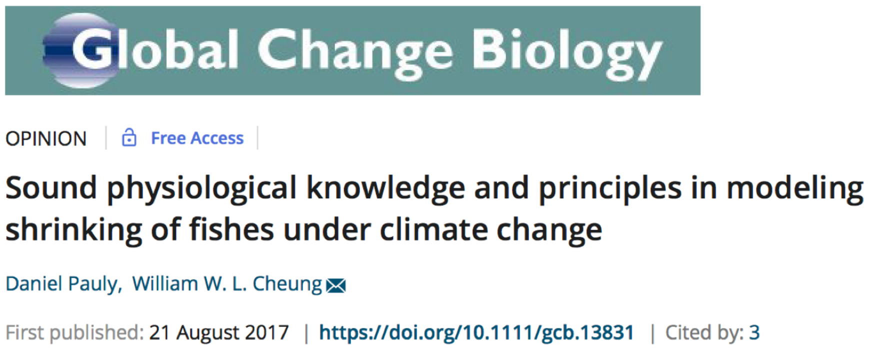


Design by Lindsay Lafreniere

Pauly D, Cheung WWL. Sound physiological knowledge and principles in modeling shrinking of fishes under climate change. *Glob Change Biol.* 2017;00: 1-12. https://doi.org/10.1111/gcb.13831

Warmer waters hold less oxygen, causing fish to shrink.

Global Change Biology

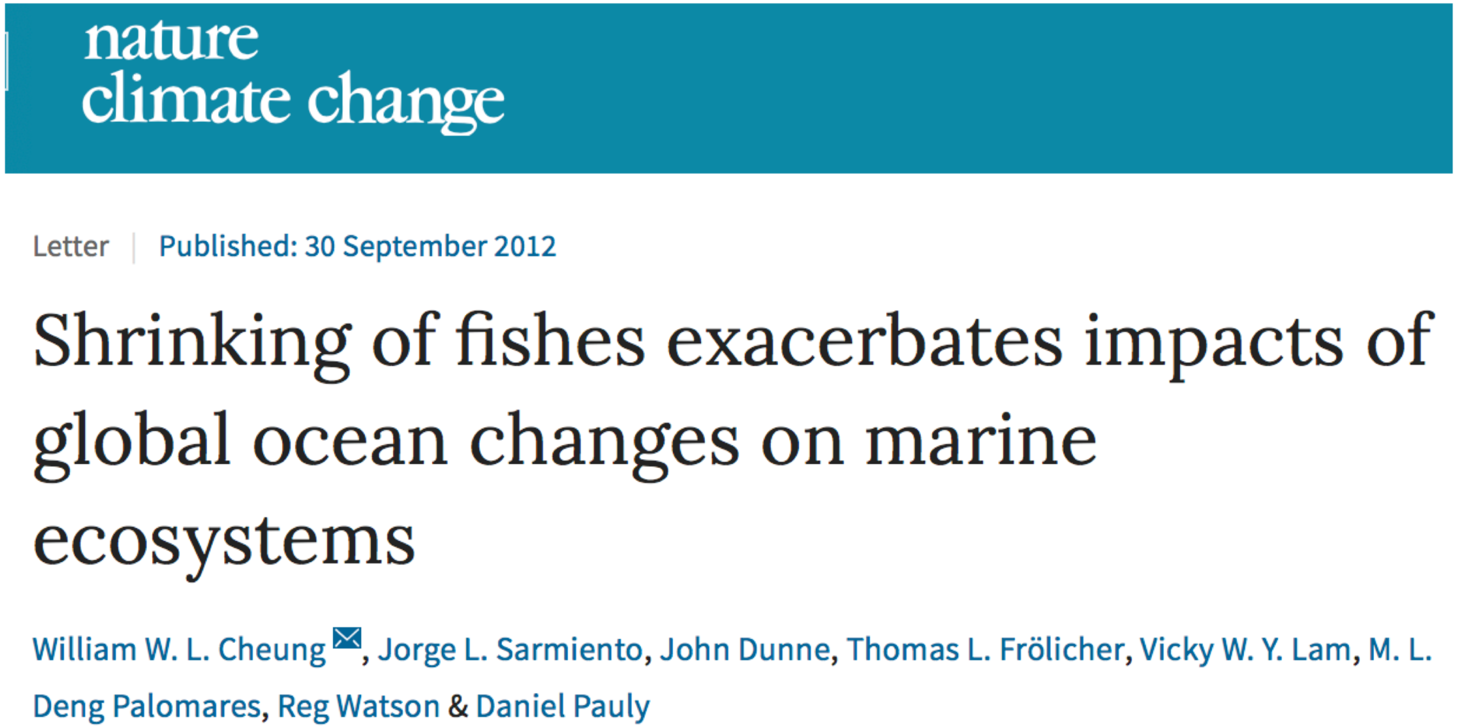

Global Change Biology

OPINION | Free Access |

Sound physiological knowledge and principles in modeling shrinking of fishes under climate change

Daniel Pauly, William W. L. Cheung

First published: 21 August 2017 | https://doi.org/10.1111/gcb.13831 | Cited by: 3



nature
climate change

Letter | Published: 30 September 2012

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

William W. L. Cheung ✉, Jorge L. Sarmiento, John Dunne, Thomas L. Frölicher, Vicky W. Y. Lam, M. L. Deng Palomares, Reg Watson & Daniel Pauly

„We show that assemblage-averaged maximum body weight is expected to shrink by **14–24% globally from 2000 to 2050** under a high-emission scenario. About half of this shrinkage is due **to change in distribution and abundance, the remainder to changes in physiology.** The tropical and intermediate latitudinal areas will be heavily impacted, with an average reduction of more than 20%. Our results provide a new dimension to understanding the integrated impacts of climate change on marine ecosystems."

Temperature change causes migration of bigger fish in colder waters and greater depths, and the invasion of smaller fish in warmer waters.

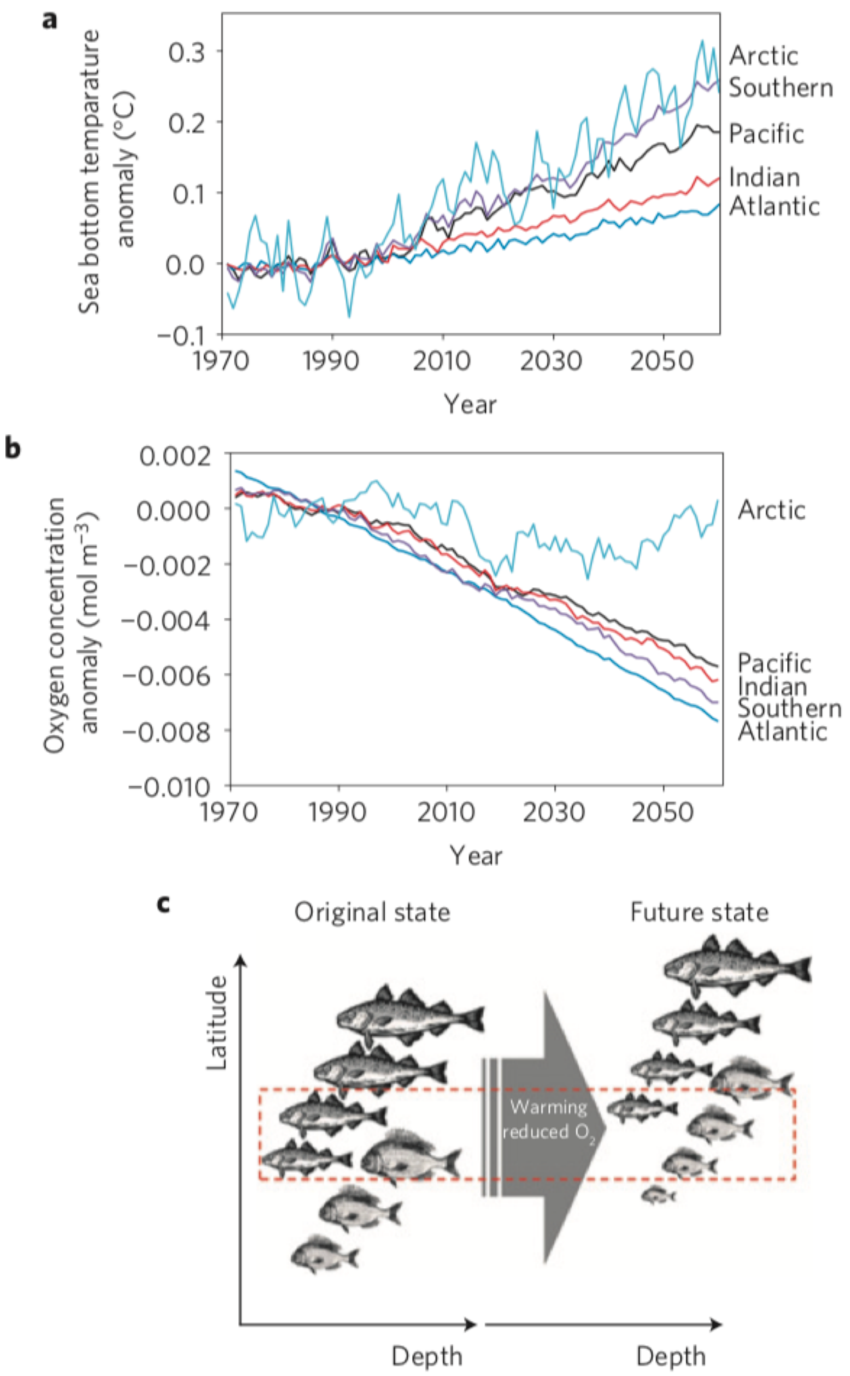
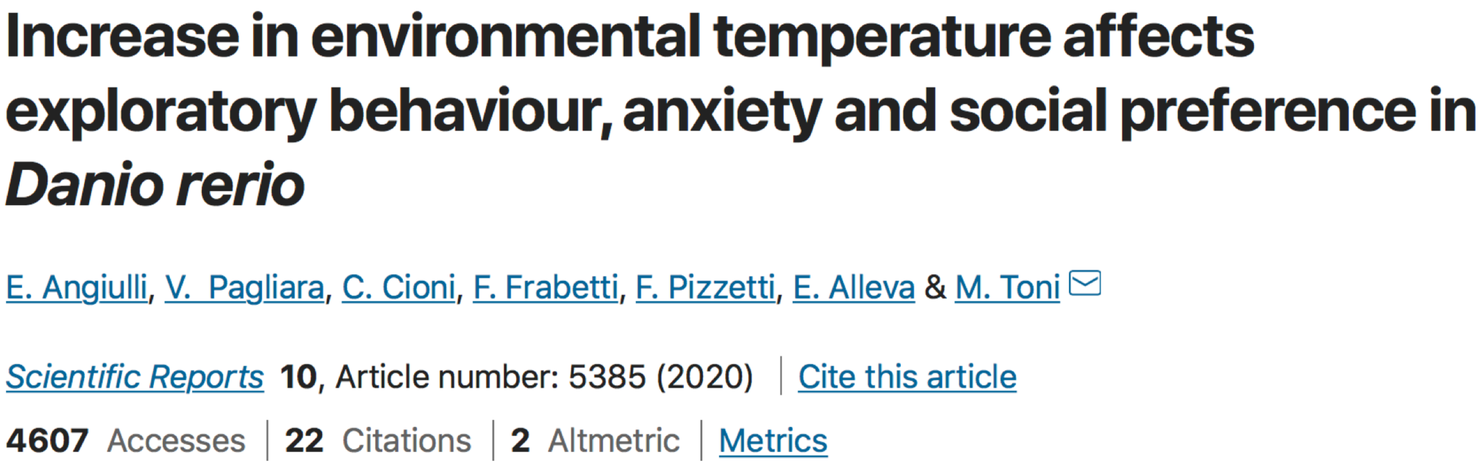


Figure 1 | Projected changes in ocean conditions and the expected biological responses of fish communities in terms of distribution and body size. a, Projected changes in sea bottom temperature. **b**, Dissolved oxygen concentration. Anomalies in temperature and oxygen are average projections from GFDL ESM2.1 and IPSL-CM4-LOOP relative to the average 1971–2000 values under the SRES a2 scenario. **c**, Schematic illustrating the expected changes in body size at individual and assemblage levels in a specific region (area enclosed by dashed red line). It is hypothesized that under warming and reduced oxygen levels, the fish at a particular location will have smaller body weight. Together with the invasion/increased abundance of smaller-bodied species and local extinction/decreased abundance of larger-bodied species, mean maximum body weight is expected to lower at the assemblage level.



Increase in environmental temperature affects exploratory behaviour, anxiety and social preference in *Danio rerio*

E. Angiulli, V. Pagliara, C. Cioni, F. Frabetti, F. Pizzetti, E. Alleva & M. Toni

Scientific Reports **10**, Article number: 5385 (2020) | Cite this article

4607 Accesses | **22** Citations | **2** Altmetric | Metrics

- higher temperature alters brain proteome of zebrafish (neurotransmiters and synapse functioning)
- changes in exploratory behaviour

higher temperature decreases anxiety and increase the courage- individuals get more exposed to predators

Climate change

affects distribution, growth rates, temperature preferences for over 600 fish species

- smaller fish:
  - less offspring
  - change of predatory prey interactions (decrease in predation of bigger prey)
  - changes in competitive interactions in ecosystems
  - reduces global fish supply

  - changes in age at maturity

nature
ecology & evolution

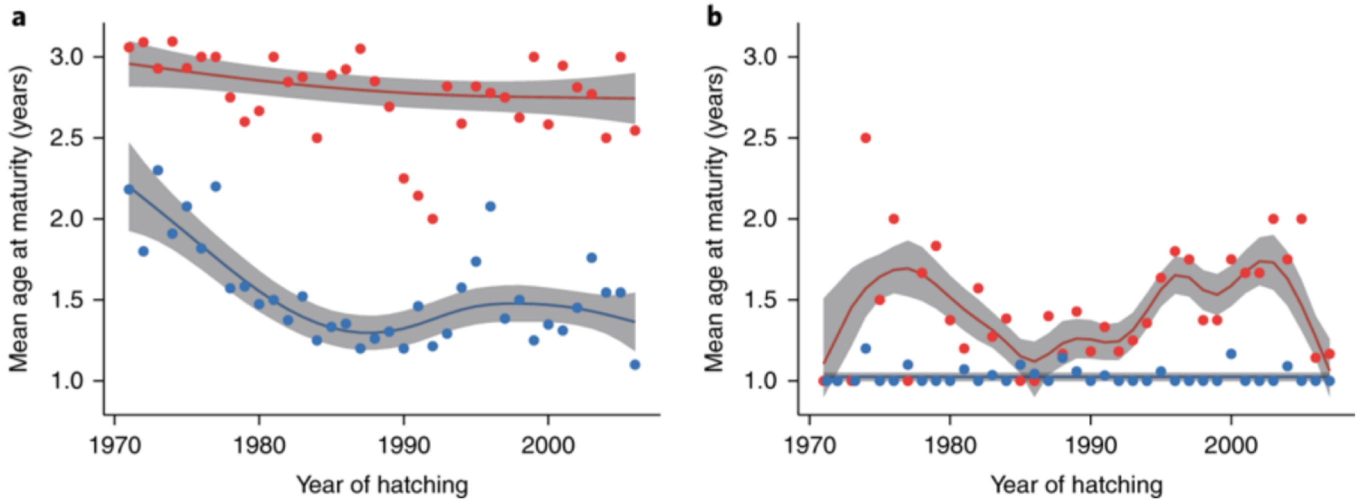
Article | Published: 01 October 2018

Rapid sex-specific evolution of age at maturity is shaped by genetic architecture in Atlantic salmon

Yann Czorlich, Tutku Aykanat, Jaakko Erkinaro, Panu Orell & Craig Robert Primmer

Fig. 1: Change in mean age at maturity.

From: Rapid sex-specific evolution of age at maturity is shaped by genetic architecture in Atlantic salmon



a, Tenojoki population. **b**, Inarijoki population. Females are shown in red (*n* = 467 for Tenojoki; *n* = 261 for Inarijoki) and males are shown in blue (*n* = 699 for Tenojoki; *n* = 570 for Inarijoki). Lines represent fitted values from the generalized additive model ± 1.96 s.e.m. Points are observed annual means.

In Atlantic salmon, age at maturity reflects a classic evolutionary trade-off, as larger, later-maturing individuals typically have higher reproductive success, but run a greater risk of mortality before first reproduction

Age at maturity determined by vgll3 gene and is quite population specific

Selection changes the trait mainly in males.

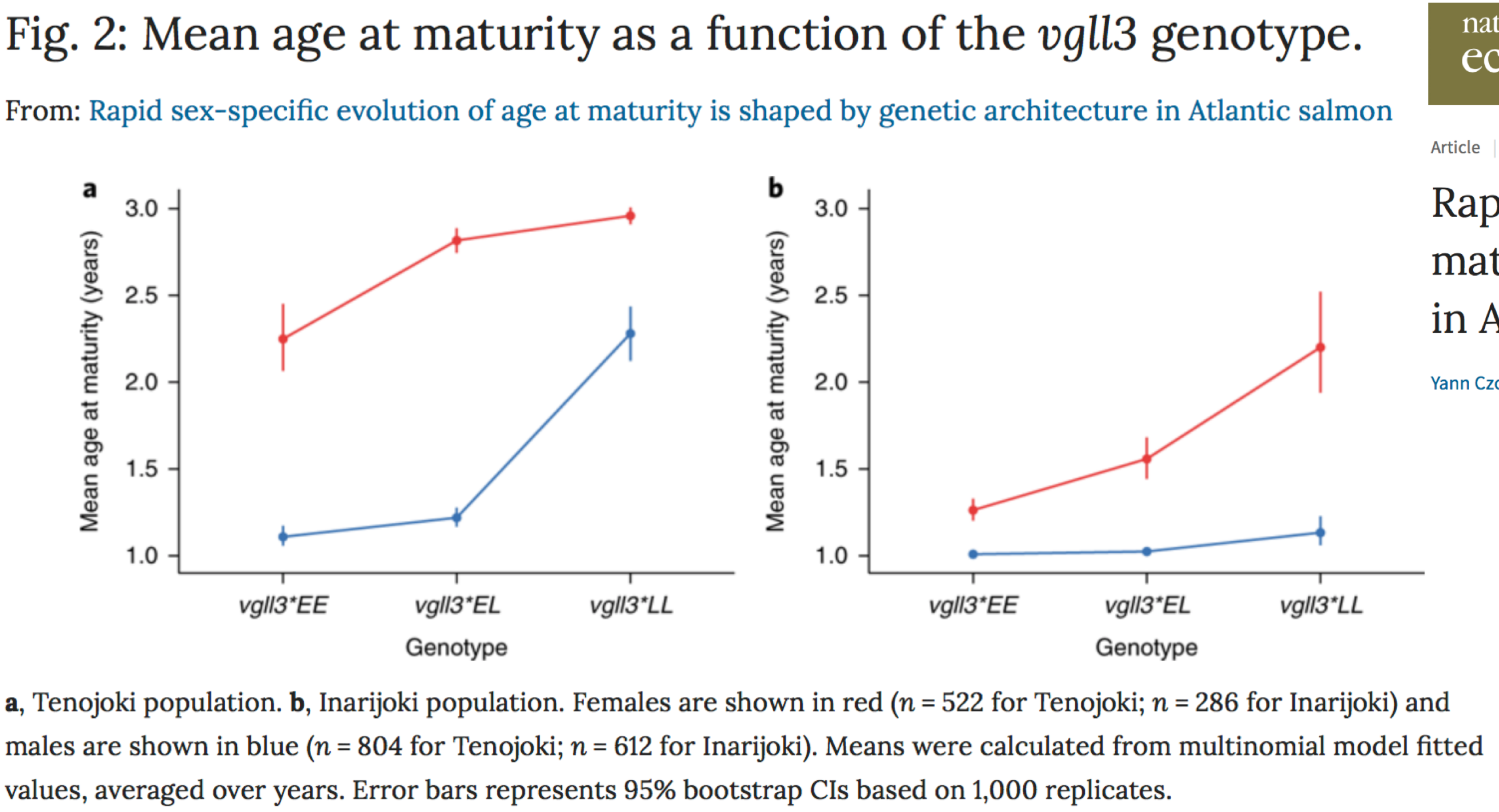
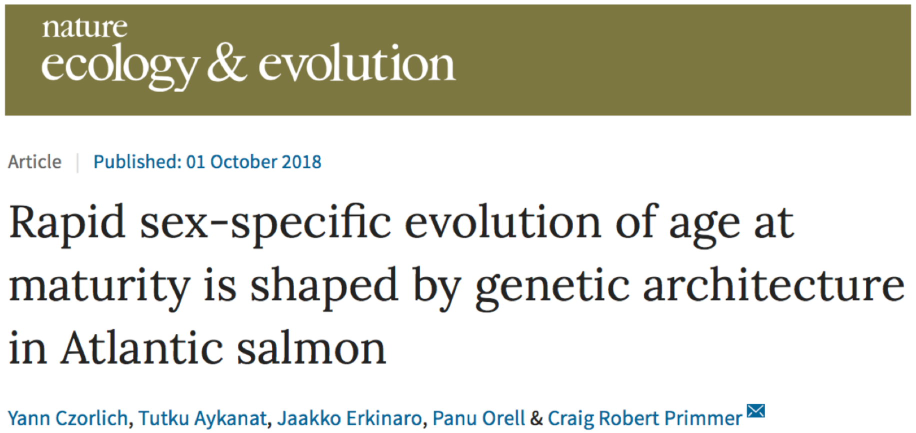


Fig. 2: Mean age at maturity as a function of the *vgll3* genotype.

From: Rapid sex-specific evolution of age at maturity is shaped by genetic architecture in Atlantic salmon

a, Tenojoki population. **b**, Inarijoki population. Females are shown in red (*n* = 522 for Tenojoki; *n* = 286 for Inarijoki) and males are shown in blue (*n* = 804 for Tenojoki; *n* = 612 for Inarijoki). Means were calculated from multinomial model fitted values, averaged over years. Error bars represents 95% bootstrap CIs based on 1,000 replicates.



nature
ecology & evolution

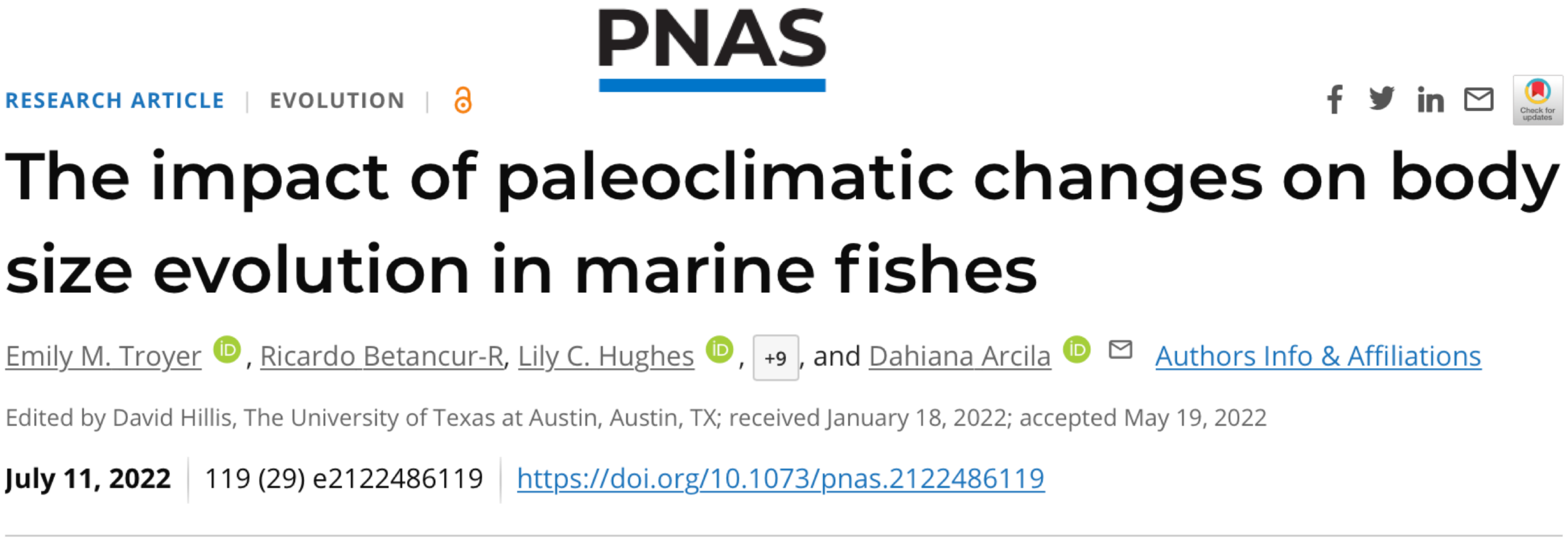
Article | Published: 01 October 2018

Rapid sex-specific evolution of age at maturity is shaped by genetic architecture in Atlantic salmon

Yann Czorlich, Tutku Aykanat, Jaakko Erkinaro, Panu Orell & Craig Robert Primmer

-E alele- early maturity; L alele late maturity

- testis maturity, adipogenesis, timing of puberty, growth and condition factor in humans
- sexual conflict at that locus due to different phenotypic optima in males and females



PNAS

RESEARCH ARTICLE | EVOLUTION |

The impact of paleoclimatic changes on body size evolution in marine fishes

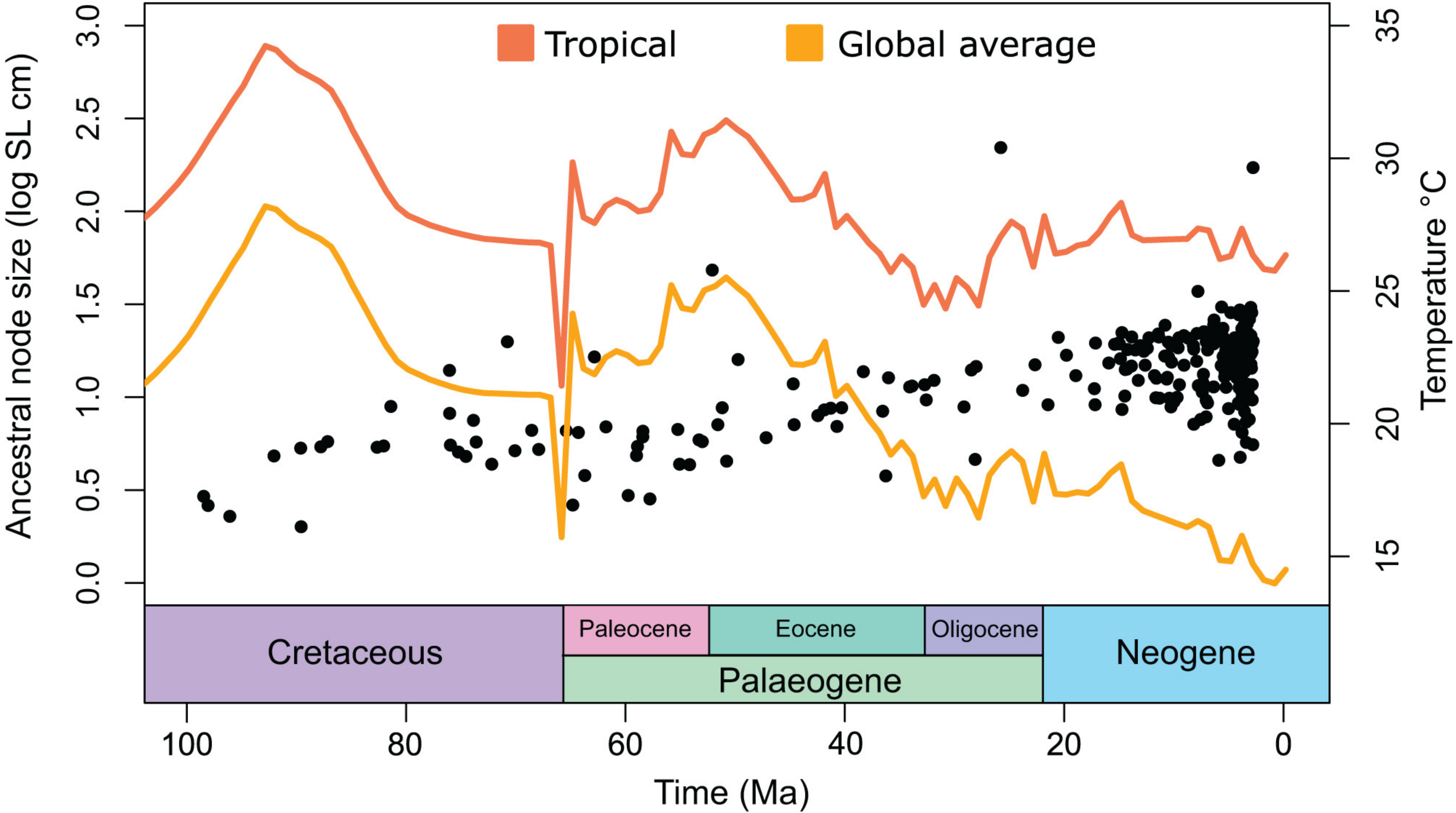
Emily M. Troyer, Ricardo Betancur-R, Lily C. Hughes, +9, and Dahiana Arcila Authors Info & Affiliations

Edited by David Hillis, The University of Texas at Austin, Austin, TX; received January 18, 2022; accepted May 19, 2022

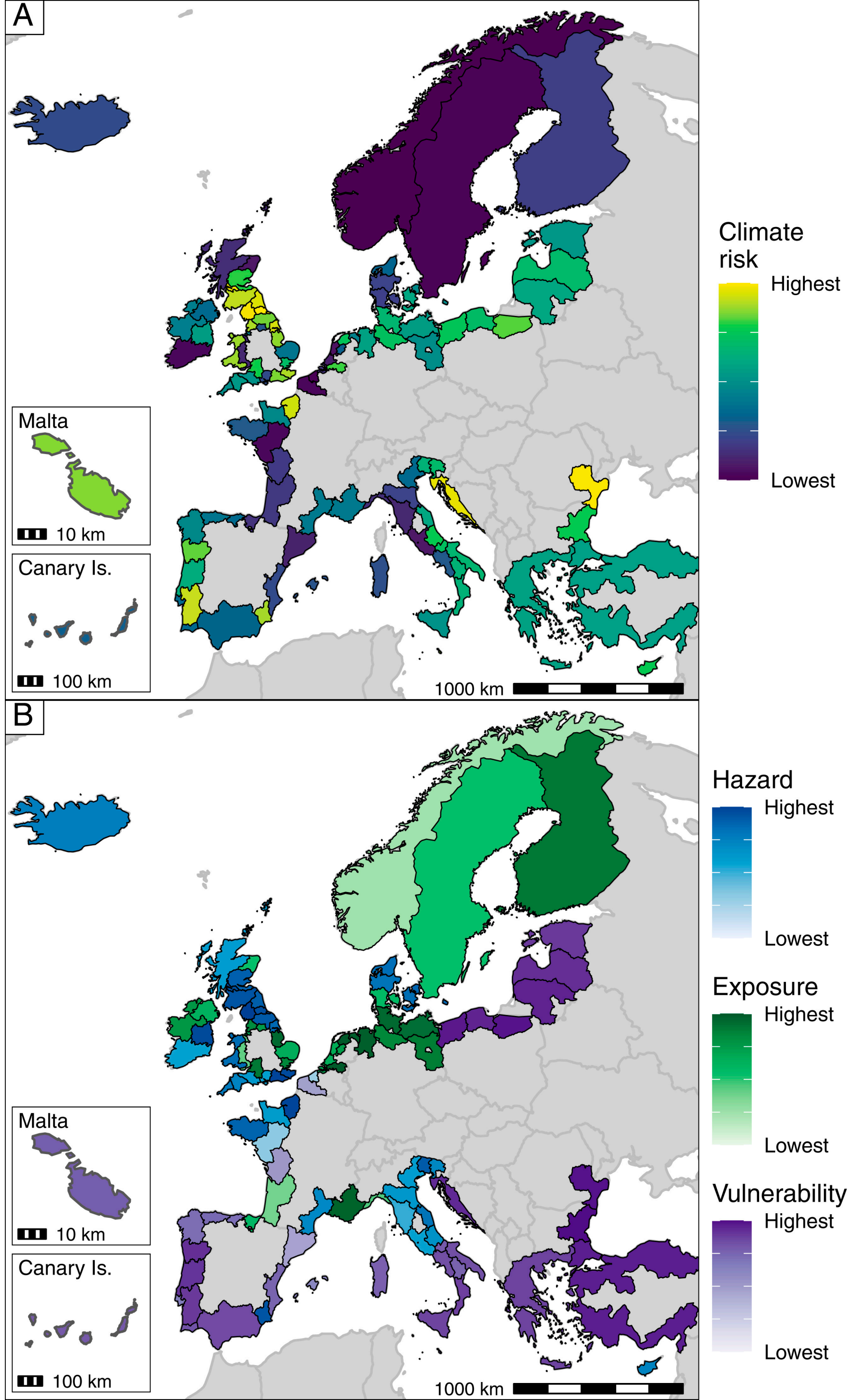
July 11, 2022 | 119 (29) e2122486119 | https://doi.org/10.1073/pnas.2122486119

„General rules are useful tools for understanding how organisms evolve. ***Cope's rule (tendency to increase in size over evolutionary time) and Bergmann's rule (tendency to grow to larger sizes in cooler climates)*** *both relate to body size, an important factor that affects the biology, ecology, and physiology of organisms. These rules are well studied in endotherms but remain poorly understood among ectotherms. Here, we show that paleoclimatic changes strongly shaped the trajectory of body size evolution in tetraodontiform fishes. Their body size evolution is explained by both Cope's and Bergmann's rules, highlighting the impact of paleoclimatic changes on aquatic organisms, which rely on their environment for temperature regulation and are likely more susceptible than terrestrial vertebrates to climatic changes."*

https://www.pnas.org/doi/10.1073/pnas.2122486119



Tetraodontiform body size and temperature over time. Sea surface temperature for tropical latitudes (15°N to 15°S; orange line) and a global average sea temperature (yellow line) are plotted for the past 100 Ma. The reconstructed ancestral node body size (log mean maximum SL in centimeters) for tetraodontiforms is also plotted against time. Sea surface temperatures have been slowly cooling since the Late Cretaceous, while tetraodontiform body size has gradually increased. SI Appendix, Fig. S20 provides a version of this plot colored by family.



Climate risk of European regions. Maps show (A) the combined climate risk ranking for each region and (B) the individual component (blue: hazard, green: exposure, and purple: vulnerability) making the largest contribution to the combined risk. Color scales on both panels are linear in the ranking of the corresponding score but are presented without values, as they have little direct meaning; the full range of color schemes can be seen in the scale bars at right. National borders are also shown for reference. Insets at bottom-left of each panel show small regions. Maps showing the hazard, exposure, and vulnerability for each coastal region are included in SI Appendix, Fig. S1.

https://doi.org/10.1073/pnas.2018086118

Overfishing

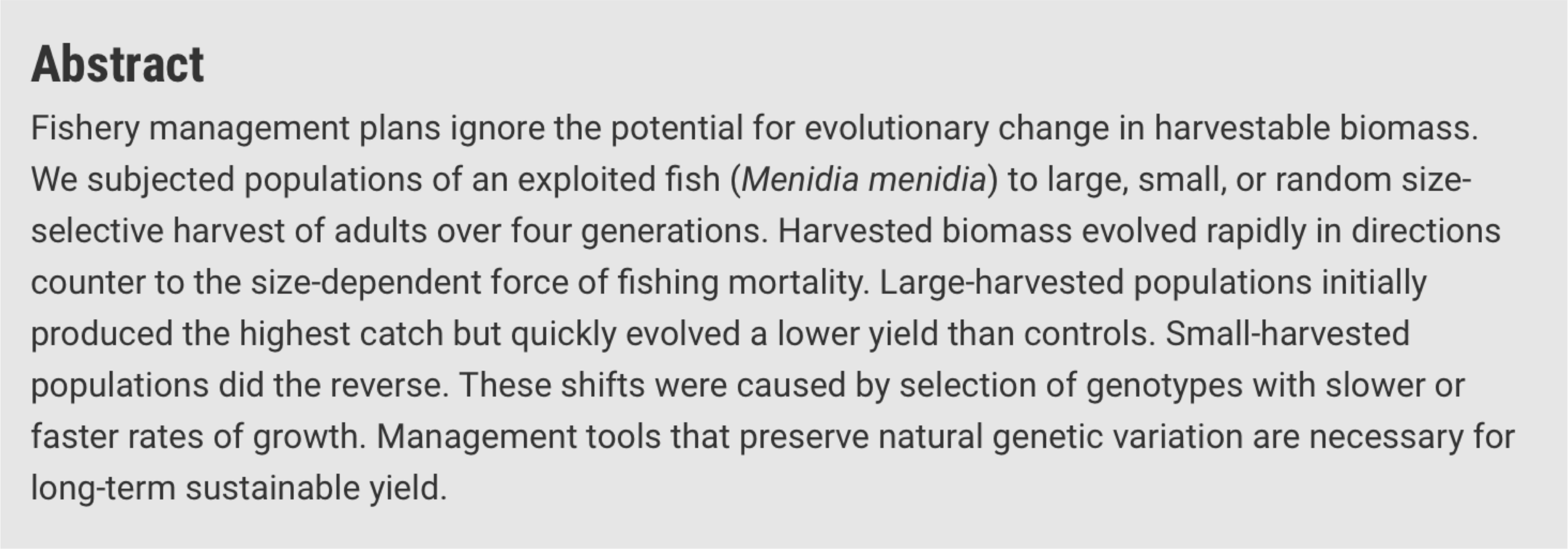
REPORT

Sustaining Fisheries Yields Over Evolutionary Time Scales

David O. Conover*, **Stephan B. Munch**
+ See all authors and affiliations

Science 05 Jul 2002:
Vol. 297, Issue 5578, pp. 94-96
DOI: 10.1126/science.1074085

Experimental harvesting of small vs large individuals showed that harvesting of big fish drives decrease in total catch biomass, while harvesting the small fish has an opposite effect
Selection of genotypes for faster or slower growth rate



Abstract

Fishery management plans ignore the potential for evolutionary change in harvestable biomass. We subjected populations of an exploited fish (*Menidia menidia*) to large, small, or random size-selective harvest of adults over four generations. Harvested biomass evolved rapidly in directions counter to the size-dependent force of fishing mortality. Large-harvested populations initially produced the highest catch but quickly evolved a lower yield than controls. Small-harvested populations did the reverse. These shifts were caused by selection of genotypes with slower or faster rates of growth. Management tools that preserve natural genetic variation are necessary for long-term sustainable yield.

Overfishing

Experimental overfishing over 4 generations show that overfishing of large individuals causes decrease in mean body size and overfishing of small individuals drives increase in mean body mass

- selection of particular genotypes determining growth!

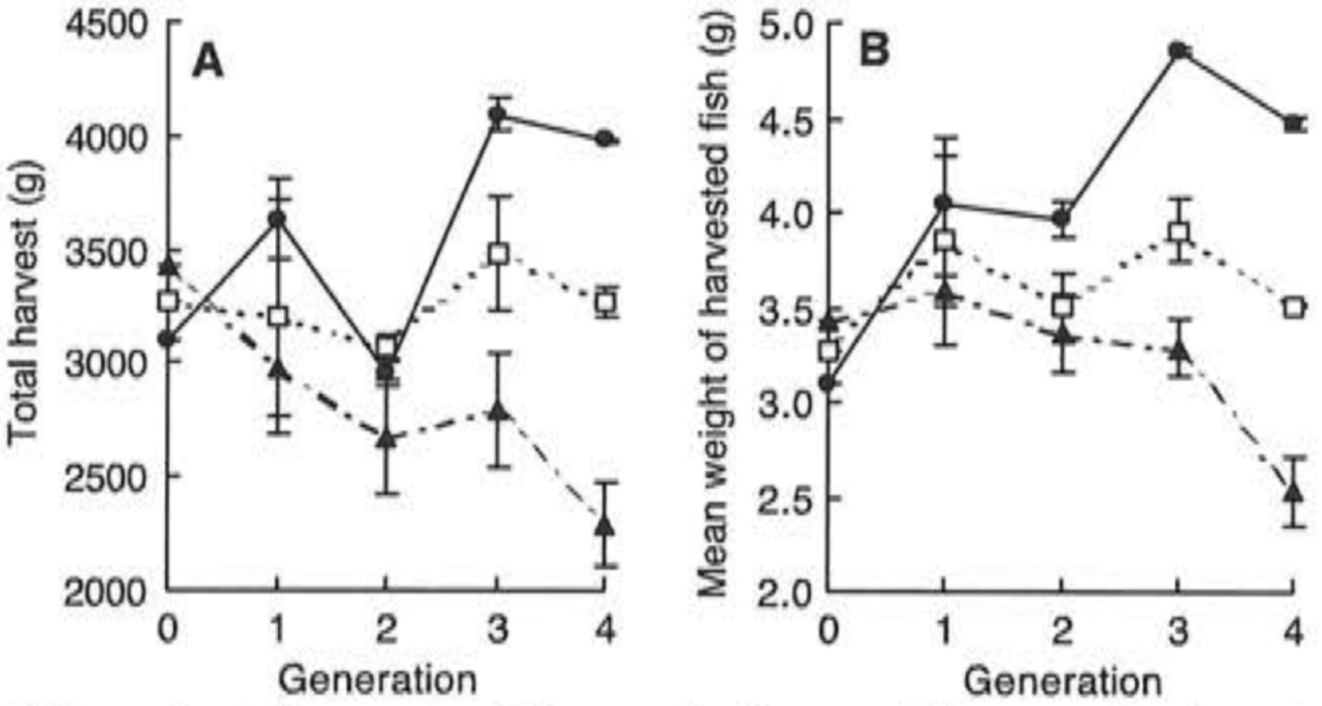


Fig. 1. Trends in average total weight harvested (**A**) and mean weight of harvested individuals (**B**) across multiple generations of size-selective exploitation. Closed circles represent small-harvested lines, open squares are the random-harvested lines, and closed triangles are the large-harvested lines. Each datum is the mean, and the vertical lines show the range of two replicate populations per treatment. Regression analyses showed that both total weight and mean weight harvested declined significantly in the large-harvested lines (slope = −0.82, SE = 0.20, P = 0.004; slope = −0.75, SE = 0.23, P = 0.01, respectively), increased significantly in small-harvested lines (slope = 0.67, SE = 0.26, P = 0.03; slope = 0.83, SE = 0.19, P = 0.002, respectively), and did not change in random-harvest lines (slope = 0.13, SE = 0.35, P = 0.70; slope = 0.21, SE = 0.34, P = 0.55, respectively).

Overfishing

Experimental overfishing over 4 generations show that overfishing of large individuals causes decrease in mean body size and overfishing of small individuals drives increase in mean body mass
- selection of particular genotypes determining growth!

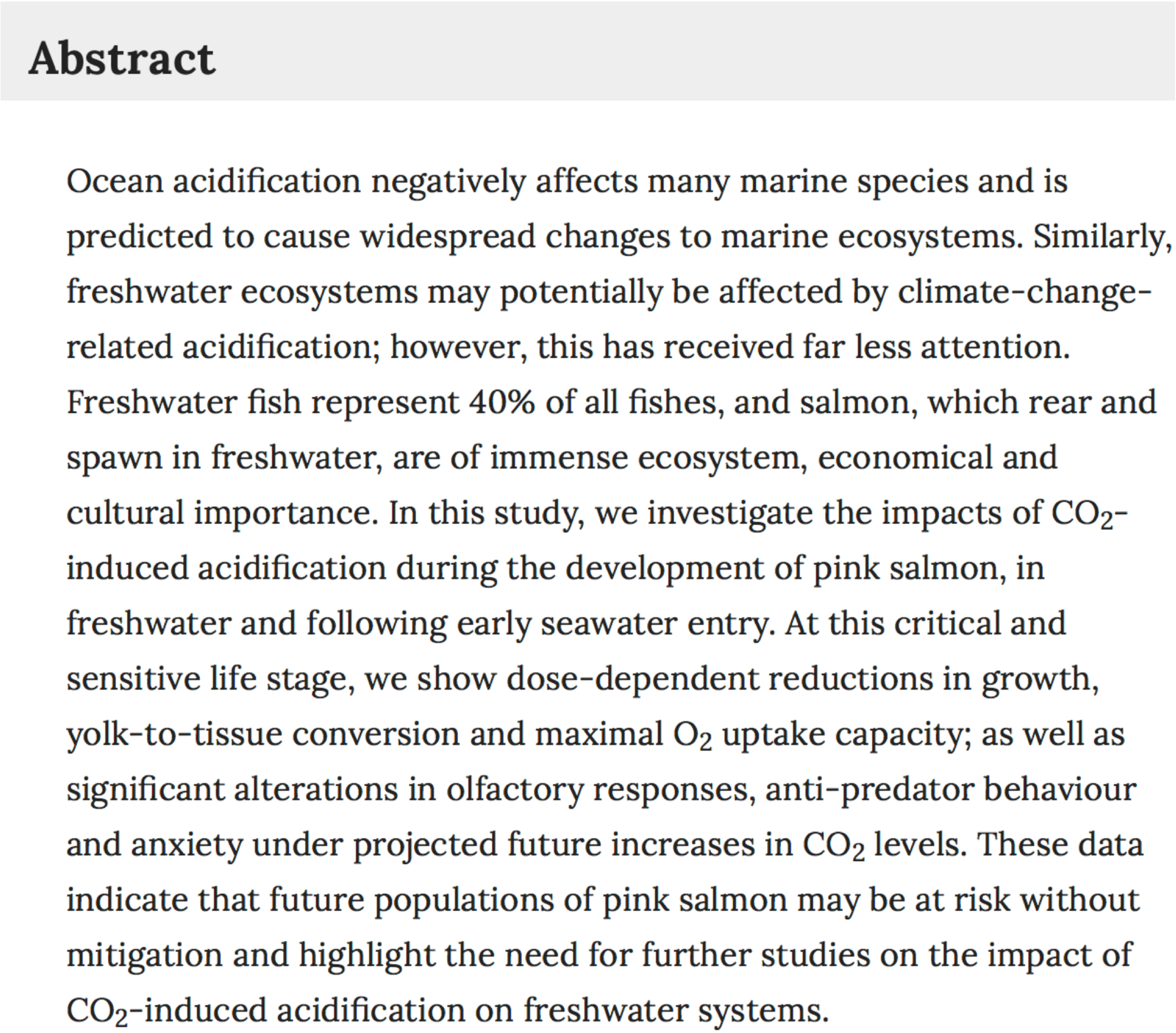
Overfishing

Problem?

1. Harvesting of smaller fish demands much larger number of individuals for same catch biomass result.
2. It is not feasible to selectively harvest considering the fish age, and the large amount of young individuals are constantly removed from population.

https://youtu.be/GSO6ALu2hUU

Acidification



Abstract

Ocean acidification negatively affects many marine species and is predicted to cause widespread changes to marine ecosystems. Similarly, freshwater ecosystems may potentially be affected by climate-change-related acidification; however, this has received far less attention. Freshwater fish represent 40% of all fishes, and salmon, which rear and spawn in freshwater, are of immense ecosystem, economical and cultural importance. In this study, we investigate the impacts of CO_2-induced acidification during the development of pink salmon, in freshwater and following early seawater entry. At this critical and sensitive life stage, we show dose-dependent reductions in growth, yolk-to-tissue conversion and maximal O_2 uptake capacity; as well as significant alterations in olfactory responses, anti-predator behaviour and anxiety under projected future increases in CO_2 levels. These data indicate that future populations of pink salmon may be at risk without mitigation and highlight the need for further studies on the impact of CO_2-induced acidification on freshwater systems.

nature
climate change

Article | Published: 29 June 2015

Responses of pink salmon to CO_2-induced aquatic acidification

Michelle Ou, Trevor J. Hamilton, Junho Eom, Emily M. Lyall, Joshua Gallup, Amy Jiang, Jason Lee, David A. Close, Sang-Seon Yun & Colin J. Brauner

Nature Climate Change **5**, 950–955 (2015) | Download Citation

Acidifying affects the behaviour of ocean and freshwater fish. Pink salmon reared in CO_2-rich water were smaller, less fearful of predators, and less responsive to the chemicals environmental clues that shall guide them toward the streams where they hatched.

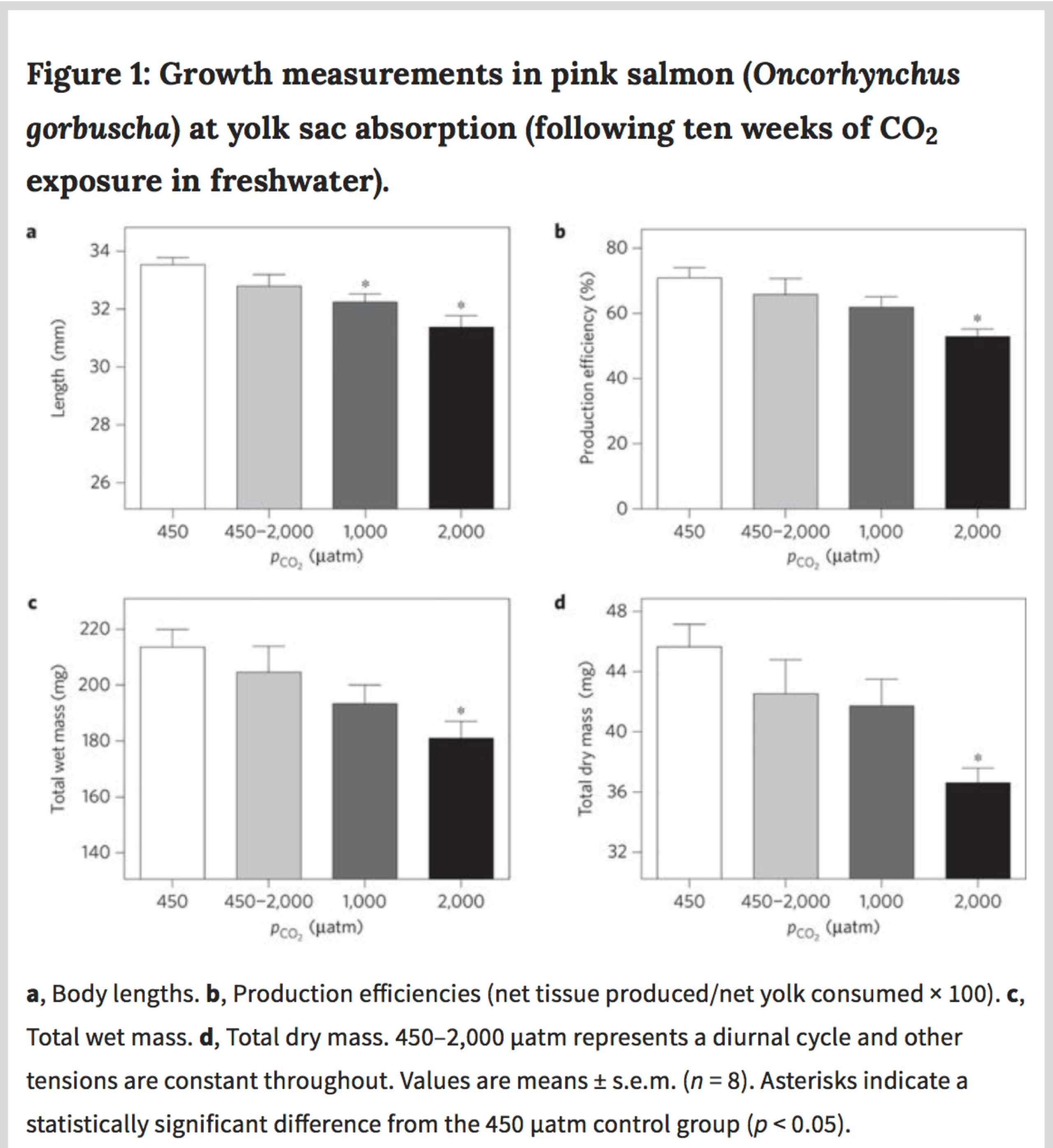


Figure 1: Growth measurements in pink salmon (*Oncorhynchus gorbuscha*) at yolk sac absorption (following ten weeks of CO_2 exposure in freshwater).

a, Body lengths. **b**, Production efficiencies (net tissue produced/net yolk consumed × 100). **c**, Total wet mass. **d**, Total dry mass. 450–2,000 µatm represents a diurnal cycle and other tensions are constant throughout. Values are means ± s.e.m. ($n = 8$). Asterisks indicate a statistically significant difference from the 450 µatm control group ($p < 0.05$).

Growth and development of pink salmon is decreasing with increased CO2 concentrations

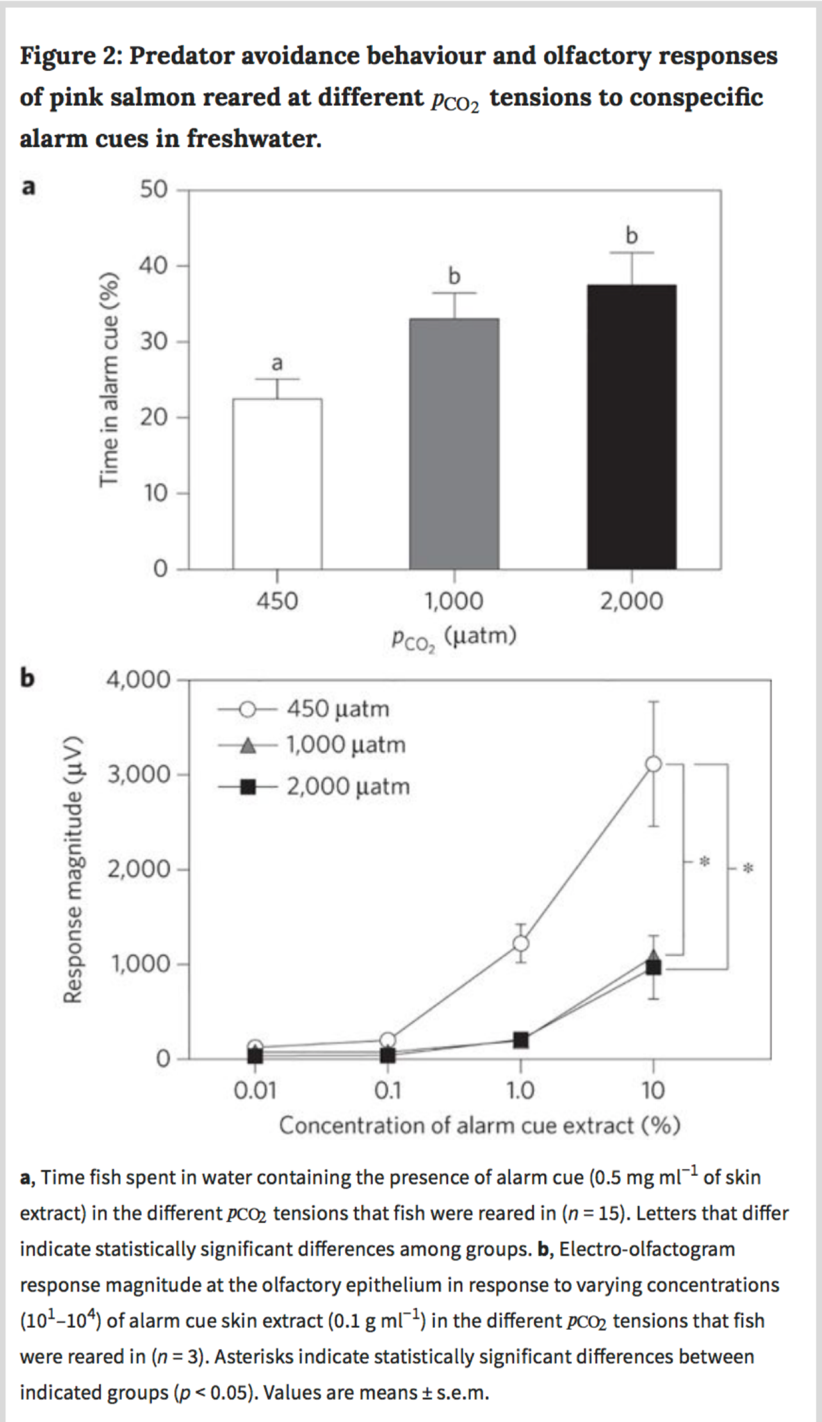


Figure 2: Predator avoidance behaviour and olfactory responses of pink salmon reared at different p_{CO_2} tensions to conspecific alarm cues in freshwater.

a, Time fish spent in water containing the presence of alarm cue (0.5 mg ml^{-1} of skin extract) in the different $p\text{CO}_2$ tensions that fish were reared in ($n = 15$). Letters that differ indicate statistically significant differences among groups. **b**, Electro-olfactogram response magnitude at the olfactory epithelium in response to varying concentrations (10^1–10^4) of alarm cue skin extract (0.1 g ml^{-1}) in the different $p\text{CO}_2$ tensions that fish were reared in ($n = 3$). Asterisks indicate statistically significant differences between indicated groups ($p < 0.05$). Values are means ± s.e.m.

Predator avoidance and response to predatory olfactory cues
Fish exposed to higher concentrations react less and slower to predator presence