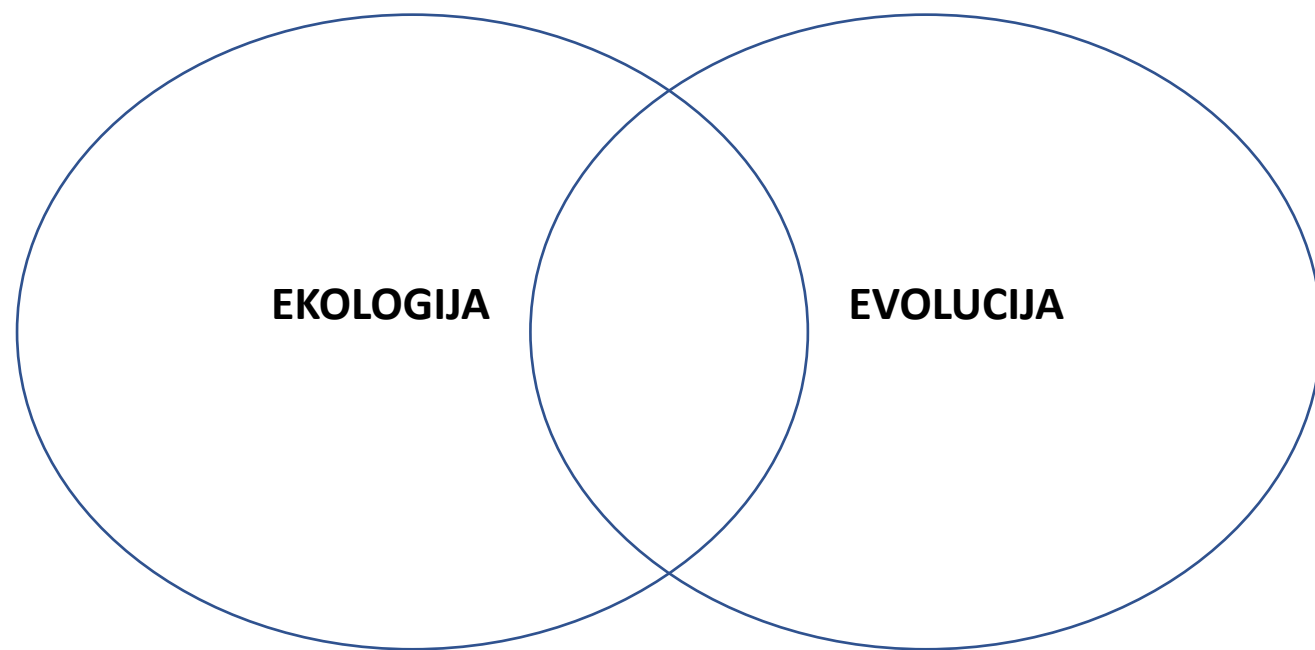


EVOLUCIJSKA EKOLOGIJA



Eko-evolucijska dinamika – prvi put pojam Oloriz et al 1991,
moderna upotreba pojma od 2007, specijalno izdanje *Functional ecology*

*Functional
Ecology* 2007
21, 387–393

EDITORIAL

Evolution on ecological time-scales

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**Eko-evolucijska dinamika: interakcija između ekologije i evolucije koja se odvija u
suvremenoj vremenskom skali (godine do stoljeća)**

EKO - EVO

- adaptacija populacija na promijenjeni okoliš

EVO - EKO

- promjena svojstava u populaciji mijenja populacijsku dinamiku, utječe na strukturu zajednice ili mijenja procese u ekosustavu (suvremena evolucija dovodi do ekološke promjene)

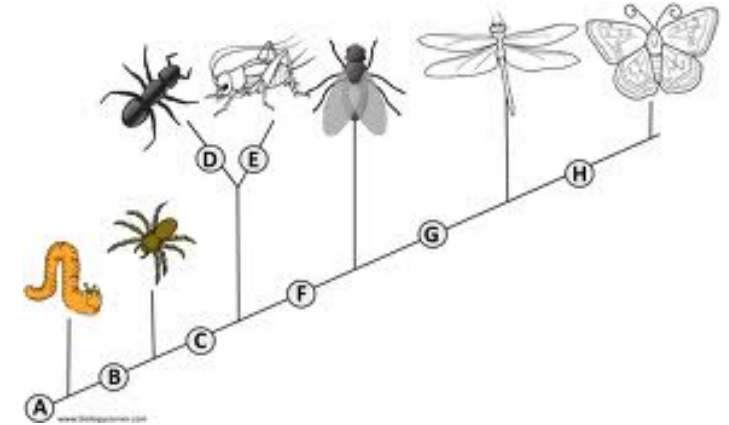
ECO → EVO → ECO

S obzirom na vremenski tijek i obim promjena koje proučava, evoluciju možemo podijeliti na:

EVOLUCIJA

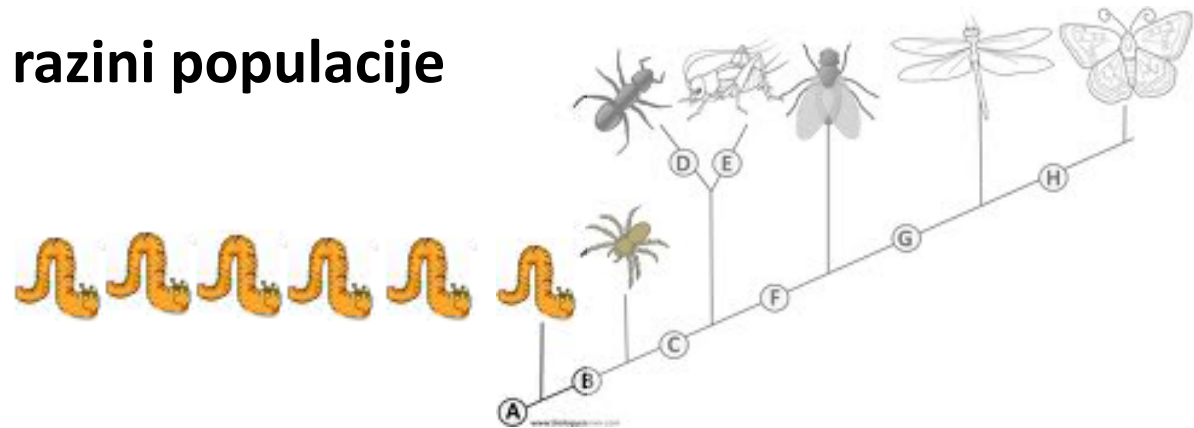
1. MAKROEVOLUCIJA

- nastanak novih vrsta i viših sistematskih kategorija



2. MIKROEVOLUCIJA

- promjene u frekvenciji gena na razini populacije



EVOLUTION: „Descent with modification“ transformacija vrste kroz vrijeme, uključujući promjene unutar vrste, kao i nastanak novih vrsta“

Losos et al. Princenton guide to Evolution, 2014

ECOLOGY: Heckel: “sveukupna znanost o odnosima organizama i okoliša”

EVOLUCIJSKE SILE:

Selekcija
Protok gena
Genetički drift
Mutacija
Rekombinacija



EKOLOŠKI ČIMBENICI:

Abiotički
Biotički (kompeticija, mutualizam,
komenzalizam, predacija, parazitizam,
patogeni...)

ZAŠTO SE RIBE SMANJUJU?



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



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.

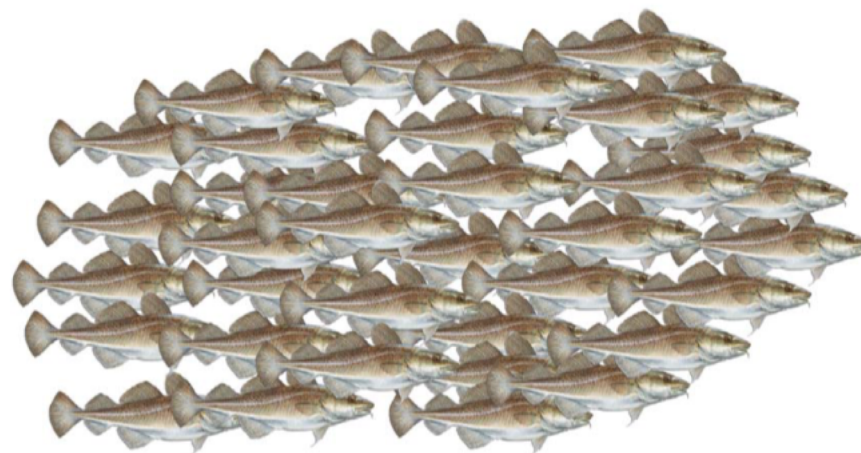
Reproduktivni uspjeh

Manje ribe stvaraju manje potomstva nego veće ribe. Smanjenjem prosječne veličine jedinki u populaciji **smanjuje se produktivnost populacije.**

B



$$\begin{aligned} n &= 1 \\ \sum R_i &\approx 61 \text{ MJ} \\ \sum M_i &= 30 \text{ kg} \end{aligned}$$



$$\begin{aligned} n &= 37 \\ \sum R_i &\approx 61 \text{ MJ} \\ \sum M_i &= 74 \text{ kg} \end{aligned}$$

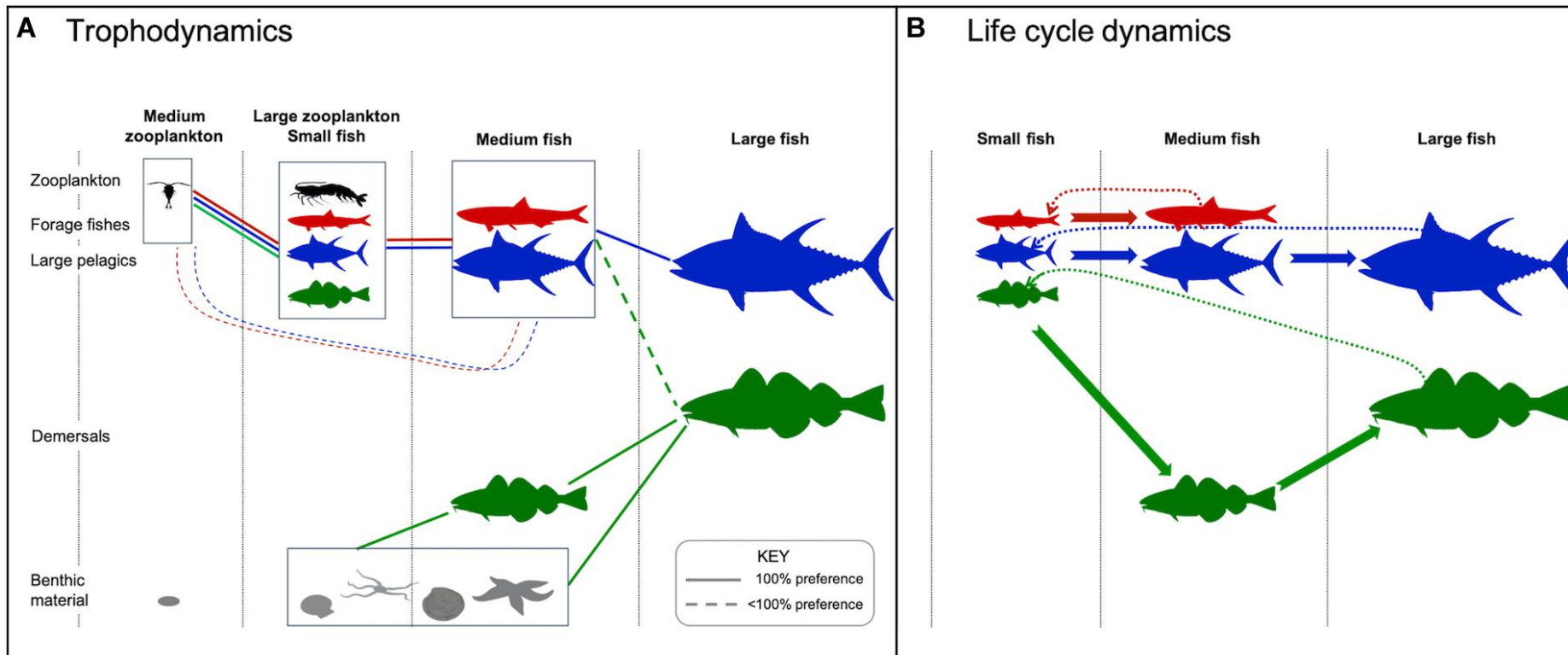
Gadus morhua (Norveški bakalar) – jedinka od 30 kg stvara više potomstva nego dvije jedinke od 28 kg



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.

Hrandibene mreže

S obzirom da veličina jedinki određuje odnose predator-plijen, dolazi do **promjena u hranidbenim mrežama**. Veće ribe mogu pojesti veći plijen, i imaju manje predatora od malih riba. Utjecaj veličine jedinki na ribarstvo vidljiv je već u mnogim dijelovima svijeta.



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



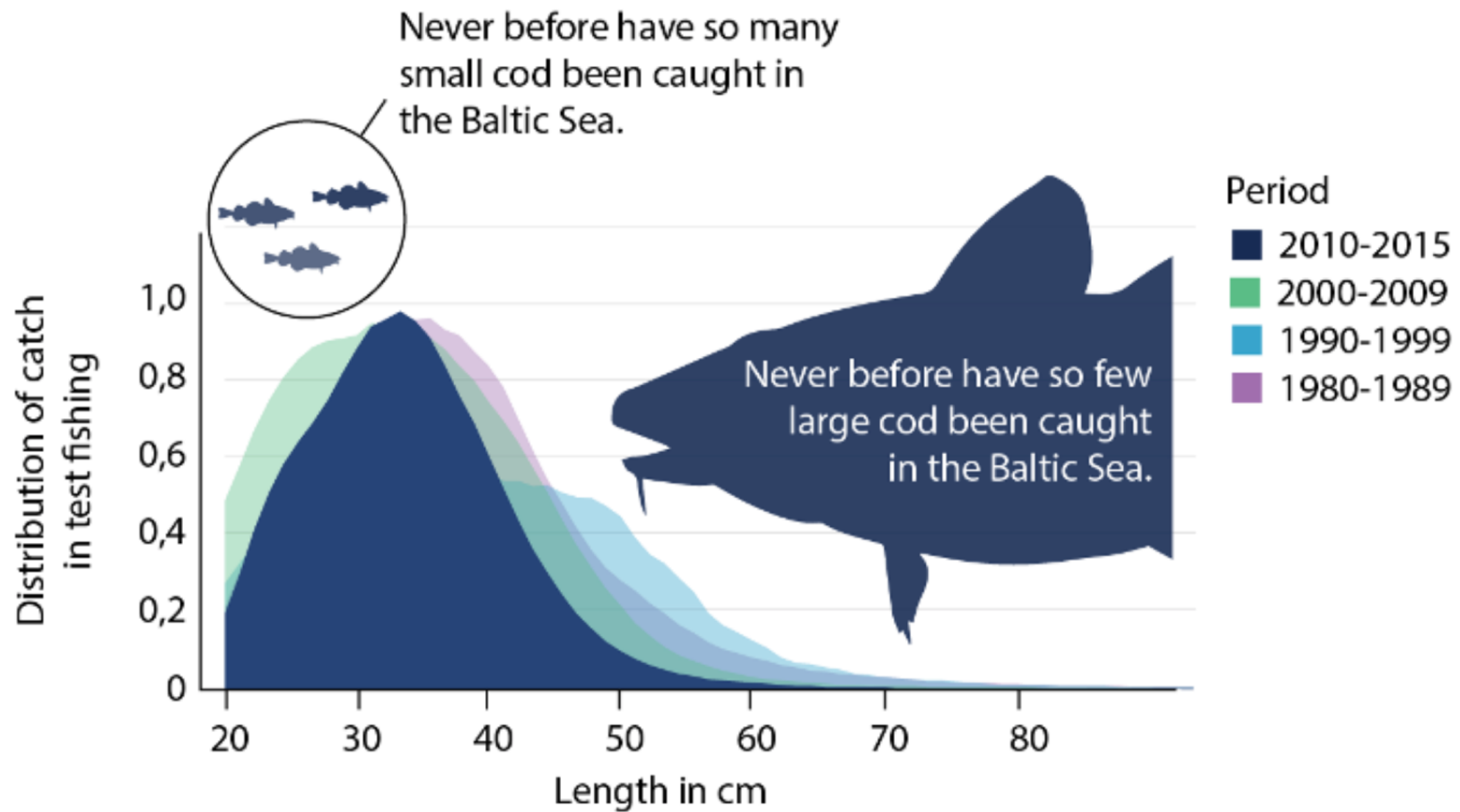
@JON BALDUR HLIDBERG

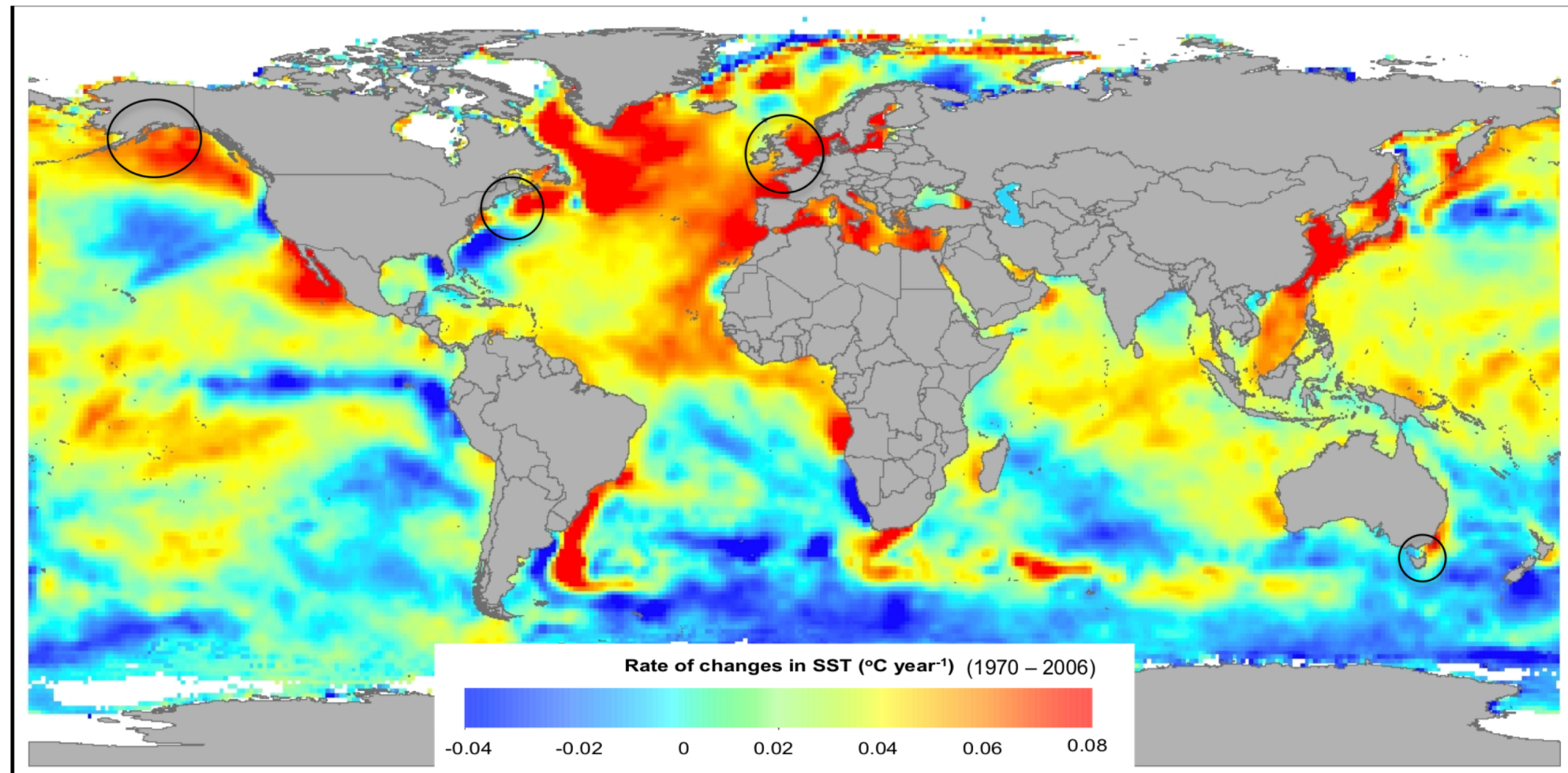
THE EARLY 1990s: 38 CM



@JON BALDUR HLIDBERG

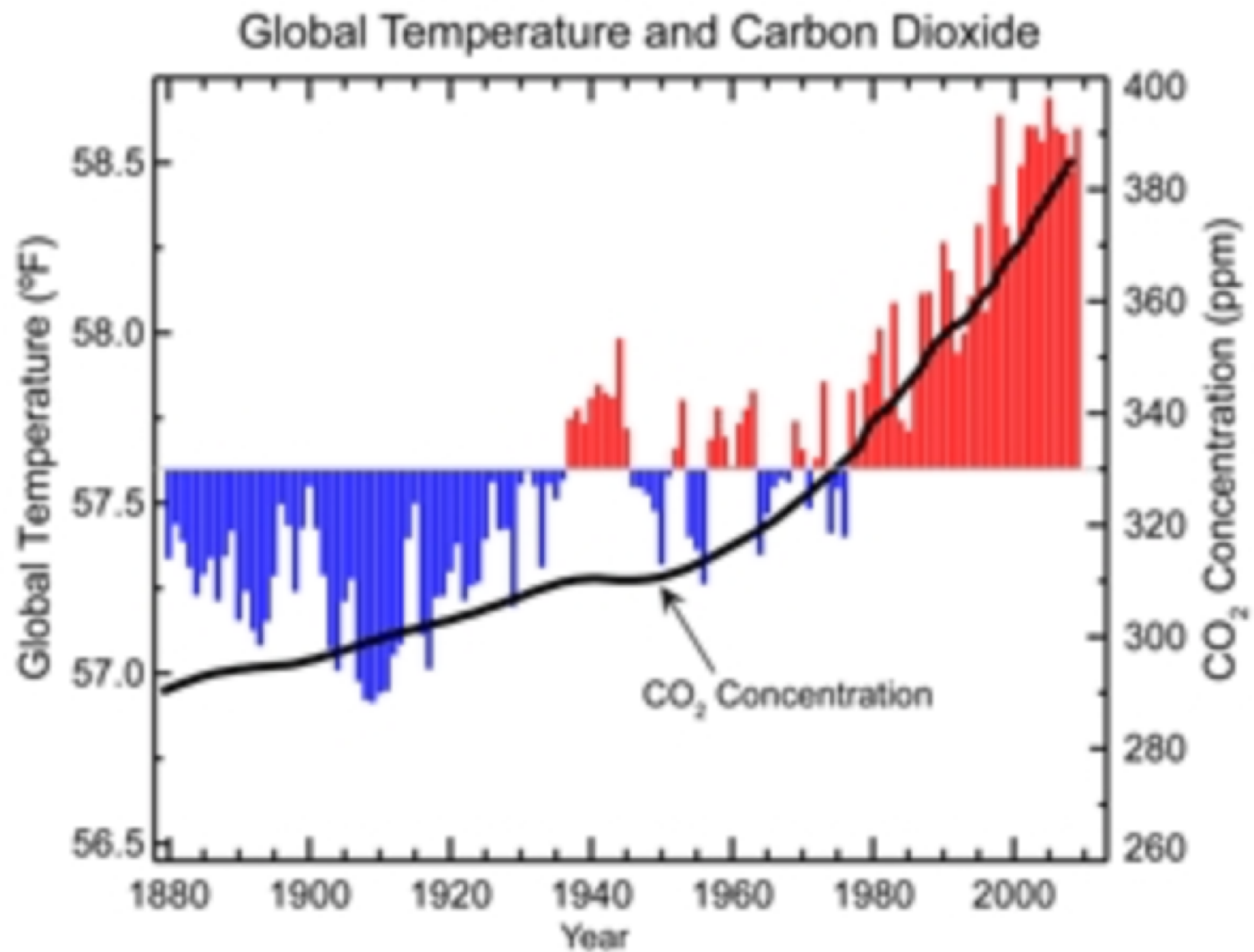
YEAR 2018: 20 CM

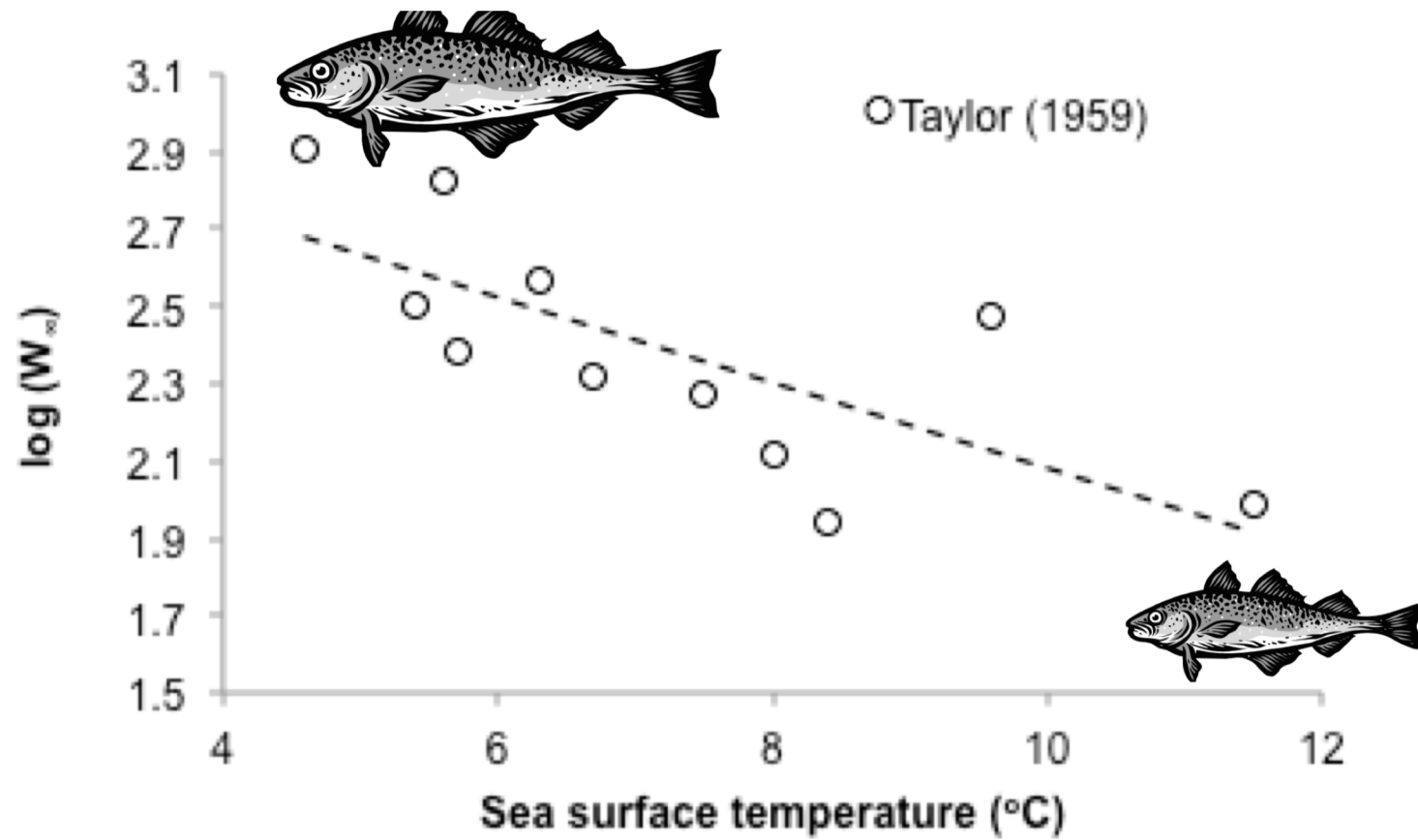




- Promjene u distribuciji i abundaciji ribljih populacija
- Promjene u fenologiji

povećanje temperature i koncentracije CO₂





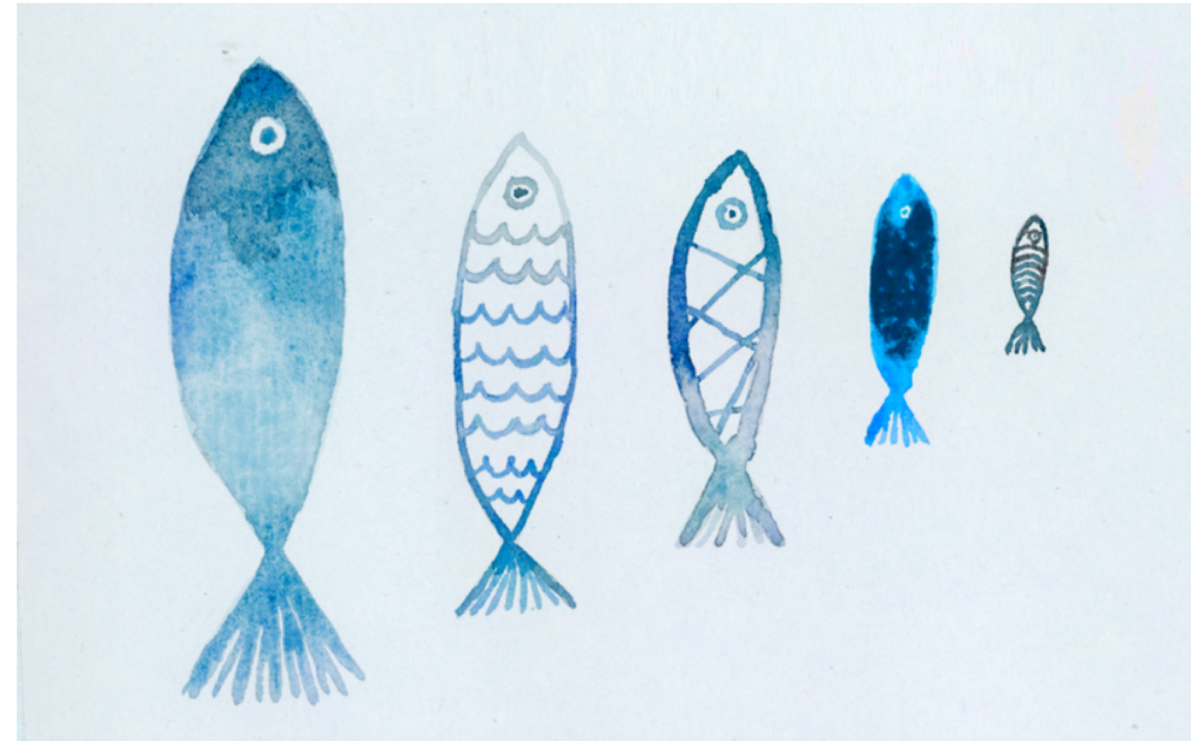
Povećanje temperature mora uzrokuje smanjenje veličine riba. Zašto?

Utjecaj klimatskih promjena na veličinu riba

Povećanje temperature povećava i **metabolizam** riba (poikilotermi), što dovodi do povećanja potrošnje kisika.

Viša temperatura vode – niža količina otopljenog kisika

Škrge ne mogu apsorbirati dovoljno kisika za velika tijela



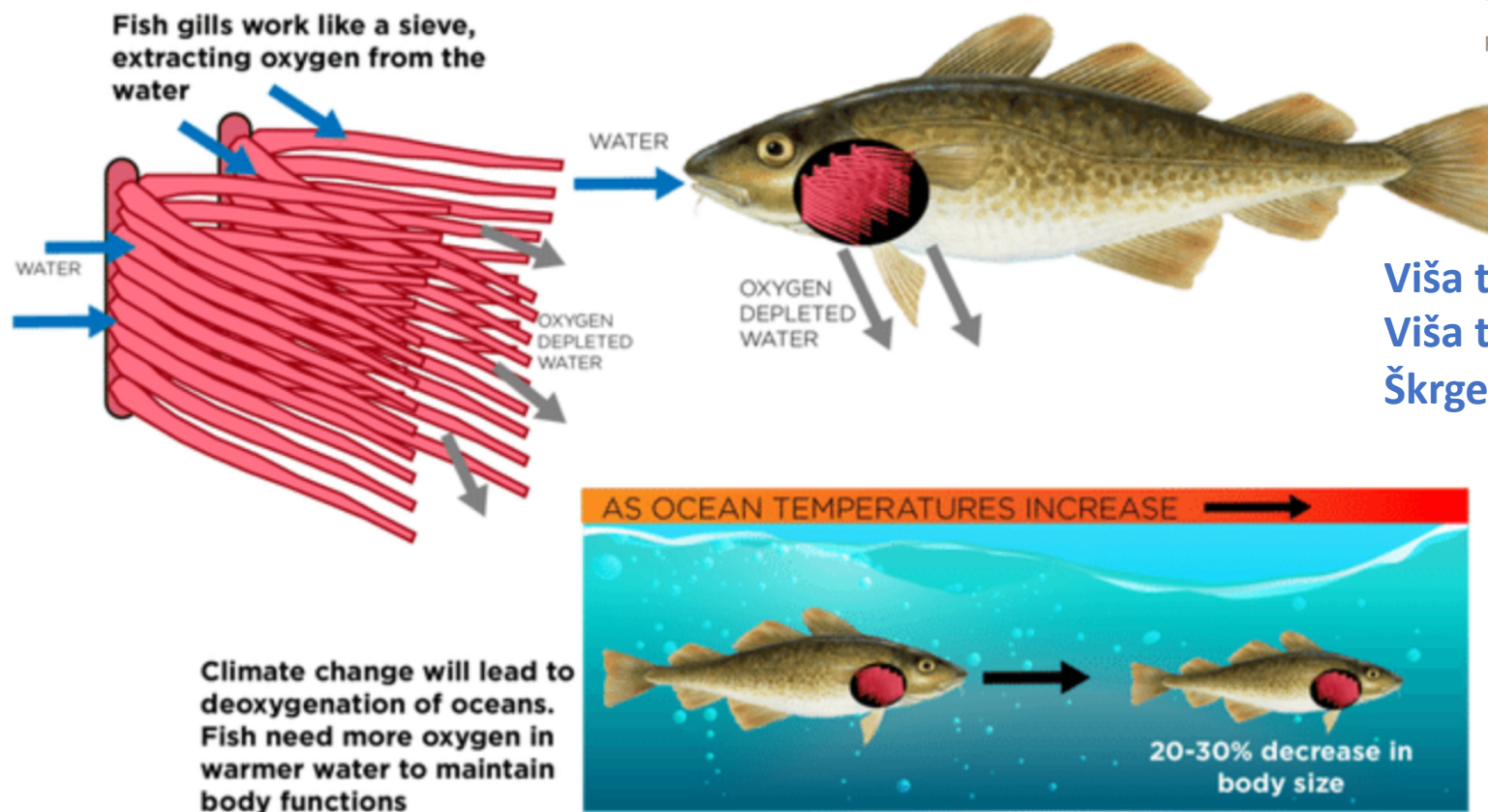
Utjecaj klimatskih promjena na veličinu riba

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

Warming waters will leave fish gasping for air and shrinking in size



Viša temperature vode- veća potreba za kisikom
Viša temperature vode- manja koncentracija kisika
Škrge ne rastu proporcionalno s tijelom

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

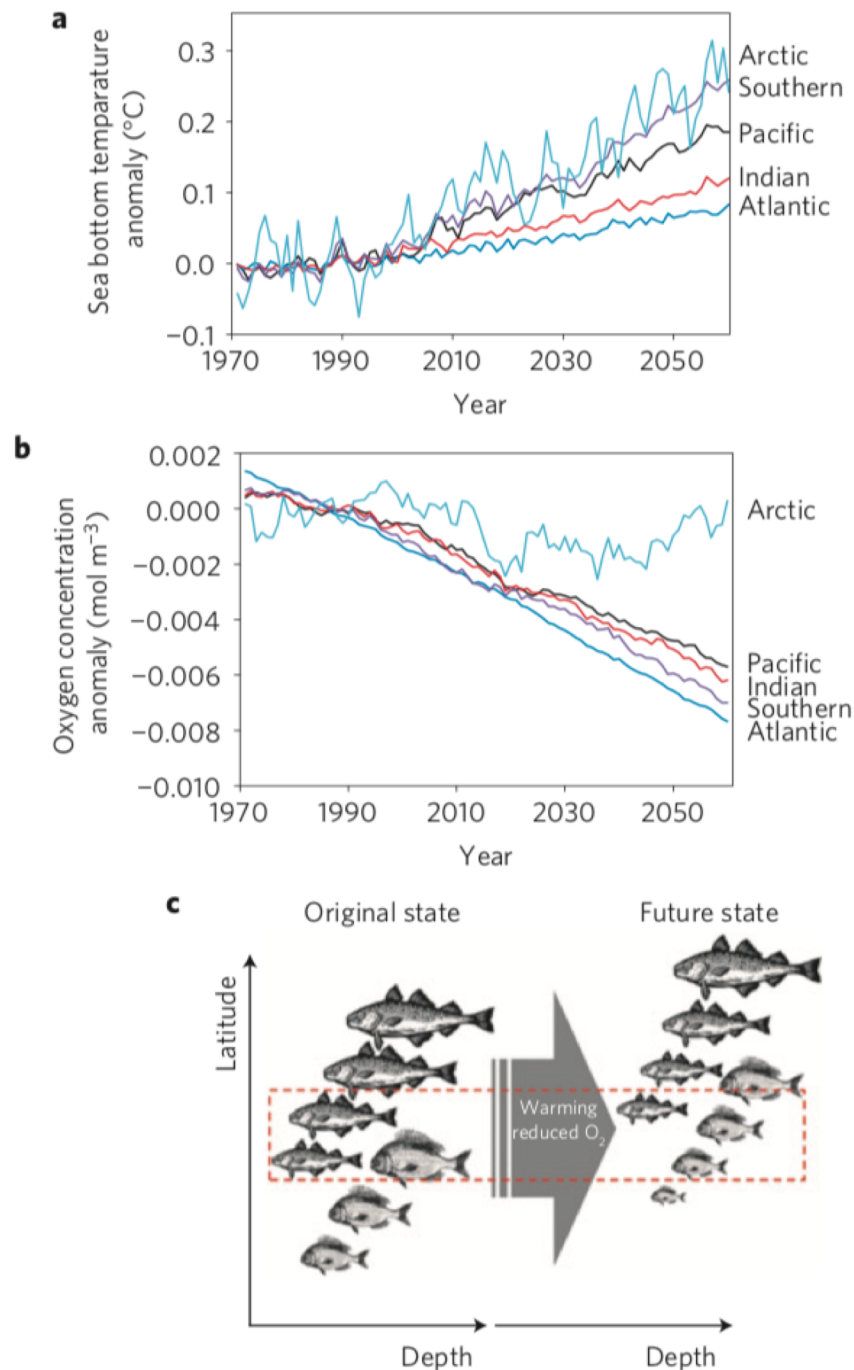
Letter | Published: 30 September 2012

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

predviđanja da će
srednja vrijednost
tjelesne mase riba
smanjiti do 2050 g. za
14-24%

„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.”



Promjena temperature uzrokuje lokalno izumiranje većih vrsta, migracije većih riba u hladnija i dublja područja, kao i invaziju manjih vrsta u toplija područja.

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](#)



- povišena temperatura mijenja proteom mozga zebrice (oslobađanje neurotransmitera i funkcioniranje sinapsi)- mijenja se istraživačko ponašanje riba
- povišena temperatura smanjuje anksioznost i povećava hrabrost- smanjuje se zaštita od predatora

Utjecaj klimatskih promjena na veličinu riba

Klimatske promjene utječu na rasprostranjenost, ratu rasta i temperaturne preferencije za više od 600 ribljih vrsta

Manje ribe:

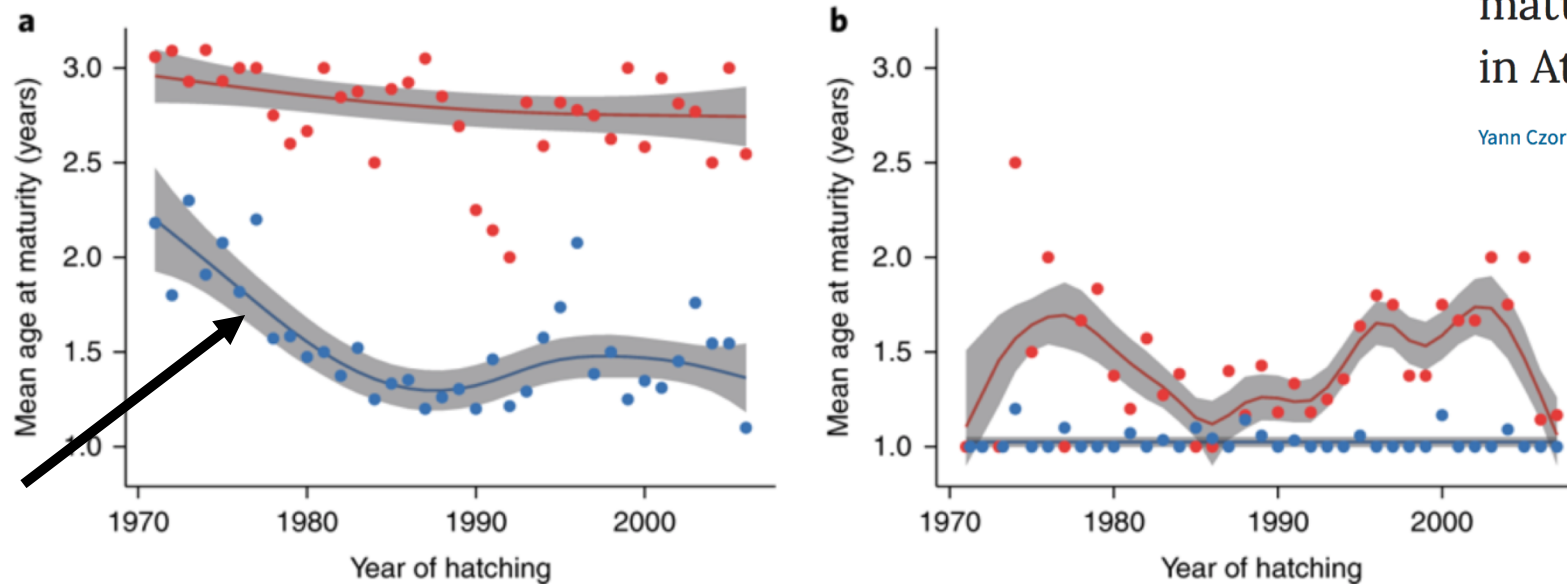
- manje potomaka
- promjena odnosa predator-plijen (smanjuje se predatorstvo nad većim plijenom)
- smanjenje svjetskih ribljih fondova
- promjene u sastavu biocenoza (npr. glavonošci zamjenjuju riblje predatore)
- promjena dobi stupanja u spolnu zrelost

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](#)

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



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.

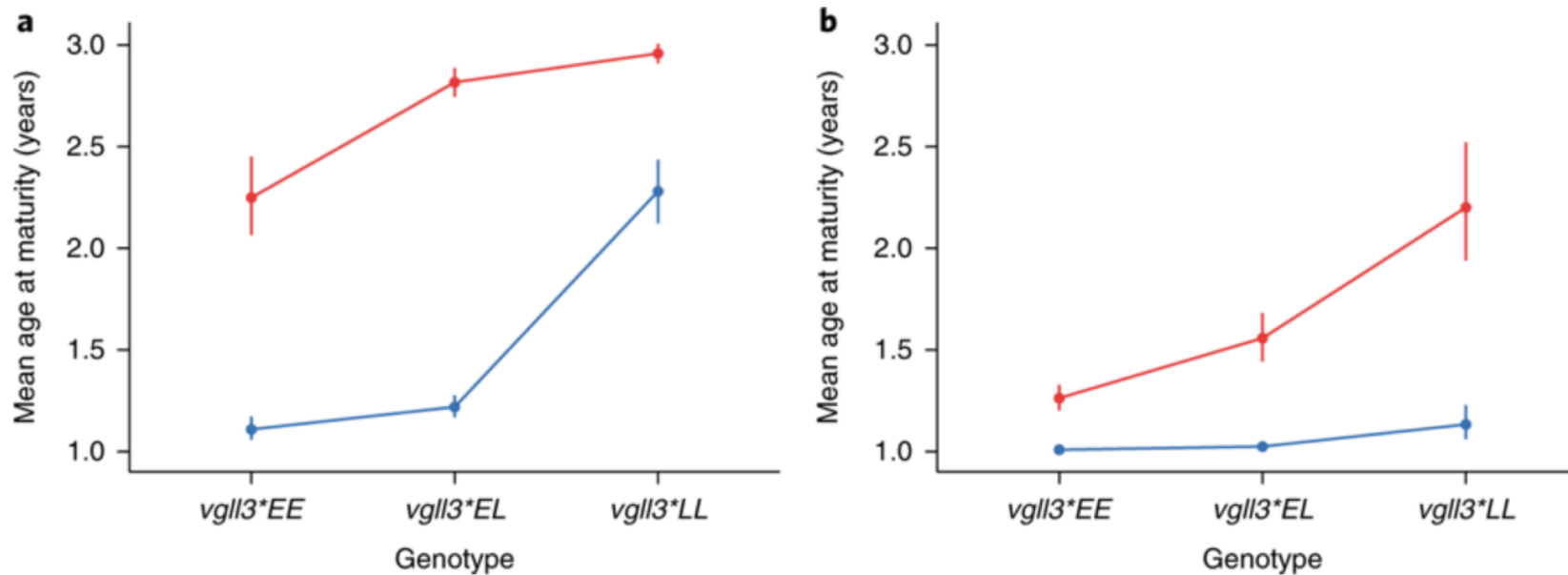
Dob stupanja u spolnu zrelost određena uvelike jednim genom *vgl3*, te je populacijski specifična
Promjene pod utjecajem selekcije samo kod mužjaka

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](#)

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



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.

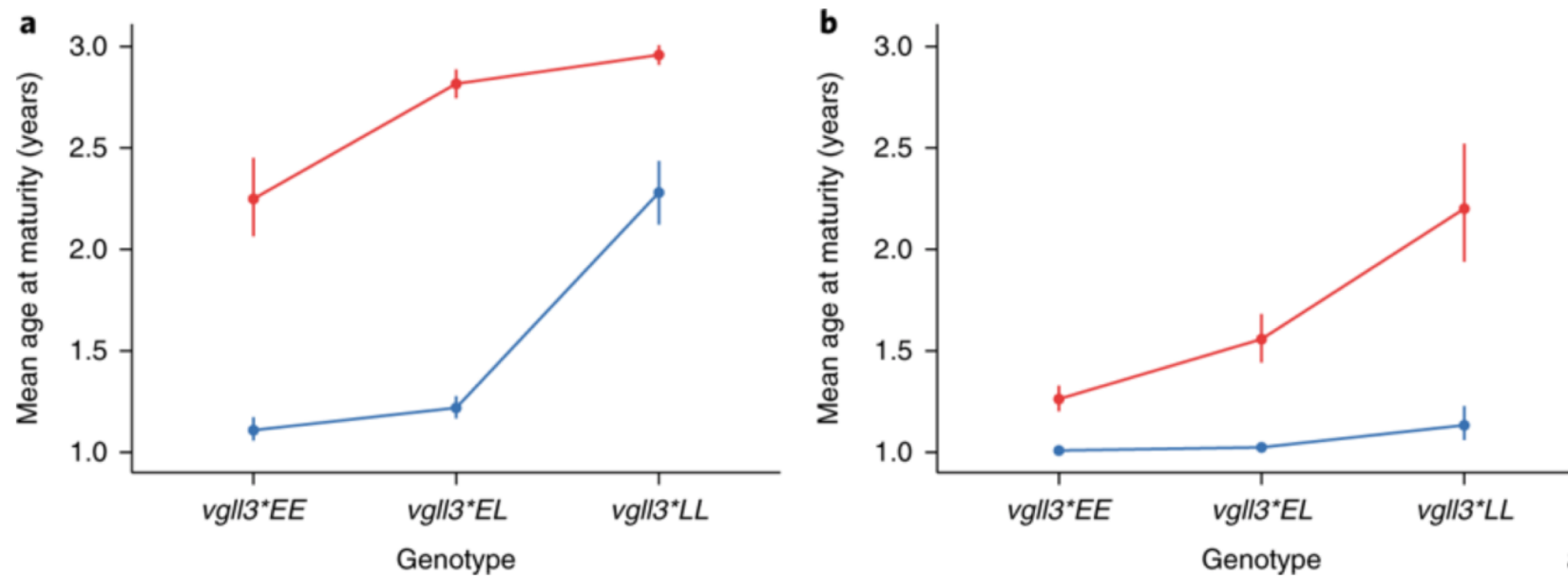
-E alel- rano sazrijevanje; L alel kasno sazrijevanje

-sazrijevanje testisa, adipogeneza; vrijeme ulaska u pubertet, rast i kondicijski faktor tijela ljudi

-lokusni seksualni konflikt- različiti fenotipski optimum za mužjake i ženke

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

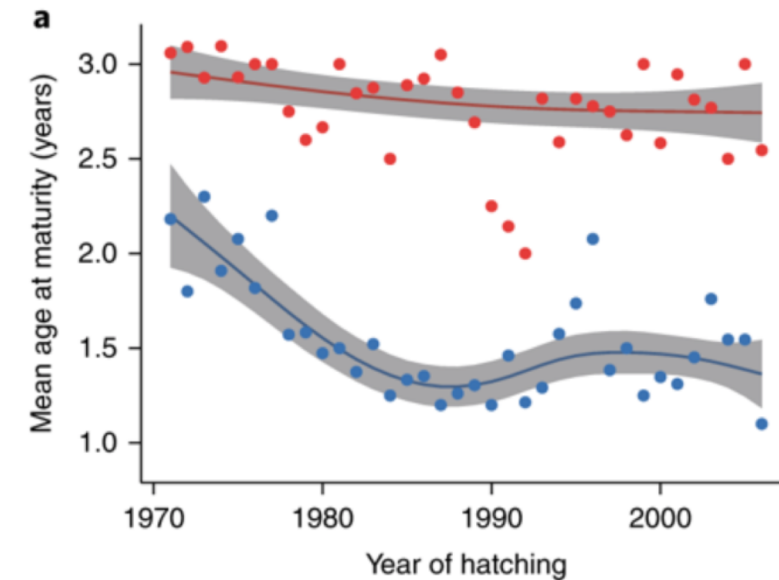
From: [Rapid sex-specific evolution of age at maturity is shaped by genetic architecture in Atlantic salmon](#)



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

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



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

Emily M. Troyer , Ricardo Betancur-R, Lily C. Hughes , , and Dahiana Arcila   [Authors Info & Affiliations](#)

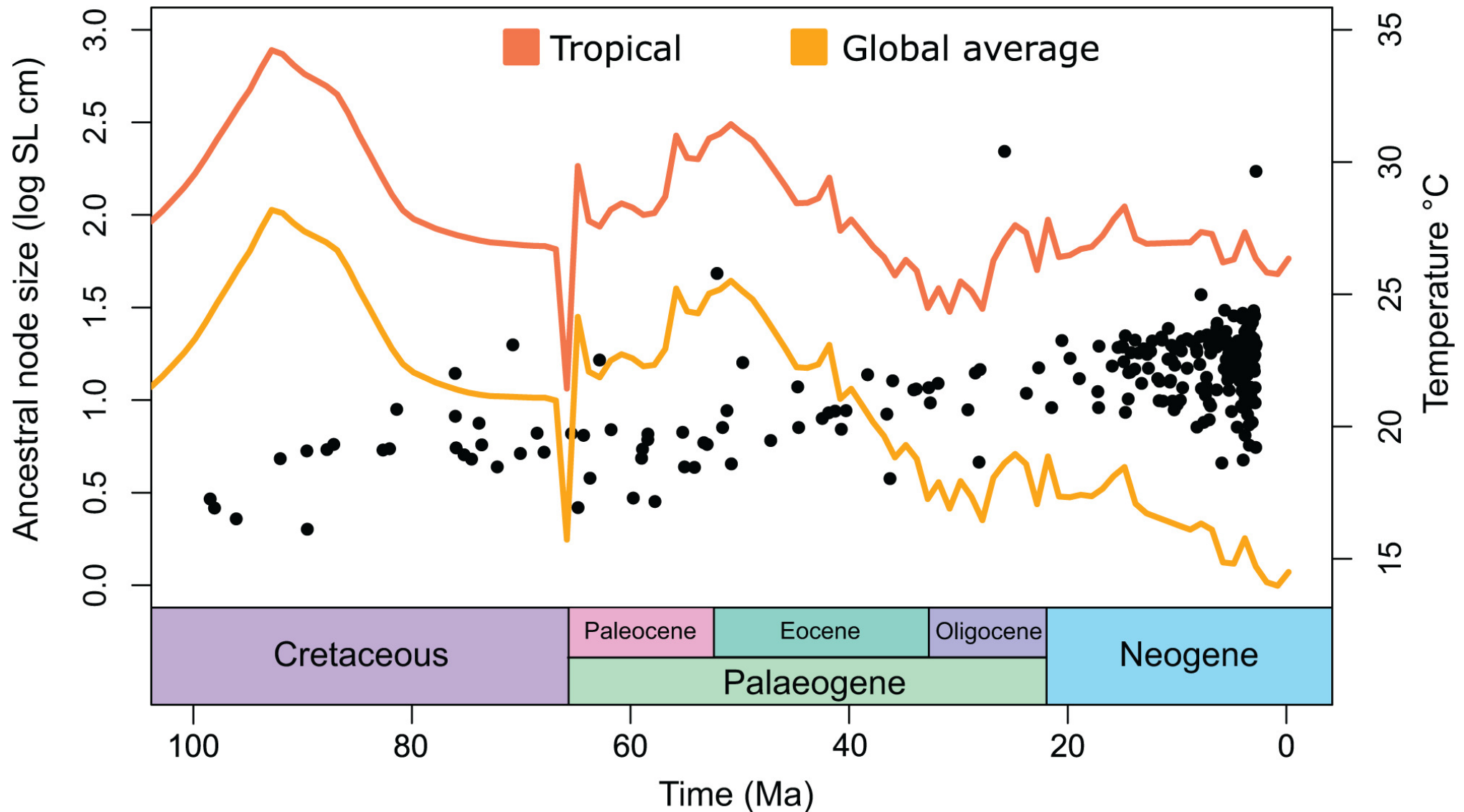
Edited by David Hillis, The University of Texas at Austin, Austin, TX; received January 18, 2022; accepted May 19, 2022

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

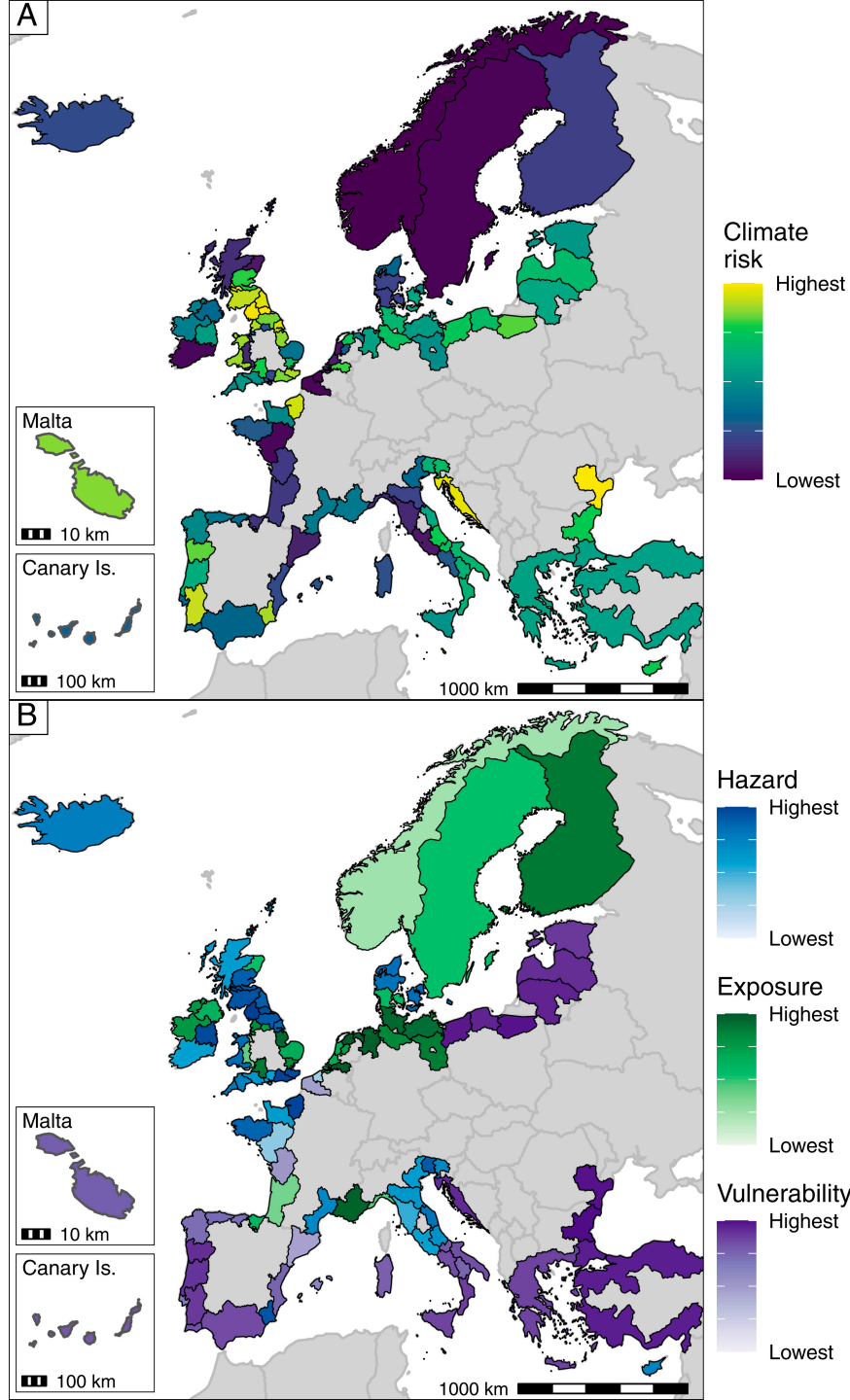
Ovisnost veličine tijela i temperature
vidljiva i na makroevolucijskim obrascima

*„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](#).

Izlovljavanje ribljih populacija uzrokuje smanjenje jedinki

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

Izlovljavanje različite veličine jedinki u eksperimentalnim uvjetima kroz 4 generacije pokazalo je da izlov velikih jedinki uzrokuje brzo smanjenje biomase, dok izlov manjih jedinki ima obrnuti učinak – selekcija genotipova za brži ili sporiji rast.

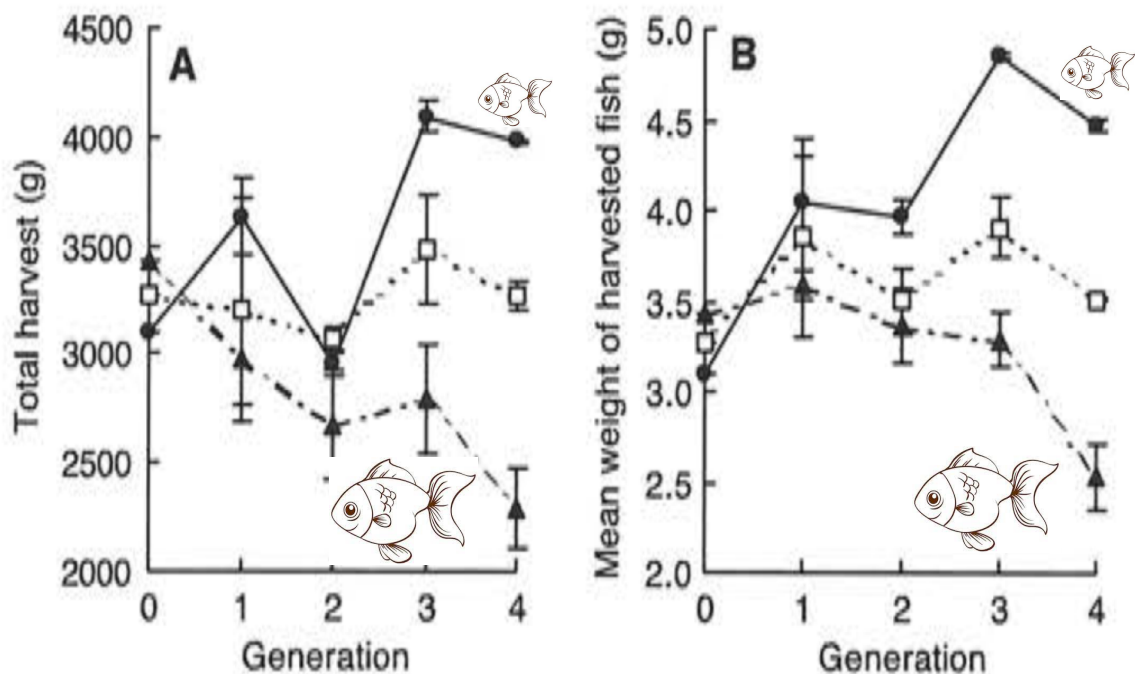
Abstract

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.

Izlovljavanje ribljih populacija uzrokuje smanjenje jedinki

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).



**selekcija pojedinih genotipova
uvjetuje veličinu populacije!**



Izlovljavanje ribljih populacija uzrokuje smanjenje jedinki

Problem?

1. Izlovljavanjem malih jedinki u prirodnim populacijama mora se uloviti puno veći broj jedinki za istu biomasu ulova u danom trenutku.
2. Nemoguće je vršiti selektivni izlov prirodnih populacija s obzirom na starost riba, pa se na taj način konstantno izdvaja veliki broj mladih jedinki iz populacije.

<https://youtu.be/GSO6ALu2hUU>

Zakiseljavanje voda uzrokuje smanjenje jedinki riba

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 CO₂-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 O₂ uptake capacity; as well as significant alterations in olfactory responses, anti-predator behaviour and anxiety under projected future increases in CO₂ 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 CO₂-induced acidification on freshwater systems.

nature
climate change

Article | Published: 29 June 2015

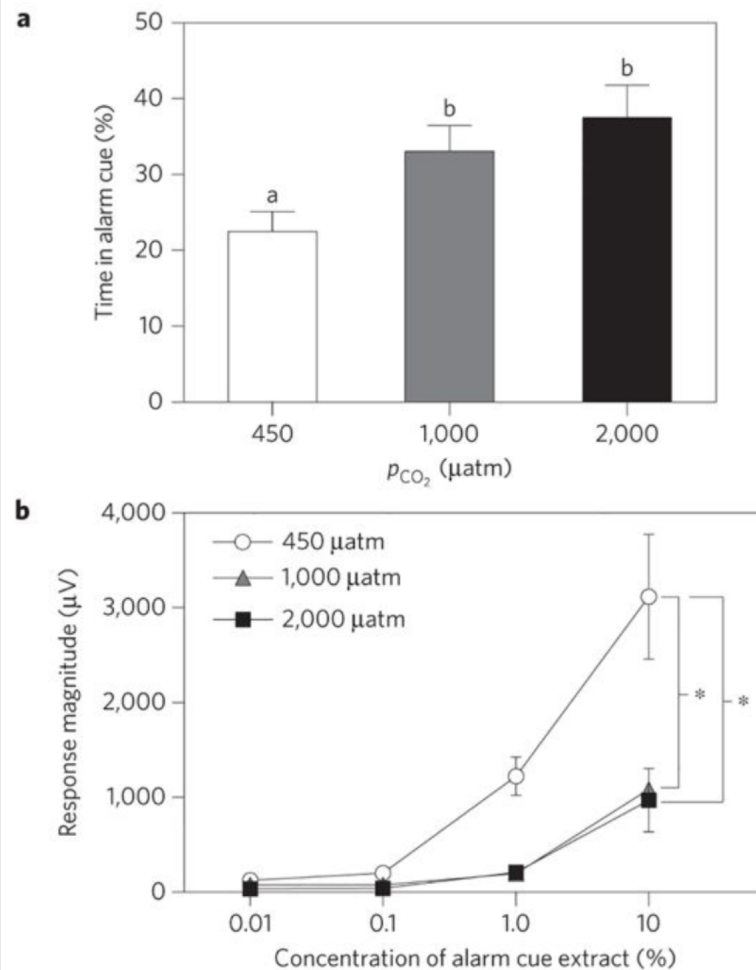
Responses of pink salmon to CO₂-induced aquatic acidification

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](#) 

Zakiseljavanje voda uzrokuje smanjene rasta, smanjenje apsorpcije kisika, promjene u olfakftornim odgovorima i anti-predatorskom ponašanju, te ankisoznost mladih jedinki lososa.

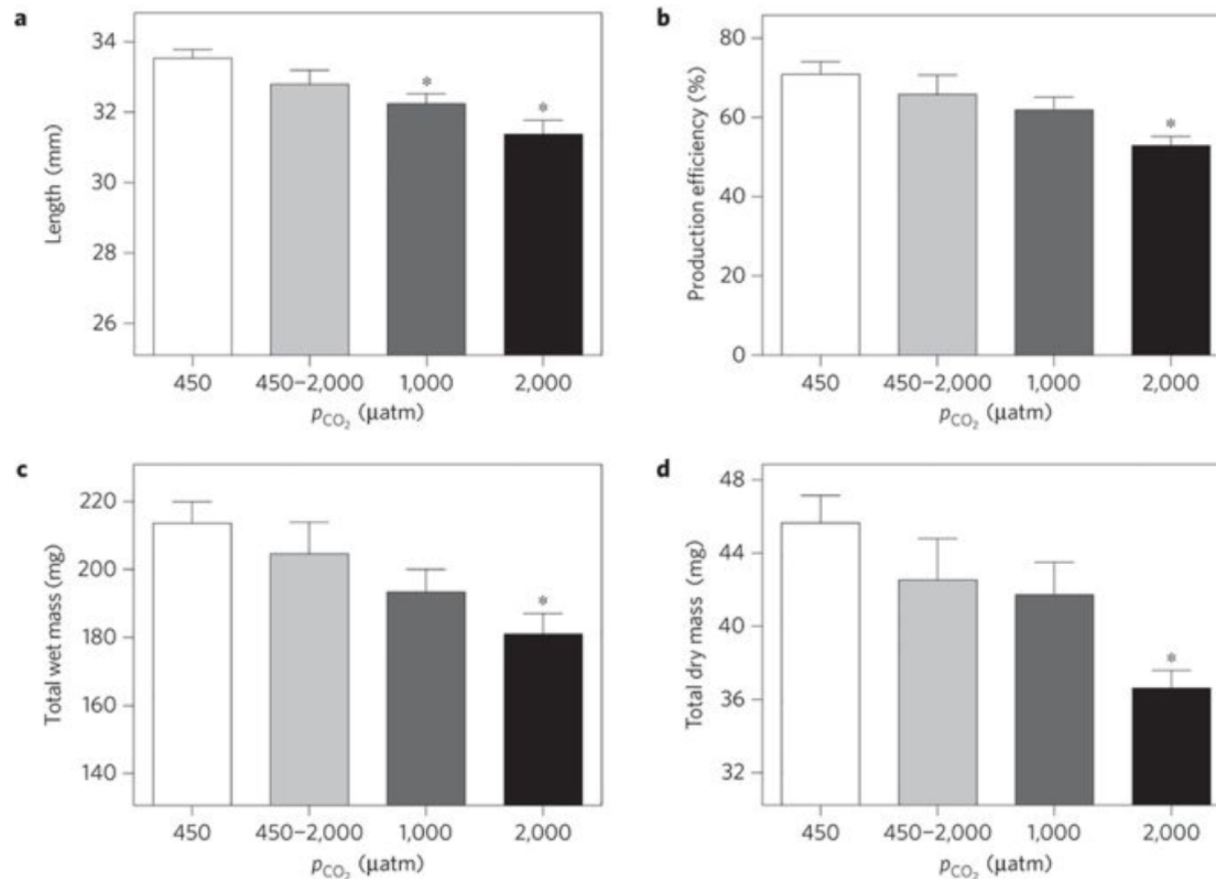
Figure 2: Predator avoidance behaviour and olfactory responses of pink salmon reared at different $p\text{CO}_2$ tensions to conspecific alarm cues in freshwater.



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 $\pm$ s.e.m.

Izbjegavanje predatora i olfaktorni odgovori kod lososa izloženih rasponu koncentracija CO_2 – ribe izložene višim koncentracijama sporije i manje reagiraju na opasnost

Figure 1: Growth measurements in pink salmon (*Oncorhynchus gorbuscha*) at yolk sac absorption (following ten weeks of CO₂ 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).

Rast i apsorpcija žumanjačne vreće kod lososa izloženih rasponu koncentracija CO₂ – svi parametri smanjuju se pri višim koncentracijama