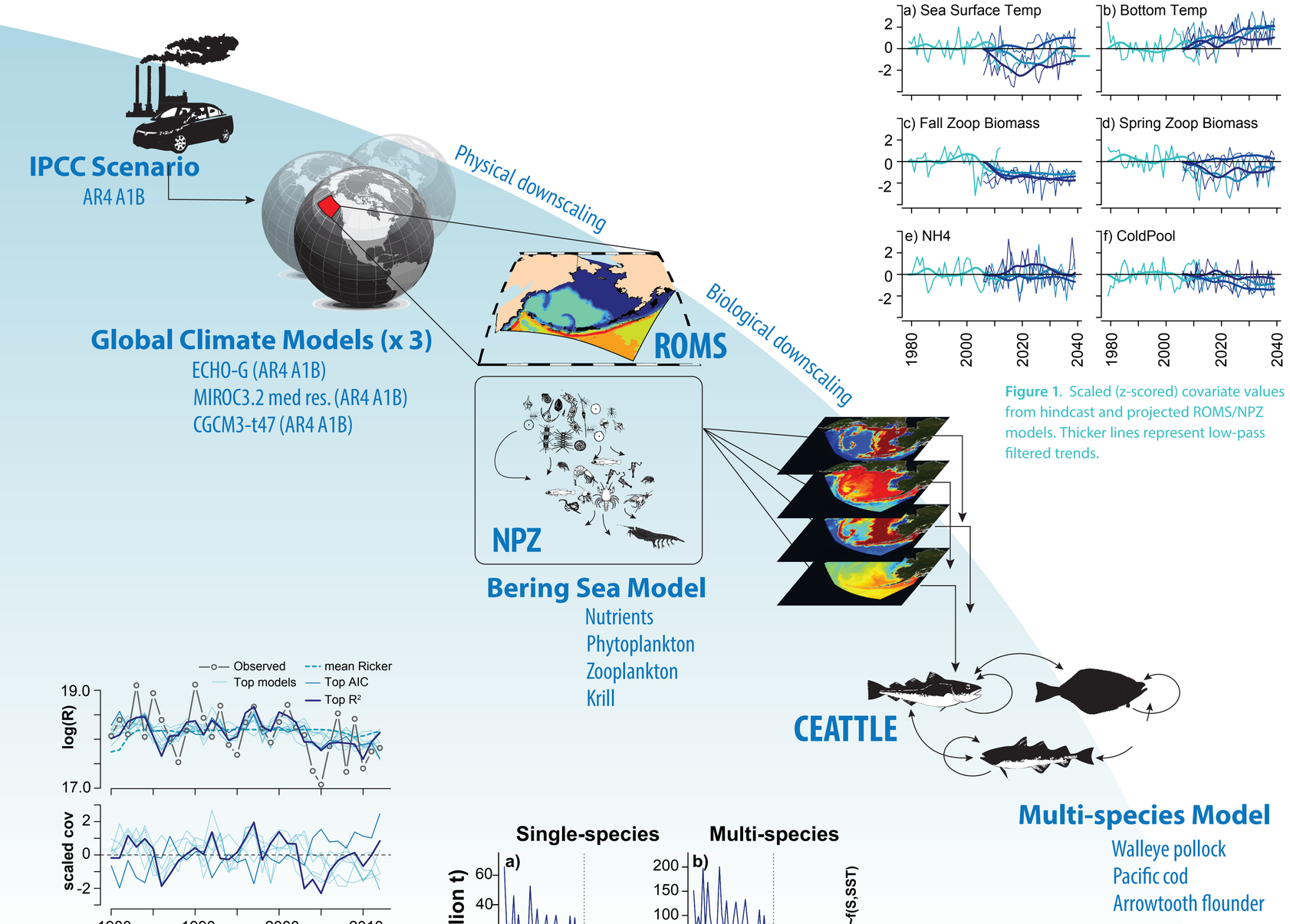
Trophic amplification of climate change impacts on groundfish species in the eastern Bering Sea (USA)



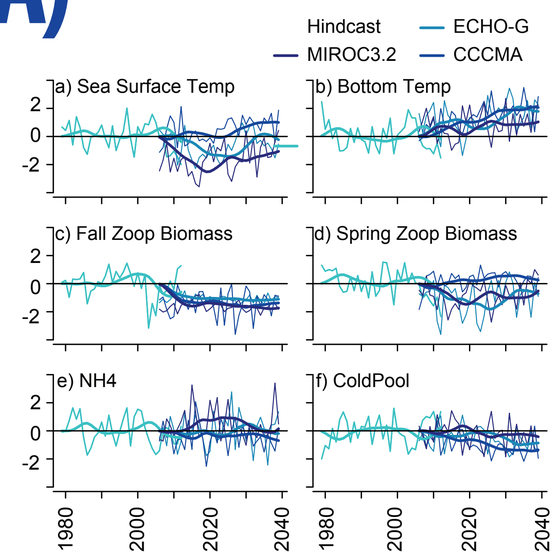


Figure 1. Scaled (z-scored) covariate values from hindcast and projected ROMS/NPZ models. Thicker lines represent low-pass filtered trends.

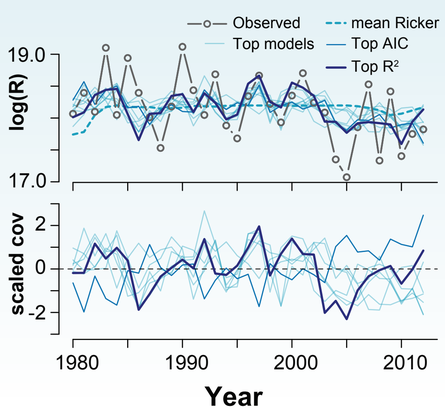


Figure 2. Pollock recruitment (R , 1 yr olds) time-series. Assessment model estimates of R ("Observed") and model estimates of R from top selected models with covariates for recruitment based on ROMS/NPZ indices.

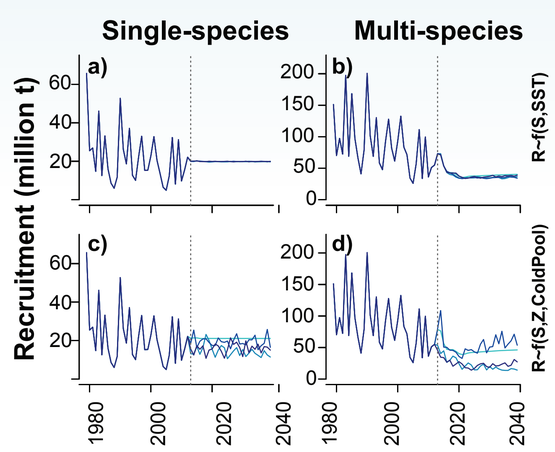


Figure 3. Historical estimates and future projections of pollock R from 3 climate scenarios and from climate enhanced single- and multi-species assessment models with SST covariates on Ricker recruitment models (a &) or Cold Pool, and spring and fall zooplankton covariates for R (c & d).

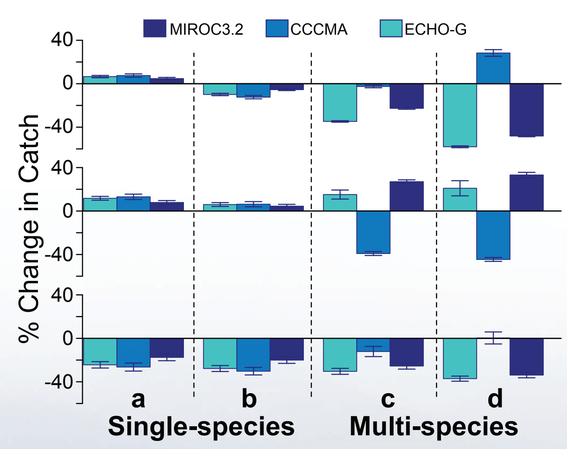


Figure 4. Change in catch from projections under stationary future conditions (set at mean of historical values) for the assessment model run without trophic interactions (a & b), or with predation mortality (c & d), with recruitment as a function of spawning biomass and SST (a & c) or as a function of spawning biomass and spring and fall zooplankton abundances and cold pool area.

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Approach

We used multi-species stock-assessment models to link climate-driven changes in physical and trophodynamic conditions to recruitment and mortality of three Eastern Bering Sea groundfish species (*Gadus chalcogrammus*, *G. macrocephalus*, and *Atheresthes stomias*, herafter pollock, P. cod, and arrowtooth, respectively) in order to distinguish harvest impacts on fish populations from large-scale climate pressures.

Methods

- A multi-species stock assessment model with temperature-specific growth and predation (CEATTLE) was used to derive estimates of age 1 recruitment (R) and spawning biomass (B) for 3 species of groundfish from the Bering Sea (walleye pollock, Pacific cod, and arrowtooth flounder).
- A coupled ROMS-NPZ model was used to derive 30+ historical indices of physical and biological conditions for the eastern Bering Sea (USA), such as bottom temperature, ice-melt derived cold water area ("Cold Pool"), aand seasonal zooplankton abundance.
- We then fit spawner-recruitment models using CEATTLE estimates of historical B and R and modeled residual error as a function of ROMS/NPZ indices. AIC was used to identify ROMS/NPZ indices that were most correlated with residuals.
- CEATTLE was projected forward to 2040, where recruitment in each projection year was based on IPCC scenario-driven ROMS/NPZ future indices.

Results

- Inclusion of zooplankton and Cold Pool area indices improved model estimates of annual recruitment (Fig. 2).
- All models project declines in recruitment and acceptable biological catch (ABC) under future conditions relative to scenarios based on stationary future conditions set at mean historical values (except for the multi-species mode under future conditions predicted from the CCCMA model; Figs. 3, 4).
- Projected declines in ABC were sensitive to model specifications of trophic interactions. Stock assessment models with predation exhibited the largest projected declines in ABC, whereas single-species models without bottom-up controls on recruitment had the lowest projected changes in ABC (Figs. 3, 4).

Implications

Inclusion of trophic interactions amplified climate-driven declines or increases in fish abundances, implying that fisheries models that do not include trophic interactions or climate effects might over-estimate sustainable harvest rates for fish species negatively impacted by climate change (e.g., pollock), and under-estimate harvest rates for predator species positively impacted by climate change (e.g., arrowtooth). Our work emphasizes the need to evaluate multiple future scenarios and model structures when projecting climate effects on fishery species.

Photo credit: Mark Holsman mark@boxwood-photo.com

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