North Pacific Decadal Predictability of Subsurface Temperature, Oxygen, and the Metabolic Index

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I. Motivation

- Global Earth System Models have demonstrated skill in predicting physical and biological variables important to fish and fisheries on seasonal to decadal time scales of significance to management (Tommasi et al., 2016; Park et al., 2019).
- Interannual variations in ocean temperature and oxygen concentration contribute to the habitat variability of valuable marine fish species, but it is difficult to disentangle few predictive studies incorporate this information in developing projections of impacts on living marine resources.
- A physiologically mechanistic Metabolic Index (Φ) was recently developed that explicitly combines the joint influence of oxygen concentration and temperature-dependent metabolic demands.

II. Data & Methods

North Pacific 12 Large Marine Ecoregions (LMEs)

- The CESM-DPLE shows much higher potential predictability over the FOSI reconstruction persistence forecast and CESM-DPLE ensemble mean forecast: largely increased predictability over the Kuroshio Current region, EBS and the AI, and Gd, decreased predictability over the Kuroshio Extension and the mid of North Pacific;
- Subsurface temperature has very different spatial potential predictability of CESM-DPLE that are mainly located over the Northeast of North Pacific as a "dove" shape.

The Forced Ocean-Sea Ice (FOSI) Reconstruction

- The FOSI reconstruction has the identical spatial resolutions as the CESM-DPLE.

The Metabolic Index Φ

- The Metabolic Index (Φ) is defined as the ratio of oxygen supply (Σ) to an organism's resting metabolic demand (D), which can be calibrated with physiological data of certain marine taxa (Deutsch et al., 2015): Φ = D / Σ = A0 B^n + p DÎ2 e^-kt
- Where A0, B, n, p, D, k, and t are the rate coefficients for gas exchange (S) and minimum metabolic rate (D), and Σ is the difference between scaling exponents applied to biomass B for oxygen supply and demand, DÎ2 is the temperature sensitivity of hypoxia tolerance, and k is the Boltzmann constant (Gillooly et al., 2001).
- The Metabolic Index is calculated using the measured values of metabolic traits database from Deutsch et al. (2015), the values of A0 and B are 7.35 and 0.34, respectively.

Prediction Skill Assessments

- Potential predictability is assessed by calculating the Anomaly Correlation Coefficient (ACC) and root mean square error (RMSE) between the CESM-DPLE ensemble mean forecast and the FOSI reconstruction, both of which are on annual time scale (annual averages over January-December).
- Statistical significance of ACC is tested at the 90% confidence level via a Student's t-test, and statistical significance between two ACCs is also tested at the 90% confidence level following Steiger (1980).

III. Results & Discussions

A. Spatial Distribution of Decadal Potential Predictability of the Metabolic Index Φ, temperature, and oxygen at 200-600 m

- The CESM-DPLE shows much higher potential predictability over the FOSI reconstruction persistence for all three variables over the decadal time scales. Generally, the longer the lead time, the higher the increased prediction skill;
- Spatial distributions of potential predictability of the Metabolic Index are very similar to those of the oxygen at the 200-600 m layer for both reconstruction persistence forecast and CESM-DPLE ensemble mean forecast: largely increased predictability over the Kuroshio Current region, EBS and the AI, and Gd, decreased predictability over the Kuroshio Extension and the mid of North Pacific;
- Subsurface temperature has very different spatial potential predictability of CESM-DPLE that are mainly located over the Northeast of North Pacific as a "dove" shape.

B. Decadal Potential Predictability in North Pacific LMEs

- The CESM-DPLE shows very different potential predictability of the Metabolic Index in the 12 North Pacific LMEs: largely increased ACC (>0.25) in the AI (6-7 lead years), CC (7-10 lead years), GSC (1-3 lead years), and ECS (1-3 lead years);
- The California Current (LME03) has a decreased potential predictability when lead time increase from 1-year to 5-year, but it increases again when the lead time increase from 5-year to 10-year;
- The Metabolic Index in the California Current LME is decreasing during the recent time series, suggesting an increased habitat constraints for fisheries.

IV. Conclusions

- The Metabolic Index is predictable on decadal time scales that enables quantifying habitat constraints arising from the metabolic dependence on temperature and requirements for oxygen, as well as temperature and oxygen at the 200-600m layer;
- The CESM-DPLE provides higher potential predictability in the three metrics at 200-600m over the simple, low-cost FOSI reconstruction persistence forecast, in the North Pacific with a lead time of 1-10 years;
- Spatial difference in potential predictability and its increase from persistence exists in the North Pacific as well as the 12 Large Marine Ecosystems;
- Interannual variability of oxygen is the dominant role against that of temperature in contributing the potential predictability of the Metabolic Index over the North Pacific.

References


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