Species distribution model predictability doesn't always decline under novel temperature conditions

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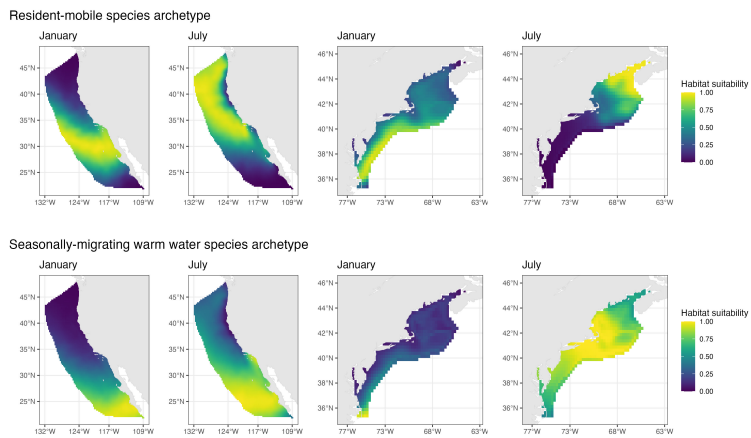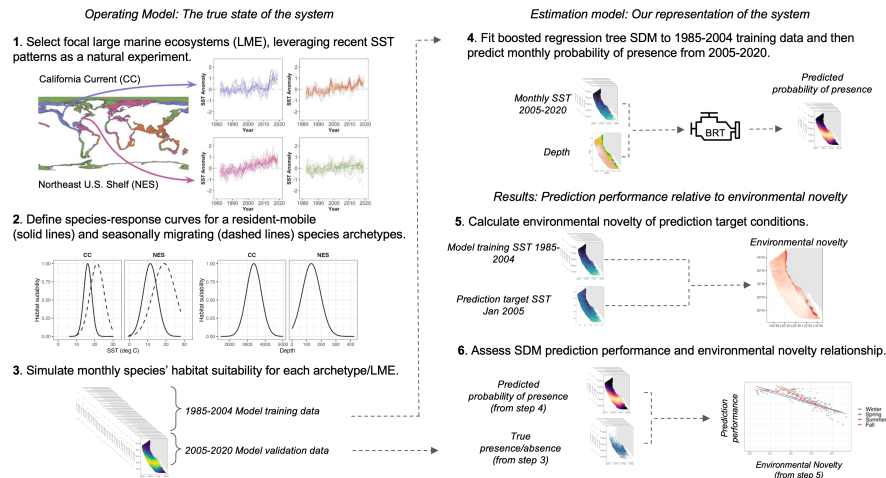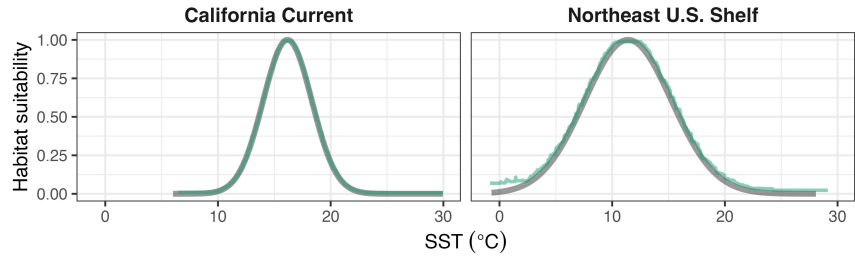[7]San Diego State University

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Abstract

Despite the rapid development and application of species distribution models (SDMs) to predict species responses to climate-driven ecosystem changes, we have a limited understanding of model predictive performance under novel environmental conditions. We aimed to address this gap using a simulation experiment to evaluate how novel ecosystem conditions and species movement influence SDM predictability. We leveraged observed sea surface temperature responses in the California Current and Northeast U.S. Shelf large marine ecosystems (LMEs) and prescribed species-response curves to simulate the distribution of a resident but mobile ectotherm, and a seasonally migrating ectotherm in each LME. For each LME and species archetype, we fitted boosted regression tree SDMs using data from 1985-2004 and then predicted the monthly probability of presence from 2005-2020 and calculated the environmental novelty of prediction month conditions. Generally, climate-driven ocean warming resulted in increasing environmental novelty over time, though patterns varied seasonally as warming caused novel conditions to increase over time in the summer and fall and decrease in the winter and spring as novel, cool conditions became more rare. Overall, predictive performance declined as novelty increased and occurred before prediction conditions became distinguishable from observation conditions. There were also unexpected increases in performance under novel environmental conditions when these novel conditions occurred at optimum species-response curve temperatures. These results highlight that environmental novelty may not always pose prediction challenges and will depend on where novel conditions map onto species-response curves. As SDM applications expand, there will be an ongoing need to maximize data quantity and quality to more fully characterize a species' fundamental niche, explore environmental novelty relative to species-response curves, and continue to improve methods for quantifying and communicating model uncertainty. These efforts will open opportunities for model improvement and support stakeholders' capacity to understand and integrate predictions into decision-making processes.

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Operating Model: The true state of the system

1. Select focal large marine ecosystems (LME), leveraging recent SST patterns as a natural experiment.

California Current (CC)

Northeast U.S. Shelf (NES)

2. Define species-response curves for a resident-mobile (solid lines) and seasonally migrating (dashed lines) species archetypes.

3. Simulate monthly species' habitat suitability for each archetype/LME.

1985-2004 Model training data

2005-2020 Model validation data

Estimation model: Our representation of the system

4. Fit boosted regression tree SDM to 1985-2004 training data and then predict monthly probability of presence from 2005-2020.

Monthly SST 2005-2020

Depth

Predicted probability of presence

Results: Prediction performance relative to environmental novelty

5. Calculate environmental novelty of prediction target conditions.

Model training SST 1985-2004

Prediction target SST Jan 2005

Environmental novelty

6. Assess SDM prediction performance and environmental novelty relationship.

Predicted probability of presence (from step 4)

True presence/absence (from step 3)

Resident-mobile species archetype

Seasonally-migrating warm water species archetype

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Resident-mobile species archetype

Seasonally-migrating warm water species archetype

Resident-mobile species archetype

Seasonally-migrating species archetype

Winter   Spring   Summer   Fall

Resident-mobile species archetype

Seasonally-migrating species archetype

Winter   Spring   Summer   Fall