# Modeling larval northern anchovy (*Engraulis mordax*) abundance distributions using fine-resolution imagery data

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## Motivation

- Modeling anchovy abundance distributions will aid in anticipation of climate change effects on populations
- Models must adequately capture mechanistic drivers that underpin response to environment
- Larval anchovy abundance distributions are difficult to predict under novel environmental conditions[1]
- Fine-scale abundance data may allow more accurate characterization of mechanistic drivers of abundance

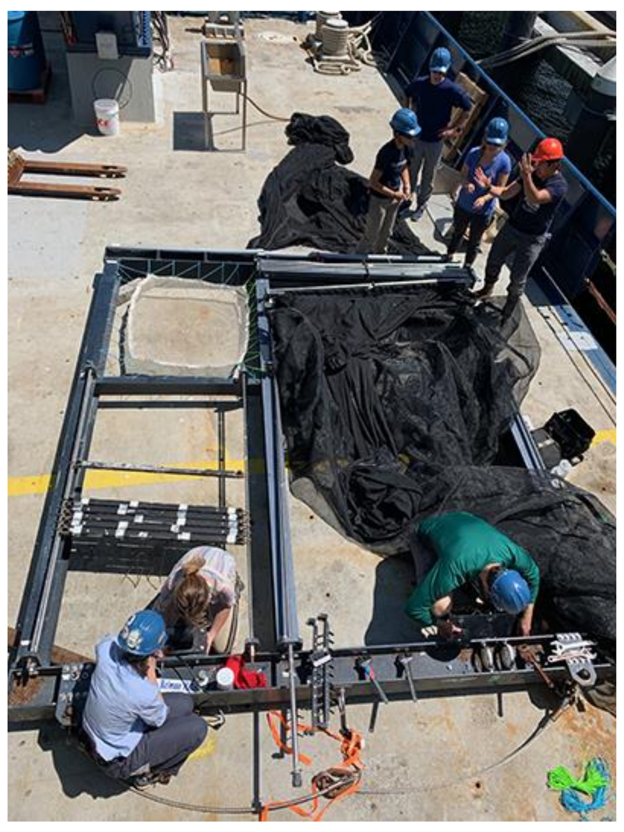

**Fig. 1.** Coupled 1-m² and 4-m² Multiple Opening/Closing Net and Environmental Sensing System (MOCNESS)

**Fig. 2.** The *In Situ* Ichthyoplankton Imaging System (*IS*IIS), which uses two shadowgraph cameras and environmental sensors to measure fine-scale plankton abundance and physical parameters.

**Fig. 3.** Clupeiformes larvae imaged by *IS*IIS, which cannot be distinguished to species in *IS*IIS images.

## Data Collection

- Winter and summer 2018–2019
- MOCNESS to collect larvae (25-m depth strata)
- *In Situ* Ichthyoplankton Imaging System (*IS*IIS) to collect fine-scale (1-m) larval clupeiform abundance in top 100 m across 17 transects (>120 km each)

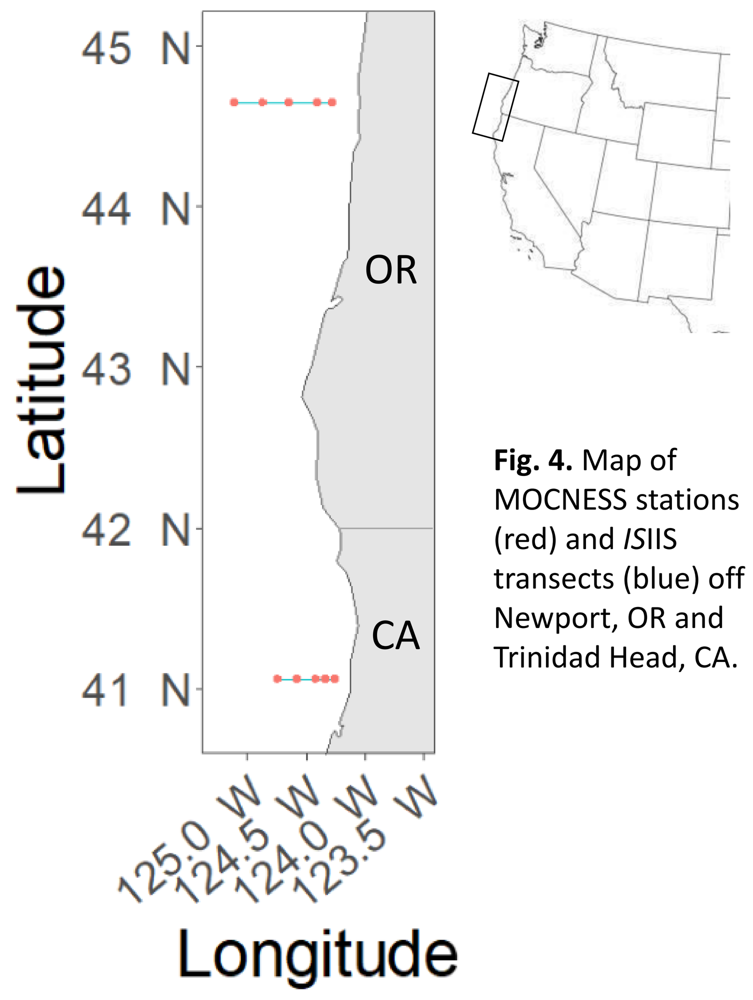


**Fig. 4.** Map of MOCNESS stations (red) and *IS*IIS transects (blue) off Newport, OR and Trinidad Head, CA.

## Data Analysis

### Use MOCNESS to distinguish between *IS*IIS clupeiform larvae

- Separate random forests (RFs) were fit to summer 2019 MOCNESS anchovy and sardine abundance data
- Predictors: temperature, salinity, depth, latitude, longitude
- Applied ratio of predicted anchovy to sardine abundance during co-occurrence to *IS*IIS clupeiform abundance

### Predict *IS*IIS larval anchovy abundance

- RF fit to random 75% of *IS*IIS larval anchovy (corrected clupeiform) abundance data
  - Out-of-bag (OOB) testing to assess predictive performance
- 4-fold spatially and temporally blocked cross-validation on withheld 25% of data
  - Assess influence of autocorrelation on model performance
- Predictors: temperature, salinity, chlorophyll a, dissolved oxygen, depth, latitude, longitude, season, year

## Results

- CV RF $r$ = 0.35, OOB RF $r$ = 0.36
- Depth allowed greatest reduction in node impurities (Fig. 5)
- RF was more likely to predict high anchovy abundance at:
  - Shallow depths
  - High dissolved oxygen
  - High chlorophyll a
  - Extreme salinities
  - High temperatures
  - Offshore and extreme inshore locations

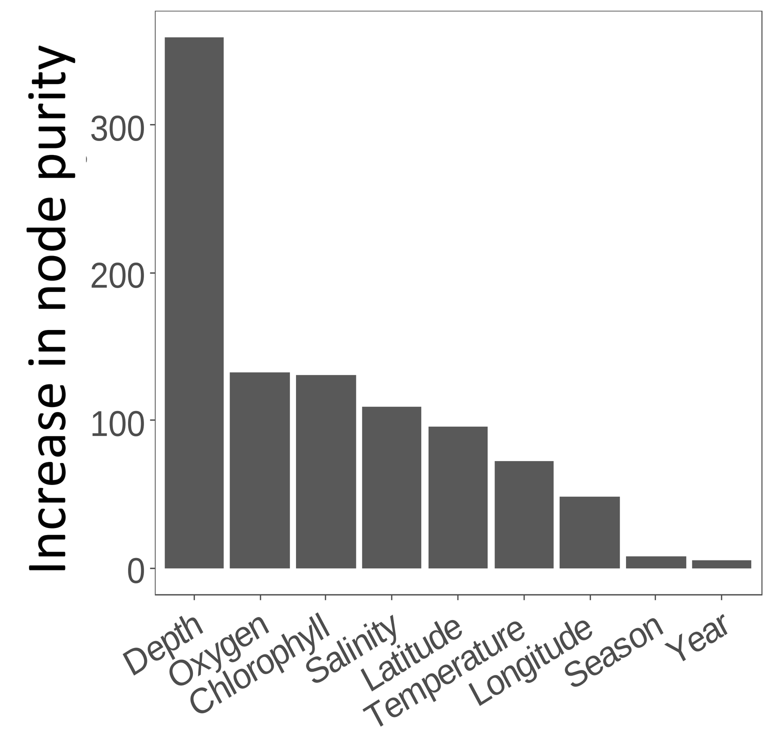


**Fig. 5.** Variable importance plot of predictors included in model fit to randomly selected 75% of *IS*IIS larval anchovy abundance observations. Bars indicate the total increase in node purity (Gini index) averaged across all trees for each predictor.

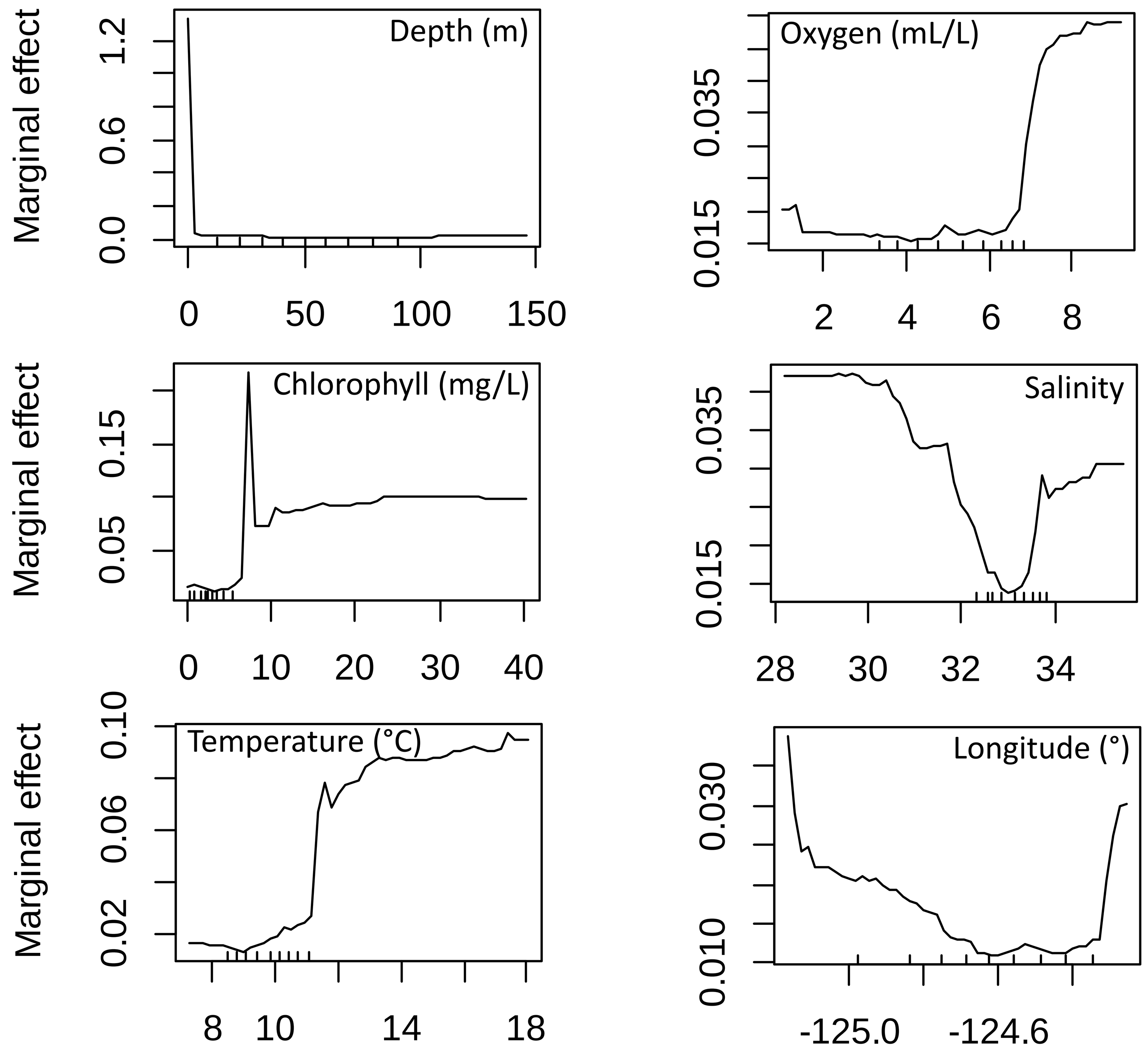


**Fig. 6.** Partial effect plots for a subset of predictors included in RF fit to randomly selected 75% of *IS*IIS larval anchovy abundance observations. Hash marks indicate deciles of predictors. Note: Y-axis scales differ among plots.

## Conclusions and Future Directions

- Similar performance of CV and OOB RFs suggest negligible influence of autocorrelation on model performance
- Partial effect plots (Fig. 6) support hypothesized effects of most important predictors (*e.g.*, depth, oxygen, chlorophyll)
  - Unexpected effect of salinity
- Low predictive performance may indicate that other ecological factors (*e.g.*, currents, predators) are also important
- Time lags may obscure relationships between larval anchovy abundance and environmental conditions
- Zero inflation may be addressed using a two-step model
- Other modeling frameworks (*e.g.*, SDMTMV) may be useful

## Acknowledgements

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## Reference

Muhling, B. A., *et al*. 2020. Predictability of species distributions deteriorates under novel environmental conditions in the California Current system. *Front. Mar. Sci.* 7:589.