Fish from space: Predicting mid-trophic levels biogeography via remote sensing and in-situ acoustic data fusion

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SUMMARY

We merge EK60 acoustic observation with remote sensing and reanalysis data to quantify the patterns and drivers of variability of **Mid-Trophic Level** (**MTL**) organisms.

Successful machine-learning reconstruction of multi-frequency acoustic backscatter along the US West Coast (USWC) provides new insights into the dynamics of MTLs.

By extrapolating sparse observations, our reconstructions reveal broad-scale patterns of MTL variability (spatial, seasonal, interannual) and elucidate regional drivers of MTL dynamics.

CONTEXT: Mid-Trophic Level (MTL) organisms

Key component of ecosystems (Prey for large marine predators / Modulate carbon flux / Valuable fisheries).

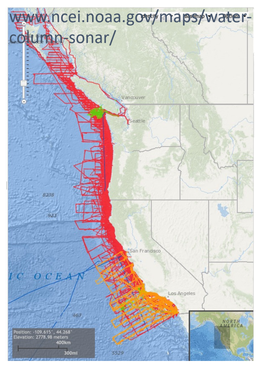
Complex dynamics (Bottom-up and top-down control / Heterogenous distribution / Inter-annual variability).

Hard to sample (Trawls & acoustic data are biased).

Goal : Quantify patterns and drivers of MTLs dynamic.

METHOD: Reconstruction of the dynamic of MTLs with Neural Networks

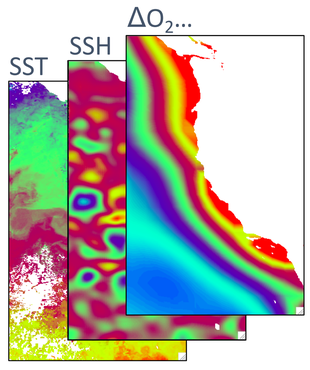
EK60 acoustic tracks along the US West Coast (USWC)



(1) Target

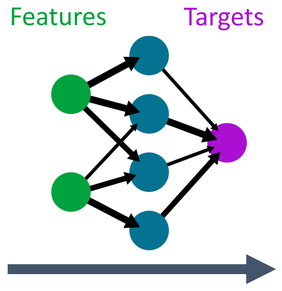
+

Environmental observations



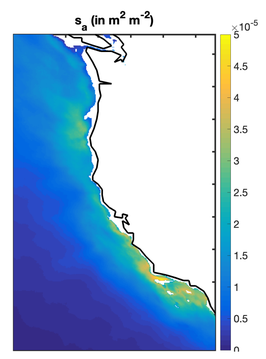
(2) Features

Machine learning



(3) Neural Net.

Regional acoustic reconstructions



(4) MTLs' dynamics

1-TARGET:

1,155 days (62,782 locations at 4km binning) of processed multi-frequency EK60 acoustic observation along USWC from 2005 to 2016.

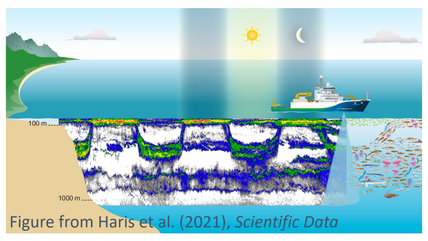
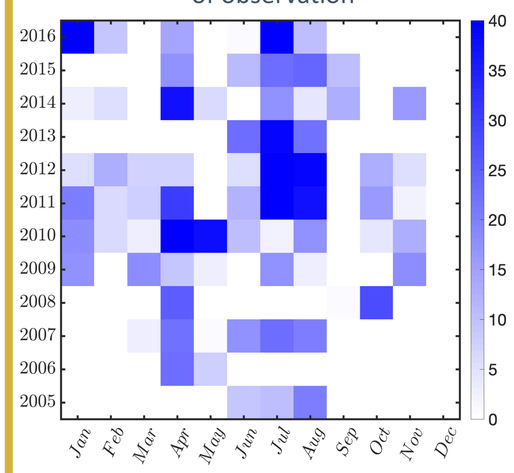
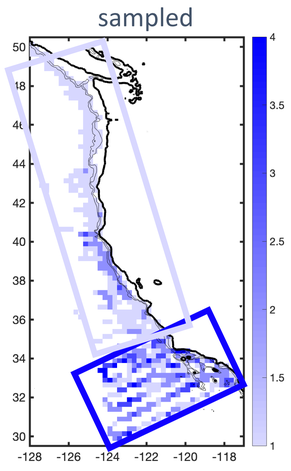


Figure from Haris et al. (2021), *Scientific Data*

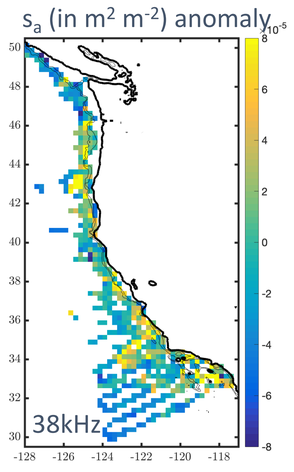
Number of days of observation



Number of seasons sampled



Mean surface (15-215m) s_a (in m^2 m^{-2}) anomaly



Sparse acoustic observations of local MTL abundance.
High resolution locally, but with spatial and seasonal limitations.

2-FEATURES:

Co-located environmental observation along acoustic transect (interpolated in 4km bins) from remote sensing, reanalysis and climatology.

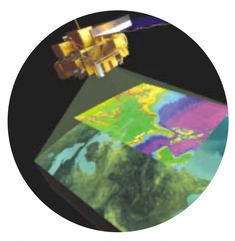


Figure from MODIS Brochure

Features co-located along cruise tracks

Sensor/Product	Variables	Resolution
MODIS-A	Chl, SST, POC, PAR & computation of front index (dsst)	4km -day/8days
MEaSUREs	SSH	1/6° - 5days
Reanalysis SODA	MLD & U/V for (dU_x, dU_y, dV_x, dV_y)	1/2° - 5days
Reanalysis ERA	Vel10	1/4° - hourly
Climatology WOA18	temp, o2 & gradients 0-100m (dT, do2), sal	1° - month
ETOPO	BATHY	1/10°
f(LAT,LON,TIME)	Solar Angle	-

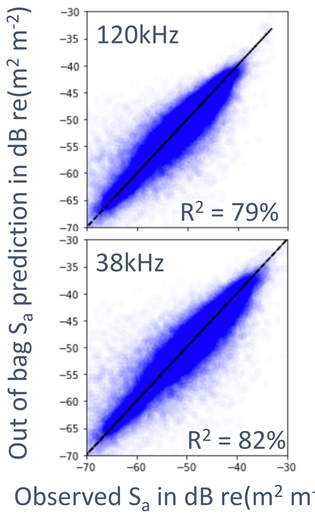
Features that affect the environment experienced by MTLs.
Large-scale observation at coarse spatio-temporal scales.

3-NEURAL NETWORKS (NNs):

Successfully learn the variability of surface (here 15-215m) area acoustic backscatter s_a from well-resolved co-located environmental variables.

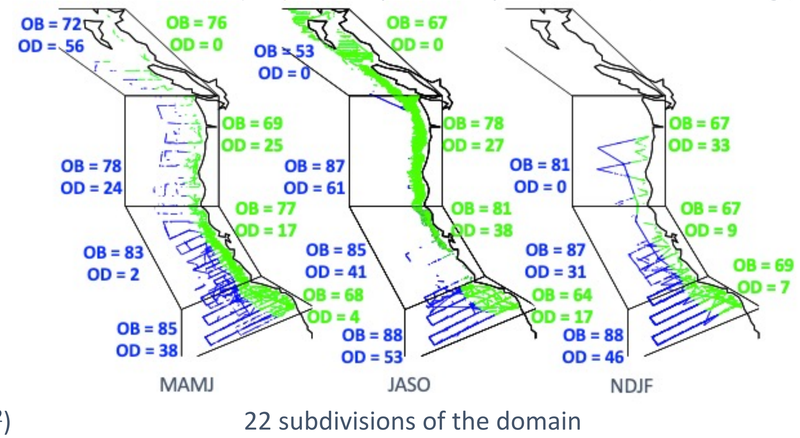
Overall performance of NNs
(feed-forward; stochastic gradient descent with warm restart; 5-fold cross validation)

Local evaluation
(in seasonal, latitudinal, onshore/offshore subdivisions)



Observed S_a in dB re(m^2 m^{-2})

Out of Bag (OB) : "Interpolation" performance of NNs (76% on avg.)
Out of Distribution (OD) : "Extrapolation" performance (24% on avg.)



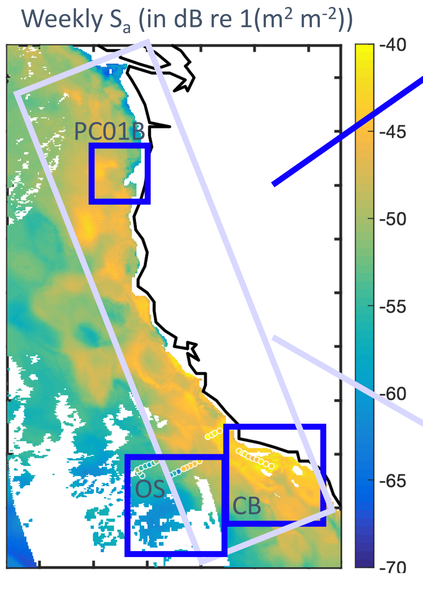
22 subdivisions of the domain

Fusion of acoustics with remote sensing results in excellent regional interpolation of MTLs signals (OB), but limited extrapolation (OD).

4-RECONSTRUCTIONS:

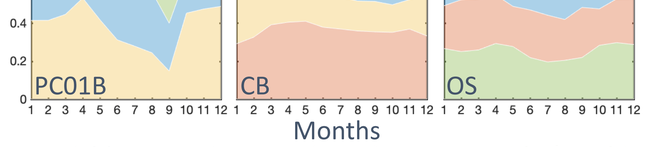
Reconstructed dynamic of MTLs…

Weekly S_a (in dB re 1(m^2 m^{-2}))



… allows analysis of local drivers.

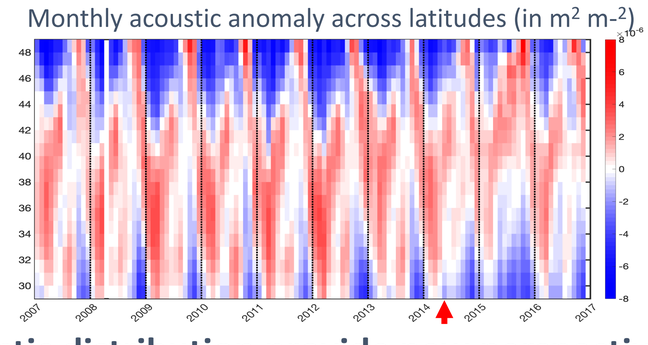
Relative contribution of environmental drivers



Bio (chl, poc, o2) - Temp (T, sst) - Currents (dU/V, ssh) - Vert. gradients (dT, do2) - MLD - Others (par, dsst)

… reveals inter-annual variability.

Monthly acoustic anomaly across latitudes (in m^2 m^{-2})



Reconstructions of MTLs' acoustic distribution provide new perspectives.
Next step, link with abundance and community composition from trawls.

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