DEFINING ISOSCAPES IN THE NORTHEAST PACIFIC AS AN INDEX OF OCEAN PRODUCTIVITY

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Stable isotopes of an element are naturally present in the environment.

Building blocks for Autotrophs
- preferentially use lighter isotopes
Stable isotopes of an element are naturally present in the environment.

Autotrophs take up elements and their isotope ratio (denoted by \( \delta \)) reflects the natural availability:

- \( \delta^{15}\text{N} \) is inversely correlated with nitrate concentration.
- \( \delta^{13}\text{C} \) is correlated to \( \text{CO}_2 \) concentration, which in turn is driven by water temperature.
**INTRODUCTION**

**Stable** isotope values are transferred conservatively though the food web with predictable enrichment of the heavy isotope at each trophic transfer due to metabolic processes.

- $^{13}\text{C}$
- $^{15}\text{N}$
- $^{14}\text{N}$
- $^{12}\text{C}$

**Zooplankton**

**Salmon**

**Trophic enrichment factor:**
- $\delta^{15}\text{N} = \sim 3.4\%$
- $\delta^{13}\text{C} = \sim 1.1\%$
The Isotopic “landscape” - Isoscapes are produced by mapping stable isotope distributions of organisms from a particular trophic level

Depending on the generation time (autotrophs) or the turnover time of tissue collected (fish, birds), stable isotope values will be representative of different time scales.

Potentially one of the first $\delta^{15}$N isoscapes produced. Schell et al., 1998.
INTRODUCTION: ISOSCAPE APPLICATIONS

➢ provide SI baseline for food web studies

➢ index of ocean productivity

➢ Identify predator foraging locations and movement in the ocean

Isoscapes produced in the Southern Ocean as a means to track albatross. *Jaeger et al., 2010.*
AIMS OF THIS STUDY

1. Define isoscapes for the Northeast Pacific using large calanoid copepods;
2. Determine if isoscapes can be used as an index for secondary productivity.
Summer (June) zooplankton samples were collected from:

- Line P (Bongo) - 42 samples, 2009-2016, size class 2-4 mm;
- CPR - 240 samples, bulk (2010-2013), and large copepods only (2000-2007 and 2014-2017);
- Stable isotopes analysis ($\delta^{15}N$ & $\delta^{13}C$);
- C Isotope values corrected for lipid and Suess effect.
A set of potential predictors was assembled using different sources:

**Satellite data**
- SST
- Chlorophyll $\alpha$ concentration
- Sea level anomaly (SLA)

**Bathymetry**
- Distance to 200 m isobath

**Argo float**
- Mixed layer depth

**Atmospheric**
- Wind data
Developing a Generalized Additive Model (GAM):

Model parameters
- SST and sla averaged for 1-2 weeks before sampling date;
- Chl-a – different integration periods tested
- MLD - May 1 to July 31

Checked for outliers, and collinearity between predictors.

Test relationship between the response variable and the predictors, keeping only significant ones.
Best model results: $\delta^{15}N \sim s(\text{chla}_4m) + s(\text{sla}) + s(\text{SST}) + s(\text{MLD})$

- 50.3% of variance explained
- up to 59.4% if MLD included

*Limited spatial coverage for MLD estimates therefore excluded.*
**METHODS**

Best model results: $\delta^{13}C \sim s(\text{chla}_4m) + s(\text{sla}) + s(\text{SST}_{June}, \text{dist2coast})$

- $\delta^{13}C$: 43% of variance explained
RESULTS

Model based Isoscapes were produced for 1998-2017.

Similarities between C and N stable isotope distributions, but also differences.

- Values higher on shelf
- Elevated in eddies (particularly $\delta^{15}$N)
RESULTS: MODEL VALIDATION

Compared observed and predicted $\delta^{15}\text{N}$ & $\delta^{13}\text{C}$ values along Line P.

- The modelled $\delta^{15}\text{N}$ & $\delta^{13}\text{C}$ values used came from a submodel that did not include the Line P data.
RESULTS: VALIDATING MODELS

More variability in observational data but general patterns are reproduced.

Modelled C and N values compared to observation data along Line P
RESULTS: VALIDATING MODELS

Standard error associated with predicted value

Usually low, except when predictors values were out of the range define by the sampled values (for example SST < 4°C in the eastern part of the domain in 2012); and eddies.
**APPLICATIONS**

**Index of ocean productivity** requires defining relationship between SI values and zooplankton abundance/biomass.

Two sub-regions appear:
1. the Gulf of Alaska
2. off BC coast

with opposite correlation signs.
APPLICATIONS

Why different sign in the sub-regions?

Positive correlation in Gulf of Alaska

- High $\delta^{15}N$ is usually associated with higher productivity, therefore higher $\delta^{15}N = $ more large copepods.

Negative correlation along BC coast

- Propose that this reflects off-shelf transport of copepods from high productivity coastal regions (and circulation dynamics)
SUMMARY

• $\delta^{15}N$ and $\delta^{13}C$ isoscapes at for the primary consumer level (calanoid copepods) were generated for 1998-2017.

• We identified two different regimes in the Northeast Pacific based on the relationship between $\delta^{15}N$ and $\delta^{13}C$ and copepod abundance:
  • GoA characterized by subarctic species
  • Off BC coast characterized by frequent intrusion of Boreal shelf and southern copepods

• Data can be used for different purposes (ocean productivity, fish tracking, SI baseline) and are freely available (doi:10.5061/dryad.d2547d7z6).

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NEXT STEPS – COUPLE ISOSCAPES WITH PREDICTED SALMON DISTRIBUTIONS

*In review*

Predicted distributions (estimated using salmon isotopes time series)