Defining isoscapes in the Northeast Pacific as an index of ocean productivity

Boris Espinasse, Brian Hunt, Sonia Batten and Evgeny Pakhomov

INTRODUCTION

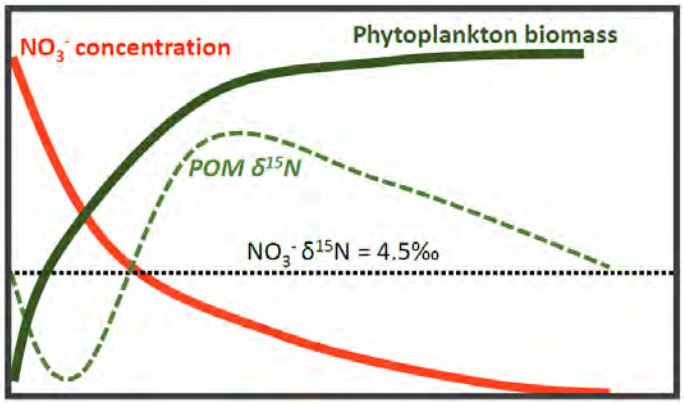
STABLE ISOTOPES

Stable isotopes are naturally present in the environment, the common isotope is found in higher abundance compare to heavier isotope, e.g., $^{12}C >> ^{13}C$.

Autotrophs preferentially use light isotopes against heavy isotopes.

$\delta^{15}N$ is correlated to nitrate concentration.

$\delta^{13}C$ is correlated to CO_2 concentration, which in turn is driven by water temperature.

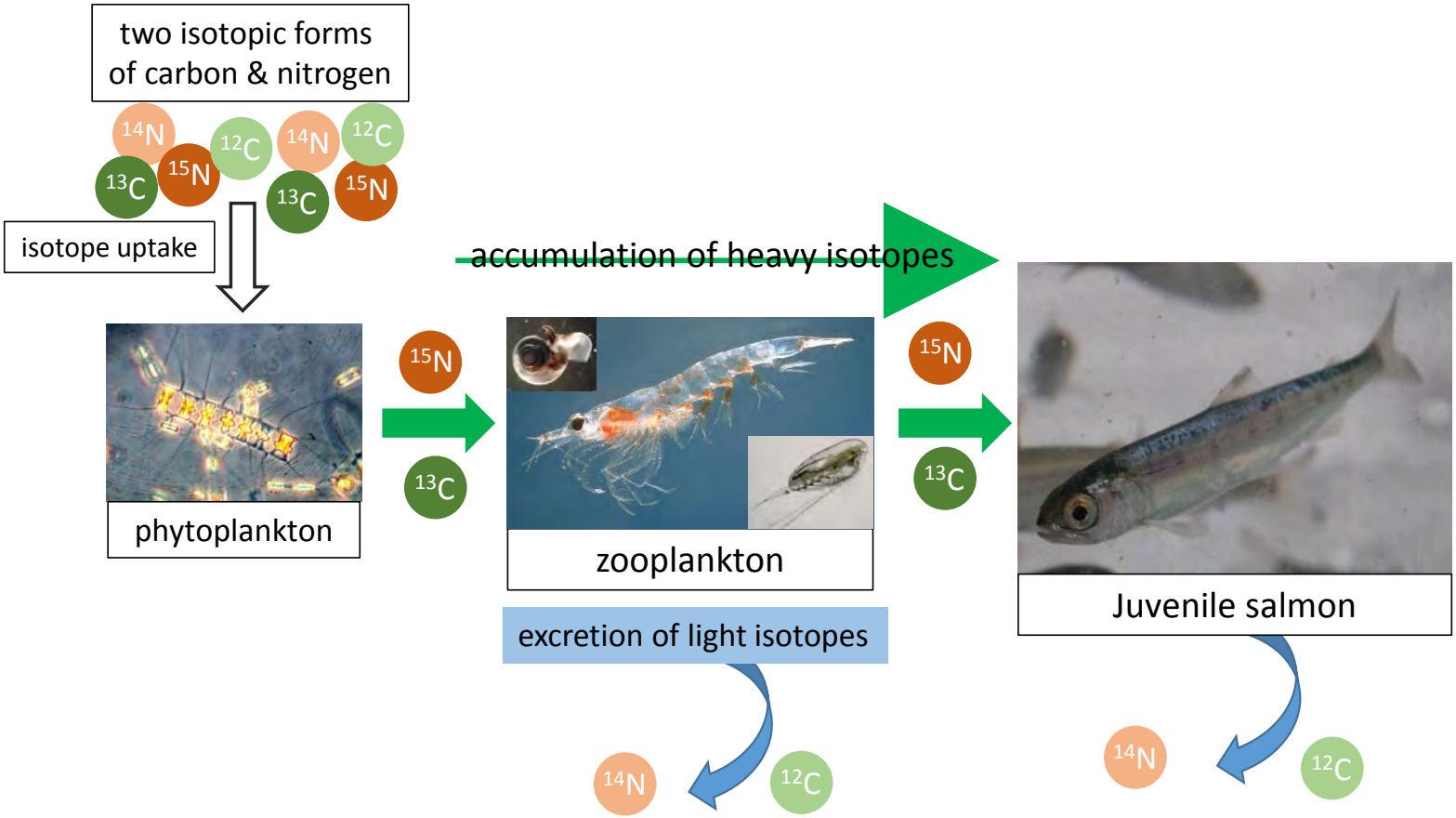


Sketch of the change in $\delta^{15}N$ in function of nitrate concentration

INTRODUCTION

STABLE ISOTOPES

Enrichment between trophic levels

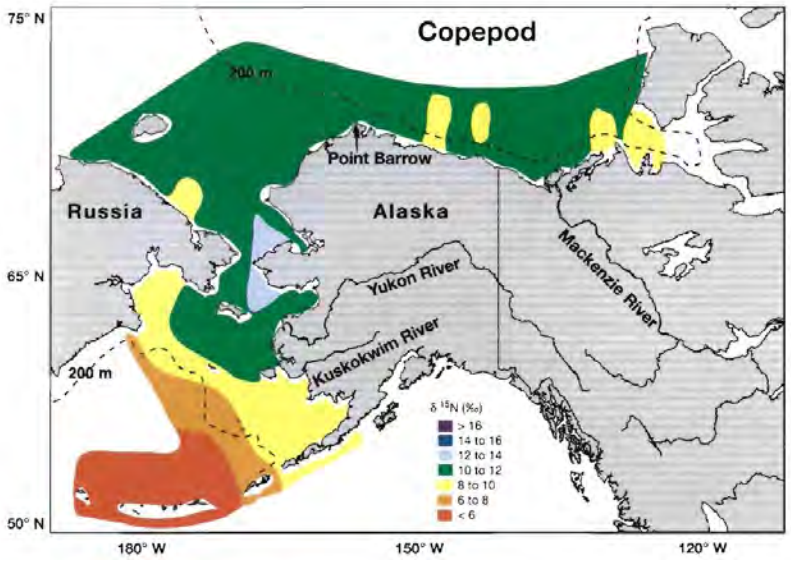


INTRODUCTION

ISOTOPE LANDSCAPE “ISOSCAPES”

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.

Isoscapes are produced by mapping stable isotope distribution of organisms that preferentially belongs to the same trophic level.



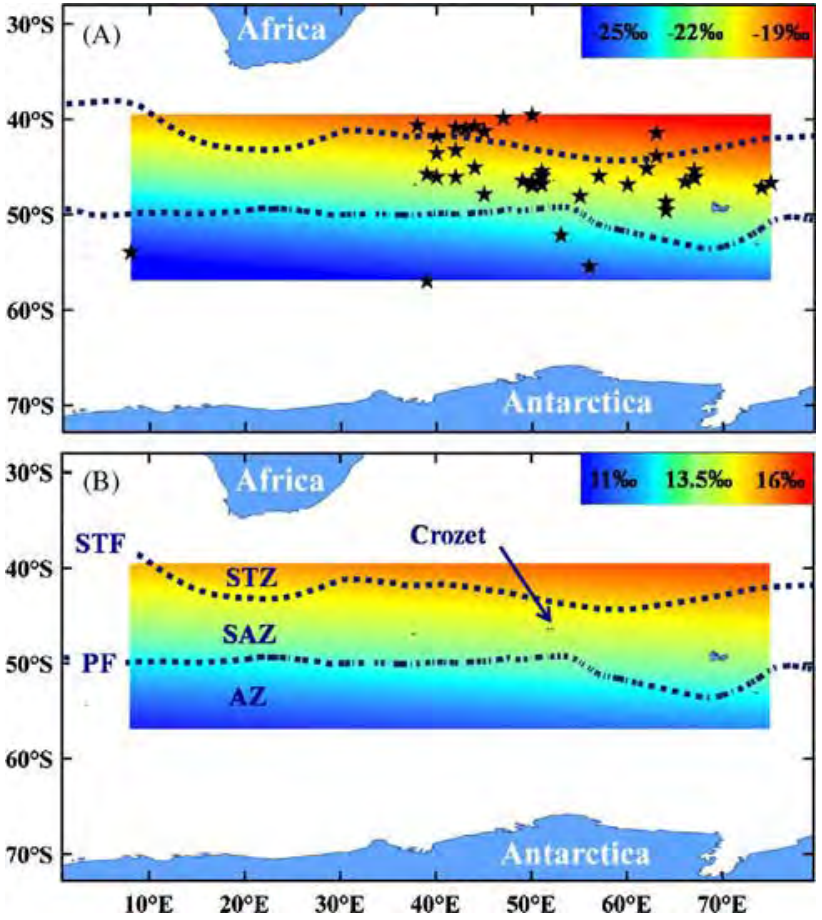
Potentially one of the first $\delta^{15}N$ isoscape produced. *Schell et al., 1998*.

INTRODUCTION

ISOSCAPE DEFINITION AND USES

Isoscapes can be used for different purposes:

- to provide SI baseline for trophic structure study
- to define an index for ocean productivity
- to track fish or other organisms over their migration into the ocean



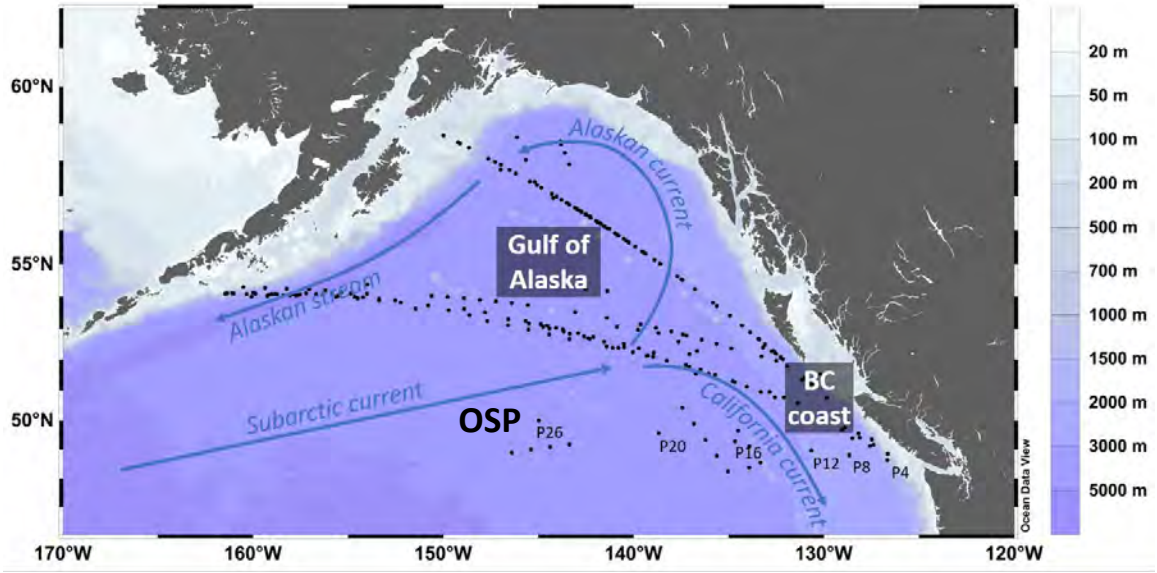
Isoscapes produced in the Southern Ocean as a means to track albatross. *Jaeger et al., 2010*.

METHODS

COLLECTING SAMPLES

Summer zooplankton samples were collected from:

- Line P, 42 samples, 2009-2016, size class 2-4 mm
- Continuous Plankton Recorder (CPR), 240 samples, bulk (2010-2013), and large copepods only (2000-2007 and 2014-2017)



Study area with location of zooplankton sampling

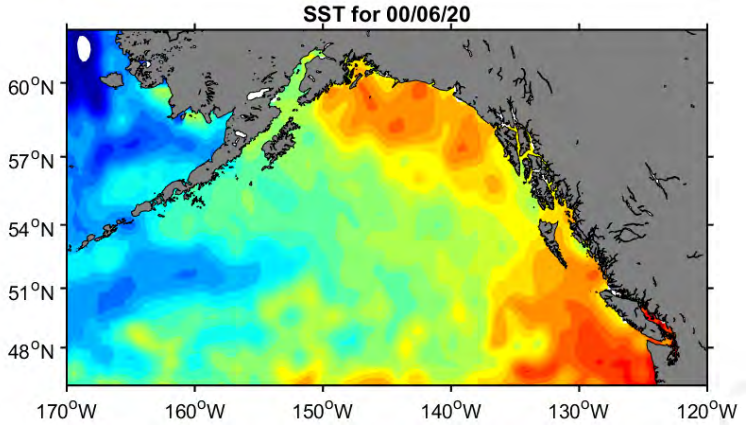
Then run for stable isotopes analysis, $\delta^{15}N$ and $\delta^{13}C$ (corrected from lipids and Suess effect)

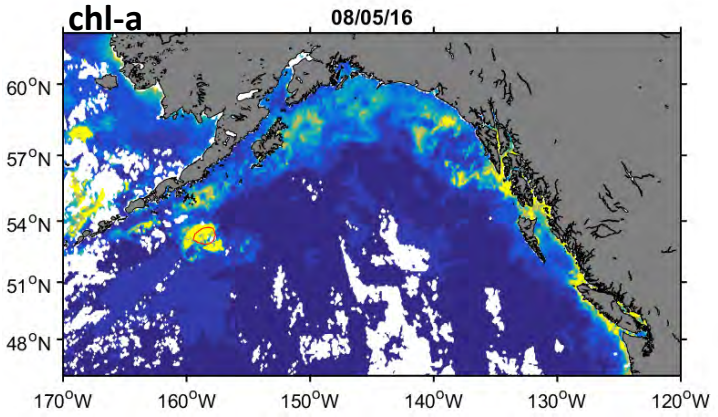
METHODS

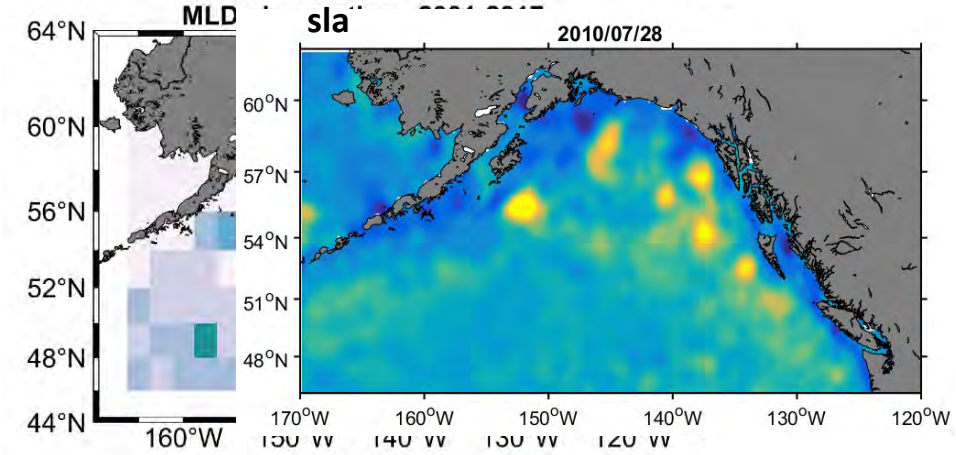
DEFINING PARAMETERS

A set of potential predictors was assembled using different sources:

- Satellite data
  - SST
  - Chlorophyll *a* concentration
  - Sea level anomaly
- Bathymetry
  - Distance to 200 m isobath
- Argo float
  - Mixed layer depth
- Atmospheric
  - Wind data





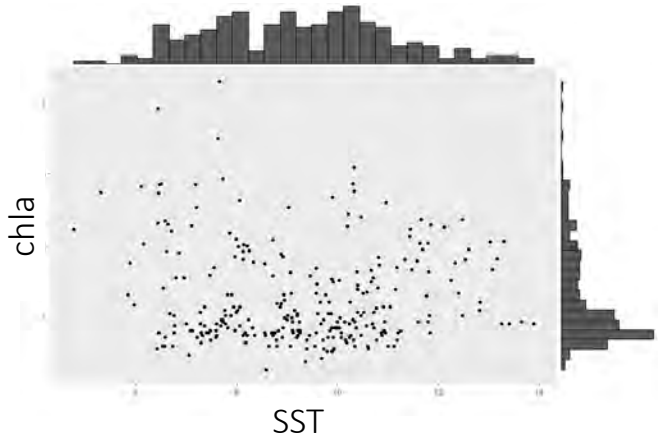


METHODS

GAM MODEL

Developing a GAM model:

- Building parameters
  - SST and sla averaged for 1-2 weeks before sampling date or at a fixed date.
  - Chl-a integrated over different time range to represent production over spring (4 months average) and recent state of the system (1 month).



Example of non-collinearity between two predictors

- Checking for presence of outliers, collinearity between predictors and relationship between the response variable and the predictors.
- Testing them to keep only the ones which are significant.

METHODS

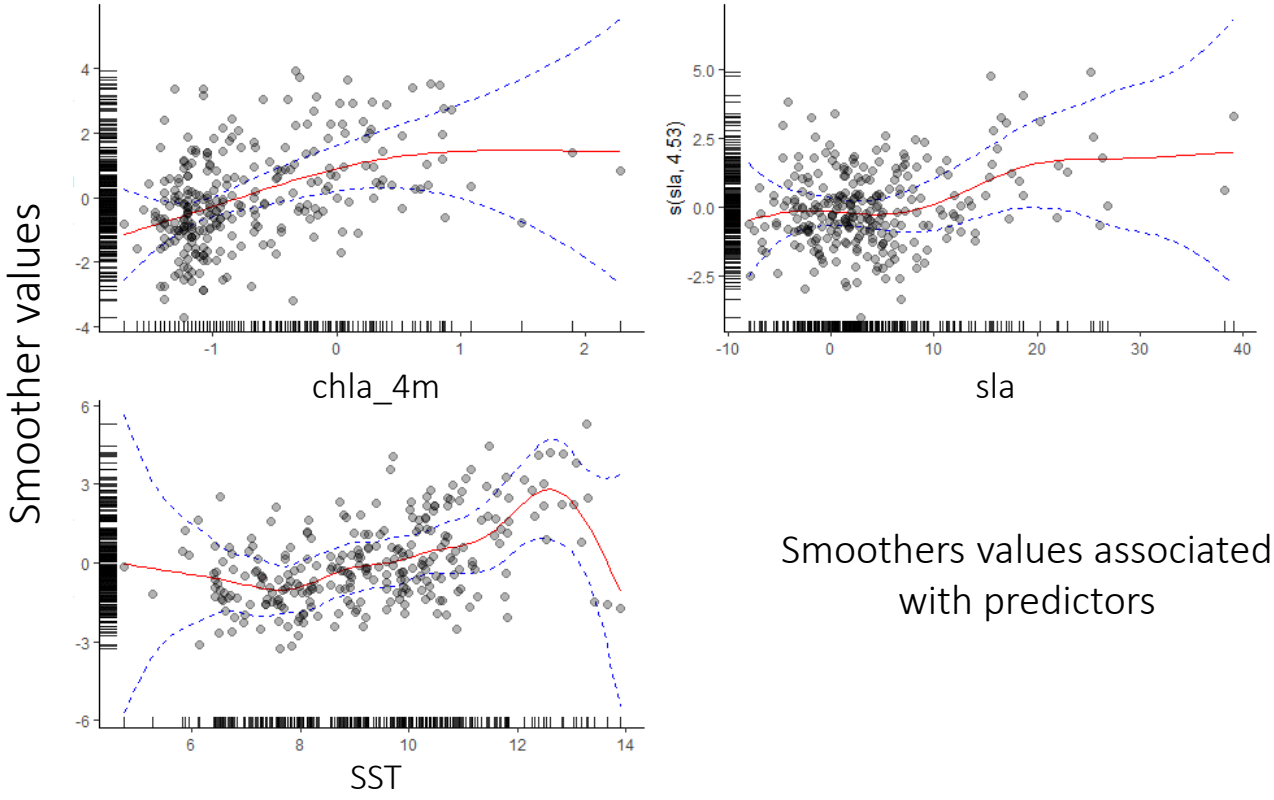
GAM MODEL

Model results

$\delta^{15}N \sim s(chla\_4m) + s(sla) + s(SST) + s(MLD)$

50.3% of variance explained, up to 59.4% including MLD

$\delta^{15}N$



Smoothers values associated with predictors

METHODS

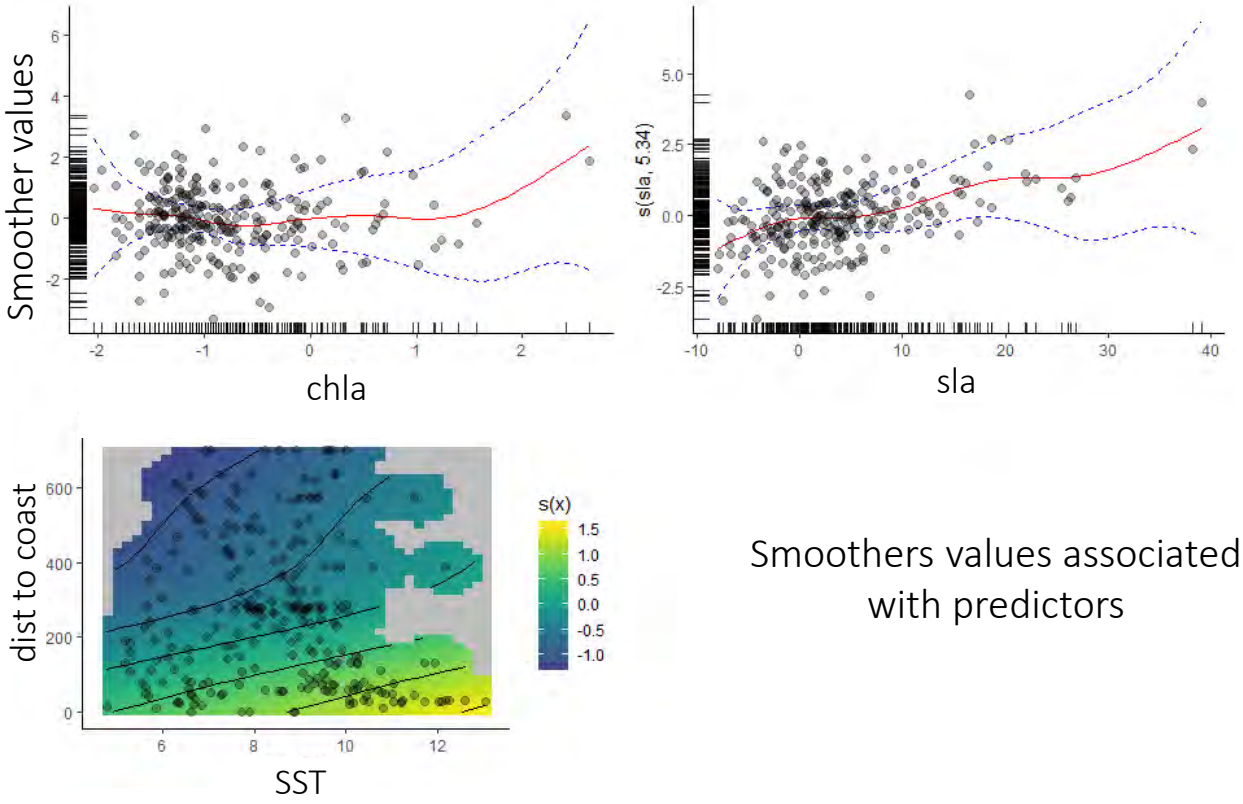
GAM MODEL

Model results

$\delta^{13}C \sim s(chla) + s(sla) + s(SST\_June, dist2coast)$

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

$\delta^{13}C$



Smoothers values associated with predictors

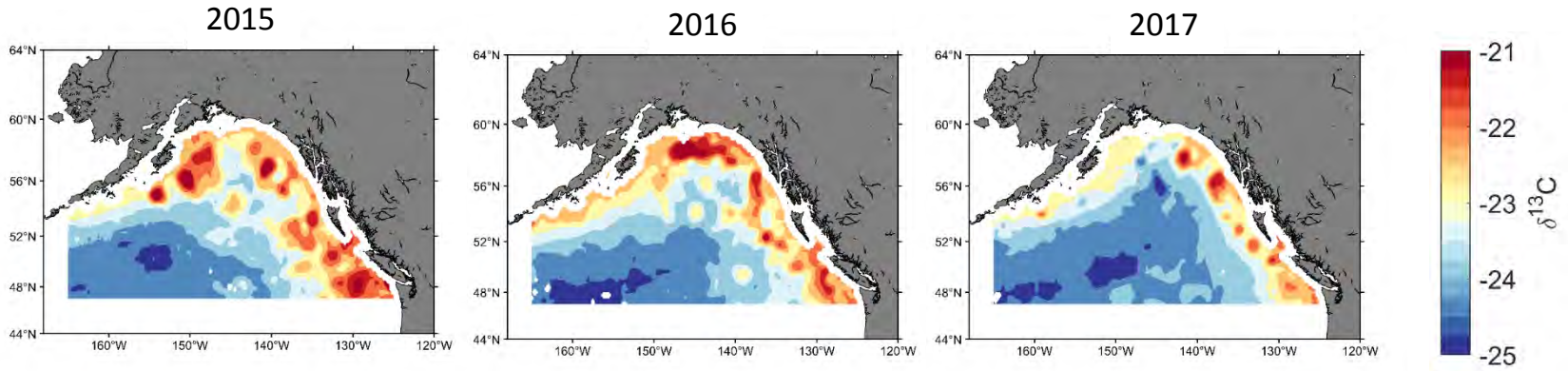
RESULTS

MODEL BASED ISOSCAPES

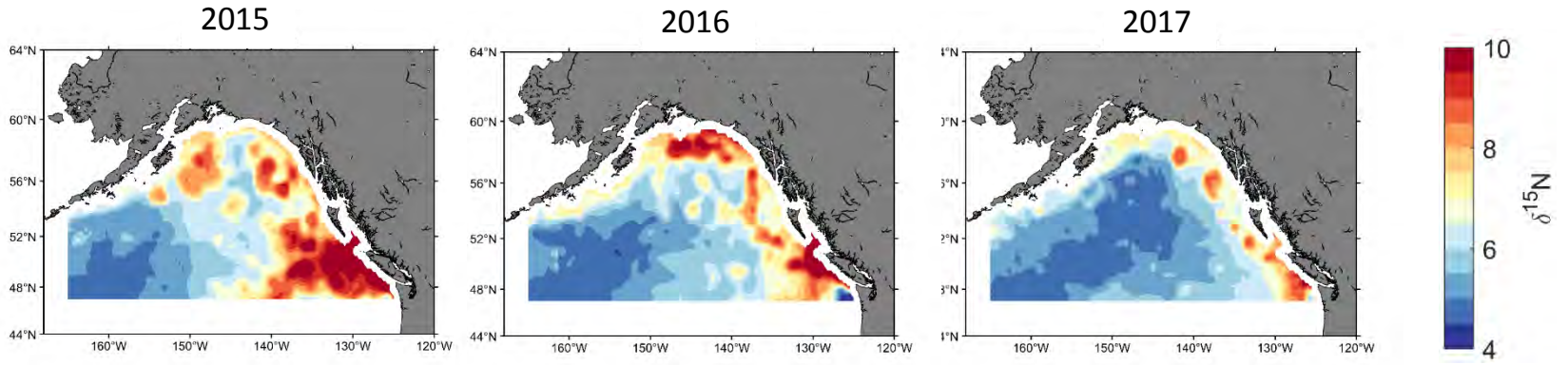
Isoscapes were produced for 1998-2017.

There are similarities between C and N SI distributions, but also differences.

$\delta^{13}C$



$\delta^{15}N$



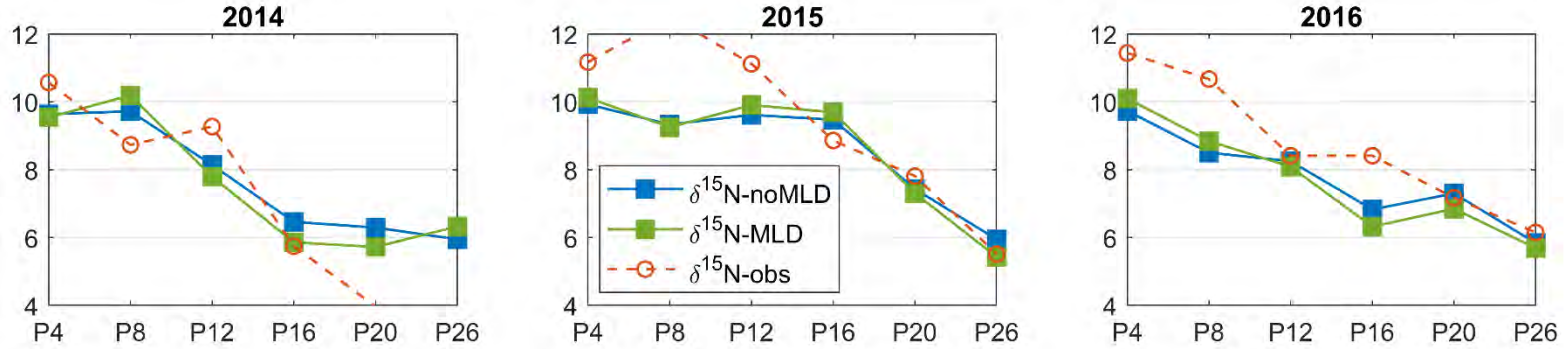
Isoscapes predicted using GAM model for the last three years

RESULTS

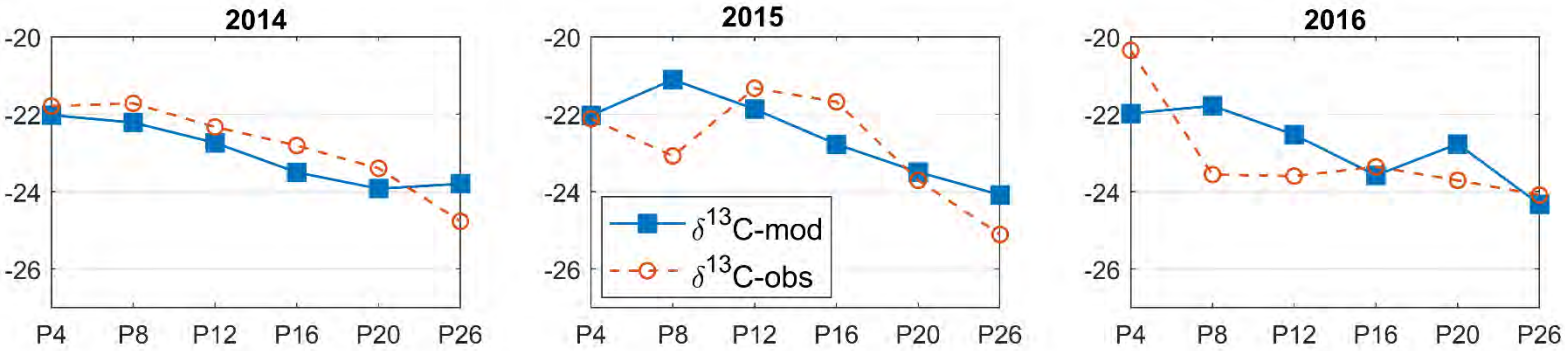
VALIDATING MODELS

coast → offshore

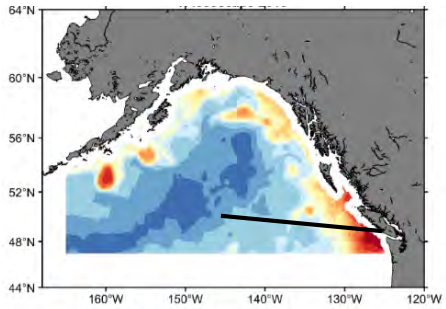
$\delta^{15}N$



$\delta^{13}C$



Modelled C and N values (produced by a submodel not including the data modelled) compared to observation data along Line P



The model was validating by plotting modelled values along the Line P against observations.

More variability in observational data but general patterns are reproduced.

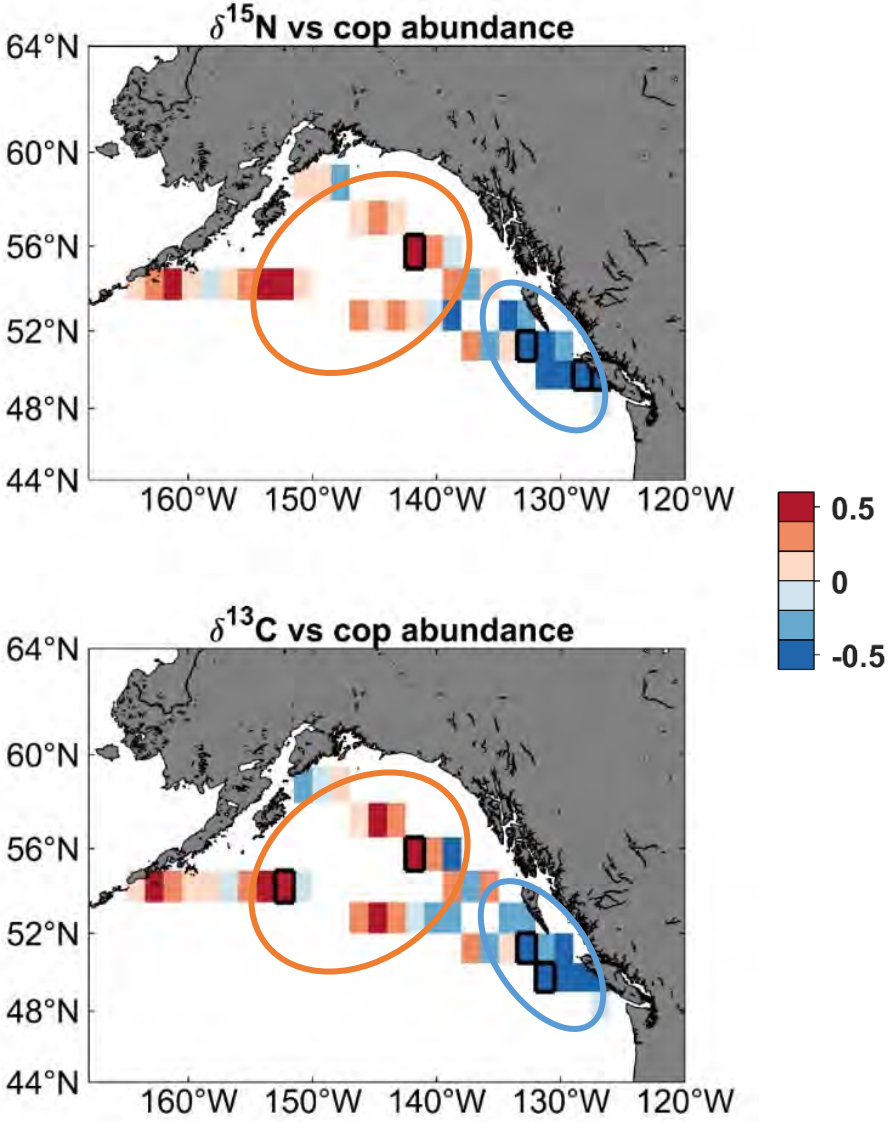
APPLICATIONS

INDEX OF OCEAN PRODUCTIVITY

Developing an index of ocean productivity requires to define relationship between SI values and zooplankton abundance/biomass.

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

with opposite correlation signs.



Correlation between N and C SI and large copepod abundance from CPR

APPLICATIONS

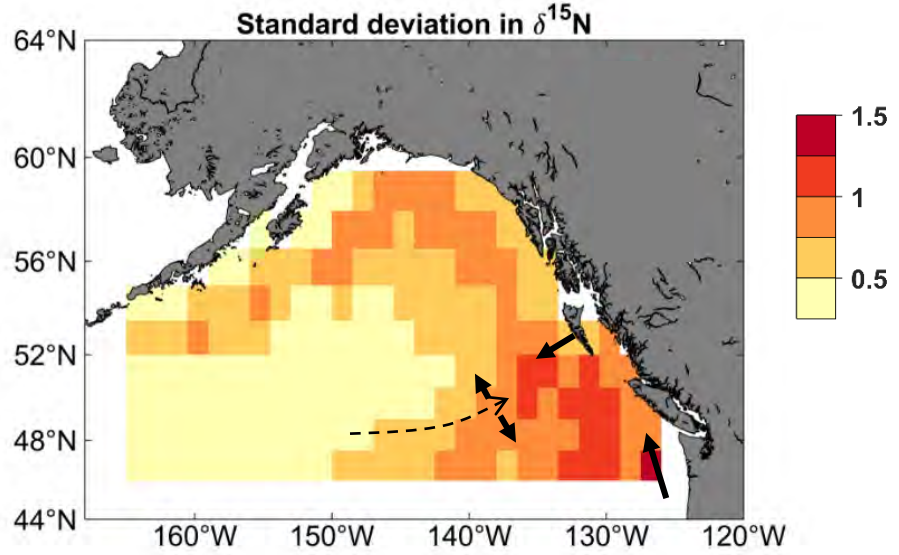
INDEX OF OCEAN PRODUCTIVITY

Why different sign in the sub-regions?

Positive correlation in Gulf of Alaska is rather intuitive, $\delta^{15}N$ being usually referred to as an index of productivity, so higher $\delta^{15}N$ = more large copepods.

But along BC coast, the sign is reverse.

This area is exposed to sharp changes in environmental conditions due to eddies, upwelling and current variability.



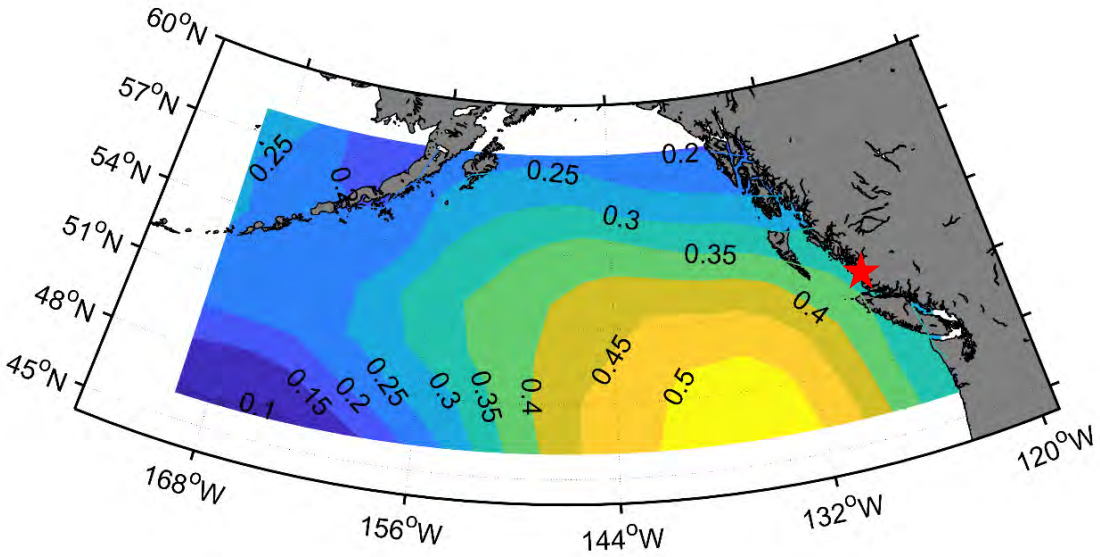
Interannual variability in modelled $\delta^{15}N$ and potential mechanisms influencing it

APPLICATIONS

FISH MIGRATION PATHWAYS

Fish migration pathways can be inferred in a few different ways.

Previous work have shown that the relationship between $\delta^{13}C$ and SST can be used to estimate feeding ground location of salmon stocks (see poster S7-P7).



Proposed feeding area for Rivers Inlet sockeye stock over the 9 months prior to returning to river. *Espinasse et al., CJFAS In press*

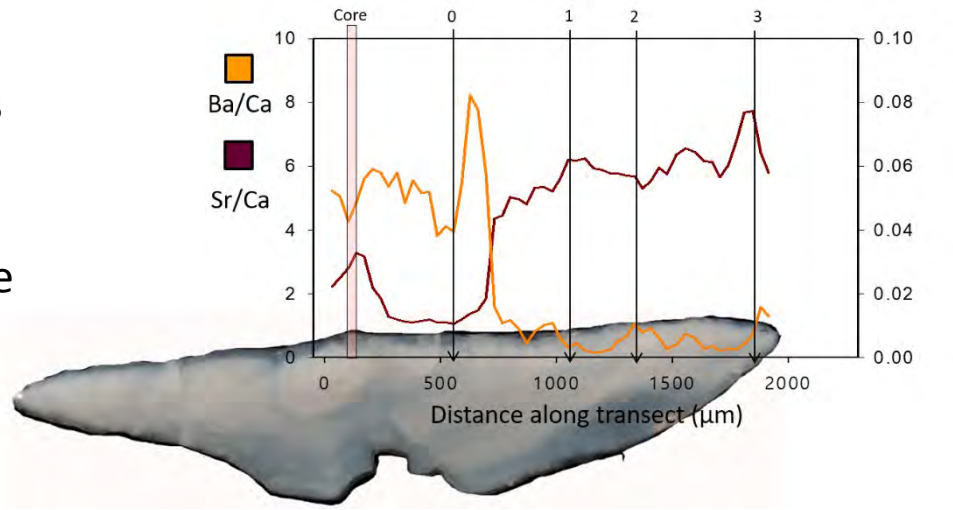
APPLICATIONS

FISH MIGRATION PATHWAYS

The isoscapes can provided information on a yearly basis by comparing salmon SI with prey SI distribution and defining area where they match.

Some limitations will occur due to the SI integration time (tissue turnover) and non-unique value distribution.

However, the use of complementary methods, such as microchemistry and SI in otoliths can help to narrow down the spatial and temporal ranges of the fish location estimate.



Example of changes in two element to calcium ratios across the lifetime of a sockeye salmon from Rivers Inlet. Ages are identified by drop-down arrows. Courtesy of Wade Smith, UBC.

SUMMARY

To conclude:

- C and N isoscapes at zooplankton level were generated for 1998-2017.

- We identified two different regimes in the Northeast Pacific based on the relationship between C and N SI ratio 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 will be freely available.

Thank you!

Please come to visit poster S7-P7 for more information about fish tracking and long term change in salmon SI.