Modeling Environmental Factors Affecting Assimilation of Bomb-produced $\Delta^{14}C$ in the North Pacific Ocean: Implications for Age Validation Studies

NOAA FISHERIES

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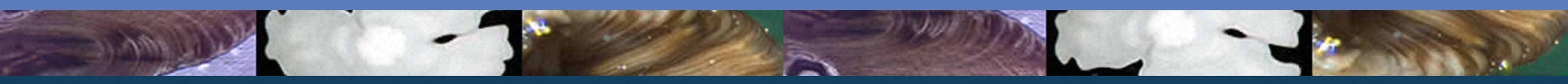

Introduction

- Bomb radiocarbon (^{14}C) is a widely used tool for fish age validation, and considered the gold standard.
- Uses a known age reference chronology, like Pacific halibut (Fig. 1).
- Measured values of ^{14}C cored from otoliths of fish of unknown age (validation sample) are statistically compared to the ^{14}C reference.
- A principle assumption is that the reference chronology must be biologically and environmentally representative of the validation specimens evaluated.
- Oceanographic processes such as currents, wind or upwelling may affect the level of ^{14}C in fish otoliths.

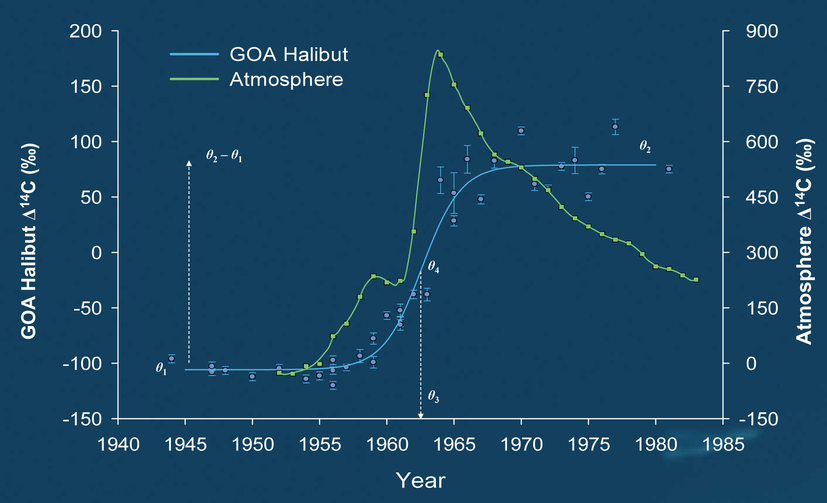

Figure 1. Atmospheric and Pacific halibut reference ^{14}C (from Piner and Wischniowski, 2004).

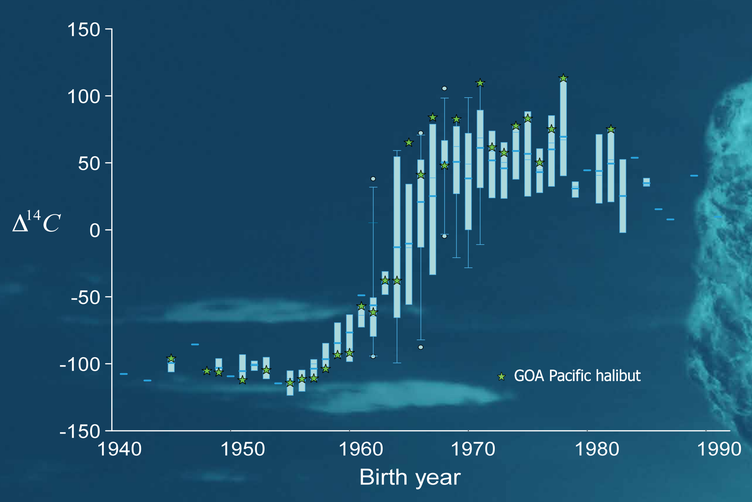

Figure 2. ^{14}C plotted by birth year for 13 data sets in the eastern North Pacific Ocean.

Objectives

We investigated the timing and strength of bomb-derived ^{14}C marine signal and its relationship to oceanographic gradients in the North Pacific Ocean.

Methods

- Thirteen north Pacific species analyzed $\Delta^{14}C$ by latitude and upwelling index (Fig.2).
- A hierarchical Bayesian logistic model was fit to $\Delta^{14}C$ data: $\Delta^{14}\hat{C} = \theta_1 + \frac{\theta_2}{1+\exp[(\theta_3 - t)/\theta_4]} + \sigma_e^2$
  - *θ_3 = year of 50% rise in logistic curve.*
  - *θ_2 = magnitude of rise in the logistic curve.*
- Systematic changes in model parameters $\theta_{1\text{-}4}$ (fit using Markov Chain Monte Carlo simulation) as a function of latitude and upwelling were tested.

Results

- Latitude and upwelling were important factors in predicting the timing and total rise of $\Delta^{14}C$ increase in the North Pacific Ocean (Fig. 3 & 4).
- Total rise in $\Delta^{14}C$ concentration (θ_2) increased linearly with latitude, while the timing of $\Delta^{14}C$ rise (θ_3) declined (Fig. 3).
- Model parameters showed a similar linear response to upwelling; θ_2 declined while θ_3 increased as upwelling intensified (Fig. 4).
- Within the observed latitudinal and upwelling range of the data sets examined in this study the predicted timing of the bomb pulse curve varied by as much as 3 years, which could be misinterpreted as ageing error.

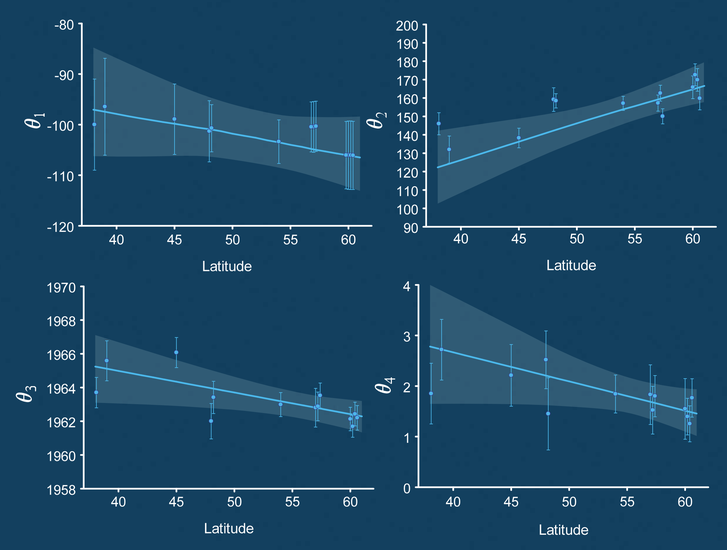

Figure 3. Observed magnitude (θ_2) of ^{14}C rise and year of 50% (θ_3) rise (dots) and predicted (solid line) relationship with latitude. Credible intervals (95%) shown in shaded area.

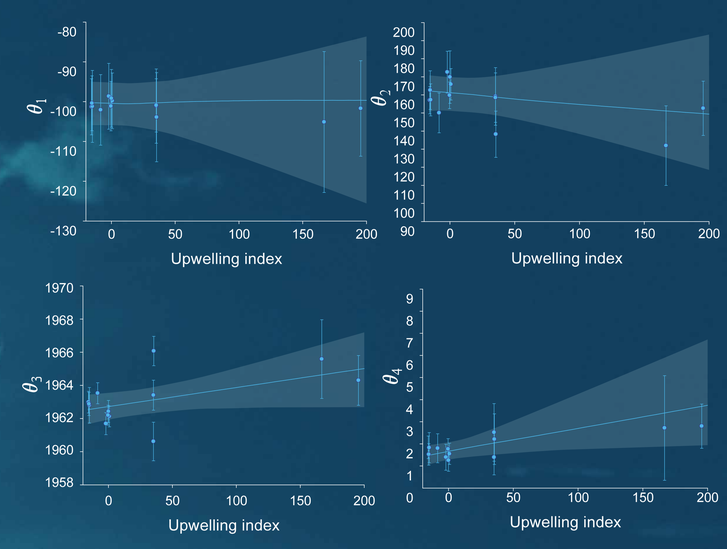

Figure 4. Observed magnitude (θ_2) of ^{14}C rise and year of 50% (θ_3) rise (dots) and predicted (solid line) relationship with upwelling. Credible intervals (95%) shown in shaded area.

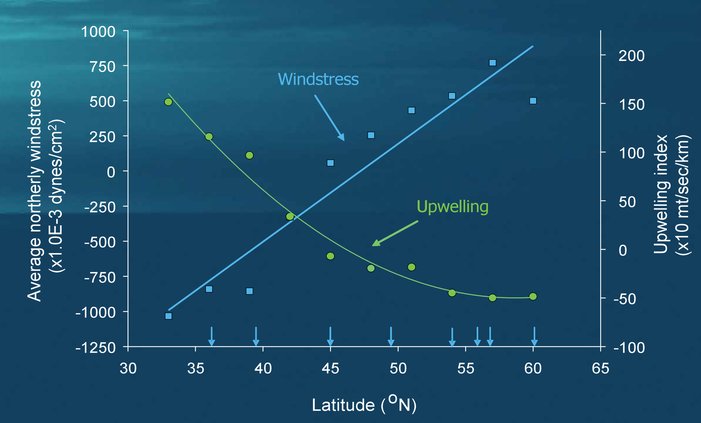

Figure 5. Average northerly wind stress and upwelling index versus latitude. Arrows indicate general latitude of various ^{14}C data sets used in this analysis.

References

Helser, T.E., Kastelle, C.R., Lai, Han-L. 2014. Modeling environmental factors affecting assimilation of bomb-produced $\Delta^{14}C$ in the North Pacific Ocean: Implications for age validation studies

Piner, K.R., Wischniowski, S.G. 2004. Pacific halibut chronology of bomb radiocarbon in otoliths from 1944 to 1981 and a validation of ageing methods. J. Fish Biol. 64(4):1060-1071.

Conclusions

- Oceanographic factors likely affect the level of $\Delta^{14}C$ uptake in hard structures (otoliths) of marine organisms in the North Pacific Ocean.
- Transition from the California Current system with intense upwelling to the Gulf of Alaska Current with net downwelling and wind stress may explain observed patterns in $\Delta^{14}C$ change (Fig. 5).
- It is important to use the environmentally correct reference chronologies for bomb $\Delta^{14}C$ age validation studies.
- Our results suggest that new reference chronologies may be needed for regions of the North Pacific Ocean differing in latitude, seasonal upwelling strength and other mixing factors that can potentially change the functional form of the $\Delta^{14}C$ curve.

The recommendations and general content presented in this poster do not necessarily represent the views or position of the Department of Commerce, the National Oceanic and Atmospheric Administration, or the National Marine Fisheries Service.