**Supplementary Information Text**

**1. Methods for compound specific stable isotope analysis**

Collagen samples have been analyzed for both CSSIA and bulk δ15N which require 10 mg of purified collagen (100 mg of bone). Preliminary analyses were conducted to determine the highest rate of collagen return from bone sampled from different parts of the skull to minimize destruction. Samples were taken from the internal occipital shelf to maintain external integrity. Laboratory preparation occurred in the Holgrieve Ecosystem Ecology Lab at University of Washington. Bone was decalcified using 0.2 M HCl for 24-72 hours depending on bone thickness, followed by centrifugation and nanopure water rinse. Removal of humic acids was conducted using 0.125 M NaOH for 20 hours. Samples were washed to a neutral pH, then solubilized in 0.01N HCl. Once solubilized samples were blown down under N2 to prevent isotopic fractionation, and freeze dried. Freeze dried collagen was be analyzed for bulk isotopic composition of nitrogen by the UW IsoLab (isolab.ess.washington.edu) using a coupled elemental analyzer-isotope ratio mass spectrometer following the standard protocols of the laboratory. C:N ratios were calculated from this data, which is a measure of the quality for carbon and nitrogen analyses of bone collagen for isotopic analysis. Only three observations were outside of the acceptable rang of 2.7-3.6; indicating there was no substantial loss of glycine or addition of nitrogen due to microbial processing from mortality, decay, curation, and analysis.

δ15N of eleven amino acids[[1]](#footnote-1) were measured in the new UW Facility for Compound-Specific Isotope Analysis of Environmental Samples. Samples were prepared following the procedures developed by Popp Marine Lab at University of Hawaii Manoa. Briefly, proteins were hydrolyzed in 6N HCl and purified using a cation exchange column. Amino acids were esterified using isopropanol acetyl chloride, and derivatized via acylation with 4:1 toluene: pivaloyl chloride. Samples were brought up in ethyl acetate and analyzed using a coupled gas chromatography-combustion-isotope ratio mass spectrometer system (GC-C-irMA; Thermo Scientific Trace GC + GC IsoLink coupled to a Delta V irMS) in continuous flow mode monitoring masses (m/z) 28 and 29 using a db-35 column. For each run a 12 amino acid external standard with known isotopic composition was injected three times followed by sample injections. Samples were injected in triplicate, with the 12 amino acid standard injected every two samples (or six injections). A two-hour column oxidation was performed after 6 samples(25 injections). Samples and standards included norleucine as an internal standard.

For each machine run, a linear model was fit for each individual amino acid using the following equation:

Where m represents the slope of the precision drift, t represents the injection number since last column oxidation, and Std represents the δ15N of an individual amino acid for a standard observation. The data was then corrected using the following equations:

Where Daa,t is the difference between an observed standard δ15N (Stdaa,t) for a given amino acid at a given injection number and the true δ15N for that standard. Then:

Where the drift value, Daa,t, is subtracted from the sample value for a given aa and a given injection to correct the observed sample values for precision drift since last column oxidation. Mean sample corrected values for the triplicate injections were used for all amino acid δ15N.

**2. Methods for dynamic factor analysis**

To reduce collinearity among environmental variables and limit the number of models tested, datasets were categorized *a priori* into four main mechanistic processes: climatic condition, surface mixing, sea surface temperature, and upwelling. To reduce the dimensionality of the data associated with each process we used fit a dynamic factor analysis (DFA) model to time series from each driver category to estimate a latent trend (Appendices 1 - 3). DFA is a dimension reduction technique that identifies common processes underlying a set of time series. The underlying model in DFA treats observed data as linear combinations of latent unobservable "trends" which are modeled as a random walk (Zuur et al. 2003). Latent variables are weighted based on the portion of temporal variation they explain taking the following form:

where δ15Nsource, and additional environmental variables (Table 1-3) were natural log transformed and then standardized.The observed data **y*t*** are modeled as combinations of latent trends **x**t at time *t* (the dimensions of  **x**tmatching the number of states) and factor loadings (**Z**) at time *t*, in addition to optional covariates (observed variables **d**t and estimated coefficients **D**) plus random observation error (**vt**) which are multivariate normal . DFA is commonly applied to multivariate time series problems in fisheries and ecology and has been used to identify patterns of oceanographic variability that drive Pacific salmon stocks (Stachura et al. 2014), and environmental drivers and stock structure of Chinook salmon (Jorgenson et al. 2016, Ohlbereger et al. 2016). Often, a question of DFA is to identify how many latent trends are supported for a particular dataset, and model selection methods are used to compare alternative model structures. Because we were interested in using DFA to generate indices of the environmental data, however, we limited the scope of our DFA models to just having one latent trend. We fit one DFA to the climatic drivers (which are shared across regions) and separate region-specific DFAs to data for sea surface temperature, upwelling, and surface mixing.

**3. Methods for Bayesian dynamic factor analysis using a Gaussian process model**

Gaussian Processes have been widely used in fisheries and other fields (Munch et al. 2018, Fish and Fisheries). Instead of modeling a time series as an autoregressive process, GPs model a time series via a mean and variance function, where represents and optional mean vector and a covariance matrix. For GPDFA, we assume the mean to be zero, letting just the covariance function determine the GP smoothing. GPs are flexible in that the covariance matrix can be described by a wide range of flexible functions; for this application we use a Gaussian kernel (squared exponential) so that , where is a variance parameter controlling the magnitude, is a shape parameter controlling how quickly covariance declines, and is the known distance between time points *i* and *j*. A benefit of modeling with a covariance function is that regardless of the dimensionality, all elements can be described by a small number of parameters. For GPDFA, we choose to use a GP predictive process model, because the number of time points may be large. This predictive model estimates the function values at a subset of locations (knots), and combines these estimates with the distance to locations at which data are observed to make predictions. More specifically, the values of the time series at the knot locations are . Given the known distances between the locations of knots and locations of data, the covariance matrix between the two can be calculated, . Finally, the predictions of the time series at the observed data can be calculated as

**SI References**

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**Table S1:** Collection dates, locations, δ13C, δ15N, and δ15Nphenyalanine from archival museum specimens of adult harbor seal (*Phoca vitulina*) collected in the northeast Pacific. Institution Codes:

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Institution | Specimen ID | δ15Nphenyalanine | δ13C | δ15N | Year | Subregion |
| BM | 20228 | 10.8623166 | NA | NA | 1959 | Coastal |
| BM | 32052 | 9.91983305 | NA | NA | 1977 | Inland |
| BM | 32053 | 13.6774433 | NA | NA | 1977 | Inland |
| BM | 32516 | NA | NA | NA | 1979 | Coastal |
| BM | 34967 | 11.9382852 | NA | NA | 1987 | Coastal |
| BM | 34969 | 12.5501195 | NA | NA | 1987 | Coastal |
| BM | 34974 | 9.54586125 | NA | NA | 1987 | Coastal |
| BM | 34983 | 9.2755683 | NA | NA | 1986 | Coastal |
| BM | 34988 | 12.6410841 | NA | NA | 1987 | Coastal |
| BM | 34989 | 11.1619124 | NA | NA | 1987 | Coastal |
| BM | 34990 | 9.579375 | NA | NA | 1987 | Coastal |
| BM | 34991 | 9.79343686 | NA | NA | 1987 | Coastal |
| BM | 34997 | 11.5592848 | NA | NA | 1987 | Coastal |
| BM | 35001 | 10.8781977 | NA | NA | 1988 | Coastal |
| BM | 36044 | 11.9247794 | NA | NA | 1979 | Inland |
| BM | 36045 | 10.8456686 | NA | NA | 1989 | Inland |
| BM | 36047 | 12.0507174 | NA | NA | 1989 | Inland |
| BM | 39398 | 10.5220344 | NA | NA | 1980 | Inland |
| BM | 51206 | 10.8345894 | -11.8316 | 17.4742 | 1980 | Inland |
| BM | 51213 | 13.8306357 | -10.4525 | 19.7667 | 1983 | Inland |
| BM | 80771 | 10.220875 | NA | NA | 2004 | Inland |
| BM | 80772 | 11.4124502 | -10.9489 | 16.5705 | 2007 | Inland |
| BM | 80773 | 11.9995455 | NA | NA | 2007 | Coastal |
| BM | 80774 | 11.2979197 | NA | NA | 1994 | Coastal |
| BM | 80776 | 11.8000833 | -12.3599 | 17.5523 | 2006 | Inland |
| BM | 80777 | 11.4316589 | -13.1147 | 17.2891 | 2007 | Coastal |
| BM | 80778 | 10.7881529 | -12.8056 | 16.2282 | 2008 | Coastal |
| BM | 80780 | 17.5675 | -11.1575 | 17.2182 | 2006 | Inland |
| BM | 80782 | 10.7441074 | -11.9114 | 17.1076 | 2007 | Inland |
| BM | 81078 | 10.2594863 | NA | NA | 2008 | Inland |
| BM | 81979 | 13.8418926 | NA | NA | 2011 | Inland |
| BM | 82369 | 13.1576383 | NA | NA | 2014 | SE |
| BM | 82370 | 9.22638359 | NA | NA | 2014 | SE |
| BM | 82371 | 8.39169029 | NA | NA | 2014 | SE |
| BM | 82372 | 7.97098881 | NA | NA | 2014 | SE |
| BM | 82685 | 11.9543471 | -13.3727 | 18.71 | 2012 | Inland |
| NM | 1905 | 14.863087 | -10.1656 | 18.211 | 1999 | Inland |
| NM | 1915 | 13.476083 | -10.5641 | 17.8098 | 1996 | Inland |
| NM | 1917 | 5.88511243 | -9.9073 | 17.8737 | 1998 | Inland |
| NM | 1918 | 12.5821423 | -10.3121 | 18.2801 | 1998 | Inland |
| NM | 1919 | 11.9090567 | -10.5249 | 17.9926 | 1998 | Inland |
| NM | 1984 | 11.158561 | -12.966 | 17.8156 | 1991 | Coastal |
| NM | 1995 | 13.2690556 | -13.1746 | 17.6423 | 1991 | Coastal |
| NM | 2001 | 10.2991199 | -14.0639 | 16.7595 | 1991 | Coastal |
| NM | 2016 | 12.0347667 | -13.4448 | 17.2948 | 1991 | Coastal |
| NM | 2024 | 10.7354811 | -14.0446 | 17.0014 | 1992 | Coastal |
| NM | 2025 | 10.6528742 | -14.9391 | 16.3401 | 1992 | Coastal |
| NM | 2027 | 10.9826908 | -13.3855 | 17.4521 | 1992 | Coastal |
| NM | 2028 | 8.86571359 | -12.1156 | 17.7579 | 1992 | Coastal |
| NM | 2032 | 11.2609154 | -13.1559 | 17.2414 | 1992 | Coastal |
| NM | 2044 | 10.8120396 | -13.3601 | 17.9678 | 1981 | Coastal |
| NM | 2045 | 13.2075799 | -13.4284 | 17.6852 | 1981 | Coastal |
| NM | 2048 | 9.85235045 | -13.9664 | 17.3541 | 1981 | Coastal |
| NM | 2050 | 14.390432 | -13.2173 | 17.923 | 1981 | Coastal |
| NM | 2062 | 12.9127312 | -12.6153 | 18.3572 | 1982 | Coastal |
| NM | 2064 | 12.8399082 | -12.6263 | 18.1152 | 1982 | Coastal |
| NM | 2065 | 13.3588333 | -12.3241 | 16.9694 | 1982 | Coastal |
| NM | 2067 | 11.4549931 | -12.7824 | 17.8405 | 1982 | Coastal |
| NM | 2068 | 15.1706409 | NA | NA | 1982 | Coastal |
| NM | 2231 | 12.1170868 | -10.5979 | 17.8413 | 2013 | Inland |
| NM | 2232 | 12.0560298 | -12.9218 | 16.9191 | 2013 | Inland |
| NM | 2233 | 14.3269783 | -12.46 | 17.02 | 2013 | Inland |
| NM | 2234 | 11.6237319 | -13.1792 | 16.3416 | 2013 | Inland |
| NM | 2235 | 10.2722802 | -13.7537 | 16.3935 | 2013 | Inland |
| NM | 2236 | 13.8693558 | -14.1314 | 16.394 | 2014 | Inland |
| RM | 10273 | 14.4132727 | -12.290 | 18.155 | 1979 | Inland |
| RM | 10834 | 13.9125226 | -13.4412 | 18.4654 | 1982 | Inland |
| RM | 11409 | 18.1993329 | -11.7278 | 16.9206 | 1983 | Inland |
| RM | 11449 | 14.9120444 | NA | NA | 1982 | Inland |
| RM | 11768 | 14.1161123 | -11.9683 | 18.6133 | 1983 | Inland |
| RM | 12847 | 14.7157926 | -12.8222 | 18.8131 | 1979 | Inland |
| RM | 2361 | 14.093963 | -14.1979 | 17.739 | 1937 | Inland |
| RM | 4934 | 14.9492205 | -13.58 | 18.8514 | 1942 | Inland |
| RM | 7412 | 14.737796 | -12.3778 | 16.4037 | 1971 | Inland |
| RM | 7714 | 11.2880657 | -10.3845 | 17.795 | 1969 | Inland |
| RM | 9723 | 9.85352664 | -12.9282 | 18.5437 | 1977 | Inland |
| RM | 9729 | 11.6436986 | -12.0156 | 17.5623 | 1969 | Inland |
| RM | 9730 | 11.6587833 | -12.76 | 15.46 | 1969 | Inland |
| RM | 9732 | 15.2131932 | -10.845 | 16.6755 | 1969 | Inland |
| RM | 9733 | 14.7256953 | -14.03 | 15.755 | 1969 | Inland |
| RM | 9802 | 12.3662414 | -11.7358 | 17.0746 | 1970 | Inland |
| RM | 9804 | 10.9290416 | -12.1834 | 17.43 | 1969 | Inland |
| RM | 9874 | 11.5138104 | -12.973 | 17.4517 | 1970 | Inland |
| SI | 253041 | 16.6356981 | -6.6578 | 18.021 | 1928 | Inland |
| SI | 253042 | 8.92594457 | -10.5404 | 17.7126 | 1928 | Inland |
| SI | 253043 | 17.5322387 | -11.2747 | 17.8662 | 1928 | Inland |
| SI | 274144 | 15.8408808 | -13.5214 | 19.3902 | 1942 | Coastal |
| SI | 274146 | 7.49957829 | -13.3494 | 17.4496 | 1942 | Coastal |
| SI | 274152 | 11.6162273 | -11.9956 | 17.4284 | 1942 | Inland |
| SI | 274153 | 12.5795868 | -10.5314 | 18.4356 | 1942 | Inland |
| SI | 274154 | 9.83852265 | -9.8041 | 18.3495 | 1942 | Inland |
| SI | 274156 | 13.9458307 | -12.1703 | 17.3823 | 1942 | Coastal |
| SI | 276058 | 10.4771263 | -11.8847 | 18.8113 | 1942 | Coastal |
| SI | 276059 | 6.01404923 | -13.789 | 18.8196 | 1942 | Coastal |
| SM | 15182 | 9.72537195 | -11.9991 | 17.6128 | 1970 | Inland |
| SM | 15204 | 10.7313333 | -12.4283 | 18.4696 | 1971 | Inland |
| SM | 15209 | NA | -11.807 | 18.3053 | 1970 | Inland |
| SM | 15210 | 9.89149184 | -10.8364 | 17.1887 | 1970 | Inland |
| SM | 15274 | 11.6273824 | -11.4084 | 17.5144 | 1969 | Coastal |
| SM | 16043 | 11.9269644 | -11.7217 | 17.5863 | 1972 | Inland |
| SM | 16044 | 11.146665 | -10.3312 | 18.2331 | 1977 | Inland |
| SM | 16056 | NA | -13.5745 | 16.9248 | 1972 | Inland |
| SM | 16062 | 9.59978007 | -13.1759 | 17.5725 | 1972 | Inland |
| SM | 16095 | 8.93229472 | -15.0031 | 17.1952 | 1972 | Coastal |
| SM | 16096 | 7.73641992 | -13.4157 | 16.851 | 1972 | Coastal |
| SM | 16096 | 7.73641992 | -13.6958 | 17.5096 | 1972 | Coastal |
| SM | 16097 | 10.3729908 | -11.4618 | 19.1099 | 1972 | Coastal |
| SM | 20085 | 13.5794267 | -11.4019 | 18.802 | 1975 | Inland |
| SM | 20087 | 16.0277285 | -12.1974 | 17.5347 | 1976 | Inland |
| SM | 21180 | 13.4519858 | -13.853 | 18.1675 | 1976 | Inland |
| SM | 21182 | 15.1469016 | -11.7437 | 18.6728 | 1976 | Inland |
| SM | 25695 | NA | -12.8034 | 16.8882 | 1977 | Coastal |
| SM | 25696 | 11.6357048 | -12.4578 | 18.1578 | 1977 | Coastal |
| SM | 25700 | NA | -12.8295 | 17.0688 | 1977 | Coastal |
| SM | 25701 | 12.4860347 | -12.1046 | 17.2099 | 1977 | Coastal |
| SM | 25702 | 13.1044966 | -14.3053 | 19.5393 | 1977 | Coastal |
| SM | 25705 | 10.3948613 | -11.6794 | 17.185 | 1977 | Coastal |
| SM | 25706 | 11.529208 | -14.1653 | 18.958 | 1977 | Coastal |
| SM | 25711 | 12.6216987 | -12.5467 | 16.933 | 1977 | Coastal |
| SM | 25712 | NA | -12.7521 | 17.1176 | 1977 | Coastal |
| SM | 25714 | 13.3201865 | -12.7949 | 18.3784 | 1977 | Coastal |
| SM | 25740 | 11.5662606 | -13.9958 | 18.7539 | 1978 | Coastal |
| SM | 25742 | 12.3044051 | -13.2305 | 18.7861 | 1978 | Coastal |
| SM | 25743 | 11.4113888 | -12.887 | 17.1007 | 1978 | Coastal |
| SM | 25744 | 7.3297839 | -12.9062 | 17.905 | 1978 | Coastal |
| SM | 25892 | 11.9492324 | -12.7032 | 18.5754 | 1977 | Inland |
| SM | 25893 | NA | -11.0742 | 18.8966 | 1977 | Inland |
| SM | 25894 | 9.89588316 | -12.672 | 18.0628 | 1977 | Inland |
| SM | 25895 | 10.3296318 | -12.9734 | 18.2419 | 1977 | Inland |
| SM | 25896 | 12.5248969 | NA | NA | NA | Coastal |
| SM | 27370 | 12.1358527 | -11.2825 | 18.3517 | 1979 | Inland |
| UA | 11475 | 11.2990351 | -12.9576 | 17.2376 | 1962 | SC |
| UA | 11712 | 10.1143544 | -14.30 | 16.195 | 1972 | SE |
| UA | 11713 | 11.3619661 | -13.8185 | 16.5685 | 1965 | SE |
| UA | 11738 | 8.28702428 | -13.7299 | 16.215 | 1973 | SC |
| UA | 11740 | 9.3091116 | -13.7008 | 15.971 | 1973 | SC |
| UA | 11742 | 10.1263168 | -13.4086 | 18.375 | 1973 | SC |
| UA | 11743 | 21.5003681 | -12.765 | 20.2015 | 1973 | SC |
| UA | 11747 | 13.4925347 | -13.8089 | 16.6759 | 1973 | SC |
| UA | 11770 | 13.0072898 | -13.4265 | 16.713 | 1972 | SC |
| UA | 11771 | 13.3684849 | -13.2065 | 16.538 | 1980 | SC |
| UA | 11774 | 9.24325807 | -13.4397 | 16.7945 | 1972 | SC |
| UA | 11777 | 10.8613387 | -12.7731 | 19.0281 | 1972 | SE |
| UA | 11779 | 8.82982312 | -14.3894 | 16.1616 | 1972 | SE |
| UA | 11816 | 9.62096777 | -14.2481 | 16.5144 | 1973 | SC |
| UA | 11817 | 10.9212976 | -13.9599 | 16.3531 | 1973 | SC |
| UA | 11827 | 13.6658131 | -12.9853 | 17.4308 | 1975 | BB |
| UA | 11836 | 13.5114335 | -14.7285 | 16.7699 | 1973 | SC |
| UA | 11920 | 11.0535946 | -14.8142 | 16.1103 | 1975 | SC |
| UA | 11921 | 14.9429422 | -13.605 | 17.427 | 1972 | SC |
| UA | 19119 | 12.681466 | -11.7186 | 18.8274 | 1972 | SE |
| UA | 19122 | 8.19330121 | -14.4495 | 16.0257 | 1972 | SE |
| UA | 19123 | 10.5001745 | -12.4359 | 18.7451 | 1972 | SE |
| UA | 19124 | 12.9600576 | -12.5804 | 17.1481 | 1972 | SE |
| UA | 19159 | 16.9251129 | -11.6924 | 20.4049 | 1981 | BB |
| UA | 19161 | 17.1673392 | -11.8283 | 19.7269 | 1981 | BB |
| UA | 19172 | 14.4105091 | -13.1271 | 19.3342 | 1981 | BB |
| UA | 19173 | 15.0223985 | -12.8453 | 20.248 | 1981 | BB |
| UA | 19174 | 13.3093117 | -14.1078 | 18.5015 | 1981 | BB |
| UA | 19175 | 15.3560406 | -12.6304 | 19.1445 | 1981 | BB |
| UA | 21485 | 11.0335671 | -13.1363 | 17.0044 | 1965 | SE |
| UA | 28932 | 11.8915948 | -13.0549 | 18.9773 | 1965 | SE |
| UA | 28933 | 11.425295 | -12.725 | 16.3271 | 1965 | SE |
| UA | 28935 | 14.8610934 | -12.9681 | 18.9912 | 1966 | BB |
| UA | 28936 | 18.8883 | -11.9112 | 20.1751 | 1966 | BB |
| UA | 28937 | 18.3886608 | NA | NA | 1966 | BB |
| UA | 28938 | 12.4208443 | NA | NA | 1966 | BB |
| UA | 28940 | 14.8932749 | -11.7847 | 19.9807 | 1966 | BB |
| UA | 28941 | 14.393741 | -12.5614 | 18.5995 | 1966 | BB |
| UA | 28943 | 14.5233276 | -12.5438 | 19.4857 | 1966 | BB |
| UA | 28950 | 9.30623461 | -13.6715 | 17.0457 | 1980 | SC |
| UA | 35432 | 13.5108253 | -12.8831 | 17.2253 | 1995 | SE |
| UA | 35434 | 10.357398 | -13.833 | 17.216 | 1996 | SE |
| UA | 35437 | 10.1778118 | -14.4468 | 16.8447 | 1996 | SC |
| UA | 35438 | 13.8793888 | -14.4945 | 17.7283 | 1996 | SC |
| UA | 35439 | 11.2625176 | -14.502 | 16.1952 | 1996 | SC |
| UA | 35440 | 20.1294198 | -14.6401 | 17.6696 | 1996 | SC |
| UA | 35442 | 12.0368354 | -14.6612 | 16.7648 | 1996 | SC |
| UA | 35445 | 12.4497688 | -13.9779 | 16.7023 | 1996 | SC |
| UA | 35446 | 12.4572474 | -13.7989 | 17.5925 | 1996 | SC |
| UA | 35447 | 10.7507313 | -15.4261 | 16.7039 | 1996 | SC |
| UA | 35449 | 14.1612684 | -13.6245 | 17.6873 | 1996 | SC |
| UA | 35450 | 10.7196675 | -14.5832 | 16.7397 | 1996 | SC |
| UA | 36254 | 10.0466567 | -13.7833 | 17.4365 | 1965 | SE |
| UA | 3702 | 12.0151169 | -13.309 | 18.4749 | 1955 | SC |
| UA | 37972 | 11.9497681 | -14.3699 | 17.0816 | 1996 | SE |
| UA | 37973 | 10.0446158 | -13.1675 | 17.003 | 1995 | SE |
| UA | 37974 | 9.78095004 | -13.2195 | 16.4499 | 1995 | SE |
| UA | 41613 | 9.46262648 | -13.4057 | 16.7201 | 1996 | SE |
| UA | 41615 | 9.75198957 | -14.4843 | 15.5507 | 1995 | SE |
| UA | 41616 | 8.87896566 | -13.542 | 16.3578 | 1995 | SE |
| UA | 42151 | 12.6348952 | -14.2255 | 17.8114 | 1996 | BB |
| UA | 42152 | 16.2767 | -13.0812 | 19.9123 | 1996 | BB |
| UA | 43044 | 16.6540216 | -13.3326 | 19.511 | 1996 | BB |
| UA | 47510 | 16.8942847 | -12.087 | 20.201 | 1985 | BB |
| UA | 47511 | 14.1602642 | -13.1303 | 19.497 | 1985 | BB |
| UA | 52183 | 15.2402827 | -13.967 | 17.5393 | 1997 | BB |
| UA | 52184 | 14.5776567 | -13.4857 | 19.7202 | 1997 | BB |
| UA | 84943 | 9.80194646 | -14.0599 | 17.028 | 2002 | SC |
| UA | 84950 | 12.4622811 | -15.1774 | 17.7951 | 2002 | SC |
| UA | 84958 | 6.20969938 | -15.8971 | 15.283 | 2002 | SC |
| UA | 84959 | 12.0308762 | -14.3023 | 16.7556 | 2002 | SC |
| UA | 85206 | 15.2120005 | -13.300 | 18.873 | 2006 | SE |
| UA | 85207 | 11.8285987 | -13.9234 | 17.3032 | 2006 | SE |
| UA | 85208 | 9.53462404 | -14.3804 | 16.439 | 2006 | SE |
| UA | 85212 | 11.3934155 | -14.3123 | 15.6869 | 2005 | SE |
| UA | 87032 | 11.4399093 | -14.4095 | 17.2477 | 2003 | SC |
| UA | 99535 | 13.4953303 | -14.2715 | 16.6342 | 2003 | SE |
| UA | 99536 | 11.5484895 | -15.0758 | 16.4169 | 2003 | SE |
| UA | 99537 | 12.0955695 | -14.297 | 5.9016 | 2003 | SE |
| UA | 99543 | 10.9499828 | -16.4521 | 16.1704 | 2003 | SE |
| UA | 99544 | 10.7881889 | -13.3729 | 16.8769 | 2003 | SE |
| UA | 99563 | 9.90637033 | -14.4738 | 16.4207 | 2003 | SE |
| UA | 99566 | 12.1861326 | -14.1097 | 17.2562 | 2003 | SE |
| UA | 99570 | 11.8430805 | -14.2529 | 17.3091 | 2003 | SE |
| UA | 99572 | 10.9547323 | -15.8402 | 16.2203 | 2003 | SE |
| UA | 99575 | 9.96113155 | -14.2496 | 18.0476 | 2005 | SC |
| UA | 99641 | 10.7223248 | -13.8314 | 16.9496 | 2004 | SC |
| UA | 99657 | 11.0373154 | -14.3081 | 15.3521 | 2004 | SE |
| UA | 99658 | 9.59744472 | -14.4079 | 14.8852 | 2004 | SE |
| UA | 99665 | 8.58792555 | -15.2125 | 14.9035 | 2006 | SE |
| UA | 99667 | 11.2176845 | -14.3017 | 16.1819 | 2005 | SE |
| UA | 99693 | 12.4762904 | -14.2467 | 17.1331 | 2003 | SC |

**Table S2:** Environmental datasets. SST data was obtained from NOAA\_ERSST\_V5 data provided by the NOAA/OAR/ESRL PSD, Boulder, Colorado, USA, from their Web site at https://www.esrl.noaa.gov/psd/ (Huang et al. 2017).

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| **Environmental Driver Category** | **Eastern Bering Sea** | **Gulf of Alaska** | **Coastal Washington** |
| Discharge | Total discharge from the Kuskokwim River at Crooked Creek, AK during the winter months of low discharge (Nov-Apr) and summer months of high discharge (May-Oct) from monthly U.S. Geological Survey discharge data. 1951-2018. **N = 3**  Data Source: [USGS 15304000](https://waterdata.usgs.gov/nwis/inventory/?site_no=15304000) | Estimates of total freshwater discharge for a location near Seward, Alaska during winter months of low discharge (Jan-Jul) and summer months of high discharge (Aug-Dec) from monthly data. 1931-2011. **N= 3.**  Data Source: Tom Royer, Royer and Grosch 2007 | Total discharge from the Columbia River at Dalles, WA and Fraser River at Hope during the winter months of low discharge (Nov-Apr) and summer months of high discharge (May-Oct) from monthly U.S. Geological Survey discharge data. 1879-2018 and 1913-2016. **N= 6.** Data Source: [USGS 14105700](https://waterdata.usgs.gov/nwis/uv?site_no=14105700); [BC Fraser 08MF005](https://wateroffice.ec.gc.ca/report/real_time_e.html?stn=08MF005) |
| Sea Surface Temperature (SST) | Average of monthly NOAA Extended Reconstructed SST for winter (Jan-Mar), spring (Apr-Jun), summer (Jul-Sep), and fall (Oct-Dec) and annually at 60°N, 170°W. 1854-2019. **N = 5**  Data Source: [NOAA ERSST V5](https://www.esrl.noaa.gov/psd/data/gridded/data.noaa.ersst.v5.html) | Average of monthly NOAA Extended Reconstructed SST for winter (Jan-Mar), spring (Apr-Jun), summer (Jul-Sep), and fall (Oct-Dec) and annually in southcentral AK (60°N 149°W). 1854-2019. **N = 5**  Data Source: [NOAA ERSST V5](https://www.esrl.noaa.gov/psd/data/gridded/data.noaa.ersst.v5.html) | Average of monthly NOAA Extended Reconstructed SST for winter (Jan-Mar), spring (Apr-Jun), summer (Jul-Sep), and fall (Oct-Dec) and annually in coastal Washington (48°N, 125°W). 1854-2019. **N=5**  Data Source: [NOAA ERSST V5](https://www.esrl.noaa.gov/psd/data/gridded/data.noaa.ersst.v5.html) |
| Upwelling/Circulation | Average winter (Oct-Apr) cross-shelf and along-shelf wind at 60°N, 170°W from monthly NCEP/NCAR reanalysis data. 1949-2011. **N = 2**  Data Source: Megan Stachura, Stachura et al. 2014 from [NOAA ESRL](http://www.esrl.noaa.gov/psd/) | Mean coastal upwelling index (CUI) the Gulf of AK (57°N, 137°W) using Bakun upwelling calculation based on Ekman's theory of mass transport due to wind stress, for spring, summer, winter and annual.1946-2019. **N = 4**  Data Source: [NOAA ERD SWFSC](https://oceanview.pfeg.noaa.gov/products/upwelling/dnld) | Mean coastal upwelling index (CUI) coastal Washington (45°N, 125°W) using Bakun upwelling calculation based on Ekman's theory of mass transport due to wind stress, for spring, summer, winter and annual. 1946-2019. **N = 4**  Data Source: [NOAA ERD SWFSC](https://oceanview.pfeg.noaa.gov/products/upwelling/dnld) |
| Climate Regime | Multivariate ENSO Index (1950-2019), Oceanic Nino Index (1950-2019), Pacific Decadal Oscillation Index (1900-2018), the Northern Oscillation Index (1928-2019), North Pacific Gyre Oscillation (1950-2019). **N = 5**  Data Sources: [PDO](http://research.jisao.washington.edu/pdo/PDO.latest.txt); [NPGO](http://www.o3d.org/npgo/); [NOI](https://www.integratedecosystemassessment.noaa.gov/regions/california-current/cc-indicator-climate-ocean-drivers); [MEI](https://www.integratedecosystemassessment.noaa.gov/regions/california-current/cc-indicator-climate-ocean-drivers); [ONI](https://www.integratedecosystemassessment.noaa.gov/regions/california-current/cc-indicator-climate-ocean-drivers) | Same as eastern Bering Sea | Same as eastern Bering Sea |

**Table S3:** Candidate models described by included covariates to identify environmental drivers of trophic position and δ15Nsource. Covariates are derived from the latent trends of the environmental time series described in Table 1, strength and interpretation of model support will be determined by the magnitude and sign of the covariate coefficient.

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| **Candidate Models** |
| 1. Subregion |
| 2. Climate Regime, Subregion |
| 3. Sea Surface Temperature, Subregion |
| 4. Upwelling/Circulation, Subregion |
| 5. Discharge, Subregion |
| 6. Climate Regime; Sea Surface Temperature, Subregion |
| 7. Climate Regime; Upwelling/Circulation, Subregion |
| 8. Climate Regime; Discharge, Subregion |
| 9. Discharge; Sea Surface Temperature, Subregion |
| 10. Discharge; Upwelling/Circulation, Subregion |
| 11. Sea Surface Temperature; Upwelling/Circulation, Subregion |
| 12. Sea Surface Temperature; Upwelling/Circulation; Climate Regime, Subregion |
| 13. Sea Surface Temperature; Upwelling/Circulation; Discharge, Subregion |
| 14. Sea Surface Temperature; Discharge; Climate Regime, Subregion |
| 15. Discharge; Climate Regime; Upwelling/Circulation, Subregion |

**Figure S1**: Analysis of a) δ15NSource and b) δ13C by month. For both models, there was no significant slope (p>0.1)

**Figure S2**: Analysis of a) δ15NSource and b) δ13C by month. For both models, s(month) p>0.1 indicating no seasonality of harbor seal bone collagen stable isotope signature.



**Figure S3**: Residuals for the model with the most support plotted by year.



**Figure S4:** Model residual plots for the model with the most support from the candidate model set described in Table S3.

1. Alanine, glycine, proline, aspartic acid, leucine, isoleucine, valine, threonine, serine, glutamic acid, phenylalanine [↑](#footnote-ref-1)