Summary of Funding Goals, Results, and Implications

The QRC provided $15K in funding toward the purchase of a new isotope ratio mass spectrometer equipped to analyze light isotopic ratios (\textsuperscript{13}C:\textsuperscript{12}C, \textsuperscript{15}N:\textsuperscript{14}N, \textsuperscript{18}O:\textsuperscript{17}O, \textsuperscript{2}H:\textsuperscript{1}H) of individual compounds separated by gas chromatography. The instrument is available to the UW community through a new on-campus cost center. Purchased and installed in late 2016, there are currently six functional methods routinely used by ten research groups at the University of Washington. On occasion the cost center provides service to off-campus researchers, although this is fairly rare. Information about the instrument and the cost center can be found at http://depts.washington.edu/csia.


In addition, the instrument has supported the research of five graduate students, four post-doctoral scholars, and one undergraduate capstone across three departments. We have not directly tracked research funding derived from the instrument, but PI Holtgrieve has received one Washington Sea Grant award (3/1/18 – 2/28/20, $288,425) for a project based entirely on the analytical capabilities the instrument provides. Co-PI Sachs also has an award from NSF which leverages the capabilities of the instrument (10/1/17 – 9/30/20, $681,864).

To the extent there have been research successes, there have also been challenges with the instrument. The primary challenges have been keeping the cost center financially sustainable and managing staff turnover. The cost center has not fully supported itself and will require an increase in per sample costs after an internal audit. The center also had to replace its primary
technician, which has resulted in additional costs and downtime for training. Nonetheless, the instrument remains operational and available to the UW community.

Attachments:
1) Fact sheet describing the harbor seal trophic level reconstruction project funded by WA Sea Grant (intended for a public audience).
2) Reprint of Bogard et al. 2019. The main data source for this paper was generated on the instrument.

Example Graduate Student Project Based on the New Capabilities of the Instrument

RECONSTRUCTING A CENTURY OF COASTAL PRODUCTIVITY AND PREDATOR TROPHIC DYNAMICS USING COMPOUND-SPECIFIC STABLE ISOTOPES FROM ARCHIVAL BONE SPECIMENS

This project applies nitrogen compound-specific stable isotope analysis of individual amino acids (δ15N-AAs) of bone collagen from archived harbor seal (Phoca vitulina) bones from the Salish Sea and outer Washington coast to reconstruct almost a century of the trophic dynamics of this generalist pinniped predator. This new and powerful method quantifies both trophically conserved and trophically fractionated amino acids within each individual, thereby allowing robust estimates of consumer trophic position through time that are independent of environmental changes to baseline nitrogen chemistry. Using this technique, we have generated a decadal or better resolution time series of harbor seal trophic position that spans at least two ocean productivity regimes and large population swings in both predators and prey. These data are allowing us to test whether seal trophic position has increased as other potential prey (cod, herring) have declined, remained stable, or exhibits fluctuations that mirror changes in productivity regimes. An additional benefit of this method is the ability to reconstruct basal food web 15N/14N over this same time frame via the analysis of the essential AAs. This provides a separate indicator of coastal N dynamics driven by upwelling of nitrate and N uptake via primary production, and thus a record of broad change in ecosystem productivity through time. Ultimately this information will inform the relationship between ocean climatic regime shifts (i.e., changes in the Pacific Decadal Oscillation) and basal food web productivity. Together with the trophic position analysis, we strive to infer the relative strength of changing predator and prey abundances against ecosystem drivers on trophic position of harbor seal, with broad implications for understanding overall food web predator-prey dynamics.

Each of these analyses have been performed on samples from both the outer Oregon and Washington coasts near the Columbia River and the Salish Sea including Puget Sound (WA). With these data, we are able to address the following hypotheses about the role of increasing marine predator biomass on coastal ecosystems:

Trophic-related Hypotheses
1. Has the trophic position of harbor seals exhibited long-term trends, and do these changes differ between inland and coastal waters in Washington state? Long term changes would
be indicative of shifts in prey, for example from lower trophic level forage fish to higher trophic level salmon.

2. Do changes in the trophic position of harbor seals support evidence of food web response to changing environmental regimes in response to large-scale climate drivers? Long term changes in fish assemblages of South Puget Sound have been documented in previous work though the effects of these changes on seals and their role in the food web is unknown.

3. Do changes in the trophic level of harbor seals support evidence of changing diet in response to the well-documented collapse of forage fish populations? Similarly, have changes in the trophic position of harbor seals responded to the increase and subsequent decline of salmon hatchery programs?

Ecosystem-related Hypotheses

4. Has coastal nitrogen dynamics—which is related to upwelling and ecosystem primary productivity—exhibited long-term trends over the last 80-100 years, and how do these changes compare between inland and coastal waters in Washington state?

5. Do changes in the $^{15}$N/$^{14}$N of phytoplankton, an indicator of primary productivity, support evidence of changing environmental regimes in response to climate drivers?

Results

While the data are considered final, results of analyses of these data are just beginning. Nonetheless, we have included a few preliminary figures here. The first figure shows the geographic location at time of collection of the samples and the year they were collected. There are two geographic groups, Puget Sound and the Washington coast near the Columbia River. The majority of the samples are from between 1960 and 1990 which covers two distinct climate regime periods in the Pacific Northwest.

The second figure includes data on our two main metrics: trophic position of individual harbor seals and $\delta^{15}$N$_{phe}$, which is the isotopic signature of nitrogen at the base of the food web. Plots for the two locations (upper) and for males and females (lower). Trophic position estimate fall in the range of what is expected for harbor seals. There is significant individual variation in trophic position that is expected for a generalist predator. $\delta^{15}$N$_{phe}$ shows a slight trend for enrichment (higher values) later in the time series in Puget Sound, which indicates an increasing in human derived N to the sound.

The last figure contains preliminary plot of a Gaussian DFA time series analysis. This analysis looks for trends through time of trophic position or $\delta^{15}$N$_{phe}$ that is shared with other potential covariates such as salmon or herring abundance, or human population in the region. One pattern that seems to emerge is a change in trend among a number of variables coincident with the 1978 Pacific Decadal Oscillation regime change.
Figure 1: Spatial and temporal distribution of harbor seal specimens that have been sampled for this project.

Figure 2: Trophic position and δ¹⁵N of phenylalanine through time by location (inland versus coastal) and by sex, and trophic position verse standard length. Trophic position of herring and apex predators is included as a reference.
Figure 3: Latent trend and factor loadings for the Gaussian DFA on trophic position (upper two panels) and δ¹⁵Nphe (bottom two panels) each with two trends.