**Introduction**

Anthropogenic climate change will impact nutrient cycles, primary productivity, and thus ecosystem structure in the world’s oceans, although considerable uncertainty still exists regarding the variability of these changes and how ecosystems will respond. Climate conditions alter physiological conditions, nutrient limitations (light and resources), water column stratification, and community composition of primary producers (Winder et al. 2012), all of which vary at different spatial and temporal scales under different climate scenarios. Earth system model predictions suggest both increases and decreases in global net primary productivity of up to 20% by 2100 (Bopp et al. 2013; Kwiatkowski et al. 2017, Gregg et al. 2003). Changes in primary production has implications for dependent marine ecosystems, as it influences abundance and interactions in both adjacent and non-adjacent trophic levels in many marine systems (Ware and Thomson 2005, Winder 2012, Frank et al. 2015). This bottom-up control of marine food webs is expected to reduce fishery yields by as much as 20% globally by 2100 due to productivity constraints at lower trophic levels (Moore et al. 2018). Given both resource availability and community composition of resources impact the function and stability of food webs (Narwani and Mazumder 2012) it is likely ecosystem interactions will change in response to environmentally induced shifts in resources.

Ecological interactions are a fundamental component to studying the function and dynamics of ecosystems. Currently, anthropogenic and climatic changes are altering ecological interactions at a global scale, thus, understanding how interactions function and how environmental perturbations will alter interactions is imperative. Studies of environmental control of food webs are often limited to only examining low trophic level species (Pershing et al. 2010), or only include indices of either primary production or environmental change (Ware and Thomson 2005, Chassot et al. 2007), typically excluding indices of nutrient availability. Lower trophic levels are sensitive to environmental variation in bottom-up drivers of productivity (sensu. Ware and Thompson 2005, Frank et al. 2006, Jennings and Brander 2010), but few studies have demonstrated how the impact of these changes span entire food webs on long time scales. Oceanic conditions such as sea surface temperature, freshwater discharge, wind, and ice cover, have been linked to abundance and recruitment of many fish species in the Northeast Pacific (Cunningham et al. 2018, Puerta et al. 2019, Stachura et al. 2014), but rarely include proxies or indicators of either nutrient availability or primary productivity that enable mechanistic understanding of ecosystem response to the environment. Additionally, somatic growth of large bodied marine predators is not continuous and typically occurs on a longer temporal scale than phytoplankton dynamics making it challenging to link higher trophic level species to forcing lower in the food web. Similarly, marine predators can utilize resources at multiple spatiotemporal scales, creating a challenge for linking species abundance to independent observations of phytoplankton or nutrient dynamics. How environmentally induced changes in primary productivity ultimately influences nutrients available to and assimilated by the food web is thus poorly understood.

An empirical understanding of food web responses to environmental drivers requires long time series data that span multiple changes in climate regimes to decouple natural oscillations with long-term changes (Litzow and Cianelli 2007, Cury et al. 2008, Tallis et al. 2010, Hastings et al. 2018). In recent decades extreme changes in marine environments have become more common and these events have had substantial impacts on ecosystems. Marine ecosystems in Alaska are experiencing unprecedented environmental change that has altered abundance and size distributions of many fish species (Barbeaux et al. 2020, Holsman et al. 2019, Oke et al. 2020, Suryan et al. 2021). More recently, atmospheric circulation anomalies in the northeast Pacific Ocean have resulted in abnormally warm sea surface temperatures during the past decade (Walsh et al. 2018) and this environmental shift has altered fish abundances (Bond 2015, Litzow et al. 2020). For example, the unprecedented marine heatwave that occurred in 2014 - 2016 triggered dramatic ecosystem change, including a 71% decline in Pacific cod in the Gulf of Alaska (Barbeaux et al. 2020) and declines in phytoplankton biomass, forage fish abundance, and changes in community structure (Suryan et al. 2021).

Reconstructing time series of indicators of ecosystem interactions is important to understand how ecosystems have responded to environmental variability in the past and ultimately interpret potential food web responses to environmental conditions in the future; such datasets are distinctly lacking. Modern chemical analyses, such as compound specific stable isotope analysis (CSIA) of inorganic nitrogen sources or amino acids, have potential to improve our understanding of food web interactions by 1) extending time series through retrospective analyses 2) identifying environmental forcing of the entire food web when measured in predators and 3) informing biologically relevant mechanisms of interactions, a former limitation of many ecosystem studies.

Analysis of nitrogen stable isotopes usually applies bulk stable isotope techniques which measures the 15N/14N ratio of nitrogen as a weighted average of all nitrogen present in a given sample. In soil analyses, this typically means 15N/14N includes both organic and inorganic form and in tissue samples, this means 15N/14N measurements are a weighted average of the concentrations of all amino acids present in the protein of an individual tissue. However, the 15N/14N of an individual compound, known as compound-specific stable isotope analysis, represents the kinetic and diffusive fractionation factors exerted on that compound through chemical conversions, typically from biogeochemical or physiological processes. Thus, isotopes can provide a useful link between biogeochemical reactions that regulate nutrient availability and primary production, and ecological responses, without being confounded by nitrogen containing compounds that are not utilized by an ecosystem.

Here we aim to reconstruct historical food web interactions using stable isotopes as chemical tracers to:

1. Identify how long-term (20-years) changes in salmon abundance impact nitrogen dynamics in riparian soils.
2. Understand the how ocean condition alters food web-assimilated nitrogen resources and primary production in the northeast Pacific
3. Identify dominant historical drivers of predator foraging ecology in the northeast Pacific, using trophic position as an indicator of major changes in foraging.
4. Establish a framework to improve trophic position estimation of bulk and compound-specific stable isotope analysis for historical and contemporary studies.