Abstract:
The northern Gulf of Alaska is a highly productive downwelling system, however the nutrient source for this high productivity remains unknown. In an effort to elucidate the distribution and source of the nutrients on the Gulf of Alaska shelf, we measured the cross-shelf seasonal and inter-annual variation of the major nutrients in relation to the regional physical structure. Samples from the Seward Line transect provided profiles of nitrate, phosphate, ammonium, and silicate from the inner-shelf, mid-shelf, shelf-break, and offshore regions, thus encompassing both the Alaskan Coastal Current and the Alaska Stream. This data will provide insight to the source and movement of the major nutrients to help explain the high levels of productivity in this unusual region and to assess the food environment available to the next trophic level.

The nitrate, silicate, and phosphate concentrations expressed a positive relationship with salinity. Generally, nutrient concentrations increased with depth were observed, particularly within the off-shelf regime, which has close contact with the nutrient-rich waters below the permanent thermocline. A distinct difference between the end of winter 1998 and the end of winter 1999. Nutrient concentrations in March 1999 were 30-50% higher than those in March 1998. The shelf waters were much warmer and fresher throughout spring 1998 with respect to spring 1999. Available surface nutrients were severely depleted by summer 1998 and 1999. They were then replenished throughout late fall and winter. In mid-April 1999, enhanced chlorophyll levels over the inner-shelf and shelf-break regions were observed. In mid-April 1999, enhanced chlorophyll levels were found over the inner-shelf and shelf-break regions. The nutrients across the Gulf of Alaska shelf follow the general trends of increasing concentrations with depth and surface depletion between spring and early fall with renewal of nutrients to the surface waters due to winter mixing.

Introduction:
As a part of the GLOBEC monitoring program for the Gulf of Alaska, nutrient analyses were completed on water samples collected from the Seward Line. Samples were collected in 1998 and 1999 in the months of March, April, May, July or August, October, and December. Here we have compared spring and summer of 1998 to spring and summer 1999. These collection times provided an opportunity to observe the seasonal and inter-annual variations in the chemical and physical properties. This nutrient data represents the first systematic yearly record of nutrients provided a preliminary look at the first systematic yearly record of nutrients properties. This nutrient data represents the variations in the chemical and physical properties. This nutrient data represents the variations in the chemical and physical properties. This nutrient data represents the variations in the chemical and physical properties. This nutrient data represents the variations in the chemical and physical properties. This nutrient data represents the variations in the chemical and physical properties. This nutrient data represents the variations in the chemical and physical properties. This nutrient data represents the variations in the chemical and physical properties. This nutrient data represents the variations in the chemical and physical properties. This nutrient data represents the variations in the chemical and physical properties.

Methods:
1) Water samples were collected from each CTD station along the Seward Line Transect.
2) Samples were collected from the following standard depth intervals:
   - Inner-shelf, mid-shelf, and shelf-break stations: 0, 5, 10, 20, 30, 40, 50, 75, 100, 150, 200 m.
   - Off-shelf stations: 0, 25, 50, 75, 200, 250, 500, 1000, 1500 m.
3) Samples were analyzed either shipboard or in the lab using a Rapid Flow Analyzer following the techniques according to Whitehead et al. 1991.

Observations:
The data reflect large variations in the physical, nutrient, and fluorescent properties within the seasonal and inter-annual time scales. These variations apparently were driven by differing climate forcing, precipitation/runoff variations and eddies. The most pronounced difference occurred for the spring bloom periods of 1998 and 1999.

Figure 1. The physical and chemical hydrography collected from March, April, July of 1998 revealed:
- Water temperatures were homogenous throughout the water column in March and April. The surface temperature increased throughout the water column in April and late-summer when the water column reached maximum stratification.
- Salinity decreased over the inner-shelf as fresh water inputs increased due to snow melt and river inflows.
- Nitrate, NO3 concentrations were relatively low, < 20 µm/l, in the upper 100m and increased to >30 µm/l below 250m. Cross-shelf gradients in NO3 were evident, especially below ~ 150m. In summer the NO3 was depleted from the surface due to phytoplankton uptake.
- Fluorescence profiles showed relatively low activity in March and April. April data showed higher activity over the inner-shelf and shelf-off. The highest values occurred in July in the surface waters across the whole shelf. This sub-surface layer is within the region of maximum thermal stratification.

Figure 2. The physical and chemical data collected in March, April, and August of 1999 showed:
- Water temperatures were homogenous in March and April. Surface temperatures increased throughout spring into late summer to eventually regain stratification.
- Salinity showed increasing freshwater inputs over the inner-shelf as the year progressed into early fall.
- NO3 concentrations were ~ 15 µm/l above 100m in March and April. NO3 concentrations increased to >30 µm/l below 250m. Cross-shelf gradients in NO3 were apparent as NO3 concentrations were completely depleted from the upper 25m by late summer. NO3 was brought onto the inner-shelf by high salinity shelf-off.
- Fluorescence showed phytoplankton activity in early spring which extended throughout the water column. In April the phytoplankton was enhanced over the inner-shelf and shelf-break regimes. By late summer, the fluorescence values were highest in the sub-surface layer across the entire shelf.
- Shelf waters were warmer (by ~2°C) and fresher (by ~0.5 PSU) in March 1999 compared to March 1998. NO3, which is well correlated with salinity, was elevated by approximately 30-50% in March 1999 with respect to March 1998. The shelf waters were ~50% higher in NO3 in the summer of 1999 than 1998 possibly due to the onshore meandering of the Alaska Stream.

Conclusions:
- NO3 was depleted to undetectable concentrations from the upper 25 m by mid-summer in 1999 and 1998.
- Inter-annual variability in spring, March and April, NO3 concentrations across the shelf were large. NO3 concentrations were 30-50% less in spring 1999 compared to spring 1998. These differences were associated with fresher shelf water in 1998 than 1999. NO3 concentrations in the off-shelf waters were 50% less in summer 1999 due to the position of the Alaska Stream.
- Since inter-annual freshwater variability is large in the upper ocean, variability in NO3 concentrations were also large.
- Salinity and NO3 are positively correlated. This suggests that the 29 years of historical salinity data for the Seward Line can be used as a proxy for nutrient concentrations.

Variability in pre-bloom NO3 concentrations has direct implications on inter-annual variations in primary productivity. These nutrient conditions are very important to the growth and productivity of phytoplankton and consequently the rest of the food web.