Seasonal and Spatial Dynamics of Phytoplankton and Microzooplankton in the Gulf of Alaska

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INTRODUCTION

The goal of this project is to describe the seasonal and spatial variability in abundance, biomass and size-structure of the microplankton (phytoplankton and microzooplankton <200 um) and to interpret these distributions in the context of physical, chemical and biological data collected on the CGOA LTOP cruises. The size-structure, taxonomic composition and growth dynamics of the lower trophic food web can be highly responsive to physical forcing and, in turn, exert strong influences on zooplankton growth, fecundity, community composition and nutritional state.

The composition of phytoplankton and microzooplankton communities and their seasonal development in the coastal Gulf of Alaska are poorly known. Published reports are few and focus on subsets of the plankton (Larrance et al. 1977, Howell-Kübler et al. 1996 and Strom et al. 2001). This is the first study to use epifluorescence microscopy techniques to distinguish phototrophs and heterotrophs and to include all size ranges from picoplankton to microplankton. This study provides critical data for extrapolating and interpreting phytoplankton and zooplankton rate information obtained on the Process cruises to the larger region and to construct realistic annual food web models. The data will also provide mechanistic insight and validation for coupled biological-physical models of the Gulf of Alaska shelf ecosystem, and vital information for comparison with the GLOBEC California Current System study.

Figure 1. **LTOP sampling stations**. Seward Line data presented

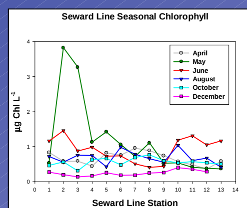

Figure 2. **Seasonal chlorophyll development across the Seward Line.** From inshore to the shelf break (Sta 9), the spring chlorophyll increase was underway by April and reached a seasonal maximum in May, even though surface temperatures remained ca. 5.5ºC during this period. Offshore, the chlorophyll seasonal maximum occurred in late June. Chlorophyll increases were due to diatoms inshore in May and June, and offshore in June. Otherwise, most 'blooms' were due to phytoplankton <5 µm in size. Chlorophyll data courtesy of Terry Whitledge. Data are averages in the top 50 m.

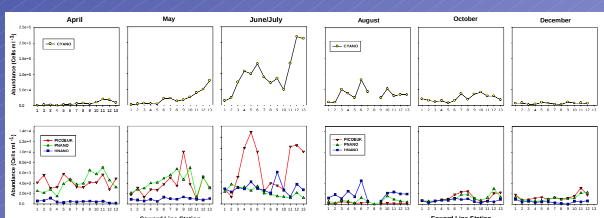

Figure 3. **Seasonal changes and spatial distributions in pico/nanoplankton abundances.** Average picoplankton and nanoplankton cells ml^{-1} in the upper 50 m across the Seward Line. Upper plots are cyanobacteria (CYANO); lower plots show picoeukaryotes (PICOEUK), photosynthetic nanoflagellates (PNANO) and heterotrophic nanoflagellates (HNANO). Note different scales.

Cyanobacteria increase dramatically offshore and seasonally to very high numbers (max >2 x 10^5 ml^{-1}). Very high abundances occurred mid-shelf in June.

Picoeukaryotes were present at all stations and showed seasonal and spatial variability; nanoflagellates showed less seasonal variability.

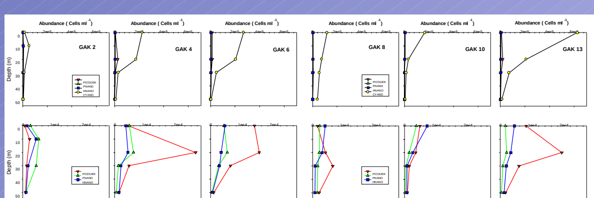

Figure 4. **Vertical distributions of pico/nanoplankton**. An illustration of the variability in vertical distributions of different phyto groups (from the June/July sampling). Abundance maximum for CYANO was at the surface, while PICOEUK was in the subsurface.

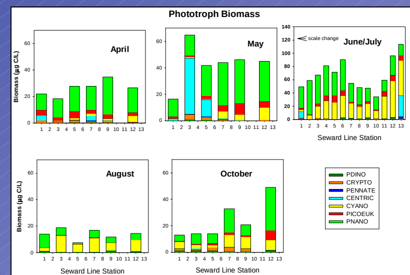

Figure 5. **Distribution and seasonal changes in biomass of phytoplankton groups**..
Total phytoplankton biomass reached a maximum in June/July (note scale change). Highest total biomass was at the most offshore station. Total biomass was not accurately reflected by chlorophyll (see Fig. 2). C:Chl ratios were much higher in June/July than earlier in the year.
Diatoms dominated only at the inshore station (ACC) in May. They contributed significantly in the ACC and at the oceanic stations in June/July. Otherwise, PNAN dominated phytoplankton biomass at the inshore and midshelf stations throughout much of the year. The exception is during the summer, CYANO dominated the biomass, even at mid-shelf stations. *(Note: diatom data missing from June/July stations 2-12, and August)*

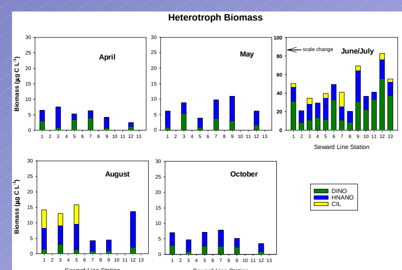

Figure 6. **Distribution and seasonal changes in biomass of heterotrophic protist groups.** Heterotrophic protists increase in biomass in response to the increase in phytoplankton, reaching seasonal maxima in June/July. HNANO and HDINO were the dominant protist groups at most times. Ciliates (CIL) were present everywhere, but generally did not dominate the biomass (*Note: ciliate data not complete wherever yellow bars are missing).*

METHODS

Samples for pico- , nano-, and microplankton (<200µm) identification and enumeration were taken on the April, May, June/July, July/August, October and December 2001 LTOP cruises. We sampled all stations along the Seward Line (GAK 1-13), select stations along the Cape Cleare Southeast (CCSE), Cape Fairfield (CF) and Hinchenbrook Entrance (HE) Lines and select stations within Prince William Sound (PWS). At each station, either detailed vertical samples were taken (0, 20,30,40,50 & 100m) or samples from individual depths were taken and combined to form an upper (0, 10, 20, 30, 40, 50m) and lower water column (5 & 100m) integrated sample. Discrete vertical samples were taken at GAK 2,4,6,8,10,13 and PWS2 while integrated samples were taken at GAK 1,3,5,7,9,11 & 12, CCSE 2,5 & 8, CF 3 & 9, HE 2,7 & 10, Montague Straight 3, and Knight Island Pass 2.

At each of the above stations, subsamples were preserved with either 0.5% glutaraldehyde or 10% acid Lugols's iodine. The glutaraldehyde-fixed samples were used to enumerate, and distinguish between, heterotrophic and autotrophic organisms with epifluorescence microscopy. Settled Lugol's-fixed samples were used to enumerate and size ciliates and other rarer large microplankton with combined transmitted light and epifluorescence microscopy. Glutaraldehyde-fixed samples were filtered onto 0.2µm (for pico- and nanoplankton) and 0.8 µm (for microplankton) black polycarbonate membrane filters and stained with 4', 6-diamidino-2-phenylindole (DAPI) and proflavin. Organisms were counted and sized using a Zeiss Axiovert microscope and a computer-aided digitizing system (Roff & Hopcroft, 1986). Biovolumes were estimated using appropriate geometric shapes and converted to biomass using the equations in Menden-Deuer & Lessard (2000). In addition, samples were fixed and frozen for flow cytometry.

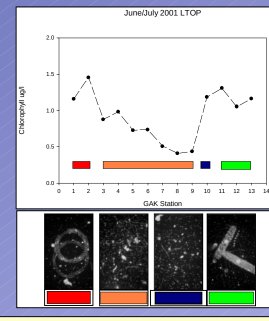

Figure 7. Community changes across Seward Line: June/July example. Several distinct communities, in terms of species and size structure, were typically found – inshore, mid-shelf, shelf-break and off-shore. Elevated chlorophyll at inshore stations was due to PNANO and the large diatom, *Guinardia* (150 µm dia. chains), while elevated chlorophyll offshore was due CYANO and the large diatom (*Corethron*) (122 x 25 µm). Mid-shelf stations were a mixture of CYANO, PNANO, CRYPTO, while nano-diatoms (*Nitzschia* sp.) were abundant at the shelf-break.

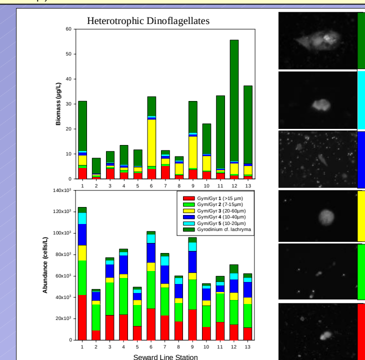

Figure 8. Heterotrophic Dinoflagellate diversity and distribution: June/July. Athecate dinoflagellates were abundant (up to 125 ml-1) and diverse. There were more than five different types, ranging in size from 5-150 µm (illustrated at right). All sizes were seen to ingest cyanobacteria, even the very large *Gyrodinium* species, which are also capable of ingesting diatom chains. Thecate dinoflagellates were also sometimes abundant, but are not included in these plots

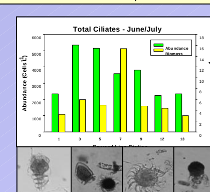

Figure 9. Ciliate diversity and distribution: June/July. The dominant ciliates (illustrated) were nonloricate oligotrichs that ranged in abundance from ca 1-10 ml-1. Ciliates are a modest biomass component of the total hetetotroph biomass in June/July

Summary

1. Although there was a high degree of heterogeneity in plankton communities over short distances, three to four biological regimes were discernable: Inshore (ACC), mid-shelf, shelf-break and offshore.
2. Diatom-dominated spring blooms generally occurred only at inshore stations. Mid-shelf and offshore blooms were dominated by nano- and picoplankton.
3. Although small cells usually dominated offshore, a bloom of very large diatoms occurred during the June/July sampling. This suggests that upwelling or mixing may be occurring offshore of the shelf-break.
4. Heterotrophic dinoflagellates dominated the early summer heterotrophic biomass. This may be due to their ability to feed on a wide range of prey sizes and types (cyanobacteria to chain diatoms).
5. Heterotrophic protists (nanoflagellates, dinoflagellates and ciliates) showed dramatic seasonal increases, reaching biomass levels equivalent to the phytoplankton. They also showed a strong decline after the seasonal maximum in June/July, presumably due to consumption by higher trophic levels. Heterotrophic protists must play a key role in trophic dynamics in all the biological/physical regimes in this complex region.

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