# Trophic cascading within the planktonic food web of the Gulf of Alaska in May 2001, induced by *Neocalanus* grazing

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## INTRODUCTION

Three species of large calanoid copepods of the genus *Neocalanus* dominate mesozooplankton biomass throughout the entire subarctic Pacific and its marginal seas in the spring and early summer. All three species of *Neocalanus* are particle-grazing copepods that consume both phytoplankton and microzooplankton. Previous studies revealed that *Neocalanus* spp. are capable of capturing particles as small as 2-3 µm but are much more efficient at capturing larger particles. As a result of this behavior, *Neocalanus* grazing can modify the size (and species) composition of the planktonic food web. Here we describe preliminary results of experiments for measuring the direct and indirect effects of grazing by *Neocalanus* spp. on plankton community dynamics, i.e., the trophic cascade.

As a part of the GLOBEC CGOA Process Study, we conducted a total of 36 grazing experiments during 3 cruises in 2001 to study the role of *Neocalanus* spp. in mediating the microbial food web structure (Table 1). Here we show the preliminary results of the 4 experiments conducted during the May cruise in the mid-shelf waters. Two experiments were conducted under phytoplankton "bloom" conditions; two were not.

Table 1. Summary of *Neocalanus* grazing experiments conducted during 3 cruises in 2001. IS – inner shelf, MS – mid shelf, OS – outer shelf, PWS – Prince William Sound. The exact location of each station differs slightly between cruises.

| Cruise | Date | Number of Experiments Conducted | | | | |
|---|---|---|---|---|---|---|
| | | IS | MS | OS | PWS | TOTAL |
| HX242 | 17 April – 1 May | 4 | 1 | 3 | 4 | 12 |
| HX244 | 17 May – 1 June | 3 | 4 | 3 | 3 | 13 |
| HX247 | 12 – 26 July | 3 | 3 | 3 | 2 | 11 |

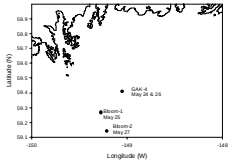


Fig.1. Map shows the locations of 4 grazing experiments presented in this poster.

Table 2. Information on the 4 *Neocalanus* grazing experiments presented in this poster. *Neocalanus* species: C – *N. cristatus*; F – *N. flemingeri*; P – *N. plumchrus*.

| Experiment | NG-8 | NG-9 | NG-10 | NG-11 |
|---|---|---|---|---|
| Date | May 24 | May 25 | May 26 | May 27 |
| Location | 59.408N 149.048W | 59.265N 149.274W | 59.408N 149.047W | 59.141N 149.214W |
| Phytoplankton bloom | NO | YES | NO | YES |
| *Neocalanus* species used | C, F, P | C | C | F, P |
| Chlorophyll a (mg m$^{-3}$) | 0.367 | 3.403 | 0.518 | 3.225 |
| Chl-*a* in <5 µm (%) | 73 | 12 | 76 | 5 |
| Chl-*a* in >20 µm (%) | 15 | 83 | 13 | 92 |
| *Synechococcus* (x10$^3$ cells ml$^{-1}$) | 139 | 51 | 136 | 15 |
| Picoeukaryotes (x10$^3$ cells ml$^{-1}$) | 34 | 21 | 41 | 13 |

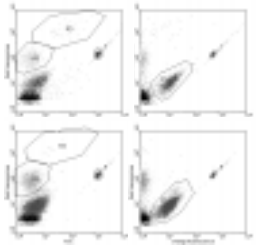

Fig. 2. Flow cytometric cytograms that display picophytoplankton compositions in two *Neocalanus* grazing experiments. Upper: Exp. Ng9, May 25, bloom. Lower: Exp. Ng10, May 26, no bloom. R1 - *Synechococcus*, R2 - picoeukaryotes, R3 - noneukaryotes, R4 - 1 µm beads.

## MATERIAL AND METHODS

Live *Neocalanus* spp. were collected with a plankton net from the upper 100 m immediately before the experiments. Animals in good condition were sorted and a variable number of each species was placed into 2-L polycabonate bottles filled with seawater and incubated on deck for 24 hours. Bottles with no *Neocalanus* added were also prepared as controls. Chlorophyll *a* concentrations in 3 size class (<5, 5-20 and >20 µm) were determined for each incubation bottle at the beginning and end of the experiments. Additional samples were preserved for enumerating the abundance of phytoplankton and microzooplankton.

For enumerating picoplankton, 1 ml seawater was taken from each experimental bottle before and after incubation, preserved with paraformaldehyde (0.2% final concentration), quick frozen and stored in liquid nitrogen for flow cytometric analysis. A BD LSR flow cytometer equipped with 20 mW blue (488nm) and 8 mW UV (325) lasers was used to enumerate the picoplankton. Forward and right angle light scattering (FSC and SSC) and green (515-545 nm), orange (564-606 nm) and red (>650 nm) fluorescence were collected, saved, and analyzed with CYTOWIN software. All signals were normalized to that of the 1 µm Fluoresbrite YG beads (Polysciences, Warrington, PA) that were added to each sample. *Synechococcus* spp. were distinguished from picoeukaryotes primarily by the strong orange fluorescence from phycoerythrin.

Table 3. *Neocalanus* clearance rates (L copepod$^{-1}$ day$^{-1}$) calculated from 4 experiments conducted during May 2001 at mid-shelf stations of contrasting chlorophyll concentrations. Rates were calculated for chlorophyll a in <5, 5-20 and >20 µm size fractions. A negative rate implies a positive cascading effect, i.e., chlorophyll *a* concentration in the small size fraction increased in the presence of *Neocalanus* due to the reduced consumption of small phytoplankton by microzooplankton which were presumably grazed by *Neocalanus* spp.

| Species | Low Chlorophyll a | | | | High Chlorophyll a | | | |
|---|---|---|---|---|---|---|---|---|
| | <5 | 5-20 | >20 | n | <5 | 5-20 | >20 | n |
| *N. cristatus* CV | -0.267 (0.157) | 0.155 (0.069) | 0.652 (0.280) | 9 | -0.154 (0.119) | -0.107 (0.232) | 0.308 (0.193) | 6 |
| *N. flemingeri* CV | -0.074 (0.018) | -0.042 (0.045) | 0.124 (0.042) | 3 | -0.018 (0.041) | -0.002 (0.041) | 0.072 (0.021) | 4 |
| *N. plumchrus* CV | -0.050 (0.031) | 0.143 (0.034) | 0.192 (0.082) | 3 | -0.020 (0.038) | -0.007 (0.071) | 0.084 (0.040) | 4 |

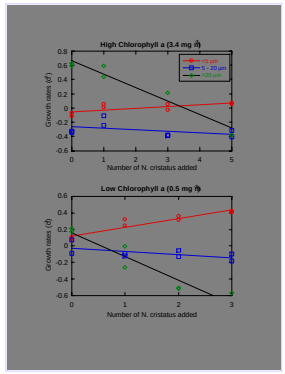


Fig. 3. The impact of *Neocalanus* grazing on the growth rates of phytoplankton in different size categories, measured by the changes in chlorophyll-*a* concentration in 3 size fractions after 24 h incubation. Upper: Exp.ng9 - bloom; Lower: Exp.ng10 - no bloom.

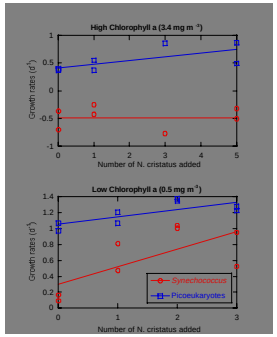


Fig. 4. Cascading effects of *Neocalanus* grazing on picoplanktonic *Synechococcus* and picoeukaryotes during phytoplankton bloom conditions (upper) and non-bloom conditions.

## RESULTS

The chlorophyll *a* concentration under non-bloom conditions was 0.3 – 0.5 µg L$^{-1}$, with more than 70% found in the <5 µm fraction. In contrast, the chlorophyll a concentration under bloom conditions was greater than 3.5 µg L$^{-1}$ and the community was dominated by large phytoplankton (about 90% in >20 µm fraction, Table 2).

In all experiments, *Neocalanus* fed mostly on phytoplankton cells larger than 20 um (Fig. 3). We saw little grazing on small or intermediate sized cells and sometimes observed an increase (a positive cascading effect) on the < 5 um fraction. This could result from two processes: (a) the lower retention efficiency of *Neocalanus* on smaller particles; (b) the consumption of microzooplankton by *Neocalanus*, which reduces grazer-induced mortality on the < 5 um cells. This cascading effect was more apparent under non-bloom conditions than bloom conditions. Consistent with the size fractionated chlorophyll data, we observed the abundance of picoplankton (*Synechococcus* and picoeukaryotes) increased in the presence of *Neocalanus* (Fig. 4). Additional details on community dynamics await analysis of the microzooplankton samples by microscopy and Flow-CAM.

As expected, the clearance rate per individual *Neocalanus* was higher under non-bloom conditions (Table 3). However, the amount of phytoplankton consumed by each copepod is much higher under bloom conditions because phytoplankton in the preferred size category is abundant. (Table 4).

Because the abundance of large cells is low under non-bloom conditions, the relative impact of *Neocalanus* grazing on this size category will be high, compared to bloom conditions. The potential for cascading effects induced by *Neocalanus* grazing is greater under non-bloom conditions.

In conclusion, ingestion of phytoplankton by *Neocalanus* spp. is much higher under bloom conditions but not under non-bloom conditions. A stronger cascade effect on the microbial food web is expected under-non-bloom conditions because of higher *Neocalanus* clearance rates and the relatively greater impact on the microzooplankton component of the system.

Table 4. *Neocalanus* ingestion rates (µg Chl-*a* copepod$^{-1}$ day$^{-1}$) calculated from 4 experiments conducted during May 2001 at mid-shelf stations of contrasting chlorophyll concentrations. Rates were calculated for chlorophyll *a* in >20 µm size fraction only. Numbers in parentheses are standard deviation.

| Species | Low Chlorophyll a | High Chlorophyll a |
|---|---|---|
| *N. flemingeri* CV | 0.0065 (0.0018) | 0.2025 (0.0767) |
| *N. plumchrus* CV | 0.0091 (0.0031) | 0.2236 (0.1237) |
| *N. cristatus* CV | 0.0276 (0.0118) | 0.7563 (0.4911) |

Table 5. Comparison of the effects of *Neocalanus* grazing in microbial food web dynamics in bloom and no-bloom conditions based on data from 4 experiments conducted during May in the mid-shelf waters of Gulf of Alaska.

| | | NO-BLOOM | BLOOM |
|---|---|---|---|
| Impact of *Neocalanus* grazing on phytoplankton | <5 µm | + | + |
| | 5-20 µm | + or – (mostly –) | + or – (mostly +) |
| | >20 µm | – | – |
| Cascading effects | | Strong | Weak |
| *Neocalanus* clearance rate for >20 µm phytoplankton (L copepod$^{-1}$ day$^{-1}$) | | High | Low |
| *Neocalanus* ingestion rate for >20 µm phytoplankton (µg Chl copepod$^{-1}$ day$^{-1}$) | | Low | High |
| Portion of daily phytoplankton growth (for > 20 µm cells) consumed | | High | Low |

+ increasing after addition of *Neocalanus* spp. – decreasing after addition of *Neocalanus* spp.

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