Growth rates of *Neocalanus flemingeri* in the northern Gulf of Alaska in 2001 and 2002

H. Liu ,C. Clarke & R.R.Hopcroft

Institute of Marine Science, University of Alaska Fairbanks

Fairbanks,Alaska,99775

Abstract:

Growth and development rates for copepodites of *Neocalanus flemingeri* were estimated in coastal and offshore waters during the spring of 2001 and 2002 in the northern Gulf of Alaska. Growth and development rates were similar between both years, with the duration of each of the first 4 copepodite stages ~10 days at ~5°C. Corresponding growth rate appears to decline with stage, from approximately 0.13 to 0.07 per day. Prior to the onset of the spring bloom, growth and development rates were much lower. Food concentration explained a significant proportion of the variability in growth rates but not developmental times.

Introduction:

Of the ~15 common species of copepods in the Gulf of Alaska (GoA), the three *Neocalanus* species (*N. plumchrus, N. femingerii, N. cristatus*) frequently dominate the zooplankton community biomass over the entire spring. Their abundance and large size may make them important prey species for higher trophic levels. As such, they are considered the primary copepod target species in the Gulf of Alaska.

Although we have an overall picture of the life cycles of the large-bodied copepods in the Northern Pacific (see review Mackas & Tsuda, 1999), the details are largely inferred. Despite the presumed importance of *Neocalanus,* there are three estimates of development rate and one for growth rate in copepodites, and only two studies of egg production or naupliar development. Here we present preliminary results to address this deficiency for the copepodites of *N. flemingerii* with experimental results from the 2001 and 2002 field seasons.

Methods:

Experiments were executed during the GoA LTOP cruises at Stations Gak1, 4, 9, 13 and PWS2 (Figure 1). Zooplankton were gently collected with a 64 µm, large cod-end plankton ring net, between from 50 m to the surface (~14 m^3 of water). The zooplankton were sorted into size classes of "artificial cohorts" by serial passage through submerged screens of the following mesh sizes: 1300, 1000, 800, 600, 500, & 400 µm. Each fraction was divided into equal parts with half preserved immediately as the time zero, and the remainder equally divided between several 20L carboys containing 80 or 100 µm prescreened water from the mixed layer collected by Niskin bottles. Carboys were incubated on-deck in large tubs (~2 m^{-3})maintained at surface water temperature, with ship movement providing constant jostling and 'mixing' of the carboys. After 5 days, the zooplankton in the carboys were screened onto a 45 µm mesh pooled by size fraction, and preserved. Parallel experiments were executed for *Neocalanus* at the same locations by removing single stages of copepodites from an additional ring net collection and incubating under the same conditions. In the laboratory, zooplankton samples were identified to species, staged, measured and the progression of the cohort determined by changes in the mean or median size. We established the relationship between prosome length (PL-µm) & weight (W-µg): Log(W)=3.7189*Log(PL)-13.5275.

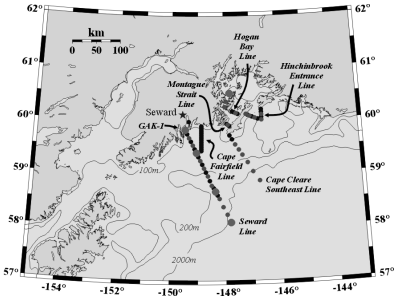

Figure 1. LTOP sampling area. Typical experimental sites indicated in purple

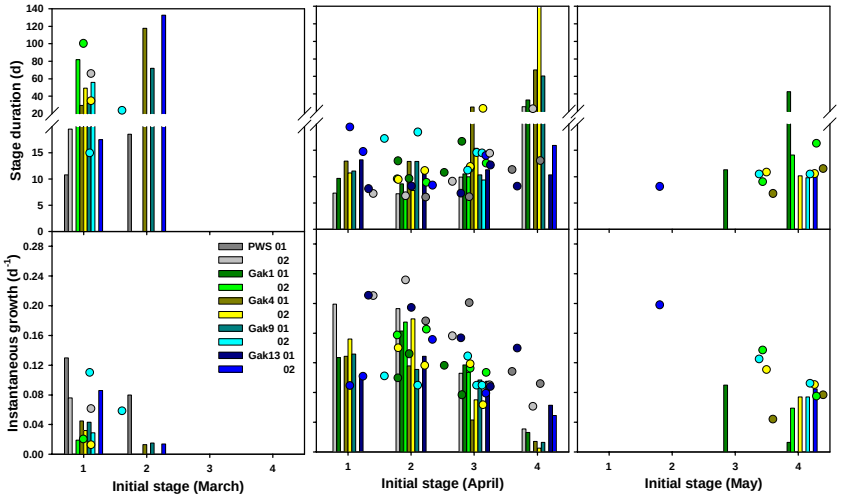

Figure 2. (Left) Stage duration(upper panels) and growth rates (lower panels) of *N.flemingeri* for the Gulf of Alaska verses initial developmental stage. Results from single stage populations (bars) and artificial cohorts (circles) referenced to the 'average' copepodite stage present at the start of the experiment.

Table 1. Model results for variables explaining growth rate by the artificial cohort method and single picked stages.

Model variables	Cohorts R^2	Picked R^2
Total Chlorophyll, stage, interaction	0.33	0.40
>20 µm Chlorophyll, stage, interaction	0.26	0.50
5-20 µm Chlorophyll, stage, interaction	0.39	0.53
>5 µm Chlorophyll, stage, interaction	Not Sig	Not Sig
Total Chlorophyll, stage, interaction	0.32	0.52

*Stage duration is unexplained by variables

Results:

In general, both the picked-stage method and the artificial cohorts method produce similar results (Figure 2), although the latter appears to produce more variable results. In March, only the first two copepodite stages are present, but stage duration is long and growth rate slow. In April, the first 4 copepodite stages are common, with the first 3 stages being of similar duration (~10 days), but C4 generally developing more slowly while it accumulates lipid stores. During April, growth rate appears to decline with increasing stage. In May, only C4 and C5 are common, but C4 growth is generally more rapid than experienced during the previous month. We were unable to observe molting or growth in C5 copepodites, due to that stage's long duration while lipid is accumulated prior to diapause. Estimates of growth rate fall between 0.20 and ~0.01 d^{-1}.

Variability in growth rates were significantly explained by chlorophyll in the fractions >5 µm, copepodite stage, and the interaction of these two varibles (Table 1). These models explained up to 50% of the observed variability. Chlorophyll >5 µm was uncorrelated to growth. All model attempts to explain variability in stage duration proved non-significant.

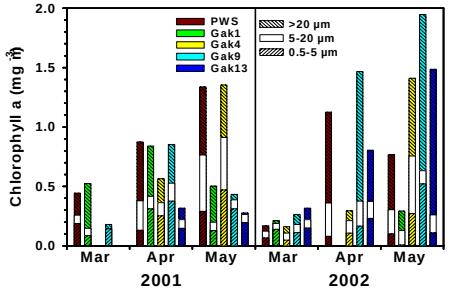

Figure 3. Distribution of size-fractionated chlorophyll for the Gulf of Alaska in 2001 and 2002.

Discussion:

Preliminary results indicate that both artificial cohorts and single-stage populations of copepodites appear to be viable methods for estimation of copepod growth rates. These techniques have been relatively successful even for larger more delicate *Neocalanus* species, although damage during collection remains a cause for concern.

Results in April for the earlier copepodites appear surprisingly consistent with the values of 12.6-16.6 days estimated by Miller (1993) from examination of natural field cohorts. The only directly determined stage durations for 24-25 days for C3 & C4 copepodites (Miller and Nielsen, 1988) is also within the range observed here, although even longer stage duration appears common for C4s. The more rapid development of C4s in May correspond to highest chlorophyll concentrations in the larger phytoplankton (i.e. >20 µm). Based on the rates presented here, the first 4 copepodite stages would be completed in 40-60 days assuming conditions remained comparable to those experienced during these incubations. Saito & Tsuda (2000) estimated the duration of naupliar stages for *N. cristatus* to be 30-40 days at these temperatures, and similar – if not shorter – times should be expected for *N. femingeri.* Thus, it would appear that 70-100 days from hatching are required to reach C5. It remains to be determined how long the stage 5 copepodites remain in the upper water column feeding until they descend to depth for diapause, although this stage is generally expected to be of longer duration than the previous stages. The virtual absence of *Neocalanus* species during August indicates an upper time limit of 150-180 days to the initiation of diapause. Two more year of experimentation should help to better resolve these patterns.

References:

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