Growth rates of Neocalanus species in the Gulf of Alaska

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Abstract:

Growth and molting rates for copepodites of *Neocalanus* species were estimated monthly in coastal and offshore waters of the northern Gulf of Alaska during 2001. Incubations of 4 or 5 days duration were executed in waters from 5 to 10 C employing both single 'picked' stages and artificial cohorts. Both methods appeared to yield similar data on molting rates and growth increment, once one considers initial stage composition. For *N. femingeri/plumchrus*, duration of the first 3 copepodite stages appears similar, approximately 9-13 days at 5-6 C. In contrast, stage 4 copepodites appear to take significantly longer, 25-65 days. Corresponding growth rate appears to decline with stage, from approximately 0.16 to 0.01 per day.

Introduction:

Of the ~15 common species of copepods in the Gulf of Alaska, the three Neocalanus species (*N. plumchrus, N. femingeri, 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 over all picture of the life cylecs of the large-bodied copepods in the Northern Pacific (see review by Mackas & Tsuda, 1999), the details are largely inferred. Despite their presumed importance, there are three estimates of development rate, and one for growth rate, in copepodites of *Neocalanus plumchrus* (Miller & Nielsen, 1988; Miller, 1993), and only two publications considering egg production of naupliar development (Fulton, 1973; Saito & Tsuda, 2000). Here we describe preliminary results to address this deficiency for the copepodites of *N. femingeri/plumchrus* with experimental results from the 2001 field season.

Methods:

Experiments have been run during the GoA LTOP cruises at Stations Gak1, 4, 9, 13 and PWS2 (Figure 1). Zooplankton for incubation will be collected by slowly pulling a 64 µm plankton ring net, equipped with a large cod end, from 50 m to the surface (~14 m^3 of water). The zooplankton was sorted into size classes of "artificial cohorts" by serial passage through submerged screens of the following mesh sizes: 1800, 1300, 1000, 800, 600, 500, 400, 300, 200, 150 and 100 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 µm prescreened water from the mixed layer collected by 10L Niskin bottles. Carboys were incubated on-deck in large commercial fish-tubs (~1.7 m^3) maintained at surface water temperature. During incubation, ship movement provided constant jostling and 'mixing' of the carboys. After 4 or 5 full days of incubation, the zooplankton in the carboys will be screened onto a 45 µm mesh pooled by size fraction, and preserved. In the laboratory, zooplankton samples will be identified to species, staged, measured and the progression of the cohort determined by changes in the mean or median size (see Hopcroft *et al.*,1998).

Additional experiments were executed at the same and at additional locations for *Neocalanus* species by removing their copepodites from a slowly hauled 200 µm ring net. Populations of single stages of all copepodites stages available were incubated as indicated for the artificial cohorts, although on some occasions a photo-controlled refrigerated incubator of the same temperature as those on-deck was employed.

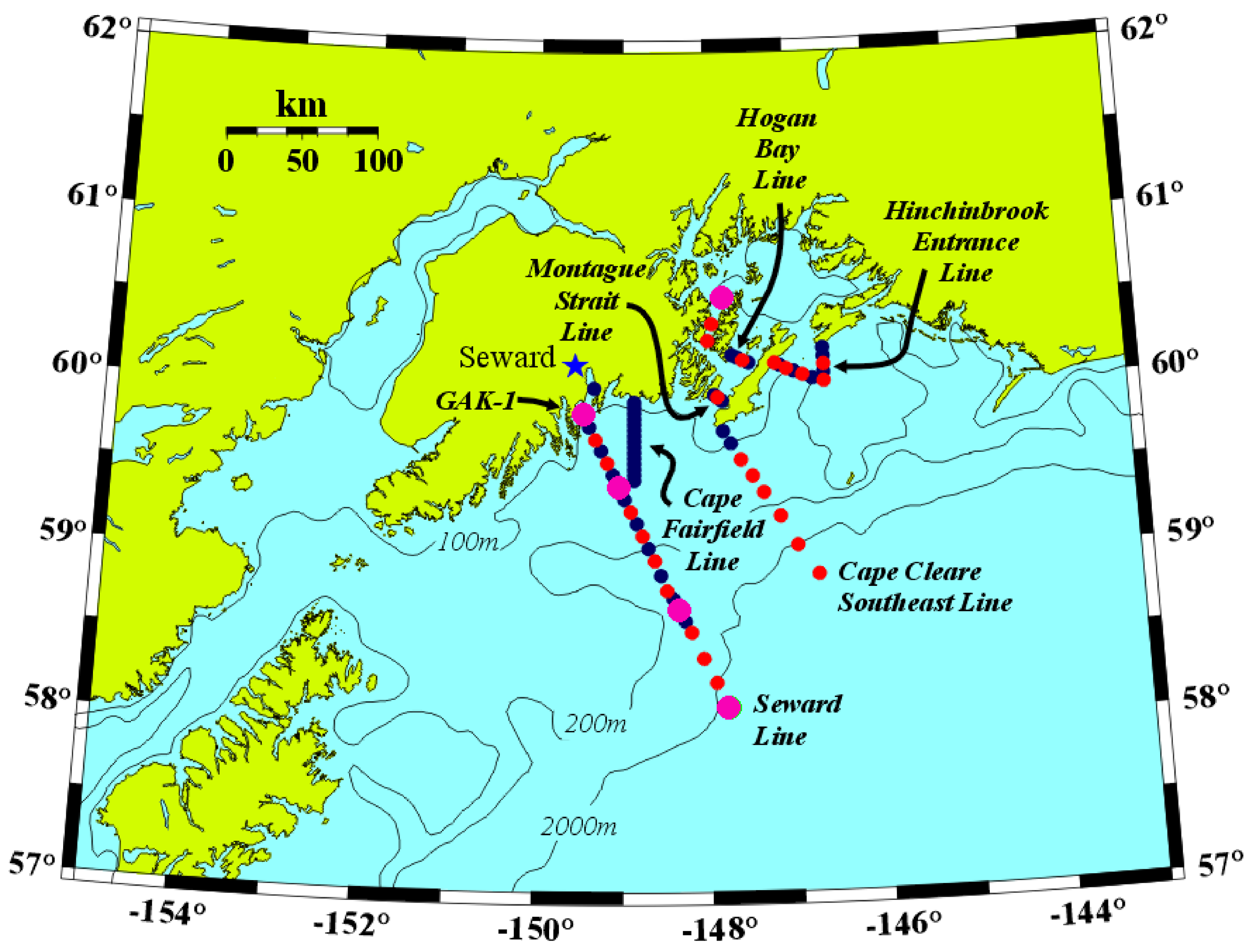

Figure 1. LTOP sampling area. Typical experimental sites indicated in purple

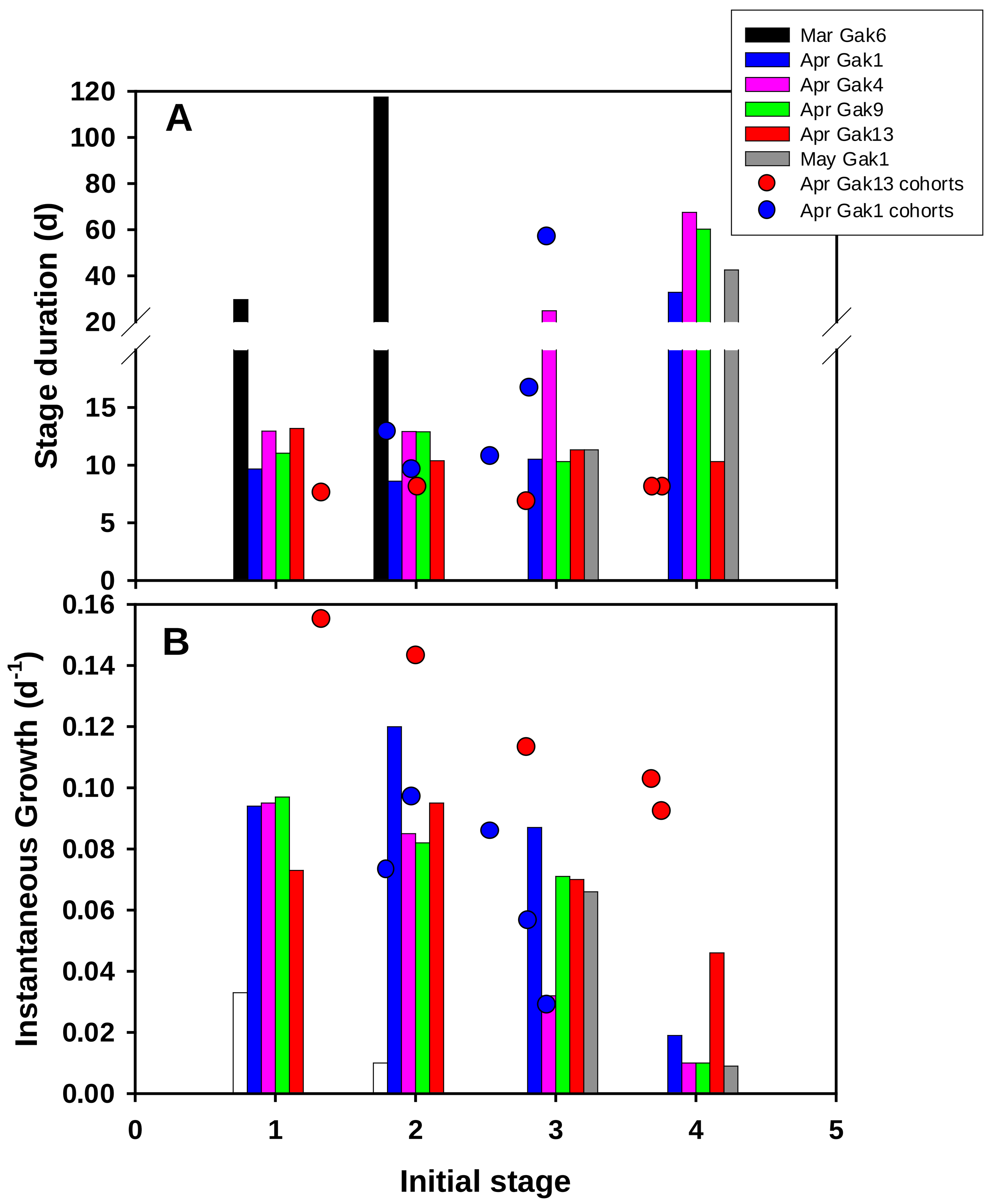

Figure 2. (To Right). A) Stage duration and B) growth rates of Neocalanus for the Gulf of Alaska. Results from single stage populations (bars) and artificial cohorts (circles) referenced to the average copepodite stage at the start of the experiment.

Results:

On the 6 LTOP cruises executed thus far in 2001 twenty-two experiments have been executed to estimate growth rates of copepod copepodites at Gak1, 4, 9, 13 and PWS2. *Neocalanus femingeri/plumchrus* were present in all experiments except for August and October. These two species have proven difficult to distinguish in the early copepodites and have for the moment been grouped.

Rates in March were available for only the first 2 copepodite stages, and are the slowest developmental rates recorded (Figure 2). Given that March temperatures were very similar to those observed in April, we can only presume food limitation was operational. Development rates were surprising constant for the first 3 stages in April, with both single stages and artificial cohorts giving similar results. The apparent discrepancy between single stages and artificial cohorts at Gak1 is spurious and due to the accumulation of longer-lived stage 4 copepodites in larger sizes classes of the artificial cohorts. Lastly, the fact that both single stages and artificial cohorts give similar results for copepodite stage 4 at Gak 13, suggests that these short developmental times are real rather than erroneous. This suggests that resources may have been superior on the oceanic end of the line as compared to more nearshore waters. Rates in May appear similar to those of the previous month.

We have yet to generate a length-weight relationship for *Neocalanus femingeri/plumchrus* to convert lengths to appropriate weight to estimate growth rates, in the interim we have employed a generalized relationship (slope of 2.84). If this relationship is representative, instantaneous growth rates fall between 0.16 and ~0.01 d^{-1} (Figure 3), declining with increasing stage, and dropping significantly for copepodite stage 4. (Rates will be even higher if a higher length-weight slope parameter is more appropriate)

There was not an obvious effect of temperature based on the currently available data. Animals that molted were often smaller at stage than animals freshly collected, possibly due to increased temperature during incubation, reduced food concentration, or damage during collection/handling.

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 from the ship's roll remains a cause for concern.

Results 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 of 24-25 days for stage 3 & stage 4 copepodites (Miller and Nielsen, 1988) is also within the range observed here, although even longer stage duration appears common for copepodites 4. 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/plumchrus*. 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 it descends to depth for diapause, although this stage is generally expected to be of longer duration 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. Although there was not an obvious effect of temperature based on the current data, we expect such a relationship to emerge, along with one to food concentration, once more data is available.

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