Development, growth, and egg production of *Neocalanus flemingeri* in the eastern subarctic Pacific: a synthesis of laboratory and field approaches

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Abstract:

*Neocalanus flemingeri* is one of the dominant copepods in the subarctic Pacific, yet there are few estimates of the rates at which many processes occur during its life-cycle. Growth and development of *N. flemingeri* CI to CV copepodies were determined in the field by both the artificial cohort method, and the incubation of single stages, each March, April and May over 3 years (~5 C). Development, growth, and egg production were also determined at 5 C in the laboratory at saturating food concentrations. In the field, CI to CV stage durations ranged from 7 to more than 100 days, dependent on chlorophyll concentration, with the duration of each stage ~10 days under optimal conditions. Stage durations varied from 5-24 days for CI to VI, and 6-16 days for CI to CV in the laboratory, with development time from egg to CV of 117 days. Weight-specific growth rates ranged from 0.23 d⁻¹ close to zero in the field, but was typically between 0.20 and 0.08 d⁻¹ under more favorable conditions. This compares favorably to 0.07 to 0.27 d⁻¹ obtained in the laboratory. In both cases, growth rate typically decreased with increasing stage. Fecondity of *N. flemingeri* was 534 ± 43 (mean ± S.E.) eggs female⁻¹, representing ~70% of the female's initial weight. Results are compared to rates of other copepods determined concurrently in this ecosystem.

Introduction:

Of 15 common species of copepods in the Gulf of Alaska (GoA), the three *Neocalanus* species (*N. plumchrus, N. flemingeri, N. cristatus*) frequently dominate the zooplankton community biomass over the entire spring. Their abundance and large size make them important prey sources for higher trophic levels. Although we have an overall picture of the life cycles of the large-bodied copepods in the Northern Pacific (Mackas & Tsuda, 1999), the details are largely inferred. Despite the presumed importance of *Neocalanus*, there are only three estimates of development rate and one for growth rate in copepodies, and only two studies of egg production or nauplius development. Here, we present results to address this deficiency for the copepodies of *N. flemingeri* with field experimental results from the 2001, 2002, and 2003 spring seasons and that from the laboratory.

Method:

Field experiments were executed at stations GAK1, 4, 9 and Prince William Sound (PWS) (Fig. 1). Copepodies were collected from the upper 50 m with a 64 µm net and sorted into size classes of "artificial cohorts" by serial passage through mesh sizes from 1300 µm down to 400 µm. Half of each fraction was preserved immediately as the time zero, and the remainder equally divided among several 20L carboys filled with 80 -100 µm prescreened seawater. Carboys were incubated on-deck in large tanks at sea surface temperatures with ship movement providing a gentle "current" to the "environment". The rest of each fraction was screened onto a 45 µm mesh, pooled by size fraction, and preserved. Parallel experiments were executed simultaneously for *N. flemingeri* by picking single stages of copepodies from an additional net and incubating under the same conditions. Later, in the lab, copepodies were identified to species, stage, and the prosome lengths (PL-mm) were measured. The progression of the cohort was determined by changes in the mean size. The dry weights (DWg) were predicted from the relationship:

\[ \text{Log}(\text{DWg}) = -3.56 \times \text{Log}(\text{L}) - 2.32; R^2 = 0.95 \]

Based on the field results presented here, the first 4 copepode stages would be completed in 40-60 days assuming conditions remained comparable to those experienced during these incubations, consistent with the lab estimate of 44 days (Table 1). Saio & Tsuda (2000) estimated the duration of nauplius stages for *N. plumchrus* to be 30-40 days at 4°C. Our lab estimates for *N. flemingeri* were 56 days, close to the 55 days for *N. plumchrus* (Mackas & Tsuda, 1999). Our lab estimated development time from eggs lain to CV was 117 days. Lab estimated weight-specific growth rates of CI to CV averaged 0.15 d⁻¹, and decreased with stage from 0.28 to 0.07 d⁻¹ (Table 1).

Discussion:

Field estimated stage duration for the earlier copepodie stages appear surprisingly consistent. Our lab-determined values of 11-15 days (Table 1) were comparable to durations of 12.6-16.6 days estimated by Miller (1993) from examination of natural field cohorts. The only directly determined stage durations of 24-25 days for CI and CV copepodies (Miller & Nielsen, 1986) were obtained from the range observed here, although even longer stage duration appears common for CV in GoA during lipid accumulation. The more rapid development of CV in May 2002 corresponds to highest chlorophyll concentrations in the larger phytoplankton (Fig. 3). Based on the field results presented here, the first 4 copepodie stages would be completed in 40-60 days assuming conditions remained comparable to those experienced during these incubations, consistent with the lab estimate of 44 days (Table 1). Saio & Tsuda (2000) estimated the duration of nauplius stages for *N. plumchrus* to be 30-40 days at 4°C. Our lab estimates for *N. flemingeri* were 56 days, close to the 55 days for *N. plumchrus* (Mackas & Tsuda, 1999). Our lab estimated development time from eggs lain to CV was 117 days. Lab estimated weight-specific growth rates of CI to CV averaged 0.15 d⁻¹, and decreased with stage from 0.28 to 0.07 d⁻¹ (Table 1).

Results:

Fecondity of *N. flemingeri* was high with 535 ± 28 female⁻¹ (mean ± S.D.) and a maximum of 1036 female⁻¹. There were up to 5 single clutches of eggs that could be identified with an average size of 225 ± 154 eggs (mean ± S.D.), and a trend of decreasing clutch size with successive clutches (Fig. 7). Egg production appears to range from 70% of the females initial weight. Egg production was nearly synchronous with over 90% of the eggs hatching between Day 2 and 3. Development of stages was also relatively synchronous and least-squares regressions of CPS were significantly different at P<0.005 (Fig. 8). The estimated median development time from eggs lain to copepodite CV was about 117 days. Lab estimated weight-specific growth rates of CI to CV averaged 0.15 d⁻¹, and decreased with stage from 0.28 to 0.07 d⁻¹ (Table 1).

References:


