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Growth and development of *Metridia pacifica* (Copepoda: Calanoida) in the northern Gulf of Alaska

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Abstract:

Juvenile growth and development rates of *Metridia pacifica*, one of the dominant large copepods in the subarctic Pacific, were investigated March through October of 2001- 2004 in the northern Gulf of Alaska. Stage duration of copepodite C1 to C5 were between 8 and 15 days under optimal conditions. Seasonally, growth rates increased from March to October, and reached up to and 0.28 d^{-1}. After standardization to 5°C (using a Q10 of 2.7), growth rates, averaged 0.083±0.005 d^{-1} (mean ± S.E), and were significantly correlated to chlorophyll *a*, with saturated growth rates of 0.15 d^{-1} for C1-3 and 0.10 d^{-1} for C4-5. A comparison of our rates to those predicted by global models of copepod growth rate suggested further refinement of these models is required.

Introduction:

In the subarctic Pacific, *Metridia pacifica* is a major player in the seasonal zooplankton cycle, generally ranking behind *Neocalanus* species within the zooplankton community biomass in spring and early summer, but ranking first during the late summer through winter seasons after the departure of large grazing copepods (*Neocalanus* spp.; *Eucalanus* spp.) from the upper mixed layer. Although we have an overall picture of the life cycles of the large-bodied copepods in the Northern Pacific, the details are largely inferred. Despite the presumed importance of *Metridia pacifica,* there are only few field estimates of development rate, two for egg production rate and one for somatic growth in copepodites. Here, we present seasonally rates on growth and development of *M. pacifica* in the northern Gulf of Alaska with field experimental results from the 2001-2004, explore the functional relationships between growth and food resource, temperature and body size, and compare estimated somatic growth rate to predicted values from global models.

Method:

Six cruises were conducted annually in 2001-2003 plus three more cruise in 2004. Field experiments were set up along the Seward line at stations GAK1, 4, 9, 13 and Prince William Sound (PWS) (Fig.1). Copepods were collected from the upper 50 m and sorted into "artificial cohorts" by serial passage through mesh sizes from 800 µm to 200 µm. Half of each fraction was preserved immediately as the time zero, and the remainder equally divided among several 20L carboys. After 4-5 days of incubation, carboys were screened and preserved. In the lab, copepods were identified to species, staged and the prosome lengths (PL-µm) were measured. The progression of the cohort was determined by changes in the mean size. The dry weights (DW-µg) were predicted from the relationship: $\log_{10}DW = -3.29*\log_{10}PL - 8.75$ (r^2=0.98, n=83). The calculation of *in situ* weight–specific growth rate was based on the $g = (\ln DW_t - \ln DW_0)\ t^{-1}$. When necessary, growth rates were standardized to 5°C using Q10 of 2.70 for food-saturated broadcast-spawning copepods (Hirst and Bunker, 2003).

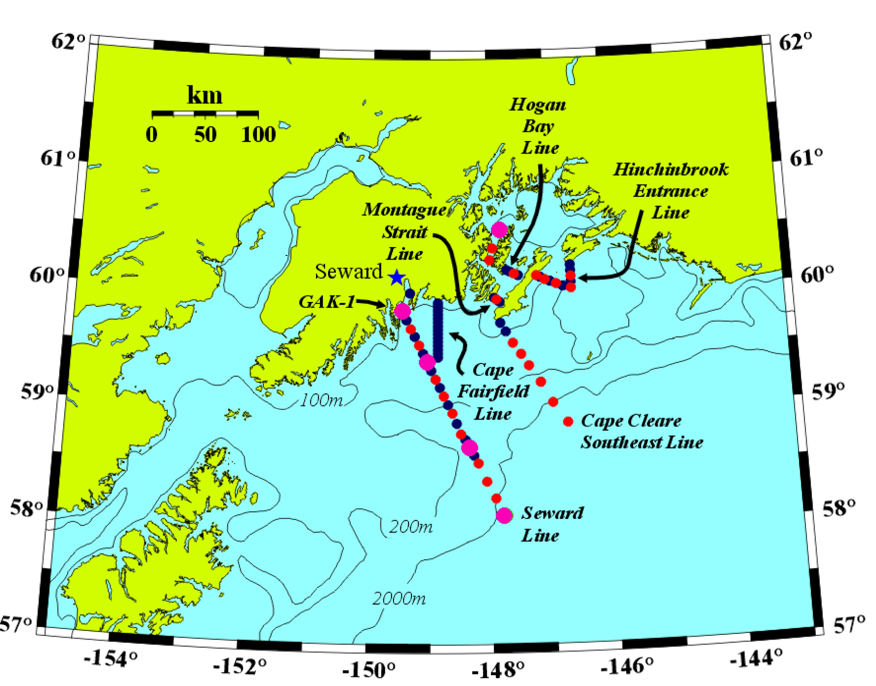

Fig.1. Sampling area. Experimental sites indicated in larger red dots.

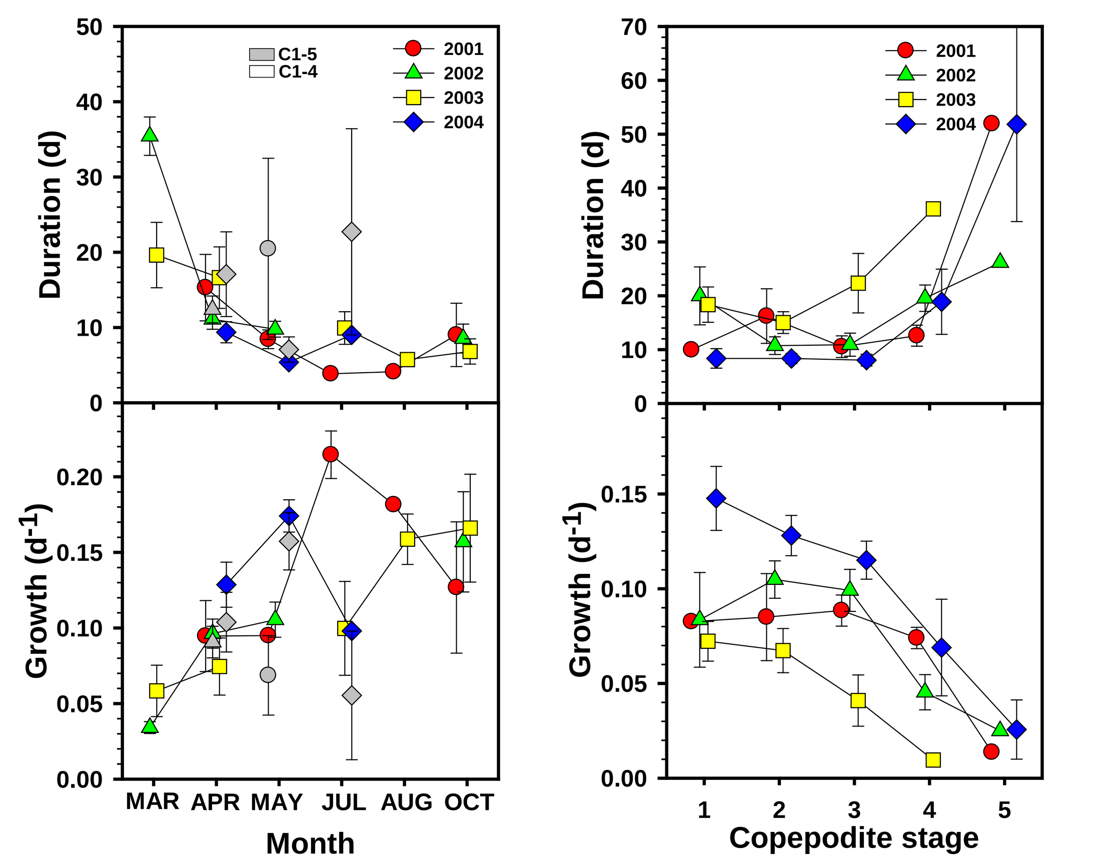

Fig.2. Seasonal mean stage duration and growth rate of *Metridia pacifica* copepodites (left column), and the standardized mean stage duration and growth rate to 5°C (right column) in the northern Gulf of Alaska 2001-2004. Values plotted against initial stage and offset to improve interpretation. Bars indicate standard errors.

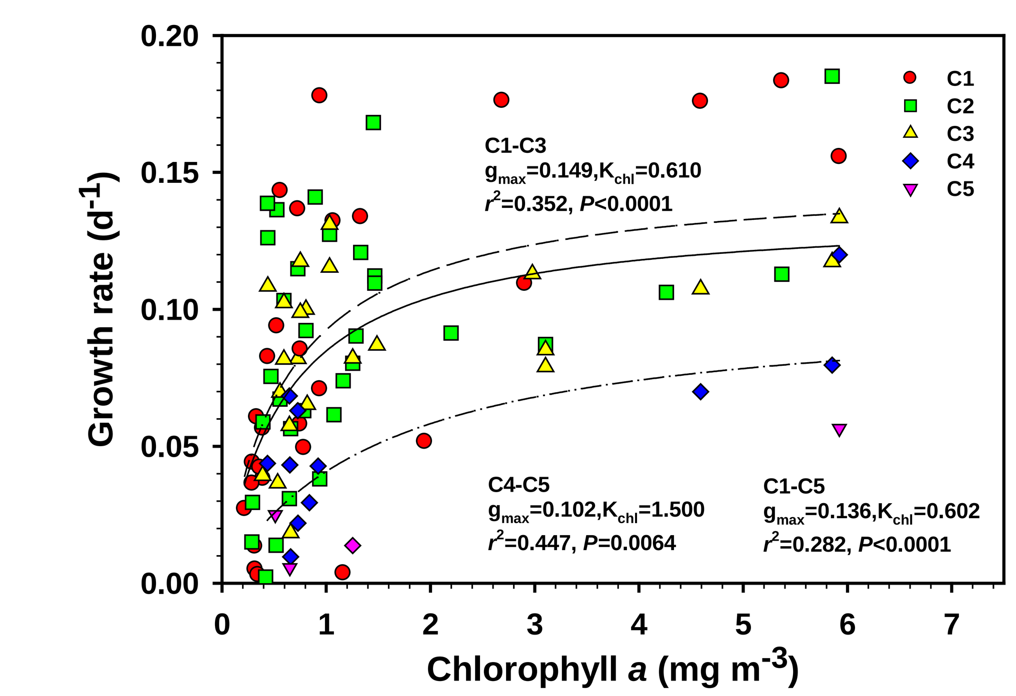

Fig.3. Relationship between temperature-corrected growth rates and chlorophyll *a* for *Metridia pacifica* in the northern Gulf of Alaska. Michaelis-Menten curves fitted for C1-C5 (solid line), for C1-C3 (dashed line), and C4-C5 (dashed dot line).

Table 1. Functional relationships of *Metridia pacifica* between growth rate (d^{-1}), initial stage, incubation temperature, body weight (µg C ind^{-1}), and chlorophyll *a* concentration (mg m^{-3}) in the northern Gulf of Alaska.

Function	Equation	n	T (°C)	Coefficients (*p*)					$r^2(p)$
				a_1	a_2	a_3	a_4	a_5	
Multiple Regression	$g=a_1+a_2T+a_3\log Chl+a_4\log BW+a_5 Stage$	98	4.1-14.7	0.4033 (0.0497)	0.0095 (<0.0001)	0.0549 (0.0012)	0.3689 (0.0021)	-0.1694 (0.0006)	0.425 (<0.0001)
Michaelis-Menten	$g=Chl[g_{max}]/(Chl+K_{ch})$ (C1-C5)	98	5		g_{max} 0.136 (<0.0001)		K_{chl} 0.602 (0.0005)		0.282 (<0.0001)
Michaelis-Menten	$g=Chl[g_{max}]/(Chl+K_{ch})$ (C1-C3)	83	5		g_{max} 0.149 (<0.0001)		K_{chl} 0.610 (0.0003)		0.352 (<0.0001)
Michaelis-Menten	$g=Chl[g_{max}]/(Chl+K_{ch})$ (C4-C5)	15	5		g_{max} 0.102 (0.0011)		K_{chl} 1.500 (0.1089)		0.447 (0.0064)
Composite Nonlinear	$g=a*\log BW+Chl[g_{max}]/(Chl+K_{ch})$ (C1-C5)	98	5	a -0.0301 (0.0015)		g_{max} 0.144 (<0.0001)		K_{chl} 0.646 (<0.0001)	0.354 (<0.0001)

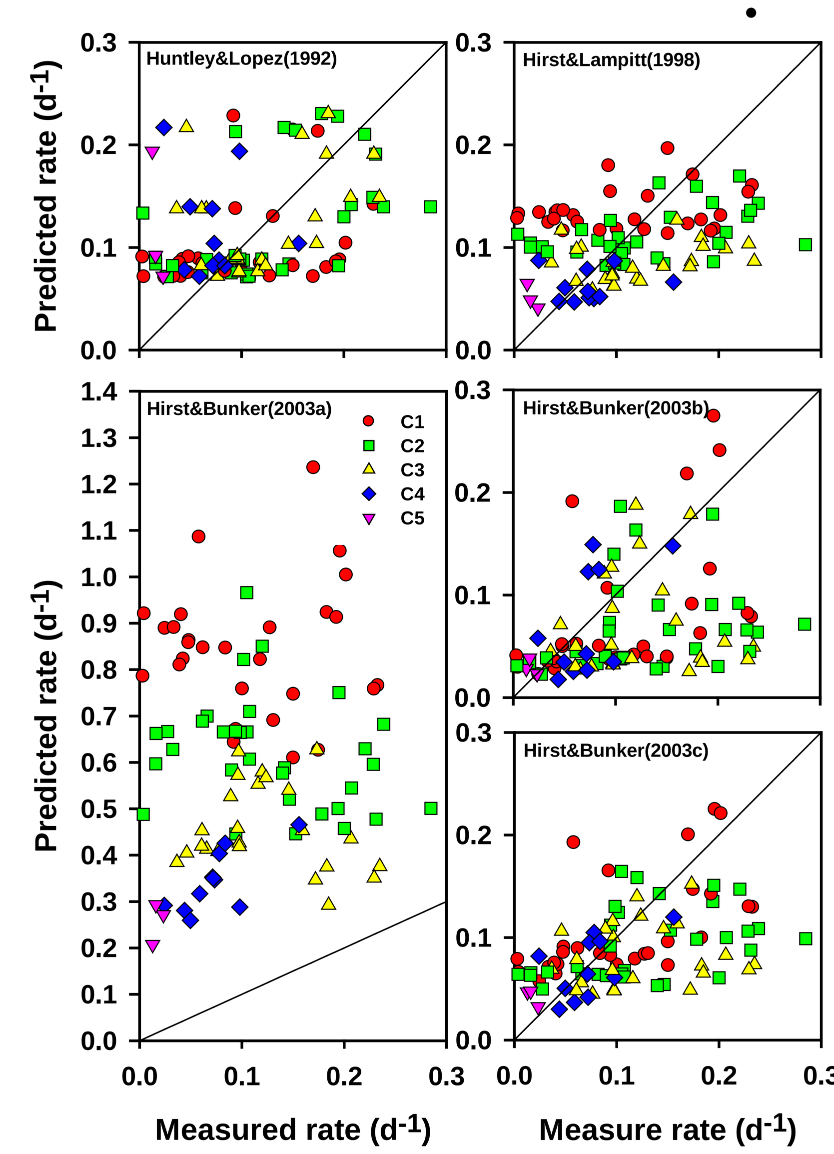

Fig.4. Comparisons of measured growth rates for *Metridia pacifica*, and growth rates predicted from the models of Huntley & Lopez (1992), Hirst & Lampitt (1998), and Hirst & Bunker (2003). Here, we employ the Hirst & Lampitt (1998) equation for all data (adults and juveniles of both broadcast and sac-spawners); Hirst & Bunker (2003) a: for juveniles broadcasters; b: for adult broadcasters; c: for all data combined.

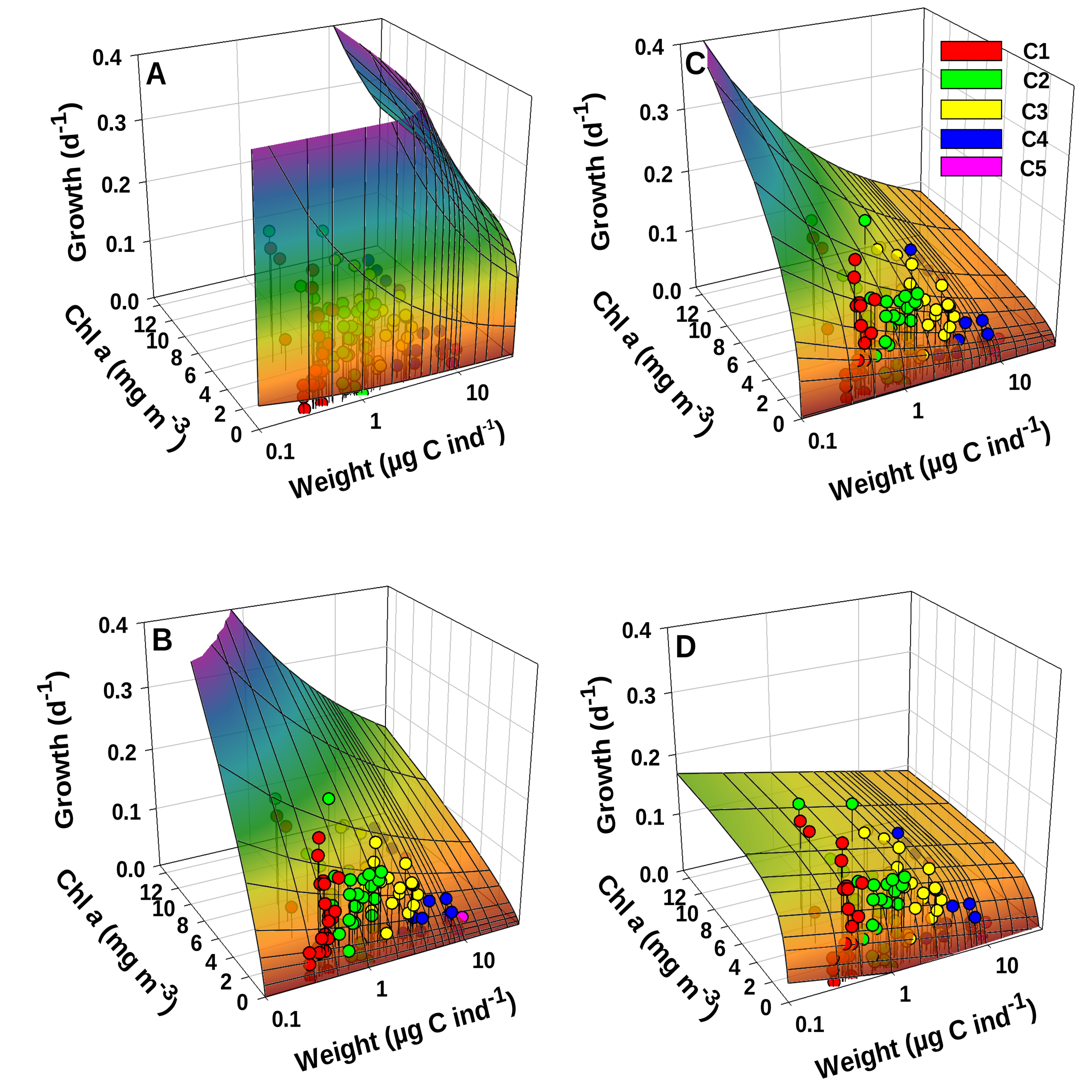

Fig.5. Comparisons of temperature-corrected growth rate for *Metridia pacifica* in this study with those predicted by Hirst and Bunker (2003) model at 5°C (colored surface). A: for juveniles broadcasters; B: for adult broadcasters; C: for all data combined; D: composite nonlinear model developed in this study.

Conclusions:

A. Seasonally, growth and development tend to be faster through March to October, and the overall mean growth rate of four years was 0.114 ± 0.007SE d^{-1}.
B. After removing temperature effects, growth and development rates decline with increasing copepodite stage, and the overall mean standardized growth rate was 0.083 ± 0.005 d^{-1}
C. Growth rates of *Metridia pacifica* were significantly related with temperature, chlorophyll *a*, body size, and stage by multiple regression analysis. Standardizing for temperature, chlorophyll *a* concentration explained 28.2 - 44.7% of variance in growth rate, while the inclusion of body size produced a single model with more exploratory power.
D. Comparison of growth rate predicted by models with measured rates in this study showed that some caution should be taken for the widespread use of these models, especially in the cold waters.
E. Growth rates and development time for *Metridia pacifica* in this study are consistent with other calanoid copepods in this area.

References:

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