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Effects of Temperature on Length of Intermolt Periods in Juvenile Male *Chionoecetes bairdi*

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ABSTRACT: The purpose of this study was to examine the effect of temperature on the intermolt duration of juvenile Tanner crabs *Chionoecetes bairdi* Rathbun. The average length of the intermolt period for Gulf of Alaska male Tanner crabs, with carapace widths (CW) of 24–26 mm, was ascertained for captives held at 3°, 6°, and 9°C. No test specimens died, and regardless of rearing temperature they fed avidly during captivity. Molting intervals were summarized in units of days and degree days. Increasing the rearing temperature from 3° to 6°C reduced the number of days between molts, but raising it to 9°C did not result in a similar reduction. The intermolt periods were 154 (SD =24), 78 (SD = 14), and 74 (SD = 8) days for juveniles held at 3°, 6°, and 9°C, respectively. The number of days between molts for the 3°C test group was significantly longer than the intermolt duration of juveniles reared at 6° and 9°C. There was no significant difference in the number of days between molts for the 6° and 9°C groups. In units of degree days, the mean intermolt periods at 3° and 6°C were nearly identical: 462 (SD = 74) and 467 (SD = 87) days, respectively. At 9°C molting occurred after an average of 665 (SD = 73) degree days. At 3° and 6°C, degree-day intermolt durations were not significantly different, but at 9°C the intermolt duration was significantly longer than those observed at 3° and 6°C. Thus, at 9°C, a temperature commonly encountered by Gulf of Alaska Tanner crabs during fall, a prolonging of the degree-day intermolt duration occurred. The degree-day method of describing intermolt durations worked adequately at 3° and 6°C, but above 6°C additional experiments are needed to better comprehend the influence of temperature on molting frequency. There was no obvious relationship between rearing temperature and growth. The average increase in carapace width for males held at 3°, 6°, and 9°C was 33% (SD = 4), 32% (SD = 6), and 32% (SD = 8) with no significant differences detected in growth per molt relative to rearing temperature.

INTRODUCTION

The Tanner crab *Chionoecetes bairdi* Rathbun is a common Gulf of Alaska benthic invertebrate. There is information on growth per molt (Donaldson 1980; Paul and Paul 1996) and an estimate of the time span between molts in degree days for Gulf of Alaska juveniles and adolescents (Paul and Paul 2001). This latter estimation was obtained by holding males in seawater where the temperature fluctuated seasonally between ≈3° and 10°C. Although that experiment simulated the thermal conditions juvenile *C. bairdi* encounter in nature, there had been no tests done to validate the assumption that the degree-day method for predicting molting schedules was reliable. In this study we measured the intermolt periods for 24–26-mm carapace width (CW) males held at constant 3°, 6°, and 9°C to better understand the appropriateness of forecasting molting frequencies with the degree-day method. Information on intermolt duration is critical to understanding population recruitment because aging of Tanner crabs is difficult (Rosenkranz et al. 1998).

METHODS

Male Tanner crabs were captured with a small otter trawl at 20- to 100-m depths in Resurrection Bay (Gulf of Alaska) and transferred to the Seward Marine Center Laboratory. The rearing seawater came from 75-m depth, depths that juvenile Tanner crabs naturally inhabit. Individuals with carapace widths of <20 mm were held in tanks with flowing seawater. Some of these small crabs were held in tanks with high seawater flow rates, to keep conditions cool, and fed once per week, and others were held in low flow-rate tanks,

Authors: A. J. PAUL AND J. M. PAUL are marine biologists with the University of Alaska Institute of Marine Science, Seward Marine Center Laboratory, P. O. Box 730, Seward, Alaska 99664. E-mail: ffajp@uaf.edu
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to create warmer conditions, and fed every other day so not all molting would be synchronous. Some captives molted once before being used in the experiment while others molted twice. The timing of molting for these captives might not have been synchronous with cohorts living in situ due to holding temperatures and feeding conditions. One week after molting the new CW was measured to the nearest 0.1 mm using a vernier caliper. If the new CW was 24–26 mm, the crab's subsequent intermolt durations were calculated. Males of this size would be juveniles (Paul 1992).

Individual newly molted males were put into 12-L numbered, perforated plastic tubs floating in 800-L tanks. The seawater exchange rate in the tanks was 10% per day. They were kept in near darkness (1 lux) except during feeding and cleaning periods. During their captivity the crabs were fed every Monday, Wednesday, and Friday with alternating meals of live intertidal mussel *Mytilus trossulus* Gould, 1850, tail meat and carapace from the northern shrimp *Pandalus borealis* Krøyer, 1838, and coho salmon *Oncorhynchus kisutch* (Walbaum 1729) fillet. They were fed a surplus of food every time with excess food removed after 48 h.

Test individuals were held in temperature-regulated tanks at either 3° (n = 13), 6° (n = 12), or 9°C (n = 12). The standard deviation for the mean 3 test temperatures was ≤0.5°C. One week after they molted, their new CW was measured to the nearest 0.1 mm, and growth was recorded as the percent increase in CW. Intermolt periods were described in days and degree days. The degree-day intermolt period is considered to be the sum of the average daily temperature during the intermolt period. For example, if the intermolt interval was 30 days and the temperature every day was 6°C, the event spanned 180 degree days (30 days × 6°).

The ANOVA test and the Student–Newman–Keuls pairwise multiple comparison procedure were used to compare the intermolt durations for groups held at the 3 test temperatures. The ANOVA test was used to compare the percent increase in CW for the 3 test groups after converting the percentages to arcsine values.

RESULTS

No test specimens died during the study, and at all 3 test temperatures captives fed voraciously. Increasing the rearing temperature from 3° to 6°C reduced the number of days between molts, but the trend did not continue when the holding temperature was 9°C. The intermolt duration (Figure 1a, b) for specimens held at 3°C was 154 days (SD = 24) or 462 (SD = 74) degree days. At 6°C comparable values were 78 days (SD = 14) or 467 (SD = 87) degree days. At 9°C individuals molted after 74 days (SD = 8) or 665 (SD = 73) degree days. The number of days between molts for juvenile males held at 3°C was significantly longer than the intermolt period in days for males at 6°C (ANOVA, Student–Newman–Keuls P<0.05) and 9°C (P<0.05; Figure 1a). There was no significant difference in the number of days between molts for the 6° and 9°C (P< 0.05) test groups (Figure 1a). When the molting schedules were expressed in degree days the pattern of statistical similarity among the test groups was reversed. At 3° and 6°C intermolt durations in units of degree days were not significantly different (ANOVA, Student–Newman–Keuls P<0.05), but at 9°C the degree-day intermolt period was significantly longer than those observed at 3°C (P<0.05) and 6°C (P<0.05; Figure 1b).

At 3°, 6°, and 9°C, CW increased by an average of 33% (SD = 4), 32% (SD = 6), and 32% (SD = 8), respectively (Figure 1c). The ANOVA test indicated that there was no significant difference between the percent (arcsine) change in CW following the molt for groups held at the 3 temperatures (P = 0.855). Thus,

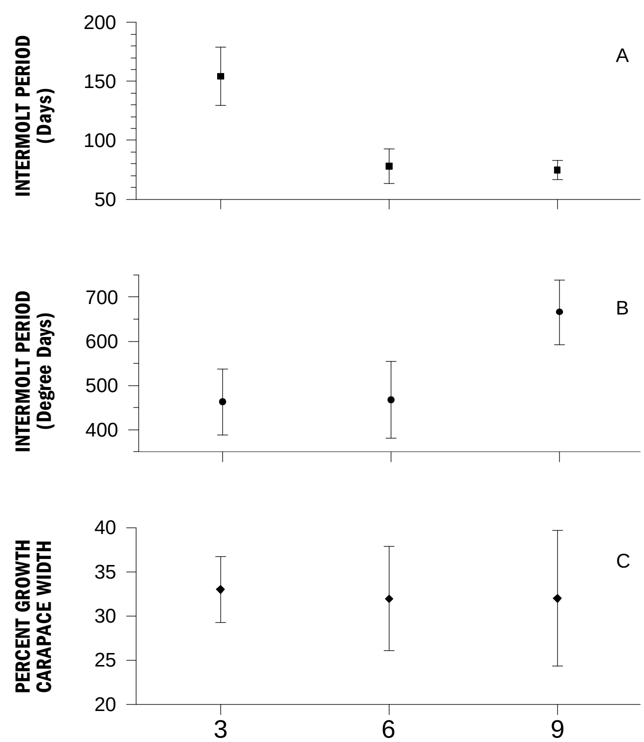

Figure 1. Intermolt duration of juvenile male Tanner crabs held at 3°, 6°, and 9°C in units of days (A) and degree days (B). The percent increases in carapace widths of captives held at 3°, 6°, and 9°C (C). Error bars are standard deviations.

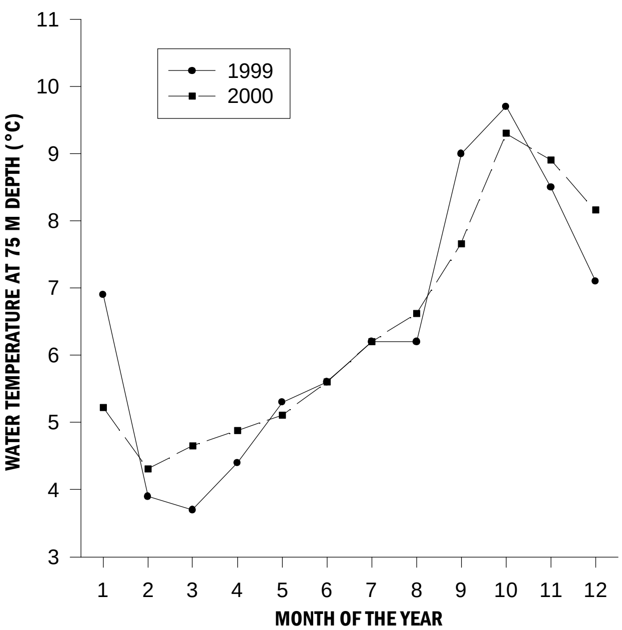

Figure 2. Temperatures at 75-m depth in Resurrection Bay where Tanner crabs were captured.

the rearing temperature had little effect on carapace growth per molt of test specimens.

DISCUSSION

Typically when rearing crabs, increasing the temperature reduces the intermolt period (see Leffler 1972 for example). However, the prolonged degree-day intermolt duration seen in Tanner crabs reared at 9°C (Figure 1b) showed that at some point between 6° and 9°C increases in rearing temperature ceased to reduce the time between molts. In Resurrection Bay sea bottom temperatures at 75-m depth, one depth where these specimens were collected, ranged from about 4°–9.5°C (Figure 2). At the capture site, Tanner crabs would have encountered about 9°C during September–November (Figure 2). This is a nonlethal temperature but one that modifies molting frequency (Figure 1). Currently the upper thermal limits of Tanner crabs have not been described. This experiment indicates that the degree-day method of describing intermolt durations works well at 3°–6°C, but above 6°C additional experiments are necessary to improve our understanding of the effect of temperature on molting schedules. Our experiments did not measure intermolt frequencies at the lowest temperatures Tanner crabs might encounter in habitats like the Bering Sea.

In this study captives were well fed. Currently we have no information on the nutritional status of Tanner crabs in the wild, so these results should be used with caution when predicting in situ molting frequencies. Experimental studies in which food is limited to varying degrees are needed to describe the importance of energy consumption levels on intermolt durations. However, understanding how the results of such a study relate to in situ molting frequencies would be problematic because we do not know if food is limited or abundant for wild Tanner crabs.

In addition to modifying the intermolt duration, thermal conditions impact growth in some species. In juvenile blue crabs *Callinectes sapidus*, increase in size is less at higher temperatures than at lower ones (Leffler 1972). We did not observe conspicuous thermal-related growth differences in juvenile Tanner crabs, but that may be because we did not examine growth over the whole range of temperatures that *C. bairdi* inhabits. The results of this study suggest that the effect of temperature on molting in Tanner crabs is complicated, and caution must be used when predicting intermolt durations with the degree-day method.

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