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Growth of Juvenile Golden King Crabs *Lithodes aequispinus* in the Laboratory

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ABSTRACT: Growth observations were made for juvenile male golden king crabs *Lithodes aequispinus* with carapace lengths (CL) of 2 to 35 mm to improve our understanding of the recruitment process. Gravid females were captured in Prince William Sound, Alaska, and juveniles were reared in the laboratory at 3°–10°C to obtain information on growth per molt and intermolt duration. The equation describing the increase in CL for crabs 2 to 35 mm CL was: New CL mm = Initial CL (1.25) + 0.14; $r^2 = 0.99$, $n = 76$. The average increase in CL after molting was 28% (SD = 8%), and the corresponding value for chela height (CH) was 33% (SD = 17%). The intermolt duration, in units of degree days, of crabs 2 to 35 mm CL was described by the equation: Intermolt Duration = Initial CL mm (16.32) + 259; $r^2 = 0.76$. The results from this study provide new insight into the growth patterns of this commercially important species.

INTRODUCTION

Managers of crab fisheries use information on growth rates to anticipate recruitment to the fishery and understand the relative age structures of populations. In Alaska and other regions of the North Pacific, the golden king crab *Lithodes aequispinus* is harvested commercially, but there is little information on growth rates of the early benthic stages. There is some information on growth per molt and morphometric changes in adult golden king crabs (Koeneman and Buchanan 1985; Paul and Paul 1999a) and growth rates of larvae (Paul and Paul 1999b), but similar information for juveniles is not available. This species is often found in deep water, on untrawlable bottom, and in remote regions, so studying growth in situ is difficult. The objective of our study was to measure growth per molt of captive juvenile golden king crabs and to obtain information on their intermolt durations.

METHODS

Gravid golden king crabs were captured with pots on the west side of Prince William Sound, Alaska, 20 October 1998 at depths of 100 to 150 m. They were held in 800- to 1,000-L seawater tanks at the Seward Marine Center Laboratory (see Paul and Paul 2001a and 2001b for methods). After the eggs hatched the nonfeeding larvae were reared (see Paul and Paul 1999b and Adams and Paul 1999 for methods). In golden king crabs the female reproductive cycles are not synchronized (Adams and Paul 1999; Paul and Paul 1999a), so juveniles can molt in any month, several instars may coexist, and specimens of a given size may encounter different thermal conditions. Once the juveniles had reached Crab I stage they were mass reared in shallow tanks. The carapace length (CL) and chela height (CH) of 32 Crab I-stage individuals were measured before they were put into the rearing tank with several others to portray the size of the Crab I stage. Crabs were fed to excess every Monday with whole northern shrimp *Pandalus borealis* Krøyer, 1838; Wednesday they were given octopus *Octopus dofleini* (Wülker, 1910) or squid (species unknown), and Friday coho salmon fillet *Oncorhynchus kisutch* (Walbaum, 1792). Despite being well fed there was considerable cannibalism. Juveniles molted during all months of the year and both during the day and at night. Molting individuals were especially susceptible to cannibalism. These growth observations were carried out between the fall of 1998 and the end of 2000. Juveniles used in the study came from several female parents, and new specimens were incorporated into the study during all years of the project.

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Periodically individuals (n = 76) showing signs of preparing to molt (changes in color, swelling of the abdomen) were taken from the mass rearing tanks and isolated in individual, numbered 20-L tanks to measure growth and intermolt durations. Test animals were held in separate numbered tanks for the duration of one molt to prevent cannibalism. When an isolated crab molted, the date of molting was recorded. After 2 weeks had passed and the carapace had hardened, its maximum CL and CH was measured to the nearest 0.1 mm. The carapace was measured from the right eye notch directly to its posterior edge. Chela height was measured across the widest portion of the largest claw. The date of each crab's second molt was recorded to calculate the intermolt duration. The new CL and CH were measured 2 weeks later. The shape of the abdominal flap was examined to determine the sex of the crabs. Specimens under 10 mm CL were difficult to sex based on gross examination of abdominal flap shape, so they were not assigned a sex. All the larger test specimens used in the study were males. After molting specimens were measured and then returned to the mass rearing tank. It is possible that an individual was used more than once for intermolt and growth observations, but crabs were not marked so we could not identify such individuals.

The seawater for the Seward Laboratory comes from 75 m depth in a fjord, and its temperature during the study was 3°–10°C. The temperature of the incoming water changes with season and has marked interannual variations in monthly values. Each day the seawater temperature in the tanks was recorded. Salinity ranged from 31 to 33 ppt. The intermolt duration was described in both days and degree days. Degree days were calculated by summing the daily seawater temperatures that occurred during the intermolt period. For example, if an event took 10 days, and each day the temperature measurement in the tank was 10°C, then the process would have taken 100 degree days. Changes in CL and CH associated with growth were plotted using linear regressions.

RESULTS AND DISCUSSION

Size of Crab I

The CL and CH of the Crab I stage (n = 32) averaged 2.5 mm (SD = 0.06) and 0.57 mm (SD = 0.04), respectively. This information is provided to identify the size of newly metamorphosed individuals, but no observations on intermolt durations were made for these 32 individuals.

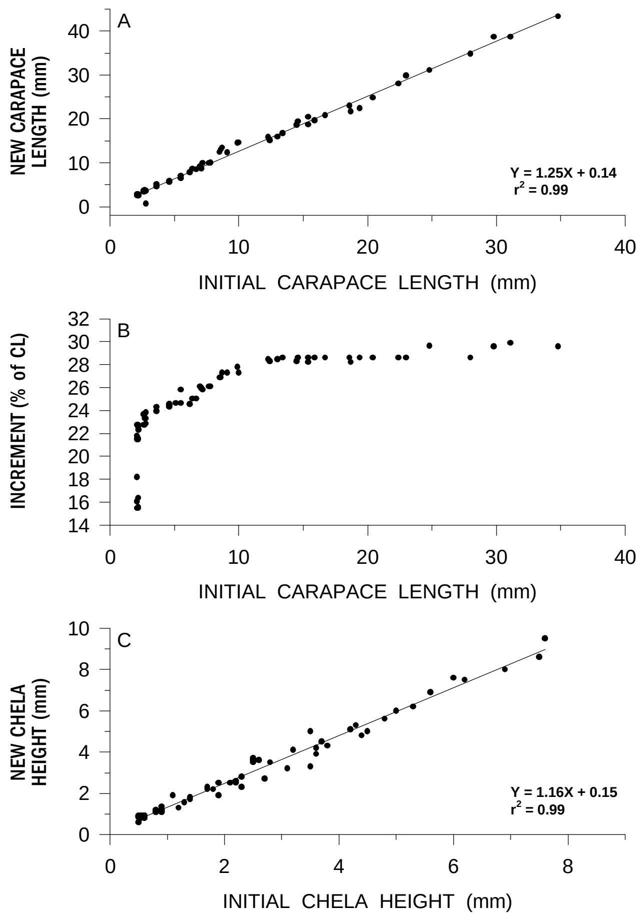

Figure 1. Morphometric changes of juvenile *Lithodes aequispinus* molting in captivity. The relationship of initial carapace length (mm) and postmolt carapace length (A). Percentage growth in carapace length (mm) relative to initial carapace length (B). The relationship of initial chela height (mm) and postmolt chela height (C).

Growth and Intermolt Duration

The equation describing the increase in CL from Crab I to individuals of 35 mm CL was: New CL mm = Initial CL (1.25) + 0.14; r^2 = 0.99, n = 76 (Figure 1a). The average increase in CL was 28% (SD = 8%) for all 76 specimens for which intermolt duration information was available (Figure 1b). Individuals under 5 mm CL exhibited a much smaller growth increment than specimens over 10 mm CL (Figure 1b). The relationship between initial CH and postmolt CH (Figure 1c) was: New CH mm = Initial CH (1.16) + 0.15; r^2 = 0.99. The average increase in CH was 33% (SD = 17%). The relative increase in CL and CH observed in these juveniles is markedly larger than that seen in sexually mature golden king crabs. In adult females and

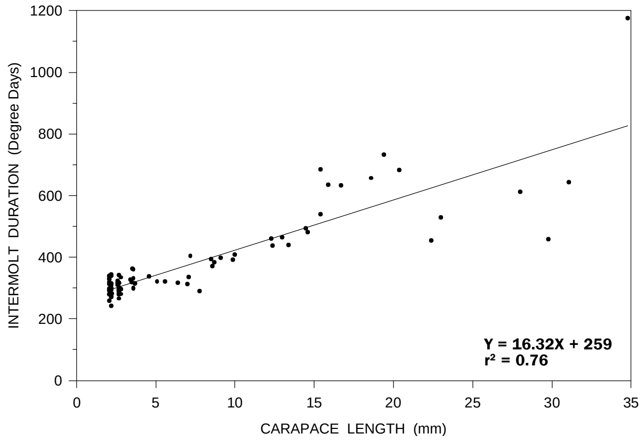

Figure 2. Intermolt duration (degree days) of juvenile *Lithodes aequispinus* molting in the laboratory relative to initial carapace length (mm).

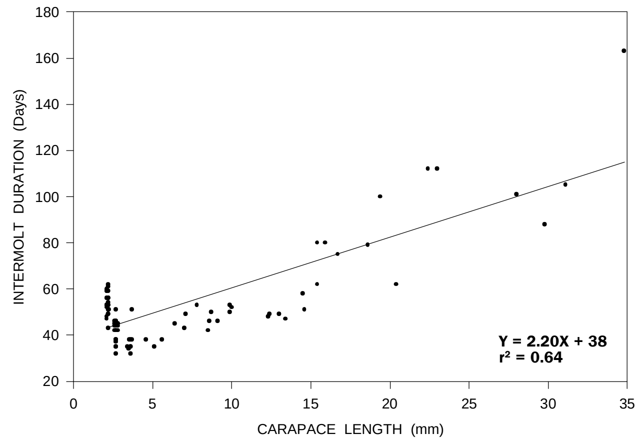

Figure 3. Intermolt duration (days) of juvenile *Lithodes aequispinus* molting in the laboratory relative to initial carapace length (mm).

males the increase in CL averaged 5% and 8%, respectively (Paul and Paul 1999a), compared to 28% for the juveniles in this study. Adult CH increased 16% for females and 12% for males, compared to 33% for juvenile males.

No other information on the growth per molt for juvenile golden king crabs is available for comparison to our results. In the southern king crab *Paralomis granulosa* (Lithodidae) increases in CL for 10–60 mm individuals varied between 2% and 23% (Lovrich and Vinuesa 1994) while in *Lithodes santolla* the increase in size is about 25% for early juveniles (Vinuesa et al. 1990). In juvenile red king crabs *Paralithodes camtschaticus* CL increases about 23–27% after molting (Weber 1967).

The intermolt duration of male crabs 2 to 35 mm CL was described by the equation: Intermolt Duration in degree days = Initial CL mm (16.32) + 259; r^2 = 0.76. Based on the growth rate in Figure 2, a newly settled individual at ≈2 mm CL would require 5,200 degree days to grow to 35 mm, our largest specimen. Assuming an average benthic temperature of 6°C that would be about 866 days. Intermolt durations in terms of days (Figure 3) showed a linear pattern similar to that of the degree day characterization (Figure 2), but the r^2 value was only 0.64. This poorer fit to the linear equation was expected since specimens of similar size existed in both warm and cool periods of the year.

Typically juvenile crabs have much shorter intermolt periods than adults, and this was true for golden king crabs. The intermolt duration for adult female golden king crabs is about 1.5 to 2 years (Paul and Paul 2001a), and adult males have intermolt periods around 10–33 months (Koeneman and Buchanan 1985). At our predicted molting rate for juveniles (Figure 2) a newly settled crab would molt about 6 times during its first year if the bottom temperature averaged 6°C. Of course, in this laboratory study food was plentiful, and in nature nutritional limitations may alter intermolt durations. Likewise, the thermal conditions in which the crabs were held may have been warmer than the environment inhabited by juvenile golden king crabs, so the results of the study must be viewed with caution.

Male golden king crabs from Prince William Sound mature at ≥107 mm CL (Paul and Paul 2001b). The number of molts juveniles would have to undergo to reach this size after metamorphosing as a Crab I is unknown. In Figure 4 the growth-per-molt increments for the juvenile males from this study and males 99 to 155 mm CL from a previous report (Paul and Paul 1999a) are plotted together to illustrate the growth increment patterns of these 2 size groups. To better understand developmental patterns for males >35 mm we need additional growth rate observations for males between 35 and 99 mm CL. In the North Pacific brachyuran Tanner crab *Chionoecetes bairdi*, the carapace growth patterns of juvenile and mature males fit closely along the same regression line (Paul and Paul 1996), a pattern similar to that observed for juvenile and adult golden king crabs (Figure 4). However, as male Tanner crabs begin to produce spermatophores, intermolt durations dramatically increase (Paul and Paul 2001c). Currently we do not know if the onset of maturity is also accompanied by longer intermolt durations in golden king crabs. Additional studies should be done rearing or tagging *L. aequispinus* from southeastern Alaska, the Aleutian Islands, the Bering Sea, and Asian waters to compare their growth rates to those of Prince William Sound golden king crabs to see if there are regional variations in growth patterns.

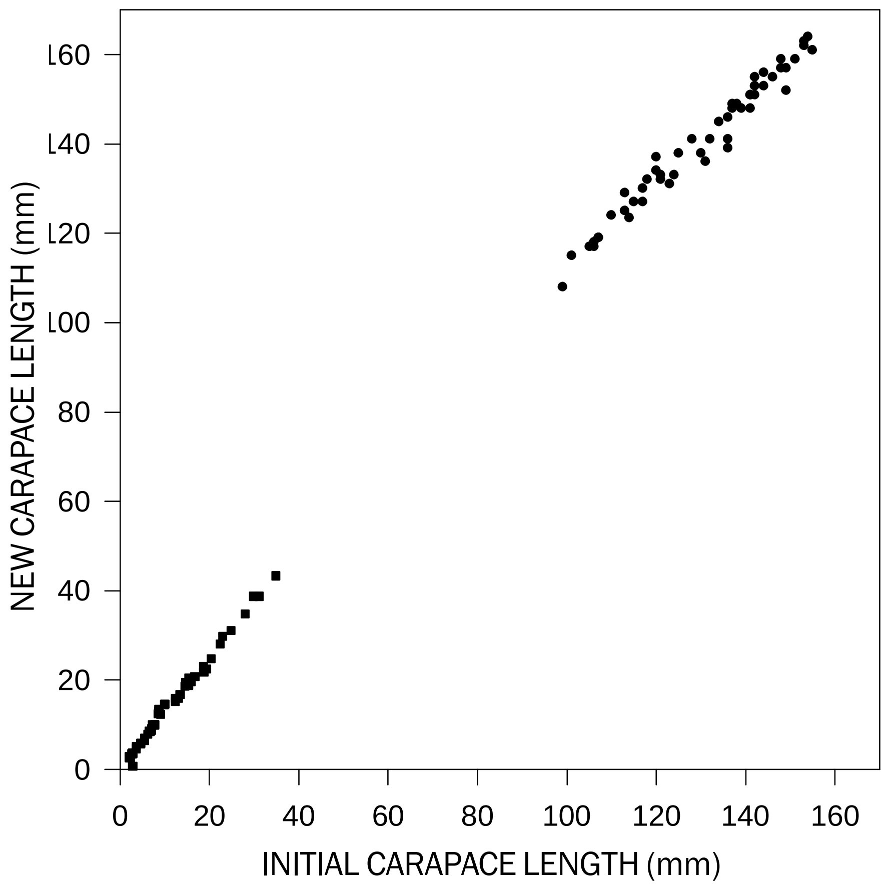

Figure 4. The relationship of initial carapace length (mm) and postmolt carapace length of 2–35 mm male *Lithodes aequispinus* (■ this study) and males 99–155 mm (● from Paul and Paul 1999a) molting in captivity.

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