COMPARISON OF FIRST YEAR GROWTH AMONG FIELD, HATCHERY- AND LABORATORY-RAISED JUVENILE RED KING CRAB, *PARALITHODES CAMTSCHATICUS* (TILESIUS, 1815), IN ALASKA

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A B S T R A C T

In an effort to better understand juvenile growth in the first year and to determine potential effects of hatchery larval rearing, we compared growth of juvenile red king crab, *Paralithodes camtschaticus* (Tilesius, 1815), in the field and under laboratory-rearing conditions. Glaucothoe were obtained from the Alutiiq Pride Shellfish Hatchery and field; once molted to first stage juveniles, both sets were raised individually in the laboratory under ambient conditions (hereafter called hatchery/laboratory-reared and wild/laboratory-reared, respectively) and measured at each molt. Field-surveyed juveniles were observed and measured monthly in the intertidal in Juneau, AK, USA. Size, molt interval, cumulative molt interval, and molt increment did not differ significantly between hatchery/laboratory-reared and wild/laboratory-reared crab or between male and female crab over one year. Crab reached an average size ± SD of 13.6 ± 2.1 mm CL after 10-11 molts/year with 24% average molt increment at ambient temperatures. Carapace lengths of hatchery/laboratory-reared, wild/laboratory-reared, and field-surveyed juveniles were not significantly different in five of eight months from January through August, with small differences in January, February, and May, likely resulting from differences in hatch timing. Spine lengths differed from January through March but not from April through August. Spine lengths of hatchery/laboratory-reared crab were significantly larger than field-surveyed crab from January through March. Wild/laboratory-reared crab had significantly longer spine lengths than field-surveyed crab in February and March. In conclusion, growth did not differ significantly among juveniles reared in the laboratory and from the field.

KEY WORDS: carapace length, ecdysis, enhancement, molt, spine length

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INTRODUCTION

Until the collapse of the fishery, red king crab, *Paralithodes camtschaticus* (Tilesius, 1815), was the most valuable crustacean species in Alaska. Across Alaska, commercial *P. camtschaticus* fisheries peaked throughout the mid-1960s into the late 1970s. The largest Alaskan stock, in Bristol Bay, had a record harvest of 58,943 metric tons during 1977-1980 (Zheng and Sideek, 2010). Shortly thereafter, in the early 1980s, all of the major Alaskan stocks of *P. camtschaticus* collapsed. Despite the absence of fishing pressure, *P. camtschaticus* failed to recover to pre-collapse abundance levels (Orensanz et al., 1998; Zheng and Kruse, 2000) and seven of the nine commercial Alaskan king crab stocks are currently closed to fishing.

In Alaska, rehabilitation, also termed restocking, enhancement, or rebuilding, is being explored as a potential tool for the restoration of *P. camtschaticus* populations. Rehabilitation is intended to address a bottleneck during early life stages; adult females release hundreds of thousands of larvae, but very few individuals reach maturity and recruit into the fishery. Crab rehabilitation requires capturing ovigerous females from wild populations, allowing the females to incubate and hatch their clutches in captivity,

and rearing the larval and juvenile crab in a hatchery. The hatchery can enhance larval and juvenile survival through lack of predation and adequate feeding. The goal is to maximize survival in the wild when large numbers of larvae or juveniles are released (Davis et al., 2005; Oliver et al., 2006) into nursery habitats with the intent of replenishing the indigenous brood stock (Robinson and Tully, 1999; Johnson et al., 2008). Stock rehabilitation has been implemented in other commercially harvested marine invertebrate species, including giant tiger prawn, *Penaeus monodon* Fabricius, 1798 (Davenport et al., 1999), kuruma prawn, *Marsupenaeus japonicas* (Bate, 1888) (Hamasaki and Kitada, 2006), fleshy prawn, *Fenneropenaeus chinensis* (Osbeck, 1765) (Wang et al., 2006), bay scallop, *Argopecten irradians irradians* (Goldberg et al., 2000), Japanese scallop, *Patinopecten yessoensis* (Uki, 2006), European lobster, *Homarus gammarus* Linnaeus, 1758 (Beal et al., 2002), spiny lobster, *Jasus edwardsii* Hutton, 1875 (Oliver et al., 2006), queen conch, *Strombus gigas* (Stoner, 1994), mud crab, *Scylla olivacea* (Herbst, 1796) and *S. serrate* (Forskål, 1755) (Le Vay et al., 2008; Lebata et al., 2009), and Atlantic blue crab, *Callinectes sapidus* (Rathbun, 1896) (Davis et al., 2005). Crustacean rehabilitation efforts strive to minimize

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costs and maximize survival by releasing late stage larvae or young juveniles, as in the case of the American lobster, *Homarus americanus* Milne Edwards, 1837 (Castro et al., 2001), and Atlantic blue crab, *C. sapidus* (Johnson et al., 2008), respectively. Since late stage larvae or small juveniles are the most likely stages to be released during a rehabilitation endeavor, the foundation of any restoration effort lies with research on early life stages.

Growth of crustaceans is inextricably linked to temperature (Hartnoll, 2001). Increased temperature results in an increased growth rate and decreased molt interval for the Chesapeake Bay blue crab, *C. sapidus* (Brylawski and Miller, 2006), and the red clinging crab, *Mithraculus forceps* Milne-Edwards, 1875 (Penha-Lopes et al., 2006). Early stage (C1 to C2) juvenile *P. camtschaticus* held individually grew larger with a shorter molt interval at 12°C compared to 1.5, 4.5 or 8.0°C over a 60-80 day period in the laboratory (Stoner et al., 2010). The range of temperatures tested by Stoner et al. (2010) approximates the range of temperatures experienced in nature by juvenile *P. camtschaticus*.

Growth of juvenile *P. camtschaticus* in the laboratory is less than that reported in situ. In the field, newly settled stage 1 crab (C1) have an average carapace length (CL) of 2.2 mm and within a year grow to stage 9 crab (C9), measuring approximately 10.5-11.2 mm CL, for a total growth of 8.3-9.0 mm per year (Donaldson et al., 1992; Loher et al., 2001). C1 crab in the laboratory grow from 1.8-1.9 mm CL to a size range of 3.7-4.9 mm CL (C6) in four to six and one half months (Nakanishi, 1987; Kovatcheva et al., 2006), which is less than the in situ size reached at 4-5.5 months (4.47-6.58 mm CL; Donaldson et al., 1992). The molt interval for laboratory mass-reared juvenile *P. camtschaticus* from stages C2 to C3 is estimated to be between 7-17 days, C3 to C4 estimated between 26-44 days and C4 to C5 estimated between 50-68 days (Kovatcheva et al., 2006).

Previous growth experiments with juvenile *P. camtschaticus* have been mainly conducted on juveniles reared en masse, at fixed temperatures in the laboratory or from an undetermined life stage. We examined growth of juvenile *P. camtschaticus*, starting with hatchery-reared and wild-caught glaucothoe and raising them individually in the laboratory from the first crab stage (C1) to compare molt interval and molt increment between these two source populations over a period of one year at ambient southeast Alaska temperatures. Simultaneously, we surveyed and measured juvenile crab monthly in the field to compare sizes with that of our laboratory-reared individuals in order to document any differences, or similarities, in growth.

MATERIALS AND METHODS

Experimental Animals

Hatchery-reared larvae were obtained from 20 ovigerous *P. camtschaticus* that were collected in Bristol Bay, AK, USA on 15 November 2008 and shipped to the Alutiiq Pride Shellfish Hatchery in Seward, AK, USA on 2 December 2008. The larvae hatched in March 2009 and were reared in 1200-l continuous flow through tanks at densities of approximately 50 larvae/l at 11°C (Swingle et al., 2013). On 9 May 2009, glaucothoe of *P. camtschaticus* were shipped to the University of Alaska Fairbanks, School of Fishery and Ocean Sciences in Juneau, AK, USA.

Wild *P. camtschaticus*-glaucothoe were collected using sausage-shaped artificial collectors (SACs) modeled after Donaldson et al. (1992). Lar-

val collectors were placed in the coastal waters near Juneau at the Couverden Islands (58°9.10′N, 135°2.80′W) and Indian Point (58°22.34′N, 134°41.65′W) at depths of 6 m and 9 m in late April 2009 and retrieved by SCUBA divers in mid-June through early July 2009 (Pirtle, 2010). SACs were enclosed in plastic bags under water and brought to the surface where they were placed in coolers with ice packs. In the laboratory, the SACs were deconstructed, rinsed carefully with filtered seawater, contents strained through 1 mm mesh and sorted, and all *P. camtschaticus*-glaucothoe were retained.

Rearing Conditions

Hatchery-reared and wild glaucothoe were sequestered into individual containers and entered into the experiment on the day of metamorphosis from glaucothoe to first stage juvenile. Juvenile *P. camtschaticus* were reared in individual 10.2 cm diameter by 25.4 cm tall PVC cylindrical containers with 1 mm fiberglass mesh set 5.1 cm above the bottom (1657.9 cm^3 living volume) set into Living Stream$^©$ tanks (LS-700; Frigid Units) in flow-through seawater with ambient photoperiod at the University of Alaska marine laboratories at Auke Bay and Lena Point in Juneau. A small amount of tangled gillnet was placed inside each container to provide settlement structure for the glaucothoe as well as vertical structure for the juvenile crab. Temperature was recorded every 30 min using a HOBO water temp Pro-VR logger. Salinity measurements were provided by the National Oceanic and Atmospheric Association's (NOAA) Auke Bay Laboratory (W. L. Wing, unpublished data). Salinity and temperature were maintained at ambient levels and varied seasonally from 10.1-31.2 and 3-12°C, respectively. Crabs received, to excess, a gelatin bound raw seafood diet enriched with mineral calcium. A typical batch yielded approximately 355 mL and contained the following: 3600 mg Caltrate$^®$ calcium, 12 g Knox$^©$ gelatin, 177 ml water, 28 g Otohime™, 20 g Ocean Nutrition™ brine shrimp (*Artemia* spp.), 20 g San Francisco Bay Brand™ cyclops, plus approximately 250 g wet weight of available raw seafood (krill, prawn roe, salmon roe, herring roe, silversides, salmon, shrimp, squid, mussels, and/or sea urchin) chopped finely in a food processor. The seafood-gelatin was refrigerated and used within two weeks.

Molt Interval and Molt Increment

Growth was monitored starting at the glaucothoe to first stage juvenile molt, which occurred in May 2009 for hatchery glaucothoe ($n = 46$) and July 2009 for wild glaucothoe ($n = 35$). The earlier molt to first stage juvenile observed in hatchery glaucothoe was due to higher larval rearing temperatures at the hatchery and shortened larval stage durations. Crab measures for hatchery/laboratory and wild/laboratory crab was standardized by comparing molt stage. Crab were monitored daily for molts through August 2010, with molt dates recorded, and exuvia removed, labeled and frozen in seawater until photographed. Carapace length (CL) of the exuvia was measured digitally to the nearest 0.01 mm on photographs using ImageJ software (version 1.42, Rasband, W.S., ImageJ, US National Institutes of Health, Bethesda, MD, USA, available online at http://rsb.info.nih.gov/ij/, 1997-2009; accuracy ±5 pixels at 150%). Molt increment was determined by subtracting CL of the current exuvia from the preceding exuvia and then dividing that difference by the CL of the exuvia (($CL_{i+1} - CL_i$)/CL_i) (where i = instar). The individual molt interval for each crab was standardized to degree-days (the summation of the average laboratory water temperature for each day in between successive molt stages). Spine length was determined by subtracting carapace width at the widest point not including spines (CW) from the carapace width including the last set of lateral spines on the carapace (CWS), and dividing by two equaling single spine length (($CW - CWS$)/ 2 = SL).

Field Surveys

Regular monthly field surveys were conducted, concurrent with the laboratory experiment, in order to look at differences in sizes and growth between laboratory-reared and field cohorts. Field surveys were conducted during monthly low tides at two survey sites in Juneau, AK, USA: Indian Point (between 58°22.71′N 134°41.34′W and 58°22.43′N, 134°41.50′W) and the beach located behind the University of Alaska Southeast's marine laboratory, hereafter referred to as Anderson Beach (between 58°22.81′N, 134°38.77′W and 58°22.95′N, 134°38.78′W), from January 2010 through December 2010. In the intertidal, vertical transects were surveyed from approximately 0.5 m below the water line to 3 m above the water line, as topography allowed (surveys never extended above the first mussel band in

the intertidal zone). Surveys were typically broken up into two or three transects and were dependent on the tide level and exposed topography. Transect lengths were measured using GPS coordinates. The average area $\pm$ SD surveyed at Indian Point was 703.6 ± 561.3 m^2 and at Anderson Beach the average area $\pm$ SD was 300.5 ± 127.1 m^2. Juvenile *P. camtschaticus* were counted and CL, CW and CWS were measured using either digital or dial calipers.

Statistics

Size, molt increment, molt interval, and time (standardized to degree-days) to the C9 stage were analyzed using repeated measures MANOVA with the measures of each crab at each molt stage as the repeated measure (response variables) and crab lot (hatchery/laboratory-reared or wild/laboratory-reared) as the predictor variable. Either matched pairs (paired t-tests with two repeated measures) or Tukey-Kramer HSD post-hoc tests were used to discern differences. The data for the repeated measures MANOVA met the criteria that $N - M > k + 9$ (N = total number of animals, M = number of between-subject treatments and k = number of factors in the dependent variable). The robustness of the repeated measures MANOVA depends on the assumption of sphericity, which can be unreliable (Quinn and Keough, 2002). Therefore, we assumed that in all instances sphericity was violated and used the F-statistic from the more conservative Greenhouse-Geisser adjusted ε (Quinn and Keough, 2002). To maintain robustness of the analysis, missing data accounted for less than 5% of all data for the response variables. Individual crab that were missing data, as well as crab that died during the experiment, were excluded from the analysis. With the removal of crab that did not molt to the C9 stage and crab that had measures missing, the final sample size for hatchery/laboratory-reared crab was $n = 10$ and wild/laboratory-reared crab, $n = 23$. Since sample sizes only permitted the MANOVA to be used up to the C9 stage, we compared the sizes of hatchery/laboratory-reared and wild/laboratory-reared crab on 3 September 2010 at the conclusion of the experiment with ANOVA. The sex of all crab was determined at this time, which allowed for a comparison of the growth of male and female juvenile crab at each stage using repeated measures MANOVA and at the end of the experiment by ANOVA. Sex was determined by the presence or absence of a gonopore on the coxa of the third periopod.

RESULTS

Molt Increment

Carapace lengths for C1-C9 molts were not significantly different between hatchery/laboratory-reared and wild/laboratory-reared crab (MANOVA, G-G $\varepsilon = 0.22$, df $= 1.73$, 44.98, $p = 0.49$) (Fig. 1). As expected, size increased over time (MANOVA, G-G $\varepsilon = 0.22$, df $= 1.73$, 44.98, $p < 0.001$). Molt increment differed significantly between hatchery/laboratory-reared and wild/laboratory-reared crab but not in a consistent manner, as evidenced by a significant
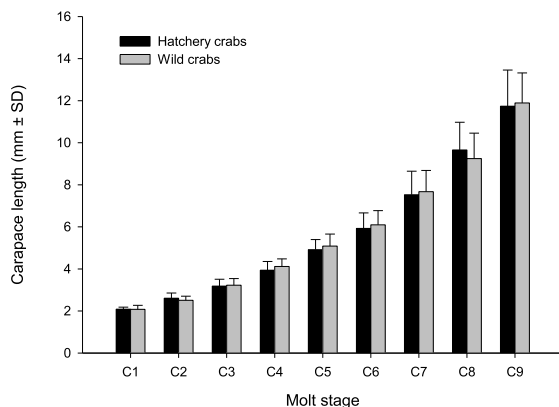

Fig. 1. Carapace length (CL) for the first nine molt stages for juvenile hatchery/laboratory-reared (black bars, $n = 10$) and wild/laboratory-reared (grey bars, $n = 23$) *P. camtschaticus*. Results are given as mean $\pm$ SD.
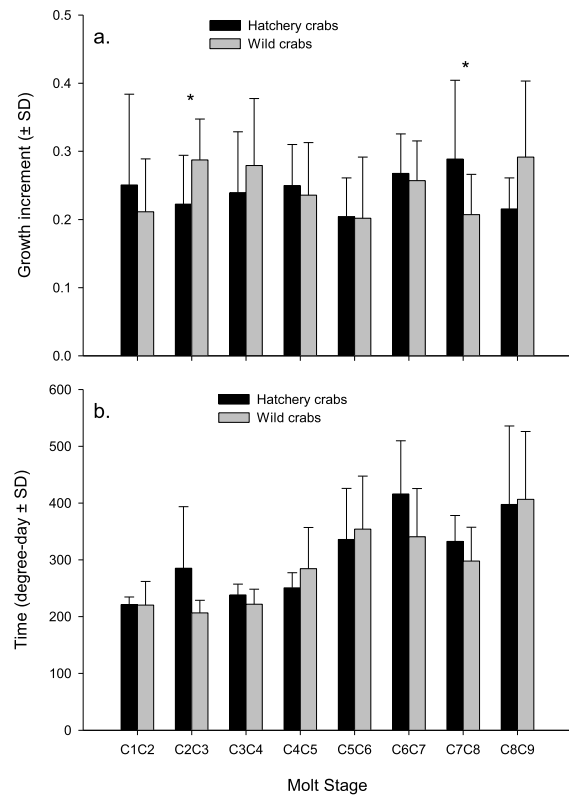

Fig. 2. (a) Growth increment $((CL_{i+1} \text{ (mm)} - CL_i \text{ (mm)})/CL_i \text{ (mm)})$ (i = instar) and (b) molt interval (degree-day) for the first nine molts of hatchery/laboratory-reared (black bars, $n = 10$) and wild/laboratory-reared (grey bars, $n = 23$) juvenile *P. camtschaticus*. Results are given as mean $\pm$ SD and an asterisk denotes significant differences.

interaction (MANOVA, G-G $\varepsilon = 0.74$, df $= 5.17$, 134.42, $p = 0.04$). Wild/laboratory-reared crab had a larger growth increment in the C2-C3 molt (Tukey HSD, $p = 0.02$), while hatchery/laboratory-reared crab had a larger molt increment in the C7-C8 molt (Tukey HSD, $p = 0.02$) (Fig. 2A). Between stages, molt increment C5-C6 was significantly smaller than molt increments C2-C3, C3-C4, C6-C7, and C8-C9. The molt increment averaged approximately 24% for both hatchery/laboratory-reared and wild/laboratory-reared crab over all molt stages (Fig. 2A).

At the conclusion of the experiment, carapace length did not differ significantly between hatchery/laboratory-reared and wild/laboratory-reared crab (ANOVA, $F = 0.18$, df $= 1, 31$, $p = 0.67$). After one year, hatchery/laboratory-reared and wild/laboratory-reared crab reached (average $\pm$ SD) 13.71 ± 1.45 mm CL (with a minimum size of 11.45 mm CL and a maximum of 15.59 mm CL) and 13.95 ± 1.59 mm CL (with a minimum of 11.46 mm CL and a maximum of 18.73 mm CL), respectively. The maximum molt stage reached by hatchery/laboratory-reared crab over one year was C11 ($n = 1$) and by wild/laboratory-reared crab was C12 ($n = 1$), with the majority of hatchery/laboratory-reared and wild/laboratory-reared crab attaining the C10 stage ($n = 6$ for hatchery/laboratory-reared and $n = 14$ for wild/laboratory-reared).

Molt Interval

Molt interval did not differ significantly between hatchery/laboratory-reared and wild/laboratory-reared crab (Fig. 2B; MANOVA, G-G $\varepsilon = 0.46$, df = 3.21, 99.58, $p = 0.08$). Molt intervals were longer at later molt stages (MANOVA, G-G $\varepsilon = 0.46$, df = 3.21, 99.58, $p < 0.0001$). In general, the first three molts (C1-C2, C2-C3, and C3-C4) had shorter molt intervals than all later molts. The C4-C5 molt and the C7-C8 molt were of intermediate duration, while the C5-C6, the C6-C7 and the C8-C9 molts were the longest. Cumulative time to molt did not differ between hatchery/laboratory-reared and wild/laboratory-reared crab (MANOVA, G-G $\varepsilon = 0.29$, df = 2.06, 61.67, $p = 0.17$).

Male vs. Female Crab

There were no significant differences between male and female crab in carapace length (final measurements (mean ± SD) 13.73 ± 1.77 mm and 14.13 ± 1.22 mm for males and females, respectively; MANOVA, G-G $\varepsilon = 0.22$, df = 1.79, 46.52, $p = 0.71$), molt increment (average ± SD 0.25 ± 0.09 and 0.24 ± 0.08 for males and females, respectively; MANOVA, G-G $\varepsilon = 0.77$, df = 5.40, 140.46, $p = 0.14$), molt interval (MANOVA, G-G $\varepsilon = 0.49$, df = 3.43, 102.91, $p = 0.31$) or cumulative time to molt (average time to C9 molt ± SD 2416.0 ± 230.2 days and 2340.8 ± 263.8 days for males and females, respectively; MANOVA, G-G $\varepsilon = 0.81$, df = 2.05, 61.58, $p = 0.45$).

Field Surveys

Juvenile *P. camtschaticus* were found at field survey sites from January through December except for September when crab were absent from both sites. Crabs were found at Indian Point from January through April (with one crab found in July) and at Anderson Beach from February through December (except September). During the months when crabs were observed, densities ranged from 0.01 to 0.43 crab/m^2 (the highest density was at Anderson Beach in February and the lowest at Indian Point in March and Anderson Beach in December). Field-surveyed crabs were directly comparable to laboratory-reared hatchery and wild/laboratory-reared crab from January through August. Overall, there were no consistent differences in size (Fig. 3A) between field-surveyed, wild/laboratory-reared and hatchery/laboratory-reared crab for most months (February, April, June, July and August). Hatchery/laboratory-reared crabs were larger than wild/laboratory-reared crab in January (Tukey HSD, $p = 0.0052$) and March (Tukey HSD, $p = 0.04$). Field-surveyed crab were larger than wild/laboratory-reared crab in May (Tukey HSD, $p = 0.003$).

Spine Lengths

Spine lengths differed significantly between field surveyed and hatchery/laboratory-reared crabs (Fig. 3B) in January (ANOVA, $F = 9.89$, df = 2, 40, $p < 0.001$), February (ANOVA, $F = 17.43$, df = 2, 67, $p < 0.0001$) and March (ANOVA, $F = 17.57$, df = 2, 77, $p < 0.0001$). In January, hatchery/laboratory-reared crab had significantly longer spines than field-surveyed crab (0.65 ± 0.11 mm and 0.45 ± 0.14 mm (all values in this paragraph are given as mean ± SD) for hatchery/laboratory-reared and field-surveyed crab respectively; Tukey HSD,
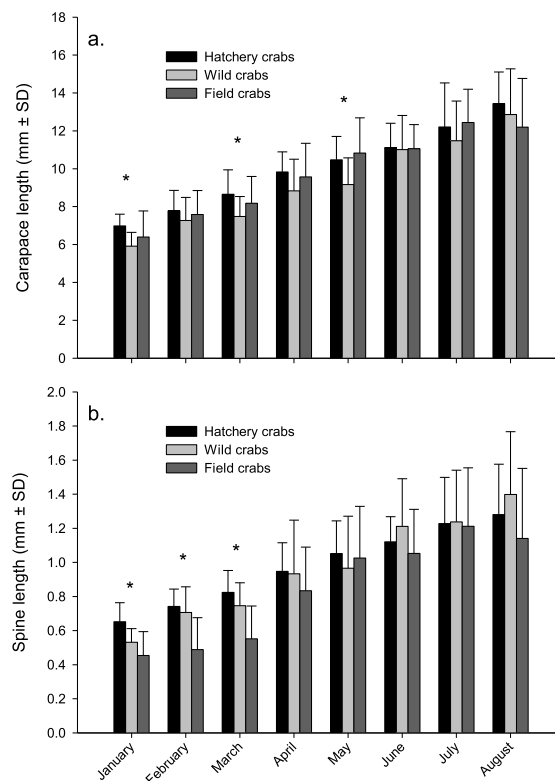

Fig. 3. (a) Carapace length (CL) and (b) spine length (SL) by month for hatchery/laboratory-reared (black bars, $n = 10$), wild/laboratory-reared (light grey bars, $n = 23$) and field-surveyed (dark grey bars; January, $n = 12$; February, $n = 41$; March, $n = 50$; April, $n = 57$; May, $n = 19$; June, $n = 23$; July, $n = 24$; August, $n = 9$) juvenile *P. camtschaticus* from January through August 2010. Results are given as mean ± SD and an asterisk denotes significant differences.

$p < 0.001$) as well as wild/laboratory-reared crab (0.53 ± 0.08 mm; Tukey HSD, $p = 0.005$). In February and March, hatchery/laboratory-reared (0.74 ± 0.10 mm and 0.82 ± 0.13 mm for February and March, respectively; February Tukey HSD, $p < 0.0001$; March Tukey HSD, $p < 0.0001$) and wild/laboratory-reared crab (0.71 ± 0.15 mm and 0.75 ± 0.13 mm for February and March respectively; February Tukey HSD, $p < 0.0001$; March Tukey HSD, $p < 0.0001$) both had longer spines than field-surveyed crab (0.49 ± 0.19 mm and 0.55 ± 0.19 mm for February and March, respectively). There was no difference in mean spine length from April through August among any of the groups (Fig. 3B).

DISCUSSION

Hatchery/laboratory-reared *P. camtschaticus* do not differ significantly in size or time to molt from their wild/laboratory-reared or field-surveyed cohorts. The similarity in juvenile *P. camtschaticus* growth is striking across a diversity of studies from different parts of the world and from both field and laboratory studies. Studies from Japan (Nakanishi, 1987), Russia (Kovatcheva et al., 2006) and Alaska (Weber, 1967; Donaldson et al., 1992; Stoner et al., 2010) all observe juvenile CL *P. camtschaticus* in the range of 1.5 to 2 mm at the C1 stage and 3.5 to 5 mm at the C5 stage (Table 1). Growth studies in Unalaska and Kodiak Island, AK

Table 1. Comparison of mean ± SD carapace length (CL in mm) for juvenile *P. camtschaticus*.

Rearing conditions	This study, hatchery crab	This study, wild crab	Donaldson et al. (1992)	Nakanishi (1987)	Kovatcheva et al. (2006)
	Laboratory, 3-12°C	Laboratory, 3-12°C	In situ, temperature not given	Laboratory, 8°C	Laboratory, 10-11°C
C1	2.09 ± 0.09	2.08 ± 0.20	2.18 ± 0.155	1.572 ± 0.042	1.81 ± 0.022
C2	2.61 ± 0.25	2.51 ± 0.20	2.84 ± 0.152	2.280 ± 0.322	2.01 ± 0.041
C3	3.18 ± 0.33	3.23 ± 0.31	3.76 ± 0.243	2.850 ± 0.080	2.43 ± 0.065
C4	3.94 ± 0.42	4.11 ± 0.36	4.85 ± 0.338	3.700 ± 0.140	2.85 ± 0.114
C5	4.91 ± 0.48	5.09 ± 0.57	5.64 ± 0.394	4.185 ± 0.207	3.41 ± 0.188
C6	5.93 ± 0.74	6.10 ± 0.68	6.67 ± 0.560	n/a	4.03 ± 0.179
C7	7.52 ± 1.12	7.67 ± 1.01	8.0 ± 0.64	n/a	n/a
C8	9.66 ± 1.32	9.25 ± 1.21	9.5 ± 0.77	n/a	n/a
C9	11.74 ± 1.72	11.89 ± 1.42	11.2 ± 0.93	n/a	n/a

reported the cumulative average growth after one year at approximately 11 mm CL with an average of 11 molts/year in Unalaska and 9 molts/year in Kodiak at ambient temperatures (Weber, 1967; Donaldson et al., 1992). In the laboratory, our crab were very similar in size at the C9 stage to the previously studied Kodiak crab (Donaldson et al., 1992), yet our crab achieved more molts in a year, ultimately reaching a size of 13.6 ± 2.1 mm CL (average ± SD) after 10-11 molts per year at ambient temperatures.

In this study, juvenile crab (both hatchery/laboratory-reared and wild/laboratory-reared; C1-C9) grew on 24.5 ± 0.02% with a range of 20 ± 9.0% to 29 ± 12.0% (all average ± SD) increase at each molt which agrees with growth studies in Unalaska, AK, USA (Weber, 1967), Kodiak, AK, USA (Donaldson et al., 1992) and Newport, OR, USA (Stoner et al., 2010). Even though growth appears to be consistent across studies, temperature still has an effect on growth rates. From the C1-C2 stage, juvenile growth rate of *P. camtschaticus* increases significantly from 17.6 ± 7.8% at 1.5°C to of 25.4 ± 5.2% (both average ± SD) at 12°C over 60 days (Stoner et al., 2010). Since juvenile *P. camtschaticus* reside in the intertidal and shallow subtidal during the early life phases (Weber, 1967), they most likely experience a wide range of temperatures. Wild crab may be able to compensate for slow growth at low temperatures in winter with high growth rates at higher temperatures in spring and summer.

Molt interval for individual juvenile *P. camtschaticus* is highly variable and details for molt intervals for each stage are sparse in the literature. One explanation is that there are currently no known reliable methods for aging juvenile crab and the only way to determine accurate age information is to rear crab individually from a known larval or early juvenile stage. Growth studies of *P. camtschaticus* rarely rear crab individually since it is extremely labor intensive. For the first three juvenile stages (C1-C3) our results concerning molt interval for both hatchery/laboratory-reared and wild/laboratory-reared crab are comparable to published literature (Stoner et al., 2010).

Cumulative molt interval is reported in the literature more often than molt interval at each stage. For the three molt stages that are comparable across studies, our findings for cumulative molt interval fall below what has been reported for juvenile *P. camtschaticus* by Mortensen and Damsgard

(1996) but well above what was reported by Kovatcheva et al. (2006). Since the other reports for cumulative molt interval are given for mass reared crab, it is possible that the molt stages were misestimated or that it was not possible to accurately discern the molt interval for crab reared en masse since individual molt intervals vary greatly. Another explanation could be the difference in crab stocks. While our crab originate from Alaskan waters, crab in the other published studies originate in Norway and Russia. Although it has not been discussed in the literature, there could potentially be adaptive differences between these stocks.

Body spines likely improve predator defense (Young et al., 2008) and vary in size between hatchery/laboratory-reared and wild crab (Stoner, 1994; Davis et al., 2004), and we did not find exception to this trend in this study. Hatchery-reared juvenile Atlantic blue crab, *C. sapidus*, grow significantly shorter spines than those in the wild (Davis et al., 2004). Spine length, in this case, is plastic and varies as a function of whether or not juvenile crab are exposed to their natural environment (Davis et al., 2004). Our hatchery/laboratory-reared crab had significantly longer spines than the field-surveyed crab for the first three months (January, February and March) that surveys were conducted in the intertidal. Interestingly, the wild/laboratory-reared reared crab had significantly longer spines than their field-surveyed cohorts in February and March, suggesting that short spines may be an artifact of laboratory rearing during the early phases of crab growth. Additional studies are needed to determine the significance and plasticity of spine length for juvenile *P. camtschaticus*.

We observed higher survival rates in this growth experiment for juvenile *P. camtschaticus* collected from the wild as glaucothoe than for hatchery-reared glaucothoe. From the C1 to C2 stage, survival in the hatchery/laboratory-reared crab decreased from 100% to 30.4%, while survival remained at 100% for the wild/laboratory-reared crab. Thereafter, overall survival was relatively constant for both hatchery/laboratory-reared and wild/laboratory-reared crab, with survival of 26.1% and 97.1%, respectively, to the C7 stage and 23.9% and 88.6%, respectively, at the C9 stage. Possible explanations include: 1) high-density larval rearing conditions at the hatchery produced less robust juveniles, 2) stress during shipment resulted in high mortality, 3) stress in the laboratory resulted in high mortality, or 4) only the

most robust glaucothoe settled in the wild, thereby selecting for more robust juveniles for this experiment. Information from a companion study (Stoner et al., 2010) with hatchery-reared juveniles of *P. camtschaticus* from the same hatchery cohort did not experience a similar decline in survival during the early juvenile stages, even after being shipped, suggest that the decline we observed in hatchery-reared animals may be a unique to this study. Even though we saw a difference in survival between hatchery/laboratory-reared and wild/laboratory-reared juveniles, this did not translate into a difference in growth.

When considering stock enhancement for any species, it is important to discern any advantages or disadvantages that the hatchery-reared animals may have. Advantages over wild counterparts may have considerable consequences for native stocks while many disadvantages make enhancement a futile endeavor. Ideally, hatchery and wild cohorts would be indistinguishable from one another in physiology as well as behavior. This study is the first to show that growth, when compared between hatchery/laboratory-reared and wild/laboratory-reared juveniles, is not significantly different from field-surveyed cohorts in southeast Alaska. Although this is not definitive proof that differences do not exist between these groups of juvenile *P. camtschaticus*, it does show that rehabilitation efforts in Alaska deserve further research efforts. Future experiments should address growth and behavior of stock specific hatchery crab in the wild in comparison with wild counterparts in areas where rehabilitation is been proposed.

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