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MORPHOMETRICS, FECUNDITY, AND HATCH TIMING OF BLUE KING CRABS (*PARALITHODES PLATYPUS*) FROM THE BERING STRAIT, ALASKA, USA

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ABSTRACT

The Bering Strait marks the northern species boundary for blue king crabs (*Paralithodes platypus*), but the life history of the population at this latitude has never been described in scientific literature. Blue king crabs were collected in shallow (10-23 m) waters near King Island (n: males = 199; females = 260) in July of 2005 and from near Little Diomede Island (n: males = 40; females = 19) in April of 2007 for morphometric, fecundity and hatch timing information. Crabs from Little Diomede and King Islands showed no significant difference in male carapace length (CL) by location and were smaller than blue king crabs from more southern parts of the state (mean CL ± SE: 108.45 ± 0.70 mm). Females from King Island (mean CL ± SE: 99.47 ± 0.52 mm) were significantly larger than female crabs collected from Little Diomede Island (mean CL ± SE: 93.11 ± 2.96 mm) and male crabs (mean CL ± SE: King = 107.98 ± 0.73; Diomede = 110.13 ± 2.24) were significantly larger than female crabs at both locations. Weight of female crabs (mean ± SE: 810.0 ± 61.9 g) increased with CL according to a non-linear function; Crab weight = $0.00165*(CL)^{2.8995}$ ($r^2 = 0.86$). Fecundity estimates based egg counts (mean ± SE: 62,955.6 ± 4981.2) were slightly higher than visual estimates of hatched larvae (mean ± SE: 56,570 ± 6690). Timing of larval release differed significantly between female crabs held in the laboratory for 1 and 13 months. Crabs held for 1 month began hatching in mid-May 2008 with more larvae released per day and over a shorter duration (12 d). Crabs held for 13 month released fewer larvae per day over a longer duration (20 d) starting in mid-February 2009. Long-term laboratory holding may impact hatch timing due to differences in ambient temperature and perhaps other suppressed seasonal effects of the artificial environment.

KEY WORDS: broodstock, King Island, larvae, Little Diomede Island, *Paralithodes platypus*, size frequency

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INTRODUCTION

Blue king crabs, *Paralithodes platypus* (Brant, 1850), range throughout the eastern Bering Sea from the Pribilof Islands to Little Diomede Island, Alaska, and in the western Bering Sea from the Gulf of Olyutorsk to the Gulf of Anadyr, Russia (Pereladov et al., 2002). Commercial blue king crab harvest in the eastern Bering Sea began in the mid-1960s and peaked in 1981 with a catch of 6000 tons (t) (Bowers et al., 2008; Zheng and Kruse, 2000). United States harvest in the Pribilof Islands peaked in 1980 at 4960 t and was closed in 1988 due to population decline (Zheng et al., 1997). The fishery reopened in 1997 but closed again in 1999 (Chilton et al., 2008). The St. Matthew fishery peaked in 1983 with a harvest of 4288 t but experienced a similar decline and was closed in 1999 (Bowers et al., 2008; Chilton et al., 2008). The Pribilof stock has not significantly improved (Bowers et al., 2008; Chilton et al., 2008), but the St. Matthew Island fishery was recently declared to be rebuilt and was opened for a total allowable catch of 530 t in the 2009-2010 season (ADF & G, 2009).

Blue king crabs are similar to red king crabs, *Paralithodes camtschaticus* (Tilesius, 1815), in morphology and life history (Jensen and Armstrong, 1989; Klitin and Nizyaev, 1999; Stevens, 2006a). Both species have planktotrophic larvae that undergo four zoeal stages and a non-feeding, semi-benthic glaucothoe stage. Habitat is the main factor separating the range of blue and red king crabs in the Bering Sea (NPFRC, 2005). Red king crabs prefer shallow, muddy or sandy habitats in Bristol Bay and Norton Sound (NPFRC, 2005; Soong and Kohler, 2005), while blue king crabs prefer the disparate, deeper areas comprised of cobble, gravel, and rock that occur around the Pribilof, St. Matthew (Vining et al., 2001; Zheng et al., 1997), St. Lawrence, King, and the Diomede Islands.

Female blue king crabs tend to aggregate in shallow water for brooding and hatching from spring to summer (6-10 m depth with eggs, 50-80 m without eggs) and are found deeper (130-180 m) by trapping and diving surveys during winter months (Pereladov and Miljutin, 2002). Male crabs come into nearshore areas for mating in the spring, but are otherwise found in deeper water (120-250 m) (Pereladov and Miljutin, 2002). In Russian waters, nearshore areas with aggregations of female crabs are found in the Gulf of Anadyr, the area to the west of Cape Navarin, and Natalia, and Glubokaya Inlets. Similarly, aggregations of ovigerous females are observed on the steep, rocky slopes around the

aforementioned Bering Sea islands in U.S. waters (Vining et al., 2001; Zheng et al., 1997).

The population of Bering Strait blue king crabs has rarely been subjected to commercial harvest, with a total catch of approximately 28,000 kg since statehood from the southeast side of St. Lawrence Island (Soong et al., 2008). Development of a commercial blue king crab fishery in the Bering Strait has generally been hampered by remote location and because of regulations established in 1989 which extended the conservation zones around inhabited islands of the Northern Bering Sea from three miles to 10 miles offshore. King Island was included in this fishery exclusion even though the Native Village of Ukivok (King Island) was abandoned in 1959. A large portion of the harvestable blue king crab biomass lies within habitats covered by this restriction, either within the King or St. Lawrence Island boundaries, as per a 1996 survey by the Alaska Department of Fish and Game (Fair, 1997). Since commercial fishing near Bering Strait Islands is prohibited, harvest pressure on these blue king crabs has generally been restricted to light subsistence fishing by the Native Villages of Inalik (Little Diomede), Ukivok (King Island), Wales, Savoonga, and Gambell, Alaska.

In this paper, we present information on Bering Strait blue king crab morphometrics, fecundity, and hatch timing made available in two studies. First, a pot-based size frequency distribution survey of King Island crabs was conducted by Norton Sound Economic Development Corporation (NSEDC) in July of 2005. This survey determined the proportion of male crabs larger than the legal commercial harvest limit of 140 mm (5.5″) carapace width, including lateral spines, and was successfully used to reduce the minimum legal size required for commercial blue king crab harvest in the Bering Strait region through the Alaska Board of Fisheries process (Alaska Board of Fisheries, 2008).

Second, our data come from an April 2008 broodstock acquisition effort near Little Diomede Island by Alaska Sea Grant (ASG) as part of the Alaska King Crab Research, Rehabilitation, and Biology program (AKCRRAB). Because of declines and closures in Alaska blue king crab fisheries, ASG and partners are interested in potential hatchery rearing of blue king crabs, and have begun a comprehensive study of king crab rearing feasibility and early life history research. Blue king crab broodstock for these activities was collected from the Pribilof Islands in 2006, from Little Diomede Island in 2008, and from St. Matthew Island in 2009. The minimal commercial harvest in the Bering Strait makes the region an ideal location for broodstock collection from a population conservation perspective, but also difficult to collect and transport due to sea-ice cover and remote location.

Materials and Methods

King Island Adult Size Frequency Distribution and Morphometrics

Blue king crabs (n: females = 249, males = 204) near King Island, Alaska, USA (star, 64.975°N, 168.067°W; Fig. 1) were sampled by pots at 104 stations (Fig. 2) in July 2005 at depths 10-23 m. Pots were positioned 1 km apart northeast of King Island, an area known for high blue king crab abundance, and were soaked approximately 36 h prior to sampling. Carapace length was measured as the maximum distance from the posterior margin of the right or left eye orbit to the medial-posterior margin of the carapace. For crabs approaching or above the pre-2008 minimum size requirement for harvest (117 mm CL), carapace width was measured as per the fishery harvest regulations, including lateral spines (n = 61; (Donaldson and Byersdorfer, 2005; Jadamec et al., 1999).

Diomede Island Broodstock Collection and Adult Morphometrics

Blue king crabs were captured with pots from five locations just north of Little Diomede Island, Alaska USA, during the second week of April 2008 (65.44503°N, 168.5635°W). Crabs (n: females = 19, males = 40) were fished from the 20 m isobath where water temperature near the ocean floor was −1.7°C and salinity 32.7 ppt. Carapace length and width were measured with the same methods used in the King Island survey, except that width measurements did not include lateral spines. Ovigerous female crabs were flown to Nome, Alaska where they were kept in a recirculating sea-water tank for several days before shipment to the Alutiiq Pride Shellfish Hatchery in Seward, Alaska, USA on 14 April 2008. Live crab wet weights (including the clutch) and clutch measurements of dead crabs were collected at the hatchery on arrival.

Care of Ovigerous Females, Fecundity Estimates, and Hatch Timing

Ovigerous crabs were kept in 2000 L tanks containing flow-through ambient seawater ranging from 3.4 to 8°C (mean ± SE: 5.15 ± 0.1°C) and fed 20 g of chopped herring and squid per crab twice each week. Crabs were held for approximately one month (n = 3) or 13 months (n = 4) before hatching occurred, depending on the maturity of the clutch at the time of capture. In crabs that died prior to hatching (n = 5), egg clutches were removed and weighed wet for fecundity estimates after blotting off excess water. For each clutch, the eggs in five sub-samples weighing 0.25 g were counted and the average count was multiplied by the total wet weight of the clutch. In surviving crabs (n = 7), females were placed in separate bins to isolate larvae once hatching began. Realized fecundity was estimated using daily visual estimates to the nearest 10, 50, 100 or 1000 larvae hatched per female. After daily visual estimates were taken for individual females, larvae from all females were pooled. Volumetric sub-samples were then taken to get an estimate of the total number of pooled larvae hatched daily. Daily estimates of pooled larvae were consistently similar to the summed individual female estimates, suggesting that the individual daily estimates were accurate. The total number of larvae hatched from each crab was estimated by summing daily estimates for individual females. All females were sacrificed after the hatch.

Statistical Analyses

Data were analyzed with SAS statistical software (v. 9.2). Mean carapace length for Bering Strait blue king crabs was analyzed by 2-way general linear model with fixed factors of location (King Island, Little Diomede Island) and sex (male, female). The relationship between carapace length (independent variable) and carapace width (dependent variable) for crabs around Little Diomede was first assessed with an analysis of covariance including sex (male, female) as a fixed factor. The effect of sex was not significant and ultimately the relationship between carapace length and width was determined with a linear regression procedure. A general linear model was used in this analysis, which is robust to unequal sample sizes among factors.

In female crabs from Little Diomede Island, crab weight including the clutch (dependent variable) was assumed to increase with carapace length (independent variable) raised to a power: Weight = $A \cdot CL^B$, where CL is carapace length in mm, and A and B are parameters (Somerton and MacIntosh, 1983a). The same type of non-linear regression was used to determine the relationship between carapace length (independent variable) and clutch weight (dependent variable). Parameters of best-fit were estimated for these model using the Gauss-Newton method (Hartley, 1961). Adult crab and clutch weight data were normally distributed with standard variance and independent error values, fulfilling the assumptions of non-linear regression.

Linear regression was used to describe the relationship between carapace length and the estimated number of eggs per clutch (dependent variable) for females from Little Diomede Island. Errors were independent

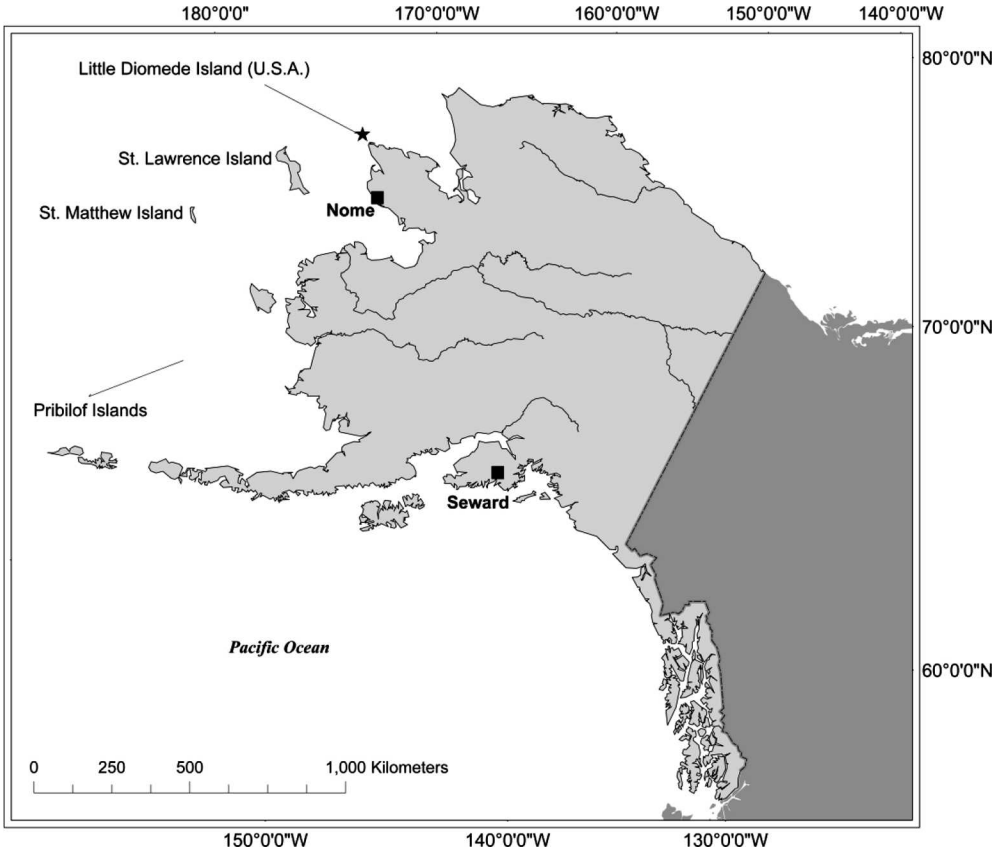

Fig. 1. Map of Alaska USA showing Little Diomede Island (star, 65.44503°N, 168.5635°W), King Island (star, 64.975°N, 168.067°W), other eastern Bering Sea islands with blue king crab populations (labels only) and cities Nome and Seward (squares), which were the intermediary and ultimate shipping destinations for Diomede blue king crabs, respectively.

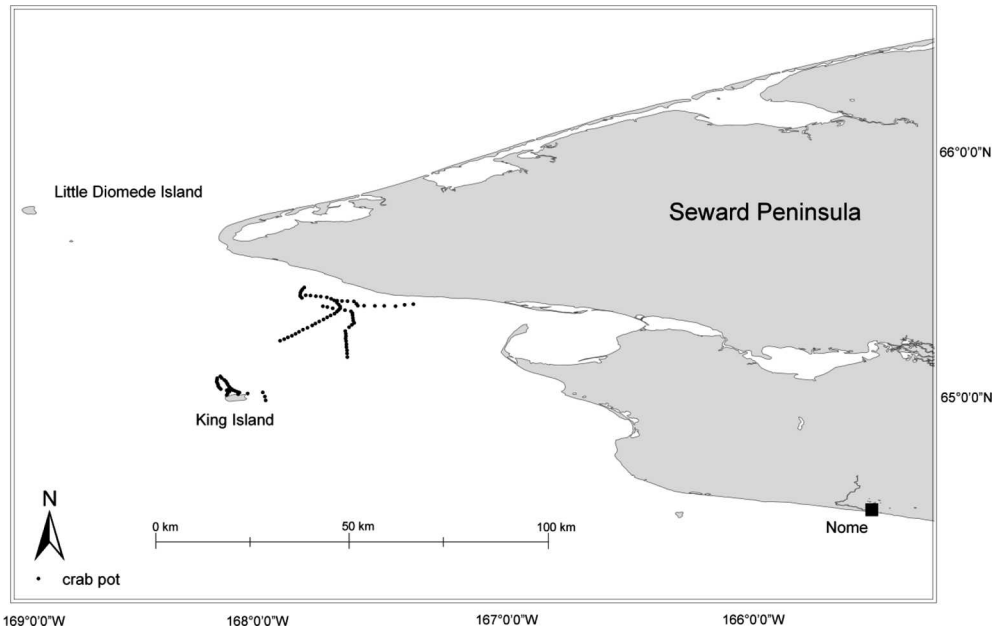

Fig. 2. Map of the Bering Strait region, Alaska, including Little Diomede Island (65.44503°N, 168.5635°W) and King Island (64.975°N, 168.067°W) with pot locations from the 2005 summer blue king crab survey at ocean depths 10-23 m.

Table 1. Results of a 2-way general linear model relating carapace length (dependent variable) to fixed factors location (Little Diomede Island, King Island) and sex (male, female).

Source of variation	*d.f.*	Mean square	*F*	*P*
Sex	1	7537.30	77.76	< 0.0001
Location	1	205.39	2.12	0.1461
Sex*location	1	836.26	8.63	0.0035
Error	514	96.93		

and normally distributed with constant variance, satisfying the assumptions of linear regression.

The total number of larvae released by crabs held in the laboratory for 1 month (2008) and 13 months (2009) was compared with a 2-tailed *t* test. The timing of larval hatch was also compared between year groups, according to Stevens et al., 2008. Because larvae from the same females were counted on consecutive days, autocorrelation occurs in this type of data set (Bence, 1995). To account for the effect of time, daily larval release was multiplied by the day of release (starting from 1) for each crab. Adjusted daily larval release values for each crab were then summed, and the totals were divided by actual totals to find the "mean day of maximum hatch" for each crab. These values were compared with a 2-tailed *t* test to determine whether or not there was a difference in hatch timing between years 2008 and 2009.

Results

Adult Morphometrics

Male blue king crabs captured in the Bering Strait ranged in size from 74 to 145 mm CL with no significant difference between crabs from King and Diomede Islands (mean CL ± SE: 108.45 ± 0.70 mm; Table 1). Females around King Island ranged from 77 to 130 mm CL, and were significantly larger than female crabs collected from Little Diomede Island, which ranged from 74-132 mm CL (mean CL ± SE: King = 99.47 ± 0.52; Diomede = 93.11 ± 2.96 mm; Table 1). Male crabs were significantly larger than female crabs at both locations (*d.f.* = 3; MS = 4006.36; F = 41.33; $P < 0.0001$; Table 1; Fig. 3). The mode CL near King Island was 100 mm for both male and female crabs (Fig. 4). More large crabs were captured than small crabs, skewing the size frequency distribution to the right for both sexes (skewness: males = 0.375; females = 0.333).

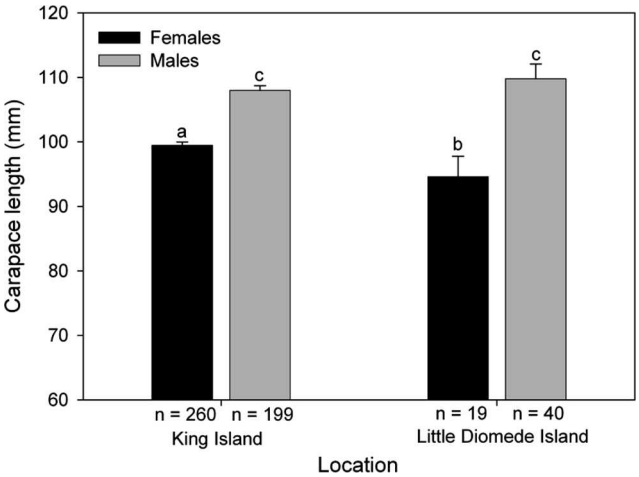

Fig. 3. Carapace length of blue king crabs from Little Diomede (n: male = 40; female = 19) and King (n: male = 199; female = 260) Islands with significant differences (α = 0.05) represented by letters. No significant difference in male carapace length between locations (P = 0.1461).

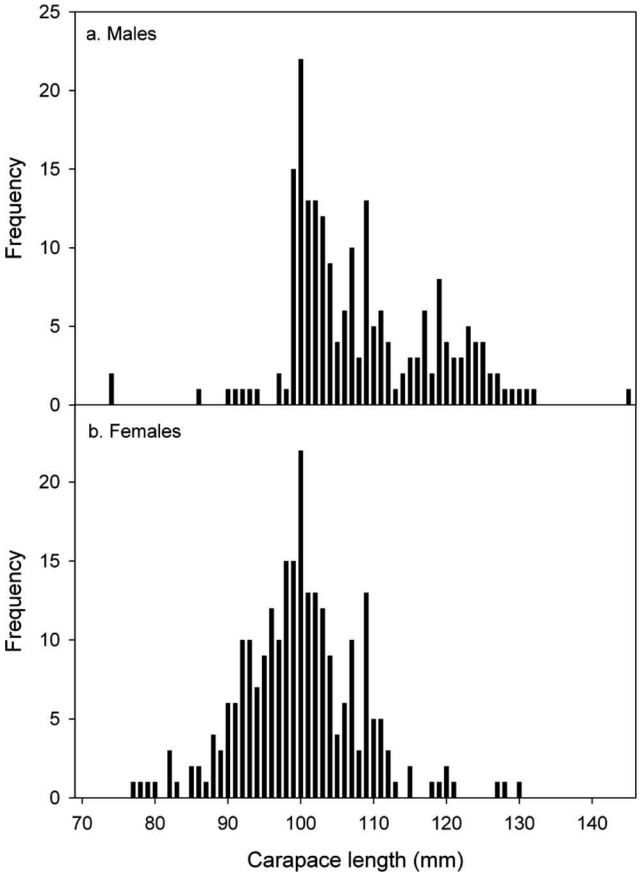

Fig. 4. Carapace length frequency of mature a) male (n = 204) and b) female (n = 249) blue king crabs captured in shallow water near King Island, Alaska in July 2005. The near absence of smaller males and juvenile females suggests that the depths sampled were not appropriate for catching juvenile crabs.

The linear relationship between CL and carapace width without spines for crabs from Diomede Island was not significantly affected by sex (ANOVA; *d.f.* = 1; MS = 7.56; F = 0.20; P = 0.6567), or by an interaction between sex and CL (*d.f.* = 1; MS = 3.12; F = 41.33; P = 0.7752). Linear regression was therefore the more parsimonious model and used to estimate regression parameters regardless of sex. Crabs ranged in carapace width from 93 to 153 mm in males and from 84 to 152 mm in females (mean carapace width ± SE: male = 123.30 ± 2.75 mm; female = 101.95 ± 3.48 mm). Carapace width of crabs from Little Diomede Island (n = 59) increased significantly with CL (Fig. 5a; r^2 = 0.90; $P < 0.0001$) by the following linear regression line of best fit: Carapace width = 1.161*CL − 5.097 (Table 2). Application of this regression equation to the mean CL for all male crabs from the Bering Strait and females from Diomede Island estimates a mean carapace width of 120.81 mm for males and 103.00 mm for female crabs.

Unlike measurements of Little Diomede crabs, King Island width measurements (n = 56) were only made for large male crabs and included the lateral spines, as is the

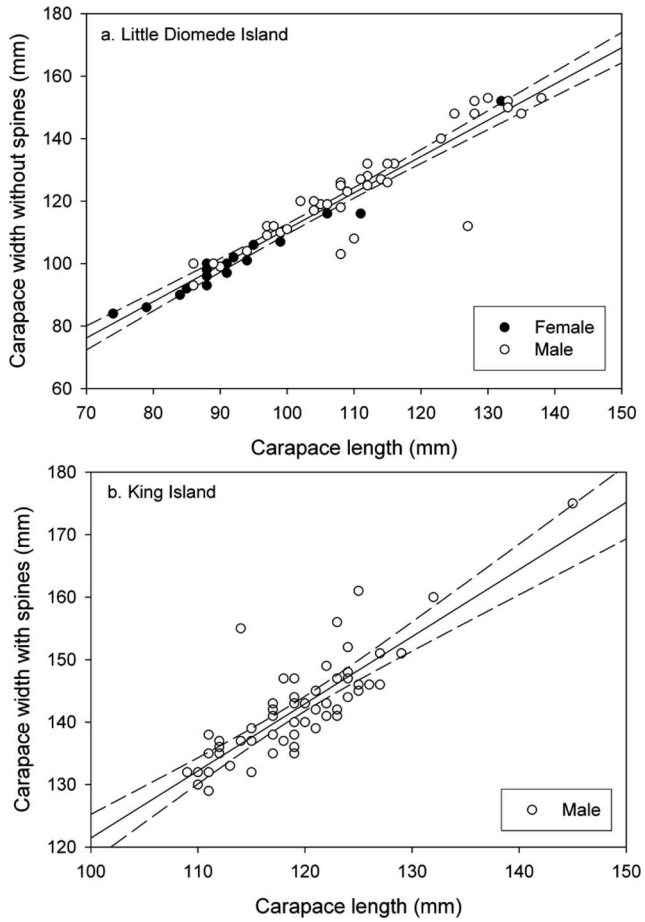

Fig. 5. Linear regression describing the carapace length to width (mm) relationship for male (open circle) and female (closed circle) blue king crabs from a) Little Diomede Island (n: male = n = 40; female = 19). Carapace width without spines = 1.161*CL − 5.097; r^2 = 0.90; and b) King Island (n: male = 61); Carapace width with spines = 1.075*CL + 13.985; r^2 = 0.69. Shown with confidence intervals of 95%.

standard in commercial king crab fisheries. The carapace width of male crabs near King Island ranged from 129 to 175 mm (mean ± SE: 142.73 ± 1.11 mm). Carapace width of male King Island crabs increased significantly with CL (Fig. 5b; r^2 = 0.69; P < 0.0001), according to the following equation: Carapace width = 1.075*CL + 13.985 (Table 2). Application of this regression to the mean CL for male Bering Strait crabs estimates a commercial measurement of 130.57 mm carapace width including lateral spines.

Table 2. Parameter estimates for linear regressions relating carapace length (CL) and width for blue king crabs near Little Diomede (width without lateral spines) and King (width includes lateral spines, males only) Islands.

Parameter	*d.f.*	Estimate	Error	*T*	*P*
Little Diomede Island (width without lateral spines)					
Intercept	1	−5.097	5.35	−0.95	0.3451
Slope CL	1	1.161	0.05	22.95	< 0.0001
King Island males (width includes lateral spines)					
Intercept	1	13.985	11.16	1.25	0.2153
Slope CL	1	1.075	0.09	11.49	< 0.0001

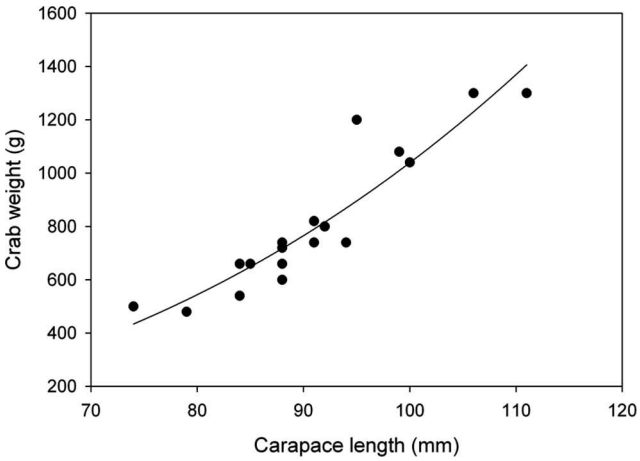

Fig. 6. Non-linear regression between carapace length (mm) and crab weight (g) for female blue king crabs from near Little Diomede Island (n = 18). Crab weight = 0.00165*CL$^{2.8995}$; r^2 = 0.86.

The weight of female crabs, plus their clutch, ranged from 480 to 1300 g (n = 19; mean ± SE: 810.0 ± 61.9 g). Weight increased significantly with carapace length by the following non-linear equation of best fit: Crab weight = 0.00165*(CL)$^{2.8995}$ (Fig. 6; Table 3; r^2 = 0.86; P < 0.0001). Clutch weight (n = 10; mean ± SE: 84.20 ± 7.98 g) ranged from 40 to 124.6 g and increased significantly with carapace length according to the following non-linear relationship: Clutch weight = 0.0031*(CL)$^{2.2606}$ (Fig. 7; Table 3; r^2 = 0.70; P = 0.0025).

Fecundity Estimates

Clutch size (mean ± SE: 62,955.6 ± 4981.2 eggs) ranged from 23,070 to 87,663 eggs and increased linearly with increasing clutch weight according to the following relationship: Number of eggs = 3120*CL − 202,836; (n = 5; r^2 = 0.94; P = 0.0062; Fig. 8). Female blue king crabs from Little Diomede Island (n = 7) released an average ± SE of 56,570 ± 6690 larvae, with total hatch ranging from 37,500-84,920 larvae per female.

Hatch Timing

There was no significant difference in the total number of larvae released per crab in years 2008 (n = 3) and 2009 (n = 4), suggesting that an increased laboratory holding period does not significantly increase egg mortality (mean ± SE: 56,570 ± 6690; *d.f.* = 5; t = −0.368; P = 0.728).

Table 3. Parameter estimates for non-linear regressions relating female crab weight and clutch weight to carapace length (CL) in mm for blue king crabs near Little Diomede Island. Weight = A · CL^B, where and A and B are parameters.

Parameter	Coefficient	Error	*T*	*P*
Crab weight				
A	0.0017	0.0022	0.7551	0.4611
B	2.8995	0.2903	9.9881	< 0.0001
Clutch weight				
A	0.0031	0.0083	0.3753	0.7172
B	2.2606	0.5856	3.8605	0.0048

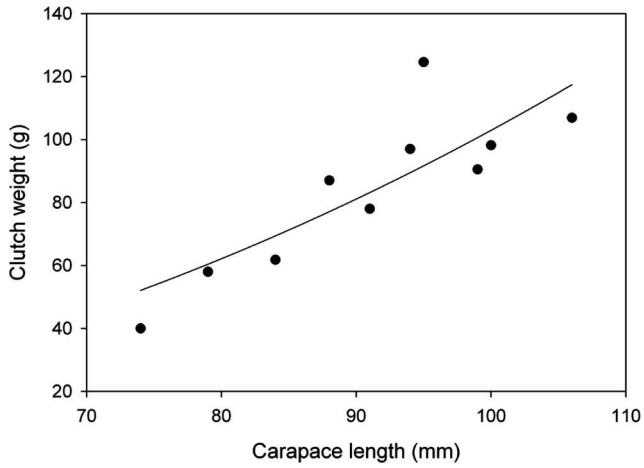

Fig. 7. Non-linear regression between female carapace length (mm) and clutch weight (g) for blue king crabs from Little Diomede Island (n = 10). Clutch weight = $0.0031*(CL)^{2.2606}$; r^2 = 0.70.

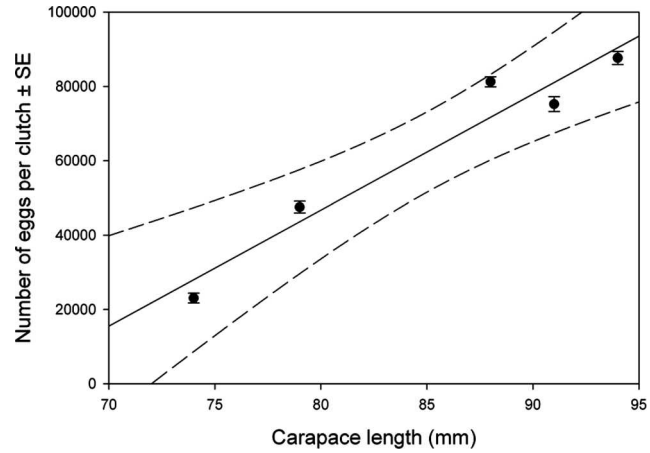

Fig. 8. Linear regression between carapace length (mm) and estimated fecundity for female blue king crabs from Little Diomede Island based on replicate subsamples of unhatched eggs multiplied by clutch weight (n = 5). Number of eggs = 3119.62376*CL − 202,836; shown with 95% confidence interval; r^2 = 0.94.

Timing of larval release differed significantly because of holding time in the lab ($d.f.$ = 5; t = −3.678; P = 0.014), with the mean day of maximum hatch at 6 ± 0.4 days after hatch began in 2008 and 8 ± 0.5 days after hatch began in 2009. Crabs that were held for thirteen months (2009) hatched larvae over 20 days with lower daily hatches, whereas crabs held for only one month (2008) hatched more larvae per day over only 12 days total. At peak hatch, each crab released as many as 15,000-20,000 larvae each per day in 2008 and 10,000 larvae each per day in 2009 (Fig. 9).

Discussion

Adult Morphometrics

This study is the first to document morphometric and life history information for Bering Strait blue king crabs. There was no significant difference in mean CL between male crabs from King and Little Diomede Islands and we expect that crabs caught near the two areas are from the same population. Females around Diomede Island were significantly smaller than those caught near King Island, possibly an artifact of a smaller sample size or less range in fishing depth at Diomede. Alternatively, the size difference in female crabs from the two islands could result from fishing pressure at Diomede Island where local residents are legally allowed to keep female crabs caught in their subsistence harvest. Fishing pressure may slightly drive down the average size of female crabs at Diomede Island, whereas there is no such fishing pressure at King Island.

In the 2005 King Island pot survey, NSEDC successfully demonstrated that Bering Strait blue king crabs have a smaller size-at-age than crabs from the more southern St. Matthew and Pribilof Islands. The minimum legal size for harvest was reduced from a carapace width of 140 mm (5.5″), including lateral spines, to 127 mm (5.0″) by the Alaska Board of Fisheries in their March 2008 work session (ADF & G, 2008).

The size frequency distribution for King Island was right skewed for both male and female crabs because sampling took place in shallower water where one is more likely to capture mature adults than juveniles. Shallow pot placement resulted in a catch of primarily egg bearing female blue king crab and mature males. Since immature females generally live in deeper water and were rarely captured in these studies (Pereladov and Miljutin, 2002), we were not able to estimate the minimum size of 50% reproductive maturity in Bering Strait crabs. However, we have collected some helpful information which allows a better estimate of this parameter. Near King Island, the smallest ovigerous female captured was 77 mm CL and one each of mature and immature crabs of 79 mm CL were captured. The smallest ovigerous females observed from Diomede Island were similarly CL 74 and 79 mm, suggesting that the size at 50% maturity is somewhere in the vicinity of 77-79 mm CL. This would be slightly smaller than SM50 for crabs from near St. Matthew Island, which is 80.6 mm CL (Somerton and MacIntosh, 1983a; Somerton and MacIntosh, 1983b). Female blue king crabs near the Pribilof Islands have the largest SM50 for Bering Sea crabs at 96.3 mm CL (Somerton and MacIntosh, 1983b). A winter survey ranging in depth from approximately 6-40 m, the maximum depth in the northern Bering Sea, would be necessary to determine SM50 for Bering Strait crabs (Pereladov and Miljutin, 2002).

Carapace measurement conversions are helpful in communication between the research community, which usually refers to carapace length or width without lateral spines, and commercial fisheries management that regulates harvest based on shell width including lateral spines. Increase in carapace width is proportional to increase in CL for Little Diomede Island crabs with no difference in this rate of increase between male and female crabs. Width measurement including lateral spines resulted in a less significant relationship between carapace length and width, although one that may be more helpful in fisheries management applications.

The average carapace width of male king crabs from Little Diomede Island was 123.3 mm (without spines),

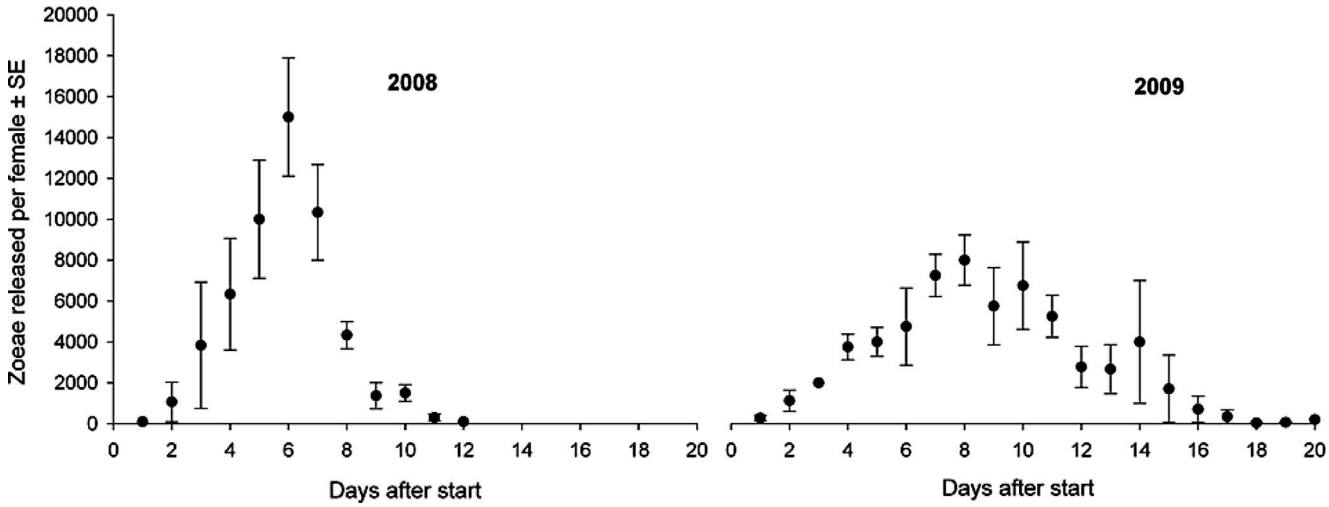

Fig. 9. Larvae released from crabs held for 1 month (2008; n crabs = 3) and 13 months (2009; n crabs = 4), shown as the mean number of larvae released per female per day ± SE. Hatch day 1 represents the first day that larvae were released for each crab.

slightly smaller than the minimum 127 mm carapace width required for harvest of Bering Strait blue king crabs since 2008 (Alaska Board of Fisheries, 2008). Blue king crabs from the Bering Strait are smaller than crabs near St. Matthew Island, which are legal for harvest at 140 mm (5.5″) carapace width, and much smaller than Pribilof Island crabs which require a minimum carapace width of 165 mm (6.5″) for harvest (ADF&G, 1998; Zheng et al., 1997).

Female crabs exhibited a constant non-linear increase in weight with an increase in carapace length. In a similar study on male blue king crabs from near St. Matthew Island, the Pribilof Island, and Olga Bay in the Gulf of Alaska (Kodiak Island), the slope of the non-linear regression was not significantly different among those populations (slope = 3.119), but the intercepts of these lines varied slightly on account of decreasing crab weight from the southern to northern Bering Sea (Somerton and MacIntosh, 1983a). Differences in weight among crab populations was discussed as being the result either of genetic isolation among populations or the result of differences in morphological responses due to variation in environmental variables, such as temperature. The slope of this non-linear regression for females from Diomede Island was slightly lower at 2.8995 because the weight of female crabs from Diomede Island increases more slowly with increased CL than male crabs from more southern locations. The intercept for female crabs from Diomede Island was much lower than that of the male crabs from St. Matthew Island, the Pribilof Islands and Kodiak Island, reflecting the lower average weight of female than male crabs, and of crabs from northern latitudes.

Fecundity Estimates

Clutch weight and egg count estimates for crabs from Diomede Island increased with increasing adult size, demonstrating that larger females produce more eggs. Egg counts ranged from 37,500 to 84,920, with an average of 56,570 larvae released from each female from Diomede Island. Fecundity estimates based on egg counts are typically higher than those based on released larvae as not all eggs survive to hatch (Stevens, 2006a). Crabs from Pribilof Island, which are larger than those from Diomede, produce an average of 162,360 eggs (Somerton and MacIntosh, 1985), and release an average of 110,033 first stage zoeae (Stevens, 2006a), which amounts to a 32% decline in fecundity between egg and larvae stages. Of Diomede crabs with CL = 88 mm, one crab had an egg count of 81,258 and two others released approximately 57,000 larvae each. This rough estimate represents a reduction in fecundity by 30%, suggesting that egg loss in Bering Strait crabs may be similar to that of blue king crabs from the Pribilof Islands.

Hatch Timing

The few female crabs collected in 2008 suggests that blue king crabs around Diomede Island extrude eggs in late March and that larvae hatch in early May for a brooding period of approximately 14 months. Crab collection took place during the second week of April 2008. No female crabs were caught which did not have eggs, suggesting that the hatch period probably had not yet begun. Reproductive timing was similar to that of blue king crabs from near the Pribilof Islands, which mate and extrude eggs in late March to early May (Jensen and Armstrong, 1989; Somerton and MacIntosh, 1985). Similarly, multiparous blue king crabs in the laboratory required 13.7 to 14.5 months at 2 to 6°C for an egg clutch to develop (Stevens et al., 2008). This schedule inhibits larval release and mating within the same year so that clutches are produced every other year (Jensen and Armstrong, 1989; Stevens, 2006a). Primiparous females, which are producing an egg clutch for the first time in their lives, are smaller (< 105 mm CL) and therefore able to mature ovarian and somatic tissues in a shorter window of time. This allows them to molt annually and produce another clutch the following year (Jensen and Armstrong, 1989).

Three Diomede crabs captured with eyed eggs survived to hatch at the Alutiiq Pride Shellfish Hatchery in Seward, AK in 2008. Hatch began on 15 May and was completed on

26 May, with an average hatch period of 12 days per crab. It is unclear how the increase in ambient water temperature from approximately −1.7°C in their natural habitat to approximately 6°C in the laboratory affected embryonic development during that last month in the lab. Embryonic development for king crabs is known to speed up with increased temperatures (Stevens, 2006a). Female blue king crabs near the Pribilof Islands naturally release larvae around the middle of April (Jensen and Armstrong, 1989) but crabs held at warmer temperatures in the laboratory may release larvae as early as February (Stevens, 2006a). Our research suggests that the length of time that females around Diomede brood their eggs is on the longer end of the spectrum observed for this species.

Four crabs captured with newly extruded eggs in the spring of 2008 survived to hatch their larvae in the spring of 2009. Holding crabs over the course of the year was not ideal because of increased problems with bacterial infestation of the clutch, but we found it to be possible. Hatch began on 21 February and was completed on 19 March, lasting 20 days on average. A year of holding crabs in the laboratory resulted in an earlier hatch and a prolonged hatch period in comparison with crabs held for a shorter duration. This may be an artifact of missing environmental cues. In nature, variables such as tides, temperature, salinity, light, phytoplankton blooms, and predation are seasonally pulsed and likely serve as cues for larval release (Morgan, 1995; Shirley and Shirley, 1989). In the laboratory these seasonal cues are dampened or missing. For example, incoming water is chilled in summer months so that temperatures do not exceed the crab's upper threshold for temperature tolerance. Ambient light and predator abundance are not parameters crabs are exposed to while being held in the laboratory, thus seasonality is less perceptible. Larval release in the laboratory may therefore be less focused as seasonality is less evident.

With weaker seasonal cues, release of larvae over a longer period may serve to give the female a larger window for larvae to correspond with any favorable environmental conditions that may exist, also known as "bet-hedging" (Slatkin, 1974). The number of days when hatching was observed was far fewer than the 33 days previously observed for hatching by blue king crab from Pribilof Island in the laboratory (Stevens, 2006a, b), which may be due to factors such as differences in temperature effects on egg development, or increased total number of larvae. Holding the crabs long term (13 months) did not reduce fecundity. Average number of larvae released per crab was similar suggesting that long-term holding is viable if annual broodstock collection is not possible.

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