Mating Success of Female Dungeness Crabs (*Cancer magister*) in Oregon Coastal Waters

Paul Dunn and Alan Shanks
Oregon Institute of Marine Biology
63466 Boat Basin Rd. Charleston, OR 97420

Abstract
The Dungeness crab is an important commercial and sports fishing species in Oregon. The fishery is regulated by sex, size, and season. This study examined whether female crabs are mating despite the removal of almost all legal-sized male crabs each year. Of particular concern is whether large females are finding large enough males to mate with. Females were collected from three Oregon fishing ports, dissected, and checked for evidence of recent mating. Captured male and female crabs were also measured to determine the size distribution of the populations. The data suggest that a majority of female crabs examined (69%) mated this year, and when combined with crabs that still carried sperm from previous mating encounters, the percent of females that would have produced viable eggs climbs to 83%. Crabs that had definitely molted this year showed even higher mating success (95%). The largest females examined in our study (160-169 mm CW) showed very high mating success (84% mated this year, 95% could have produced viable eggs). These numbers compare favorably to a similar survey conducted in northern California in the 1990s, where 69% of molting females had mated (Hankin et al. 1997). We conclude from the data that molting females in these three Oregon fishing ports are successfully finding mates, regardless of size.

Introduction

The Dungeness crab, *Cancer magister*, supports commercial and sports fisheries in the Pacific Northwest, from Alaska to California. These fisheries account for thousands of jobs and millions of dollars for the economies of coastal states. The importance of maintaining a healthy fishing stock of crabs necessitates the placement of regulations to control which crabs can be fished and when. Only male crabs larger than a minimum size can be harvested, and only during a defined fishing season. In Oregon, male crabs must have a carapace width of at least 6.25 inches (159 mm) when measured just anterior to the 10^{th} lateral spines. The Oregon fishing season begins on December 1 and runs through August 14, avoiding the fall period in which most males molt and are in poor market condition. Without any regulations directly limiting the number of large males that can be taken each year, there is the possibility that nearly all male crabs of legal size could be harvested. Indeed, the exploitation rates in some Pacific fisheries have exceeded 90% in some years (Hankin 1985; Smith and Jamieson 1989).

The mating behavior of *Cancer magister* involves a premating embrace, in which the male holds the female for several days before the female molts. At the time of female molting, the male holds her in the true mating embrace and deposits seminal secretions inside the two female reproductive tracts. These secretions later harden into a sperm plug that extends from the spermathecae into the vagina (Hartnoll 1969; Jenson et al. 1996). Although the mating process

may last 1-2 weeks, the period during which females molt lasts for several months, and male crabs can mate with several females each year. Female crabs typically reach maturity during their second year at a carapace width of around 100 mm (Tasto 1983). They will then typically molt once each year for the remainder of their growing period, potentially mating following each molt. Once they reach a carapace width of 155 mm or larger, female Dungeness crabs typically stop molting (Hankin et al. 1985). In order for the male to embrace the female, he must be larger than she. If, following the fishing season, there are too few large males remaining, then it stands to reason that some of the larger females may not have an opportunity to mate (Smith and Jamieson 1989).

A study to determine whether or not intensive fisheries on male Dungeness crabs impair mating success and/or limit egg production among female crabs was conducted by Hankin et al. (1997) in northern California. They used the presence of the sperm plug in the female reproductive tract as well as presence of sperm in the spermathecae as evidence for mating. A later study showed that sperm plugs disintegrate at a slow enough rate that their presence alone is a reliable indicator of recent mating (Oh and Hankin 2004). Presence of sperm in the spermathecae indicates both recent and past mating success. Sperm stored in the spermathecae can be used to produce viable egg masses for at least 2.5 years, albeit with reduced fecundities compared to crabs that had recently mated following molting (Hankin et al. 1989). Hankin et al. (1997) concluded from their study that "virtually all large molting females mated…in the intensely harvested northern California population of Dungeness crabs."

We present here the results of a similar survey of female Dungeness crabs conducted along the coast of Oregon. We examine the mating success of females as well as a size distribution of males. We discuss the impact of the results of this study on the Oregon Dungeness crab fishery.

Materials & Methods

With the aid of commercial fishermen, adult female Dungeness crabs were collected out of the three fishing ports of Brookings, Coos Bay, and Newport. All collections occurred in July, following the regular female molting and mating season. At Brookings and Coos Bay, 14 fish traps with ½ inch mesh were connected by 15 or 30 foot lines to commercial crab pots and allowed to soak overnight (12-18 hours). At Newport, all females were collected using commercial crab pots. Potentially mature females (over 100 mm CW) from both the fish traps and the commercial pots were kept and transported back to the laboratory at the Oregon Institute of Marine Biology for freezing and dissecting. The carapace width of the first 100 males caught in the traps and pots at both Coos Bay and Brookings was also measured (not including spines), but no males were kept for further study. All males captured at Coos Bay were counted for abundance estimates.

At the laboratory, each female crab's carapace width (CW) anterior to the 10^{th} lateral spine was measured to the nearest millimeter. The hardness of the shell was tested by placing pressure on the ventral side of the carapace with both thumbs. If the shell flexed, the crab was labeled "soft," if it did not, the crab was considered "hard." Dissections were carried out following the methods described in Hankin et al. 1997. The presence or absence of sperm plugs was noted, as well as whether the spermathecae were swollen (contained sperm) or not.

Results

Male Crab Carapace Width and Abundance

We measured 112 male crabs from the Coos Bay traps. Carapace width ranged from 101 to 170 mm, with an average of 144.95 mm. We also measured 100 male crabs from Brookings. Carapace width ranged from 150 to 184 mm, with an average of 161.71 mm. The size frequency distribution of all measured males from both sites is presented in Figure 1. We can produce and index of crab abundance by determining the number of crabs caught per trap per hour of fishing time. For male crabs caught at the Coos Bay site, abundance is estimated at an average of 1.92 males per trap per hour. Figure 2 displays the size frequency of Coos Bay males adjusted by fishing effort.

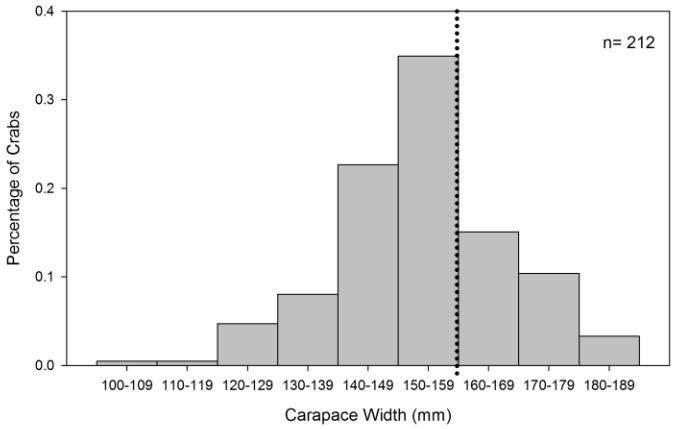

Figure 1. Size frequency distribution of male Dungeness crabs captured from Coos Bay and Brookings waters. The dotted line shows the size of a legal male.

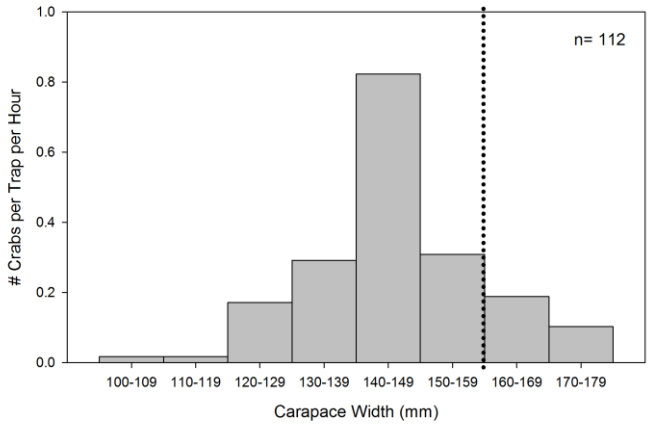

Figure 2. Size frequency distribution of male Dungeness crabs captured from Coos Bay waters corrected for catch per unit effort. The dotted line shows the size of a legal male.

Female Crab Carapace Width and Abundance

The size of the 427 female crabs captured in this study varied from 100 to 168 mm. A size frequency distribution is presented in Figure 3. Abundance estimated by catch per unit effort at Coos Bay was 0.33 females per trap per hour, while off Brookings it was 0.24. Figure 4 shows the size frequency of females off Coos Bay adjusted for unit effort, and Figure 5 shows the same for Brookings.

Female Mating Success and Site

Dissections provided evidence that 69% (295/427) of the captured females had sperm plugs in their reproductive tracts, indicating that these crabs mated this year. The percentage of females with swollen spermathecae but no sperm plugs (indicating mating success during a previous year) was 14%. This means that 356/427 (83%) of the females examined could produce viable eggs this year. Crabs from each of the three ports showed similar mating trends, and can thus be grouped together for analysis (Table 1).

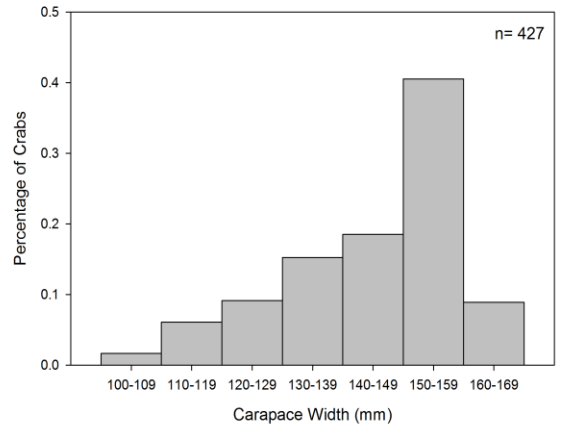

Figure 3. Size frequency distribution of all female Dungeness crabs captured from Coos Bay, Brookings, and Newport waters.

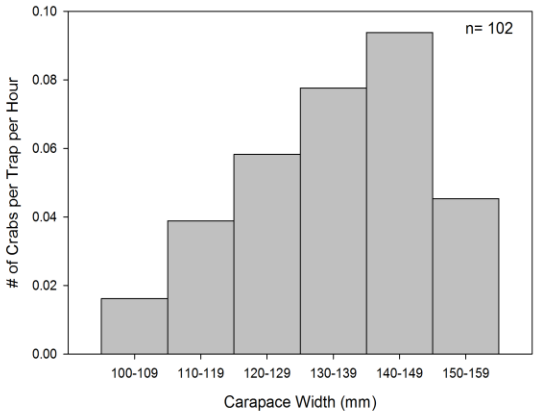

Figure 4. Size frequency distribution of female Dungeness crabs captured from Coos Bay waters corrected for catch per unit effort.

Female Mating Success and Size

All females were placed into one of seven size categories to determine whether large females were mating less successfully than smaller crabs. The results did not display this trend, in fact, mating success increased with female size (Table 2). Large females showed very high mating success (Figure 6).

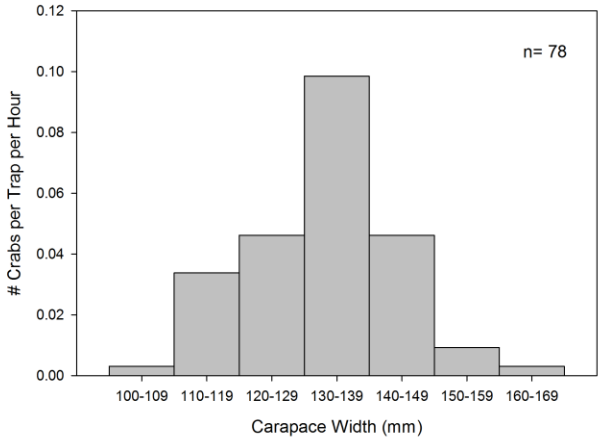

Figure 5. Size frequency distribution of female Dungeness crabs captured from Brookings waters corrected for catch per unit effort.

Table 1. Mating success of female Dungeness crabs from three ports on the Oregon coast

Port	Females Dissected	Recently Mated (% with Sperm Plug)	Previously Mated (% Swollen Spermathecae Only)	With Viable Sperm (% with Sperm Plug or Swollen Spermathecae)
Brookings	150	67%	10%	77%
Coos Bay	102	68%	16%	84%
Newport	175	72%	14%	86%
Total	427	69%	14%	83%

Female Mating Success and Shell Condition

Of the 427 crabs examined, 86 were classified as "soft." The female molting season begins in the spring, and the shells of females that molted in April and May would have been hard in July when we trapped them. Only the females that had molted towards the end of the season would have been considered "soft." The 86 "soft" females showed very high fertilization success: 95% with a sperm plug and 97% including those with swollen spermathecae only. Among the 341 "hard" crabs, 62% contained sperm plugs and another 18% had swollen spermathecae without sperm plugs.

Table 2. Mating success of female Dungeness crabs of different sizes

Carapace Width	Females Dissected	Recently Mated (% with Sperm Plug)	Previously Mated (% Swollen Spermathecae Only)	With Viable Sperm (% with Sperm Plug or Swollen Spermathecae)
100-109 mm	7	43%	14%	57%
110-119 mm	26	58%	4%	62%
120-129 mm	39	56%	13%	69%
130-139 mm	65	74%	3%	77%
140-149 mm	79	67%	20%	87%
150-159 mm	173	71%	18%	89%
160-169 mm	38	84%	11%	95%
Total	427	69%	14%	83%

Discussion and Conclusions

The results from this study are almost identical to the results from the study in the late 1990s in northern California (Hankin et al. 1997). These researchers found sperm plugs in 69% of all female crabs classified as having definitely molted. Although we did not classify our crabs in the same way, we found that 69% of all crabs examined carried sperm plugs and had mated this year. If, however, we only consider crabs we are sure molted this year (those classified as

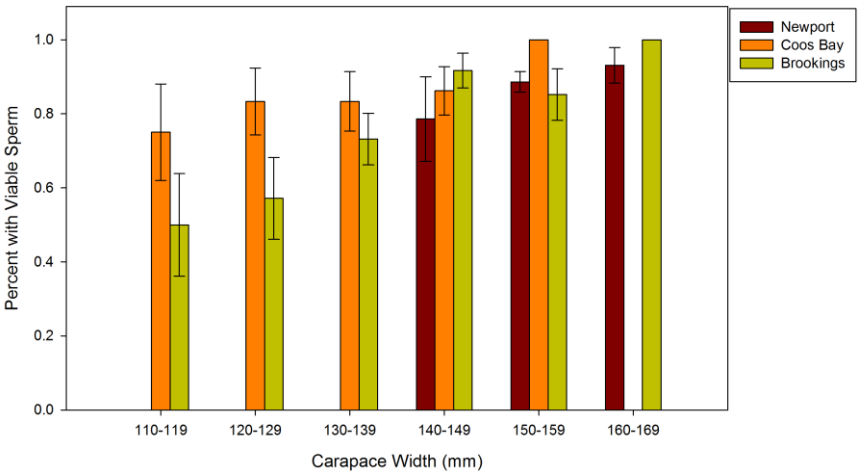

Figure 6. Percent of females carrying viable sperm by size class and port. Error bars represent standard error. The smallest size class is not shown because of the small sample size.

"soft" and all those carrying sperm plugs), we find much higher mating success (99%). The hypothesized problem of large females being unable to locate large enough males is also rejected on the basis of our data. Females larger than 150 mm CW mated just as successfully as smaller females, and the largest females (CW >160 mm) had the highest mating success of all. There is also an interesting trend if one examines the percent females with swollen spermathecae by size class (Figure 6). The larger a female crab is, the higher the probability that it would have mated in the past and have some sperm saved in its spermathecae.

The smallest size class of females in this study (100-109 mm CW) was included because female Dungeness crabs typically reach sexual maturity when they are around 100 mm CW (Tasto 1983). The lower mating success this group exhibited may represent immaturity at the time of molting. Our sample size (7) was too small to achieve an accurate estimate of mating success for this size class. Although the mesh size of our fish traps was small enough to keep smaller crabs from escaping, we did not capture a large number of smaller crabs. The fishermen we worked with informed us that crabs will often segregate by size and sex, and different groups will be found at different depths during the year. One fisherman also suggested that females and small crabs of both sexes avoid close contact with large male crabs. If a large male entered the trap first, its presence there may affect the composition of the other crabs that might enter the trap. Another possibility may be that the mesh opening on either side of the trap was more difficult to reach for smaller crabs. Anyone wishing to capture smaller size classes of crabs in the future should take these ideas into consideration. If these obstacles could be removed, small crab data would be very useful in studying the size frequency distribution of a crab population as well as tracking the evolution of a specific cohort of recruits.

Our data suggest that the mature molting female Dungeness crabs from these three Oregon fisheries are mating successfully, regardless of size. Under the current management system, female mating success is probably not an important limiting factor affecting this fishery.

Acknowledgements

We would like to thank the Oregon Dungeness Crab Commission for funding this project and aiding us in working with the commercial fishing fleet. We would also like to thank Mike Lane (Coos Bay), John Terebesi (Brookings), and Al Pazar (Newport) for use of their boats, traps, and knowledge in collecting the crabs for this study. Finally, we would like to acknowledge the work done by Ashley Bulseco and Kyle Krumsick for their help collecting, freezing, and dissecting the crabs.

References

Hankin, D. G. 1985. Proposed explanations for fluctuations in abundance of Dungeness crabs: a review and critique. *In* Proceedings of the Symposium on Dungeness Crab Biology and Management. Alaska Sea Grant Rep. No. 85-3. Alaska Sea Grant Program, Fairbanks, Alaska. pp. 305-326.

Hankin, D. G., N. Diamond, and M. S. Mohr. 1985. Molt increments, annual molting probabilities and survival rates of adult female Dungeness crabs in northern California. *In* Proceedings of the Symposium on Dungeness Crab Biology and Management. Alaska Sea Grant Rep. No. 85-3. Alaska Sea Grant Program, Fairbanks, Alaska. pp. 189-206.

Hankin, D. G., N. Diamond, M. S. Mohr, and J. Ianelli. 1989. Growth and reproductive dynamics of adult female Dungeness crabs (*Cancer magister*) in northern California. J. Cons. Int. Explor. Mer. 46: 94-108.

Hankin, D. G., T. H. Butler, P. W. Wild, and Q. Xue. 1997. Does intense fishing on males impair mating success of female Dungeness crabs? Can. J. Fish. Aquat. Sci. 54: 655-669.

Hartnoll, R. G. 1969. Mating in the Brachyura. Crustaceana 16: 161-181.

Jenson, P. C., J. M. Orensanz, and D. A. Armstrong. 1996. Structure of the female reproductive tract in the Dungeness crab (*Cancer magister*) and implications for the mating system. Biol. Bull. mar. biol. Lab., Woods Hole 190: 336-349.

Oh, S. J. and D. G. Hankin. 2004. The sperm plug is a reliable indicator of mating success in female Dungeness crabs, *Cancer magister*. J. Crustacean Biol. 24: 314-326.

Smith, B. D. and G. S. Jamieson. 1989. Exploitation and mortality of male Dungeness crabs (*Cancer magister*) near Tofino, British Columbia. Can. J. Fish. Aquat. Sci. 46: 1609-1614.

Tasto, R. N. 1983. Juvenile Dungeness crab, *Cancer magister*, studies in the San Francisco Bay area. Fish. Bull. 172: 135-154.