# Fishery Profile of Dungeness Crab in Washington State

The Dungeness Crab, *Metacarcinus magister* (sometimes known as *Cancer magister*), is a saltwater crab in the family *cancidae* that is native to the Pacific Northwest and important not only to the ecosystem but the economy of the area as well.

Their range stretches between Alaska and California, with each of five locations having different timing for reproduction and molting (Rasmuson 2013). Generally, the split in populations is put between the California and Alaska currents, but the gene variation in different locations shows a few separate populations. The electrophoretic variation of the species in the Pacific Northwest was low, "indicating that this species dispersed widely and prevented local gene differentiation of populations" (Pauley 1989). Thus, for the purposes of this report there are not different populations.

There are five main life stages of *M. magister*; the prezoea, the zoea, the megalopae, the juvenile, and the adult (Rasmuson 2013). In the Puget Sound the hatching occurs in February to May but can start as early as January on the coast (Rasmuson 2013). This means that they are synchronous spawners, giving relatively reliable yearly cohorts. The larvae have five zoea stages and one megalopa stage before molting into adults (Rasmuson 2013). These larval stages are characterized by "large compound eyes, four spines (one dorsal, one rostral, and two lateral) and swim by flexing their maxipeds) (Rasmuson 2013). The megalops generally appear in Washington around April and their abundance peaks around May to June (Pauley 1989). The larvae generally feed on zooplankton and phytoplankton, but the zooplankton are more favorable

(Pauley 1989). Through all stages of their life they are actively seeking out food and prey, as well as actively pursuing mates.

Mating is generally performed with a recently molted female and a molted and hardened male, which is generally at about two years of age and a carapace width of 100 mm (Rasmuson 2013) and in May and June in Washington (Pauley 1989). These crabs can live up to eight to ten years in the wild, and usually mate every year, switching to every other year as they get towards the end of their life span (Rasmuson 2013). The males grab onto a female up to two weeks before her molt in a 'premating embrace' and they copulate as soon as the female molts (Rasmuson 2013). The purpose of the embrace is to protect the female, who is soft from the molt, from predators as well as to ensure that she is only able to mate with one male.

During the mating process the spermatophores are deposited into the female's spermathecae, at which point the male usually embraces the female again (Pauley 1989). This 'post mating embrace' may be to protect the soft female from predation (Pauley 1989). The sperm are kept by the female for up to two and a half years if she does not molt again (Rasmuson 2013). The male also deposits seminal secretions which harden into a plug that extends from the spermathecae into the vagina, but this does not stop subsequent copulations from depositing sperm into the female's bursa (Jensen et al. 1996). As the eggs are extruded they pass through the first male's sperm before encountering the subsequent males' sperm in the bursa (Jensen 1996) before attaching to her setae (Rasmusen 2013). Females can have up to two million eggs, which adds up to five million eggs during her lifetime (Pauley 1989). The carapace size does not have much to do with the female's fecundity (Rasmuson 2013). The female carries the eggs until they hatch into zoea and they begin the cycle anew. The crabbing season, if it is restricted at all in the Puget Sound, is October to December (WDFW), which avoids the mating season and most

of the brooding and settlement season. This ensures that the population can recruit new members and keep the fishery stable, in theory at least. After this mating season and the eggs hatch, they become free floating zoea that drift through the water column before settling and molting.

Settlement occurs from April (on the coast) or June (Puget Sound) to August, where the megalops molt into juveniles (Rasmuson 2013). The juveniles are found in shallow coastal waters and hide in the eelgrass for protection, and they also use shells of clams and oysters as important habitat (Pauley 1989). The adults are found in coastal regions from the continental shelf to estuaries to the inland waters of the Puget Sound. Crabs usually migrate to deeper water within a few years after molting into juveniles, and that males migrate into colder water than females (Rasmuson 2013). It is at this stage of their life that they begin to pursue food in earnest.

*M. magister* are opportunistic feeders and don't generally discriminate on what they can catch in their sandy habitat. Analysis of the stomach contents of one year old crabs in Washington the diet tended towards crustaceans and mollusks, and the two year old crabs had less mollusks and more fish (Rasmuson 2013). These crabs also tend to be highly cannibalistic, especially the females, and go after smaller and recently molted crabs (Rasmuson 2013). They feed by digging in the substrate with their claws until they detect a prey item, at which point they clamp down with their claws and extract the prey from the sand (Rasmuson 2013). This is expanded upon later in the report.

The Dungeness crab has different habitat preferences at different stages of its life. As a plankton they float freely, but as larvae they settle onto sand and gravel and in eelgrass beds, with adults being found all throughout the tidal and subtidal (Essington et al 2011). They do not usually inhabit completely bare seafloor due to lack of cover to avoid predation and a low amount of food (Essington et al 2011). They rely on intertidal estuaries, especially the juveniles,

as they are particularly sensitive to predation (Essington et al 2011). Generally, crabs do not move more than 10 miles once they have settled (Dungeness Crab Report 2014). They have been tagged as far offshore as 750 feet but most of them are around 350 feet from shore (Dungeness Crab Report 2014).

Pelagic larvae are eaten by a variety of species, including coho salmon, gray whales, and birds. Octopuses, larger crabs, rockfishes, flatfishes, lingcod, as well as other species of fish, and cabezon also prey on larvae and juveniles (Dungeness Crab Report 2014). They are a significant prey item of leopard sharks through Washington (Ebert and Ebert 2005). A full and comprehensive list of everything that eats these crabs is hard to discern, as they are eaten by a great many organisms in all life stages.

The role of Dungeness crabs as predators is much better documented, especially their tendency towards cannibalism. In terms of the index of relative importance (IRI value), Dungeness crabs are 34.36% of small Dungeness crab diets (Stevens et al 1982). Just behind that are bivalves, acorn barnacles, and shrimp (BG Stevens et al 1982). When hunting clams, crabs have been observed twitching their antennae before scuttling to the clam and repeatedly manipulating it with its periods, maxillae, and maxillipeds (Juanes and Hartwick 1990). The crab then tries to outright break the shell with its claws, and if that fails it manipulates the clam again and retries crushing (Juanes and Hartwick 1990). If still that does not open the clam the crab will attempt to chip the edge of the shell with its dactylus and then insert a cheliped to break the clam from the inside (Juanes and Hartwick 1990). Interestingly cannibalism decreases at night, where crabs switch to hunting shrimp, most likely due to the nocturnal nature of the Crangon species they prefer (Stevens 1982).

There is debate about how far inshore these crabs move, and the lower bounds of salinity they can tolerate. They move in and out of estuaries with the high tides, experiencing slightly lower salinity as they migrate (Curtis and McGaw 2008). Temperature tolerance can range from 3 to 19 degrees C (Cleaver 1949). During mating they prefer temperatures around 8 to 10 degrees C (Pauley 1989), but this is disputed. There is a risk for adult crabs in eel beds to become stranded at low tides, which puts them at risk of drying out and or being discovered and eaten (Curtis and McGaw 2012).

Interestingly, Dungeness crab megalops prefer shell habitat to bare mud for settling, some even preferring it over eelgrass beds (Eggleston and Armstrong). This environment probably provides more cover and protection than bare mud, giving these crabs more camouflage. Estuarine fronts seem to provide important habitat for megalopa and are instrumental in their dispersal (Eggleston et al 1998). Larvae are found commonly within around 15 miles of the coast (Lough 1971). The implication is that Dungeness crabs start life by floating around in the open ocean before moving into estuarine fronts as a megalopa, settling into the benthic life as juveniles, and then shuffling around the intertidal zone as adults.

It is difficult to apply fish growth models such as the Von Bertalanffy to crustaceans, mostly because of their growth by molting. Directly assessing the age of a *Cancer magister* is difficult (Wainwright 1993), aside from larger size generally corresponding to an older adult. Some put the recruitment age at two to three and others at seven to eight, which presents a challenge to assessing the cohorts and overall health of the species. The best interpretations so far are the bent line model and the Misra equation (Wainwright 1993). The actual computation of both isn't particularly important, but they both show that the molt increment (how much the crab grows each molt) goes down considerably when the crabs are of a certain carapace size

(Wainwright 1993). Generally, the commercial size of a crab to be harvested is 6 ¼ inches, and they must be male (WDFW). Crabs of this size are assumed to be "harvestable surplus" and have mated at least once (WDFW). The crabs are also closed off from harvest from September to early December as many crabs molt during this period and are vulnerable to death if handled (WDFW). Population is generally measured by catch and landing data of crabs, without much emphasis on megalopes and zoea.

During the 2010-2020 period the state and tribal fisheries (combined) harvested between 8.3 to 11.9 million pounds of crabs (WDFW Crab Report 2020). However, the total catch has trended downward since 2015 (WDFW Crab Report 2020). The long-term trends tend to point towards stability, especially in the last 30 years (CDFG 2012). Most assert that the crab population is as stable today as it was in 1905 (CDFG 2012). There is some concern that the fishery is turning towards a low abundance. This is covered more in the last section.

If males reach maturity at age four (Smith 1988), the sub-size but mature males have a high natural mortality rate of 2.8-4.5 with a survival rate of about 10% (Smith 1988). The fishing mortality of legal-size males is high at around 5.1 to 6.9 (Smith 1988). Natural mortality among Dungeness crabs is usually due to predation by octopuses, sharks, a variety of fish species, cannibalism, or disease. This is expounded on in later sections. The mortality rate is interesting as the population has been stable for a long time, probably due to the incredible fecundity of these invertebrates. There is considerable concern however that removing the largest males from the population could result in overall smaller crabs as only the sub-legal males are reproducing with females (Jamieson 1998). There is precedent for this among other fish species, but it is difficult to assess with crabs. It could be helpful if a maximum size was implemented, as it is with lobsters (NOAA), to ensure that the largest and oldest males mate with females to produce

large offspring. No such law exists for Dungeness crabs, but in the long run it could help the fishery continue to thrive.

The Dungeness crab industry produced around 15.7 million pounds of crab in the 2019-2020 season, which was one of the largest harvests on record (Whittaker 2020). Between 2014 and 2019 the industry was estimated at 45 million dollars (Bernton 2022) and is a pillar of Washington's economy. Some crab is sold whole, or live, and others are processed in canneries and shipped to grocery store shelves.

The primary location of harvest in Washington for Dungeness crabs is on the coast, split into eight regions (Reed 2009). The fishery north of Pt. Chehalis is managed by Washington state and four treaty tribes: the Makah, the Quinault, and the Quileute, with the Hoh no longer maintaining the historic fishery (Reed 2009). Tribes are entitled to harvest 50% of the available crabs in their usual and accustomed territory. Approximately 500 square miles of the Makah and Quileute territory is closed for the first few months of the season, with the Quinault maintaining the sole rights to their fishing grounds year round (Reed 2009). This is incredibly important and rather unique to Washington, where tribes retain control of their usual territories to use as they traditionally have. This is not always upheld very well, but in many cases it is better (sadly) than the rest of the country. The fishery is managed directly by Washington state instead of the federal government, not being shifted to the federal government in 1997 (WDFW).

In 1979 there were 400 crabbing vessels in the commercial fishery, but to keep the fishery viable, that number was reduced using a limited number of licenses. There is a maximum of 250 commercial Dungeness crab licenses (Puget Sound Crab Association (PSCA)) and as the recreational fishery grows, multiple licenses are currently held by singular individuals to ensure the fishery is viable economically. The only way to acquire a new license is to buy it from an

existing license-holder (WDFW). Because of the mandated 50% reserve for indigenous tribes and the booming industry, the Washington Department of Fish and Wildlife is engaging in a buyback program to reduce the commercial crab fleet (WDFW 2008). This has not entirely come to fruition yet, but it would take some of the pressure off the coastal crab fishery.

Crab pots are used by recreational and commercial fishers alike, however the commercial pots have more regulated size and structure than recreational ones. Crab pots are set in rows on individual lines and retrieved using winches (called "crab-blocks"), and individual crews can pull in and rebait up to 400 pots a day (Oregon DFW). In Washington each pot and buoy must have a tag that displays the license holder's name and license number (WAC 220-340-430). This is to ensure that if something is found to be out of order or if a trap is found abandoned the correct people are held responsible or contacted. Each pot must also have escape holes (WAC 220-340-435) which allows smaller animals to escape, and the trap itself cannot be larger than 13 cubic feet (WAC 220-340-435). There are two main levels of license, one with a cap of 500 pots and one with a limit of 300 pots though the maximum in Gray's Harbor is a flat 200 (WAC 220-340-480). These regulations limit bycatch and the accidental catch of smaller crabs. There have also been increasing efforts to reduce whale entanglements including a reduced pot number and reduced line lengths to only the bare minimum needed to account for ocean conditions to reduce marine mammal deaths due to pot lines (Hall 2019 and 2020).

The recreational fishery has laxer regulations than the commercial. Licenses are required for crabbers over the age of 15 and a catch card is to be filled out as soon as the crabs are landed (or upon returning to the dock if not fishing from a boat with a pot) (WDFW). On the coast the limit is 6 crabs per day, reduced to 5 in the Puget Sound, and increased to 12 on the Columbia River (Reg 2022). Unlike with the commercial fishery a variety of methods are allowed for

catching Dungeness crabs, though the maximum square feet for pots is the same. The state requires that pots have escape rings and the pot must rest flat on the bottom (Reg 2022). Each crabber is limited to two units of crab gear (nets, pots, etc) (Reg 2022). This all ensures that the recreational sector is not taxing the fishery too much. However, the rise of commercial crab fishing is starting to tax the fishery slightly, as seen by the increasing amount of individuals with more than one commercial license.

There is currently no stock assessment for Dungeness crabs. Population estimates are based on landings and catches, which excludes certain sizes of crabs and thus does not give entirely accurate assessments of population. Assessments of this kind favor the most gullible of the population and leave out the more clever or wary specimens. Many sources claim that the fishery is stable because the catches and landings have been stable, however the same could be said of the snow crab fishery which collapsed this fall after an 80% decline in population (Foy 2022).

The snow crab stock crash was attributed to the 2019 heat wave, which in turn is attributed to climate change (Foy 2022). Along with the heat waves Washington is experiencing warmer waters, increasingly large algal blooms, and hypoxic environments (Breda 2022). There needs to be more research into how the Dungeness crab will respond to these changing conditions, and a more comprehensive stock assessment. A lot of data collected for this paper is twenty to thirty years old and doesn't account for the current unpredictable state of our ocean. As the commercial and recreational demand for Dungeness crabs increases the pressure will be on the crabs to keep the fishery afloat, and with the decline seen in snow and king crabs in Alaska that could be a ticking clock.

The good news is that these studies are underway. Currently several NOAA departments are collaborating to fund a four-year project aimed at understanding multifaceted impacts of climate change on marine ecosystems, which includes Dungeness crabs. The program includes more than 18 scientists and eight institutions in the Pacific Northwest. It is not too late to prevent a total fishery collapse, and with the data currently being collected and reviewed, these crabs will continue to be a pillar of the Pacific Northwest culture, cuisine, and ecosystem.

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