Report on the Recruitment of Dungeness Crab Megalopae During the 2020 Recruitment Season

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Light trap sampling began on 1 April 2020 with a trap placed near the end of F dock in the Charleston Outer Boat Basin. Daily sampling continued through 30 September 2020. Total catch of Dungeness crab megalopae for the recruitment season was 161,062 (Figure 1). Peak catches of megalopae occurred in May about a month later than usual. Catch peaked again in early June. There were no dates with catches in the 100,000 range. Catch dropped to close to zero or zero at the end of August.

Due to the pandemic, OIMB was closed to classes spring, summer, and fall 2020. There were no students available to help with the work. I ended up doing all the daily sampling; 184 days! Hopefully, this year I will have help.

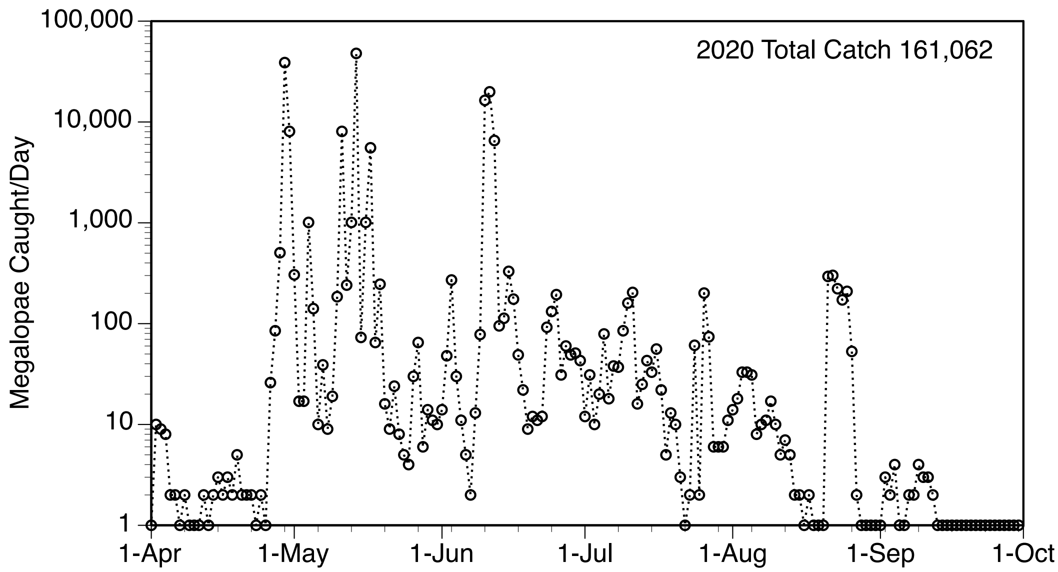

Figure 1. Daily catch of Dungeness crab megalopae in a light trap fished from F Dock in Charleston Harbor during spring, summer and early fall of 2020. To plot the data on a log scale one has been added to each daily count.

Over the 20 years of sampling the number of returning megalopae has varied from 2,000 to 2.8 million megalopae. The years appear to fall into two groups, years with < 100,00 (low) and >100,000 (high) numbers of returning megalopae (Figure 2). Whether a year's catch is low or high appears to depend initially on the phase of the Pacific Decadal Oscillation (PDO) and whether there is a strong El Niño occurring. When the PDO index is positive or there is a strong El Niño, catches tend to be low as was the case in 2016 (strong El Niño), and the reverse when the PDO index is negative (Figure 3A). However, this relationship is not perfect explaining about 37% of the variability

Dungeness crabs in Northern California and Oregon release larvae in winter (January through February, maybe into March) and the larval period is three to four months, hence, after July we should not catch anymore megalopae, but in most years we catch megalopae in August and September. Off Vancouver Island and northward, larval release occurs in spring and summer; the megalopae we catch in late summer and fall in Coos Bay are likely from this source. If this is true then we would expect to see more megalopae caught late in the season when the PDO index is negative and more water is flowing southward in the California Current. In Figure 3B I have plotted the PDO index and the late season catch of megalopae; there is a significant correlation between the two variables. This result is consistent with the hypothesis that during years with negative PDOs more water travels south in the California Current transporting megalopae southward and leading to higher catches of megalopae in Oregon. Roughly 36% of the variability in late season megalopae catch can be explained by the PDO.

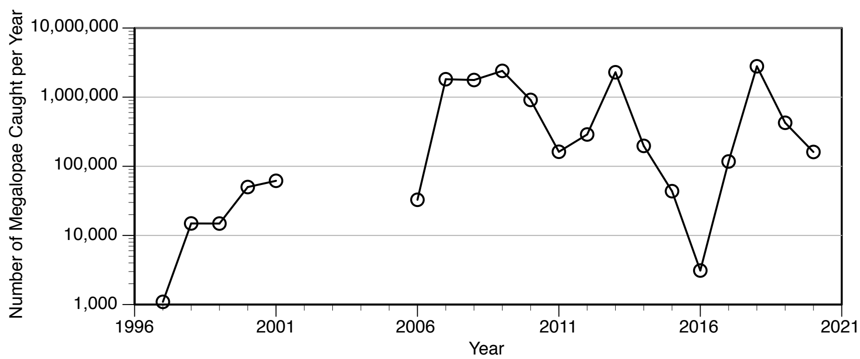

Figure 2. The annual catch of megalopae during the 20 years of study. During the first six years, catches were all < 100,000, between 2007 and 2014 catches were > 100,000. In 2015, the year of the 'warm blob', catch dropped down to 44,000 and in 2016, a year with a strong El Niño, catch was only 3,106 comparable to the catch during the last strong El Niño in 1997/1998. Catch in 2018 was a record with roughly 2.8 million megalopae caught. Catch in 2020 was 161,062.

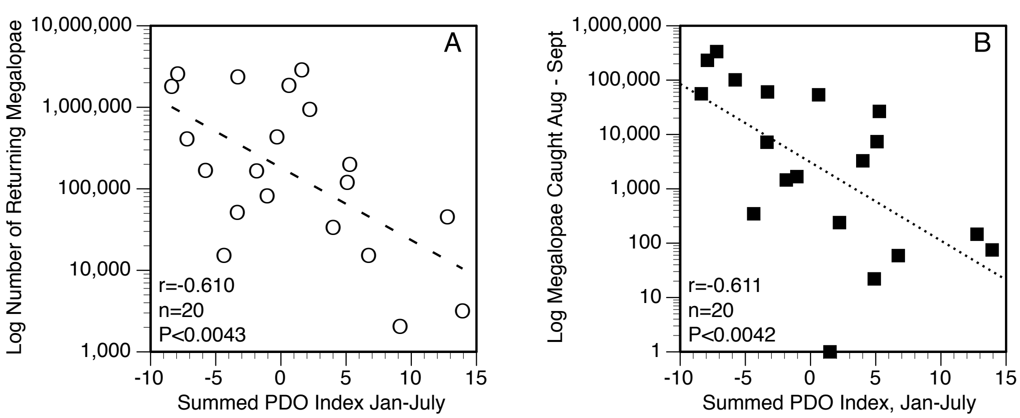

Figure 3. A) Relationship between the summed monthly PDO index from January through July and the log number of megalopae caught per season. The dashed line and statistics are the result of a regression run between the two factors. About 36% of the variability in the annual catch of megalopae is explained by the PDO index. B) PDO index summed for the months of January through July plotted with the log number of megalopae caught in August and September. The PDO index explains about 36% of the variability in the late season catch of megalopae.

In Figure 4 I have plotted the day of the year of the spring transition against the number of megalopae caught. The spring transition occurs when the winter winds from the south shift to the spring/summer winds from the north at which time the upwelling season begins. The catch data have been split into two groups, years with <100,00 megalopae caught and years with >100,000 megalopae caught. Data from 2017 fall right at the break between these two groups and for this analysis I have placed these data with the years with lower returns of megalopae. The relationship between catch and the day of the year of the spring transition remains significant explaining a bit more than 40% of the variability for both the low and high catch data sets; the earlier the spring transitions the more megalopae are caught in years with both low and high numbers of returning megalopae.

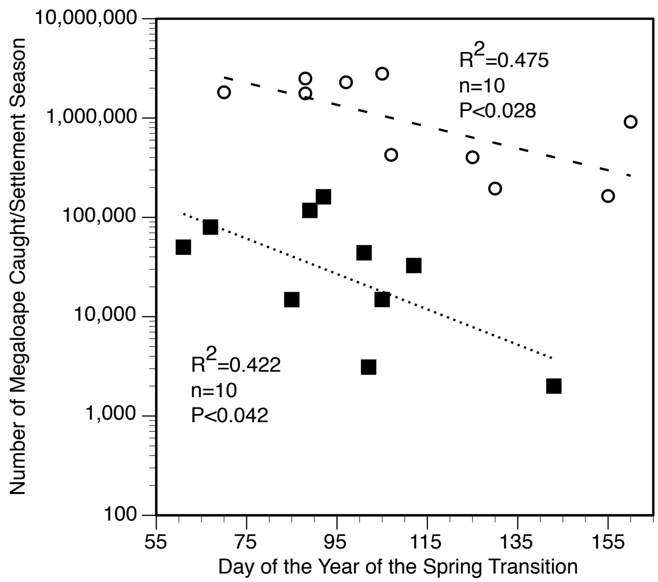

Figure 4. Day of the year of the spring transition plotted with the annual catch of megalopae. The catch data have been divided into years with low catch (<100,000 caught, filled squares) and high catch (>100,000 caught, open circles). The dotted lines and statistical results are from regressions run between the variables.

The relationship between the number of megalopae caught and the size of the commercial catch four years later is (currently) made up of two curves, years with low (<100,000) and high (>100,000) numbers of returning megalopae (Figure 5). I am not sure why this relationship takes the form of two curves; something different is happening post-settlement during years with high to very high returns of megalopae (i.e., when >100,000 megalopae are caught in the light trap). Note that the number of megalopae caught in 2017 (117,000) is right at the transition between these two groups of data. I was not sure if, when calculating the future commercial landings, I should use the equation associated with the low or the high catch years. As it has turned out, the 2017 megalopae catch fits best in the curve for years with megalopae catches >100,000, a high catch year.

Marine heat waves are predicted to become more common under the conditions of climate change. We saw a marine heat wave in 2014/2015 (the blob), then a strong El Nino in 2016, in fall 2018 a new marine heat wave (a new blob) started but then subsided, and in 2019 there was a new marine heat wave (blob 2.0). If, as predicted, these sorts of marine heat waves are going to become a regular occurrence then I think that my previous models of the relationship between the number of returning megalopae and the size of the commercial catch will regularly underestimate the commercial catch following marine heat waves. I think that eventually what we will see is two new curves; one relating lower returns of megalopae (i.e., <100,000) to the commercial catch where the recruits grew during marine heat waves and a second curve for years when there were many megalopae returning (i.e., >100,000) also growing during marine heat waves. We may eventually end up with four curves! At this point I am trying to determine what would be a good objective way to quantify the 'amount' of marine heat wave seawater temperatures recruits experience during the four years it takes them to become commercial sized crabs.

There was a marine heat wave during the summer of 2019, northeast Pacific waters were warmer than normal by about +2 C and coastal waters appear to have been warmer by about +1 to +2 C. This suggests that the roughly 400,000 megalopae caught in 2019 may produce a higher than expected commercial landing in 2022/2023 fishing year. How high? Given that I have only one data point for megalopae with a high return growing during a heat wave I really can't make a prediction any better than a guess. To guess, and this is truly a guess, perhaps a total landing of around 22 million pounds.

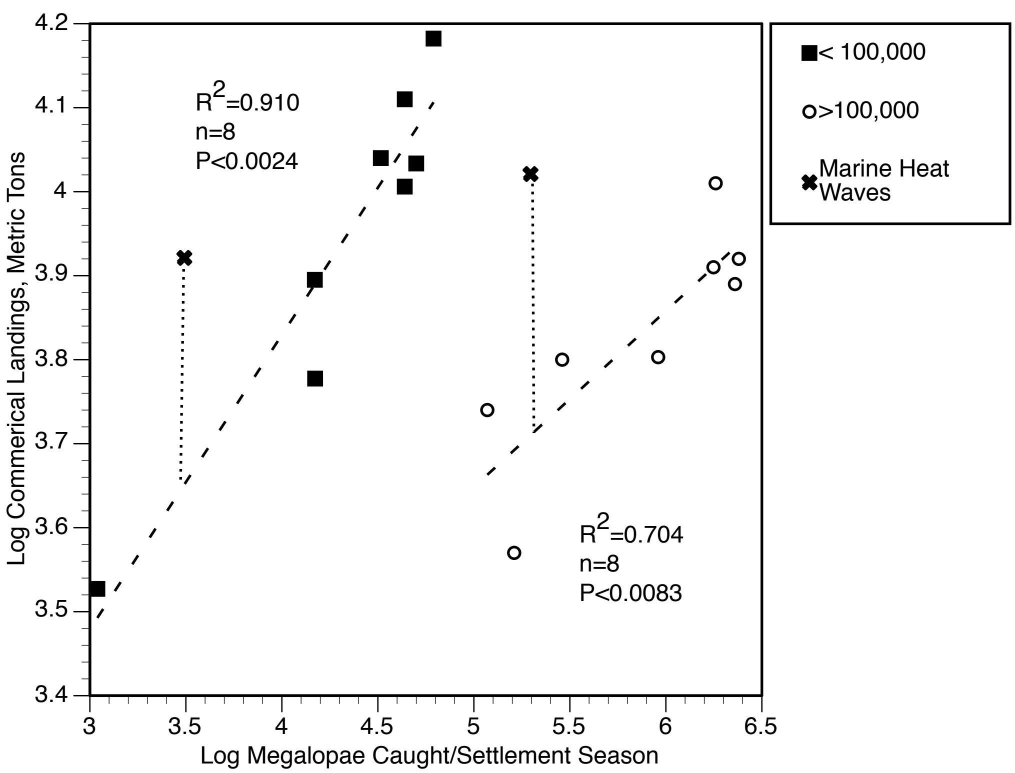

Figure 5. Log of the total number of *C. magister* megalopae caught per settlement season plotted against the log of the commercial landings lagged four years with years with catches < and > 100,000 (filled squares and open circles, respectively) plotted separately. The Oregon landings data are up to date (commercial landings for 2020/2021 were estimated from the catch through March). The Xs indicate the data point for 2017/2018 and the 2019/2020 fishing seasons, which relates the 2014 and 2016 megalopae returns. Note that these data points fall between the two curves and I have not used it in the subsequent statistics nor have I used it to calculate the future commercial

landings. Both of data points are from periods when the developing crabs experienced warmer seawater temperatures due to marine heat waves.

As I stated in my last annual report, I think that the crab commission should begin to consider climate change and the Dungeness crab fishery. The Pacific coast is clearly starting to be affected by climate change. In an earlier report I described a number of possible scenarios that might be caused by marine heat waves. I have added a new one in the previous paragraph. In the lab it would be fairly easy to determine if juvenile crabs grow more rapidly at higher temperatures. With the light trap we have access to many megalopae who would be the stock for the experiment. The tricky part of the question is whether by growing faster a greater percentage survive in the wild.

Table 1. Predicted Oregon commercial catch of Dungeness crab for fishing years 2018/2019 through 2023/2024. However, bear in mind that I do not understand the effect of marine heat waves on the prediction of the commercial landings and I do not have an objective way of telling when marine heat waves might be having an affect. Very tentatively, it looks like marine heat waves allow a greater percentage of new recruits to grow into the fishery enlarging the commercial landings relative to my earlier predictions, but I don't know when this should be expected.

Megalopae Recruitment Year	Log Number of Megalopae Caught	Commercial Fishing Year	Estimated Future Commercial Landings, lbs	Actual Commercial Landings, lbs
2015	4.64	2018/2019	24,730,100	≈23,800,000
2016	3.49	2019/2020	8,446,214	≈18,349,000
2017	5.07	2020/2021	8,729,129 or 35,010,300	≈12,106,086
2018	6.45	2021/2022	19,600,000	
2019	5.63	2022/2023	12,400,000	
2020	5.21	2023/2024	11,000,000	