Report on the Recruitment of Dungeness Crab Megalopae During the 2018 Recruitment Season

Dr. Alan Shanks
Oregon Inst. of Marine Biology
University of Oregon

Light trap sampling began on 28 March 2018 with a trap placed near the end of F dock in the Charleston Outer Boat Basin. Daily sampling continued through 25 September 2018. Total catch of Dungeness crab megalopae for the recruitment season was 2,795,426 (Figure 1), a record high for the 18-year time series. Nearly 80% of the catch for the entire recruitment season took place between 4/20 and 5/9. During this period there were 14 days in which the daily catch was >100,000 (one or more gallons of megalopae). There were three days in May and June when catch approached 100,000 per day. By July daily catch decreased to <10/day and we caught 1 megalopa in all of August and September. The continuous high catches at the end of April and into May suggest that there was an abundance of megalopae on the shelf and the conditions for shoreward transport were present throughout this period. The pattern of daily catch in this year is fairly unique; we have not previously seen sustained high catches for such a long period and we have never seen such low catches in August and September.

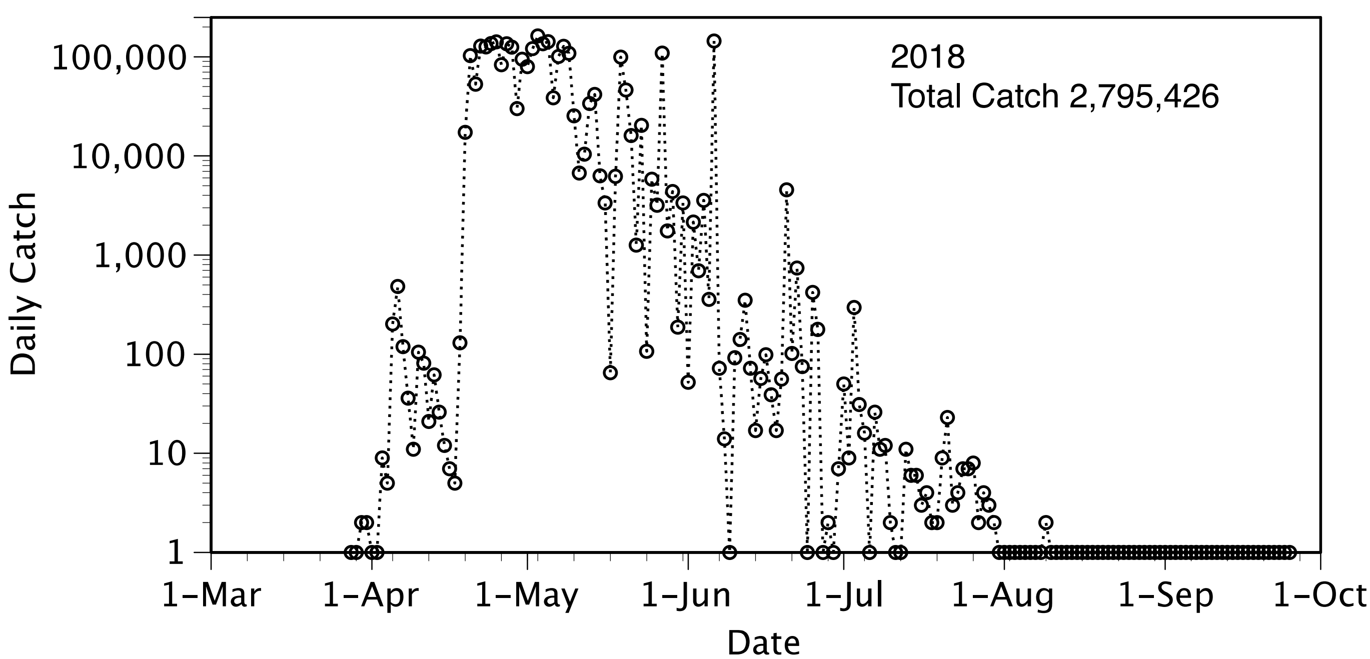

Figure 1. Daily catch of Dungeness crab megalopae in a light trap fished from F Dock in Charleston Harbor during spring, summer and early fall of 2018.

Over the 18 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) 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 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 index is negative (Figure 3A). However, this relationship is not perfect explaining only about 37% of the variability. For example, this year the PDO was close to 0 (1.49) yet the catch of megalopae was a record high.

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. But 2018 is an exception to this pattern; we caught only one megalopa in all of August and September.

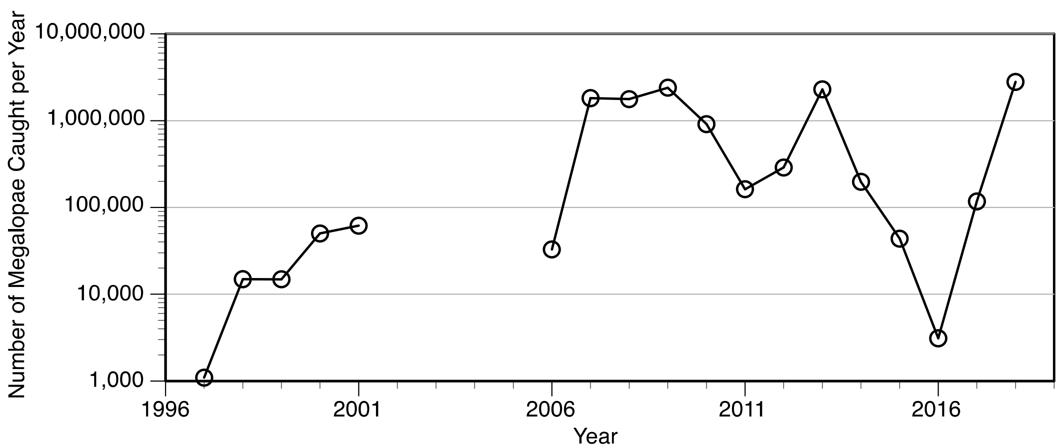

Figure 2. The annual catch of megalopae during the 18 years of study. During the first six years, catches were all < 100,000, between 2007 and 2014 catches have been > 100,000. In 2015, the year of the 'warm blob', catch dropped down to 44,000 and in 2016, a year with a strong El Niño, catch was only 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.

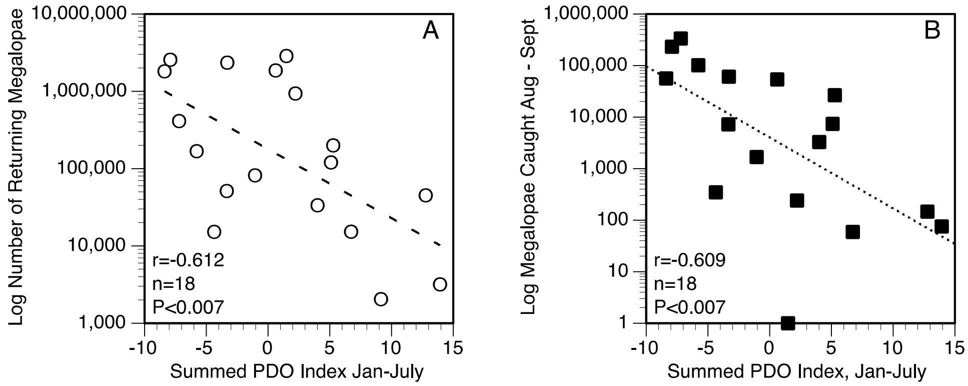

Figure 3. A) Relationship between the summed monthly PDO index from January through July and the log number of megalopae caught per season. The dashed line and statistics are the result of a regression run between the two factors. About 37% of the variability in the annual catch of megalopae is explained 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 37% of the variability in the late season catch of megalopae. Note the point on this graph that falls on the baseline. This point represents the results from 2018. Late season catch in this year was uniquely low with only one megalopa caught during August and September

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; the earlier the spring transitions the more megalopae are caught in both types of years.

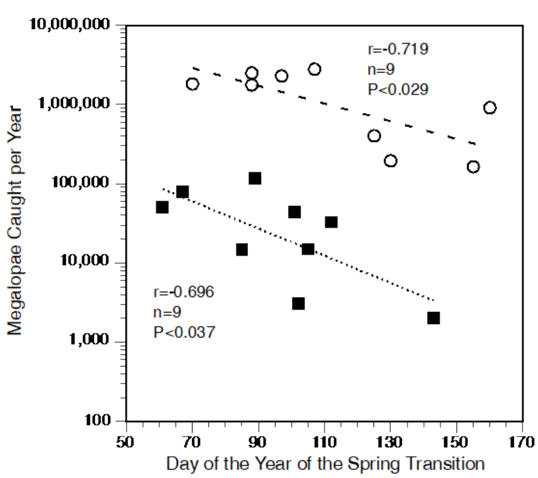

Figure 4. Day of the year of the spring transition plotted with the annual catch of megalopae. The catch data have been divided into years with low catch (<100,000 caught, filled squares) and high catch (>100,000 caught, open circles). The dotted lines and statistical results are from regressions run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

The relationship between the number of megalopae caught and the size of the commercial catch four years later is 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 return). Note that the number of megalopae caught in 2017 (117,000) is right at the transition between these two groups of data. I am not sure if, when calculating the future commercial landings, I should use the equation associated with the low or the high return years. For predictive purposes I have done it both ways and these predictions are both presented in Table 1.

What I wrote last year was the following: 'Given the number of megalopae caught in 2014 (197,394), I predicted that the commercial landings for the 2017/2018 season should be around 10,000,000 lb. and the total landing ended up close to 23,000,000 lb. My estimate is way way off (X symbol in Figure 5), which is fascinating as this is the first year where my estimated landings have been so far off. What might have caused this disparity? Starting in 2013 due to climate change dynamics (*1*), the water in the Eastern North Pacific warmed substantially. This was due to a persistent high-pressure ridge that formed in the northern North Pacific, which blocked storms moving across the Eastern North Pacific (*2*). This decreased mixing allowing a huge mass of water to warm up; this was dubbed the 'warm blob'. The blob persisted into 2016 and in spring/summer 2014 moved from the open ocean onto the shelf. Average high tide (i.e., coastal ocean water) seawater temperatures in winter 2015 measured at the OIMB pier near the mouth of Coos Bay were around 12 ºC compared to a normal winter when temperatures average around 10 ºC. In 2016 there was a major El Niño and the water was again warmer than average by at least 1 ºC. All else being equal, coldblooded animals, like crabs, tend to grow faster when conditions are warmer. Under warmer conditions, perhaps megalopae that settled in spring/summer 2015 reached market size in three rather than the typical four years. If this were the case, then the landings for the 2017/2018 commercial season would be due to crabs that returned in 2014 augmented by crabs that returned in 2015.' If last year's landings were a combination of animals recruited in 2014 and 2015 than I speculated that the commercial catch in 2018/2019 might be lower than my estimate because some portion of the crabs that settled in 2015 had already reached market size. This did not prove to be the case, the 2018/2019 landings fall right on the regression line defined by the open circle data points. This suggests that perhaps the higher than expected landings in 2017/2018 was due to better survival of recruits such that more of them survived to become market sized adults. Why this would happen I do not know.

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. How might these changes affect the Dungeness crab. I am going to speculate so as to give you some idea of potential threat to the species and fishery due to climate change. Ocean acidification is clearly occurring and it is not clear how this will affect larval and settled crabs. In some organisms, high CO_2 concentrations has been observed to cause the lose of their sense of smell. If this happened with adult crabs, then the current fishing method might fail as the crabs would be unable to smell the bait. The warm 'blob' and the strength of the 2016 El Nino were both due to climate change. Research predicts that 'blob' marine heat waves on the Pacific Coast may occur every five years and, in fact, a blob like event started to form in the fall of 2018 and then dissipated. Warmer water could speed development of larvae, which could alter their pattern of dispersal and the current relationship between coastal hydrodynamics and larval return to the coast. Faster development of new recruits could cause male crabs to enter the fishery after 3 rather than 4 years, which could decrease the number of mating opportunities a male crab may have before it enters the fishery and is caught. This could decrease the spawning success of female crabs – there may be too few male crabs for mating success. If this were to happen it might require that the size limit be increased so that male crabs have more opportunity to mate. As I said, this is purely speculation at this point, but the potential for serious problems I think is real and I think it would be wise to keep a close eye on the changes to the ocean brought on by climate change and how these might affect the crabs.

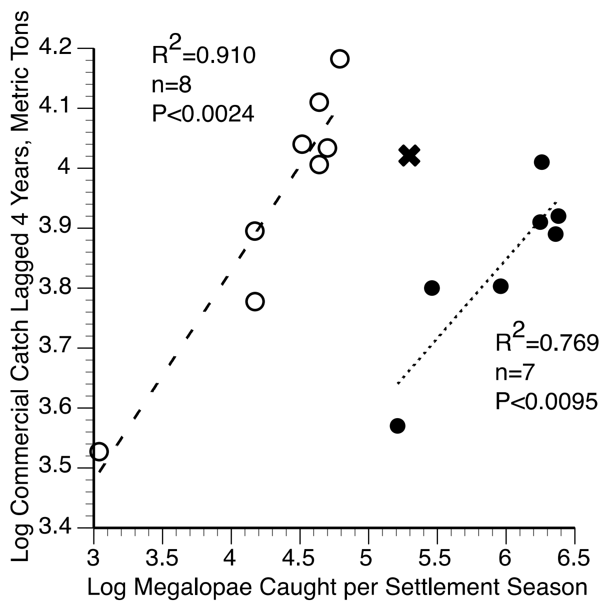

Figure 5. Log of the total number of *C. magister* megalopae caught per settlement season plotted against the log of the commercial landings lagged four years with years with catches < and > 100,000 (open and filled circles, respectively) plotted separately. The Oregon landings data are up to date (commercial landings for 2018/2019 were estimated from the catch through March). The X indicates the data point for 2017/2018 fishing season, which relates the 2014 megalopae return. Note that this data point falls 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.

My estimate from last year for the commercial landings in the 2018/2019 season was 24,730,100 lbs and the actual landings looks like it will be around 23,800,000; my estimate was high by about 1,000,000 lbs, off by about 4%. Note that next years commercial landings (2019/2020) is from the 2016 settlement season. 2016 was a strong El Nino year and the return of megalopae was very low (about 3,000 animals). This should translate into poor commercial landings next year. I predict landings will be down around 8,400,000 lbs. During the last strong El Nino, 1997, only about 2,000 megalopae were caught and the commercial landings were around 7,300,000 lbs. I have mixed emotions about this prediction. I would like it to be correct, which would continue to confirm the model, but a low landing year is going to mean smaller income for the fishing community, not a good outcome.

Table 1. Predicted Oregon commercial catch of Dungeness crab for fishing years 2018/2019, 2019/2020, and 2020/2021. The 2017 return of megalopae could lead to poor or great commercial landing and I have calculated the estimated landings using both regression equations from Figure 5. The equations relating low and high megalopae catches to commercial landings are Log metric tons of landing= 0.3505512(log megalopae caught)+2.427270 and Log metric tons of landing=0.2630169(log megalopae caught)+2.269794, respectively.

Recruitment Year	Log Number of Megalopae Caught	Commercial Fishing Year	Estimated 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	
2017	5.07	2020/2021	8,729,129 or 35,010,300	
2018	6.45	2021/2022	19,600,000	

References

1. E. C. Oliver, S. E. Perki6.45ns-Kirkpatrick, N. J. Holbrook, N. L. Bindoff, 9. Antrhopogenic and natural influences on record 2016 marine heat waves. *Bulletin of the American Meteorological Society, Special Report*, S44-S48 (2018).
2. N. A. Bond, M. F. Cronin, H. Freeland, N. Mantua, Causes and impacts of the 2014 warm anomaly in the NE Pacific. *Geophysical Research Letters* **42**, 3114-3420 (2015).