Report on the Recruitment of Dungeness Crab Megalopae During the 2015 Recruitment Season

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

Light trap sampling began on 27 March 2015 with a trap placed near the end of F dock in the Charleston Outer Boat Basin. Daily sampling continued through 30 September 2015. Total catch of Dungeness crab megalopae for the recruitment season was 44,000 (Figure 1). Over the 15 years of sampling the number of returning megalopae has varied from around 2,000 to 2.4 million megalopae. The years fall into two groups, years with < 100,00 and >100,000 returning megalopae (Figure 2). 2015 was one of the lower return years (Figure 2). Whether a year's catch is high or low appears to depend initially on the phase of the Pacific Decadal Oscillation (PDO). When the index is positive, catches tend to be low as was the case in 2015 and the reverse when the index is negative (Figure 3). PDO is an index of the amount of water from the West Wind Drift (the current that crosses the N. Pacific from Japan) that makes its way into the California Current or the Alaska Gyre. When the PDO index is negative more water moves into the California Current, the current is faster and seawater temperatures are lower (hence the negative index), but when the PDO index is positive the reverse is true. Dungeness crab larvae are released in winter and are carried northward by the Davidson Current. As they develop they are carried seaward and northward and eventually end up off the shelf in the California Current and up off Vancouver Island or even further north. Once in the California Current they will be transported southward. During negative PDO years, when the California Current is strengthened, catches of megalopae tend to be higher (Figure 3) perhaps because more megalopae are carried southward to the waters off Oregon and Northern California. My graduate student, Leif Rasmuson, as part of his PhD dissertation tested this hypothesis using a physical oceanographic model of currents coupled with Dungeness crab larval behavior. The model results fit our hypothesis nicely. Leif defended his thesis this past summer, is currently working for NOAA studying blue fin tune, and is preparing the model results for publication.

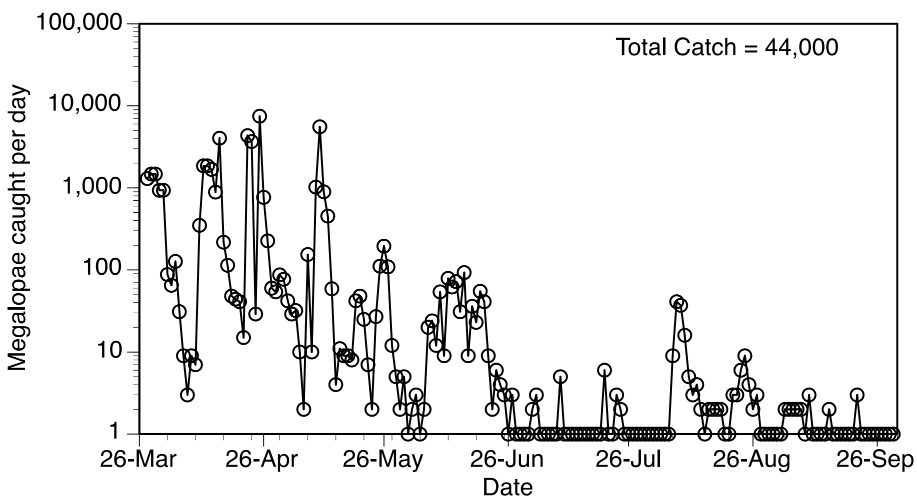

Figure 1. Daily catch of Dungeness crab megalopae in a light trap fished from F Dock in Charleston Harbor (open circles solid line) during spring, summer and early fall of 2013.

For a paper on this research that appeared in the journal Fisheries Oceanography, I explored another possible effect of the PDO on the number of returning megalopae. 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, as you can see in Figure 1, we catch megalopae into the fall although the number caught in 2015 was quite low. Off Vancouver Island and northward, larval release occurs in spring and early summer; the megalopae we catch in late summer and fall in Coos Bay maybe from this source. If this is true then we 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 4 I have plotted the PDO index and the late season catch of megalopae; there is an excellent 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.

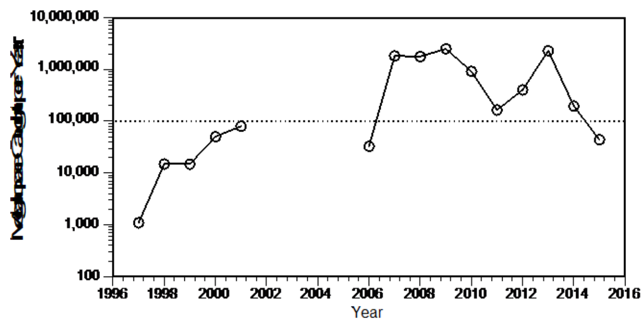

Figure 2. The annual catch of megalopae during the 15 years of study. During the first six years, catches were all < 100,000, between 2007 and 2014 catches have been > 100,000, and this year, 2015, catch dropped down to 44,000.

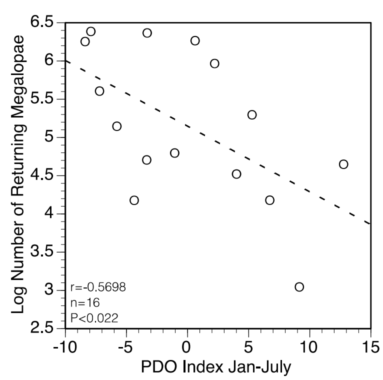

Figure 3. Relationship between the summed monthly PDO index from January through July and the log number of megalopae caught per season. The dashed line and statistics are the result of a regression run between the two factors using all the data. About >32% of the variability in the annual catch of megalopae is explained by the PDO index.

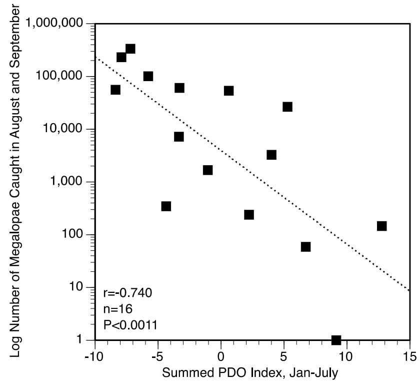

Figure 4. PDO index summed for the months of January through July plotted with the log of the number of megalopae caught in August and September. The PDO index explans about 55% of the variability in the late season catch of megalopae.

During this past year there was a relatively strong El Nino. Northward flow tends to be stronger during El Nino years and this flow may push larvae far enough north that they do not return to Oregon. During the 15 years of sampling I think we have enough data from El Nino years of various strength that we can investigate this hypothesis. In Figure 5 I have plotted the summed El Nino index for January through March against the log number of megalopae caught. There is no relationship between the two. The PDO index clearly affects the return of megalopae but, so far, the El Nino index does not have an effect.

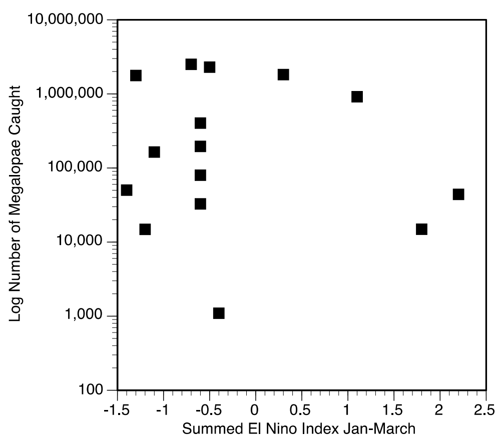

Figure 5. The summed El Nino index for January through March plotted against the log of the number of returning megalopae. There is not a significant relationship between the two variables.

In Figure 6 I have plotted the day of the year of the spring transition against the number of megalopae caught. The spring transition occurrs when the winter winds from the south shift to the spring/summer winds from the north. The catch data have been split into two groups, <100,00 catch and >100,000 catch. 2015 falls into the first group and is the first year since 2006 when we have had a catch lower than 100,000. The relationship between catch and the day of the year of the spring transition remains significant, the earlier the spring transition the more megalopae are caught. I think the most interesting thing to come out of Leif's thesis work was that we discovered that at the spring transition the thermocline, the zone where temperature changes rapidly so that there is a warm layer of less dense water floating on top of colder denser water, becomes much more shallow. It is after the spring transition that we begin to see megalopae returning to shore and the day-to-day variability over the recruitment season strongly suggests that the return to shore is due to transport by large internal waves (waves under water within the water column) generated by the tides. During the fall/winter, the thermocline depth causes the internal waves to be ones that do not cause onshore transport of megalopae. After the spring transition and the movement of the thermocline to shallower depths, the internal waves that are produced can cause onshore transport, hence, the significant relationship between catch and the day of the year of the spring transition.

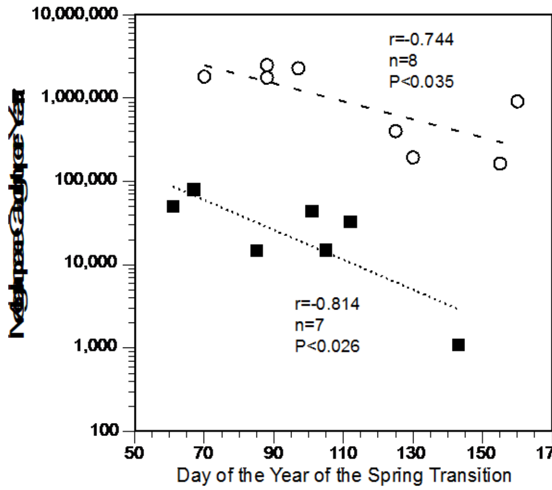

Figure 6. Day of the year of the spring transition plotted with the annual catch of megalopae. The catch data have been divided into years with low catch (<100,000 caught, filled squares) and high catch (>100,000 caught, open circles). The dotted lines and statistical results are from correlations run between the variables.

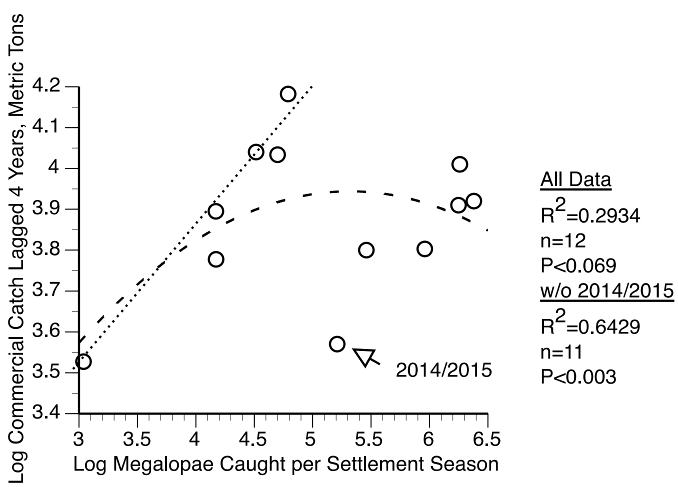

Figure 7. Log of the total number of *C. magister* megalopae caught per settlement season plotted against the log of the commercial landings lagged four years. The data are up to date (commercial landings for 2015-2016 were estimated from the catch through mid March). The regression (dashed line) was run with and without last year's (2014/2015) commercial landings. This data point appears to be an outlier. The dotted line indicates the linear relationship between megalopae catch and the commercial landings when the number of returning megalopae is <100,000.

Since 2007, when the PDO shifted to negative, I have been plotting the relationship between the number of returning megalopae and the commercial catch as a parabolic curve (dashed line Figure 7). As time has passed and I have accumulated more data this parabolic relationship does not seem so solid; there are a number of data points that fall very close to the dotted line in Figure 7 but are very far off the parabolic curve (dashed line) plus there is the 2014/2015 data point that appears to be an outlier falling far below the dashed line. Perhaps what we are seeing is the effects of two oceanographic states, negative vs. positive PDO, on the relationship between the number of returning megalopae and the size of the 4-year old year class. To test this I plotted the data from negative and positive PDO years separately and ran regressions on these two data sets (Figure 8). Despite the fact that both data sets are quite small, 6 data points for each curve, the regressions are both significant. There are no outlier points and both sets of data fall quite close to the two regressions lines. These results suggest that there are two regimes, negative and positive PDO years, and the two regimes affect both the number of returning megalopae, much higher during negative PDO years, and relative recruitment success after the megalopae settle. From Leif's modeling work and the relationship in Figure 4 (more late season returning megalopae during negative PDO years likely because they are transported from the far north) we have a good idea how negative PDO years effect larval return; the stronger southward flow in the California Current during negative PDO years carried more larvae back to the Oregon coast while during positive PDO years larvae are left further north and never make it down to Oregon. I am not sure what changes during negative PDO years such that the relative success of recruitment shifts so dramatically. I need to think about this more as I have only just discovered this new relationship (i.e., on 24 March), but we know very little about the drivers of relative recruitment success in Dungeness crabs and, in fact, in most marine organisms. This time series is constantly generating new surprises!

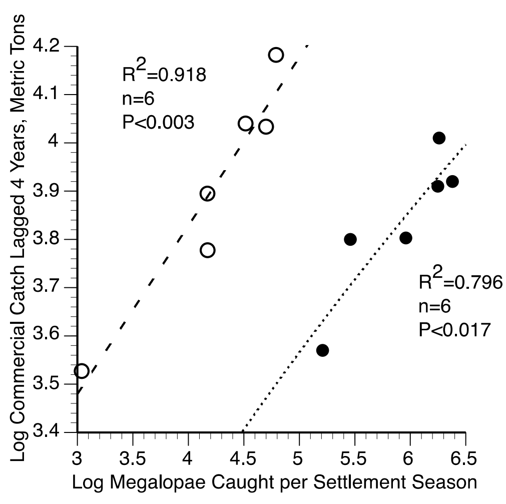

Figure 8. Log of the total number of *C. magister* megalopae caught per settlement season plotted against the log of the commercial landings lagged four years with positive and negative PDO years (open and filled circles, respectively) plotted separately. The Oregon data are up to date (commercial landings for 2015-2016 were estimated from the catch through mid March).

I can use the new equations from the regressions in Figure 8 to back calculate the expected commercial landings and compare these values to the actual landings. The results are encouraging;

my estimated landings are off by on average only 14% (range 4.5 to 28%). I can use the new equations to calculate the future catches as well as an estimate of the likely range in catch using the ±14% average error (Table 1).

Table 1. Predicted Oregon commercial catch of Dungeness crab for fishing years 2016/2017, 2017/2018, and 2018/2019. Predictions are based on the new model presented in Figure 8. The recruitment of megalopae that will lead to the 2016/2017 and 2017/2018 fishing years were years with negative PDO (filled circles in Figure 8) while the recruitment supporting the fishing year 2018/2019 was a positive PDO year (open circles in Figure 8). Using the average ±14% error in my predictions, I have calculated a probable range in commercial landings.

Recruitment Year	Log Number of Megalopae Caught	Commercial Fishing Year	Estimated Commercial Landings, log metric tons	Estimated Commercial Landings, lbs (range)
2013	6.36	2016/2017	3.960	20,073,594 (17,400,000-22,800,000)
2014	5.295	2017/2018	3.658	10,025,247 (8,700,000-11,400,000)
2015	4.64	2018/2019	4.051	24,784,142 (21,400,000-28,100,000)

My best guess is that the megalopae return data from 2015 will fit the curve for positive PDO years (i.e., the open circle in Figure 8) and that is what I have used to estimate the future commercial catch in Table 1, but this is a best guess. Alternately, the relationship between the number of returning megalopae in 2015 and the commercial catch 4 years later might fall on the negative PDO years curve (filled circles Figure 8). Perhaps the poor recruitment success of megalopae returning during negative PDO years is due to the intense competition that must be occurring during these years of large settlement of megalopae. If this competition actually damages the habitat such that the habitat for some period of time is only capable of supporting lower numbers of new recruits, then the 2015 data may fall on the curve delineated by the filled circles (Figure 8). If this is the case, then the predicted commercial catch will be very very much lower than that project in Table 1, only 6,500,000 lbs. The only way to know if the 2018/2019 fishing year will be this terrible is to monitor the 2015 recruits as they grow into the fishery. This could be most easily done by modifying the fall test fishery such that it will sample small crabs efficiently.