Influence of wave action on *Mytilus californianus* mussel beds

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Project Summary:

It is the intention of this study to analyze the amount of influence that wave action has on specific population characteristics of the California mussel, *Mytilus californianus*. Wave action is defined as the amount of force in N/m^2 that a single wave exerts on the shore when it crashes. The population characteristics being considered in this study are percent mussel cover, mussel biomass, mussel length, and mussel bed depth. If wave action plays a role in affecting the distribution and abundance of *M. californianus* populations then at least one of the population characteristics listed above will show a strong correlation associated with wave action.

To determine whether or not wave action is indeed a determinant of the distribution of *M. californianus*, multiple study sites, each with varying amounts of wave action will be considered. At each site wave action will be recorded over a set period of time and then an average wave action will be determined for each site. Also at each site, mussel samples will be taken in order to determine the average percent mussel cover, mussel biomass, mussel length, and mussel bed depth. Quadrat sampling will be the main sampling method used to quantify these population characteristics. To obtain values for mussel biomass, mussel length, and mussel bed depth, a set number of small quadrats must be physically removed from the rock surface to allow for the weighing and measuring of individual mussels. After all the data have been collected, which should be approximately two and half months after the start of the study, then statistical analysis can be performed. If there is in fact a correlation between the amount of wave action an

environment experiences and a population characteristic then the statistical tests will yield significant results.

The importance of this study lies in the fact that *M. californianus* is not only abundant in the intertidal communities of western North America, but it is also a key ecological species in determining the biodiversity of many intertidal ecosystems. If *M. californianus* is present in an ecosystem then the ability of that ecosystem to support a more diverse number of species is greatly enhanced. The mussel beds made up of many layers of *M. californianus* individuals provide suitable habitat for hundreds of invertebrate species that could not exist without the shelter these mussels provide. Therefore, the significant role *M. californianus* plays in the composition of intertidal ecosystems makes it an important issue to understand the factors, such as wave force, that determine their distribution.

Problem Introduction, Background, and Significance:

The rocky intertidal communities of the Western coast of North America are complex and integrated ecosystems that support a wide diversity and abundance of marine organisms. The ability of these ecosystems to support such a diverse number of species is due, in part, to organisms that modify the environment to create highly diverse habitats within each system (Kautsky and Norling, 2008). The California mussel, *Mytilus californianus*, is one of the most common inhabitants of West coast communities and is a key habitat modifier; as such it is an essential contributor to biodiversity. Mytilid mussels form beds or patches composed of layers of mussels growing on top of each other to make a mussel matrix. A mussel matrix creates spatial refuges from environmental stresses and predation. It is one of the main reasons that mussel populations are major players in the maintenance of local species diversity (Kautsky and Norling, 2008). A matrix provides the shelter and habitat structure necessary for less hardy invertebrate organisms to exist in the harsh environmental conditions of the intertidal zones. A study by O'Donnell (2008) that measured the reduction of wave forces experienced by an object due to a surrounding artificial mussel bed, found that a sheltered test object 1 cm in diameter experienced 30 to 62% reduction in wave forces compared to an unsheltered object. The layers of mussels of the matrix significantly reduce the light penetration and dampen temperature fluctuations and wave action that would otherwise be characteristic of the same habitat without a mussel matrix (Griffiths and Hammond, 2004). By doing this, mussel matrices can harbor diverse assemblages of organisms that could not otherwise persist under these environmental conditions. In one study, Suchanek (1980) showed that over three hundred species of invertebrate organisms utilized the layers of *M. californianus* mussel beds as their primary habitat. Mytilids, along with providing structure and support, are also capable of supplying the populations of organisms that exist in their matrices with 24 to 31% of their energy demands. As filter feeders, mussels clear the water around them and regenerate nutrients that benefit algae growth, which in turn attracts even more species to the community. Furthermore, *M. californianus* provides food for deposit feeders with the biodeposition of organically enriched faeces that profoundly change the surface sediment characteristics, allowing deposit feeder growth (Kautsky and Norling, 2008). A study done on *M. edulis* populations in the Baltic Sea found that the presence of *M. edulis* contributed to the presence of fifty species of associated fauna and what is more that the number of associated species increased from 6 to 18.5 species at study sites where *M. edulis* was found as compared to bare sediment sites (Kautsky and Norling, 2008). This study is further evidence that Mytilid mussels are major factors in the biodiversity of intertidal environments. Due to their important role in promoting diverse ecosystems and to their relative abundance in intertidal zones of the West coast, *M. californianus* is a key species to the success of these environments. The presence of *M. californianus* significantly affects the composition of intertidal ecosystems and it is, therefore, an important issue to understand the factors that determine its distribution.

Of all the factors that determine the distribution and abundance of intertidal marine organisms, including *M. californianus*, one of the most important is wave action. In this study wave action is defined as the amount of force in N/m^2 that a single wave exerts when crashing on shore. Wave action, like the presence of *M. californianus* in an ecosystem, can act on a broad scale by influencing the species composition of communities (Lindsay and McQuaid, 2007). Wave activity has such a profound impact on the species composition of communities because in a large part the amount of wave activity in an intertidal zone determines many other abiotic factors that each organism must cope with for survival, such as the rate of nutrient and sediment cycling. The amount of wave activity in an environment determines how well nutrients and larva are circulated, which is critical to suspension feeders like mussels [Griffiths and Hammond, 2004]. The larger the wave action the more nutrient cycling that occurs in the habitat, but the larger the hydrodynamic force that inhabitants must withstand. On the other hand, the less wave action that a habitat experiences the less hydrodynamic force its inhabitants must endure, however they must deal with the reduced rate of nutrient cycling. Every organism that composes the communities of intertidal zones has to be able first and foremost to deal with the hydrodynamic forces of the wave action characteristic of that environment. If an organism can not withstand the amount of wave action of its habitat it is irrelevant whether or not it can cope with the other abiotic and biotic interactions of the habitat because the hydrodynamic forces will forcibly remove it from the community. Thus, wave action is large determinant of the species composition of the intertidal communities because all individuals must be adapted and equipped to survive the constant barrage of hydrodynamic forces characteristic of these environments.

Inhabitants of the intertidal zones have developed body structures that allow them to deal with the hydrodynamic forces of wave action. The structure that Mytilid mussels employ to attach to rocks and withstand intense wave action is known as a byssus. This byssus is made up of many fibrous byssal threads that each independently extend from the mussel and attach to the substrate (Figure 1). Essentially a mussel's byssal threads are their lifelines. A mussel, especially *M. californianus* mussels which inhabit exposed shores of large wave action, must maintain a strong byssal thread attachment to its substrate to withstand the hydrodynamic forces of their environments (Carrington et al., 2008). Byssal threads are effective in keeping the mussel attached to the rock even under very large amounts of hydrodynamic forces because the use of many different points of attachment to the substrate allows for the whole force of the wave to be spread out so that each thread does not experience the full force of each wave, but rather must only withstand a fraction of it (Denny et al., 2001). Also, as shown in Figure 2, if a mussel is experiencing an increase in hydrodynamic force that the number of byssal threads already attached to the rock will not be able to withstand, then it can extend more threads to attach to the substrate so as to avoid being dislodged (Bell and Gosline, 1996). *M. californianus* is able to thrive in intertidal ecosystems that experience high amounts of wave action because of the effective strength of its byssal threads. Another characteristic of Mytilid populations that allows individuals to thrive in intertidal zones is that they occur and grow together in aggregations of mussel beds. Organisms in aggregations, shielded by their neighbors, are exposed to much lower flow velocities and hydrodynamic forces than those characterizing the flow at exposed sites. Therefore, each individual mussel only withstands a fraction of the true force of each wave that it encounters. Although *M. californianus* is well adapted to withstand high levels of wave action, wave action is still a limiting factor to its distribution and abundance in intertidal habitats. Thus, because this species is a vital contributor to the species diversity of its communities it is of ecological importance to understand how wave action effects its populations.

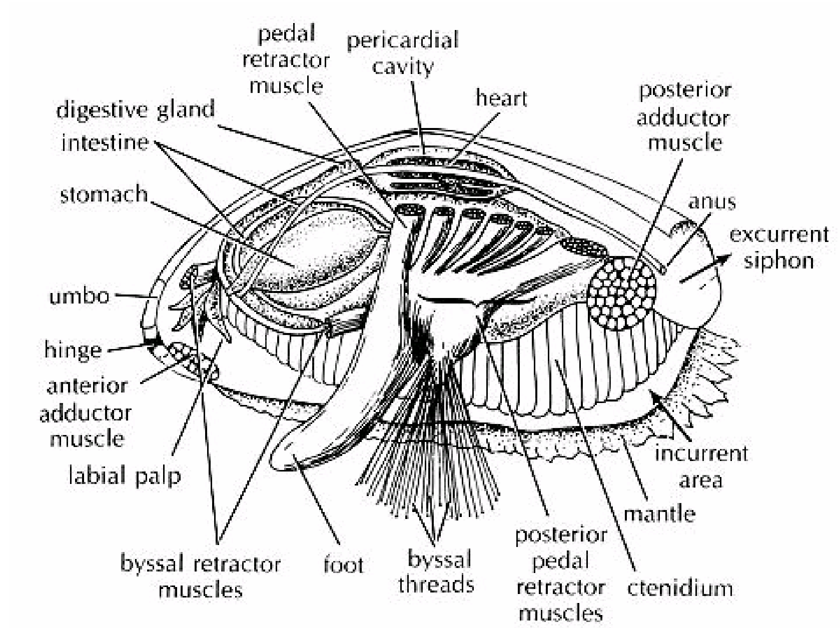

Figure 1. Diagram of the internal structures of *Mytilus edulis*. Byssal threads are clearly labeled (manandmollusk.net).

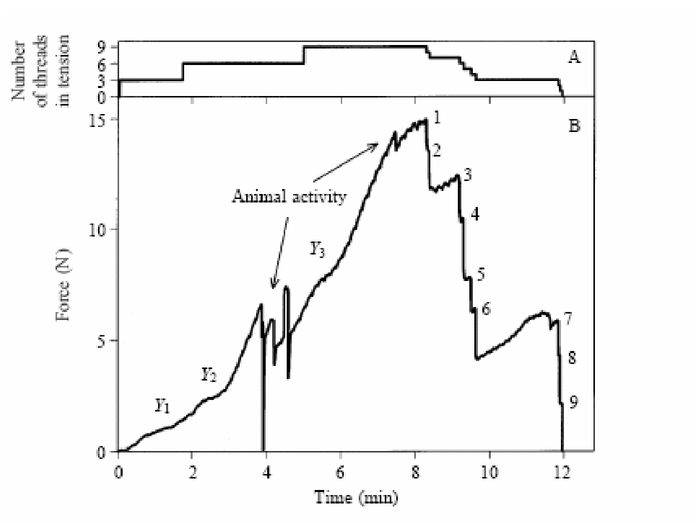

Figure 2. Tensile test of a live mussel attached to a small granite boulder by nine byssal threads. (A) Number of threads visually determined to be load-bearing. (B) The amount of hydrodynamic force being applied to the mussel over a twelve minute time interval (Bell and Gosline, 1996).

Project Objectives:

The level of wave action that an intertidal ecosystem is subjected to on a regular basis determines the types and the number of organisms that can persist there. For this reason, it is hypothesized that the level of wave action that a population of *M. californianus* experiences will have a significant effect on the characteristics of that population; including percent mussel cover, mussel length, mussel biomass, and mussel bed depth. The aim of this study is to determine if the effects of wave action actually do significantly affect the population characteristics discussed above for *M. californianus*. Furthermore, if the results conclude that wave action does play a significant role in determining the population characteristics of *M. californianus*, then the results will be analyzed to determine what amount of wave action is optimal to maximize each of the population characteristics. Mussel populations are subject to selective pressures due to wave force that favor a biomass and length that maximizes reproductive output without compromising the integrity of byssal thread attachment. Above a certain size an increase in size results in a decreased contribution to the next generation (Daniel et al., 1985).

The achievability of this experiment is considered to be fairly high based on the reasoning that a very similar study has already been performed in South Africa on a close relative of *M. californianus*. In 1998, off the South African coast, researchers analyzed the effect of wave action on populations of the South African mussel, *Mytilus galloprovincialis*. Its procedural methods were very similar to the ones that will be employed in this study on *M. californianus* and therefore, it is expected that all the data necessary for this study will be able to be successfully obtained and analyzed based on the success of the South African study (Griffiths and Hammond, 2004).

Experimental Procedures and Data Analysis:

To begin this experiment eight sites of varying wave action will be selected along the coast of San Luis Obispo County. Of these eight sites, four of them will be sites that experience lesser amounts of wave action (between 2 and 10 N/m^2) and the other four will experience large amounts of wave action (between 10 and 20 N/m^2). At each site one 5/8" diameter and 7" deep hole will be drilled by a Cal Poly drill technician into the substrate using a Chicago Pneumatic CP9A drill. Each hole should be facing out to sea and be in the same vicinity of the where the mussels will be sampled. After the hole is drilled a previously constructed dynamometer will be screwed into its collar and then glued into the drilled hole using marine epoxy. Each dynamometer will be constructed following the directions laid out by Palumbi (1984). Once in place, the dynamometers will record the largest force experienced since they were last read. The dynamometers at each site will be read and the maximum wave action recorded once a week for six weeks. After each reading the dynamometers will be reset so that the maximum wave action value will be recorded for the following week. The values for each site will then be averaged together to determine the mean wave action that each study site encounters.

While dynamometers are in place recording the amount of wave action of each study site, the mussel population sampling will be performed. In order to determine the population characteristics for the populations of *M. californianus,* mussel samples will be taken once from the exact sites where the dynamometers were placed. At each study site a 50m base line will be laid out in the mid-intertidal zone, parallel to the shoreline and a random number table will be used to determine the coordinates of the quadrat locations. To estimate percent mussel cover at each site ten 50x50cm quadrats will be randomly selected and within each quadrat the percent mussel cover will be estimated and recorded (Griffiths and Hammond, 2004). After all ten quadrats are read the numbers will be averaged together to get an average percent mussel coverage for each site.

In order to measure the mussel length, mussel biomass, and mussel bed depth, three 10x10cm quadrats will be randomly selected from each site along the previously described 50m baseline and physically removed from the substrate using a paint scraper. From each of these three quadrats the 20 largest mussels will be selected and weighed on scales in order to determine their mussel biomass. All of these data for each study site will then be averaged together so that each study site has a mean mussel biomass value. Those same twenty mussels from each 10x10cm quadrat that were weighed to determine biomass will then be measured using calipers to determine their mussel length. All of these data for each site will then be averaged together so that each site has a value for mean mussel length. The final population characteristic to be measured is mussel bed depth and this will be determined by using a ruler to measure the height above the rock surface of the each of the removed 10x10cm quadrats. The values for each site will be averaged together so that each site has a single mean mussel bed depth value.

After all of the data have been collected, recorded, and averaged so that each site has a mean value for wave action, percent mussel cover, mussel biomass, mussel length, and mussel bed depth, then statistical analyses will be performed. Data will be analyzed with a one-way analysis of variance (ANOVA) to determine if there is a significant difference in the means of each population characteristic between each site. If the ANOVA yields a p-value that is less than .05 then at least one of the study site's means is significantly different than the mean value at another study site. In order to find out which means from which study sites are significantly different a Tukey test will be run and any comparisons yielding a p-value less than .05 indicate a significant difference. Finally, in order to determine if wave action has a significant effect on any of the mussel population characteristics a regression analysis will be run with wave action as the independent variable and the mussel characteristics as dependent variables. Any p-value less than .05 indicates that a significant effect was observed.

If the results determine that wave action has a significant effect on any or all of the population characteristics of *M. californianus*, then further analysis of the data will be performed in order to see the value of wave force at which the population characteristics are maximized. To observe this effect each population characteristic whose regression analysis showed that wave action had a significant effect, will be graphed on an x, y axis against the observed wave action values. The mean value for each site of the particular population characteristic being analyzed will be plotted as the y variable and wave action in N/m^2 as the x variable (Figure 3). After plotting the points as a scatter plot, a best fit line will be determined by Excel for which an equation will be given. Finally, to see at what wave action value yields the most optimal results of that population characteristic, the maximum y value for the best fit line will be plugged into the line equation and x will be solved for.

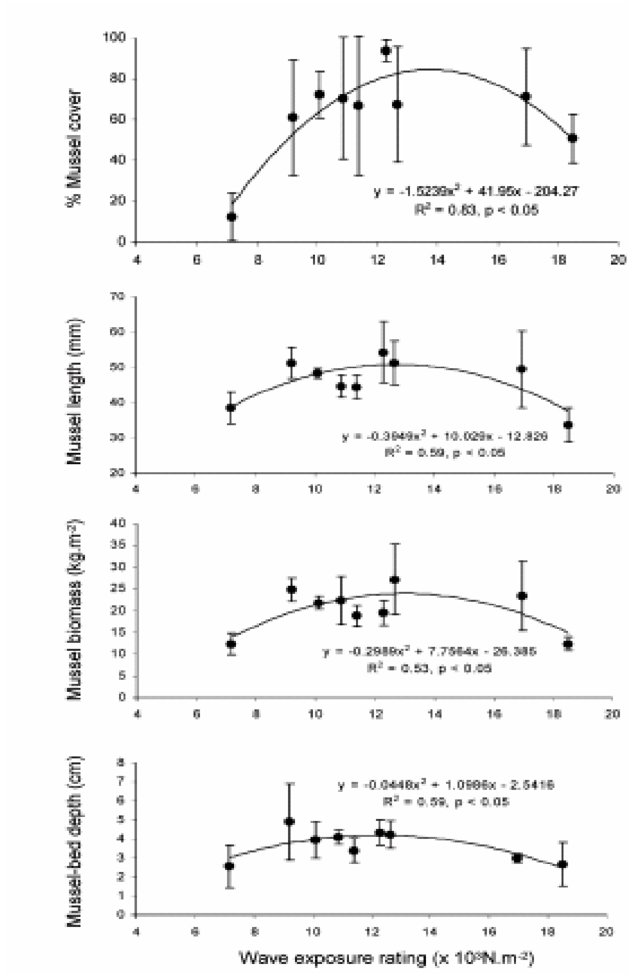

Figure 3. Results from Griffiths and Hammond's South African mussel study. Mussel population characteristic variables plotted against a wave action gradient [Griffiths and Hammond, 2004].

Project Timeline and Budget:

The estimated time allotment for this study is a little over two and a half months to construct all the necessary tools, sample the data, and finally analyze the results. Before any data sampling and recording can take place, all eight dynamometers have to be constructed. Two weeks should be allowed for the delivery of materials because the extension springs, polypropylene balls, Delrin rods, and black nylon molybdenum filled rods have to be ordered from manufacturing companies. All the other materials can be bought at a hardware store (Palumbi, 1984). Each dynamometer should take about one day for a Cal Poly drill technician to manipulate the materials to the correct sizes and to then be assembled together as a complete dynamometer. After the dynamometers are constructed one hole at each sampling site will have to be drilled. If weather conditions are favorable this can be completed in five days. At this point one month has passed since the beginning of the study, see Table 1. After all the holes are drilled then all eight dynamometers need to be screwed and glued into their respective holes and data sampling can begin. It will take 6 weeks from the day that the dynamometers are put into place to finish the recordings of wave action because, as described in the procedure, one reading will be recorded once every week for six weeks. The quadrat sampling for the mussel population characteristics can take place while the dynamometers are recording wave action. Based on my previous quadrat sampling experience, it should only take one day at each site to sample the ten 50x50cm quadrats, remove the three 10x10cm quadrats and then take all the necessary measurements. Thus, the mussel sampling will be finished by the time the six weeks are up. At this point two and half months have passed since the beginning of the experiment and all that is left is to do is run the statistical analysis tests. Statistical analysis should take about three days to perform. In total the entire project should be complete 60 days after its start.

Table 1. Summary of time estimates to complete each step of the study.

Task	**Estimated Time to Perform**
Obtain materials for dynamometers	2 weeks
Construct dynamometers	8 days
Drill holes at sites	5 days
Record wave action data and take quadrat samples	6 weeks
Statistical Analysis	3 days
Total time:	**58 days**

To complete this project a budget of 200 dollars needs to be allowed for. Of the 200 dollars, 180 dollars will go to buying the supplies necessary to build the dynamometers, see Table 2. The CPVC tubing, PVC coupling collars, stainless steel machine screws, wiffle balls, marine epoxy glue, sheet rubber, multipurpose PVC cement, and purple PVC primer can all be purchased at the local Home Depot for 50 dollars. The Izorline test Dacron fishing line can be bought at a tackle store in Morro Bay for around 15 dollars. The other materials for the dynamometers, the extension springs, polypropylene balls, Delrin rods, and molybdenum filled rods have to be ordered from the online manufactures of Small Parts Inc. and Associated Spring/Raymond which costs around 110 dollars including shipping expenses. Also, a paint scraper will need to be purchased from Home Depot for approximately 5 dollars to remove the 10x10cm quadrats from each site. The final 20 dollars of the budget is allotted for gas money to commute to all eight study sites multiple times. All of the remaining sampling equipment, such as the rulers, calipers, scales, and 50m bases lines can be found in the Bio labs on Cal Poly's campus. Also, the drilling equipment necessary for the construction of the dynamometers and to drill the hole at each study site can be found on campus as well and can be operated by a Cal Poly technician. Therefore, the total budget of this study is an estimated 200 dollars.

Table 2. Allotment of budget money for dynamometer materials.

Dynamometer Material	**Cost ($)**
CPVC 1/2" tubing – 6ft	~5.00
PVC 1/2" threaded female and male coupling collars – 8 of each	~7.00
5/8" stainless steel machine screws – 1 box of 100	4.78
Wiffle balls – 8	11.40
Marine epoxy glue	11.00
Multipurpose PVC cement	5.29
Purple PVC primer	4.32
Izorline 130lb test Dacron fishing line – 1 spool	~15.00
Sheet rubber for old tires	Free
Extension springs .36" stainless steel – 8	80.47
1" polypropylene balls – 25 pack	9.61
½" Delrin rod – 1ft	11.61
½" Molybdenum filled rod – 1ft	2.00
Shipping expenses	~10.00
Total:	**177.48**

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