A Look at Crab Monitoring in the Elkhorn Slough

A Capstone Project

Presented to the Faculty of Earth Systems Science and Policy

in the

Center for Science, Technology, and Information Resources

at

California State University, Monterey Bay

in Partial Fulfillment of the Requirements for the Degree of

Bachelor of Science

by

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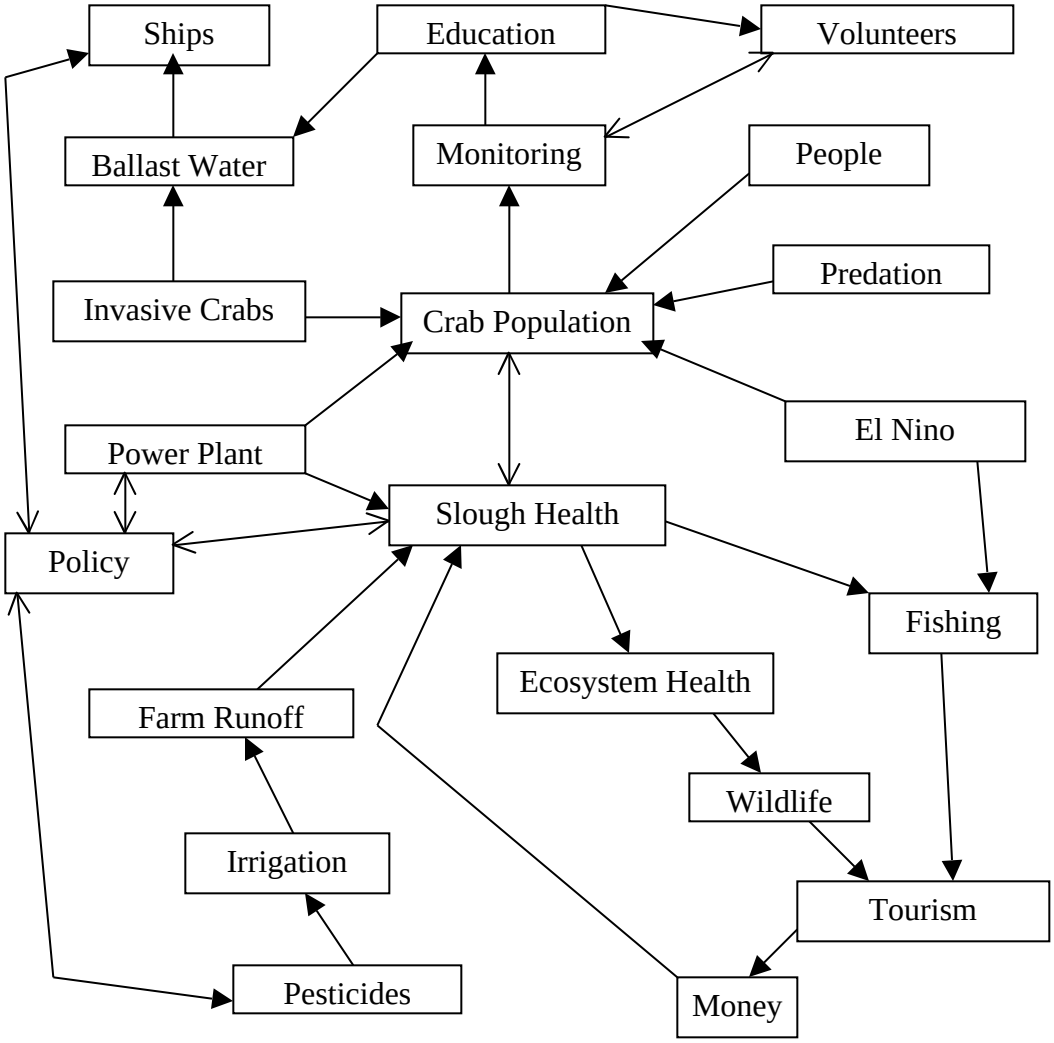
1 May, 2002

To the ESSP Faculty

Last fall I began an internship with the Elkhorn Slough National Estuarine Research Reserve (ESNERR). This internship required me to establish a long term crab monitoring program that could be carried out by volunteers, interns, and school groups because paying somebody to do the monitoring would be too expensive. I had to create and implement a set of instructions for monitoring crab, create an identification guide for species that would be caught during the monitoring process, and to initiate a beginning database. I also had a research question which I wanted to answer and it was if the crab populations changed over time and if they did how they changed.

The monitoring of crabs is important because the crab populations and their larvae are a vital resource for the slough. They play a central role in what happens in the slough. As you can see in my systems diagram below, the native crabs that live in the slough are a good indicator species. They are because everything that happens in the slough revolves around them. The crabs are a food source for many birds and other animals that people come to see. These birds and animals, that attract the people, bring money into the local economy. Crabs are also affected by the farm runoff because the chemicals that are in the water get into their food source and then that causes fluctuations in population sizes (assumption). This then can lead to different policies that protect the animals somehow from the chemical runoff. There are other relationships that coincide with the crab population that are shown in the systems diagram. There is not a lot known about the actual crab population sizes and whether they change at all or in some sort of way or pattern. Also, it is not known if the population sizes are increasing, decreasing, or

staying the same. All these things reasons are why monitoring the crab populations are important.



Some of the reasons for me getting involved in this internship and project are that ever since I was a little girl I have loved crabs. This project gives me a chance to learn more about them, how they live, and most importantly it gives me a chance to play in the mud. I am also an anthropocentric and ecocentric person. I am doing the monitoring so

that the health of the slough can be watched. Doing this will keep the ecosystem healthy and will keep people happy because then they can go to the slough and bird watch, fish, and do other leisure activities.

Coming into doing this project I assumed that the population of trapped crabs would show how big the actual crap population was. I thought that all the crabs that lived in the places we were trapping at would automatically go into the traps to obtain the bait that was in them. I thought that they all would eat the same thing so it wouldn't be a problem catching any of the crabs. I also assumed that the crab population didn't move around and that future monitoring would be done exactly the way I did it; the traps would be set and put out in exactly the same way that I did and they would be put in the same place with the same type of bait. After doing the monitoring I found that the trapped population doesn't correlate with the actual population due to many reasons. I also don't know if the populations migrate at all, but I do know that that future monitoring will be done the same way I did it until another method that yields better results is found.

For my project I collaborated with Dr. Kerstin Wasson, the research coordinator for the ESNERR and Rani, my mentor who worked along with me on the crab monitoring. Kerstin was the person who I did my internship with and she oversaw everything I did. She loaned me all of the equipment needed to monitor crabs with and she set up the goals of my internship. Rani taught me all of the techniques that I used while monitoring the crabs. Whenever I went out into the field to do work she was there along with me and guiding me through the process. Together Rani and I created the finished product which was given to Kerstin Wasson and the Elkhorn Slough National Estuarine Research Reserve so that they could use it to do future monitoring.

The Areas of Depth that my capstone is going to be assessed in are: The Application of Knowledge in the Physical and/or Life Sciences, MLO #3 and the Acquisition, Display, and Analysis of Quantitative Data, MLO #5. My capstone is to be assessed in MLO #3 because I go into detail about the different species of crabs that will be looked and look at how monitoring has advantages and disadvantages. It should also be assessed in MLO #5 because I use the data I have collected over the eleven months of monitoring the crabs and I will analyze it to answer my questions.

Sincerely,

Jennifer Everly

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Abstract

Crabs play an important role in Elkhorn Slough. The three main species found in the slough, that are native to it, and that I will be looking at are *Pachygrapsus crassipes*, the striped shore crab, *Hemigrapsus oregonensis*, the yellow shore crab, and *Cancer antennarius*, the Pacific Rock Crab. There is one non native species of crab that is found in the slough, the European green crab, *Carcinus maenas.* Not much is known about the population sizes of any of these four crab species. The goal of my project was to create and implement a long term monitoring program that could be carried out by interns and or volunteers and school groups. The research question I wanted to answer was whether or not the crab populations change over time and if they do why. In order to monitor the populations of crabs in the slough I chose four trapping sites in the upper part of the slough that had easy accessibility and not too much disturbance from the tides and people. At each of these sites, the size, sex, and species of each crab that was caught was recorded. After eleven months of collecting data I found that *Hemigrapsus oregonensis* was the most abundant crab in the slough and that Kirby Park had the largest population of crabs. I did notice that the populations of all the four crab species changed with time and that there were more male crabs caught than females. I don't know why this is and I think in order to come to a more precise conclusion more research needs to be done for a longer period of time to see if the fluctuations in populations are seasonal, due to rain, or some other unknown source.

Introduction

The Slough

One of the most important resources that California has today is estuaries. An estuary is a protected embayment with freshwater flowing in from one end and seawater coming in from the other (Monterey Bay Aquarium, 1997). Estuaries are important because they do many things that other places wouldn't be able to do. They can serve as housing for wildlife that can only survive in the environment that an estuary provides. Marshes can serve as great fish hatcheries for many fish including some commercially important species (Silberstein, 1989). Tourists can come watch birds and fish, hunt, and they bring money into the local economy. People can obtain jobs in the slough. They can be tour guides, fisherman, marsh managers and many other jobs. Coastal wetlands can serve as a protector from flooding and destructive storm waves. Salt marshes absorb carbon dioxide and turn into oxygen; therefore purifying the air (Silberstein, 1989). Water pollutants are filtered though marshland soils and then absorbed by plant and animals; they make great water treatment plants. They also serve as great places for children to learn about the environment, research places and just places to relax (Silberstein, 1989).

In California, seventy-five percent of its original coastal wetlands have been destroyed and Elkhorn Slough remains as one of the least changed (Monterey Bay Aquarium, 1997). Elkhorn Slough is one hundred miles south of San Francisco and it sits right in the middle of the Monterey Bay (See map 1). It extends inland seven miles. There are no strong water currents that go through the upper parts of the slough. At the

mouth, though, the currents can reach up to three knots. The mouth is seven hundred feet across and twenty-five feet deep (Monterey Bay Aquarium, 1997).

Elkhorn Slough is a full time slough, but only a part time estuary. This is because there is no freshwater supply year round. During the winter, Carneros Creek flows into the most inland end of the slough bringing in freshwater (Monterey Bay Aquarium, 1997). But during the summer, the creek ceases to flow. Because of this, the upper-most parts of the slough are more salty than ocean water during the summer and during the winter less salty than the ocean (Silberstein, 1989). Due to these conditions, animals have to have special adaptations.

Crabs in the Slough

Several small invertebrates, like crabs, are adapted to the conditions in the upper part of the slough and each species plays an important role. The three main native crab species in the slough are *Pachygrapsus crassipes*, the striped shore crab, *Hemigrapsus oregonensis*, the yellow shore crab, and *Cancer antennarius*, the Pacific Rock Crab. Each of these species plays an important role in the food web of the slough, whether by preying on dead animals or by being a food source for another animal.

Pachygrapsus crassipes, the striped shore crab, has a squarish carapace marked with shades of red, purple, or green. The carapace is transversely striped. They mainly feed on algae growing on rocks, dead animal matter, limpets, and kelp flies. Many animals also feed on them including octopi, birds, raccoons, sharks, otters, and humans. The average lifespan of the crab is about three years (striped shore

crab, 2002). The male crab reaches sexual maturity at seven months and females at eleven or twelve months. Mating occurs after the female molts and her shell is still soft. The female will then lay up to fifty thousand eggs between the months of February and October. She also produces one or two batches of eggs per year (Smith and Carlton, 1989). When the eggs hatch, they are called zoea larva. The zoea larva float in the slough for about a month and then they go into the megalopa phase. This is when they turn to the rocks and hide on the shore. What makes this crab interesting is that it will eat its relative, the yellow shore crab and then take over its burrow. The striped shore crab is also faster than many other crabs, which enables it to catch kelp flies. This crab is adapted for foraging on land and in water, and has been able to take advantage of kelp flies as a food source. While it is on land, it can spend up to seventy hours out of the water in the shade (Smith 1989).

 *Hemigrapsus oregonensis*, the yellow shore crab has a rectangular shaped carapace that is smooth. Its coloring varies from dull brownish-green to grayish-green to muddy yellow. In order to distinguish it from other crabs, it has three spines or teeth on each side of its carapace, two lobes on its frontal area, and hairy legs (McConnaughey, 1986). The yellow shore crab also feeds on algae and dead animal matter. It is preyed upon by birds, raccoons, sharks, otters, humans, and *Carcinus maenas* (Smith and Carlton, 1989). Just like its cousin it can live about three years (McConnaughey, 1986). The male crab reaches sexual maturity at seven months and

females at eleven or twelve months. Mating occurs after the female molts and her shell is still soft during the months of February and April. An average of 7,650 eggs are produced each year per female. She produces one or two batches of eggs per year (Jensen, 1995).

 *Cancer antennarius*, the pacific rock crab, has an oval shaped carapace that is pretty much flat and smooth. Its coloring ranges from a brownish to a redish-orange. Two pairs of antennae are what distinguish it from other crabs. One set is long and the other is short (Tenera, 2000). The main diet is Ulva and other algae. The rock crab is preyed upon by birds, big fish, sharks, and commercially by people. The average lifespan of this crab is between eight and thirteen years. Sexual maturity can be reached at three years (Tenera, 2000). They mate from spring through the fall. Males only mate after the female crabs have molted and their shells are soft. The female can carry about one million eggs. After hatching, the young crab is free swimming for four months or longer (Tenera, 2000). This shrimp-like larva is able to swim, but appears to be primarily transported through the water by currents. In the next and last stage, the megalops, the larva is recognizably a young crab with its tiny claws and other legs, but still has the tail of a shrimp and lives on the bottom of the ocean near rocks and other substrates (Tenera, 2000).

Carcinus maenas

 The European green crab, *Carcinus maenas*, is an invasive crab. It was introduced into the San Francisco Bay in 1989 (Grosholz and Ruiz, 2000). It is believed to have traveled in the ballast water of ships (Raloff, 1998). The crab, however, is native to the Atlantic coast of Europe and Northern Africa (Washington Department of Fish and Wildlife, 1998). In 1994, it was discovered in the Elkhorn Slough (Grosholz and Ruiz, 1995). Since then it has been found in many different parts of the slough.

The green crab is quite distinguishable from other crabs. Its carapace is dark brown to dark green in color and it has yellow patches. On the underside of the crab, it changes from green to orange to red. The most distinctive characteristic is the five teeth it has on either side of its eyes. It also has three rounded lobes.

The average lifespan is five years and it reaches maturity within two or three years. The crab can breed up to three times in a life time. Just like other crabs, the male crab will mate, usually from April to November, with the female after she molts and her shell is soft (Washington Department of Fish and Wildlife, 1997). After the eggs hatch, the new larvae or zoea, aggregate in surface waters during the ebb tide at night when current velocities are highest. It is thought that this swimming behavior and stream transport are a means to avoid inshore stranding. After about two weeks of growth and development in the open ocean (Washington Department of Fish and Wildlife, 1997). Megalopae, the last larval stage of the crab, aggregate at night in surface waters when the

tide is flowing back in. This allows the crab to return to coastal waters where it will molt and settle as juvenile crabs in the upper intertidal zone (Washington Department of Fish and Wildlife, 1998).

The green crab is invasive and harmful to the slough. This is because it is capable of learning and can improve its handling skills of prey while feeding. It is also quicker than most native crabs and can open shells in more ways than one. The crab is also very competitive while it is foraging and it will kill the native crab it is in competition with including the species found in the Elkhorn Slough(Washington Department of Fish and Wildlife, 1998).

Carcinus maenas has been found responsible for the destruction of habitats. The main foods that it eats are clams, oysters, mussels, polychaetes, and *Hemigrapsus oregonensis*. It has been shown that the green crab has wiped out populations of clams and yellow shore crabs ten fold and that it can eat up to one hundred and fifty clams per day (Grosholz and Ruiz, 2000).

Monitoring

Because the native crabs are important to the slough and they are good indicator species, as shown in my systems diagram, their populations need to be monitored. Monitoring is the collection and analysis of repeated observations or measurements to evaluate changes in condition and progress of whatever is being monitored. Species monitoring has many good and bad components to it. Monitoring a species directly can be a quite difficult thing. Sometimes it is easier to monitor the indicators of the surrounding area that the species live in like salinity. Because of the variability in the way people take measurements or go about trying to monitor one species, sometimes only

large changes can be detected due to some of the errors. The natural system can also fluctuate due to human interaction, like trapping. The animals can get used to the fact that if they go into the trap they will get fed or if they go into the trap they will get trapped. These are some of the problems that occur with trapping. It is suggested that there are better methods like using a bucket or pan with natural substrate in it and that they are safer for the animal. Because there are so many options, accurate monitoring of any animal or invertebrate can be difficult (Elzinga, 2001). An example of trapping difficulties would be a study done by L. C. Hastie (Hastie, 1992). The goal of this study was to determine what the distribution of the Japanese Red Crab was. During this study they deployed traps and also put bait in each of the traps. When the traps were pulled up they caught a significant number of crabs, but not as many as they thought they were going to watch. They caught more species that weren't crabs (Hastie, 1992).

My Project

The goal of my project is to create and establish a long term crab monitoring program that will track crab populations and abundances and that would be carried out by interns or volunteers and school groups. I had to create and implement a set of instructions for monitoring crab, create an identification guide for species that would be caught during the monitoring process, and to initiate a beginning database (see Appendix C). The two main questions that I focused on for my project were: do the populations of crabs change over time? If they do change over time how do the populations change? My hypothesis was that the populations of crabs do change over time and that by sampling for crabs each month you will be able to see if the population of crabs is changing.

Methods

Sampling Locations

In order to start the project I had to choose four sites that were in the slough. The four sites I chose were Kirby Park, Whistle Stop, North Marsh, Hudson Landing. These locations were chosen due to easy accessibility and because they didn't have too much disturbance from people (see map 2).

Dates and Sampling Locations

The dates and sampling locations were chosen randomly (table 1). I went out whenever I was able to go out and the location depended on who went out with me. When I went out with Rani, we went to North Marsh and Whistle Stop. When Rani was not with me, I went to Kirby Park. Hudson was only sampled a couple of times because it was not a safe place to go by yourself because it is on the main road.

Table 1: Sampling Date and Location

Date	Location Sampled
4/26/2001	North Marsh/Whistle Stop
5/3/2001	Hudson Landing/Kirby Park
5/17/2001	Hudson Landing
6/22/2001	Hudson Landing/Kirby Park
6/24/2001	North Marsh/Whistle Stop
7/7/2001	Hudson Landing/Kirby Park
7/9/2001	North Marsh/Whistle Stop
7/24/2001	Hudson Landing/Kirby Park
8/5/2001	North Marsh/Whistle Stop
9/18/2001	North Marsh/Whistle Stop
11/14/2001	Kirby Park
12/28/2001	Kirby Park
2/24/2002	Kirby Park
3/10/2002	North Marsh/Whistle Stop

Data Collection

In order to collect data I had to choose days when the tide was below the mean water level. It had to be negative so that I could get to the rocks and eel grass where the crabs liked to hide. I also had to make sure that the negative tides were on two consecutive days because one day would be needed to set the traps and the other day would be needed to go back out and collect what I had caught and write down data. Once I chose the days and location, I collected and checked my equipment. I used the following items: ten minnow traps with weights, ten PVC poles, anchovies, gloves, a clipboard, pencil, data sheet, bucket, and a ruler or caliper.

On the first day I arrived at one of my selected locations about thirty minutes to an hour before the low tide. This gave me time to scout out the area and I decided where I wanted to put out the traps. I also sketched the area on my data sheet so that I could remember where I set out all of my traps. I then assembled the traps with each trap having two anchovies in it.

The traps were then placed into the water with the actual trap sitting in the water so that the crabs didn't dry out before I got there the next day. The traps were spread out with every one about one to five meters apart from each other.

As on the day before, I arrived at the location thirty minutes to an hour before the low tide. I scouted the area and made sure all the traps were still there. I then found a level place to do all of my measuring. Once I had found my spot, I filled the bucket up half way with water. Next I went one by one and retrieved my traps. I opened them and measured the width of the crabs' carapace and I looked at their abdomens and determined what sex they were. All this information was then written down on my data sheet and the

crab was then put in the bucket of water. I did this for all ten of the traps. All of my data was then entered into a database.

Monitoring Instructions, Data Sheet, and Identification Guide Construction

Through out the eleven month period of sampling different sites for crabs, monitoring instructions, a data sheet, and an identification guide was created (Appendix C). The monitoring instructions are basically what I did before, during and after I went out to each site and sampled. I compiled everything I did into a document that was easy to follow for somebody who has never done any monitoring before. After I did this Rani and I combined out thoughts and made sure we put everything we did in the field onto the instructions sheet.

The data sheet is a guide for people to write data on. It incorporates species, sex, size, and trap number so that people will be able to collect data easily. It also makes entering the data into the database easy. The data sheet that came to be is a combination of the data sheet I made and the data sheet that Rani made. They were combined so that we could have one master data sheet that was easy for people to use and understand.

The identification guide was made over a period of two months. Pictures of everything that got caught in the traps were taken with a digital camera. The pictures were then put into a word document with features describing each species found. There was also a picture of a male and female crab added so that people can tell the difference between the two sexes. This guide was also a collaboration between Rani and I.

Results

After eleven months of monitoring crabs and collecting data, I found that the most abundant, of the four species of crabs, was *Hemigrapsus oregonensis*. The yellow shore crab abundance peaked many times and was always the most abundant of the four species of crabs (fig. 1). It peaked the highest on 11/14/01 and the number caught was one hundred and eleven. The other three species of crabs weren't that abundant at all over the eleven months. *Pachygrapsus crassipes* only peaked twice and had an average of only eleven crabs (fig. 1). *Cancer antennarius* had only a total of four and *Carcinas maenas*, just like the Pacific rock crab, only had a total of eleven (fig. 1).

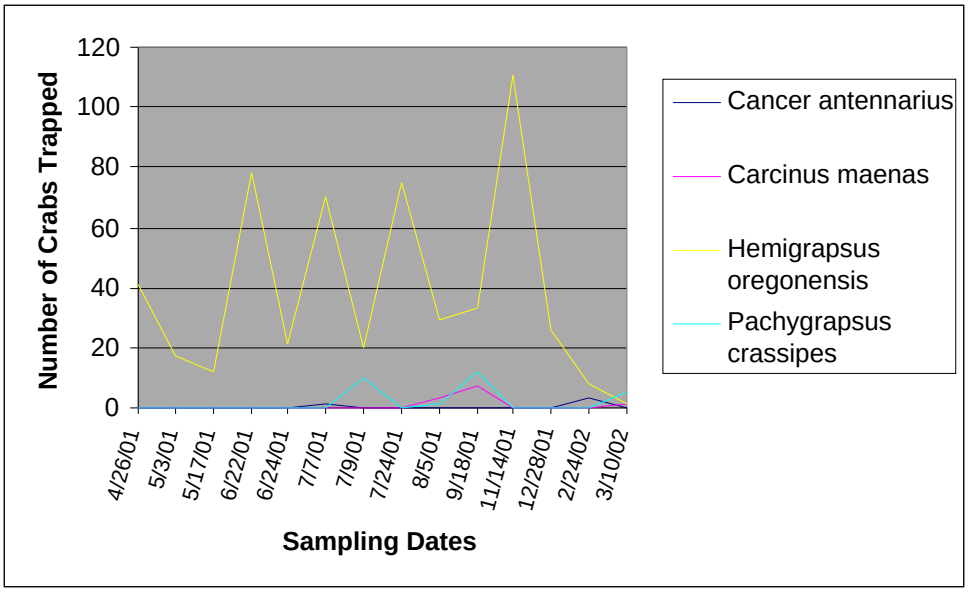


Figure 1: Total Number of Crabs Trapped by Species

Kirby Park had the largest population of crabs (fig. 2). The number of crabs caught at Kirby Park was double the number caught at the other three sites. Hudson Landing and Whistle Stop had the same number of crabs (fig. 2). North Marsh had the fewest number of crabs caught (fig. 2).

Figure 2: Total Abundance of Crabs by Site

Out of all the crabs that were caught, male crabs were caught more often than female crabs (table 1). *Hemigrapsus oregonensis* had twice the number of males caught than females. The other three species of crabs also had more males than females, but not by too much. The male to female ratio for *Cancer antennarius*, *Carcinus maenas*, and *Pachygrapsus crassipes* was about the same.

Table 2: Total Number of Crabs by Sex

	Total Number Caught	
Species	Male	Female
Cancer antennarius	3	1
Carcinus maenas	6	5
Hemigrapsus oregonensis	442	100
Pachygrapsus crassipes	22	16

At North Marsh the total overall number of crabs caught remained low every time it was sampled and only peaked one time (fig. 3). Right after the number of crabs peaked it returned to where it was before (fig. 3).

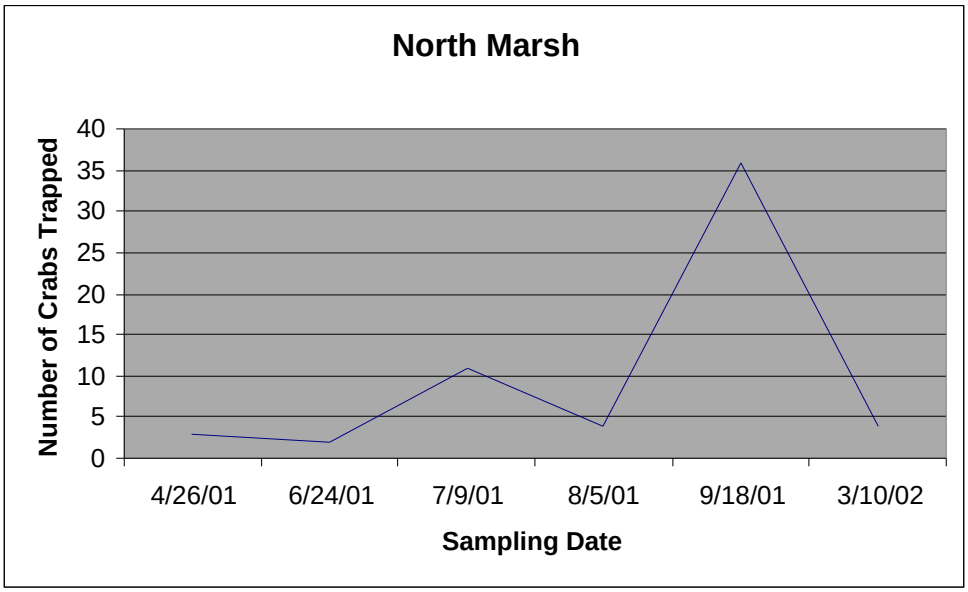


Figure 3: Total Number of Crabs Trapped on each Sampling Date

The number of crabs caught at Whistle Stop also remained low, but more was caught at this location than North Marsh. There also seemed to be a trend that was falling and the numbers got smaller each time the site was sampled (fig. 4).

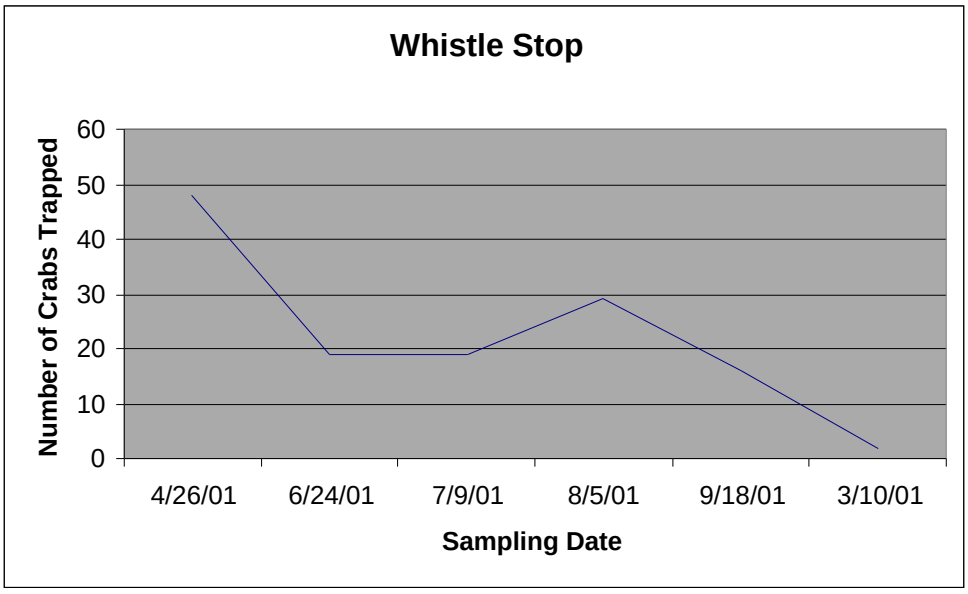


Figure 4: Total Number of Crabs Trapped on each Sampling Date

More crabs were caught at Hudson Landing than were caught at North Marsh and Whistle Stop. The number of crabs was a relatively low number except for the number caught on 6/22/01. The number of crabs caught on this date was more than all the other sampling dates put together (fig. 5).

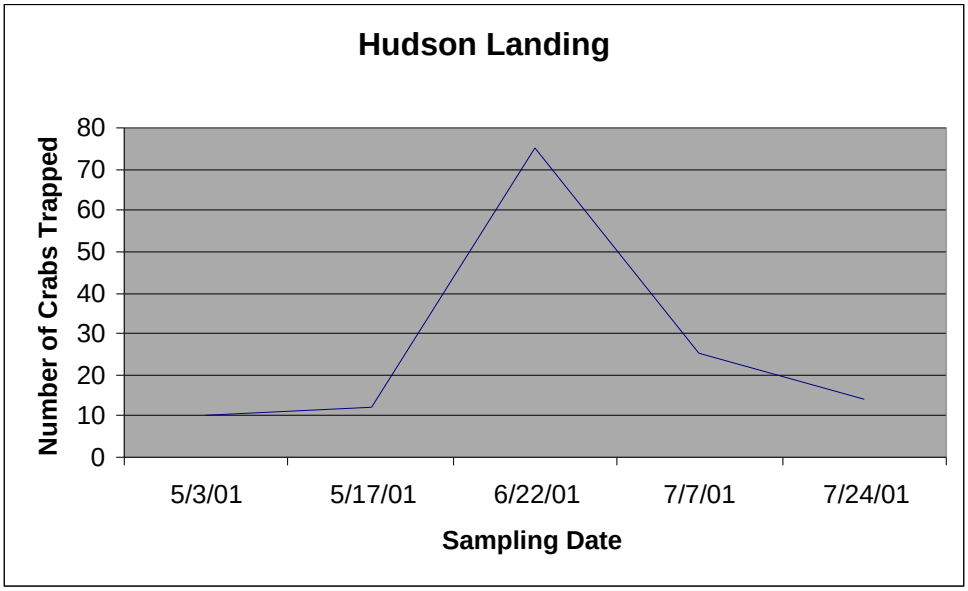


Figure 5: Total Number of Crabs Trapped on each Sampling Date

Kirby Park had the most number of crabs caught than all of the other sites. Every time this site was sampled the number of crabs caught was over twenty except for the first two times and the last time (fig. 6). The largest number of crabs was caught on 11/14/01 (fig. 6).

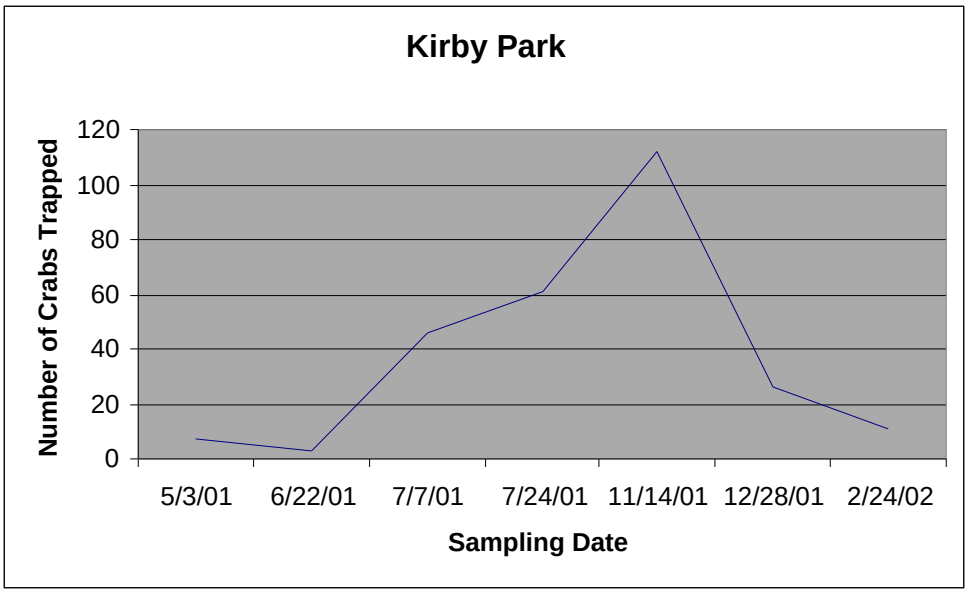


Figure 6: Total Number of Crabs Trapped on each Sampling Date

Discussion

The two main questions that I focused on for my project were: do the populations of crabs change over time? If they do change over time how do the populations change? My hypothesis was that the populations of crabs do change over time and that by sampling for crabs each month you will be able to see if the population of crabs is changing.

After eleven months of collecting data, I found that the populations did change. *Hemigrapsus oregonensis* fluctuated the most. It had the biggest differences between highs and lows (fig. 1). *Pachygrapsus crassipes* and *Carcinus maenas* also changed, but not as much as *Hemigrapsus oregonensis* because not as many were caught. The number stayed really low. This might be because the *Pachygrapsus crassipes* might not like the bait in the trap or they are too smart to go into the trap and get caught. According to

another study that was done, *Hemigrapsus oregonensis* and *Pachygrapsus crassipes* didn't seem to prefer a certain bait type (Flores and Miller, 2001). The *Carcinus maenas* might just not be that abundant so I didn't catch too many of them. Karen Flores and Susan Miller also determined that the green crab population must be small because in their experiment they only caught five (Flores and Miller, 2001). *Cancer antennarius* didn't change at all because only four were caught where they usually are not found. This crab species normally lives down near the mouth of the slough. It rarely ventures up into the upper parts of the slough. Another reason for low numbers of crabs could be that some species of crabs do not like the trap or if they have been caught before they know what will happen if they venture into the trap again. Some of the crabs caught may know that when the trap is out that they can get free food so then they go into the trap. Also the size of the crabs I caught was biased because some of the larger crabs could not fit into the trap due to the small hole sizes on each end. Another thing I noticed that when I went out and just picked up a few rocks above the low tide mark, the number of crabs underneath those rocks seemed to decrease. Each time I went out the number of crabs under each of the rocks would change and the species would also change.

The different populations of crabs did change. One thing I did notice was that when there was a large number of crabs caught at one time, the next time there would be a low number of crabs caught. This is because of location differences. Kirby Park had the most number of crabs and that is where I sampled most of the time and Whistle Stop, North Marsh, and Hudson Landing didn't have as many. This might be because Kirby Park has more of a food supply than the other three places.

There are many reasons for why the population sizes changed. Some of the reasons could be that the populations change on a seasonal basis, or they move around when the rains come and wash some of the chemicals out of the fields above the site or they could be going up and down due to predations cycles or their food source could run out and they had to move somewhere else.

After doing this project I found some new questions that I want to have answered. I want to know if the crab populations fluctuate with the amount of precipitation, salinity or water temperature and why certain species are found in different parts of the slough and why the number of crabs caught changes so much. I also want to know if the whole population of crabs changes when the trapped population number change. I think these will need to be looked at in order to see if they are the cause of the changes in population sizes. It will help narrow down and see if the populations are increasing or decreasing and maybe even the health of the upper slough overall.

For future monitoring a more regular sampling pattern should be established. Each site should maybe be sampled once a month or once every two months. This way then none of the sites are neglected and a pattern of seasonal data can be established and compared from year to year. When I went out, I didn't do it on any regular pattern and I went out whenever I could and to sites in no logical order.

I suggest more studies be down looking at the territoriality of the different crab species, the amount of predation that is done to the different crab species, and the effect that the lunar cycle has on the population.

Acknowledgements

I would like to thank my advisor Henrik Kibak for all of his time and efforts helping me produce and edit my capstone. I want to thank Suzy Worcester for all of her input on my capstone report. I also want to thank Kerstin Wasson for her help during my internship and lending me the equipment necessary to complete the internship. Finally I want to thank Rani Gaddam for being my guide and mentor during our crab monitoring adventures and for lending the six months worth of data that she collected before I began my part of the internship.

Bibliography

California Department of Fish and Game Website, http://www.dfg.ca.gov/mrd/index.html (5 March, 2002).

Elzinga, Caryl L., et al. Monitoring plant and animal populations. Malden: Blackwell Science, Inc, 2001.

Flores, Karen and Susan Miller. 2001. "Examination of the invasive green crab, *Carcinus maenas*, population in the Elkhorn Slough. CSU Monterey Bay.

Grosholz, E. D. and G. M. Ruiz. 1995. "Spread and potential impact of the recently introduced European green crab, Carcinus maenas, in central California." Marine Biology 122: 239-247.

Grosholz, E.D. and G.M. Ruiz. 2000. "The impacts of a nonindigenous marine predator in a California bay. Ecology 81: 1206-1236.

Hastie, L. C. and W.B. Saunders. 1992. "On the Distribution and Fishery Potential of

the Japanese Red Crab Chaceon Granulatus in the Palauan Archipelago, Western Caroline Islands." Marine Fisheries Review 54: 26-33.

Jensen, Gregory C. Pacific Coast Crabs and Shrimps. 1995. Sea Challengers, Monterey, California.

McConnaughey , Bayard H. & Evelyn. 1986. The Audobon Society Nature Guides, Pacific Coast. Alfred A. Knopf, Inc.

Monterey Bay Aquarium. 1997. A Natural History of the Monterey Bay National Marine Sancuary. Monterey. Monterey Bay Aquarium Press in cooperation with National Oceanic and Atmospheric Association Sactuaries and Reserves Division.

Raloff, J. 1998. "European crab leaps to Pacific Prominence." Science News 153: 373-374.

Silberstein, Mark and Eileen Campbell. 1989. Elkhorn Slough. Monterey. Monterey Bay Aquarium.

Smith, Ralph I. & James T. Carlton. 1989. Light's Manual: Intertidal Invertebrates of the Central California Coast, Third Edition. University of California Press.

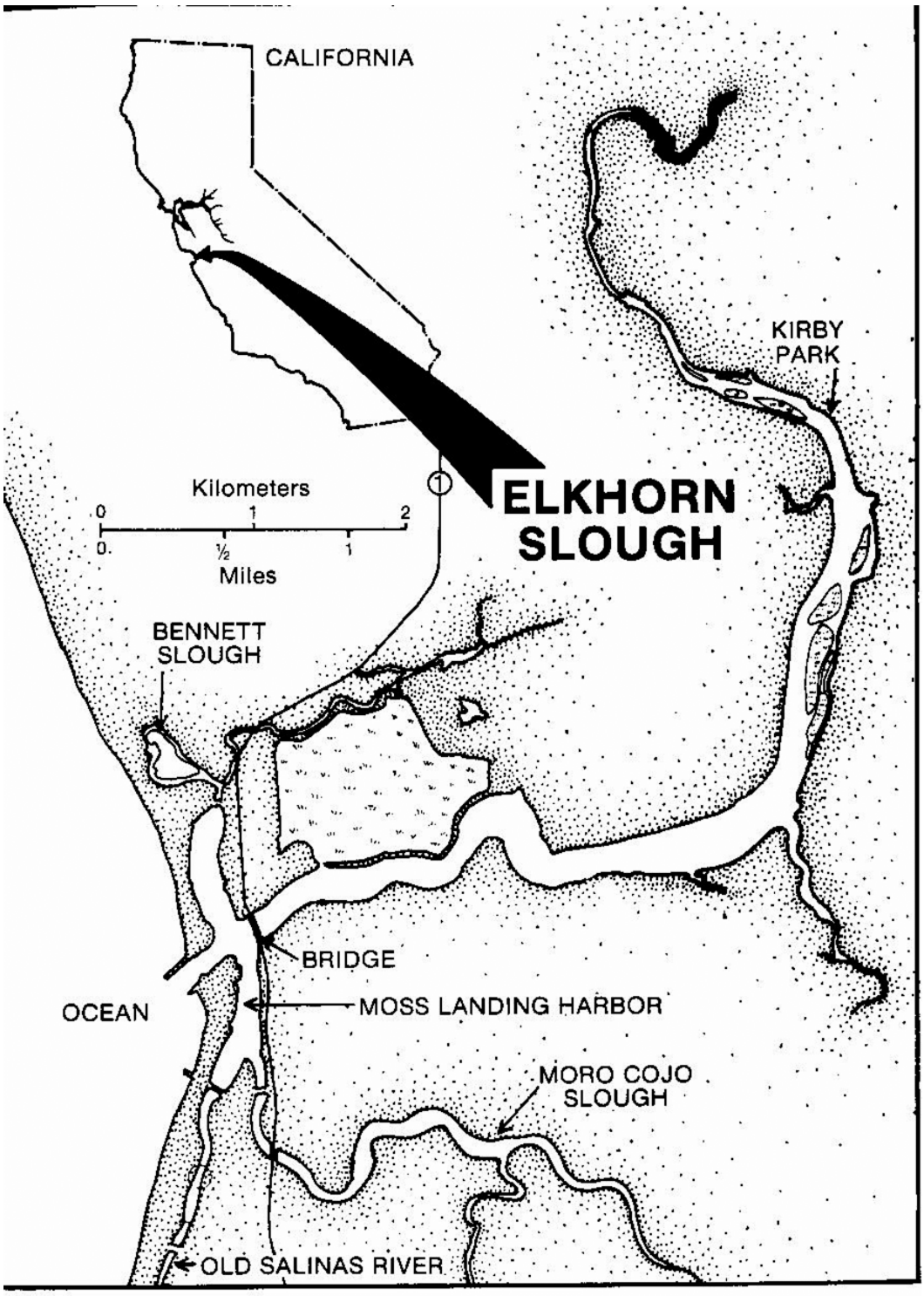
"Striped Shore Crab." http://www.odc.ucla.edu/html/body_stripedshorecrab.html (10 April, 2002).

Tenera Environmental Services. "Moss Landing Power Plant Modernazation Project 316(b) Resource Assessment." <http://www.energy.ca.gov/sitingcases/mosslanding/documents/2000-06-30_DUKE_REPORT.PDF> (27 November, 2001).

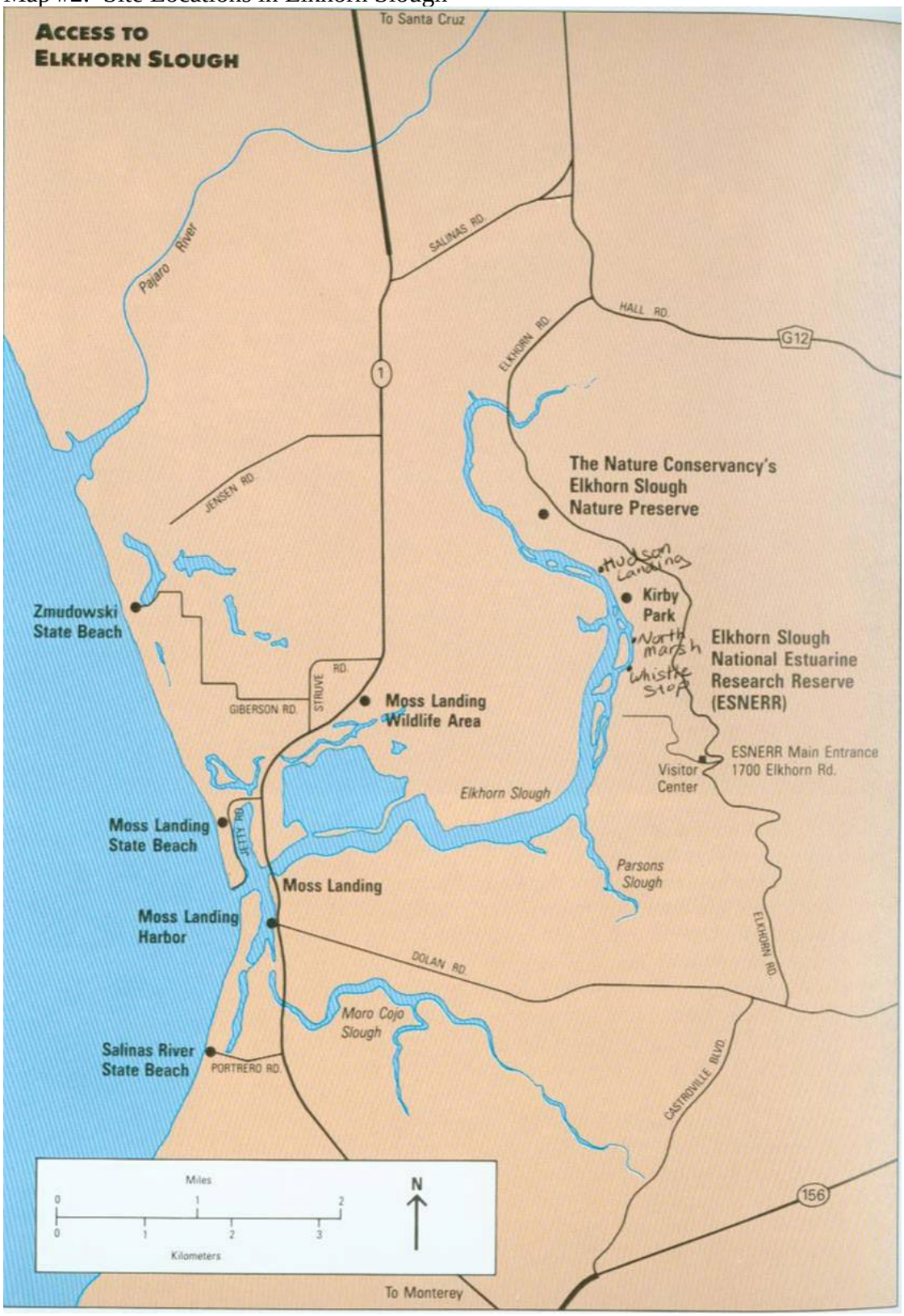
Washington Department of Fish and Wildlife. "Aquatic Nuisance Species." http://www.wa.gov/wdfw/fish/ans/greencrab.htm (8 March, 2002).

Appendix A: Maps of the Elkhorn Slough

Map #1: Elkhorn Slough Location



Map #2: Site Locations in Elkhorn Slough



Appendix B: Raw Data Used to Make Graphs

Table 3: Total Number of Crabs

Date	Total Abundance
4/26/2001	51
5/3/2001	17
5/17/2001	12
6/22/2001	78
6/24/2001	21
7/7/2001	71
7/9/2001	30
7/24/2001	75
8/5/2001	33
9/18/2001	52
11/14/2001	112
12/28/2001	26
2/24/2002	11
3/10/2002	7

Table 4: Total Number of Crabs by Species

Date	Total Abundance by Species			
	CA	CM	HO	PC
4/26/2001	0	0	41	10
5/3/2001	0	0	17	0
5/17/2001	0	0	12	0
6/22/2001	0	0	78	0
6/24/2001	0	0	21	0
7/7/2001	1	0	70	0
7/9/2001	0	0	20	10
7/24/2001	0	0	75	0
8/5/2001	0	3	29	1
9/18/2001	0	7	33	12
11/14/2001	0	0	111	0
12/28/2001	0	0	26	0
2/24/2002	3	0	8	0
3/10/2002	0	1	1	5

Table 5: Total Number of Crabs by Site

Site	Total Abundance
North Marsh	60
Hudson Landing	136
Whistle Stop	134
Kirby Park	266

Table 6: Total Number of Crabs by Species

Species	Total Abundance
CA	4
CM	11
HO	543
PC	38

Table 7: Total Number of Crabs Caught by Site

North Marsh	
Date	Number
4/26/2001	3
6/24/2001	2
7/9/2001	11
8/5/2001	4
9/18/2001	36
3/10/2002	4
Whistle Stop	
Date	Number
4/26/2001	48
6/24/2001	19
7/9/2001	19
8/5/2001	29
9/18/2001	16
3/10/2001	2
Hudson Landing	
Date	Number
5/3/2001	10
5/17/2001	12
6/22/2001	75
7/7/2001	25
7/24/2001	14
Kirby Park	
Date	Number
5/3/2001	7
6/22/2001	3
7/7/2001	46
7/24/2001	61
11/14/2001	112
12/28/2001	26
2/24/2002	11

Appendix C: Crab Monitoring Instructions, Identification Guide, Site Worksheets

Thank you for being a part of Elkhorn Slough's Crab Monitoring program! Please take a moment to read through the following instructions to familiarize your self with the procedure!

Monitoring Sites:

- Kirby Park (KP)
- Hudson Landing (HL)
- Whistle Stop Lagoon (WS)
- North Marsh Tide Gate (NM)

Materials Needed:

- 10 minnow traps with weights, including PVC poles
- Extra trap clips and zip ties
- Clipboards, data sheets, species key, crab guide, pencil(s), map.
- Ruler and/or calipers, to measure in millimeters.
- Heavy duty garden gloves
- Bait (frozen anchovies), 2 packages (enough for 2 each in 10 traps)
- Bucket
- Boots and warm clothing

Day 1, Setting the Traps:

1) Arrive at the site 30 minutes before the low tide on the scheduled day, to allow for enough time to set the traps at the low tide level.
2) To assemble the traps, put 2 or 3 anchovies (or other bait) in each of the traps, and connect the trap to the PVC pole.
3) Each data sheet includes a rough map of the monitoring area, and numbered locations corresponding to where the traps should be placed. The traps should be placed in relatively the same area as on the map. (If you are setting traps at more than 1 site in a given day, only use 5 traps at each site, and use the odd numbered trap numbers).
4) Set the trap by sticking the PVC pole (attached to the trap) into the mud, and make sure that it is secure, but not too deep (otherwise it will be difficult to retrieve the next day. Be sure to walk on the solid rocks, rather than the mud itself, to avoid getting stuck in the mud. The trap itself should be partially underwater when you set the trap.
5) Next to each trap number on your data sheet, record the following:
    - # of anchovies (bait)
    - Trap level (1/2 submerged, completely submerged, etc.)
    - Time. (It is helpful to set all of the traps, and then note the time and level of each trap all at once).

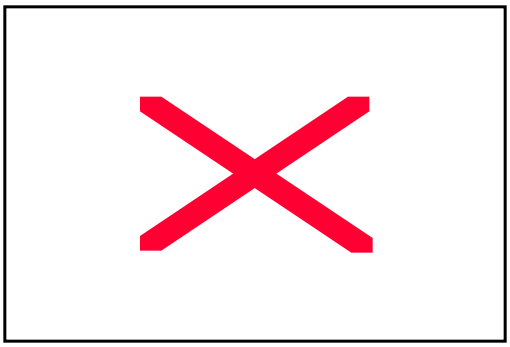
That's it for the first day! Remember to collect all of your materials, and make sure that all of your traps are secure before leaving.

Day 2, Examining the Traps:

1) Arrive at the same time you arrived on the previous day (which will be approximately 1 1/2 hour before low tide). This will give you time to access the traps once they are partially exposed by the low tide, but will ensure that they are not completely out of the water, which would kill the fish that may be inside the traps.
2) Make sure that you know which trap number corresponds to which trap, and that you can locate each trap before beginning.
3) Start with the most exposed trap, rather than going in numerical order, so that the traps remain underwater as long as possible.
4) Empty the critters from each trap into a bucket filled with water. Do this gently so as to not hurt the fish or the crabs.
5) If there are any fish, record the trap number, the total number of fish, and the species of fish onto your data sheet.
6) If there are any crabs, record the species, sex, and size of each crab. You can tell the sex of the crab by looking at the abdomen (see the diagrams on the species key). To measure the size of the crab, measure in millimeters across the widest part of the crab's carapace (see the diagram on the species key). Be sure to wear your gloves so that you are protected from being pinched. One person should measure and another person should record the results.
7) When done with each trap, release the animals from your bucket back to the same general area that the trap was found in.

That's it! Turn in your data sheets so that your results can be entered onto our database, and thanks again for your participation!

Identification Guide



Pachygrapsus crassipes
Striped Shore Crab
*Square carapace, parallel sides.
*2 teeth on the carapace following the eye
*Eyes are at the corners
*Blackish green in color, with red or purple striped markings

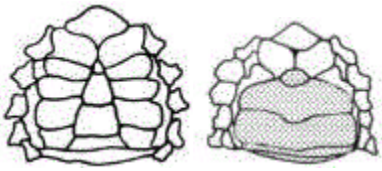
Hemigrapsus oregonensis
Yellow shore crab
*Square carapace, parallel sides
*3 teeth on carapace
*Smooth carapace, no striped markings
*Hairy legs
*Dull brownish or grayish-green in color, but can be white or mottled

Cancer antennarius
Pacific rock crab
*Broad, oval carapace, fan shaped
*5 teeth between eyes
*Crab is widest at the 8th tooth.
*Underside of body white with many red spots
*Chelipeds are large and black tipped.
*Reddish brown carapace.

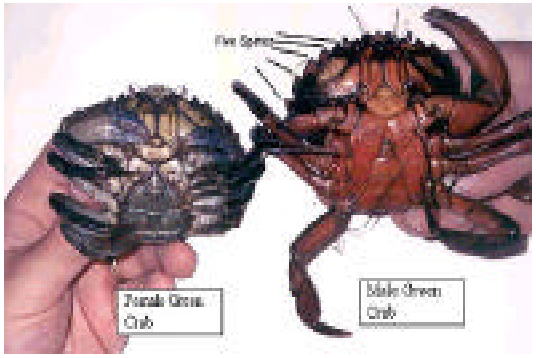
Carcinus maenas
European Green crab
*Carapace with five large teeth following the eye
*Multicolored, mottled greenish or orange
*5th pair of each legs is slightly flattened

Leptocottus armatus	SS

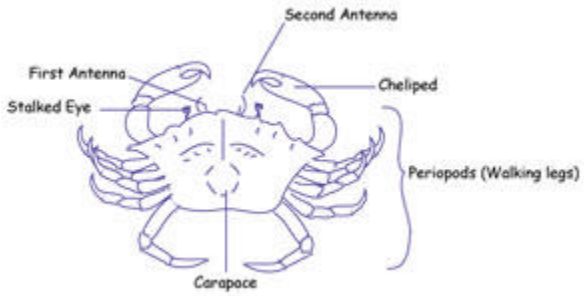
Leptocottus armatus
Pacific Staghorn Sculpin
*Body elongate, scaleless
*Long, depressed head, large mouth
*Spiny dorsal fin with black spot
*Yellowish pectoral fins with dark cross bars
*Antler-like spine just forward of gill cover



Left: Male crab abdomen
Right: Female crab abdomen



Female and Male green crab.



Take the measurement, in millimeters, along the widest part of the crab's carapace.

Species	Abbreviation
Pachygrapsus crassipes	PC
Hemigrapsus oregonensis	HO
Cancer antennarius	CA
Carcinus maenas	CM

Use the following abbreviations when noting the species on your field data sheet.

Elkhorn Slough Crab Monitoring Data Sheet

DAY 1 - TRAP SETTING
Date: **Time:** **Names:**

Hudson Landing (HL) Site Map and Trap Location

DAY 2 - TRAP COLLECTION
Date: **Time:** **Names:**

Trap #	Species	Sex	Size	Notes

Elkhorn Slough Crab Monitoring Data Sheet

DAY 1 - TRAP SETTING
Date: **Time:** **Names:**

Kirby Park (KP) Site Map and Trap Location

DAY 2 - TRAP COLLECTION
Date: **Time:** **Names:**

Trap #	Species	Sex	Size	Notes

Elkhorn Slough Crab Monitoring Data Sheet

DAY 1 - TRAP SETTING
Date: **Time:** **Names:**

North Marsh Tide Gate (NM) Site Map and Trap Location

DAY 2 - TRAP COLLECTION
Date: **Time:** **Names:**

Trap #	Species	Sex	Size	Notes

Elkhorn Slough Crab Monitoring Data Sheet

DAY 1 - TRAP SETTING

Date: **Time:** **Names:**

Whistle Stop Lagoon (WS) Site Map and Trap Location

DAY 2 - TRAP COLLECTION

Date: **Time:** **Names:**

Trap #	Species	Sex	Size	Notes