Chapter 9

A Survey of the Shore Crabs in Siletz Bay before the Invasion of the European Green Crab, Carcinus maenas

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ABSTRACT

C. maenas has recently invaded the southern Oregon coast. This study is intended to serve as a baseline study on the structure of the intertidal community in Siletz Bay in order to assess the possible impacts of the *C. maenas* invasion on the community. A survey of three species of crabs (N=334) , *Hemigrapsus oregonensis*, *Hemigrapsus nudus* and *Cancer productus*, in Siletz Bay was performed on four dates from October through December 1997. Samples were taken at both high and mid tidal levels. The size frequency distribution of *H. oregonensis* (the most abundant crab found in the bay) was calculated. More crabs were found on rocky substrate under rocks than on sandy substrate. Significantly larger sized *H. oregonensis* were found on rocky substrate than on sandy substrate. Male *H. oregonensis* were significantly larger than females in Siletz Bay on rocky substrate but not on sandy substrate. There was no significant difference in size between crabs found at mid and high tidal levels.

Introduction

The European Green Crab, *Carcinus maenas*, was introduced into to San Francisco Bay, California in 1989-1990. It became abundant in shallow, warm waters and spread throughout north, central and south bays (Cohen et. al., 1995). *C. maenas* was subsequently found in Bolinas Lagoon, Drake's Estero, Tomales Bay and Bodega Harbor in Northern California (Cohen et al., 1995). The crab was found in 1997 in Coos Bay, Oregon at two sites: a local oyster farm and near Pony Slew at the Oregon Institute of Marine Biology (S. Yamada, personal communication).

There are 5 methods proposed that may be responsible for the spread of the crab. 1. Juveniles may be carried in the ballast water of ships or transported in fouled seawater pipes of ocean-going vessels. 2. *C. maenas* may be transported in shipments of commercial fishing products via a packing algae, *Fucus* spp. used to pack live bait worms and live Atlantic lobsters. 3. *C. maenas* may arrive through the introduction of aquarium animals and biological supply houses. 4. *C. maenas* may be introduced through oyster farm transplants. 5. *C. maenas* may be spreading on the Pacific coast of

North America due to ocean currents (Cohen et al., 1995 & S. Yamada, personal communication). Any one of these methods or combination of these methods may be responsible for the spread of the crabs.

The introduction of *C. maenas* has severe potential biological and economical impacts. *C. maenas* is an ecological and physiological generalist and can tolerate a wide range of temperatures (5-30 degrees C) and salinity (5-33 ppt) (Grosholtz and Ruiz, 1995). The green crab is known to eat from 104 biological families, 18 genera, five plant and 14 animal phyla (Yamada, personal communication).

The presence of *C. maenas* may lead to the extinction of local species and a drastic change in the structure of estuarine communities on the Oregon coast. This in turn may have huge economic impacts on fishing industries including the Dungeness crab fishery and the oyster fisheries in Oregon. Grosholz and Ruiz (1995) found that *C. maenas* is a voracious predator which has significant effects on the abundance and size of native invertebrate species in California. For instance, crabs substantially reduce the survival of the bivalves *Transennela* spp. *C. maenas* preys on several common species of prey, including various species of algae, isopods, insects, echinoderms (including sea urchins and sea stars) and other mollusks. It also preys on crabs *Hemigrapsus oregonensis*, *Cancer magister* and *Hemigrapsus nudus*.

C. maenas may compete with other predatory crabs for food items including *Hemigrapsus oregonensis*, *Hemigrapsus nudus*, *Cancer magister* and *Pachygrapsus crassipes*. On an evolutionary level, predation by *C. maenas* may lead to increased anti-predator defenses such as increased shell thickness and selection for faster growth in various mollusks (S. Yamada, personal communication).

The green crab is present in Oregon and is likely to continue spreading northward on the Oregon coast. Therefore, substantial study needs to be done in order to examine the possible ecological and economic impacts of *C. maenas* in Oregon. The first step is to document the current structure of communities that are likely to be affected by this invasion. This study examines the occurrence of three species of shore crabs found in Siletz Bay in Oregon and the size frequency distributions of the most abundant of these species, *H. oregonensis*. The study is intended to provide baseline information on the structure of the crab populations in Siletz Bay before the anticipated invasion of *C. maenas* in the next few years. Possible implications of the invasion of the *C. maenas* on the crabs found in Siletz Bay are discussed.

Methods and Materials

I surveyed the Siletz Bay on the Oregon coast to measure the size frequency distributions of three species of shore crabs, *Hemigrapsus oregonensis*, *Hemigrapsus nudus* and *Cancer productus*, found in the bay. These crabs are generally easily found by overturning rocks in the intertidal zone. I measured the carapace width and determined crab species and sex at the high and mid tidal levels (high tide was approximately 1 meter feet below the barnacle line and mid tide was approximately 2 meters below the barnacle line). I estimated crab density using the rock turning method.

DESCRIPTION OF THE SITE

Siletz Bay is just south of Lincoln City on the central Oregon coast. Siletz River is the main river emptying into the bay, however, several other smaller creeks empty into the bay. The bay is a national wildlife refuge and is used for a variety of recreation purposes including, clamming, crabbing, wildlife viewing and fishing. Most of the bay is either sandy or muddy (personal observation), the rocky habitat "edges" suitable for the shore crabs studied are confined to a few areas.

Schooner creek is a good rocky habitat for these crabs and provided an adequate site for the study. The Schooner creek site is just west off the Highway 101 bridge and has a large rocky "island" with several boulders covered with smaller rocks that provide habitat for shore crabs. The surrounding area is sandy covered with rocks in various sizes. The salinity ranges from 5.6 ppt near the island to 15.4 ppt at 7.7 degrees Celsius. The bay has several species commonly found in rocky intertidal zones including barnacles, limpets, amphipods, littorine snails and several species of algae such as *Fucus* spp.

POPULATION STRUCTURE

I sampled on four dates in 1997: October 14, October 18, November 1 and December 2 during low tides. On each sampling date, a 50 m area was delineated. Within that area, 5 rocks in the high and low tides were sampled for crabs. Rock size ranged from 30-80 cm in diameter. Rocks that were overturned had to be resting on the cobble, gravel or sandy substrate and not be deeply imbedded into the substrate. I overturned 5 rocks at both the mid and high tide levels (a total of 50 rocks were turned, 30 on rocky substrate and 20 on sandy substrate). I collected all the crabs under the rocks in a bucket and identified, sexed and measured their carapace width using vernier calipers. Carapace width was measured to the nearest mm. I also noted any injuries or missing claws the crabs had. Crabs that could not be identified

by species or sex were noted but not included in the results (a total of 23 crabs were not identifiable by sex or species). This method was standardized for coastwide sampling (OSU-Green crab sampling group, 1997).

I sampled crabs by rock turning from both sides of the rocky "island" and on the sandy beach just south of the island (between the island and the large boulder that was immediately north of the Bay House Restaurant). I also collected salinity and temperature measurements each time I sampled.

I entered the data on a spread sheet in MS Excel. The figures were created using the Chart Wizard in the Excel program. The statistical analysis, t-Tests (assuming equal variances), were also done with Excel analysis tools.

Results

One species of crab dominated in Siletz Bay, *H. oregonensis*. 98.2% of the crabs sampled were *H. oregonensis* (Table 1). Because the density of the other crabs was so low, only *H. oregonensis* size frequency distributions were calculated in this study.

Table 1. Number and percent abundance of the three species of shore crabs sampled. Total N=334 crabs.

Crab Species	**N**	**Percent abundance**
Hemigrapsus oregonensis	328	98.2%
Hemigrapsus nudus	4	1.2%
Cancer productus	2	0.6%

The relative size frequency distributions for *H. oregonensis* was calculated for the entire bay sample (Figure 1). Overall, males ranged from 5-26 mm which is a wider range than the females which ranged from 7-21 mm. The mean carapace width (MCW) of males in Siletz Bay was 13.83 mm and the 12.99 mm for females. Females were more abundant than males. Of the 328 of crabs surveyed, 187 were female. A chi-square test demonstrates that there is a significantly larger number of females (p=.01). There was a signifigant difference in the size of males and females in Siletz bay (Table 2). There was a significant difference in size on rocky substrate but not on sandy substrate. The males MCW was significantly larger than the females on rocky habitat substrate as demonstrated by a one-tail t-Test analysis of the data (p<.01) (Table 3). There was no significant difference in the size of males and females on sandy substrate however (Table 4).

Table 2. One tail t-Test of size distribution of H. oregonensis between males and females in Siletz Bay.

	Mean	**S.E.**	**n**	**t**	**p**
Males	13.83	4.63	141	1.91	0.02
Females	13.0	8.63	187		

Table 3. One tail t-Test of size distribution of H. oregonensis between males and females on sandy substrate in Siletz Bay.

	Mean	**S.E.**	**n**	**t**	**p**
Males	11.56	4.49	46	1.67	0.15
Females	10.39	5.00	31		

Table 4. One tail t-Test of Size distribution of H. oregonensis between males and females on rocky substrate.

	Mean	**S.E.**	**n**	**t**	**p**
Males	14.93	3.78	95	1.65	<0.01
Females	13.51	4.97	156		

The size distributions of *H. oregonensis* varied according to the substrate (Figure 2 and 3). Crabs were more abundant on the rocky substrate of the island than on the sandy beach covered by rocks (crabs abundance for varying substrates

was calculated per rock) (p=.01). *H. oregonensis* was over four times as abundant on rocky substrates. *H. oregonensis* found on rocky substrate were significantly larger than those found on sandy substrate for both males and females (Tables 5 and 6) (p<.01 for males and females). MCW for males on rocky substrate was 13.83 mm +3.78 versus males on sandy substrate which was 11.58 mm +4.49 MCW for females on rocky substrate was 12.99 mm +4.97 versus females on sandy substrate 10.39 +5.00 (Figure 2 and 3).

Table 5. Two tail t-Test of size distribution of male H. oregonensis between rocky and sandy substrates in Siletz Bay.

	Mean	**S.E.**	**n**	**t**	**p**
Sandy	11.57	4.49	46	1.98	<0.01
Rocky	14.93	3.78	95		

Table 6. Two tail t-Test of female H. oregonensis between sandy and rocky substrates in Siletz Bay.

	Mean	**S.E.**	**n**	**t**	**p**
Sandy	10.38	5.00	31	1.97	<0.01
Rocky	13.51	4.97	187		

No significant difference on the size frequency distributions of *H. oregonensis* was found between the mid and high tidal levels for either substrate tested.

I examined the crab population structure samples for *C. maenas* while collecting the samples. No *C. maenas* were found in Siletz Bay during the course of this study. Nor were any *C. maenas* found in Yaquina Bay by the OSU students involved in this study.

Discussion

CRAB DISTRIBUTIONS IN SILETZ BAY

The results from this study differ from the results found by OSU students in Yaquina Bay. The studies in Yaquina Bay found *H. nudus* in greater abundance than was found in Siletz Bay (Yamada, personal communication). The two crabs *H. oregonensis* and *H. nudus* are often found living in the same area with distinctly different patterns in their distributions. *H. nudus* normally occupies the upper tidal region under rocks (Daly, 1981). Both species prefer larger rocks (Daly, 1981), however, the larger *H. nudus* outcompetes *H. oregonensis* for preferred habitat. Consequently, *H. oregonensis* is restricted to smaller rocks and is often found only in the mid zone in the presence of *H. nudus*.

Daly (1981) found that crab size is directly related competitive ability and larger crabs are able to secure the preferred refuge space. The average difference between *H. nudus* and *H. oregonensis* size was 4-6 mm (Daly 1981) making *H. nudus* the better competitor. *H. nudus* has a broad habitat range and is commonly found on the open coast as well as in bays whereas *H. oregonensis* is generally restricted to quiet bays and estuaries (Kolzloff, 1983). The average size of *H. oregonensis* in Siletz Bay were approximately 3 mm larger than those found by Daly (1981). Therefore, it seems possible that when *H. oregonensis* is released from competition for refuge with *H. nudus*, larger individuals of *H. oregonensis* are more common.

The near absence of *H. nudus* in Siletz Bay is a puzzle. Siletz Bay has fewer large boulders than other bays (personal observation). The smaller rocks found in Siletz may have an effect on the distributions of the two crab populations *H. nudus* and *H. oregonensis*. Siletz Bay is much sandier and less rocky than most bays on the Oregon coast where the two crabs are found. Siletz Bay is also quite saline compared to other bays on the central Oregon coast, however, *H. nudus* is able to tolerate low salinity as well as *H. oregonensis* (Dehnel, 1962). Therefore, salinity is not a limiting factor for *H. nudus* in Siletz Bay. More study is needed to determine why *H. oregonensis* dominates the bay.

The salinity in Siletz Bay is generally considered to be too low for *C. productus* (Yamada, personal communication), so it seems reasonable to suggest that the few *C. productus* that were found could have walked into the bay from the open coast area (which is approx. 0.25 km away).

The absence of *H. nudus* in the bay probably competitively releases *H. oregonensis* allowing it to occupy both the mid and high tidal ranges. The notion that crab size is an important determining factor in securing superior habitat may be further supported by the observation that in this bay the larger *H. oregonensis* were occupying the rocky habitat while smaller *H. oregonensis* were restricted to the sandier areas with fewer rocks (Figures 2 and 3).

Although the rocks measured in this study were roughly equal in size, the crabs found on rocky substrates were significantly larger crabs than the crabs found on the sandy substrate. The *H. oregonensis* found on rocky substrate were an average of 2-3 mm larger than those found on sandy substrates. This size difference appears to be large enough to allow larger *H. oregonensis* to outcompete small *H. oregonensis* on rocky substrates. It is unclear whether the rocky substrate simply provide a better refuge for crabs against predation and desiccation (in the same way that larger rocks provide superior refuge) or if rockier substrate may provide other amenities such as a greater number and variety of prey items.

Another interesting observation made during this study is that males and females significantly differ in size on rocky substrates but not on sandy substrates. This may be due to the fact that crabs found on sandy substrates are smaller and younger. These crabs are probably still growing and the size difference will probably become apparent as the crabs continue to grow.

There was no significant difference in the mean size of *H. oregonensis* in the mid and high tidal zones, however, only crabs under one size class of rocks were examined so that does not necessarily mean that larger individuals are not displacing smaller individuals under larger rocks in the high zone as Daly found in his study. The distributions of *H. oregonensis* under different size rocks would need to be tested in order to make definite conclusions about whether or not *H. oregonensis* is affected by intraspecific competition for preferred refuge. However, it must be noted that *H. oregonensis* fitness may not depend on rock size as much as *H. nudus* (Daly, 1981). It is also unclear how much bigger the larger *H. oregonensis* need to be in order to outcompete smaller crabs.

POTENTIAL EFFECTS OF *C. MAENAS* IN SILETZ BAY

The survey above provides substantial information about the possible effects of an invasion by *C. maenas* into Siletz Bay. First, the presence of *H. oregonensis* and *H. nudus* can serve as an indicator of suitable salinity ranges for *C. maenas*. Both species of Hemigrapsus are osmoregulators and can tolerate salinities down to approximately 6 ppt (Dehnel, 1962). They can also tolerate a range of temperatures from. Live animals are excellent indicators of salinity conditions because they indicate not only the current salinity and temperature conditions but also historical conditions (Yamada, personal communication). Since several adult individuals of *H. oregonensis* were found in Siletz Bay conditions must remain consistently favorable for the crabs to reach adulthood in the bay. As previously mentioned, *C. maenas*, can tolerate a range of salinities from 5-33 ppt and temperatures ranging from 5-30 degrees Celsius. The presence of both *H. oregonensis* and *H. nudus* strongly suggests that if *C. maenas* invades Siletz Bay, it should be able to survive there.

The invasion of *C. maenas* may have several impacts on the marine community in Siletz Bay. Ruiz and Groholz observed that *C. maenas* consumes both species of *Hemigrapsus*. Ropes (1968) found that crabs made up 15% of the stomach contents of green crabs at his sites in Mass and New Hampshire. Therefore, it seems quite likely that green crabs could affect the crab populations in Siletz Bay through predation. I know of no study that identifies the green crabs' preferred size of crab prey items. However, since it is able to consume both Hemigrapsus species and the larger *Cancer magister*, it is quite possible that it will be able to consume mature *Hemigrapsus oregonensis* easily and may prefer them to smaller individuals. If this is the case the presence of *C. maenas* may act as a selecting agent for adult *H. oregonensis* that are able to reproduce very quickly at an early age (and smaller size).

The green crab may decrease the overall number of *H. oregonensis* found in Siletz Bay directly through predation. As mentioned above, it may also decrease the frequency of larger individuals (if it preferentially preys on large individuals). This may lead to an increased selection pressure for earlier reproduction. *H. oregonensis* reaches sexual maturity at approx. 9 mm (Daly 1981).

The green crab may also compete directly with *H. oregonensis* for refuge. Daly (1981) found that *C. productus* outcompeted *H. nudus* for preferred refuge during its seasonal presence at his sites. *H. oregonensis*, while affected by the presence of *C. productus*, suffered less displacement than *H. nudus* due to its ability to survive in less preferred areas of the bay (i.e. under smaller rocks). As *C. maenas* is also found in the intertidal under rocks (of comparable size to the ones we used in this study) it may competitively displace *H. oregonensis* in preferred habitat in Siletz Bay. Competitive ability for refuge is directly related to body size (Daly, 1981). Thus, it seems reasonable that *C. maenas*, which is generally larger (Elner, 1981), may displace large *H. oregonensis* in areas of preferred refuge similarly to the way *C. productus* displaced *H. nudus*. If this prediction holds, we may expect to see a decrease in larger *H. oregonensis* found on rocky substrate which seems to be preferred habitat for crabs in Siletz Bay. Another potential way in which *C. maenas* may competitively displace *H. oregonensis* is through competition for prey items.

The introduction of the green crab may indirectly affect other species in the intertidal community such as limpets, barnacles and algae, although these impacts are not well studied. If *C. maenas* significantly decreases *H. oregonensis* densities, the number of limpets found in the community may increase. If limpets increase, the density of algae may decrease as a result of increased consumer predation. Farell (1986) found that the barnacle, *Balanus* increased and *Chthamalus* decreased in plots where limpets were excluded. This suggests that increased limpet populations may also

lead to a decrease in *Balanus* and an increase in *Chthamalus* density due to increased limpet bulldozing. Sucessional growth may also be affected.

The potential invasion of *C. maenas* into Siletz Bay may have several drastic consequences for native crab species. This is a preliminary study intended to provide baseline information about the organisms that may be affected by the introduction of *C. maenas*. Substantially more work is needed to define the consequences of the invasion with certainty. The direct effect that *C. maenas* may have on local crab populations will most likely indirectly affect other species in the community that interact with the crab species surveyed here. Additionally, the European Green Crab is likely to have other direct impacts on other members of the community in Siletz Bay through interactions such as predation and competition.

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