Life History of the native shore crabs Hemigrapsus oregonensis and Hemigrapsus nudus and their distribution, relative abundance and size frequency distribution at four sites in Yaquina Bay, Oregon.

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Life History of Hemigrapsus oregonensis and Hemigrapsus nudus

Much is known about the life history of the two common intertidal shore crabs *Hemigrapsus oregonensis* and *Hemigrapsus nudus*. The following summary was compiled from Batie 1975; Behrens Yamada and Boulding 1996 and 1998; Cohen et. al 1995; Daly 1981; Grosholz and Ruiz 1995; Harms and Seeger 1989; Low 1970; Morris Abbot and Haderlie 1980; Naylor 1962; and Rudy and Rudy 1983. Both of these species are Brachyuran crabs belonging to the family Grapsidae. These crabs can be distinguished from other crabs by their square carapace and eyes, which are set out towards the front corners of their carapace.

The characteristic features of *Hemigrapsus oregonensis* are the dull olive-colored hairs on its legs, and a carapace width ranging up to 34.7 mm for males and 29.1 mm for females. This carapace is colored yellow-green or gray and has a four-lobed anterior margin (Plate 1). *H. oregonensis* occurs from the high to low intertidal zones of bays and estuaries from Resurrection Bay (Alaska) to Bahia de Todos Santos (Baja California). This species is most commonly found on open mud flats and in mats of the green alga *Enteromorpha* and beds of the eelgrass *Zostera*. It can also be found in rocky habitats within estuaries and gravel shores. The diet of *H. oregonensis* consists primarily of diatoms and green algae, but occasionally includes meat if it is available. They are good diggers and are able to bury themselves in the sand rapidly to hide from enemies. In northern waters ovigerous females are seen from February to September. The number of eggs carried by females range from 100 to 11,000 (with an average number of 4,500). Hatching occurs from May to July with one pre-zoeal stage occurring inside the egg. There are five post-hatching zoeal stages and one megalopa stage during which the larvae typically spend five weeks in the plankton. They then settle and metamorphose into the first true crab stage with a size of about 1.6 mm. In August some females produce a second brood which hatches in September. Time from egg deposition to adult recruitment is variable and depends on several factors: the quantity and quality of food available, water temperature and salinity. Altogether it takes about 8-13 weeks for a brood to hatch, metamorphose and be recruit into the adult population. *H. oregonensis* is eurythermal and euryhyaline. It osmoregulates effectively in both brackish and hypersaline water and tolerates salinity as low as 4 ppt.

Hemigrapsus nudus differs from *H. oregonensis* by color and carapace characteristics. They are usually purple (sometimes greenish-yellow or reddish- brown) and are distinguished from *Hemigrapsus oregonensis* by the red or purple spots on its chelae as well as the absence of hairs on its legs (Plate 1). The anterolateral margins of the carapace are rounded and bear two teeth. Males can have a carapace width of up to 36.2 mm and females can grow up to 34 mm. *H. nudus* occurs from Yakobi Island (Alaska) to Bahia de Tortuga (Baja California), yet is uncommon in southern California and southward. It is most often found living under stones and among seaweed in the middle and low intertidal zones as well as near rocky shores, but never on mud flats as is *H. oregonensis*. It typically does not burrow, but takes over already-made burrows for its own use. The diet of *Hemigrapsus nudus* consists of diatoms, desmids and green algae that it scrapes from rocks with the help of its chelae. In addition, it also consumes a small amount of animal material including littorine snails. Ovigerous females are found from November to April and they produce only one brood per year. Hatching occurs from early May to early June. The larvae and the eggs are slightly larger than those of *H. oregonensis* and the size of the brood is also larger. The average number of eggs produced by a female is 13,000 eggs per year. The size of the brood varies with the size of the female: Females with a carapace width of 11.9 mm will produce around 441 eggs per year, while those with a carapace of 34 mm will yield 36,400 eggs per year.

Objective of study

The goal of this study is to document the status of *Hemigrapsus oregonensis* and *Hemigrapsus nudus* populations in Yaquina Bay, Oregon before *Carcinus maenas* becomes established. We accomplished this by noting the species, sex, and carapace width (CW) of each species at four separate study sites in Yaquina Bay.

Materials and Methods

Observations of two species of shore crabs were made at four sites along Yaquina Bay, Newport, Oregon. Two sites (NW Natural Gas and Sawyers Landing) are located on the northern side of the bay, while the remaining two (Hatfield Marine Science Center and Idaho Point) are located on the southern portion of the Bay (Map 1). All of these sites are a part of the largest section of the Bay nearest the ocean. The upper zone, just below the upper limit of barnacles, was sampled at each of the four sites, while the mid zone was sampled only at Hatfield Marine Science Center and Sawyer's Landing. The other two were very muddy below the upper zone and lacked suitable rocks in the mid zone. Sawyers Landing has a very smooth, gradual slope with large rocks dispersed over pebbles and silt, while the Hatfield Marine Science Center site is very steep with smaller rocks in the mid zone and larger rocks and boulders in the upper zone. Our observations took place during October and November 1997 and are presented in Table 1 and Figures 1-6 (see below for web links).

A variety of techniques, such as quadrats, trapping, and rock turning were investigated for sampling crab numbers at these four sites. Of these techniques, the rock turning method proved to be best suited for these sites. Rock turning was based on randomly chosen rocks in sets of ten. Only "suitable" rocks, measuring between 30 and 50 cm were used. They usually rested on cobble and typically were not deeply embedded in the sediment. At each site we turned 10 suitable rocks randomly within the high and mid tidal level. All crabs found beneath the rocks were carefully placed into a bucket. Sex, carapace width, and species were then recorded and the crabs were placed back into their environment. The carapace width of crabs was measured with vernier calipers to the nearest lowest mm. Species identification was determined by observing the color of the carapace, the presence or absence of hair on the legs and the presence or absence of red spots on claws. Crabs smaller than 5 mm were difficult to sex and identify to species. We recommend that a dissecting scope be used in the future.

Sex ratio and species ratio data were analyzed by chi-square tests; size data by analysis of variance (ANOVA).

Results

SEX

Hemigrapsus oregonensis and *H. nudus* exhibited no significant deviation from a 1:1 sex ratio at any site or tide level (Table 1). All chi-square tests yielded values of $X^2 <= 2.8$; df=1; p>0.05.

Males and female crabs of both species exhibited similar size distributions and similar mean sizes at any one sampling site (Table 1). Since we observed no sex differences, we lumped the males and female data sets for subsequent analysis.

SPECIES

The species ratio varied from site to site and level to level. In the upper zone at Idaho Point and at the Natural Gas site *H. oregonensis* and *H. nudus* were equally abundant. At both levels at Sawyer's Landing and in the mid zone at Hatfield *Hemigrapsus oregonensis* was the most abundant crab while *H. nudus* dominated the upper zone at Hatfield (see below).

Site	Zone	#HO	#HN	Ratio	X^2	p
Hatfield	Mid	105	21	5.0 :1	56	< 0.001
Hatfield	Upper	36	125	0.3 :1	49	< 0.001
Idaho Pt.	Upper	71	60	1.2 :1	0.92	n.s.
Nat. Gas	Upper	92	70	1.3 :1	2.98	n.s.
Sawyer's	Mid	119	4	29.8 :1	108	< 0.001
Sawyer's	Upper	119	60	2.0 :1	19	< 0.001

At each site and tide level (for which adequate sample sizes were available), the average and maximum CW of *H. nudus* was larger than that of *H. oregonensis* (Table 1, Figures 3, 4, 5-6). This size difference between the species was most pronounced in the mid zone at Hatfield Marine Science Center: 8.8 mm mean CW for *H. oregonensis* versus 17.5 mm for *H. nudus* (Figure 4.1).

TIDE LEVEL

Hatfield Marine Science Center and Sawyers Landing are the only two sites where we could sample two tidal levels. At the other sites the mid zone consisted of sand and mud. *H. nudus* increased in abundance up the shore at both Sawyer's Landing and Hatfield Marine Science Center (Figure 1). *H. oregonensis* exhibits an even distribution over both of tidal zones at Sawyers Landing but a decrease in abundance up the shore at Hatfield Marine Science Center (Figure 1).

A two-way ANOVA of site and level on size for *H. oregonensis* revealed a non-significant site effect but a significant tide level effects. At both sites *H. oregonensis* were significantly larger in the mid zone than in the upper zone (Table 1, Figure 2 and see below). Since the

mid zone is covered by the tide longer than the upper zone, it may represent a more favorable habitat for growth. The significant interaction effect of site and level and the small sample size in the mid zone at Sawyers makes the size data for *H. nudus* difficult to interpret. At Hatfield, *H. nudus* are significantly smaller in the the upper zone than in the mid zone (Figure 2.4). The high proportion of small crabs at this site may represent a strong year class of new recruits.

Hemigrapsus oregonensis

Source	SS	DF	Mean-Square	F-ratio	p
Level	179.799	1	179.799	26.383	0.000
Site	1.274	1	1.274	0.187	0.666
Level*Site	11.367	1	11.367	1.667	0.197
Error	2664.617	391	6.815		

Hemigrapsus nudus

Source	SS	DF	Mean Square	F-ratio	p
Level	495.161	1	495.161	34.118	0.000
Site	0.068	1	0.068	0.005	0.946
Level*Site	93.799	1	93.799	6.463	0.012
Error	2989.740	206	14.513		

SITE

The four sites vary in salinity, slope, wave exposure and sediment accumulation (see below). The Hatfield site exhibits the highest salinity, the steepest slope, the greatest wave exposure and the least mud accumulation. At this site, *H. nudus* dominates the upper zone and *H. oregonensis*, the mid zone. At Sawyer's Landing with the lowest salinity and the most gradual slope, *H. oregonensis* is the most abundant crab at both levels. The total number of crabs per 10 rocks varied only 1.4 fold, while the number of *H. oregonensis* varied by a factor of 3 and *H. nudus* by a factor of 2 (see below). *H. nudus* increased in abundance up the shore at both Sawyer's Landing and Hatfield Marine Science Center, while *Hemigrapsus oregonensis* exhibited the opposite trend at Hatfield Marine Science Center (Figure 1). These inverse relationships in the abundance of the two species may indicate competitive interactions.

Site	mean salinity (Chapter 1)	slope	wave exposure	mud	#HO	#HN	total#
Hatfield	29.2	very steep	highest	least	36	125	161
Idaho Pt.	27.3	steep	low	most	71	60	131
Nat. Gas	28.7	moderate	low	some	92	70	162
Saywer's	24	gradual	low	some	119	60	179

Weighted means models ANOVAs on carapace width of crabs in the upper zone at all four sites revealed significant site effects ($p < 0.0005$) for both species . The following table summarizes the mean carapace widths of both species. Sites with the same letters (third row) indicate that the mean size of crabs at these two sites are statistically similar ($p > 0.05$).

Hemigrapsus oregonensis mean CW (mm)

Sawyers Landing	Hatfield Marine Science Center	Idaho Point	Natural Gas
7.5	9.9	11.8	12.1
A	A	B	B

Hemgrapsus nudus mean CW (mm)

Hatfield Marine Science Center	Sawyers Landing	Natural Gas	Idaho Point
11.7	12.5	14.3	15.2
A	AB	BC	C

Both species of crabs are smallest at the site where they are most abundant: *H. oregonensis* at Sawyers' and *H. nudus* at Hatfield (Figures 2.4 and 3.2) This pattern may could intraspecific competition or else good recruitment of young animals in the most favorable habitat for each species.

Both crabs are significantly larger at Idaho Point than at Hatfield Marine Science Center and Sawyer's Landing (see above). The reason for this pattern in both species is not known but we suspect that predation by the red rock crab, *Cancer productus* could play a role. We trapped this crab at Hatfield Marine Science Center and observed a mated pair at Sawyers' Landing. Since soft sediments occur in the low and mid tidal zones at the Natural Gas Site and at Idaho Point, this efficient predator (Behrens Yamada and Boulding 1996, 1998)

may not be present at these sites. The presence of unusually large snails, limpets and mussels at Idaho Point also suggests that Idaho Point may experience reduced predation pressure (chapter 4). We plan to test the predation hypothesis by documenting the mortality rate of tethered snail at all four sites (Behrens Yamada and Boulding 1996).

Discussion

Hemigrapsus oregonensis and *Hemigrapsus* are sympatric in all four study sites in Yaquina Bay, indicating that these two species have broad and similar physiological tolerances. The relative distribution patterns of these species in Yaquina Bay are similar to those observed in southern British Columbia by Low (1970) and in southern Oregon by Daly (1981). The most notable difference in their distribution patterns is that *H. nudus* predominates on clean beaches with little fine, organic material in the substrate (upper zone at Hatfield), while *H. oregonensis* is usually more abundant on muddy beaches with a lot of this material (mid zone at Hatfield and both zones at Sawyers). On these muddy beaches there is usually a lot of reduced material in the substrate found just below the surface as a thick, black layer that smells of hydrogen sulfide. In contrast, *Hemigrapsus nudus* is the most common crab where the layer of reduced material is not thick and is usually deeper under the surface. *H. oregonensis* tolerates fine sediment because possesses a morphological adaptation that prevents its gills from clogging with mud. The openings of the branchial chambers are covered with a dense mat of fine bristle-like setae that prevent fine grains of sand from entering. *H. nudus* lacks this adaptation, and consequently is not able to survive in this type of environment for long. *H. oregonensis* is also able to tolerate lower oxygen levels and slightly lower salinity than *H. nudus* (Low, 1970).

Hemigrapsus oregonensis ability to live in more marginal habitats is counterbalanced by *H. nudus* greater resistant to desiccation, predator avoidance and competitive advantage for limited shelters (Low 1970). *H. nudus* grows larger than *H. oregonensis*, and thus wins out in shelter competition (Low 1970, Daly 1981). In the absence of competition, both species prefer larger, more stable rocks over smaller less stable ones. If the two species occur together, *H. nudus* typically dominates the larger rocks, while the majority of *Hemigrapsus oregonensis* are restricted to less stable and smaller rocks. Because of its larger size *Hemigrapsus nudus* is able to chase *H. oregonensis* away from the more stable larger, rocks. Without shelter *H. oregonensis* is very susceptible to predators such as birds, fishes, and larger crabs (Low 1970). In regions with only stable large boulders, *H. oregonensis* may be excluded almost entirely. On the other hand, when only less stable small rocks are present and disturbance rates are high, no individual may survive long. The higher reproductive rate of *H. oregonensis* is "selectively and competitively advantageous" (Daly, 1981). In contrast to *H. nudus* and its enhanced growth rates, *H. oregonensis* reaches maturity more rapidly and reproduces more frequently. This allows *H. oregonensis* to compete in times of high mortality, in which fast reproduction is essential to survival. On beaches between these two extremes, where there are big and small rocks and the disturbances are frequent, *H. nudus* would dominate the largest rock size and leave the smaller rocks with higher mortality rates for *H. oregonensis* (Daly 1981).

The relative distribution of species seems to depend primarily on the degree of sedimentation and the sizes of rocks available. At Hatfield, *H. oregonensis* were abundant under the smaller rocks at mid zone, while *H. nudus* was dominant under the larger rocks in the upper zone (Figure 1.2). We observed that the mid zone was muddier than the upper zone. At Sawyers Landing, where sedimentation was factor at both levels, we found high numbers of *H. oregonensis* at both levels. (Figure 1.1). Slope of the beach and competitive interactions between the species may also play a role.

Prediction of the possible impact of *Carcinus maenas* on the populations of *Hemigrapsus oregonensis* and *Hemigrapsus nudus*

Carcinus maenas is well known as a voracious, aggressive predator with strong invasive tendencies and an adaptable diet (Cohen et al. 1995, Grosholz and Ruiz 1995). Since it can live in the same habitats as *H. oregonensis* and *H. nudus* and is very tolerant to changes in salinity and temperature we may see it displacing these native crabs from their habitats. The ability of *Carcinus maenas* to live on mudflats and fine substrates may have dramatic effects on the populations of *H. oregonensis*. These habitats often act as refuges for *H. oregonensis* from the more dominant *H. nudus* (Low 1970, Daly 1981). Even the high reproductive rate of *Hemigrapsus oregonensis* may not be a competitive advantage because *Carcinus maenas* s reproductive rate is even higher. Since *Carcinus maenas* preys on smaller *Hemigrapsus oregonensis* (Grosholz and Ruiz 1995), we predict that . *oregonensis* will have difficulties maintaining its position in the ecosystem. *H. nudus* will be similarly affected by the green crab in protected waters, but viable populations may still persist on wave-exposed shores, a habitat not preferred by *Carcinus maenas*.