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Population Structure of the Crab *Hemigrapsus oregonensis* (Brachyura, Grapsidae) in Yaquina Bay Estuary, Oregon: I. Reproductive Cycle

Abstract

The *Hemigrapsus oregonensis* (Dana, 1851) population at Coquille Point in the Yaquina Bay Estuary was studied from April 1972 to May 1973. The population sex ratio slightly favored females (53.3 percent). The sex ratio did not change significantly with tidal height or season. The major reproductive season, as determined by the number of egg-bearing females, was from February to May (maximum brooding in March). Minimum brooding occurred during October. A regression model is presented for estimating fecundity.

Introduction

Hemigrapsus is a widely distributed genus of crab, occurring intertidally along the entire Pacific Rim from Alaska to Chile and in Japan, the USSR, China, Hawaii, and New Zealand. Although eleven species have been described within this genus, only two are found along the North American Pacific shores: *H. nudus* and *H. oregonensis.* Both range from Alaska to the Gulf of California (Schmitt, 1921; Hart, 1968). *H. nudus* is typically found in rocky outer coast areas with well-aerated, silt-free water. *H. oregonensis*, in contrast, is more common in regions with a higher silt load and, in general, is more typical of a muddy substratum (Way, 1917; MacKay, 1943). Hiatt (1948) has indicated that in those instances in which these two species overlap, there is usually a gradation of substrate types from a muddy or silty lower region, dominated by *H. oregonensis*, to a gravelly, well-drained upper region inhabited by *H. nudus.* At Coquille Point in the Yaquina Bay Estuary along the central Oregon coast, these two species are found in such an overlapping distribution.

Methods

The study area at Coquille Point in the Yaquina Bay Estuary (44° 37′ N. Lat., 124° 04′ W. Long.) was on the bay side of an abandoned artificial dike which had been constructed from dredge spoils. Small gravel, sandstone, and mudstone covered the dredge spoils. The substrate texture graded continuously from a fine, water-saturated mud at the 0 ft level to a pea-sized, well-drained gravel at the 5 ft level. Interspersed throughout the substrate were numerous shell fragments and large rocks measuring ½ ft-3 ft in diameter. The rocks were quite uniformly spaced from the 1 ft level to the 5 ft level, but at the 0 ft level the substrate consisted mainly of mud.

The study site was marked out in a grid from the 0 ft tidal level to the 5 ft tidal level at 1 ft vertical intervals. At each vertical foot interval, lines were extended hori-

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zontally along the beach for 15 ft. A rod was placed to mark a subplot corner every 3 ft along the horizontal lines. Thus, the total sample area contained 25 subplots, with 5 at each tidal height. Each of the subplots had an area of about 3 m². Each month during the spring tidal cycle a complete population census was taken in one subplot at each tidal height. All crabs were hand-captured, sexed, determined if berried, measured, and returned to the same subplot from which they were captured. Sampling efficiency was estimated to be greater than 90 percent as fewer than 10 observed crabs per month escaped capture. Measurements of maximum carapace width were taken with an Almkvist excaliper and reported to the nearest one-hundredth of a centimeter.

Results and Discussion

The upper two tidal intervals (3-4 ft and 4-5 ft) supported the most crabs (716 and 713, respectively). The 1-2 ft tidal interval supported the fewest crabs (220). Although the majority of crabs were found in the upper regions, no apparent major seasonal vertical population shift occurred (Fig. 1). Non-seasonal movements did occur. In comparing the number of crabs present in the 3-4 ft interval from May 1972 to August 1972, large fluctuations were noted, suggesting a highly mobile adult population.

The frequency distribution of male and female crabs (Fig. 2) showed no size class differences between the sexes. The mean carapace width of females was, however, slightly less than for males (1.44 cm and 1.51 cm, respectively; $p < .05$). The percentage of females in monthly samples indicated that the sex ratio (53.3 percent females) was biased in favor of the females ($p < .01$). There did not appear to be any significant temporal variation about the mean sex ratio, indicating that the population sex ratio was fairly stable throughout the year. The percentage of females at each tidal height interval (Fig. 3) was more variable. The sex ratio appeared slightly biased in favor of females at the higher two tidal intervals. The percentage of females

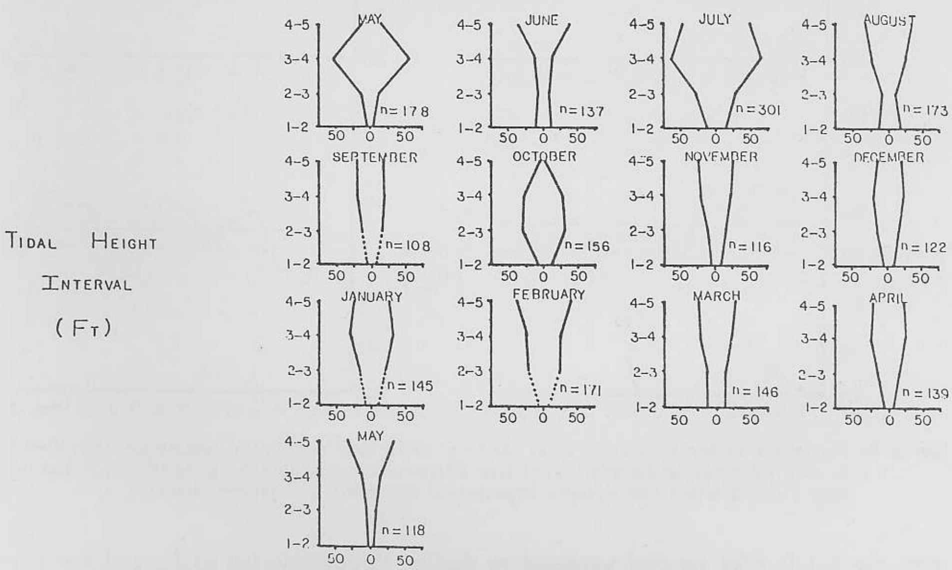

Figure 1. Total number of crabs collected monthly at each tidal height interval at Coquille Point in the Yaquina Bay Estuary, Oregon, from May 1972 through May 1973. Dotted lines indicate estimated numbers of crabs.

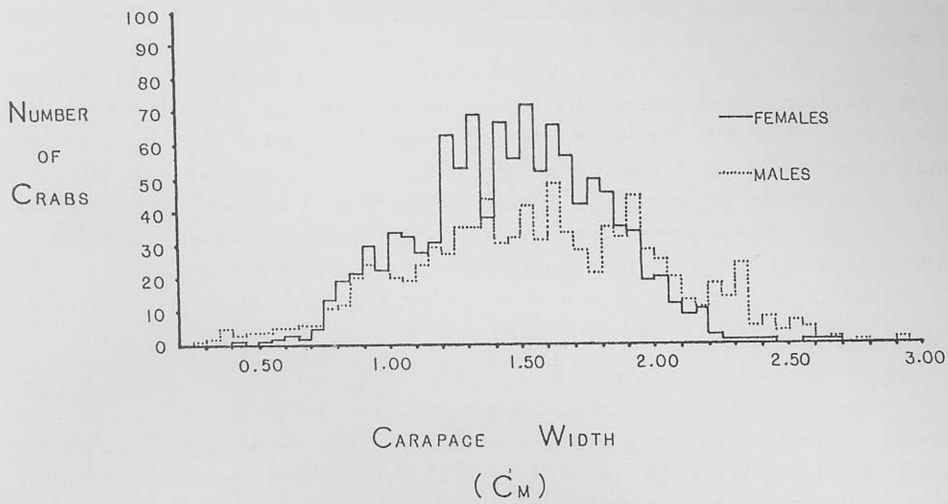

Figure 2. Histogram of number of male and female crabs in each carapace width size class during the period April 1972 through May 1973 at Coquille Point. Size class interval is 0.05 cm.

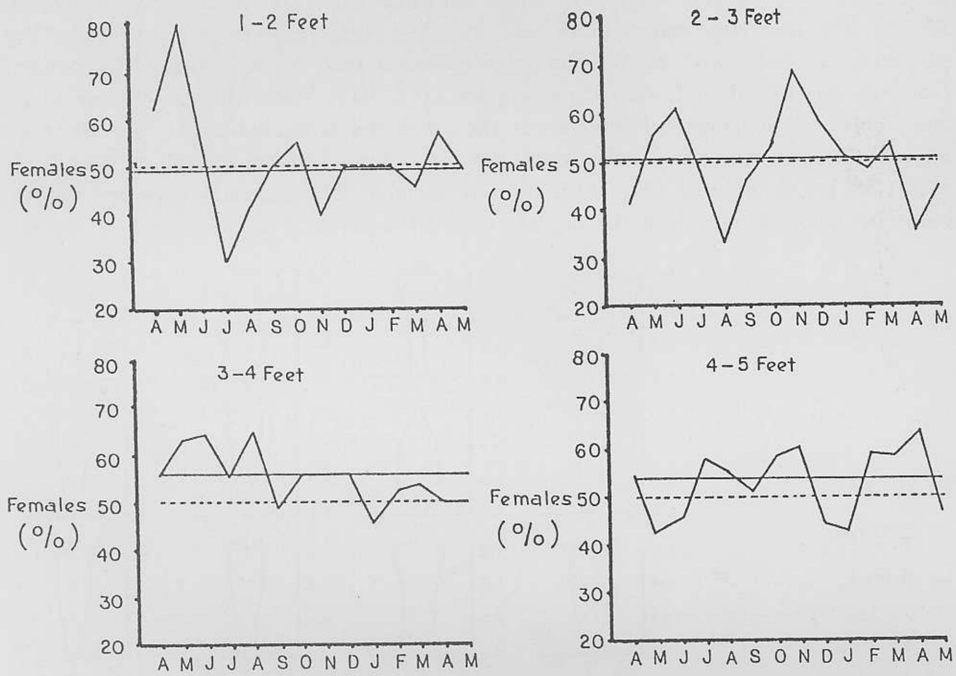

Figure 3. Percentage of female *Hemigrapsus oregonensis* in total population sample for each month at each tidal height interval. Solid line denotes average value from April 1972 through May 1973. Dashed line denotes hypothetical sex ratio (50 percent female).

from the 3-4 ft tidal interval appeared to decline throughout the study, and the percentage of females in the 4-5 ft interval appeared to increase (Fig. 3). Regression lines fitted to the data could not be shown to have a slope differing from zero ($p >$

.05), indicating a stable population sex ratio throughout the year at each tidal height interval.

The percentage of berried (ovigerous) females during the year (Fig. 4) showed a peak population reproductive effort during the late winter and spring months. The maximum percentage of berried females at any monthly interval (March 1973) was only about 33 percent of the female population. The minimum (1.4 percent) was during October. That some berried females were found each month indicated that the population was not synchronized for a major reproductive effort; rather, it exhibited a low-level, continuous yearly production which peaked in March. Fall months (September, October, November) were periods of little or no brooding at all tidal heights. The main reproductive period for this population was from February through May (maximum in March = 32.8 percent of females). The percentage of berried females at each tidal height reflected the population trend, indicating that there were no differences in reproductive seasons at the various tidal levels.

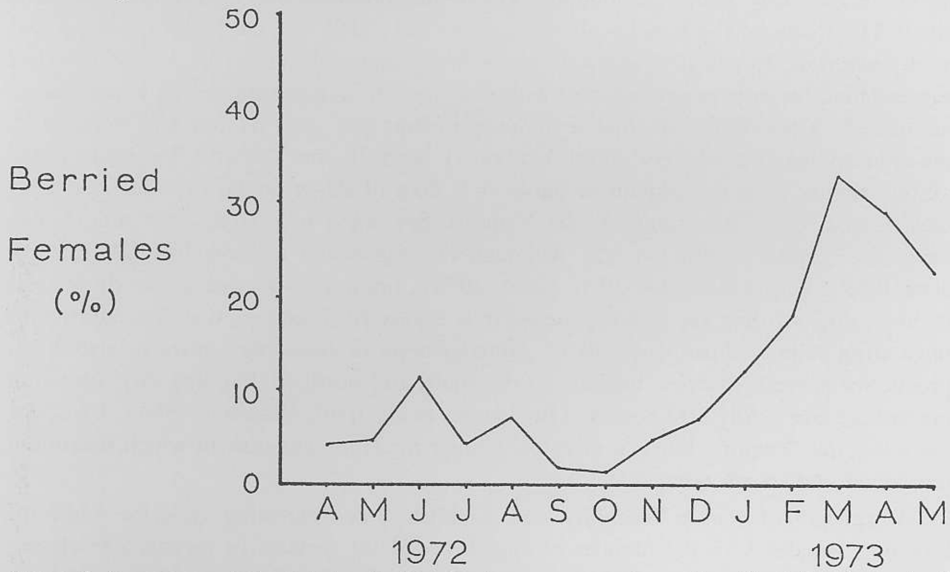

Figure 4. Percentage of berried female *Hemigrapsus oregonensis* at Coquille Point from April 1972 through May 1973. The minimum size of egg-bearing females was 0.86 cm. All female crabs smaller than this were not considered to be potentially reproductive female adults and were not included in the percentage calculations.

This is not the same brooding period that Knudsen (1964) found in Puget Sound, Washington, populations. He found that oogenesis occurred during a period of decreasing temperature (October to February). Increasing day length did not appear to regulate gametic production. Decreasing water temperature seemed to be a cue for early gametogenesis. However, a problem not resolved by Knudsen was the cue for the initiation of gametogenesis for a second brood class (70 percent of females). This second period of gametogenesis corresponded to rising water temperatures in Puget Sound. If Knudsen's assumptions are correct, then gametogenesis occurred twice yearly in the Puget Sound population, once in the fall and winter on a decreasing temperature cycle and again in late winter and spring on a rising temperature cycle.

Kuris (1971, 1978) reported that maximum brooding in *H. oregonensis* from

Bodega Bay, California, occurred from November through February (first brooding period: 65 percent of females) and from June through August (second brooding period: 43 percent of females). Summer brooding occurred in both California and Washington populations. In Puget Sound, however, no winter brooding occurred. Egg deposition first occurred in February, rapidly increased in March, and peaked in May (first brooding period: 90 percent of females). A second brooding period (70 percent of females) occurred during August. The Yaquina Bay population had a single maximum brooding period (March) which corresponded with neither the Bodega Bay nor the Puget Sound populations.

In Yaquina Bay, surface water temperature increased from December to April. A large drop in temperature (13° to 8° C) occurred from September to December. These findings suggested that decreasing temperature in the fall may also be a cue for gametogenesis in Yaquina Bay crabs just as Knudsen found decreasing water temperature to be a cue in Puget Sound populations. The results showed that in Yaquina Bay only about 33 percent of the females of reproductive size (0.86 cm and larger) were gravid at any one time. In addition, only one major brood occurred during the year. These data suggest that the bay population was either a) not well synchronized as a population for one short period of maximal reproductive effort per year, b) not well adapted to the environmental challenges of the bay, or c) both. In the Yaquina Bay Estuary, the salinity regime does not remain as stable as it does in Puget Sound or along the outer coast areas. After large rains on the Yaquina Bay watershed, freshwater runoff may lower the salinity to near 0-5 ‰. Although *H. oregonensis* is euryhaline and can tolerate 0 ‰ (tap water) for 20 h (Low, 1970), nothing is known about the effects of low salinity influx on gametogenesis. It is suspected, however, that low salinity or fluctuating salinity during periods of gametogenesis or brooding adversely affects reproductive success. In other habitats to the south and north of Yaquina Bay, brooding percentages are nearly 100 percent (Boolootian *et al.*, 1959; Knudsen, 1964). I suspect, therefore, that Yaquina Bay is a marginal habitat for *H. oregonensis* in which maximum reproduction does not occur.

A measure of female fecundity was established by regressing carapace width of brooding females with the number of eggs brooded for females in various size classes. A linear relationship ($r = 0.9018$) was established for females from 1.04 to 2.03 cm in carapace width. A regression model was established from which the number of brooded eggs could be estimated if a female's carapace width were known. The model is:

Y (number of eggs brooded) =

$r = 0.9018$

$-1.0529 \times 10^4 + (1.3344 \times 10^4)$ (carapace with in cm)

t-value

constant = −5.6813

variable coefficient = 10.4351

An estimate of the average egg production per female was about 10,000 eggs/female per year (assuming a single brooding cycle per female per year). Thus, an average of about 270,000 eggs/m^2 were produced at the collection site each year. Since it appeared that there was a large population turnover each year and since there was a fairly stable adult population, it was estimated that for about every 5000 eggs produced, one would survive to become an adult. The adjusted egg mortality rate to maintain a stable population was estimated to be 99.98 percent. Fecundity of the average (1.44 cm) female crab did not vary greatly from similar sized crabs from Bodega Bay (about 8000 eggs/brood) (Kuris, 1971). A smaller percentage of females reproduce in Yaquina Bay than in Bodega Bay. Those few females that do reproduce in Yaquina Bay appear to produce the same brood size per crab as in Bodega Bay.

Total densities of population vary dramatically. Outer coast populations have densities of up to $500/m^2$ (Low, 1970). The maximum density found in Yaquina Bay was about 20 $crabs/m^2$, indicating that Yaquina Bay may be a marginal habitat not only for reproductive success but also in supporting large numbers of adults.

Summary and Conclusions

The *Hemigrapsus oregonensis* population at Coquille Point in the Yaquina Bay Estuary was vertically stratified. The 1-2 ft vertical interval had an average of 7.89 $crabs/m^2$, the 2-3 ft interval 11.84 $crabs/m^2$, the 3-4 ft interval 20.9 $crabs/m^2$, and the 4-5 ft interval 19.73 $crabs/m^2$. Carapace width versus frequency histograms indicated no obvious size classes. Average female carapace width (1.44 cm) was slightly smaller than average male carapace width (1.51 cm). The population sex ratio was slightly biased in favor of females (53.3 percent). No obvious segregation of sexes occurred by tidal height during the study. Brooding females were found each month during the study. The main reproductive period was February through May (maximum in March = 32.8 percent). September through December was the period of fewest gravid females. The percentage of berried females at each tidal height followed the same trend: fall minimum brooding and spring maximum brooding. The minimum size of reproducing females was found to be 0.86 cm carapace width. A regression equation between carapace width and number of brooded eggs was established as a measure of fecundity:

$$Y(\#\text{brooded eggs}) = -1.0529 \times 10^4 + (1.3344 \times 10^4)(\text{carapace width in cm}).$$

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