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ESTIMATION OF INTERTIDAL HARVEST OF DUNGENESS CRAB, *CANCER MAGISTER*, ON PUGET SOUND, WASHINGTON, BEACHES[1]

There are two major methods employed in the sport fishery for the Dungeness crab, *Cancer magister*, in Puget Sound, Wash. The first is a passive method. A baited pot, trap, or ring net is placed on a subtidal substrate, left for a period of time, and retrieved. The second is an active method. During periods of low minus tides, sport crabbers seek crabs by sight. The crabbers usually wade out into water between knee and waist level, then walk parallel to the beach. A round metal loop, about 1 ft in diameter, covered with wire mesh and attached to a long handle, is generally used to capture crabs. Beginners often bring fish nets, but find it difficult to extricate the crabs caught in the net. When a crab is seen, the crabber maneuvers the hoop quickly under the crab. The crab's legs go through the mesh, making escape difficult, and the hoop is then pulled from the water. Only male crabs may be taken, and they must be a minimum of 152 mm (6 in) in width, as determined by a caliper measurement across the carapace, directly in front of the 10th anterolateral spines. The daily crab catch is limited to six per person.

Knowledge of the size and distribution of the intertidal sport fishery was limited until 1969, when the Washington Department of Fisheries began aerial surveys to estimate low tide usage of Puget Sound beaches for clam digging and crabbing. By summer 1973, enough data had been collected to show which beaches were being used for crabbing. However, the aerial surveys did not reflect the total use of beaches by crabbers over the entire low tide period, since only a single count was made sometime between 90 min before and 90 min after low tide.

This study was initiated in fall 1973 in an effort to determine the availability of crabs and the magnitude of intertidal harvest on one high-use Puget Sound beach. From data collected, an estimate was made of the total use of Puget Sound beaches by sport crabbers for daylight low tides in 1974.

Methods

From preliminary aerial survey data, Mission Beach, located 60 km north of Seattle and just beyond the Port of Everett, was selected as the study site (Figure 1). The beach is 3 km long, shallow, and sandy, with eelgrass beds below the mean lower low water (MLLW) level. This beach had only one public access, cut through a 15-m bluff. This location provided me with a good view of the entire area and made it possible to interview almost all crabbers using the beach.

From October 1973 to October 1974 there were 19 low tide series with tides lower than −0.30 m MLLW. These tidal series occurred in all months of the year except March and September. I visited Mission Beach during all tides lower than −0.30 m, except under adverse weather conditions in the winter months. I arrived 2.25 h before low water and walked to point 'a' (Figure 1), where I entered the water and moved toward the access at a depth of 0.15 to 0.85 m through the area most intensively utilized by the sport crabbers. For all crabs observed, I recorded the size to the nearest millimeter (taken in a horizontal measurement directly in front of the anterolateral spines on the carapace, by means of a caliper) and sex. Sampling was by the method used by most crabbers.

Beginning 2 h before low tide, I made half-hourly counts of the number of crabbers at the beach, but continued beach sampling of crabs until crabbers began to leave the beach, usually about 0.5 h before the low. At this time, I interviewed the crabbers about their success and time spent crabbing. About 90% of all crabbers using Mission Beach, on tides checked, were interviewed. During the interviews, I measured as many crabs as possible. From the interview data, I estimated the number of crabbers on the beach at any time during a period of 14 min before to 15 min after the half-hourly counts. The average time spent crabbing was slightly over 1.5 h; thus, if all crabbers

[1]Based on work submitted in partial fulfillment of the requirements for the degree of Master of Science.

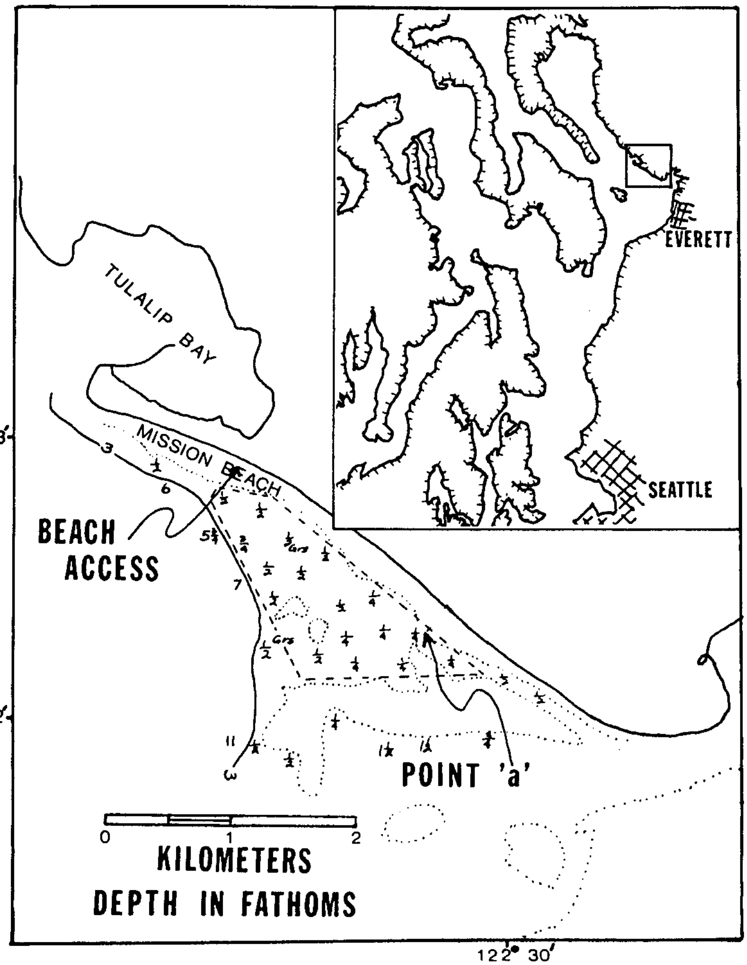

FIGURE 1.—Location of Mission Beach within Puget Sound, Wash. The area most intensively utilized by crabbers at Mission Beach is outlined with dashes.

had been interviewed, the constructed counts would coincide with actual beach use. However, not all crabbers were interviewed, so the half-hourly counts were more accurate for the lowest period of the tide when most people were crabbing.

I then constructed a table for each month which assigned the highest of the two estimates, either the constructed count from the interviews or the half-hourly beach count, to each half-hourly period. The number of crabbers using the beach was computed for each tide by dividing the total crabber hours (the sum of the half-hourly counts) by the average hours spent crabbing (obtained from crabber interviews) and totaled for each month. From the monthly table, the number of crabbers on the beach at any half-hourly interval, divided by the total number of people using the beach for each month during the low tide period, gave a percentage of people using the beach at any half-hourly count. Monthly use curves were then constructed for Mission Beach (Figure 2).

The methods that I employed to develop use curves were similar to those that have been used by researchers who have dealt with other recreational fisheries (Miller and Gotshall 1965; Brown 1969; Tegelberg[2]; Jarman et al.[3]).

In addition to the sampling that I conducted at Mission Beach, personnel from the Washington Department of Fisheries Shellfish Laboratory conducted creel sampling at six other Puget Sound beaches having differing levels of crabber use. From the survey material that they provided, I had insufficient data to construct use curves for

[2]Tegelberg, H. C. 1963. The 1962 razor clam fisheries. State Wash. Dep. Fish., 28 p.

[3]Jarman, R., C. Bennet, C. Collins, and B. Brown. 1970. Angling success and recreational use of twelve state owned lakes in Oklahoma. Paper given at 21st Annu. Meeting South. Div. Am. Fish. Soc., New Orleans, La.

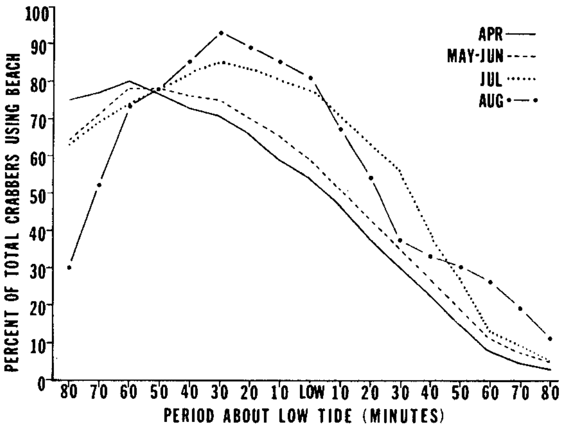

FIGURE 2.—Crabber use curves for Mission Beach based on data gathered April-August 1974.

April and August, but I was able to construct use curves for May-June and July, a combined total for those beaches based on 10 and 5 observations, respectively. These use curves, when superimposed over the corresponding Mission Beach use curves, did not vary by more than approximately 10% for the period before, or 20% for the period after, the low tide.

The Washington Department of Fisheries also provided me with data from aerial surveys conducted over Puget Sound beaches on 27 April, 25 May, 22 June, and 20 July 1974. Most of the beaches were surveyed during the hour preceding the low tide, which corresponded to the highest beach use. Thus, the curves derived for Mission Beach were used for estimates for all beaches.

While interviewing crabbers at Mission Beach, it appeared to me that both the tidal height and tidal sequence were important factors in crabbing success. I therefore analyzed the data in two different ways. The various tidal series had from three to eight tides lower than −0.15 m (−0.5 ft). I divided the low tide heights into six levels by 0.15-m increments. The first minus tide of a series to fall into a tidal height category was defined as Tide One in the tidal sequence. Each succeeding tide was consecutively numbered, with the final tide in a series designated as the last minus tide to fall into a tidal height category. Thus, low tides of equal height from different tidal series were not always the same sequence number.

Results and Discussion

The number of crabbers using Mission Beach during the winter nighttime tides was small compared with the number during the summer daytime tides. Of the estimated 762 crabbers using Mission Beach during the year, only 27 (4%) crabbed from October through February, while 735 (96%) crabbed from April through August. Of the estimated 531 crabs taken for the year at Mission Beach, the winter crabbers caught 60 (11%), while the summer crabbers caught 471 (89%).

Stepwise multiple linear regression analysis (Poole 1974) of crabber activity at Mission Beach correlated significantly ($P<0.05$) with tide height, day of week, month, temperature, and wind velocity (Table 1). However, the resultant equation was not strong enough for predictive purposes. The tide height accounted for the largest amount of the variability. The lowest three tide levels had two to four times as many crabbers as the highest three levels (Table 2). The other significant variables indicated the following: weekend use by crabbers per tide was 1.5 times greater than the average weekday use per tide; the average number of crabbers per tide was highest in April, May, and June, with the use dropping off considerably in July and August; there were more crabbers at higher air

TABLE 1.—Summary table of multiple linear regression between total crabbers at Mission Beach and nine independent variables. The resultant equation was significant at $P<0.001$ for all steps.

Step	Variable entered	Significance[1]	Mult. R	R^2	R	Overall F
1	Tide height	0.001	0.45	0.20	0.45	12.35
2	Day of week	.003	.59	.34	−0.27	12.37
3	Month	.005	.67	.45	−0.39	12.61
4	Temperature	.007	.73	.53	0.26	12.92
5	Wind velocity	.027	.76	.58	−0.06	12.37
6	Tide sequence	.078	.78	.61	0.08	11.39
7	Previous day's catch/crabber	.698	.78	.61	0.04	9.59
8	Precipitation	.769	.78	.61	−0.06	8.21
9	Cloud cover	.825	.78	.61	−0.13	7.14

[1]The α level of significance for each variable as it was entered in the equation.

TABLE 2.—Crabber use and catch taken on six different tide heights (mean lower low water) at Mission Beach, Wash., April-August 1974.

Tide height (m)	No. of tides sampled	Mean no. crabbers per tide	Mean no. of crabs caught	Mean catch legal crabs per crabber	Total legal crab catch
−0.15 to −0.29	6	6	1.4	0.2	7
−0.30 to −0.44	14	13	7.9	0.6	110
−0.45 to −0.59	16	9	6.1	0.7	92
−0.60 to −0.74	6	19	24.7	1.3	173
−0.75 to −0.89	4	25	15.0	0.6	62
−0.90 to −1.04	5	27	5.4	0.2	27

temperatures, but this corresponded with the lowest tides in June, which occurred at midday; on days with high winds there were few crabbers. This was probably due to a lowered chance of success because waves on the beach made crabs difficult to see.

The estimated use of the beach by crabbers corresponded with the daily availability of crabs on the beach that I observed by sample crabbing. This availability appeared to be affected by current and tide height. Two hours before low tide, the water level over the eelgrass portion of the beach, where most crabs were found, was generally >1 m. As the tide went out and the water became shallower, I observed few crabs in water <0.15 m deep. The current also appeared to have effects. When the tide approached its lowest level, the current became slack, at which time I observed few crabs. Even on days when a large number of crabs were active an hour before the low, few would be evident at low slack.

The monthly use curves enabled me to take a single aerial survey count of crabbers using a surveyed beach at any time during the low tide period and predict the total crabber use at the beach during the entire low tide period.

I adjusted the total calculated Puget Sound beach use by crabbers during the 1974 aerial surveys by two factors: the number of crabbers excluded because beaches were not surveyed and the improper identification of people as crabbers who were not actually crabbing. Between 1969 and 1973, at least one aerial survey at low tide was conducted over every Puget Sound beach, and all important crabbing beaches were identified. From this data I estimated that the 1974 aerial surveys included 95% of the crabbers and other recreationists on the beaches at any given low tide. At the same time 1974 aerial surveys were made over Mission Beach, I made actual counts of crabbers on the beach. The average overcount of crabbers by the aerial survey was 15.5%.

Total Puget Sound intertidal crabber use for all low tides from April through August was roughly estimated by dividing the total Mission Beach counts on the days of the aerial surveys, April through July, by the adjusted total Puget Sound beach count. The quotient was designated as the percentage of Mission Beach use relative to the adjusted total beach count (Table 3). Due to poor visibility on the day scheduled, no aerial survey was conducted in August, so I used averaged data from the preceding 4 mo. I estimated the total crabber use on all beaches for each month by dividing the percentage Mission Beach use of the total adjusted beach count into the total crabber use of Mission Beach for each month.

In order to estimate the total crabs caught in Puget Sound by intertidal sport crabbers, I needed to know whether the average catch over a low tide period at other Puget Sound beaches was the same as that at Mission Beach. Six other beaches in Puget Sound that had different levels of crabber utilization were sampled on a random basis by personnel from the Washington Department of Fisheries. Their levels of crabber use ranged from a few to 70 crabbers per tide. Four of the six beaches had three or more surveys, and these were compared with Mission Beach by Wilcoxon Rank Sum Tests (Hollander and Wolfe 1973). The four beaches had W values of 13.5, 9.5, 46.5. and 106, which in all cases were greater than the computed values of 6, 6, 39, and 66. Thus the null hypothesis that there were equal catches per crabber at the different beaches could not be rejected. This implies that the number of crabbers at a beach is self-regulating in that crabbers tend to adjust their level of effort to the rate of return, and that rates of return for all crabbers at different beaches remains fairly constant.

This same pattern of utilization was observed in the recreational trout fisheries in California lakes, where the angling effort adjusted proportionally to the numbers of catchable-size trout (Butler and

TABLE 3.—Estimate of the total monthly crabber use in the intertidal Dungeness crab sport fishery for Puget Sound beaches, April-August 1974.

Month	Adjusted total Puget Sound beach count on monthly aerial survey	No. of crabbers at Mission Beach on monthly aerial survey	Percentage Mission Beach use of total adjusted beach count (Col. 3 ÷ Col. 2)	Total crabbers at Mission Beach	Estimated total intertidal crabber use (Col. 5 ÷ Col. 4)
April	433	27	6.2	79	1,274
May	829	28	3.4	229	6,735
June	954	33	3.5	279	7,971
July	805	29	3.6	121	3,361
August	No observation		[1]4.18	27	646
Total				735	19,987

[1]Average of four previous months.

Borgeson 1965). Since the catches did not differ significantly, all beaches were treated together for predictive purposes. An estimate of the total crabs caught by intertidal sport crabbers for the daylight tides in 1974 was made by multiplying the average catch per effort for April, May, June, July, and August at Mission Beach (Table 4) by the estimated total number of crabbers (Table 3) for each month. The number of crabs caught per month increased throughout the spring, reaching a maximum of 5,099 in June. Few crabs were caught after July (Table 5).

When Spearman rank correlation coefficients were computed between a crabber's catch at Mission Beach and a number of independent variables (Hollander and Wolfe 1973), the most significant positive correlation was with the total time spent crabbing (Table 6). Crabbing was better in April-June than in July and August. The tide height and tide sequence were not significantly correlated with the catch per crabber at $P<0.05$, but were significant at $P<0.10$. The highest average catches were on tides ranging from -0.60 to -0.74 m (Table 2).

The higher tides make crabbing difficult, because crabbers have to wade into deeper water to get to the area where crabs are found. In the deeper water, crabs are less visible and the mobility of crabbers is impaired. The catches and number of crabbers arranged by tide sequence are shown in Table 7. The lowest tides of the year are generally four or five tides into a tidal series. The first low tides in the series have already allowed a fair amount of crabbing pressure on the beach, and many of the available crabs have been removed. Additionally, the combination of crabbers wading and less water over the beach on the previous low tides probably causes crabs to move to deeper water during the last low tides in a series.

The sex and size composition of crabs that I observed while sampling are shown in Figure 3. The numbers of legal males (152 mm and larger) include all crabs measured during crabber interviews.

TABLE 4.—Monthly crabber use and mean daily catch at Mission Beach, Wash., April-August 1974.

Month	Number of tides	Number of crabbers	Mean daily catch per crabber	Range of mean daily catches
April	5	79	1.76	0.4-3.0
May	11	229	.86	0.0-3.4
June	14	279	.64	0.0-2.2
July	14	121	.59	0.0-1.7
August	6	27	.30	0.0-0.5

TABLE 5.—Estimated total Dungeness crab sport catch in Puget Sound on intertidal beaches, April-August 1974.

Month	Mean catch per crabber at Mission Beach	Estimated total Puget Sound crabbers	Estimated total crab catch
April	1.76	1,274	2,242
May	.86	6,735	5,792
June	.64	7,971	5,099
July	.59	3,361	1,983
August	.30	646	194
Total		19,987	15,310

TABLE 6.—Spearman correlation coefficients between number of crabs caught per crabber and nine independent variables.

Variable	Correlation coefficient	Significance
Time spent crabbing	0.738	0.001
Month	−0.413	.002
Tide height	0.229	.055
Tide sequence	−0.222	.061
Wind velocity	−0.175	.113
Temperature	−0.105	.238
Precipitation	−0.092	.263
Time of low	0.054	.355
Cloud cover	0.010	.473

TABLE 7.—Crabber use and catch taken on different tide heights arranged according to the sequence in which they occurred in a low tide series at Mission Beach, Wash., April-August 1974.

Tide sequence	No. of tides sampled	Mean no. crabbers per tide	Mean no. of crabs caught	Mean catch legal crabs per crabber	Total legal crab catch
1	6	15	7.6	0.5	46
2	9	23	10.3	0.9	163
3	8	13	9.4	0.7	85
4	8	13	6.5	0.5	52
5	8	9	8.9	1.0	71
6	7	18	6.3	0.4	44
7	3	14	2.7	0.2	8
8	1	20	2.0	0.1	2

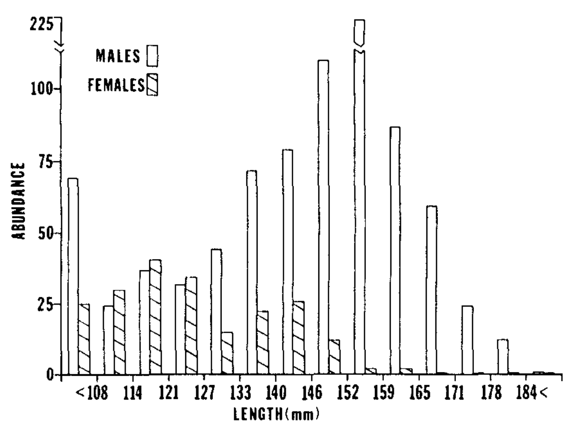

FIGURE 3.—Size composition and sex of crabs observed during sample crabbing at Mission Beach from October 1973 through August 1974. Male crabs >150 mm include those measured during crabber interviews.

In summary, the use of Mission Beach by intertidal crabbers is greatest 1 to 2 h before the low tide. This corresponds to the period when crabs are most readily observable. From the data collected at Mission Beach and aerial survey counts of other Puget Sound beaches, I estimated that about 20,000 crabbers utilized intertidal beaches from April through August 1974. The intertidal Dungeness crab sport fishery is, however, fairly small compared with other marine sport fisheries in Puget Sound.

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A CONTRIBUTION TO THE BIOLOGY OF THE PUFFERS *SPHOEROIDES TESTUDINEUS* AND *SPHOEROIDES SPENGLERI* FROM BISCAYNE BAY, FLORIDA

The general biology of the checkered puffer, *Sphoeroides testudineus*, and bandtail puffer, *S. spengleri*, is not as well known as that of the northern puffer, *S. maculatus*. For example, Chesapeake Bay populations of the northern puffer have been examined for length-weight relationships by Isaacson (1963) and Laroche and Davis (1973), for age, growth, and reproductive biology by Laroche and Davis (1973), and for fecundity by Merriner and Laroche (1977). None of this information is available on the checkered or bandtail puffer.

Checkered and bandtail puffers have greater geographic ranges and are more southern in distribution than the northern puffer. The checkered puffer is abundant from the Atlantic coast of southern Florida, throughout the Caribbean Islands, Campeche Bay, and along the coasts of Central and South America to Santos, Brazil (Shipp 1974). The bandtail puffer is common in the Caribbean Sea and along the coasts of peninsular Florida, the Bahamas, and Bermuda (Shipp 1974). I report here on growth, reproduction, and the pharyngeal dentition of these two species gathered during a study of their feeding biology (Targett 1978).

The sampling habitat was a shallow seagrass bed along the southwestern shore of Virginia Key in northern Biscayne Bay, Fla. Turtle grass, *Thalassia testudinum*, was the dominant seagrass with small amounts of shoal grass, *Halodule wrightii*, and manatee grass, *Syringodium filiforme*, also present. Monthly collections from September 1973 to December 1974 yielded 414 checkered puffers (15-215 mm SL; 56% females) and 548 bandtail puffers (16-133 mm SL; 49% females). Seawater temperatures ranged from 16.5° to 32.0°C and salinities from 30.5 to 38.5‰.

Standard length-weight relationships (Figures 1, 2) were calculated using functional regressions (Ricker 1973). Checkered puffers grow to a larger size and are heavier than bandtail puffers at a given length. Comparisons of these results with those for northern puffers from Chesapeake Bay (Isaacson 1963; Laroche and Davis 1973) was made possible by the conversion of total length to standard length using the factor: caudal fin length = 20.2% SL (Shipp 1974). Northern puffers grow