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# IMPACT OF DREDGING ON DUNGENESS CRAB, *Cancer magister*, IN GRAYS HARBOR, WASHINGTON DURING AUGUST 1987

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Brett Dumbauld, David Armstrong, Paul Dinnel and Thomas Wainwright

**FINAL REPORT**

for

Seattle District
U.S. Army Corps of Engineers
Seattle, Washington 98124

Contract No. DACW67-85-C-0033
(Modification #8)

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FISHERIES RESEARCH INSTITUTE
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Seattle, WA 98195

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Director

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# INTRODUCTION

The port of Grays Harbor has been an important maritime shipping center for the lumber industry since the late 1800's. Growth in this industry required deepening and stabilization of the harbor entrance and navigation channels. Dredging began in 1905 and it has continued intermittently with an average annual total of 1.5 - 1.7 million cubic yards (cy) for maintenance. In 1980 Congress voted to approve funds for a new "Widening and Deepening" (W&D) project for Grays Harbor which would require the removal of 11 million cy of sediment with an increase of maintenance dredging from 1.5 to 2.6 million cy per year.

Commercial and sports fisheries for Dungeness crab, Cancer magister, have existed in Grays Harbor since the early 1900's (Cleaver 1949). Sampling activities by the Washington Department of Fisheries (WDF) (Tegelberg and Magoon 1970; Tegelberg and Arthur 1977) provided evidence that Grays Harbor might also be a nursery area for juvenile crab. As a result of this information, the U.S. Army Corps of Engineers (COE) initiated studies to examine the effects of maintenance dredging on Dungeness crab as part of a larger project entitled "Maintenance Dredging and the Environment of Grays Harbor, Washington" (COE 1977). Results of this study showed that substantial numbers of crab were entrained and killed by the dredging process (Tegelberg and Arthur 1977).

The newly proposed and funded W&D project required that an Environmental Impact Statement (EIS) be prepared to address potential impacts of the project. Basic ecological studies of crab, shrimp (Crangon spp.) and finfish resources of Grays Harbor and further refined estimates of dredge - related entrainment and mortality for these groups of organisms were carried out (Stevens 1981; Armstrong et al. 1982). Hopper dredge entrainment rates ranging from 0.035 to 0.502 crab/cy were found with an average mortality of 73.1% of those crab entrained. Based on this information, the potential crab mortality associated with the W&D project was calculated to range from 1.5 to 2.6 million crab (depending on dredging scenario and based on estimates of 1981 crab population abundance with no breakdown by size class). Potential mortality of an additional 203,000 to 338,000 crab was estimated for annual maintenance dredging.

Because of the expected dredge-related impacts to Dungeness crab during the W&D project, COE is investigating and evaluating methods to reduce entrainment and mortality to this species. Joint studies were conducted by COE (McGraw et al. 1987) and the University of Washington (Dinnel et al. 1986a, 1986b) in Grays Harbor in October 1985 and August 1986. The COE monitored Dungeness crab entrainment aboard the COE hopper dredge Yaquina during both studies while the University of Washington conducted a separate assessment of crab resources in and around the dredge and dredged materials disposal sites. The dredge was equipped with dual

dragheads during the October 1985 study, one modified to reduce crab entrainment and one unmodified. The results of these joint studies showed that there was no significant difference in crab entrainment between the two different dragheads, no differences in beam trawl crab catches between day and night, no differences between total crab catch at different stations, and no differences in catch relative to the time or configuration of the trawl (e.g. before, after or during dredging and behind, in front of, or alongside the dredge) with the exception of greater crab catches from trawls made before dredging began in an area versus during dredging. The dragheads entrained an equivalent of 123 crab/ha of area swept or 0.111 crab/cy of solids dredged in October 1985 and 276 crab/ha or 0.274 crab/cy of solids dredged in August 1986 (McGraw et al. 1987) while the University trawl studies produced an estimate of average crab abundance in the dredge sites of 773 crab/ha in October 1985 and 960 crab/ha in August 1986. Comparisons showed that the dredge Yaquina entrained approximately 15.9% of the crab estimated to be present by the trawls in October 1985 and 28.8% in August 1986. Results from both of these studies were used to form the basis of entrainment versus density curves in a final dredge entrainment model (Armstrong et al. 1987).

The work presented in this report is a continuation of the joint COE - University of Washington dredge trawl studies in Grays Harbor initiated in October 1985 and was undertaken to further refine estimates of crab entrainment rate versus density. This report details the results of trawl studies conducted in early August 1987 and compares them to simultaneous crab entrainment studies conducted by COE aboard the dredge Yaquina and the previous work discussed above.

The specific objectives of the trawl study in 1987 were:

1) Estimate the density of crab during dredging at five locations (including the Grays Harbor bar) by sampling with a 3-m beam trawl.

2) Determine the age and sex of crab caught in the samples.

3) Compare the number of crab entrained during dredging by the Yaquina with the number of trawl-caught crab and estimate the proportion and significance of the crab population entrained during dredging.

## MATERIALS AND METHODS

Dungeness crab were sampled simultaneously by two different methods. First, entrainment of crab by the dragheads of the COE hopper dredge Yaquina was monitored on board the dredge by diverting the dredged material plume through screening baskets before the material entered the hopper. Second, crab in the dredge area were sampled with a 3-meter plumb staff beam trawl fished from a separate vessel beside, or independent of, the actual dredging runs.

Sampling aboard the dredge Yaquina was conducted by biologists from the Seattle District COE and University of Washington. Generally, replicate samples of the dredged material were obtained by diverting the entire intake from each draghead through screening baskets (with holes approximately 10 mm in diameter) for 30 seconds and counting and measuring all crab so obtained. Further details of the dredge Yaquina, on-board sampling by the COE, and comparison of crab entrainment by two different types of dragheads are discussed in a separate report (McGraw et al. 1987, 1988).

Trawl operations were conducted on board the chartered fishing vessel Karelia out of Westport, Washington. Crab were sampled by 3-m beam trawl (Gunderson and Ellis 1986) presently used in other Dungeness crab studies in Grays Harbor (Armstrong and Gunderson 1985; Armstrong et al. 1987), Willapa Bay (Armstrong et al. 1986), and Puget Sound (Dinnel et al. 1985, 1986c, 1987). All Dungeness crab from each trawl were counted, sexed, measured and returned live to the general area of capture.

Trawling was conducted at four stations within the dredge study area defined in previous studies and one station located just off Point Chehalis on the Grays Harbor bar (Fig. 1). Stations 1 and 2 were located between Flasher Buoys "15" and "15A" in the western portion of the "South Reach" and between Flasher Buoys "17" and "21" in the eastern portion of the "South Reach", respectively. Station 1.5 was located between these two stations (Flasher Buoys 15A and 17) and Station 3 was located in the "Crossover Channel" just east of Station 2 between Flasher Buoys "21" and "24" (Fig. 2). The Grays Harbor bar station was located between Flasher Buoys 4 and 6 off Point Chehalis.

All trawls were conducted on 1, 2 and 3 August 1987. Because previous surveys showed no relationship between crab density based on trawl configuration relative to the dredge (Dinnel et al. 1986a, 1986b), trawling was conducted either independent of the dredge (but after disruption of the station by the dredge) or alongside the dredge as it made one of its dredging cuts. No trawls were made independent of the dredge prior to dredging a station. Each tow within the five stations covered a distance of approximately 400 m (0.22 nautical mile) yielding an area swept by the net of approximately 1,065 $m^2$. Distance covered was determined by radar range readings using the various channel marker buoys as reference points. The approximate duration

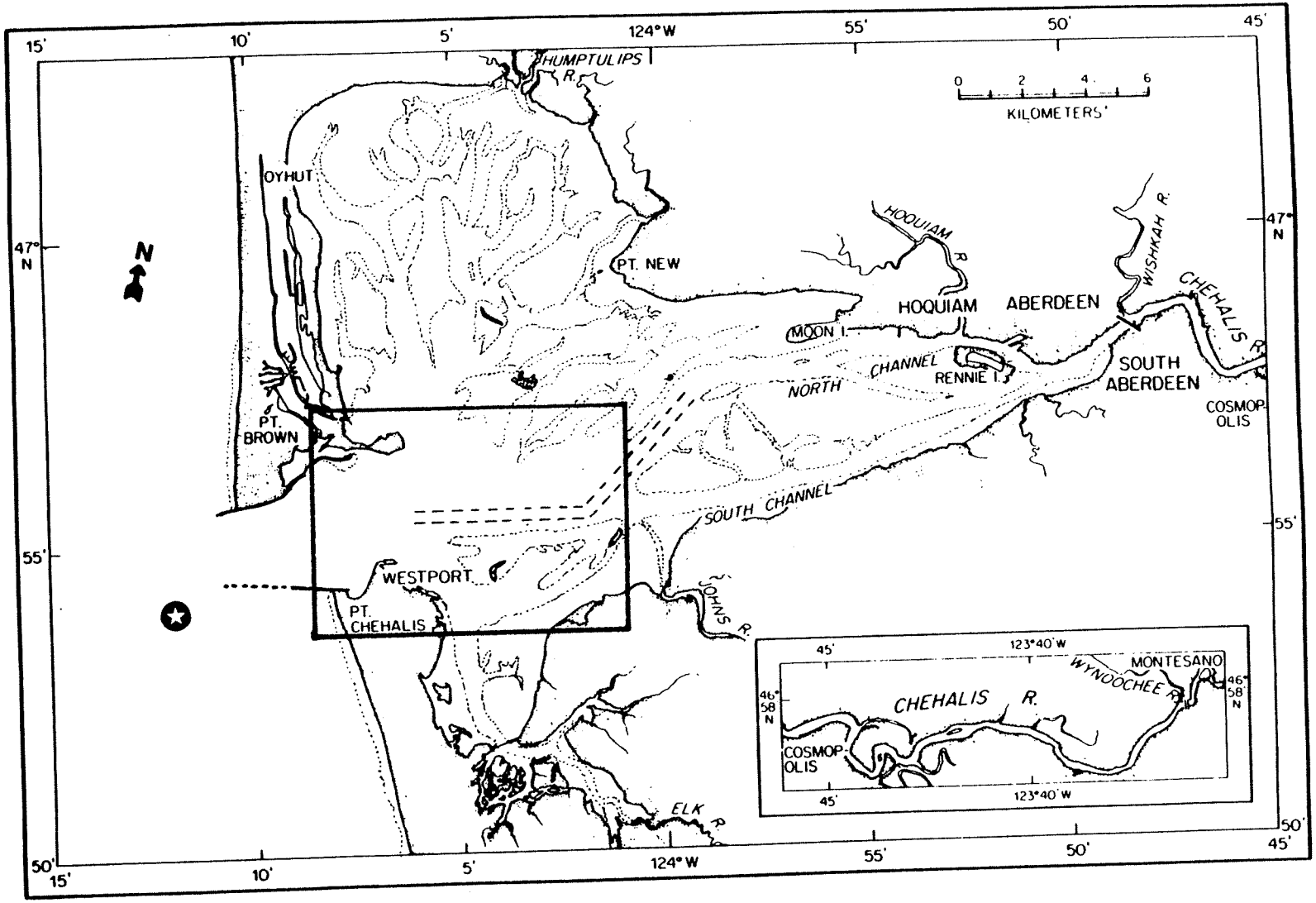


Figure 1. Map of Grays Harbor showing the approximate boundaries of the dredging study and the location of the bar station (indicated with a ✪ ).

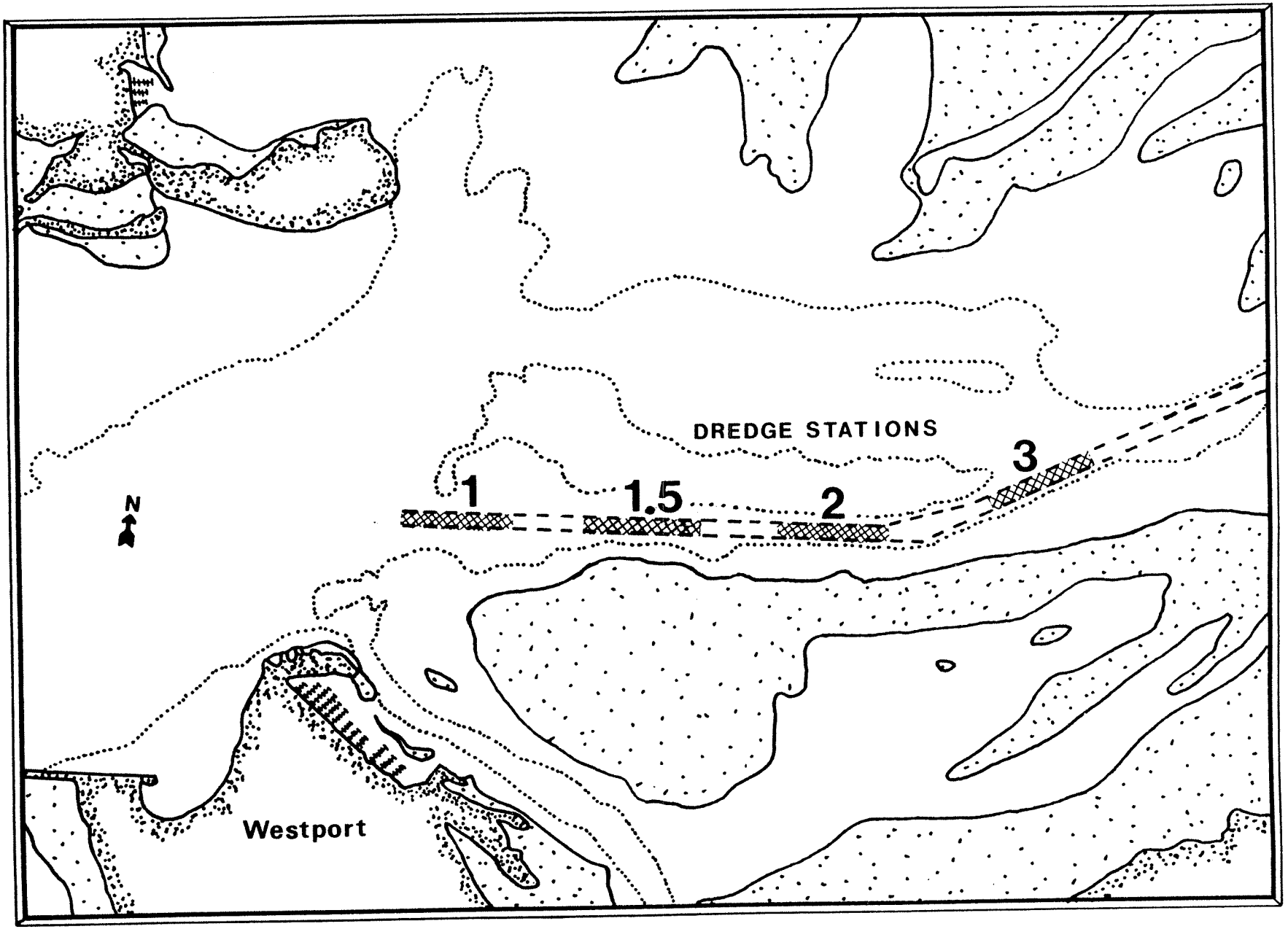


Figure 2. Map of outer Grays Harbor showing dredge Stations 1, 1.5, 2 and 3.

of each tow was 10 minutes. Surface and bottom water samples were collected from each station on a daily basis and measured for temperature and salinity.

Population estimates for Dungeness crab were calculated for August 1987 from data obtained during beam trawl sampling conducted as part of a related Sea Grant crab study (Armstrong et al. 1986; Armstrong et al. 1987; Gunderson et al. 1985). Four areas in the estuary and 3 areas in the adjacent nearshore along the coast of Washington (estuary Strata 1 through 4, 18 stations and nearshore Strata 5 through 7, 33 stations) were sampled (Fig. 3).

Data Analyses

Data analyses were performed using programs made available on the Burroughs 7800 computer at the National Marine Fisheries Service Center (NMFS) in Seattle. Some statistical analyses and graphs were also made using an IBM XT microcomputer. Catches of Dungeness crab from each trawl were converted to estimated densities per hectare (ha) using the following formula:

Catch x 10,000/area swept = estimated # crab/ha

where: area swept = trawl distance (m) x width of net opening (2.3 m).

Size frequency observations were plotted on a percentage basis to obtain size composition of the crab at each station. Because counts of benthic or epifaunal invertebrates usually show a contagious (non-random) distribution (Elliott 1977), and to avoid problems with the assumption of equal variances, a simple non-parametric Kruskall-Wallis analysis of variance and associated multiple comparisons procedure were used to detect differences in crab density by location.

Population estimates were made according to the area swept technique described by Armstrong and Gunderson (1985), and area estimates for each stratum were made with a computerized digitizer at NMFS.

## RESULTS AND DISCUSSION

Beam Trawl Crab Catches

Data from a total of 57 trawls was analyzed resulting in an average estimated density of 820 $\pm$ 788 crab/ha (1 SD) over all areas sampled. The highest average density was at Station 2 (1,561 crab/ha) and the lowest average density observed was at the bar station (94 crab/ha, Table 1). The only significant difference in average density between stations, using a Kruskall-Wallis analysis of variance procedure and multiple comparisons test, was the lower density at the bar

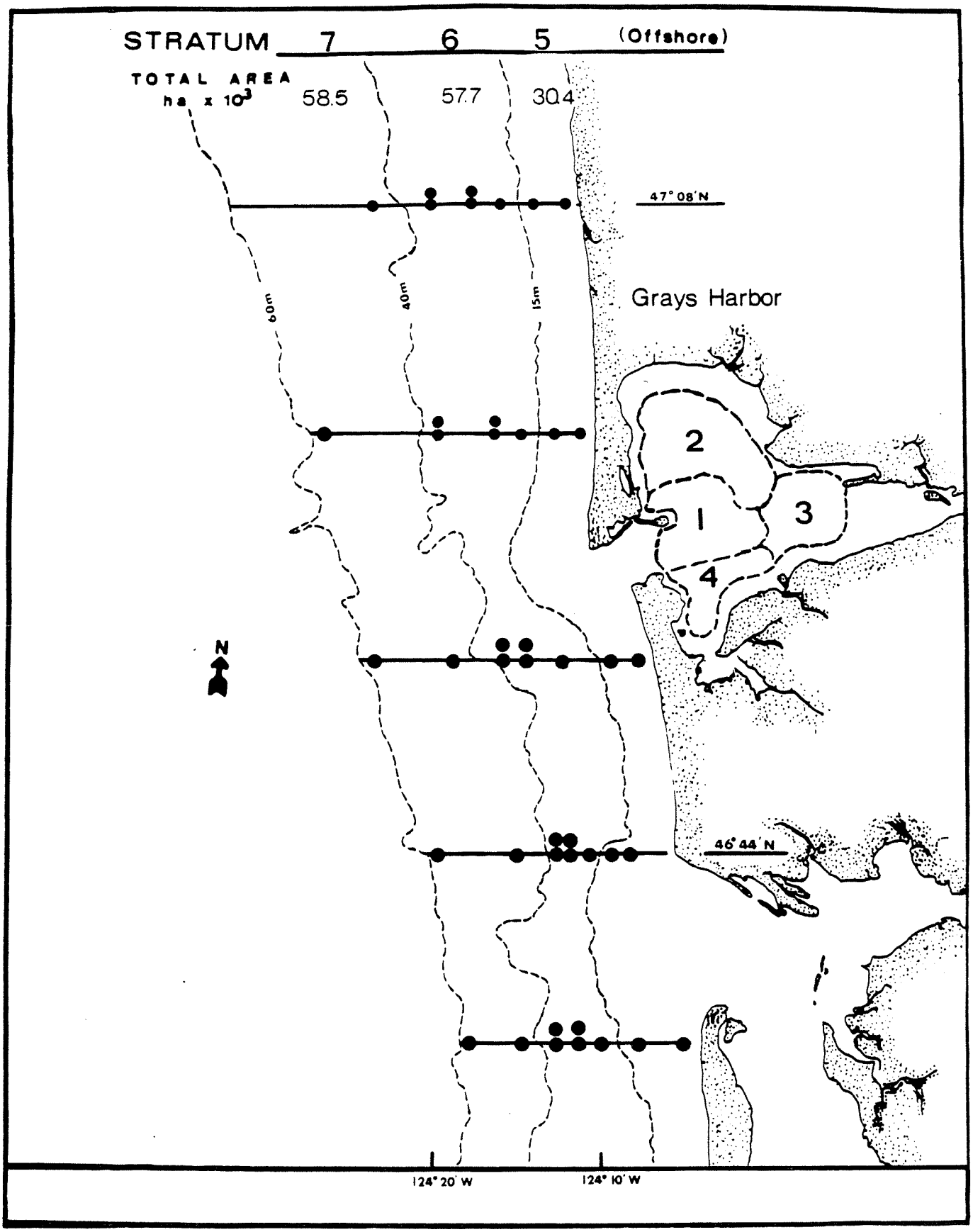


Figure 3. Map of Grays Harbor area showing the standard Sea Grant trawl survey with the estuary divided into four separate strata and the offshore area divided into three strata (by depth contours) for purposes of making comparative population estimates (Armstrong et al. 1986). There are 18 stations within Grays Harbor and 33 stations in the nearshore area used for these estimates.

Table 1. Average density of Dungeness crab by station estimated from beam trawl catches (N = number of samples, $\overline{X}$ = average density, crab/ha, SD =standard deviation).

| Location | N | $\overline{X}$ | SD |
|---|---|---|---|
| Station 1 | 13 | 504 | 323 |
| Station 1.5 | 8 | 972 | 1171 |
| Station 2 | 8 | 1561 | 835 |
| Station 3 | 8 | 968 | 201 |
| Total Estuary Stations | 37 | 934 | 774 |
| Bar | 20 | 94 | 81 |
| Total All Stations | 57 | 820 | 788 |

station (p = 0.000). The average densities observed within the estuary were very similar to those observed in August 1986 (Dinnel et al. 1986b).

Beam Trawl Crab Sizes and Sex Composition

The average carapace width (CW) of all crab caught in the beam trawls was 64 ± 34 mm (1 SD) with average sizes ranging from 55 ± 31 mm to 72 ± 31 mm at Stations 3 and 1.5, respectively (Table 2). There were significant differences (p=0.000) in mean size between stations with smaller crab at Station 3 and larger crab at Station 1.5 than at the bar station and Stations 1 and 2. Average carapace widths are somewhat misleading however, since the size distribution at all locations was composed of several age classes (Fig. 4). Two modes representing 0+ and 1+ crab occurred at about 35 mm and 50 mm respectively at all stations except the bar. Older 0+ crab were often indistinguishable from the smaller 1+ crab, perhaps due to early settlement recorded in the estuary in 1987 or the presence of a large proportion of smaller 1+ crab of 1986 nearshore origin. A range of larger and older (>1+) crab were also found at every station. The size-frequency distribution was very different for the Grays Harbor bar where a distinct mode occurred at about 9 mm CW representing newly settled 0+ crab and another distinct mode occurred at 125 mm representing larger 2+ crab, but no 1+ age class was present. The histograms presented in Fig. 5 show that most (46%) of the crab caught at all stations were of the 1+ age class (45 mm< CW < 100 mm), 36% were 0+ crab (less than 45 mm CW), and 18% were >1+ crab. These results differ from those in August 1986 where the mean CW was 101 ± 30 mm and where most of the animals caught were >1+ crab in their third year of life (Fig. 6).

Male and female crab were significantly different in average CW (p=0.000; non-parametric Mann Whitney test), with males averaging 68 ± 34 mm and females 62 ± 30 mm (Fig. 5, Table 2). The sex distribution of beam trawl-caught crab was skewed. Sixty-six percent of all sexable crab caught were males with individual station percentages of 69%, 71%, 67%, and 63% for Stations 1, 1.5, 2, and 3, respectively. The majority (51%) of all crab caught at the bar station were too small to sex (< 20 mm) and only 19% of the sexable crab were males.

Temperature and Salinity

Surface temperatures ranged from 12.5 to 19.9 °C and bottom temperatures from 9.2 to 16.5 °C (Table 3). Water salinities ranged from 28 to 34 ppt. at the surface and 29 to 34 ppt. at the bottom (Table 3). These values are typical of temperatures and salinities recorded in previous studies during summer months (Stevens and Armstrong 1984; Dinnel et al. 1986b). The fluctuations in each parameter were probably due to interchanges between ocean and estuarine waters with cooler more saline water intruding along the bottom on the flood tide while warmer fresher water was found near the surface.

Table 2. Average carapace widths ($\bar{x}$ in mm) summarized by station and by sex for trawls during August 1-3, 1987 (n = number of crabs, SD = standard deviation).

| Station | All Crab | | | Males | | | Females | | | Unsexed | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | n | $\bar{x}$ | sd | n | $\bar{x}$ | sd | n | $\bar{x}$ | sd | n | $\bar{x}$ | sd |
| 1 | 656 | 62 | 31 | 453 | 63 | 32 | 201 | 60 | 25 | 2 | 18 | 1 |
| 1.5 | 828 | 72 | 31 | 589 | 76 | 32 | 237 | 63 | 25 | 2 | 17 | 3 |
| 2 | 1287 | 65 | 33 | 862 | 68 | 35 | 424 | 58 | 24 | 1 | 19 | - |
| 3 | 741 | 55 | 31 | 467 | 58 | 33 | 269 | 51 | 26 | 5 | 14 | 7 |
| Bar | 201 | 67 | 58 | 20 | 118 | 38 | 87 | 118 | 23 | 94 | 9 | 3 |
| Total | 3713 | 64 | 34 | 2391 | 68 | 34 | 1218 | 62 | 30 | 104 | 9 | 4 |
| Total w/o Bar | 3512 | 67 | 31 | 2371 | 68 | 33 | 1131 | 58 | 25 | 10 | 16 | 5 |

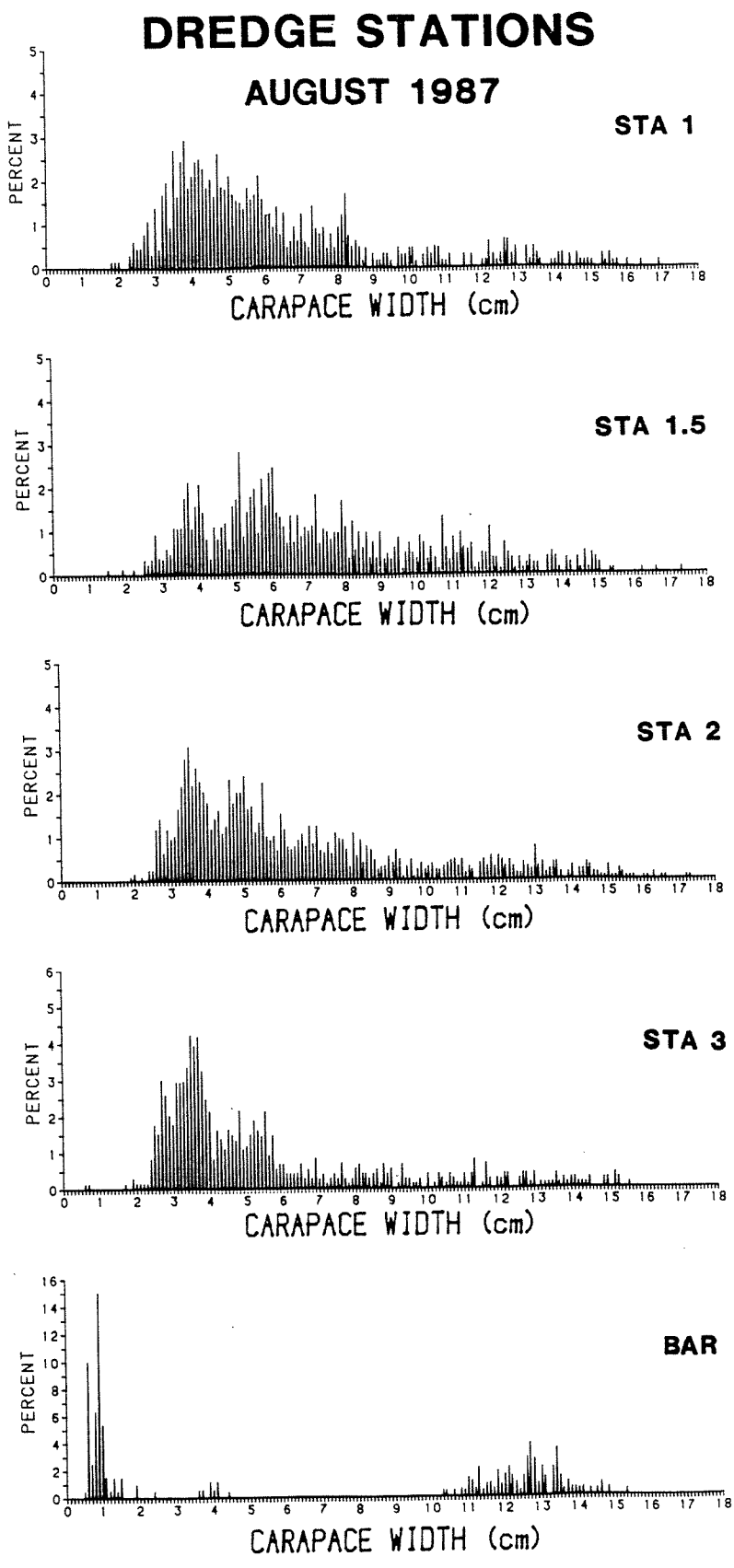


Figure 4. Size-frequency histograms for Dungeness crabs caught by beam trawl at each dredge station, August 1-3, 1987 (see Figs. 1 and 2 for station locations).

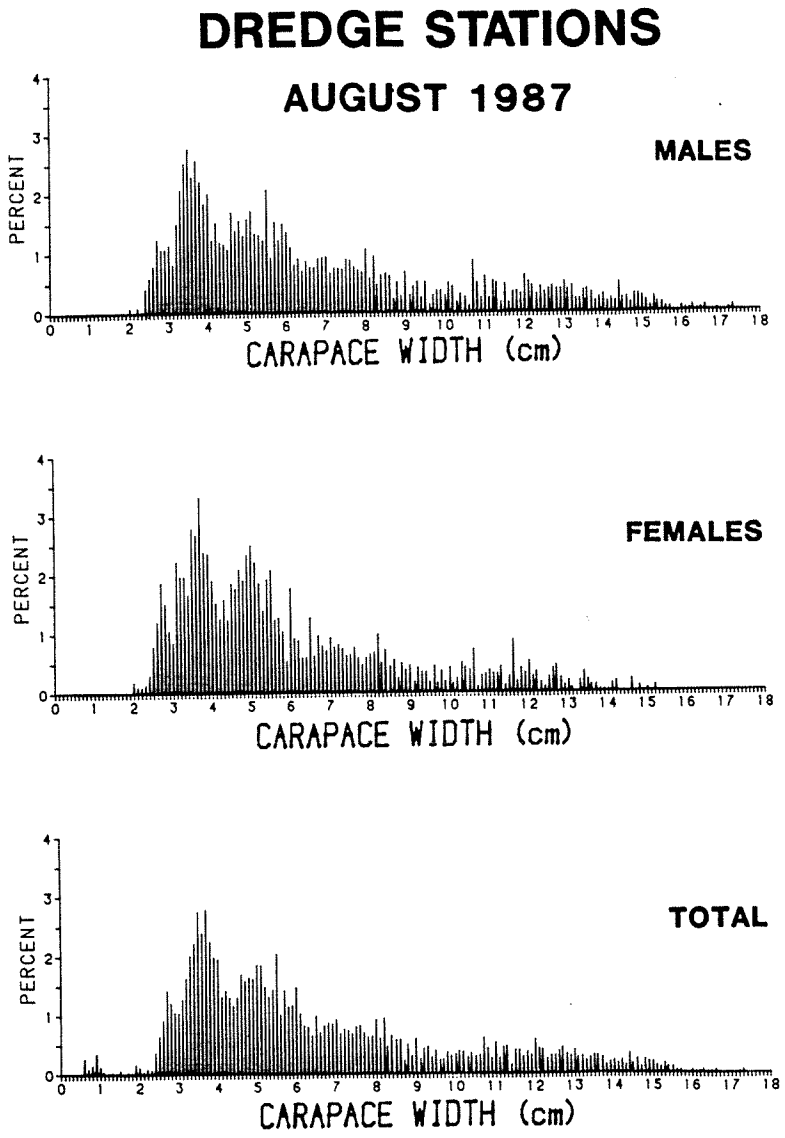


Figure 5. Size-frequency histograms partitioned by sex for Dungeness crabs caught by beam trawl at all dredge stations combined August 1-3, 1987.

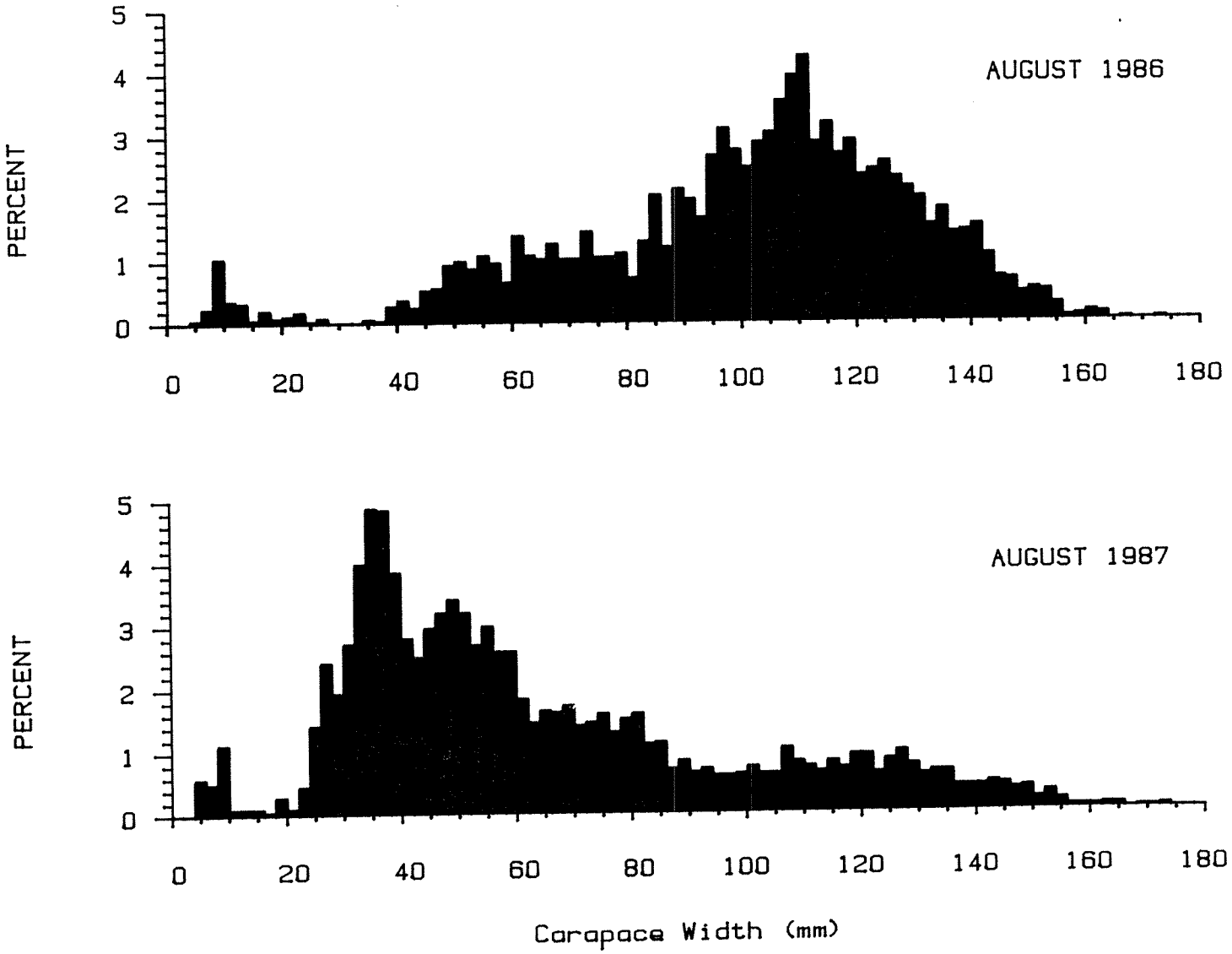


Figure 6. Size frequency histogram for crabs caught during the August 1986 entrainment study compared with that from this study in 1987. Note the large proportion of >1+ crab (>100 mm CW) caught in 1986 and the large proportion of 1+ crab (45 mm< CW < 100 mm) caught in 1987.

Table 3. Temperature and salinity data collected during the August 1987 dredging/trawling study.

| Date | Station | Tide | Temperature (°C) | | Salinity (ppt) | |
|---|---|---|---|---|---|---|
| | | | Surface | Bottom | Surface | Bottom |
| Aug. 1 | 1 | ebb | 15.9 | 15.9 | 31 | 31 |
| | Bar | flood | 15.9 | 11.7 | 32 | 33 |
| Aug. 2 | 1 | high slack | 12.7 | 12.7 | 32 | 32 |
| | 3 | flood | 19.2 | 16.5 | 28 | 31 |
| | Bar | ebb | 13.5 | 9.2 | 33 | 29 |
| Aug. 3 | 1 | flood | 12.5 | 12.5 | 34 | - |
| | 1.5 | ebb | 15.4 | 12.4 | 31 | 34 |
| | 2 | ebb | 17.7 | 15.4 | 30 | 32 |
| | | flood | 18.9 | 13.9 | 29 | 32 |
| | 3 | flood | 19.9 | 14.6 | - | - |

Crab Entrainment During Dredging

A total of 459 samples of 30 sec duration were collected during a three-day period on board the Yaquina from baskets placed at the end of the hopper distribution trough, or diffuser. A total of 2,966 crab were entrained in the samples during the three-day period, but 2,695 were taken at the bar station alone. Average rates of 0.72 crab/sample, 1.4 crab/min of sampling time, and 291 crab/ha of area swept by the dragheads or 0.244 crab/cy (i.e. cy of settled solids) calculated for all stations except the bar, were comparable to previous years estimates. Rates for the bar however, were more than an order of magnitude greater due to the presence of a large number of newly settled young of the year (YOY) crab (32.1 crab/sample, 64.2 crab/min of sampling time, and 11,222 crab/ha of area swept by the dragheads or 9.367 crab/cy of solids).

Comparison Between Dredge and Beam Trawl Crab Catches

Since the dredge entrained an order of magnitude more crab than were caught with the beam trawl at the Grays Harbor bar station, an "average entrainment efficiency" calculated as it has been previously (i.e. assuming the trawl is 100% efficient) is not satisfactory. However, entrainment efficiencies of 53%, 43%, 11%, and 32%, (relative to the trawls) for Stations 1, 1.5, 2 and 3 respectively (Table 4), were comparable to previous estimates at these estuary locations in 1985 and 1986 (Dinnel et al. 1986a, 1986b). At the bar station, where the dredge entrained the equivalent of 11,222 crab/ha, the trawl was only 8% as efficient as the dredge (Table 4). This could have been due to burial behavior by the small juvenile crab caught at this station or gear innefficiency because trawling was made somewhat more difficult by strong currents and rougher conditions on the bar.

Dredge Entrained Crab Sizes and Sex Composition

The average carapace widths of crab caught by the dredge were similar to those for trawl caught crab at each station with the exception of the bar, where the large proportion of 0+ crab caught greatly skewed both averages (Table 4). As with the data from the trawls, average carapace width is misleading, because the size distributions at all locations were composed of several age classes. The predominant size class entrained was composed of 1 year old individuals. The sex distribution of all sexable crab entrained by the dredge was 67% male and 33% female; a distribution essentially equal to the trawl samples (male = 66%, female = 34%). Individual station percentages for males were 80%, 69%, 69%, and 85% for Stations 1, 1.5, 2, and 3, respectively. The reverse was true at the bar station where the majority (98%) of all crab caught were too small to sex and only 17% of the sexable crab were males. These data are in reasonable agreement with those presented for the trawls above.

Table 4. Total and by station comparison of beam trawl versus dredge-entrained Dungeness crab catches in Grays Harbor during August 1987.

| | Number of samples (N) | Estimated Mean Density (crab/ha) | (crab/cy) | Proportion Entrained by Dredge * | Average Crab Carapace Width mm (± 1 SD) Males | Females | Total |
|---|---|---|---|---|---|---|---|
| Station 1 | | | | | | | |
| Trawl | 13 | 504 | - | - | 63 (32) | 60 (25) | 62 (31) |
| Dredge | 95 | 266 | .222 | 53 | 71 (32) | 64 (46) | 75 (46) |
| Station 1.5 | | | | | | | |
| Trawl | 8 | 972 | - | - | 76 (32) | 63 (25) | 72 (31) |
| Dredge | 94 | 419 | .397 | 43 | 52 (29) | 42 (18) | 46 (28) |
| Station 2 | | | | | | | |
| Trawl | 8 | 1561 | - | - | 68 (35) | 58 (25) | 65 (33) |
| Dredge | 92 | 172 | .133 | 11 | 47 (20) | 42 ( 9) | 45 (17) |
| Station 3 | | | | | | | |
| Trawl | 8 | 968 | - | - | 58 (33) | 51 (26) | 55 (31) |
| Dredge | 94 | 307 | .224 | 32 | 56 (41) | 53 (31) | 55 (40) |
| Bar Station | | | | | | | |
| Trawl | 20 | 94 | - | 8 | 118 (38) | 118 (23) | 67 (58) |
| Dredge | 84 | 11,222 | 9.367 | - | 97 (47) | 114 (10) | 11 (13) |

* trawl assumed to be 100% efficient except at bar station.

Not all crab entrained during dredging are killed. The Crab Study Panel (1986) adopted a set of size dependent mortality rates which was used by Armstrong et al. (1987) in their impact analysis. Because a large proportion of the crab entrained in August 1987 were 1+ crab or smaller (especially on the bar) total mortality rates were probably much lower than the 83.8% estimated by Dinnel et al. (1986b) for August 1986.

## Dungeness Crab Population Estimates

### Estuary

Population estimates calculated for four areas (Strata 1 - 4) of Grays Harbor (Fig. 3) show that approximately 2.4 million crab were present in Stratum 1 in the outer harbor area which includes dredging Stations 1, 1.5, 2, and 3 (Table 5). A substantially larger number of crab (4.9 million) were present in North Bay, and approximately 1 million were present in each of the other two strata. A total of about 9.4 million crab was estimated to be present throughout the estuary in August 1987 (Table 5). All of these figures are slightly higher than those recorded during the August 1986 dredge entrainment study (Dinnel et al. 1986b).

The average estimated crab density at Sea Grant trawl stations in Stratum 1 was 669 $\pm$ 599 crab/ha (1 SD) which compares favorably with an average density from the dredge study of 934 $\pm$ 774 for Stations 1, 1.5, 2, and 3 located in the same geographical area but in the main channel only. Although the mean density from the dredge study is slightly higher, the range of densities from individual stations are comparable.

Fifty-two percent of all crab caught during the Sea Grant beam trawl survey in Grays Harbor in August were of the 0+ year class ranging in size (CW) from about 10 to 45 mm (Fig. 7). The average crab size varied with location in the estuary, generally declining as a function of distance into the estuary with mean widths of 70, 46, 41 and 60 mm for Strata 1 through 4, respectively (Table 6). Thus, in Stratum 1, where dredging took place, the dominant age class was 1+ crab with 72% of the crab measuring between 45 and 100 mm CW. This compares with 49% of the crab in this size range caught during the dredge study at Stations 1,1.5, 2 and 3. The size-frequency histograms are similar for dredging and the Sea Grant trawl catches (Figs. 4 and 7).

### Nearshore

The August 1987 population estimate for the total nearshore area was 48.9 million crab with estimates of 13.4, 22.5 and 11.5 million crab for Strata 5, 6 and 7, respectively (Table 5). Ninety-one percent of the crab caught nearshore in August 1987 were YOY less than 25 mm in size (Fig. 8). This figure was lower for Stratum 5 (0 to 15 m depth) where 63% of the crab were YOY less than 25 mm in carapace width and a significant portion (27%) were >1+

Table 5. August 1987 Dungeness crab population estimates from Grays Harbor and nearshore Sea Grant stations. Refer to Fig. 3 for a description of the strata boundaries.

| Description and Stratum | Area (ha) | Crab Density (#/ha + 2SE) | Population Estimate (millions + 2SE) |
|---|---|---|---|
| Estuary | | | |
| 1 = Outer Harbor | 3,641 | 669 ± 599 | 2.44 ± 2.19 |
| 2 = North Bay | 2,516 | 1959 ± 875 | 4.91 ± 2.20 |
| 3 = Inner Harbor | 1,548 | 702 ± 273 | 1.09 ± 0.42 |
| 4 = South Bay | 830 | 1135 + 770 | 0.94 + 0.64 |
| Total Estuary | 8,545 | 1097 ± 374 | 9.38 ± 3.20 |
| Nearshore | | | |
| 5 = 0 to 15 m depth | 30,389 | 441 ± 264 | 13.40 ± 8.03 |
| 6 = 16 to 40 m depth | 57,659 | 391 ± 383 | 22.55 ± 22.10 |
| 7 = 41 to 73 m depth | 58,551 | 196 + 242 | 11.48 + 14.16 |
| Total Nearshore | 146,599 | 323 ± 187 | 48.90 ± 28.17 |

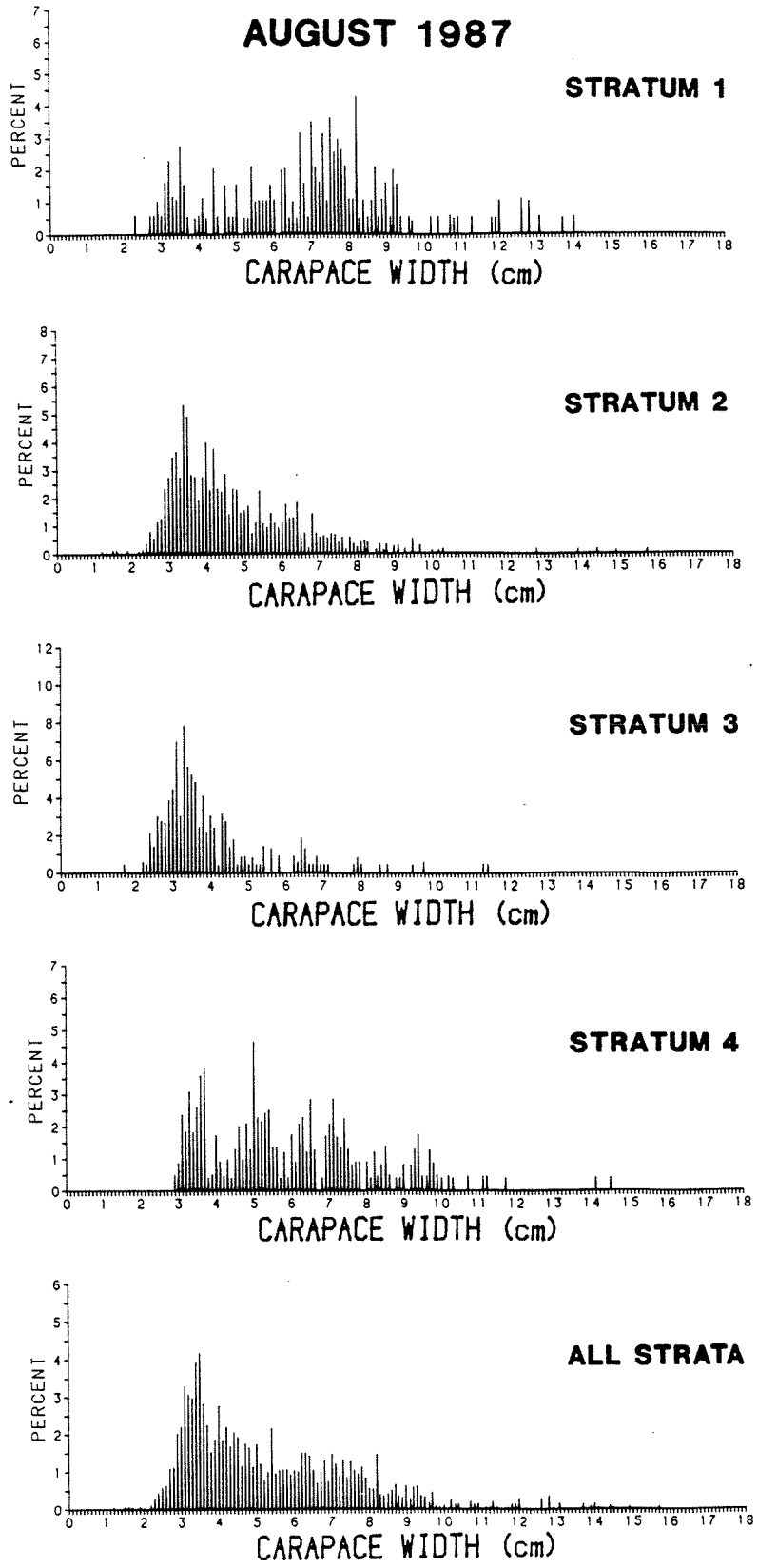


Figure 7. Size-frequency histograms for all Dungeness crabs caught in Grays Harbor in August 1987 during routine sampling to estimate the resident population in four geographic strata (see Fig. 3).

Table 6. Average carapace widths (± 1SD) summarized by stratum for trawls taken by Sea Grant researchers in Grays Harbor and the nearshore coastal area in August 1987. See Fig. 3 for stratum designations.

| Stratum | Location | Number of Crabs | Mean Carapace Width (mm) | SD |
|---|---|---|---|---|
| Estuary | | | | |
| 1 | Outer Harbor | 190 | 70 | 24 |
| 2 | North Bay | 815 | 46 | 17 |
| 3 | Inner Harbor | 187 | 41 | 16 |
| 4 | South Bay | 227 | 60 | 22 |
| Nearshore | | | | |
| 5 | 0-15 m depth | 479 | 49 | 50 |
| 6 | 15-40 m depth | 2,327 | 18 | 20 |
| 7 | 40-73 m depth | 358 | 18 | 19 |

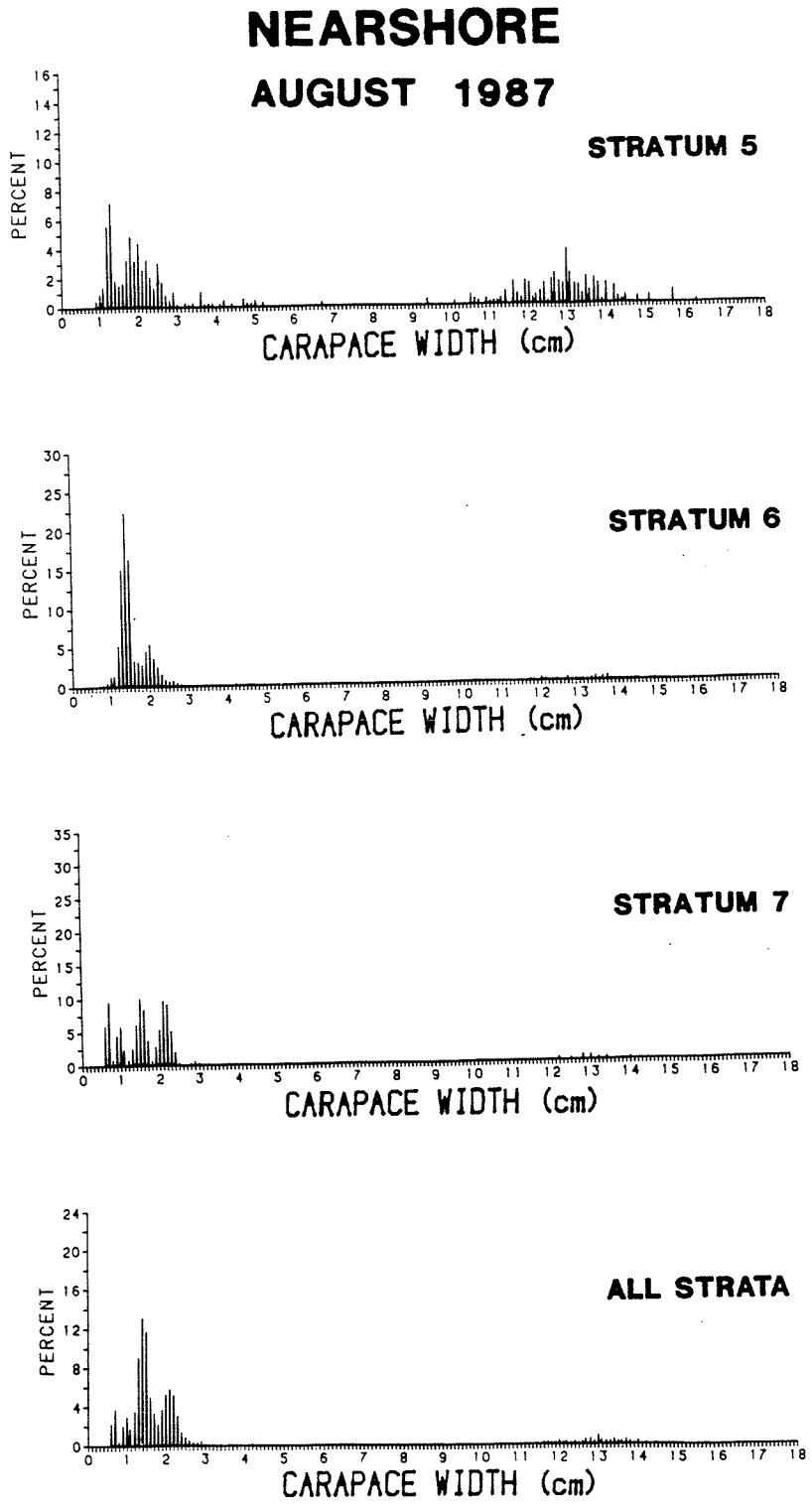


Figure 8. Size-frequency histograms for Dungeness crab caught in each of three nearshore strata in August 1987 (see Fig. 3 for strata locations).

crab (>100 mm). Mean carapace widths of 50, 20, and 19 mm for Strata 5, 6, and 7, respectively (Table 6) reflect the same trend. Data from the bar station (located within Stratum 5) in this study also compare favorably, with 47% of the crab measuring less than 25 mm CW and 49% greater than 100 mm. Most of the larger crab caught in Stratum 5 were females as was also true for both dredge and trawl samples at the bar station.

Small 0+ crab suffer a high natural mortality rate (typically greater than 90%) compared with older year class crab (Armstrong et al. 1987). Hence, only a small fraction of the roughly 49 million YOY crab estimated to be in the nearshore area will probably survive to the following year. In contrast, YOY crab caught in both Sea Grant and dredge-related trawls in the estuary had grown to a much larger size (25 to 45 mm), having spent a summer growing in the estuary. Therefore, the importance of the 9.4 million crab in the estuary to the fishery (or reproduction by the females) may be as great or greater than the eventual contribution of the entire August nearshore population (49 million).

## CONCLUSIONS

1. Beam trawl samples for Dungeness crab in August 1987 indicated average estimated densities of 504, 972, 968, and 1561 crab/ha at four stations in the South Channel of Grays Harbor and 94 crab/ha at one station on the Grays Harbor bar. The average estimated crab density for all of the estuary trawls (n=37) was 934 crab/ha.

2. There was a significant difference in beam trawl catch of crab between stations, with a lower mean density at the Grays Harbor bar station.

3. There was a highly significant difference in crab sizes between station (Station 3 < Stations 1,2, Bar < Station 1.5) and between sex (females < males). More females than males were caught at the Grays Harbor bar location.

4. Based on the areas swept by the beam trawl and the dragheads, estimated entrainment of crab by the Yaquina ranged from 11% to 53% of those caught by the beam trawl in the estuary. The dredge was more efficient than the trawl at catching crab on the Grays Harbor bar where the trawl caught only 8% of the number entrained by the Yaquina. This was probably due to sampling conditions and trawl innefficency and the fact that the majority of the crab caught on the bar were less than 20 mm CW.

5. Crab entrainment sampling aboard the dredge Yaquina caught 271 Dungeness crab during a total of 187.5 minutes of sampling (n=375 30 sec samples) in the estuary. These catches were equal to 0.72 crab/sample, 1.4 crab/min of sampling time, and 291 crab/ha of area swept by the dragheads or .244 crab/cy of solids and were comparable to previous estimates. Estimates for

the bar were calculated separately because of the high number of 0+ crab entrained (total of 2,695 crab, 2,653 0+ crab, n= 84 30 sec samples) for an equivalent of 32 crab/sample, 64 crab/min of sampling time, and 11,222 crab/ha of area swept by the dragheads or 9.367 crab/cy of solids.

6. Although large numbers were entrained, especially at the bar, total mortality of Dungeness crab entrained by the Yaquina was probably less than that in August 1986 based on the large percentage of 1+ and smaller crab entrained in 1987 and lower estimated dredge-induced mortality for these smaller crab.

7. Crab size-frequency distributions from trawl samples show that at least 3 year classes of crab (0+, 1+ and 2+) were sampled at the five dredge stations. Overall, crab entrained by the dredge averaged slightly smaller than crab caught by the trawls. The male:female ratio was about the same for both sample methods with males outnumbering females by the approximate ratio of 2 to 1 in the estuary and females outnumbering males on the bar. A large proportion of the crab caught at the Grays Harbor bar station (91% and 47% for the dredge and trawl, respectively) were newly settled 0+ crab and too small to sex.

8. Dungeness crab population estimates for Grays Harbor estuary during August 1987 indicated the presence of 9.4 million crab in the estuary and 2.4 million crab in the vicinity of the estuary mouth (Stratum 1) where dredging was taking place.

10. Beam trawl sampling nearshore of Grays Harbor and Willapa Bay generated an August 1987 population estimate of 48.9 $\pm$ 28.2 million crab. However, roughly 91% of the nearshore crab caught by the trawl were young-of-the-year (size < 25 mm) which typically suffer a high mortality and, hence, an expected great reduction in numbers by 1988. Thus, the generally older and larger crab in the estuary may contribute as many or more crab to the fishery than the August nearshore population.

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