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Title: THE ABUNDANCE, DISTRIBUTION, AND ECOLOGY OF THE TANNER CRAB, *Chionoecetes tanneri* Rathbun, ON THE SOUTHERN OREGON CONTINENTAL SLOPE.

Abstract approved: Redacted for Privacy
Andrew G. Carey

Eleven cruises were conducted on the Oregon continental slope from April 1973 to March 1975 to assess the biology and ecology of the Tanner crab, *Chionoecetes tanneri* Rathbun. Bathymetric and seasonal analysis of the distribution of adult Tanner crabs west of Coos Bay, Oregon, revealed no segregation of sexes or seasonal migration. Relative abundance of adult crabs was greatest in the 500-700m depth range. Juveniles were found throughout the adult depth range. Density estimates using a three meter beam trawl were 0-500 crabs/km^2 (mean = 56) for adult male *C. tanneri* and 0-1100 crabs/km^2 (mean = 164) for adult females. Stock estimates for the Oregon coast (500-700m) and for the Oregon and Washington coasts (457-869m) supported Pereyra's (1972) conclusion that a Tanner crab fishery would not be feasible at this time. Longline pot fishing was suggested as a better method of assessing the commercial potential of the Tanner crab stock. Hydrological and sediment data indicated that the Tanner crab environment is a relatively stable one temporally and spatially in the study

area. There was no apparent relationship between the presence or absence of adult _C. tanneri_ and temperature, salinity, dissolved oxygen, sediment organic carbon content, or sediment particle size.

The Abundance, Distribution, and Ecology of the Tanner crab, *Chionoecetes tanneri* Rathbun, on the Southern Oregon Continental Slope

by

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INTRODUCTION

Background

The recent vast increase in the fishery for *Chionoecetes bairdi* and *C. opilio* in Alaskan waters and the Bering Sea (Wheeland, 1972) has catalyzed an interest in their deep water relative *C. tanneri*, the Tanner crab. This species occurs on the continental slopes of Washington, Oregon, and California at depths from 400-2000m (Rathbun, 1925; Pereyra, 1972). Hart (1971) reported the range extending from 53° 01'N to 37°17'N.

Little was known about the Tanner crab until a cooperative investigation by the National Marine Fisheries Service and United States Atomic Energy Commission resulted in a series of 307 bottom trawls off the Columbia River mouth from June 1961 to June 1966. Large catches of Tanner crabs were made and the data were published in a series of papers by Pereyra (1965, 1966, 1967, 1968, and 1972). This work was the first attempt at a comprehensive seasonal study of the abundance, distribution, and life history of a deep water crab. There are only two other species of deep water crabs whose commercial potential would warrant an in-depth study: *Chionoecetes japonicus* in the Sea of Japan, and the red crab, *Geryon quinquedens*, of the Atlantic coast of North America. There is only meager mention of *C. japonicus* in the Japanese literature dealing with fecundity (Fukataki, 1965), crab trap efficiency (Sinoda and Kobayashi, 1969), and general occurrence (Ogata, et.al., 1973). The red crab has been the subject of isolated exploratory trawling programs (Schroeder, 1959; MacRae, 1961; Meade and Gray, 1974; Haefner and Musick, 1974). None were of a seasonal nature and all were aimed at obtaining catch per unit effort estimates. Very little is known about growth, size at maturity, migration, or stock size. Nevertheless, a pot fishery for the red crab is in the early stages of development at this time (Holmsen and McAllister, 1974).

Pereyra (1972) concluded that a fishery for *C. tanneri* alone would not be feasible because 1) trawlers are not equipped to fish deeper than 250 fathoms (457m), and 2) current commercial stocks of Dungeness crab (*Cancer magister*), king crab (*Paralithodes camtschatica*), and snow crab (*C. opilio* and *bairdi*) are larger and easier to fish than *C. tanneri*. The combination of these two factors would make a Tanner crab fishery uneconomical.

There are other considerations which make the possibility of a Tanner crab fishery more probable. Pereyra (1972) mentions several: Tanner crabs could be taken incidental to other species such as sablefish, *Anoplopoma fimbria*; a pot fishery such as that used by the Japanese for *C. japonicus* or that contemplated for the red crab in the Atlantic might be feasible; and the proximity of the Tanner crab to the West coast market is attractive. Commercial interest in the local Tanner crab stocks was expressed by Coos Bay fishermen and seafood processors (William Barss, Oregon Fish Commision, Charleston, Oregon, personal communication with Pat Tester). King crab catches have been declining in recent years (Alaskan Department of Fish and Game, 1970), causing increasing exploitation of *C. bairdi* and *opilio* stocks. The ability of the "snow" crab to withstand this increased fishing pressure is not known. The International North Pacific Fisheries Commission notes in its Annual Report of 1972 that research is lagging considerably behind fishing effort. The possibility of this situation happening to a Tanner crab fishery has prompted the research outlined below.

Research Objectives

Three areas of inquiry concerning *C. tanneri* need further study before a fishery can be intelligently established off Oregon and Washington: 1) life history, 2) distribution, and 3) abundance. Life history aspects of the benthic biology of *C. tanneri* are perhaps least well understood - growth, fecundity, and mortality; size at maturity; and population age structure. The distribution and abundance results of Pereyra should be verified, preferably in a region of the Oregon continental slope with different environmental characteristics. These areas of research are objectives of a Tanner crab research program conducted by the School of Oceanography, Oregon State University. Life history-related aspects of this program are treated in a separate M.S. thesis by Tester (1976).

The objectives remaining for this portion of the study are threefold. First, the bathymetric and seasonal distribution of *C. tanneri* is examined on the Southern Oregon continental slope. Second, a stock estimate using the three meter beam trawl is attempted which serves as a comparison to Pereyra's stock estimate. Finally, an attempt is made to examine the general ecology of *C. tanneri*, in particular the factors affecting the distribution of this crab. This final objective deserves further explanation.

The factors that might influence benthic animal distribution in the deep sea can be divided into physical and biological categories. They may act independently, or they may interact. Important physical factors are pressure, sediment characteristics, hydrological parameters, and perhaps bottom topography. Most attention has been given to animal-sediment interactions (Carey, 1965, 1972; Sanders, 1965; Hartnoll, 1962; Buchanan, 1963; Bader, 1954). I will concentrate on sediment and hydrological characteristics in this study.

The effects of pressure are not well understood and are probably underestimated (Flügel, 1972). Biochemical systems may be greatly affected by pressure (Hochachka, et.al., 1970). Any analysis of pressure effects is beyond the means of this project.

The effect of topography could be important. Do crabs prefer level areas as opposed to the sides of hills? Does topography affect migration? These questions are difficult to answer; sampling must be done on different topographic regimes. Isolation of these environments and trawling successfully on them presents real problems.

The effects of temperature, salinity, and dissolved oxygen cannot be ruled out. The distribution of the red crab in the Atlantic is believed to follow the 38-40°F (3.33-4.33 °C) isotherms (Holmsen and McAllister, 1974).

The most important biological factor in the deep sea is probably food supply. It may be a primary limiting factor (Vinogradova, 1962; Menzies, 1962; Sanders and Hessler, 1969). In order to understand its effect, one must know the feeding habits of the animal under study and obtain information on the abundance of the potential food supply. Stomach content analysis of crabs is difficult because they grind their food considerably in the mandibles and gastric mill. Consequently, the contents of the stomach are not easily identified. A Japanese worker (Yasuda, 1967) attempted to analyze the gut contents of Chionoecetes opilio. He examined the contents of 1500 stomachs under a microscope and compared this with the residues (skeletons, spicules, shell framgents) obtained by boiling various benthic animals in potassium or sodium hydroxide. His results indicated that C. opilio was a food generalist and was cannabilistic. Butler (1954) analyzed 170 stomachs of Cancer magister of the Pacific coast of Canada. Crustaceans (amphipods, mysids, barnacles) and clams were most important. His results also indicate cannibalism and a generalized feeding habit. Hartnoll (1962) examined the stomach contents of 14 species of shallow water spider crabs. He found no seasonal variation in diet; diets were never completely specialized; and stomach contents were influenced by the available food.

These studies support the idea of a generalized feeding habit with possible cannibalism and opportunism in certain Brachyuran crabs. I have not examined the food sources of C. tanneri. This is based on two factors - the difficult and time consuming nature of crab stomach analyses, and a belief that the Tanner crab is also a food generalist.

To summarize, the objectives of this research are to examine the bathymetric and seasonal distribution of C. tanneri, to assess the stock size of the Tanner crab population, and to attempt to correlate the distribution of C. tanneri with various properties of the benthic environment.

MATERIALS AND METHODS

Sampling Area

The criteria for a suitable sampling area were: 1) proximity to the fishing community, and 2) trawlability of bottom topography. The continental slope west of Coos Bay, Oregon, ($43^{o}21$'N, $124^{o}20$'W) appeared to fit these needs better than any other region of the Oregon continental slope. There is a sizeable fishery located in Coos Bay for groundfish and shrimp, and there are extensive areas of trawlable slope off Coos Bay and further south off Cape Blanco, Oregon. The topography in this region is considerably less uniform than off the Columbia River. These considerations led us to establish our standard series of track lines in the Coos Bay area (Figure 1 and Appendix 1).

Two areas were sampled in addition to the Coos Bay region. Information pertaining to large catches of Tanner crabs by groundfishermen in relatively shallow water (300m) off Cape Blanco led us to sample a series of track lines on two cruises in that area (Figure 1, Appendix 1). A desire to compare the results of our sampling gear with Pereyra's led to a series of trawls on one cruise in his area southwest of the Columbia River (Figure 1, Appendix 1).

The seasonal depth distribution of C. tanneri was studied by establishing a series of track lines covering the known depth distribution of the Tanner crab. As many as possible were sampled on each cruise. Track lines were established paralleling depth contours in areas where bathymetric charts indicated the slope to be trawlable.

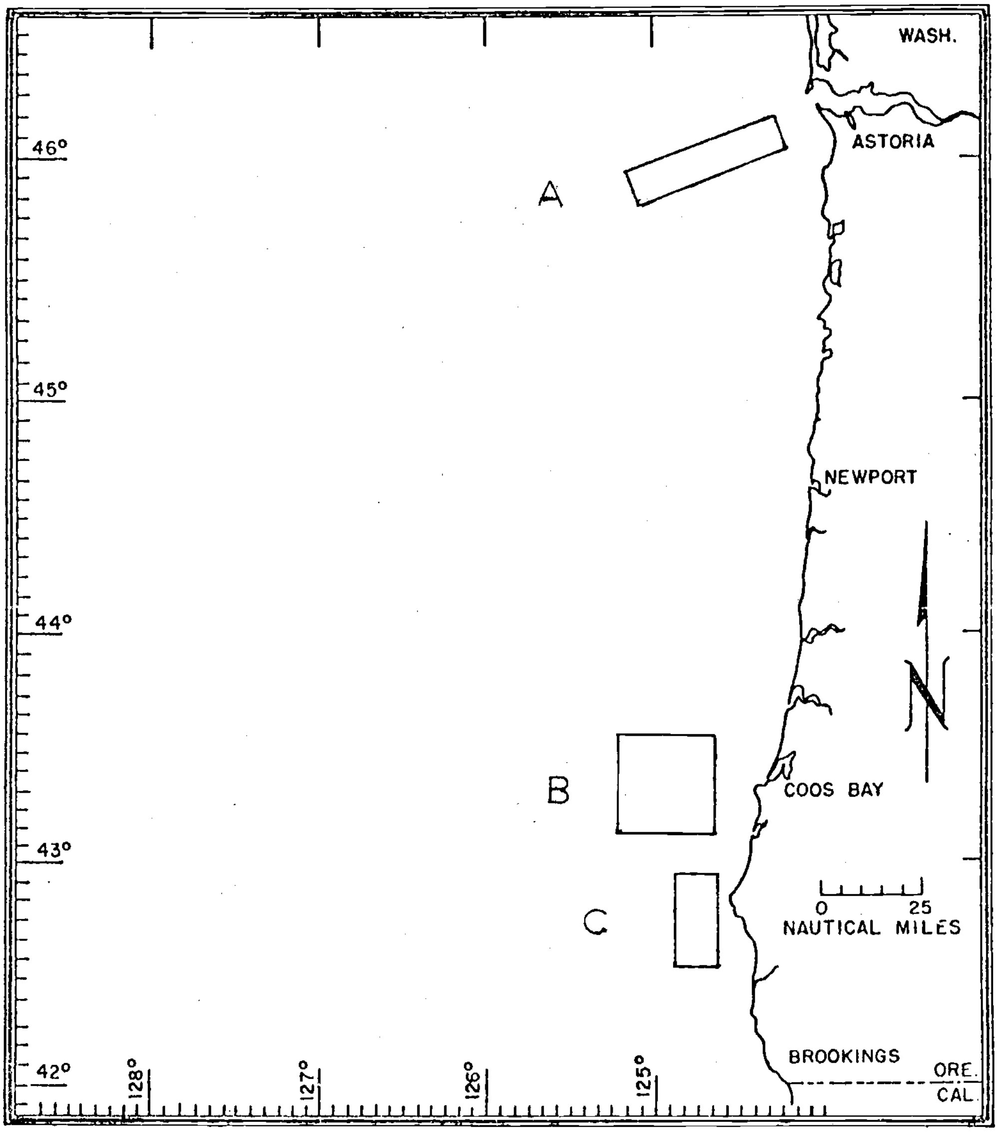

Figure 1. Tanner crab sampling areas on the Oregon continental slope. A = Pereyra's area. B = Coos Bay area. C = Cape Blanco area.

Table 1. Date, location, and duration of Tanner crab cruises on the Oregon continental slope.

No.	Date	Location	Duration in Days
1	April 1973	Coos Bay	5
2	August 1973	Coos Bay	6
3	October 1973	Coos Bay	6
4	Nov-Dec 1973	Coos Bay	5
5	March 1974	Coos Bay	5
6	June 1974	Coos Bay	10
7	July 1974	Coos Bay Cape Blanco	10
8	August 1974	Coos Bay Astoria	10
9	September 1974	Cape Blanco	3
10	January 1974	Coos Bay	3
11	March 1974	Coos Bay	5

Ship time was scheduled so as to obtain seasonal data, although complete freedom for scheduling cruises was not available. The calendar year was divided into seasons after Pereya (1972): winter - January through March; spring - April through June; summer - July through September; and fall - October through December. Table 1 lists all Tanner crab cruises, time of year, and duration. Two seasonal cycles of sampling were accomplished with the exception of a fall cruise in 1974. Approximately one fourth of the ship time was lost due to rough weather or ship malfunction.

Sampling Gear

Two types of gear were used to catch crabs and related fauna. A seven meter semi-balloon shrimp trawl (hereafter referred to as "otter trawl") with 1.5 inch (3.4 cm) stretch mesh and lined completely with 0.5 inch (1.1 cm) stretch mesh was used for qualitative sampling. A three meter beam trawl designed and built by Andrew G. Carey, School of Oceanography, was used to obtain quantitative samples. (See Carey and Heyamoto, 1972, for detailed explanations of both types of gear.)

The otter trawl is the largest size that can be conveniently fished from the R/V CAYUSE, an 80 ft. vessel used on all but the last cruise. Mechanical features of the CAYUSE (single winch and boom) and manpower considerations (scientific crew of eight) prevent the use of a significantly larger trawl with its resultant bridle length, door size, and catch-size potential.

The three meter beam trawl is essentially a modified otter trawl net suspended between a semi-rigid framework to achieve a constant mouth opening. A pair of eight inch (20.2 cm) skids serve as attachment points for the trawl, and a three meter aluminum beam connects the skids while insuring a constant fishing width. An odometer wheel two meters in circumference attached to each skid permits estimation of the distance travelled over the bottom. Since the trawl width is known and assumed constant, an estimate of bottom area covered per trawl can be calculated. The dimensions of the model used in this study resulted in an area trawled of 5.44 m^2 per revolution. Only a fraction of the standard track lines were used for beam trawling because of their relative smoothness.

The complete Benthic Ecology beam trawl records have been extensively analyzed by Carney (personal communication). The results, although inconclusize as to the reliability of area estimation, indicate that the beam trawl underestimates the area trawled. This is based on a comparison of time-depth recorder records (time on bottom), ship speed, distance trawled according to position fixes, and wheel readings. The degree of underestimation is uncertain. Ninety-five percent of the pairs of wheel readings were within a factor of two of each other. If the difference between the two readings is greater than this, and one of the readings is extremely low, the wheel registering the lower reading is considered unreliable and the higher reading should be used. The correlation between left and right wheel readings was 0.809 (N=350), highly significant (1%). Correlation between left and right wheel readings for this study was 0.72 (N=69), also significant (1%). The same correlation after eliminating pairs different by at least a factor of two was 0.84 (N=61). Based on these results and Carney's recommendations, I used an average of the two readings if the difference was less than a factor of two, and I used the higher reading if the difference exceeded a factor of two.

Sediment samples were obtained with a multiple corer (Fowler and Kulm, 1966). Prior to the June 1974 cruise, one drop was made at the beginning of each trackline. During the June 1974 cruise, a drop was made at the beginning and end of each trackline to test for trackline variation in sediment type.

Water samples and temperatures were obtained through the March 1974 cruise with a bottom-contact-activated Fjarlie water bottle and attached oceanographic reversing thermometers. A frame for the water bottle which bolted to the top of the multiple corer and permitted sampling the water approximately one meter above the sea floor was used (Ruff and Oliver, unpublished data). This design also insured intimately associated sediment and water samples. After June 1974 water samples and temperatures were obtained with an NIO bottle by separate hydro cast because of damage to the Fjarlie bottle. In this case a pinger was used to locate the sampler close to the bottom.

Sample Processing and Analysis

Trawl catches were treated differently depending on the gear used. Normally, only crabs were kept from otter trawl catches. The general character of the invertebrate and vertebrate fauna was noted before it was discarded. The entire invertebrate catch of the beam trawl was saved; fish were counted by type and discarded. For both types of gear stomach contents of the larger fish were examined for juvenile crabs.

Samples were either preserved in 10% buffered formalin or frozen (crabs only). All measurements and observations of the crabs were performed in the laboratory, not at sea. The associated invertebrate fauna from the beam trawls was sorted to the species level if possible, counted, and weighed (wet preserved weight).

On all cruises prior to June 1974, only one core was kept from each station. Two cores were kept from each drop made after March, 1974. Core tubes were capped and frozen on board ship for later analysis.

Core samples were subjected to analysis of sediment particle size and organic carbon content. For all stations where only one core was available, that core was subjected to organic carbon analysis. Particle size analysis was done by an hydrometer method (Carlson, et.al., 1966). This is a modification of the American Society for Testing and Materials method D422-63 (1963). The modification lies in filtering the sediment sample before analysis to remove the flocculating effect of sea water. Results of the hydrometer analysis were analyzed by a computer program which calculates cumulative frequencies, % silt, % clay, and various, descriptive statistics (Inman, 1952; Trask, 1932; Folk and Ward, 1957).

Total carbon and carbonate carbon content of the sediments (% by weight) were determined by a LECO carbon analyzer. A dried sample is heated in dry, purified oxygen, and CO_2 released is collected and measured. Carbonate carbon is determined by pretreating a sample in a muffle furnace at 333 ^{o}C to burn off the organic carbon. The remaining sediment is then analyzed in the LECO carbon analyzer. Organic carbon is calculated by subtracting carbonate carbon from total carbon.

Water samples were analyzed for dissolved oxygen and salinity. Dissolved oxygen was determined on board ship using the Winkler titration method (Strickland and Parsons, 1972). Salinity was determined in the laboratory using a Bissett-Berman model 6230 inductive salinometer. Temperatures were obtained with standard oceanographic reversing thermometers.

RESULTS

General Characteristics of the Tanner Crab Population

Mean carapace width was measured across the widest portion of the carapace excluding lateral spines (Table 2). Mean weights were calculated from crabs which had all ten legs present (Table 2). A regression equation for weight of adult males was generated by Tester (personal communication): Weight (g) = 15.425 (Width in mm) - 1389.7, $R^2 = 0.83$. Substituting the mean width for adult males of 140.4 mm gives a mean weight of 0.776 kg (1.71 lb). This compares favorably with the weight of 0.765 kg (1.68 lb) obtained using crabs with all legs. A suitable regression equation could not be developed for adult females because of the variation in egg mass weight (Tester, personal communication).

The adult female:male sex ratio is 2.4:1 (Tester, 1976). The juvenile sex ratio does not differ significantly from a 1:1 ratio. Size at maturity corresponds to a carapace width of 118 mm for males and 85 mm for females. For analysis of size frequency distributions, age-class structure, and growth see Tester (1976).

Distribution

Eleven Tanner crab cruises off Oregon resulted in 187 otter trawl and 86 beam trawl samples. Of these, 156 (83%) of the otter trawls and 76 (88%) of the beam trawls were successful, i.e. a bottom sample was obtained. Only trawls from the Coos Bay area were used in the distribution analysis (Table 3). Since it was necessary to maximize the

Table 2. Size of adult Tanner crabs on the Oregon continental slope. Compiled from all cruises.

	N	Mean Width (mm)	Range	Mean Weight (kg)	Range
Adult males	119	140.4	90.2-166.0	0.765*	0.329-1.120
Adult females	289	102.3	85.4-120.4	0.269*	0.156-0.471

* - N for weight is 38 for adult males and 101 for females.

Table 3. Catch analysis of Tanner crabs for the Coos Bay, Oregon, sampling area.

	CATCH											
	Actual				Per Hour							
Cruise	AF[c]	AM	JF	JM	AF	AM	JF	JM	Total[a] Number of Trawls	Number of Beam Trawls	Zero[b] Data	Trawl Time Mins.
CR1	30	6	55	31	38	8	78	46	21	0	7	826
CR2	63	37	77	93	97	59	116	145	23	0	1	885
CR3	29	16	90	88	39	22	117	114	20	0	3	860
CR4	10	8	45	66	14	11	60	90	16	0	5	695
CR5	11	12	40	30	22	23	77	57	21	0	6	690
CR6	88	12	82	81	128	16	104	106	26	8	4	1222
CR7	5	11	40	45	8	15	58	62	26	13	9	1080
CR8	3	4	53	65	6	4	67	79	19	9	5	995
CR10	9	1	42	54	10	1	45	57	10	10	4	465
CR11	4	2	27	48	5	3	36	64	8	8	1	365
Total	252	109	551	601	367	162	758	820	190	48	45	8083

a - Total number of trawls equals number of successful trawls (i.e. sample obtained)
b - Zero data refers to successful trawls which caught no crabs
c - AF = adult female; AM = adult male; JF = juvenile female; JM = juvenile male

number of crabs per depth interval, otter and beam trawl catches/hr were combined. Catch/hr of each age-sex class by otter and beam trawls follows the Poisson distribution. Mean catch/hr for the two gear types can be compared by using a test statistic which approximates the normal distribution (Brownlee, 1965):

$$t_{test} = \frac{x_1 - \frac{1}{2} - (x_2 + \frac{1}{2})}{\sqrt{x_1 + x_2}}$$

where x_1 = mean of sample one, x_2 = mean of sample two. The mean catch/hr of the two trawls is not significantly different for any age-sex class (Table 4). Based on the size of the mouth opening, the effective fishing area of the two trawls is similar. Qualitatively, the volume of the catch did not appear different at sea.

Differences in trawl performance between tows are inescapable. Every effort is made to tow at a constant ship speed, but differences in length of trawling wire, sea conditions, and bottom topography unavoidably affect trawl performance. The only correction that can be made is to normalize to one hour effort. Ricker (1940) considers catch per unit effort a valid indication of relative abundance. For this study, trawl time begins when all wire is paid out and ends when the trawl starts in. Appendix 2 lists catch data by trawl. For any one station during any one cruise, there are not enough trawls to statistically analyze catch variability. However, the large number of zero trawls (no crabs) indicates that variability from trawl to trawl was high. This should be viewed as a major qualification of the data.

After correcting all trawls to one hour effort, the data were

Table 4. Comparison of mean catch/hr of Tanner crabs by otter trawl and beam trawl for each age-sex class.

$H_o: u_1 = u_2 \quad H_a: u_1 \neq u_2$

Age-Sex Class	Test Statistic	Conclusion
Adult female	-0.3782	Do not reject H_o
Adult male	-0.3907	Do not reject H_o
Juvenile female	-0.3151	Do not reject H_o
Juvenile male	-0.4298	Do not reject H_o

partitioned into 50m depth intervals (Table 5). The results were graphed for each cruise and age-sex class of Tanner crab (Figures 2-5). For each depth interval, total catch/hr was divided by total hours fished, including zero trawls, giving an average catch/hr as the measure of relative abundance. The numbers are quite low because of the large number of zero trawls, and because of the low actual catch per trawl.

Minimum depth of occurrence of adult females was 439m; maximum depth was 904m (Figure 2). Generally, the female population appears to be centered between 400-700m. There is some tendency for decreased catches with depth. Peaks of abundance with depth are not evident. There is no seasonal bathymetric shift in the population.

Depth distribution of adult males ranged from 521-1528m (Figure 3). There is no distinct center or optimum range visible. Adult males are spread bathymetrically more than females. As with adult females there is no detectable seasonal shift in depth range.

The minimum depth for juvenile female Tanner crabs was 402m; maximum depth of ocurrence was 1500m (Figure 4). There is no strong trend of relative abundance with depth. Catch/hr generally increases to a peak at 600-700m. Below this it is unclear what the pattern is. Lack of effort below 900m in cruises 3,4,5,6,10, and 11 makes interpretation of cruises 1,2,7, and 8 difficult. No seasonal pattern is obvious. The 600-700m peak is fairly constant. When effort was made in deeper water (below 800m), we caught crabs regardless of season (cruises 1,2, 5, and 8).

Juvenile males were caught as shallow as 439m and as deep as 1550m

Table 5. Partition of trawling effort for Tanner crabs by 50m depth interval and cruise.

	Number of Trawls										
Depth Interval	CR1	CR2	CR3	CR4	CR5	CR6	CR7	CR8	CR10	CR11	Total
400-449m		1		1		1			1		4
450-499	1			2		2		2			7
500-549	1	3	4	5	2	10	2	1	1	2	31
550-599	2	2	2		5	3	5	3	3	1	26
600-649	2	4	8		5	7	5	3	4	3	41
650-699	3	6	5	4	6	2	5	4		1	36
700-749	2				2				1	1	6
750-799							1				1
800-849	1	1		2				2			6
850-899	1						1				2
900-949		1	1	2			1				5
950-999		2									2
1000-1049	1						1				2
1050-1099		1					2	1			4
1100-1149											0
1150-1199	1	1									2
1200-1249											0
1250-1299											0
1300-1349								1			1
1350-1399	2				1						3
1400-1449											0
1450-1499								1			1
1500-1549		1				1	1				3
1550-1599							1	1			2
1600-1649	2										2
1650-1699											0
1700-1749											0
1750-1799											0
1800-1849											0
1850-1899											0
1900-1949							1				1
1950-1999											0
2000-2049	1										1
2050-2099											0
2100-2149	1										1
Totals	21	23	20	16	21	26	26	19	10	8	190

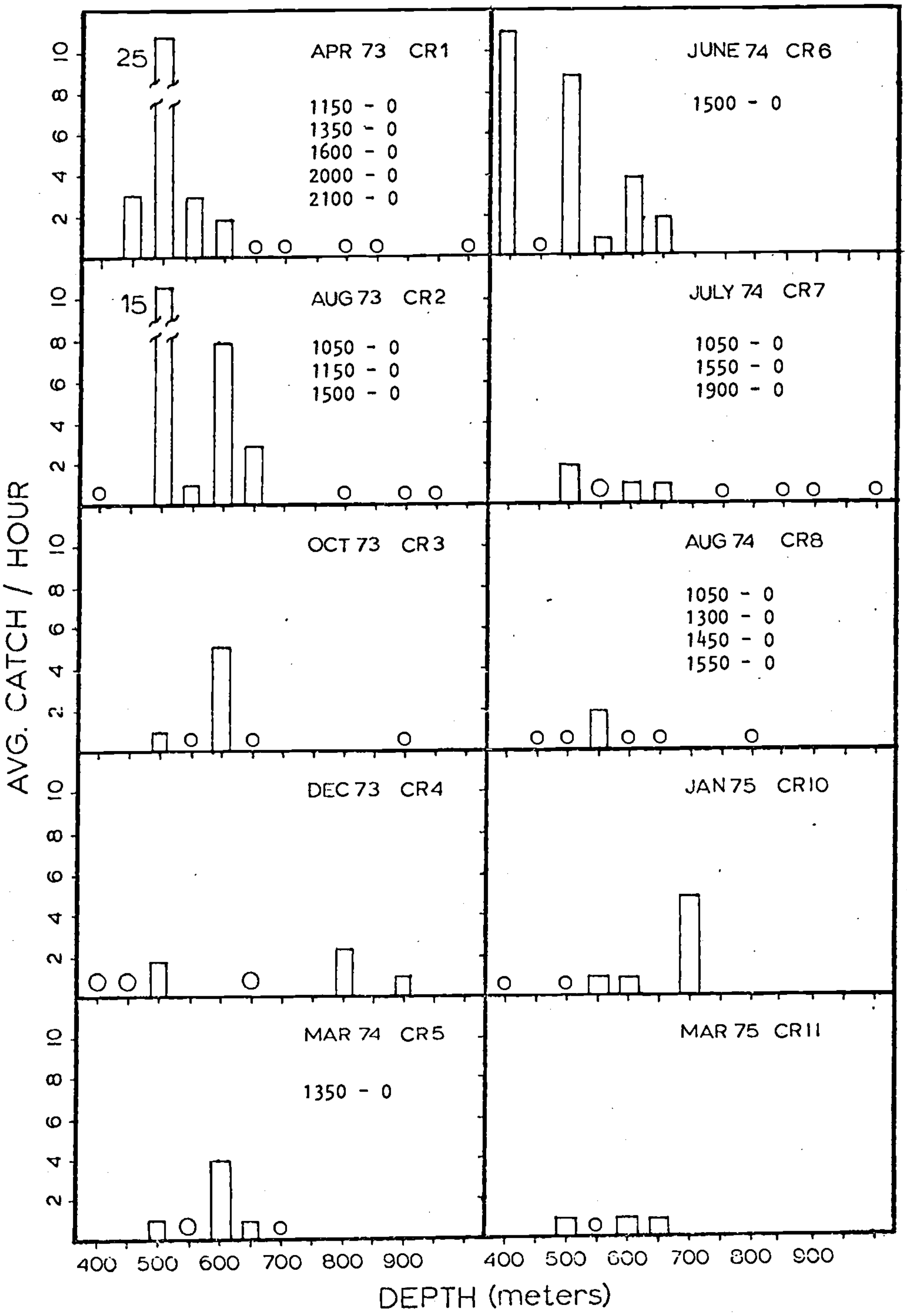

Figure 2. Distribution by depth and cruise of adult female C. tanneri on the Oregon continental slope. Zero trawls are indicated by a "0"; those off the depth scale are listed by depth. CR = cruise.

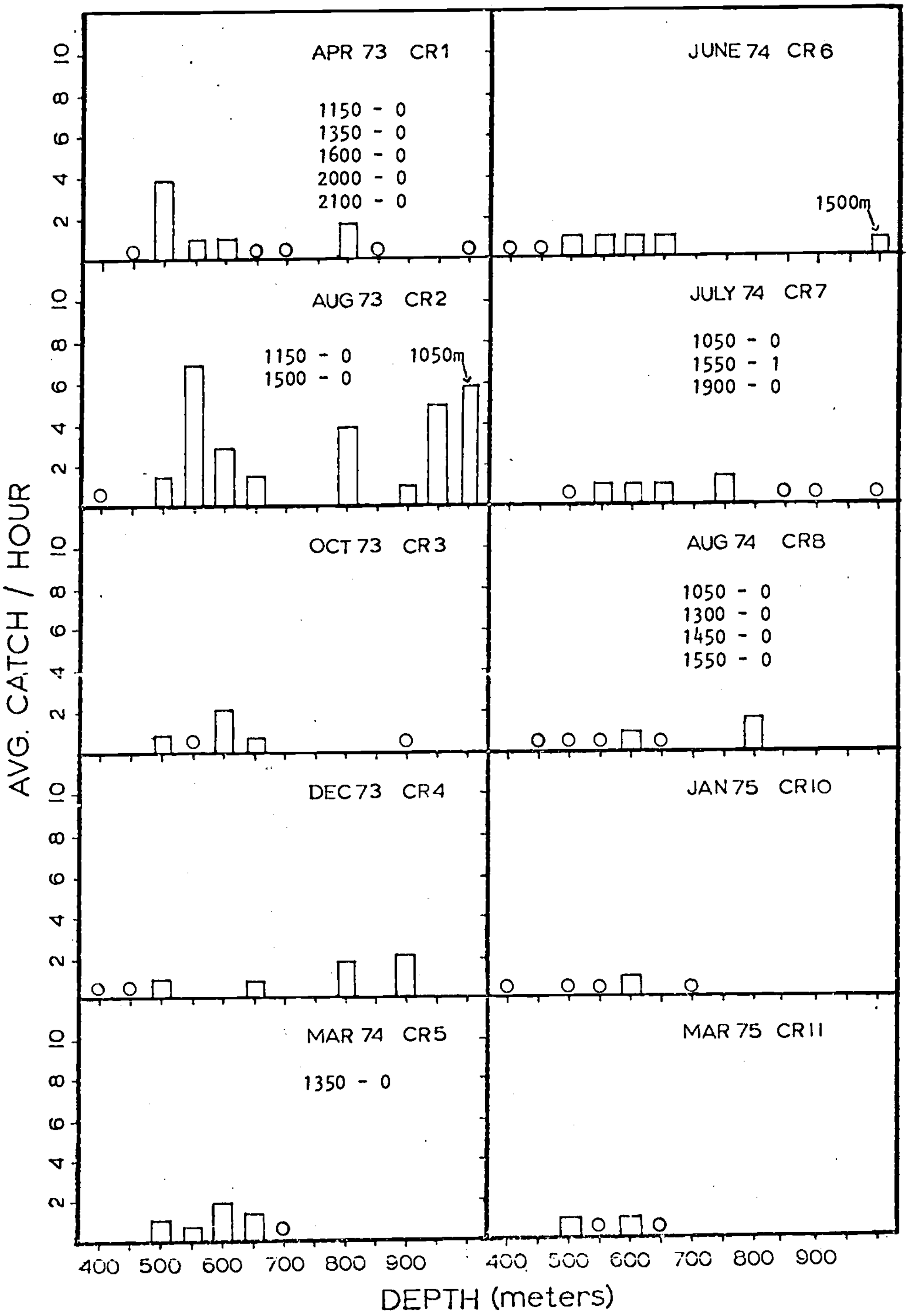

Figure 3. Distribution by depth and cruise of adult male C. tanneri on the Oregon continental slope. Zero trawls are indicated by a "0"; those off the depth scale are listed by depth. CR = cruise.

(Figure 5). Comparison of Figures 4 and 5 reveals that the distribution of juvenile males and females is similar, both bathymetrically and seasonally. The catch rates are not the same, but they follow almost identical patterns. The same features pointed out for females apply to males: the relatively shallow peak at 600-700m; the uncertain trend below 900m; and no obvious seasonal trend.

Comparison of adult-juvenile distributions demonstrates that catch rates for juveniles are higher than for adults. Juveniles are relatively abundant in the shallow end of the range. They are, in fact, more abundant than adults. Below 700m, juvenile catch rates are higher than adult catch rates. Juveniles are found over almost the entire depth range of adults.

An analysis of size vs. depth for juvenile crabs is useful when considering Pereyra's (1968) life history model. Mean size of females appears to increase with depth below 700m on cruises 1,5,and 8 (Figures 6a and 6b). The range of mean size is also relatively great below 700m on cruises 1,4,5, and 8. There is an indication of a decrease in mean size and range of females down to about 700m on cruises 3,4,5, and 7. The mean size of juvenile males increases with depth below 700m on cruises 2,4,7, and 8 (Figures 7a and 7b). There is no strong indication of a decrease in size down to 700m. Size range is relatively large at the deeper end of the depth range on cruises 4,7, and 8.

Abundance

A number of assumptions must be made when calculating abundance estimates:

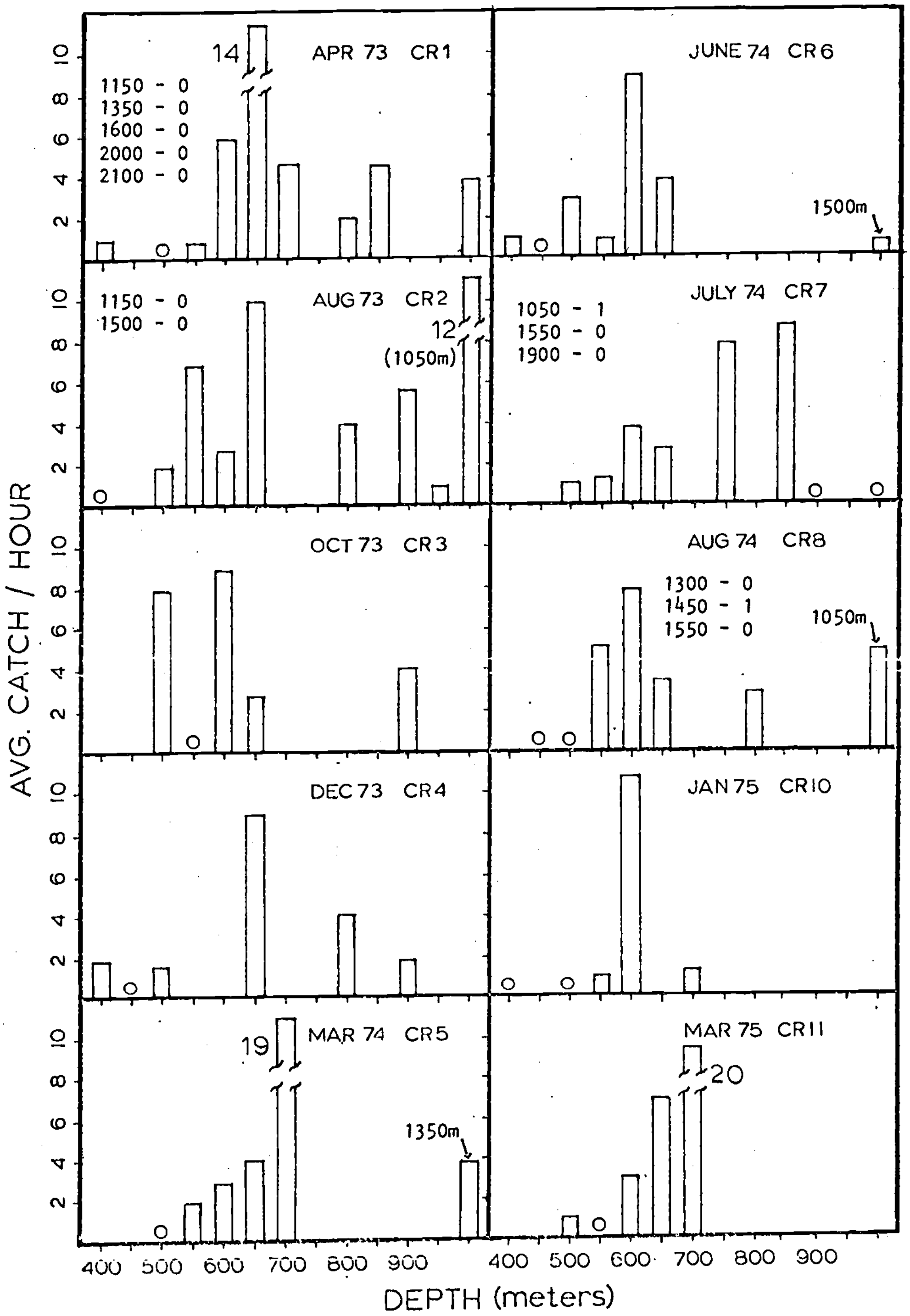

Figure 4. Distribution by depth and cruise of juvenile female C. tanneri on the Oregon continental slope. Zero trawls are indicated by a "0"; those off the depth scale are listed by depth. CR = cruise.

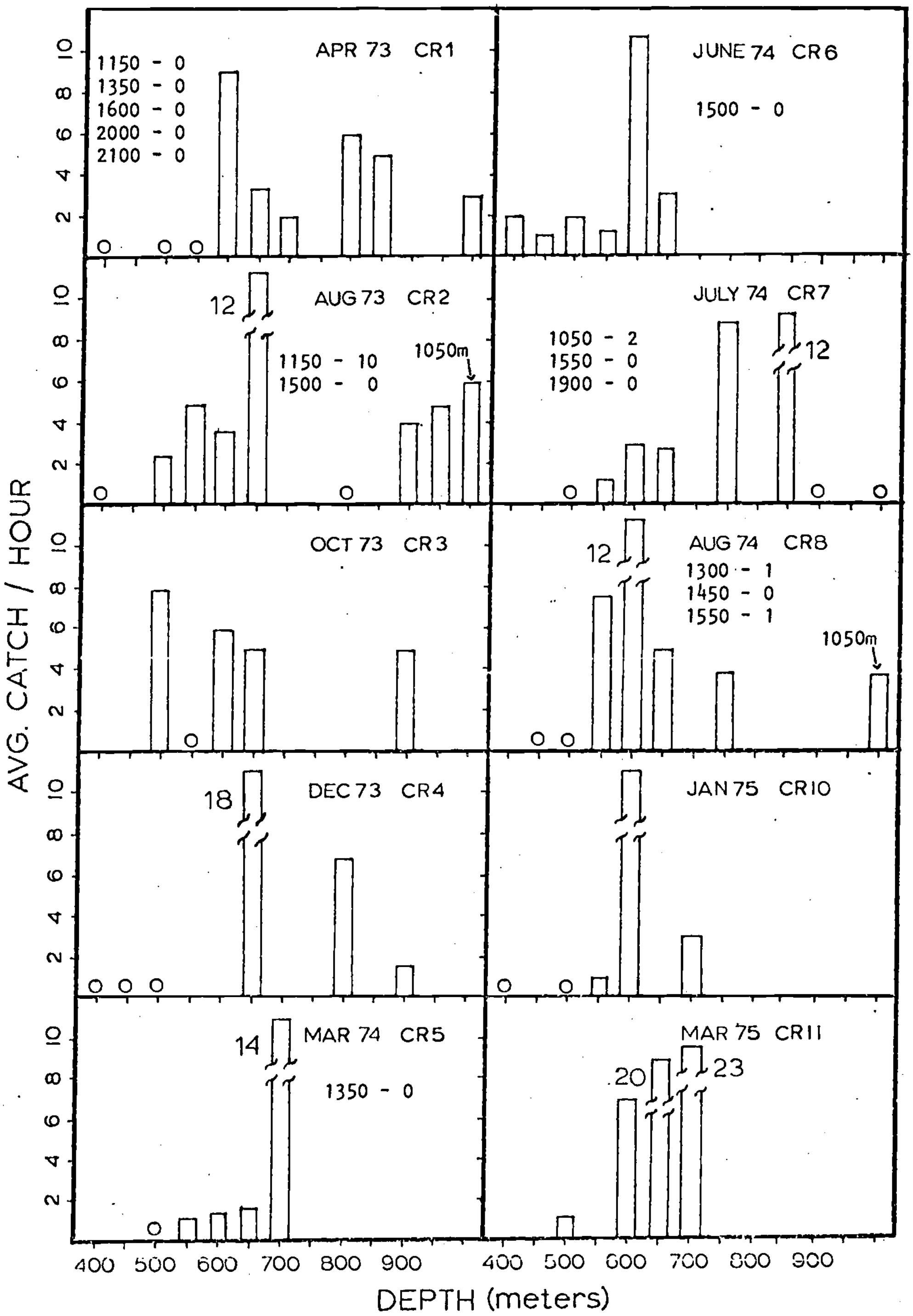

Figure 5. Distribution by depth and cruise of juvenile male C. tanneri on the Oregon continental slope. Zero trawls are indicated by a "0"; those off the depth scale are listed by depth. CR = cruise.

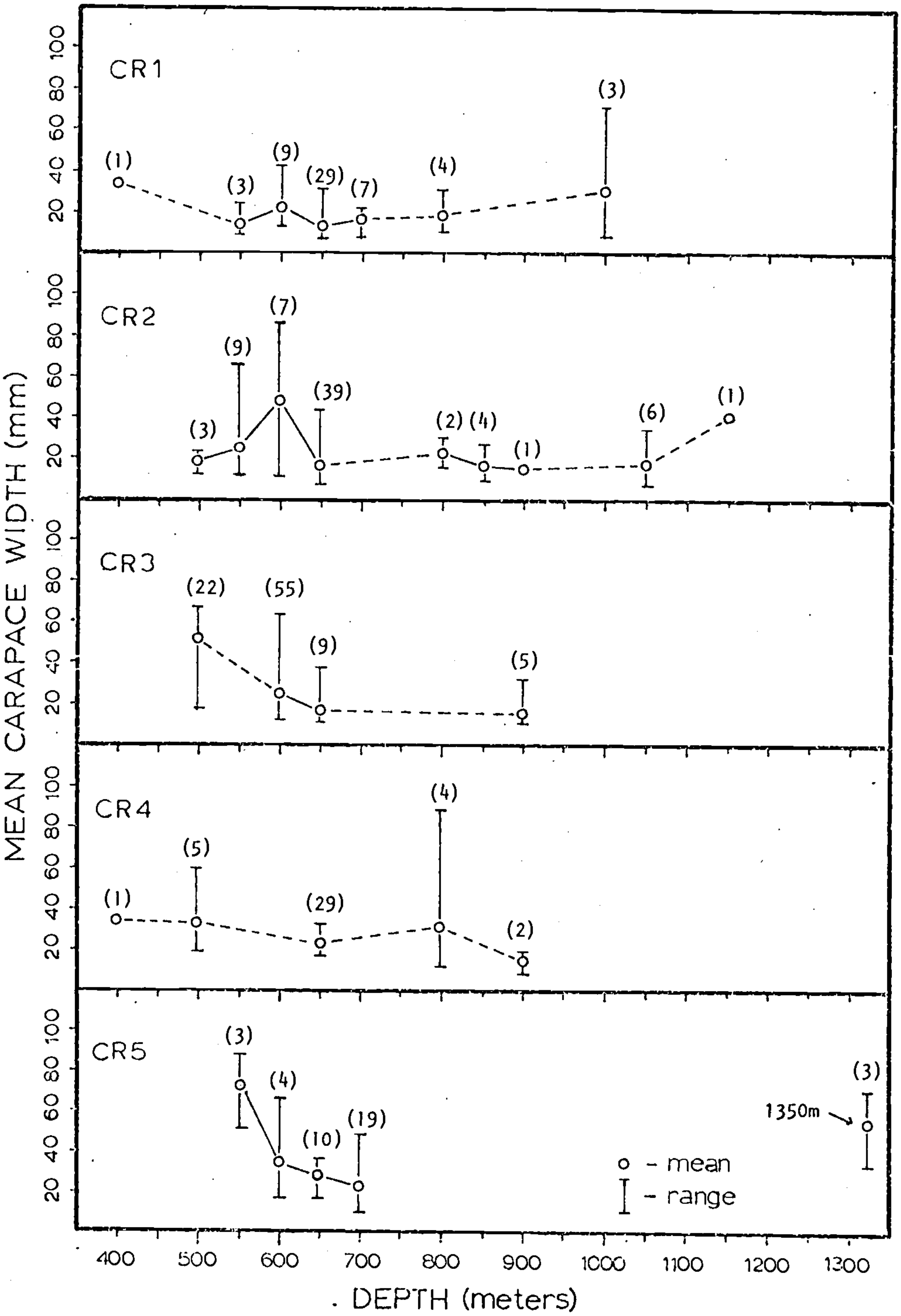

Figure 6a. Relationship of size and depth for juvenile female C. tanneri on the Oregon continental slope, cruises 1-5. Dashed lines indicate missing information between depth intervals. Mean, range, and sample size (in parentheses) are given.

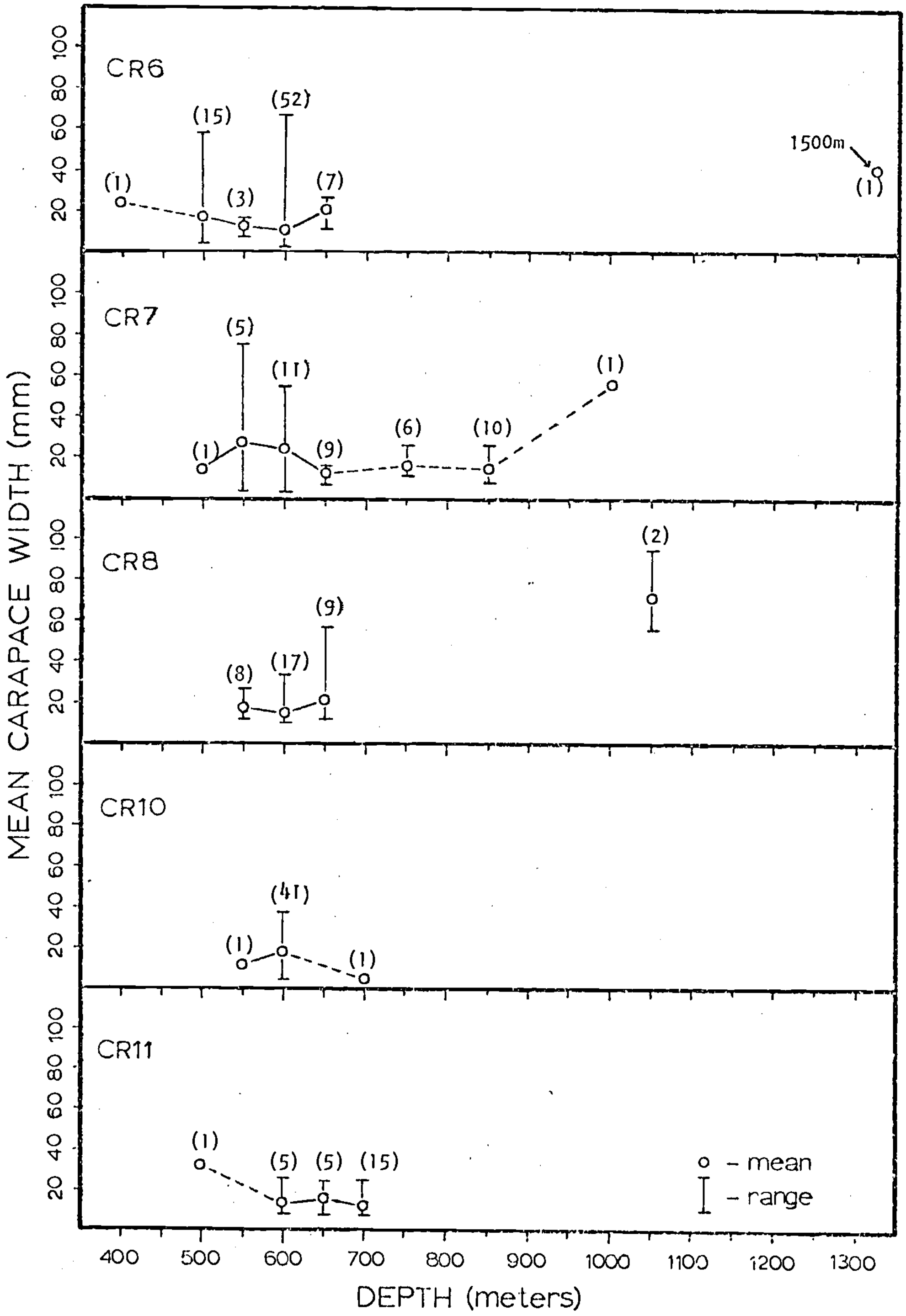

Figure 6b. Relationship of size and depth for juvenile female C. tanneri on the Oregon continental slope, cruises 6, 7, 8, 10, and 11. Dashed lines indicate missing information between depth intervals. Mean, range, and sample size (in parentheses) are given.

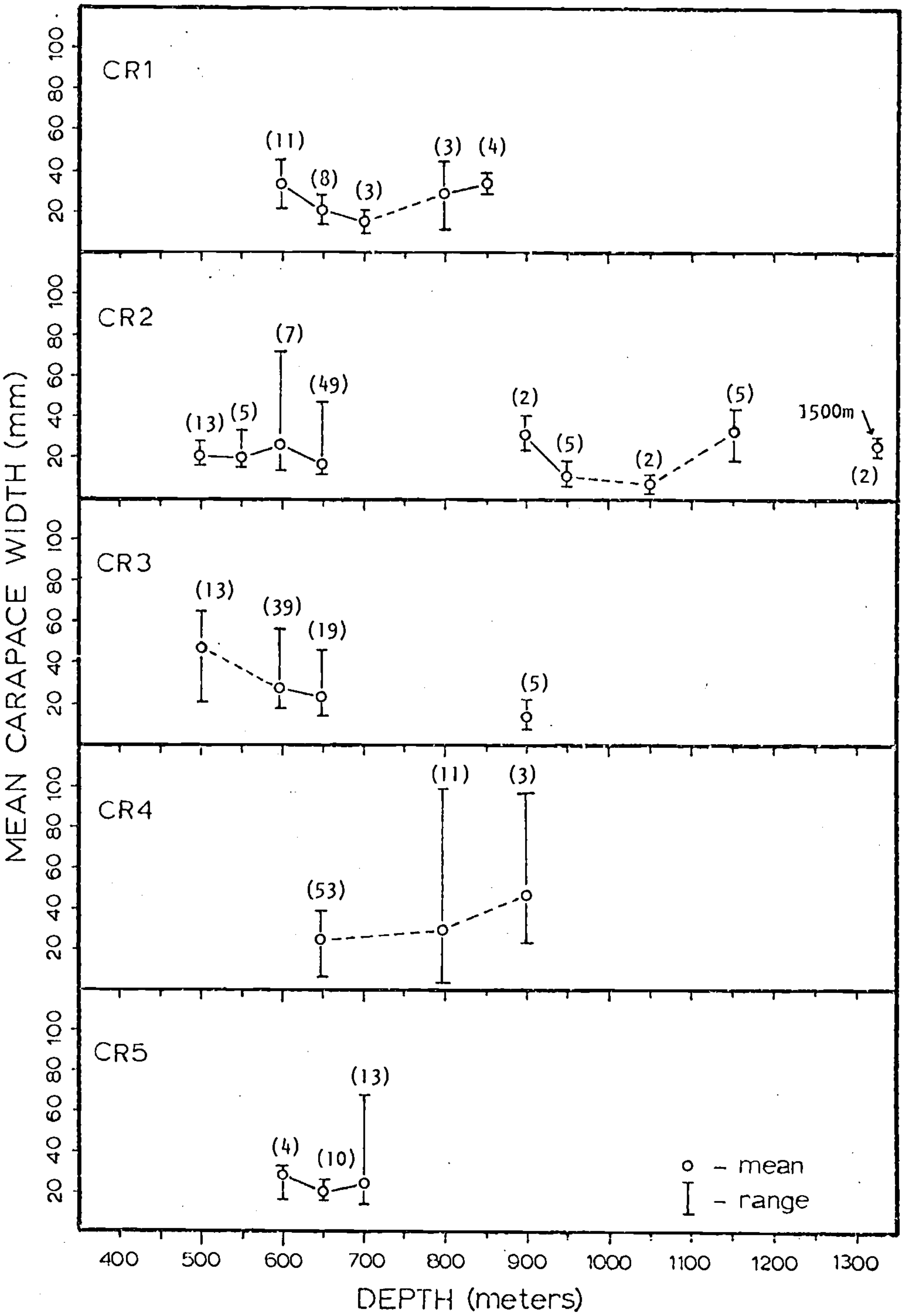

Figure 7a. Relationship of size and depth for juvenile male C. tanneri on the Oregon continental slope, cruises 1-5. Dashed lines indicate missing information between depth intervals. Mean, range, and sample size (in parentheses) are given.

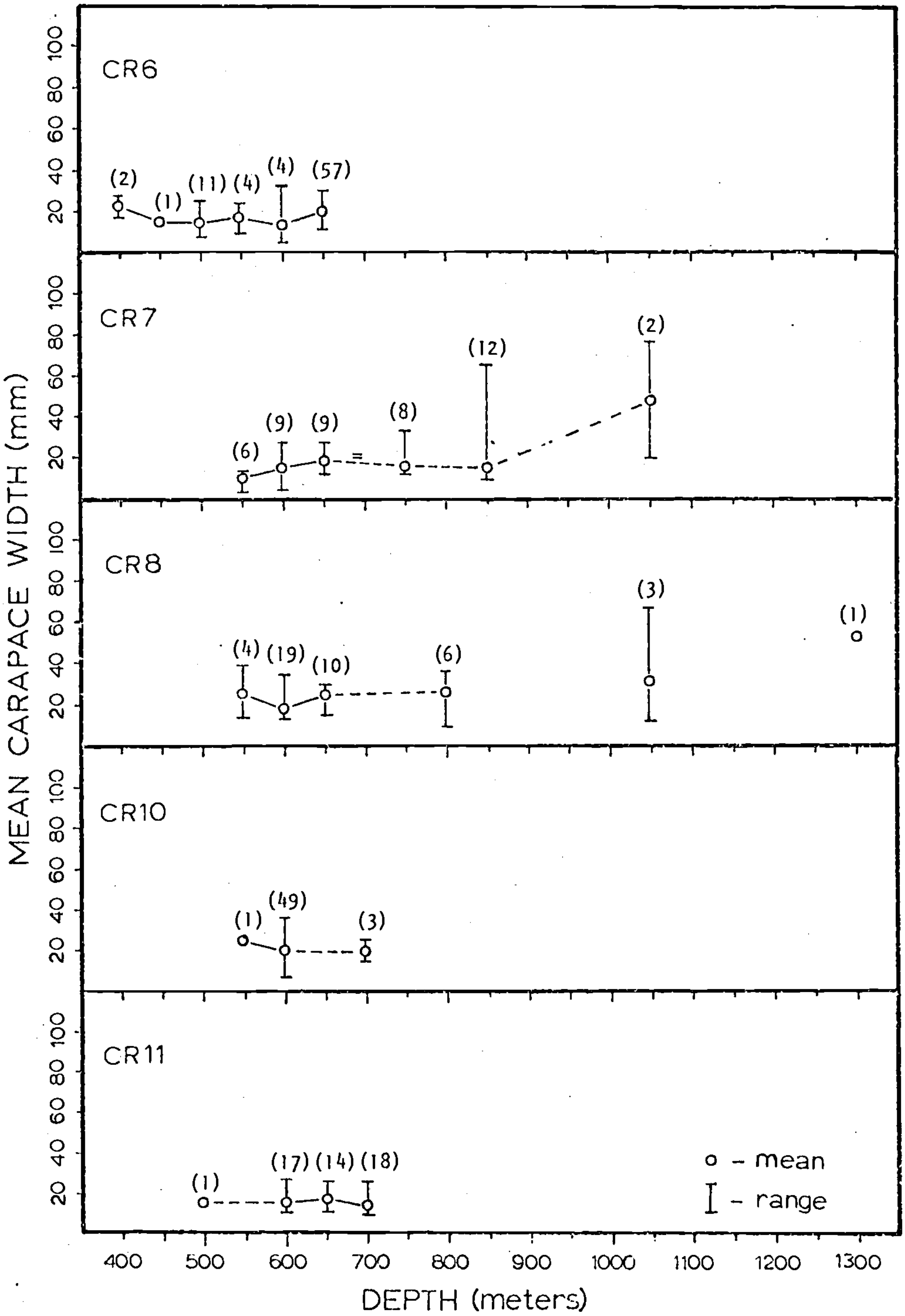

Figure 7b. Relationship of size and depth for juvenile male C. tanneri on the Oregon continental slope, cruises 6,7,8,10, and 11. Dashed lines indicate missing information between depth intervals. Mean, range, and sample size (in parentheses) are given.

1) The Tanner crab population is in equilibrium, with recruitment, growth, and mortality constant and age specific.

2) There is no variation in availability, bathymetrically or seasonally, within the depth range considered here.

3) All crabs in the path of the trawl are caught.

4) Population levels off Coos Bay are representative of the entire Oregon coast.

Assumption number 2 is based on the results of the Distribution analysis which gave no indication of seasonal or bathymetric trends.

The 500-700m depth interval was chosen because 95% of the beam trawls occurred in this range. It was also the optimal range for adults as indicated by the Distribution analysis.

The analysis of beam trawl reliability presented in Materials and Methods will not be repeated here. For each trawl, the higher wheel reading was used if the two readings differed by greater than a factor of two. If the difference was less than this, I used an average.

The surface area of the Oregon continental slope between 500-700m (2798 km^2) was determined with a compensating polar planimeter using U. S. Coast and Geodetic Survey Maps 1308N-22 and 1308N-17. I assumed the slope of the bottom was constant.

Data were used from 51 trawls which caught 22 adult males, 70 adult females, 191 juvenile females, and 235 juvenile males (Appendix 3). Twenty one trawls were not used because wheel readings were either absent or too low (<500 revolutions), or because the trawl depth was outside the 500-700m range. The total stock estimates were calculated

Table 6. Stock estimates of adult and juvenile Tanner crabs for the Oregon coast, 500-700m depth interval.

Age	Sex	Numbers	Weight (kg)**
Adult	Male	$1.6 \times 10^5 \pm 0.9 \times 10^5$*	$1.1 \times 10^5 \pm 0.6 \times 10^5$
Adult	Female	$4.6 \times 10^5 \pm 0.2 \times 10^5$	$1.3 \times 10^5 \pm 0.7 \times 10^5$
Juvenile	Male	$1.3 \times 10^6 \pm 0.6 \times 10^6$	Not calculated
Juvenile	Female	$1.5 \times 10^6 \pm 0.6 \times 10^6$	Not calculated

* - 95% confidence limits

** - For males = 2.42 ± 1.32 lbs. For females = 2.86 ± 1.54 lbs.

using the average density multiplied by the total area of the continental slope depth zone - 2798 km^2.

Adult male density ranged from 0-500 crabs/km^2 and 0-340 kg/km^2. Averages were 56 crabs/km^2 and 38.5 kg/km^2. Adult female density ranged from 0-1100 crabs/km^2 and 0-399 kg/km^2, with means of 164 crabs/km^2 and 45.7 kg/km^2. Mean density of juvenile males was 540 crabs/km^2, range 0-3400 crabs/km^2. Density of juvenile females ranged from 0-3800 crabs/km^2, with a mean of 450 crabs/km^2. Density based on weight was not calculated for juveniles.

Ecology

Habitat Characterization

Environmental data obtained for each multiple corer drop or station are listed in Appendix 4. One core kept per station prior to June 1974 was used for organic carbon analysis. Two cores retained from all further samples were analyzed for both organic carbon and particle size.

Temperature in the study area ranged from 3.8-5.81 °C, with a mean of 4.87 °C. Salinity ranged from 33.03-34.42‰, and the mean was 34.16‰. Mean dissolved oxygen concentration was 0.57 mg-at/l and varied from 0.15-0.88.

The variation of mean temperature, salinity, and dissolved oxygen for cruises 2,3,6,7, and 8 provides some indication of seasonal variation. For temperature and salinity there is complete overlap of confidence intervals for each cruise. Oxygen shows more variation in the form of non-overlapping confidence intervals for mean values (Figure 8).

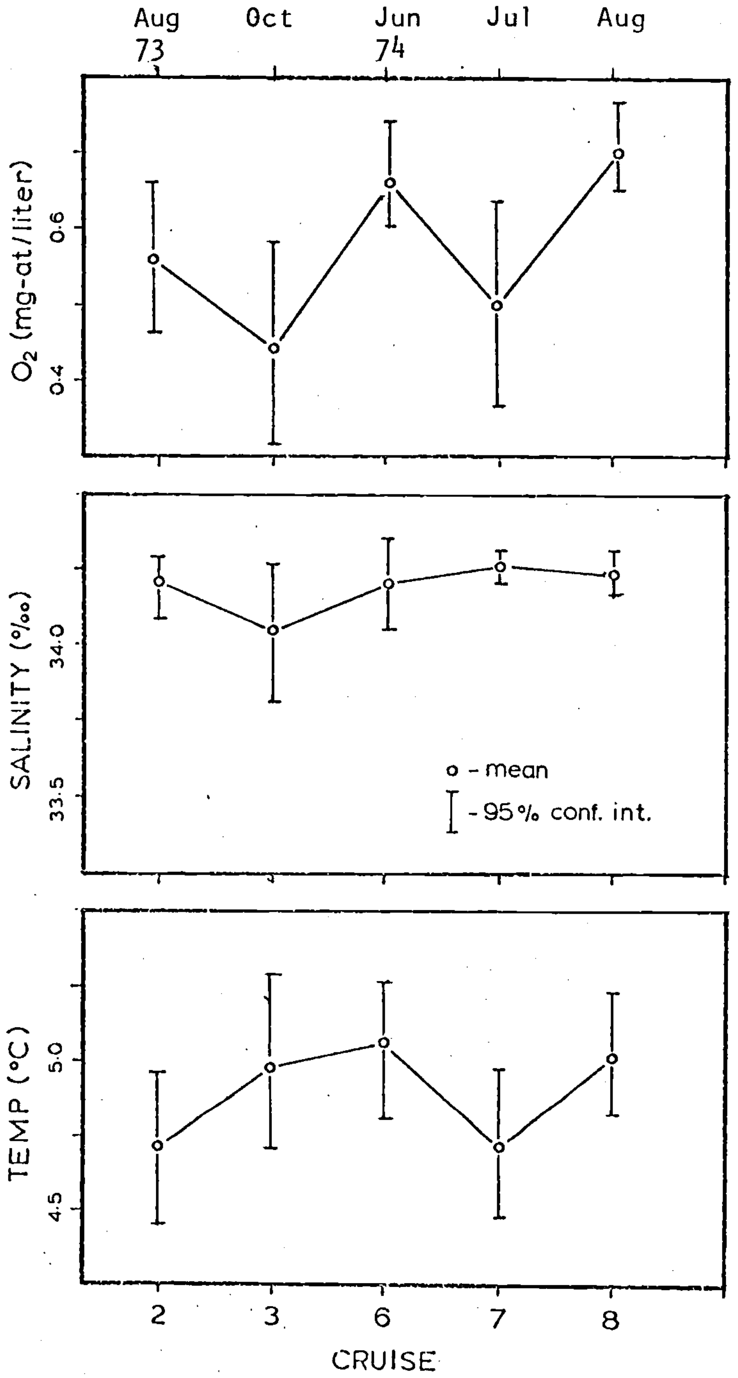

Figure 8. Variation of temperature, salinity, and dissolved oxygen of near-bottom water for five Tanner crab cruises on the Oregon continental slope. Means and 95% confidence limits are plotted.

The relationship of physical parameters with depth has been defined by means of linear regression. This provides some insight into station variation since different stations are essentially different depths. Temperature is the only parameter with a significant linear correlation (R value) with depth (Table 7).

The sediment is characterized by several descriptive statistics. As a general indication of particle size, % silt and % clay are useful. All of the sediments analyzed were 100% silt and clay with no sand fraction. Silt content ranged from 55.3-98.8%, with a mean of 80.3%. Clay ranged from 1.2-44.7%, with a mean of 19.7%. Two other indicators of particle size were used - Inman median (Inman, 1952) and Folk and Ward mean (Folk and Ward, 1957). Both are measures of central tendency based on the cumulative frequency curve for particle size from a sediment sample. Inman's median is the particle size corresponding to the 50th percentile of the cumulative frequency curve. Inman states that the median is more useful than the mean when the emphasis is on the more abundant size. In contrast, Folk and Ward believe that the median should be abandoned as a descriptive statistic since it is based on only one point of the frequency curve. Their alternative is the Folk and Ward mean which is based on the 16th, 50th, and 84th percentiles and is thus more sensitive to the extremes of the particle size range. Both statistics are given in Phi units (ϕ) which is the negative $\log_2$ (particle size in mm).

Inman median ranged from 4.19 (0.055 mm) to 7.21 (0.0075 mm); the average was 5.01 (0.049 mm). Sediment of this size corresponds to medium silt (Inman, 1952). The range corresponds with coarse silt to

Table 7. Relationship of environmental parameters with depth in the Coos Bay, Oregon, study area.

Dependent Variable	Entering F-value	R	R^2
Temperature	144.17*	-0.87	0.750
Salinity	6.56**	0.33	0.110
Oxygen	7.29*	-0.34	0.120
% Silt	0.71	-0.14	0.020
% Clay	0.71	0.14	0.020
% Organic Carbon	0.31	0.06	0.003
Inman Median	1.76	0.22	0.050
Folk & Ward Mean	1.36	0.19	0.040

* - Significant at 1% level
** - Significant at 5% level

very fine silt. Folk and Ward mean ranged from 4.40 (0.047 mm) to 7.84 (0.0043 mm), with an average of 5.93 (0.024 mm). These values can be described as ranging from coarse silt to very fine silt with a medium silt average, the same as Inman median.

Standard deviation and skewness of Folk and Ward (1957) are measures of sorting and asymmetry, respectively. The average standard deviation of the sediments was 2.156 (poorly sorted) and the mean skewness was 0.69 (very positively skewed, i.e. a tail of fines).

Organic carbon content ranged from 0.002-0.130 % by weight with a mean of 0.04 %.

Habitat correlation

Inspection of the final data set (Appendix 5) for all beam trawls revealed that only 10 trawls were associated with a complete set of environmental variables. Also, the number of trawls which caught no crabs was high, which indicated that I was looking at presence or absence of adult crabs rather than actual abundance. These two factors - lack of environmental data and actual abundance data - made a rigorous statistical treatment of the data seem unwise. In view of the nature of the catch data, presence or absence of adult crabs was chosen as an index of availability for correlation with environmental variables. This approach allowed incorporation of data associated with otter trawls in addition to the beam trawl data.

Adult crabs of both sexes are present and absent in the same range of values for all environmental variables (Table 8). Scatter plots of environmental variables against presence and absence of adult crabs

Table 8. Minimum, maximum, and average values of environmental variables when Tanner crabs are present or absent. Data from Coos Bay, Oregon, study area.

	Depth (m)			Temperature (°C)			Salinity (‰)			Oxygen (mg-at/l)			% Silt			% Clay			% Organic Carbon			Folk & Ward Mean		
	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg
AF[1] present	439	904	604	4.48	5.81	5.03	34.13	36.64	34.36	0.25	0.85	0.59	53.3	94.7	83.6	5.3	44.7	16.4	.007	.094	.037	5.19	8.15	6.04
AF absent	402	2117	755	3.80	8.09	4.86	33.03	34.42	34.12	0.21	0.88	0.57	68.2	95.8	79.5	4.2	31.8	20.5	.006	.117	.048	5.27	8.62	6.70
AM[2] present	521	1528	688	3.80	5.81	4.82	34.15	36.64	34.40	0.21	0.75	0.50	89.3	95.8	92.6	4.2	10.7	7.5	.006	.117	.039	5.00	5.04	5.02
AM absent	402	2117	724	3.93	8.09	4.98	33.03	34.34	34.09	0.29	0.88	0.63	55.3	94.7	79.7	5.3	44.7	20.3	.008	.110	.047	4.87	7.84	6.09

[1] - AF = Adult female

[2] - AM = Adult male

indicated that there is no clustering of presence and absence of adult crabs over the range of any of the variables considered here. The possibility of a combination of environmental variables affecting crab distribution is not adequately determined by this qualitative approach. The effect of combinations of two environmental variables was examined by plotting one versus the other (e.g. temperature vs. salinity) and circling the points where crabs were present. Again it was evident that there was no discernible clustering of "present" points.

Associated Fauna

A time series of catches at three stations serves as some indication of the mega-epifauna associated with *C. tanneri*. This analysis deals only with the invertebrate portion of the catch. The general composition of the vertebrate catch was characterized by rockfish (*Sebastolobus* spp.), flatfish (Dover sole), hagfish (*Eptatretus* spp.), sablefish (*Anoplopoma fimbria*), and rattails (Macrouridae). Fish were a significant portion of the catch by weight at most stations.

The total invertebrate catch at stations B, C, and D, from cruises 6, 7, 8, and 10 was analyzed (Figure 9). There is a general decrease in numbers and weight per km^2 through time, except for biomass at station B in January 1975. Of interest here is the relationship between catch and area trawled. A high correlation would affect interpretation of these graphs. Since no correlation coefficients for catch per km^2 and area trawled are significant at the 5% level (Table 9), it is assumed the catch is not dependent on simply how far the trawl traveled (area), but is rather an indication of what is there to be caught.

Table 9. Correlation between catch/km^2 and area trawled by the beam trawl at three stations on the Oregon continental slope.

Station	N	Correlation Coefficient Numbers	 Weight
B	3	-0.674	0.222
C	4	0.662	0.738
D	6	-0.167	0.056

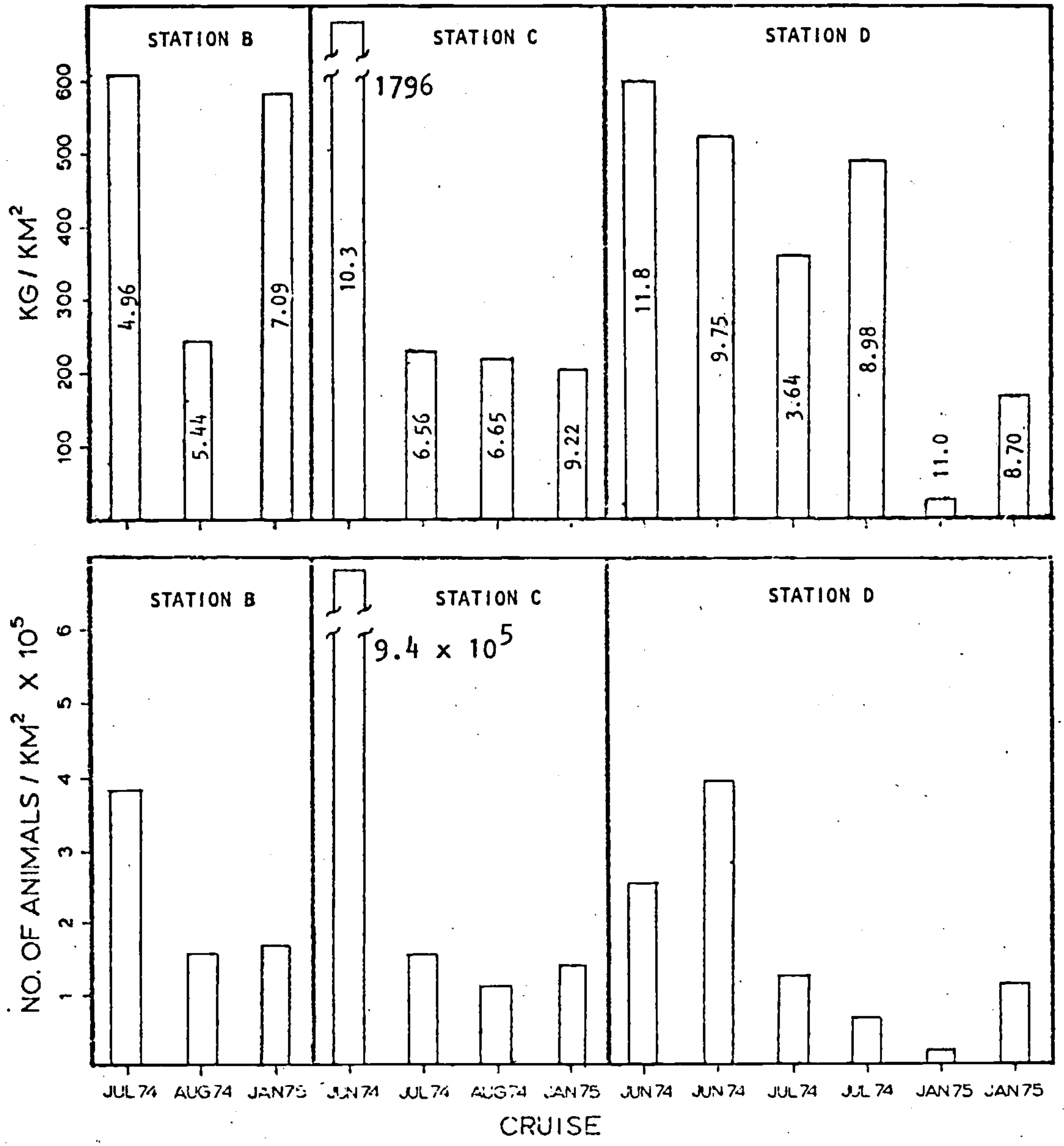

Figure 9. Variation of the total catch of mega-epifaunal invertebrates on the Oregon continental slope by biomass (top) and number (bottom) at stations B, C, and D. Numbers inside bars (top) indicate area trawled in $km^2 \times 10^{-3}$

Qualitatively, we noticed a marked decrease in catch volume during July and August 1974, and this is substantiated by the data from stations B, C, and D.

Another way of looking at faunal composition is the relative importance of taxonomic groups on the basis of weight or biomass (Figures 10 and 11) and numbers (Figures 12 and 13). At station B (Figure 10) Echinoidea (*Allocentrotus fragilis* and Decapoda (*Eualus macrophthalmus*) are consistently significant portions of the fauna in terms of biomass. The contribution of *C. tanneri* is variable. At station C, *Allocentrotus* and *Eualus* are again prominent, *C. tanneri* is generally significant and Gastropoda (*Neptunea lyrata* and Miscellaneous) appear. At station D (Figure 11), Echinoidea are far less important than at B and C. Decapoda (*Eualus*), Gastropoda (*Neptunea*), and Asteroidea (*Heterozonias* sp. and *Leptychaster* sp.) are dominant; *C. tanneri* is most dominant.

In contrast, the result based on numbers is different (Figures 12 and 13). Crustacea are the most important group, specifically Decapoda (excluding *C. tanneri*) and Mysidacea. *Chionoecetes tanneri* is an insignificant portion of the total numbers of the catch at each station.

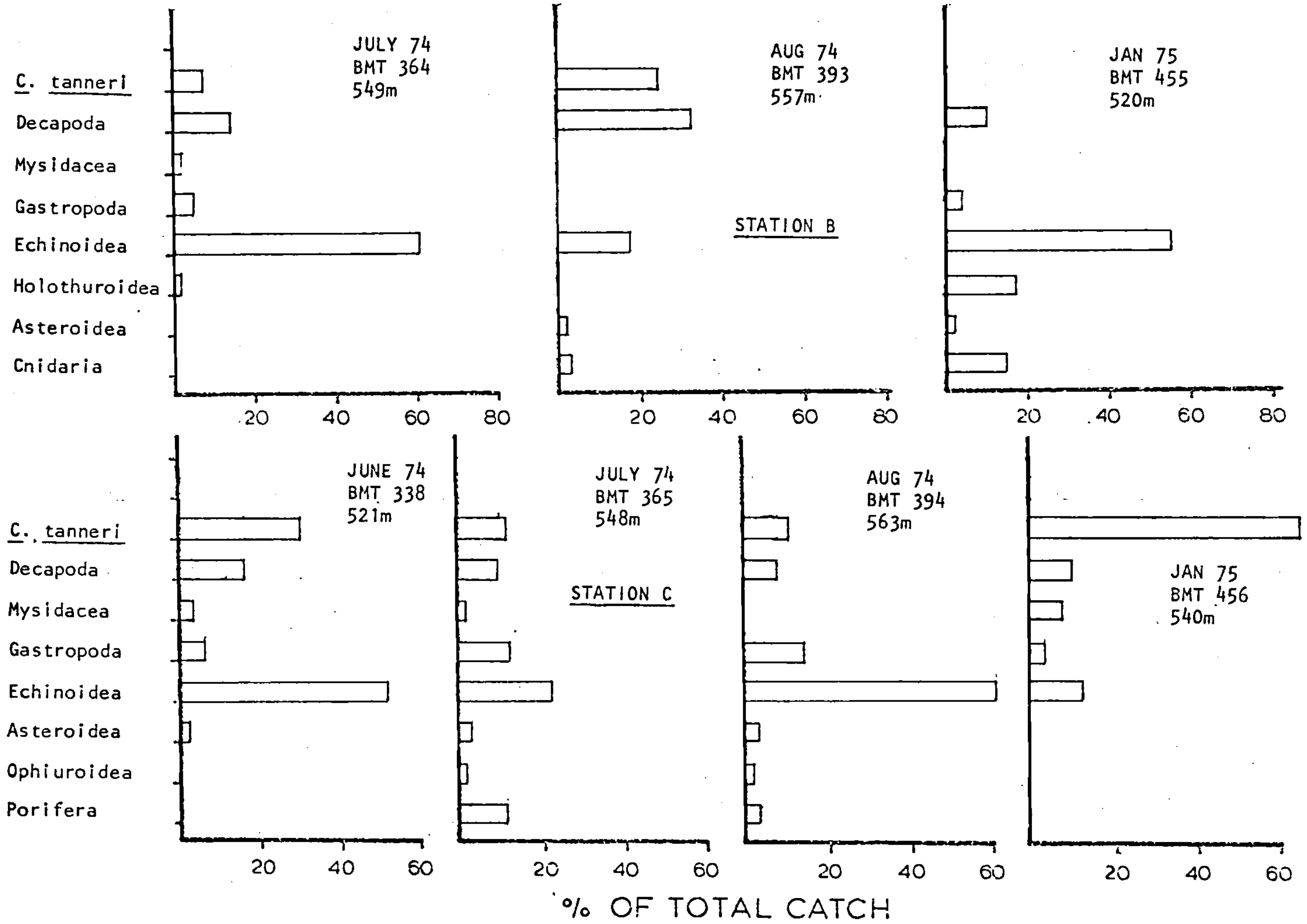

Figure 10. Percent composition by weight of mega-epifaunal invertebrates at stations B and C on the Oregon continental slope.

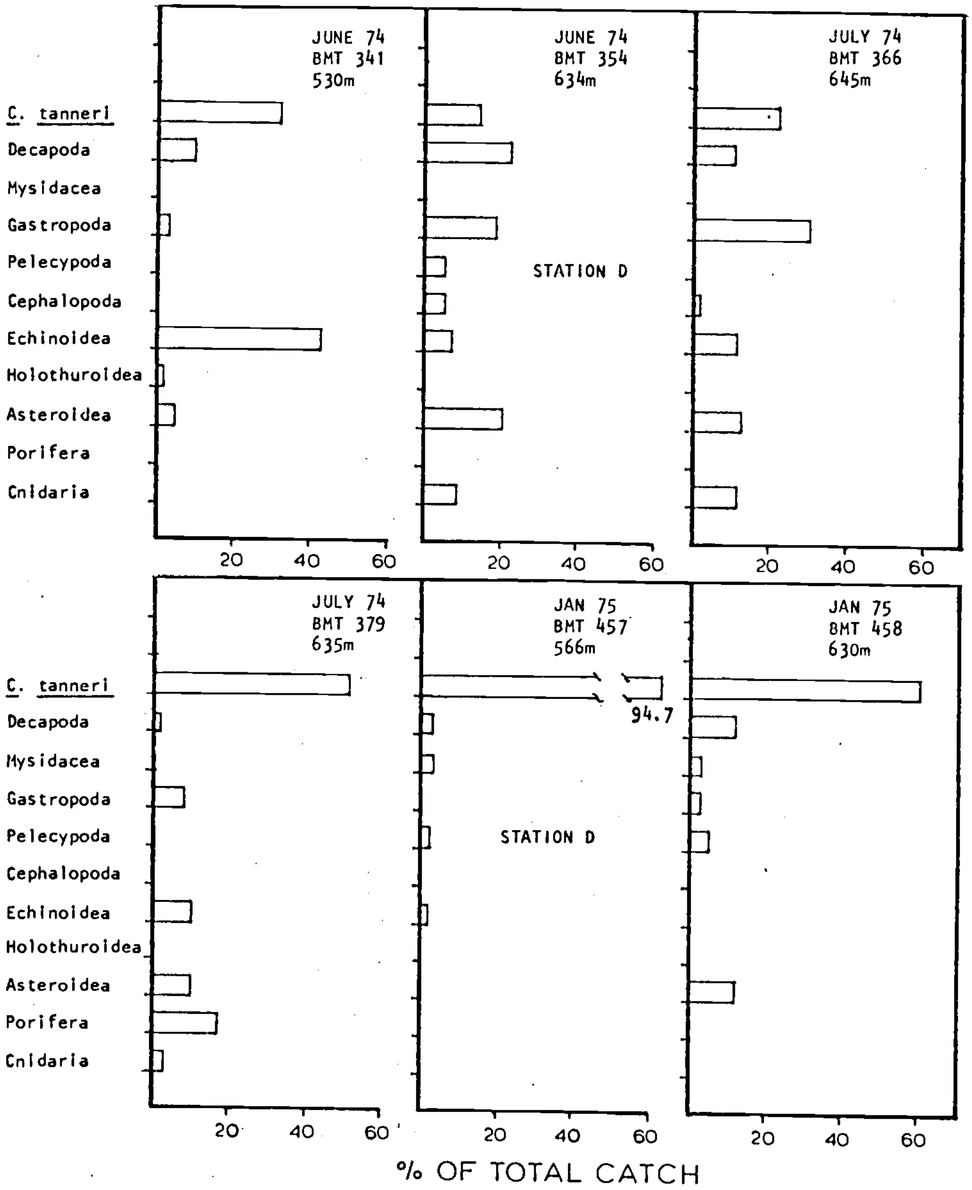

Figure 11. Percent composition by weight of mega-epifaunal invertebrates at station D on the Oregon continental slope.

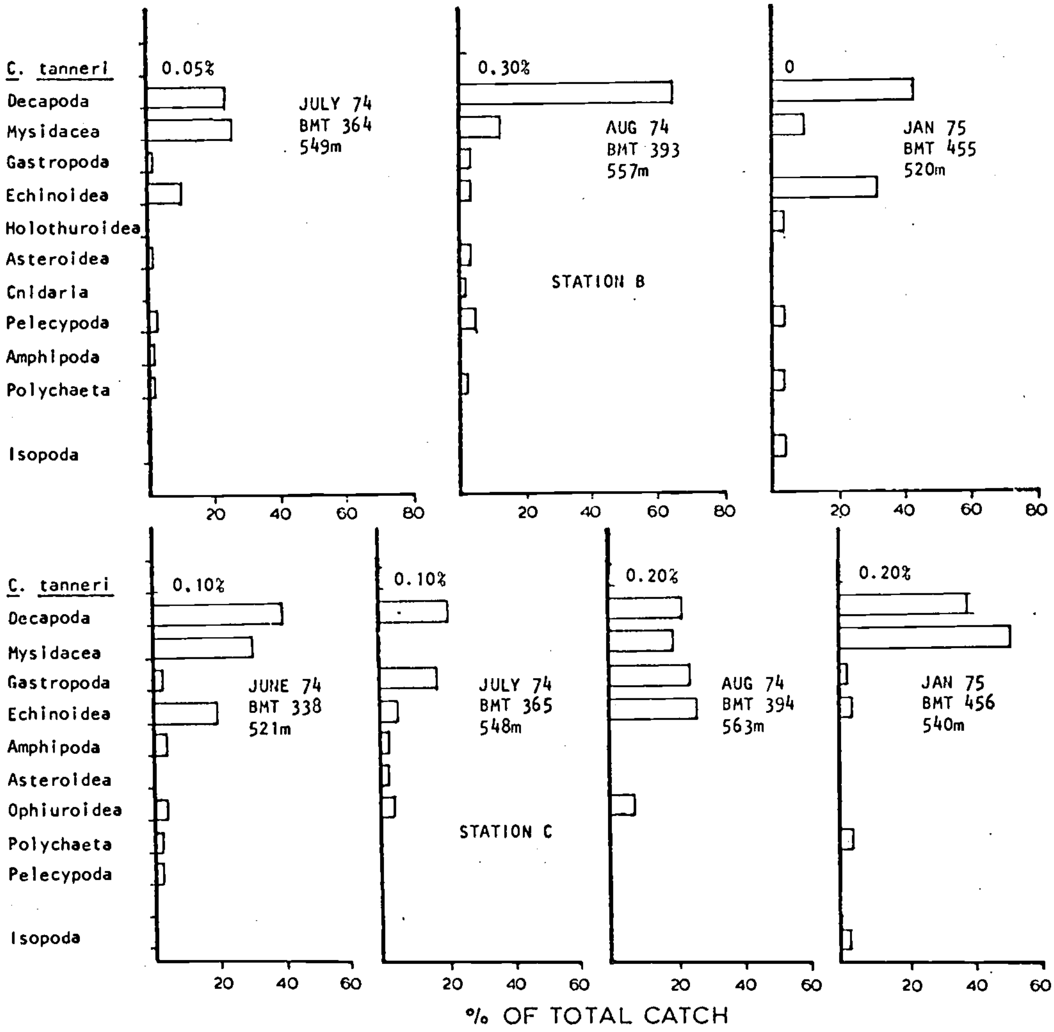

Figure 12. Percent composition by numbers of mega-epifaunal invertebrates at stations B and C on the Oregon continental slope.

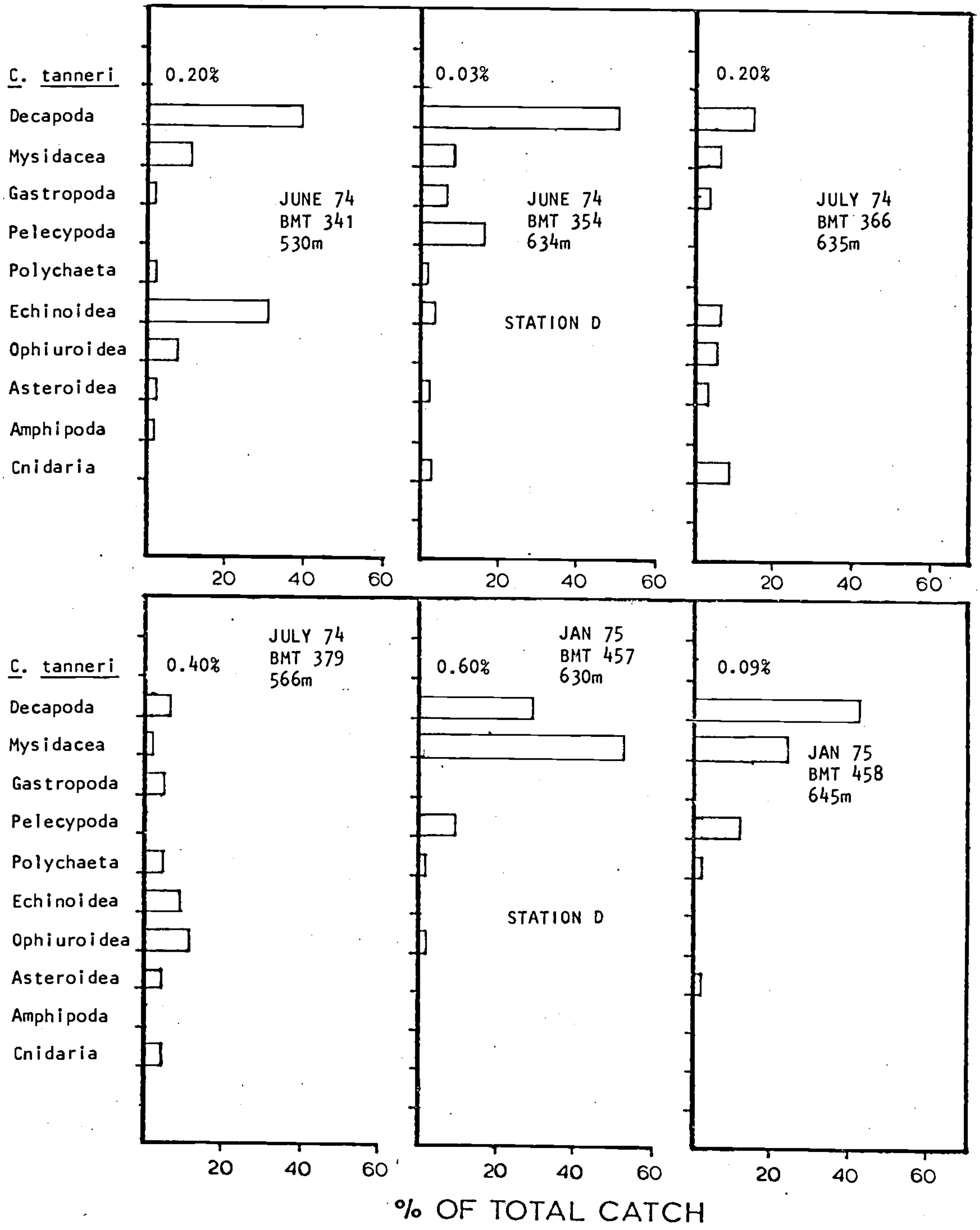

Figure 13. Percent composition by numbers of mega-epifaunal invertebrates at station D on the Oregon continental slope.

DISCUSSION

General Characteristics

Mean carapace width of adult males and females for this study was 140.4 mm and 102.3 mm. This compares well with Pereyra's (1972) results of 148.9 mm and 102.5 mm. Weights are less comparable because ours are individual wet preserved weights. Pereyra's weights are live weight estimates obtained at sea by dividing the total weight of the sample by the total number of crabs. Mean weight for adult male crabs for this study was 0.765 kg (1.681 lb) or 0.776 kg (1.71 lb) depending on the method, compared to 1.09 kg (2.4 lb) from Pereyra (1972).

Pereyra calculated the mean weight of adult female Tanner crabs to be 0.36 kg (0.8 lb). Adult female weights are not particularly informative, except to show sex differences, since the weight of mature females varies due to egg mass variation (Tester, personal communication). Mean female weight for Coos Bay Tanner crabs was 0.27 kg (0.6 lb). The difference in the weight estimates from the two studies is probably due to sample size and technique.

Tester (1976) has compared sex ratios with Pereyra's estimates, finding them in close agreement.

Distribution

Pereyra (1966, 1968, and 1972) reported Tanner crabs over a depth range of 457-1920m. Adult crabs were caught no deeper than 1554m. Crab distribution, both bathymetric and seasonal, showed considerable variation. Adult females remained fairly stationary at a depth of

640-686m throughout the year, whereas adult males showed a seasonal migration pattern. They were most abundant at 503-549m in the spring and summer, then appeared to move deeper in the winter to a depth range corresponding to the females.

Pereyra proposed a life history model to account for the seasonal migration and the presence of juveniles in much deeper water than adults (1968, 1972). As winter apporaches, the male crabs begin a downward migration which puts them near the center of the female population in January to March. After a period of aggregation and assumed mating, the males return to shallower water. Eggs mature for one year and zoea hatch the following winter (January to March again). The zoea migrate or are carried to the surface and spend an undetermined amount of time there. Upon attainment of some advanced larval stage, they settle to the bottom to begin their benthic existence. The northwesterly wind pattern during the spring and summer causes the larvae to be carried offshore before they settle, thus accounting for the deeper depth distribution of juveniles. The reason proposed for the segregation of the adult population is decreased competition for food. Also, the hatching and migration to surface waters of the zoea coincides with peak primary production periods.

The data presented in Figures 2 and 3 for the Coos Bay area show no such adult distribution pattern. Adult males exhibit no depth migration through time. Also in contrast to Pereyra's finding is the result that adult males are found more often than females in deeper water (below 700m). His data showed that males occupied the shallow end of the depth range.

There is support in the literature for segregation of sexes. It has been found in C. opilio (Katoh, et.al., 1956), the king crab, Paralithodes camtschatica, (Wallace, Pertuit, and Hvatum, 1949), and the blue crab, Callinectes sapidus, (Van Engel, 1969). Available data on the distribution of the red crab, Geryon quinquedens, does not indicate segregation of sexes (Schroeder, 1955; MacRae, 1961).

Pereyra found that juvenile crabs were concentrated at greater depths than adults. In the Coos Bay area, juvenile crabs were relatively abundant at the shallow end of the depth range (Figures 4 and 5). Effort was not concentrated below 1000m (Table 8), but the catch rates of juveniles in those trawls below this depth were not high. This result also differs somewhat from Pereya's, but both studies indicate that juveniles are found deeper than adults.

Pereyra examined juvenile carapace width vs. depth for a series of hauls from 914-1554m. He found that mean widths decreased with depth, which supports his life history model. He also noted that juveniles were more abundant during the summer, which would be expected if they are descending from surface waters before or during that time. In the Coos Bay study area, neither sex shows an overall decrease in mean width with depth (Figures 6 and 7). This is not surprising if in fact juvenile crabs are dispersed by prevailing currents in the surface waters. One would expect them to settle out at widely varying depths depending on the vagaries of winds, currents, hatching time, and developmental rate.

A problem with interpreting Pereya's juvenile data is that the mesh size of his trawls was large (3.4 and 9 cm) in relation to the size of juvenile crabs. There was obviously size selection involved. A strong point of the data presented for the Coos Bay area is that we used half inch (1.125 cm) stretch mesh liner in all trawls. We caught juveniles as small as four millimeters width. Pereyra doesn't give the smallest size caught by their trawls.

There is evidence for the segregation of adult-juvenile populations in the king crab (Powell and Nickerson, 1965) and C. opilio (Yoshida, 1941). If adults and juveniles rely on similar food sources, segregation makes sense in order to reduce competition for food. If Tanner crabs are cannibalistic (see Introduction), the advantages of segregation to juvenile crabs are obvious. However, the data from Coos Bay suggest that the segregation may not be as sharp as Pereyra suggests.

Pereyra's life history model has been partially substantiated by Lough (Ph.D. Thesis, 1974). Lough collected adult female Tanner crabs off of Coos Bay, Oregon, in late January. The crabs carried well-developed eggs which hatched in the laboratory in late February and early March, thus confirming the hatching time suggested by Pereyra. Lough's sampling in the field did not show any evidence for offshore transport of larvae. However, he concluded that the bulk of C. tanneri larvae may reside below 150m since his sampling was concentrated above this depth, and he caught few larvae.

Examination of the catch rates in Figures 2-5 reveals a significant weakness in the catch data, particularly for adults: the seven meter otter trawl and three meter beam trawl do not catch many crabs. Our catch rates for adults were 0-25/hr compared to 0-592/hr in Pereyra's work. The limited ability of the otter and beam trawls we used and the lack of effort at deeper depths prevents making definite conclusions regarding the distribution of adult Tanner crabs off Coos Bay. The data presented here does not support Pereyra's results on several points, but it cannot be used to refute his results either.

Abundance

Pereyra (1972) attempted to estimate the total standing stock of adult Tanner crabs on the Oregon and Washington continental slopes. He calculated an average catch/hr from nine independent seasonal estimates for the 94 ft (28.7 m) fish trawl. The area swept by the fish trawl in one hour was assumed to be 0.018 sq. n. mi. (0.061 km^2). From these average catch rates he calculated the total stock for the 250-475 fathom (457-869m) depth range based on a total area of 2594 sq. n. mi. (8464 km^2). Important assumptions were that population levels off the Columbia River are representative of the entire Oregon and Washington coasts, and that horizontal movement off the trackline was negligible, i.e. all movement by crabs was vertical.

The stock estimate in the present study based on the three meter beam trawl is not directly comparable since it is only for the Oregon coast between 500 and 700 meters. However, a crude comparison between these results and Pereyra's can be made if Pereyra's estimate of the bottom area of the 457-869m depth range (8464 km^2) is used. Since all trawl data in this study fall within this depth range, multiplying the average catch/km^2 by 8464 km^2 will give a rough estimate for comparison purposes (Table 10). Considering Pereyra's estimates are based on a

Table 10. Comparison of stock estimates for adult Tanner crabs on the Oregon and Washington continental slopes, 457-869m depth interval.

	Numbers X 10^6			Weight, kg(lbs), X 10^6		
Study	Adult male	Adult female	Total	Adult male	Adult female	Total
Pereyra (1972)	1.60 ± 0.61*	7.34 ± 2.57	8.98 ± 2.74	1.73 ± 0.74 (3.81 ± 1.62)	2.53 ± 0.95 (5.56 ± 2.10)	4.26 ± 1.69 (9.37 ± 3.72)
Oliver	0.47 ± 0.28	1.39 ± 0.67	1.86**	0.33 ± 0.18 (0.73 ± 0.39)	0.39 ± 0.21 (0.86 ± 0.47)	0.72** (1.59)

* - 95% confidence interval

** - Confidence interval not calculated

greater depth range and the differences in gear and method of calculation, it is significant that the estimates are of the same order of magnitude and within a factor of two at the edges of the confidence limits.

The beam trawl estimate was affected by several factors. As pointed out in Materials and Methods, the beam trawl wheel counts appear to constantly underestimate the distance trawled. This would lead to an overestimate of density since the area trawled would actually be greater than assumed. Three factors would contribute to an underestimate of density. First, the trawl net may not be in contact with the bottom, yet one wheel may still be registering. Although the trawl is designed to avoid this, it is conceivable on the continental slope. Second, there may be an avoidance problem. Watson (1969) observed, from a submersible, _C_. _opilio_ partially buried in the bottom. In contrast, Miller (1975) photographed 634 _C_. _opilio_ and all had tops and sides of the carapace and parts of most legs unburied. Also, _C_. _tanneri_ may be able to move fast enough to avoid the trawl. Miller (1975) rarely observed larger _C_. _opilio_ from a submersible, and then only at the edges of the field of view and running. Third, crabs were caught outside the 500-700m depth range.

As with the distribution analysis, it is difficult to make conclusions because of the low numbers involved. My abundance estimates are based on 22 adult males and 70 adult females, whereas Pereyra's were base on approximately 700 males and 1000 females. Consequently there is doubt as to the beam trawl's suitability for assessing the density of _C_. _tanneri_. Miller (1975) used photography as a means of estimating the density of C. opilio around Newfoundland, but only after determining that a submersible and the beam trawl were inadequate. Relative to the photographic estimates, the beam trawl consistently underestimated density of adult males: mean photographic density was 6.1 crabs/500 m^2 and mean beam trawl density was 1.4 crabs/500 m^2. Incidentally, Miller's beam trawl estimate corresponds to 2800 crabs/km^2 compared to the maximum of 500 crabs/km^2 in this study. Miller's estimates of adult male biomass (based on photographic results) ranged from 4200-8200 kg/km^2 live weight compared to 0-340 kg/km^2 wet preserved weight for C. tanneri from this study.

Miller did not estimate numbers or weight for adult females and immature crabs of both sexes because he concluded that their distributions were too highly aggregated. He based this on a variance:mean ratio (Cassie, 1962) of 26 for adult females and 0.93 for adult males. A ratio of one indicates random dispersion; a ratio of greater than one indicates aggregation or over-dispersion. The variance:mean ratio of catch/km^2 from this study was 244 for adult males and 483 for adult females. These values are probably more a reflection of the size of the beam trawl than an accurate measure of aggregation.

A further comparison can be made with Pereyra's results. His mean catch/km^2 for adult male C. tanneri, after conversion from catch/hr, was 203 crabs/km^2 with a maximum of 1623 crabs/km^2. Catch by weight averaged 218 kg/km^2 (live weight) with a maximum of 1863 kg/km^2. Although Pereyra's mean densities are greater than those for this study, they too are considerably less than Miller's for C. opilio. There is an active pot fishery for C. opilio in Miller's study area also.

All factors, considered, I conclude that the beam trawl estimates used in this study underestimate the total stock of Tanner crabs on the Oregon continental slope. There is no evidence for altering Pereyra's conclusion that a fishery for C. tanneri would not be feasible at this time. The size and remoteness of the resource limit its usefulness until demand could make it economically feasible.

Longline traps or pots would have been the best way to assess the Tanner crab stock on a purely fisheries oriented basis, since that is the method that would most likely be used in a commercial fishery. Miller (1975) used his photographic density estimates to calibrate a trap used for C. opilio. Although crude, the method shows promise for estimating crab density. If further work is done on the Tanner crab resource, longline pots should be the method.

Ecology

Habitat Characterization

Analysis of hydrological parameters (Figure 8 and Table 7) indicates that the Tanner crab environment is relatively stable with respect to temperature, salinity, and dissolved oxygen. Oxygen shows the most variation between cruises, but this may not be real because of the technique used (Winkler titration method on board ship). Temperature and salinity show little variation between cruises. Regression analysis against depth demonstrates that temperature decreases significantly with depth, but oxygen and salinity show no consistent pattern. If the depth range involved were greater, the trends would be more apparent. Most of the values fall in the 400-700m range, and the results indicate that there is considerable random variation within this range. Pereyra (1972) describes the region off the Columbia River mouth (457-1920m): temperatures ranged from 2.3-5.6 °C; salinity was 34.05-34.56 ‰. This compares well with the Coos Bay area. Oxygen is evidently not a limiting factor in the study area even at such low concentrations (0.15-0.88 mg-at/l).

Sediments in the study area were generally medium silts, with a varying component of clay. Poor sorting and positive skewness indicate a low energy environment. Pereyra described the sediments in his study area as ranging from sandy silt to silty clay. The Coos Bay area is a region of different sedimentary influences, lacking the input of a major river like the Columbia.

Organic carbon content varied considerably around the mean of 0.04% - 0.002-0.130%. This is low, generally lower than that reported by Gross, et al., (1972) for similar depths on the Oregon continental slope. Dissolved oxygen values indicate that the study area is in the oxygen minimum zone, but this is not reflected by relatively high organic carbon concentrations. Gross, et al., suggest that in areas of low oxygen concentration, reduced biological activity contributes to higher organic carbon concentrations. The correlation between organic carbon and particle size is 0.30 for Inman median and 0.28 for Folk and Ward mean, neither significant at the 5% level (N=38). High organic carbon concentrations are usually associated with fine particle size (Trask, 1932).

None of the sediment statistics show any linear relationship with depth. This is probably due to the narrow depth range involved.

The description of sediment characteristics given here is an anomalous one: fine particle size, low oxygen concentration, and low organic carbon content. No explanation for this is evident.

Habitat Correlation

The factors controlling the distribution of adult C. tanneri are not discernible using the data from this study and the qualitative technique described previously. Whether or not these factor(s) could be determined with more complete data and a rigorous quantitative approach is difficult to say. Carey (1965) found peaks of abundance of macro-infauna (polychaeta) closely associated with peaks in organic carbon content. Hartnoll (1962) found that the occurrence and relative abundance of 14 species of sublittoral crabs was related to bottom type, with different dominants on different substrates. Sanders (1965) reported no consistent pattern of animal density versus percent organic carbon content along the Gay Head-Bermuda transect (100-5000m). The distribution of shallow water (0-100m) benthic communities studied by Buchanan (1963) was poorly correlated with sediment texture. The sediment types associated with various assemblages of animals showed considerable overlap. However, this overlap was not reflected in nature by a broad overlap of the fauna. Also, similar sediments in different areas contained different fauna. Bader (1954) found a curvilinear relationship between the density of shallow water (2-45m) pelecypods and organic carbon content. He explained this by saying that the density initially increases with an increase in organic carbon (food is limiting). Beyond three percent organic carbon, decomposition products and/or oxygen become limiting and density decreases. The only deep water studies here (Carey, 1965, and Sanders, 1965) present conflicting conclusions regarding the relationship of organic carbon and faunal abundance.

The results of the Tanner study are inconclusive. The implication is that Tanner crabs are found over a range of depth, temperature, salinity, dissolved oxygen, and sediment characteristics within which there is no obvious limiting or controlling factor. At the limits of the depth range, some factor or factors becomes limiting, either physical or biological. However, the lack of good data makes these statements little more than speculation. The determination of factors controlling the distribution of deep-sea benthos is a difficult task which requires more and better data and, possibly, a different approach.

Associated Fauna

Pereyra (1972) found that *C. tanneri* was the dominant epibenthic invertebrate by weight in the depth range 503-1189m. Tanner crabs were a dominant component by weight at the three stations studied here (Figures 10 and 11), but were rarely *the* dominant group. They ranked first by weight in 4 of 13 trawls examined. Echinoidea (primarily *Allocentrotus fragilis*) ranked first in 6 of 13 trawls. The difference between the two studies is undoubtedly due in part to the trawls used. The mesh size differences discussed previously could lead to significant catch differences. It is impossible to compare catches on this basis since Pereyra's catches were not sorted.

The depth range represented by the stations analyzed is not great enough to provide an insight into compositional changes with depth, although there was depth variation within stations. There was considerable variation between trawls at the same station (Figures 11-14), implying patchy distribution, depth effects, or variable trawl performance. More trawls need to be analyzed to study these effects.

There was a drastic reduction in catch during July and August of 1974 (Figure 9). Even though area trawled was comparable to other cruises, we were bringing up very small samples (approximately 5 gal. or 19 liters) at most stations. The decrease was evident in terms of both numbers and biomass (Figure 9). Since the dominant groups were different for numbers and biomass, the implication is that at least the major groups of the invertebrate fauna all showed a reduction in relative abundance. Depth variation between trawls, size of the trawl, and the number of stations involved combine to cloud the picture. Our immediate reaction to the reduced catches was that Russian trawlers operating in the area were dragging bottom with their trawls. However their target in the Coos Bay area is hake, and they use trawls specifically designed for mid-water fishing. Communication with the National Marine Fisheries Service indicates that no one is sure if the Russians are fishing on bottom. Tester communicated with Marine Extension agents who spent a day aboard a Russian trawler, Stan Ludwig of Humboldt State University and Alan Otness, Marine Extension Agent, Astoria, Oregon. Mr. Otness' opinion was that the only time a Soviet mid-water trawl would reach bottom would be as a result of a mistake by the Captain. Stan Ludwig ascertained that they sometimes lost gear on underwater obstructions. More information from our beam trawl data and on Soviet trawling results is needed to determine if the invertebrate population is being affected by foreign fishing effort. With respect to a potential Tanner crab fishery, it is an important question.

CONCLUSIONS

1. Adult Tanner crabs show no evidence of segregation of sexes or seasonal migration in the Coos Bay study area. Low catch rates and lack of information at all depth intervals prevent conclusive statements.

2. Stock estimates are of the same order of magnitude as Pereyra's (1972). Therefore, I agree with his conclusion that a fishery would be infeasible at this time.

3. Presence or absence of adult crabs is not correlated with any single environmental variable or any combination of two of the variables considered in this study. This suggests that the distribution of Tanner crabs within the depth range included here is not limited by any of the variables temperature, salinity, dissolved oxygen, organic carbon content, or sediment particle size.

4. Longline pot fishing would be a better method for assessing the commercial potential of *C. tanneri* stocks.

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APPENDICES

APPENDIX 1

Station position and depth for Tanner crab sampling program at Coos Bay, Cape Blanco, and Astoria.

Coos Bay

Station		Depth	Trackline Positions			
CBT-	A	500m	43°29.4'N	124°41.2'W	- 43°26.8'N	124°47.0'W
CBT-	B	530m	43 25.7	124 48.0	- 43 30.8	124 48.0
CBT-	C	550m	43 26.0	124 50.0	- 43 30.0	124 50.0
CBT-	D	600m	43 26.0	124 51.6	- 43 30.0	124 51.6
CBT-	E	650m	43 26.0	124 52.3	- 43 30.0	124 53.1
CBT-	F	700m	43 26.0	124 53.0	- 43 30.0	124 54.0
CBT-	V	800m	43 27.2	124 56.6	- 43 33.7	124 56.4
CBT-	W	1000m	43 27.6	124 57.2	- 43 34.2	124 57.0
CBT-	X	1000m	43 28.2	124 57.8	- 43 33.5	124 57.6
CBT-	Y	1100m	43 27.0	124 57.0	- 43 33.3	125 00.0
CBT-	Z	1200m	43 28.9	125 08.6	- 43 30.3	124 55.7
CBT-	Z	1500m	43 27.0	125 08.8	- 43 33.5	125 12.0
CBT-	G	500m	43 17.1	124 46.3	- 43 21.1	124 45.8
CBT-	H	550m	43 18.0	124 46.7	- 43 21.5	124 46.2
CBT-	I	600m	43 19.4	124 47.7	- 43 23.0	124 46.3
CBT-	J	600m	43 22.2	124 50.3	- 43 23.7	124 54.6
CBT-	K	650m	43 21.6	124 49.7	- 43 22.7	124 54.0
CBT-	L	700m	43 21.0	124 50.5	- 43 23.7	124 54.5
CBT-	M	750m	43 21.0	124 53.3	- 43 21.2	124 58.5
CBT-	N	700m	43 20.2	124 55.7	- 43 20.7	124 50.7
CBT-	O	650m	43 20.5	124 49.8	- 43 19.7	124 54.5
CBT-	P	600m	43 19.1	124 54.6	- 43 20.1	124 49.8
CBT-	Q	800m	43 23.0	124 56.1	- 43 27.2	124 56.4
CBT-	R	1000m	43 16.0	125 04.8	- 43 18.2	125 03.0
CBT-	S	1200m	43 19.8	125 02.9	- 43 23.5	125 04.8
CBT-	T	1600m	43 18.8	125 10.2	- 43 23.5	125 09.5
CBT-	U	2000m	43 20.2	125 11.8	- 43 22.8	125 16.0

Cape Blanco

Station	Depth	Trackline Positions			
CBL-A	300m	42°37.2'N	124°42.6'W	- 42°34.2'N	124°43.5'W
CBL-B	350m	42 37.2	124 42.4	- 42 34.4	124 44.8
CBL-C	400m	42 36.2	124 44.2	- 42 33.7	124 46.2
CBL-D	450m	42 34.5	124 46.7	- 42 31.8	124 48.2
CBL-E	550m	42 36.8	124 45.2	- 42 34.3	124 47.8
CBL-F	650m	42 36.2	124 47.1	- 42 33.3	124 49.8
CBL-G	750m	42 37.0	124 47.2	- 42 33.8	124 50.0
CBL-H	300m	42 52.8	124 53.4	- 42 50.5	124 50.8
CBL-I	350m	42 50.7	124 52.8	- 42 47.9	124 54.5
CBL-J	1000m	42 59.8	125 00.3	- 42 45.9	124 58.8
CBL-K	1150m	43 00.5	125 02.7	- 42 56.5	125 01.2

Astoria

Station	Depth (Meters)	Mid Point of Transect	
AT-A	92.5	46°08'	124°13'
B	139	46°05'	124°31'
C	185	46°04'	124°39'
D	231	46°02'	124°42'
E	278	46°01'	124°43'
F	324	46°00'	124°43'
G	370	46°00'	124°44'
H	416	45°58'	124°45'
I	463	45°59'	124°45'
J	509	45°57'	124°45'
K	555	45°59'	124°47'
L	601	45°57'	124°47'
M	648	45°57'	124°49'
N	694	45°57'	124°51'
O	740	45°57'	124°53'
P	786	45°53'	124°47'
Q	833	45°52'	124°52'
R	925	45°52'	124°53'
S	1110	46°02'	124°55'
T	1202	45°45'	124.54'
U	1388	45°43'	124°55'
V	1480	45°36'	124°54'
W	1573	46°02'	125°05'
Y	1665	45°50'	125°11'
Z	1943	45°42'	125°13'

Existing topographic maps indicate the bottom contours lie north - south. Tows were from north to south or south to north depending on wind direction.

APPENDIX 2

Sampling results for all cruises except cruise 9, September 1974. Key to column headings appears at the end of the data.

T	S	Z	AF	AM	JF	JM	Time	CR
0493		460	0	0	0	0	30	1
0494	I	550	3	2	0	0	30	1
0495	BB	621	1	1	8	9	40	1
0496	Q	803	0	1	1	3	30	1
0497	R	1037	0	0	3	2	43	1
0499	OO	1351	0	0	0	0	60	1
0500	T	1628	0	0	0	0	30	1
0501	U	2008	0	0	0	0	45	1
0502	EE	2117	0	0	0	0	43	1
0503	S	1150	0	0	0	0	30	1
0504	I	570	5	1	0	0	45	1
0505	E	639	1	0	0	2	35	1
0506	M	876	0	0	4	4	45	1
0507	L	676	0	0	1	0	30	1
0509	O	657	0	0	2	0	30	1
0510	J	701	0	0	6	3	45	1
0511	B	527	21	3	0	0	50	1
0512	E	672	0	0	26	8	45	1
0513	E	700	0	0	1	0	30	1
0514	A	475	2	0	1	0	45	1
0515	A	569	0	0	2	0	45	1
0517	A	520	1	0	0	1	45	2
0518	B	530	20	2	1	8	45	2
0519	B	547	12	1	4	3	45	2
0520	C	630	0	0	0	3	45	2
0521	D	630	11	3	0	0	30	2
0522	E	659	8	1	3	8	30	2
0523	F	689	0	0	7	9	30	2
0524	V	910	0	2	2	0	30	2
0525	W	964	0	2	1	4	30	2
0526	X	951	0	3	0	1	30	2
0527	Y	1097	0	3	6	3	30	2
0529	Z	1170	0	0	1	5	30	2
0530	Z	1503	0	0	0	1	30	2
0531	G	430	0	0	0	0	30	2
0534	I	585	1	8	4	1	45	2
0537	J	597	1	2	6	6	45	2
0538	K	670	1	3	18	18	45	2
0539	L	680	0	0	5	3	45	2
0540	7	656	0	0	4	4	45	2
0541	N	659	2	2	4	5	45	2
0542	O	627	3	0	3	2	45	2
0543	P	647	3	4	4	5	45	2
0544	R	900	0	1	4	3	45	2
0549	A	506	0	0	0	0	30	3
0550	B	519	0	0	0	0	20	3
0551	C	603	0	0	0	0	30	3
0552	D	633	0	1	0	1	30	3
0553	E	659	0	0	1	1	45	3
0554	F	658	0	0	4	8	45	3
0555	W	900	0	0	5	7	75	3
0556	V	677	0	0	0	2	45	3
0557	J	612	26	5	4	7	45	3
0559	K	640	1	0	6	0	45	3
0561	L	650	0	1	3	6	45	3
0562	M	658	0	0	1	2	45	3
0563	P	610	0	4	1	0	45	3
0564	O	611	0	0	8	6	45	3
0565	J	608	0	1	0	1	45	3
0566	G	505	0	0	2	4	45	3
0567	H	535	1	1	11	13	45	3
0570	I	525	0	0	9	6	45	3
0571	J	622	0	1	11	11	45	3
0572	J	631	1	2	24	13	45	3
0574	A	512	0	0	0	0	40	4
0575	B	527	6	1	0	0	40	4
0576	C	545	0	1	2	0	40	4
0577	C	549	0	1	1	0	60	4
0578	D	670	0	1	8	16	40	4
0579	D	673	0	0	0	0	40	4
0580	E	658	0	0	0	0	45	4
0581	F	650	0	0	22	36	45	4
0582	V	800	1	2	30	50	45	4
0583	W	800	2	0	3	6	45	4
0585	X	905	0	1	2	0	45	4
0586	Z	904	1	1	1	3	60	4
0588	B	501	0	0	2	0	30	4
0589	C	402	0	0	1	0	30	4
0591	G	450	0	0	0	0	45	4
0592	H	495	0	0	0	0	45	4
0593	A	500	0	0	0	0	30	5
0594	B	545	1	1	0	0	30	5
0595	C	622	7	4	1	0	30	5

T	S	Z	AF	AM	JF	JM	Time	CR
0596	D	550	0	0	0	0	30	5
0597	E	658	0	1	0	0	30	5
0599	F	600	0	2	1	2	45	5
0600	P	595	0	1	2	2	30	5
0601	O	640	0	0	1	0	30	5
0602	N	658	0	0	0	0	45	5
0603	H	722	0	0	0	3	45	5
0604	R	570	0	0	1	0	30	5
0605	S	1380	0	0	3	0	45	5
0606	F	677	1	0	1	2	30	5
0607	E	685	0	1	0	0	30	5
0608	E	650	0	1	1	1	30	5
0610	D	600	0	0	0	0	30	5
0612	C	550	0	0	0	0	30	5
0613	B	594	0	0	0	0	30	5
0614	J	622	2	0	2	1	30	5
0615	K	658	0	1	8	7	30	5
0616	L	713	0	0	19	12	30	5
0618	ZZ	1500	0	1	1	0	60	6
0620	B	527	5	0	2	2	30	6
0621	C	541	10	0	3	1	30	6
0622	D	534	0	1	2	2	30	6
0623	E	626	0	0	2	3	30	6
0624	E	631	3	0	0	1	30	6
0625	F	622	6	1	0	2	30	6
0626	G	460	0	0	0	0	30	6
0627	G	493	0	0	0	1	30	6
B337	B	512	0	0	1	0	32	6
B338	C	521	11	1	0	0	60	6
B339	C	549	13	0	3	1	30	6
B340	C	439	11	0	1	2	60	6
B341	D	530	5	2	6	4	60	6
B342	D	585	0	0	0	0	30	6
B343	E	622	5	1	2	4	120	6
B344	F	585	0	0	0	0	60	6
B345	J	622	0	0	0	0	60	6
B346	K	658	3	1	1	2	60	6
B348	J	640	5	2	10	14	30	6
B349	L	676	0	0	7	4	60	6
B351	P	610	0	0	1	0	60	6
B352	B	527	4	0	0	1	60	6
B353	B	534	5	0	0	0	60	6
B354	D	634	0	1	37	33	60	6
B355	D	535	2	1	3	4	60	6
0628	Q	856	0	0	9	12	60	7
0629	R	1050	0	0	1	1	30	7
0630	S	1046	0	0	0	0	45	7
0632	U	1900	0	0	0	0	45	7
0633	Z	1536	0	0	0	0	30	7
0634	ZZ	1580	0	1	0	0	45	7
0635	R	1096	0	0	0	1	30	7
0636	V	900	0	0	0	0	45	7
0649	I	580	0	0	0	0	30	7
0650	K	647	0	0	5	5	30	7
B364	B	549	1	0	1	0	30	7
B365	C	548	1	0	0	0	45	7
B366	D	635	1	0	4	2	30	7
B367	E	680	0	2	2	2	45	7
B369	F	757	0	1	6	7	45	7
B370	H	550	0	0	1	0	45	7
B372	I	640	0	3	0	0	45	7
B373	J	694	0	0	0	2	45	7
B374	K	675	0	0	0	1	45	7
B375	L	603	0	0	0	0	45	7
B376	P	585	0	0	3	6	45	7
B377	B	585	0	0	0	0	45	7
B378	C	648	0	0	0	1	45	7
B379	D	565	0	3	1	0	45	7
B380	E	687	2	1	2	2	45	7
B381	F	690	0	0	5	3	45	7
0669	R	1052	0	0	5	4	60	8
0670	S	1316	0	0	0	1	60	8
0671	ZZ	1463	0	0	1	0	60	8
0673	T	1550	0	0	0	1	60	8
0677	W	841	0	1	0	0	60	8
0678	V	825	0	2	6	7	60	8
0679	G	483	0	0	0	0	45	8
0680	A	519	0	0	0	0	45	8
B393	B	557	2	0	7	6	30	8
B394	C	563	1	0	0	0	30	8
B395	D	687	0	0	5	7	30	8
B396	E	642	0	0	6	3	45	8
B397	F	675	0	0	0	0	60	8
B398	H	476	0	0	0	0	60	8

T	S	Z	AF	AM	JF	JM	Time	CR
B399	I	595	0	0	0	0	60	8
B400	J	640	0	1	14	18	60	8
B401	K	673	0	0	2	3	60	8
B402	L	619	0	0	2	4	60	8
B403	P	671	0	0	2	1	50	8
B444	B	585	3	0	1	1	45	10
B446	C	600	0	0	0	0	45	10
B447	D	600	0	0	8	9	45	10
B448	E	630	1	1	11	12	60	10
B449	F	700	5	0	1	3	60	10
B450	H	554	0	0	0	0	60	10
B451	I	550	0	0	0	1	60	10
B452	J	640	0	0	21	28	60	10
B453	I	575	0	0	0	0	60	10
B454	H	440	0	0	0	0	30	10
B455	B	520	0	0	1	0	45	11
B456	C	540	2	1	0	1	45	11
B457	D	630	1	0	1	3	50	11
B458	D	645	0	1	3	10	45	11
B459	E	665	1	0	5	14	45	11
B461	F	700	0	0	15	17	45	11
B462	H	590	0	0	0	0	45	11
B463	I	600	0	0	2	3	45	11

T - Trawl number. B = Beam trawl 0 = Otter trawl
S - Station
Z - Depth in meters
AF - Catch of adult females
AM - Catch of adult males
JF - Catch of juvenile females
JM - Catch of juvenile males
Time - Trawl time on bottom
CR - Cruise number

APPENDIX 3

Beam trawl data used in abundance calculations.

BMT	Left	Right	Area	AM	AF	AM Dens	AF Dens	AM Wt.	AF Wt.	AM Dens	AF Dens	JF	JM	JF Dens	JM Dens
338	1871	1921	.01030	1	11	100	1100	.690	3.168	67	308	0	0	0	0
339	873	885	.00478	0	13	0	720	0	.449	0	94	3	1	600	200
341	2163	585	.01180	2	5	200	400	1.397	.978	118	83	6	4	500	300
342	1008	597	.00437	0	0	0	0	0	0	0	0	0	0	0	0
343	1520	530	.00827	1	5	100	600	.978	1.268	118	153	2	4	200	500
346	1277	780	.00560	1	3	200	500	.785	1.177	140	210	1	2	200	400
348	740	16	.00403	2	5	500	1000	1.145	1.607	284	399	10	14	2500	3400
351	1326	1496	.00768	0	0	0	0	0	0	0	0	1	0	100	0
352	1021	1338	.00642	0	4	0	600	0	1.254	0	195	0	1	0	200
353	2132	2337	.01220	0	5	0	400	0	1.418	0	116	0	0	0	0
354	1716	1868	.00975	1	0	100	0	.762	0	78	0	37	33	3800	3400
355	1710	1857	.00970	1	2	100	200	.811	.549	84	57	3	4	300	400
364	911	912	.00496	0	1	0	200	0	.237	0	48	1	0	200	0
365	1165	1245	.00656	0	1	0	200	0	.228	0	35	0	0	0	0
366	522	815	.00364	0	1	0	300	0	.308	0	85	4	2	1000	500
367	1009	1146	.00586	2	0	300	0	.627	0	107	0	2	2	300	300
370	1675	1687	.00915	0	0	0	0	0	0	0	0	1	0	100	0
372	1084	1172	.00614	3	0	500	0	2.087	0	340	0	0	0	0	0
373	1013	1098	.00574	0	0	0	0	0	0	0	0	0	2	0	300
374	1938	2021	.01080	0	0	0	0	0	0	0	0	0	1	0	90
375	1978	2061	.01100	0	0	0	0	0	0	0	0	0	0	0	0
376	1779	1927	.01010	0	0	0	0	0	0	0	0	3	6	300	600
377	1797	1799	.00978	0	0	0	0	0	0	0	0	0	0	0	0
378	1365	1489	.00776	0	0	0	0	0	0	0	0	0	1	0	100
379	1635	1666	.00898	3	0	300	0	2.159	0	240	0	1	0	100	0
380	1743	1851	.00978	1	2	100	200	.587	.479	60	49	2	2	200	200
381	890	887	.00483	0	0	0	0	0	0	0	0	5	3	1000	600
393	992	1009	.00544	0	2	0	400	0	.322	0	59	7	6	1000	1000
394	1240	1206	.00665	0	1	0	200	0	.177	0	27	0	0	0	0
395	1133	1212	.00638	0	0	0	0	0	0	0	0	5	7	800	1000
396	1545	1406	.00803	0	0	0	0	0	0	0	0	6	3	700	400
397	1971	1992	.01080	0	0	0	0	0	0	0	0	0	0	0	0
399	1574	1179	.00749	0	0	0	0	0	0	0	0	3	10	400	1300
400	2134	2223	.01190	1	0	80	0	.359	0	30	0	14	18	1200	1500
401	2287	2401	.01280	0	0	0	0	0	0	0	0	2	3	200	200
402	2233	2109	.01180	0	0	0	0	0	0	0	0	2	4	200	300
403	1555	1712	.00889	0	0	0	0	0	0	0	0	2	1	200	100
447	1622	1689	.00901	0	0	0	0	0	0	0	0	8	9	900	1000
448	1512	1428	.00780	1	1	100	100	.858	.292	110	37	11	12	1400	1500
449	1376	741	.00576	0	5	0	900	0	1.547	0	269	1	3	200	500
450	2232	2204	.01210	0	0	0	0	0	0	0	0	0	0	0	0
451	1440	1546	.00812	0	0	0	0	0	0	0	0	0	1	0	100
452	2153	1641	.01030	0	0	0	0	0	0	0	0	21	28	2000	2700
453	1213	1	.00660	0	0	0	0	0	0	0	0	0	0	0	0
455	1446	1161	.00709	0	0	0	0	0	0	0	0	1	0	100	0
456	1643	1745	.00922	1	2	100	200	.716	.495	78	54	0	1	0	100
457	2006	2030	.01100	0	1	0	90	0	.270	0	25	1	3	90	300
458	1251	1949	.00870	1	0	100	0	.947	0	109	0	3	10	300	1100
459	2441	2592	.01370	0	1	0	70	0	.375	0	27	5	14	400	1000
461	1853	1859	.01010	0	0	0	0	0	0	0	0	15	17	1500	1700
463	1870	1867	.01020	0	0	0	0	0	0	0	0	2	3	200	300

BMT - Beam trawl number
Left - Left wheel reading in revolutions
Right - Right wheel reading in revolutions
Area - Area trawled in square kilometers
AM - Adult male, actual catch
AF - Adult female, actual catch
AM Dens - Density (#/km^2) of adult males
AF Dens - Density (#/km^2) of adult females

AM Wt. - Weight of adult males in kg
AF Wt. - Weight of adult females in kg
AM Dens - Density (kg/km^2) adult males
AF Dens - Density (kg/km^2) adult females
JF - Juvenile female, actual catch
JM - Juvenile male, actual catch
JF Dens - Density (#/km^2) juv. females
JM Dens - Density (#/km^2) juv. males

APPENDIX 4

Environmental data listed by multiple corer number for all cruises. Key to column headings appears at end of data list.

MC	S	Depth	T	Sal	Oxy	Silt	Clay	OrgC	I Med	F Mn	Sort	Skew	Kurt
118	A	507	5.04	0	0	0	0	.051	0	0	0	0	0
119	B	534	0	0	0	0	0	.050	0	0	0	0	0
120	B	0	0	33.64	1.18	0	0	0	0	0	0	0	0
121	C	0	4.97	34.21	1.66	0	0	.050	0	0	0	0	0
122	D	605	4.84	34.24	1.95	0	0	.016	0	0	0	0	0
123	E	612	0	0	.51	0	0	.012	0	0	0	0	0
124	F	695	0	34.03	0	0	0	.020	0	0	0	0	0
125	Y	788	4.12	34.37	.73	0	0	.117	0	0	0	0	0
126	W	856	3.80	34.37	.37	0	0	.114	0	0	0	0	0
127	X	958	0	34.42	.44	0	0	.007	0	0	0	0	0
128	G	433	0	34.12	1.53	0	0	.007	0	0	0	0	0
129	H	541	0	34.15	.78	0	0	.024	0	0	0	0	0
130	I	485	5.42	34.18	.85	0	0	.015	0	0	0	0	0
131	J	641	4.82	33.79	0	0	0	.008	0	0	0	0	0
132	K	637	4.67	34.24	.55	0	0	.022	0	0	0	0	0
133	L	673	4.62	34.25	.50	0	0	.044	0	0	0	0	0
134	M	670	4.83	34.26	.52	0	0	0	0	0	0	0	0
135	N	723	4.48	34.28	.39	0	0	.026	0	0	0	0	0
136	O	640	4.86	34.16	.60	0	0	.077	0	0	0	0	0
137	P	630	5.07	34.17	.66	0	0	.056	0	0	0	0	0
138	Q	750	4.06	34.38	.37	0	0	.066	0	0	0	0	0
139	A	434	5.74	34.10	1.66	0	0	.068	0	0	0	0	0
140	B	521	5.13	33.03	.79	0	0	.102	0	0	0	0	0
141	C	603	0	33.10	.51	0	0	.009	0	0	0	0	0
142	D	600	0	34.19	.57	0	0	.007	0	0	0	0	0
143	E	578	5.16	34.13	.73	0	0	.012	0	0	0	0	0
144	F	680	4.86	34.25	.64	0	0	.095	0	0	0	0	0
145	W	785	3.93	0	.82	0	0	.023	0	0	0	0	0
146	V	723	0	34.01	0	0	0	.015	0	0	0	0	0
147	J	622	4.99	0	.25	0	0	.007	0	0	0	0	0
148	K	630	0	0	.15	0	0	.064	0	0	0	0	0
149	L	640	4.70	34.23	.36	0	0	.005	0	0	0	0	0
150	M	640	4.79	34.23	.31	0	0	.013	0	0	0	0	0
151	P	607	4.73	34.28	.21	0	0	.038	0	0	0	0	0
152	O	607	4.72	34.24	.29	0	0	.059	0	0	0	0	0
153	G	500	5.28	34.14	0	0	0	0	0	0	0	0	0
154	H	428	5.81	34.15	.27	0	0	0	0	0	0	0	0
155	I	587	5.02	34.27	.41	0	0	0	0	0	0	0	0
156	A	417	0	0	0	0	0	.005	0	0	0	0	0
157	C	539	0	0	0	0	0	.007	0	0	0	0	0
158	D	670	0	0	0	0	0	.050	0	0	0	0	0
159	E	695	0	0	0	0	0	.010	0	0	0	0	0
160	F	600	0	0	0	0	0	.041	0	0	0	0	0
161	V	695	0	0	0	0	0	0	0	0	0	0	0
162	W	812	0	0	0	0	0	.005	0	0	0	0	0
163	Y	1100	0	0	0	0	0	.039	0	0	0	0	0
164	X	856	0	0	0	0	0	.042	0	0	0	0	0
165	Z	724	0	0	0	0	0	.006	0	0	0	0	0
166	Z	1514	0	0	0	0	0	.025	0	0	0	0	0
167	A	530	0	0	0	0	0	0	0	0	0	0	0
168	C	0	0	0	0	0	0	.040	0	0	0	0	0
169	D	324	0	0	0	0	0	.002	0	0	0	0	0
170	G	450	0	0	0	0	0	.053	0	0	0	0	0
171	H	578	0	0	0	0	0	.009	0	0	0	0	0
172	A	374	0	0	0	0	0	.005	0	0	0	0	0
173	B	520	5.22	0	0	0	0	0	0	0	0	0	0
174	C	635	5.19	0	0	0	0	.094	0	0	0	0	0
175	D	560	0	0	0	0	0	.042	0	0	0	0	0
176	B	627	0	34.19	.88	78.1	21.9	.110	0	0	0	0	0
177	B	512	0	34.18	.60	65.7	34.3	.082	6.03	7.27	3.18	.55	.76
178	C	530	0	34.17	.60	0	0	0	0	0	0	0	0
179	C	560	0	0	0	98.8	1.2	0	4.30	4.69	.86	.75	2.02
180	C	530	0	0	0	0	0	.057	0	0	0	0	0
181	C	643	4.82	34.21	.78	89.9	10.1	.050	4.41	5.21	1.51	.80	1.17
182	E	556	5.20	34.15	.75	89.3	10.7	.041	4.25	5.04	1.74	.91	4.65
183	F	640	4.98	34.11	.71	75.9	24.1	.099	5.45	6.41	2.46	.59	.92
184	F	695	0	0	0	82.9	17.1	.013	5.16	5.84	1.88	.57	.89
185	J	670	0	34.26	.58	70.4	29.6	.015	5.95	6.79	2.64	.48	.75
186	J	622	0	0	0	0	0	0	0	0	0	0	0
187	K	735	0	34.27	.55	0	0	.013	0	0	0	0	0
188	J	660	4.72	34.22	.50	75.4	24.6	.029	4.89	6.20	2.49	.75	.85
189	J	677	4.90	34.19	.60	71.8	28.2	.015	5.71	6.62	2.57	.51	.78
190	L	640	0	0	0	77.6	22.4	.057	4.45	6.01	2.53	.90	1.02
191	P	613	5.40	34.11	.75	95.3	4.7	.036	4.32	4.96	1.16	.84	1.10
192	P	636	0	0	0	87.6	12.4	.042	4.26	5.16	1.77	.91	3.97
193	B	527	5.27	34.13	.70	94.3	5.7	.008	4.99	5.32	1.24	.46	.95
194	B	629	0	34.23	.85	81.4	19.6	.054	5.40	6.01	1.98	.49	.91
195	B	530	0	0	0	81.0	19.0	.036	4.22	4.94	1.82	.92	0
196	C	0	5.11	34.22	0	94.7	5.3	.025	4.23	4.87	1.16	.88	3.92
197	C	611	0	0	0	88.7	11.2	.036	4.22	4.94	1.82	.92	0
198	D	592	5.04	34.21	.49	0	0	0	0	0	0	0	0
199	D	640	0	0	0	55.3	44.7	.055	7.21	7.84	2.86	.30	.70
200	E	629	4.74	34.24	.67	95.8	4.2	.050	4.46	5.00	1.13	.72	1.01

MC	S	Depth	T	Sal	Oxy	Silt	Clay	OrgC	I Med	F Mn	Sort	Skew	Kurt
201	E	713	0	0	0	93.6	6.4	.130	4.58	5.13	1.30	.68	1.07
202	F	747	4.34	34.29	.30	68.7	31.3	.096	6.41	6.98	2.55	.34	.75
203	F	645	0	0	0	75.9	24.1	.049	5.40	6.31	2.34	.57	.86
204	H	574	4.77	34.24	.44	0	0	.040	4.34	4.79	.77	.74	.58
205	H	480	0	0	0	75.7	24.3	.059	4.33	6.53	3.46	.94	1.30
206	I	0	4.69	0	0	0	0	0	0	0	0	0	0
207	I	574	0	0	0	70.8	29.1	.069	5.40	6.90	3.17	.68	.87
208	J	644	4.72	34.27	.39	71.9	28.1	.040	4.55	6.87	3.66	.91	.99
209	J	688	0	0	0	86.3	13.7	.039	4.24	5.13	1.93	.92	9.63
210	K	0	4.00	34.34	.34	94.7	5.3	.035	4.25	4.94	1.20	.88	2.92
211	K	603	0	0	0	60.9	39.1	.077	6.83	7.58	3.12	.36	.68
212	L	0	0	34.22	.52	0	0	.053	0	0	0	0	0
213	L	660	0	0	0	69.5	30.5	.053	6.29	6.78	2.41	.32	.69
214	P	673	4.64	34.23	.51	74.0	26.0	.036	4.31	7.18	4.50	.96	1.41
215	Q	1163	0	0	0	0	0	0	0	0	0	0	0
228	B	607	5.01	34.24	.75	74.1	25.9	.057	5.86	6.52	2.32	.43	.79
229	B	541	0	0	0	0	0	0	0	0	0	0	0
230	C	541	0	0	0	87.9	12.1	.022	4.27	5.14	1.71	.90	2.95
231	C	650	4.83	34.27	.75	0	0	.056	0	0	0	0	0
232	D	0	0	0	0	72.2	27.8	.046	5.98	6.81	2.60	.48	.85
233	D	650	4.90	0	.70	0	0	.056	0	0	0	0	0
234	E	607	0	0	0	82.6	17.4	.024	4.44	5.63	2.08	.87	1.06
235	E	695	4.77	34.28	.65	0	0	.041	0	0	0	0	0
236	F	754	0	0	0	0	0	.021	0	0	0	0	0
237	F	644	0	0	.80	72.1	27.9	.035	6.00	6.66	2.33	.41	.77
238	H	530	0	0	0	86.2	13.8	.030	4.29	5.22	1.95	.91	2.58
239	H	440	0	34.09	0	0	0	0	0	0	0	0	0
240	I	607	0	0	0	93.1	6.9	0	4.19	4.40	.93	.82	0
241	I	585	5.21	34.18	.70	68.2	31.8	.042	6.18	6.89	2.62	.41	.71
242	J	630	0	0	0	0	0	.034	0	0	0	0	0
243	J	677	5.33	34.25	.55	0	0	.045	0	0	0	0	0
244	K	0	0	0	0	0	0	.058	0	0	0	0	0
245	K	629	0	34.24	.70	0	0	.036	0	0	0	0	0
246	L	612	0	0	0	0	0	.018	0	0	0	0	0
247	L	685	4.73	0	.80	82.5	17.5	.025	4.25	5.64	2.47	.94	1.38
248	P	695	0	0	0	0	0	.027	0	0	0	0	0
249	P	610	5.35	34.17	0	0	0	.020	0	0	0	0	0

MC - Multiple corer number
S - Station
Depth - in meters
T - Temperature in (^{o}C)
Sal - Salinity in ppt.
Oxy - Dissolved oxygen in mg-at/l
Silt - % Silt
Clay - % Clay
OrgC - Organic carbon (%)
I Med - Inman median particle size
F Mn - Folk & Ward mean particle size
Sort - Sorting
Skew - Skewness
Kurt - Kurtosis

APPENDIX 5

Beam trawl catch results with associated environmental data.

Gear	S	Z	AF	AM	JF	JM	Time	CR	Temp	Sal	Oxy	Silt	Clay	OrgC	I Mean	F Mean	I Med
B 337	B	512	0	0	1	0	32	6	0	34.19	.88	78.1	21.9	.110	6.626	6.386	5.906
B 338	C	521	11	1	0	0	60	6	0	34.17	.60	0	0	0	0	0	0
B 339	C	549	13	0	3	1	30	6	4.82	34.21	.78	89.9	10.1	.050	5.608	5.210	4.413
B 340	C	439	11	0	1	2	60	6	0	0	0	0	0	0	0	0	0
B 341	D	530	5	2	6	4	60	6	0	0	0	0	0	0	0	0	0
B 342	D	585	0	0	0	0	30	6	0	0	0	0	0	0	0	0	0
B 343	E	622	5	1	2	4	120	6	5.20	34.15	.75	89.3	10.7	.041	5.430	5.037	4.250
B 344	F	585	0	0	0	0	60	6	4.98	34.11	.71	75.9	24.1	.099	6.897	6.415	5.451
B 345	J	622	0	0	0	0	60	6	0	0	0	0	0	0	0	0	0
B 346	K	659	3	1	1	2	60	6	0	34.27	.55	0	0	.013	0	0	0
B 348	J	640	5	2	10	14	30	6	0	0	0	0	0	0	0	0	0
B 349	L	675	0	0	7	4	60	6	0	0	0	0	0	0	0	0	0
B 450	H	554	0	0	0	0	60	10	0	0	0	0	0	0	0	0	0
B 351	P	610	0	0	1	0	60	6	0	0	0	0	0	0	0	0	0
B 352	B	527	4	0	0	1	60	6	5.27	34.13	.70	94.3	5.7	.008	5.482	5.318	4.991
B 353	B	534	5	0	0	0	50	6	0	0	0	0	0	0	0	0	0
B 354	O	634	0	1	37	33	60	6	0	0	0	0	0	0	0	0	0
B 355	D	585	2	1	3	4	60	6	0	0	0	0	0	0	0	0	0
B 364	B	549	1	0	1	0	30	7	0	34.23	.85	81.4	19.6	.054	6.323	6.015	5.398
B 365	C	549	1	0	0	0	45	7	5.11	34.22	0	94.7	5.3	.025	5.189	4.870	4.232
B 366	D	635	1	0	4	2	30	7	5.04	34.21	.49	55.3	44.7	0	8.153	7.838	7.210
B 367	E	680	0	2	2	2	45	7	4.74	34.24	.67	95.8	4.2	.050	5.269	5.000	4.461
B 369	F	767	0	1	6	7	45	7	0	0	0	0	0	0	0	0	0
B 370	H	550	0	0	1	0	45	7	4.77	34.24	.44	0	0	.040	0	0	0
B 372	I	640	0	3	0	0	45	7	0	0	0	0	0	0	0	0	0
B 373	J	694	0	0	0	2	45	7	4.72	34.27	.39	71.9	28.1	.040	8.026	6.868	4.551
B 374	K	675	0	0	0	1	45	7	4.00	34.34	.34	94.7	5.3	.035	5.278	4.935	4.251
B 375	L	603	0	0	0	0	45	7	0	0	0	0	0	0	0	0	0
B 376	P	585	0	0	3	6	45	7	4.64	34.23	.51	74.0	26.0	.036	8.623	7.185	4.308
B 377	B	585	0	0	0	0	45	7	0	0	0	0	0	0	0	0	0
B 378	C	648	0	0	0	1	45	7	0	0	0	0	0	0	0	0	0
B 379	D	566	0	3	1	0	45	7	0	0	0	0	0	0	0	0	0
B 380	E	687	2	1	2	2	45	7	0	0	0	0	0	0	0	0	0
B 381	F	690	0	0	5	3	45	7	0	0	0	0	0	0	0	0	0
B 393	B	557	2	0	7	6	30	8	5.01	34.24	.75	74.1	25.9	.057	6.851	6.521	5.860
B 394	C	563	1	0	0	0	30	8	4.83	34.27	.75	87.9	12.1	0	5.578	5.142	4.269
B 395	D	687	0	0	5	7	30	8	4.90	0	.70	72.2	27.8	0	7.230	6.814	5.980
B 396	E	642	0	0	6	3	45	8	4.77	34.28	.65	82.6	17.4	0	6.229	5.632	4.438
B 397	F	675	0	0	0	0	60	8	0	0	.80	72.1	27.9	0	6.981	6.655	6.004
B 398	H	476	0	0	0	0	60	8	8.09	34.09	0	86.2	13.8	0	5.681	5.218	4.293
B 399	I	595	0	0	0	0	60	8	5.21	34.18	.70	68.2	31.8	.042	7.250	6.895	6.185
B 400	J	640	0	1	14	18	60	8	5.33	34.25	.55	0	0	0	0	0	0
B 401	K	673	0	0	2	3	60	8	0	34.24	.70	0	0	0	0	0	0
B 402	L	619	0	0	2	4	60	8	4.73	0	.80	82.5	17.5	0	6.335	5.640	4.251
B 403	P	671	0	0	2	1	50	8	5.35	34.17	0	0	0	0	0	0	0
B 444	B	585	3	0	1	1	45	10	0	0	0	0	0	0	0	0	0
B 446	C	630	0	0	0	0	45	10	0	0	0	0	0	0	0	0	0
B 447	D	600	0	0	8	9	45	10	0	0	0	0	0	0	0	0	0
B 448	E	630	1	1	11	12	60	10	0	0	0	0	0	0	0	0	0
B 449	F	700	5	0	1	3	60	10	0	0	0	0	0	0	0	0	0
B 451	I	550	0	0	0	1	60	10	0	0	0	0	0	0	0	0	0
B 452	J	640	0	0	21	28	60	10	0	0	0	0	0	0	0	0	0
B 453	I	575	0	0	0	0	60	10	0	0	0	0	0	0	0	0	0
B 454	H	440	0	0	0	0	30	10	0	0	0	0	0	0	0	0	0
B 455	B	520	0	0	1	0	45	11	0	0	0	0	0	0	0	0	0
B 456	C	540	2	1	0	1	45	11	0	0	0	0	0	0	0	0	0
B 457	D	630	1	0	1	3	50	11	0	0	0	0	0	0	0	0	0
B 458	D	645	0	1	3	10	45	11	0	0	0	0	0	0	0	0	0
B 459	E	665	1	0	5	14	45	11	0	0	0	0	0	0	0	0	0
B 461	F	700	0	0	15	17	45	11	0	0	0	0	0	0	0	0	0
B 462	H	590	0	0	0	0	45	11	0	0	0	0	0	0	0	0	0
B 463	I	600	0	0	2	3	45	11	0	0	0	0	0	0	0	0	0

Gear - Beam trawl gear number
S - Station
Z - Depth in meters
AF - Adult Female catch
AM - Adult Male catch
JF - Juvenile Female catch
JM - Juvenile Male catch
Time - Trawl time in minutes
CR - Cruise number

Temp - Temperature in °C
Sal - Salinity in
Oxy - Oxygen in mg-at/l
Silt - % Silt
Clay - % Clay
OrgC - Organic Carbon (%)
I Mean - Inman mean particle size
F Mean - Folk & Ward mean particle size
I Med - Inman median particle size