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Seasonal Distribution and Abundance of Decapod Larvae for the Kodiak Island Region

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SEASONAL DISTRIBUTION AND ABUNDANCE OF DECAPOD LARVAE FOR THE KODIAK ISLAND REGION

by

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TABLE OF CONTENTS

ABSTRACT

Four bays and the continental shelf on the eastern side of the Kodiak Island Archipelago were surveyed to establish baseline information on the early life histories of nearshore decapods. Five offshore and twelve inshore cruises were conducted from fall 1977 through winter 1979. Distribution and abundance data were collected to determine the areas where decapod larvae were most abundant, the depths they were found, and the time of year they were present. Ten different taxonomic groups, including 5 commercial species, were tested for significant differences in times of occurrence, distribution, and abundance through a series of analysis of variance on bongo net data. Regionally, crab and shrimp larvae were 2-3 times more abundant inshore than offshore. Vertical distribution studies showed that the 10-50 m strata contained a majority of the larvae encountered. Times of peak abundance varied through spring and summer depending upon the taxonomic group.

SECTION I

INTRODUCTION

Background Information

Surveys of ichthyoplankton and decapod crustacea larvae in continental shelf regions of the western Gulf of Alaska were conducted October 1977 through March 1979 by the NMFS, Northwest and Alaska Fisheries Center and the University of Washington, Fisheries Research Institute. The purpose was to establish baseline data on the early life histories of nearshore fish and shellfish around Kodiak Island. The Bureau of Land Management (now Mineral Management Service) through OCSEAP funded the work and the information from these surveys was incorporated into the data base used to evaluate impacts from offshore oil and gas development.

The distribution and abundance of finfish eggs and larvae in the inshore region of the Kodiak Island shelf were described by Rogers et al. (1979) and similar information for the offshore region was presented by Kendall et al. (1980). The latter authors also included a consolidated inshore-offshore summary of information on larvae of selected species of shrimp and crab. Limitations to the data base used for the decapod larvae portion of the report restricted its scope and precluded substantive conclusions relating to Reptantia and Natantia larvae.

The following is a revised analysis of decapod larvae information which incorporates new data that was not available for the Kendall et al. (1980) report.

Description of the Study Area

The study area is generally bounded by latitudes 55°-59°N and longitudes 149°-155°W and covers approximately 75,000 km^2. This area encompasses the continental shelf east of Kodiak and Afognak Islands from the headwaters of several bays seaward to the 2,000 m contour (Figure I-1). Locations sampled extend southwest from

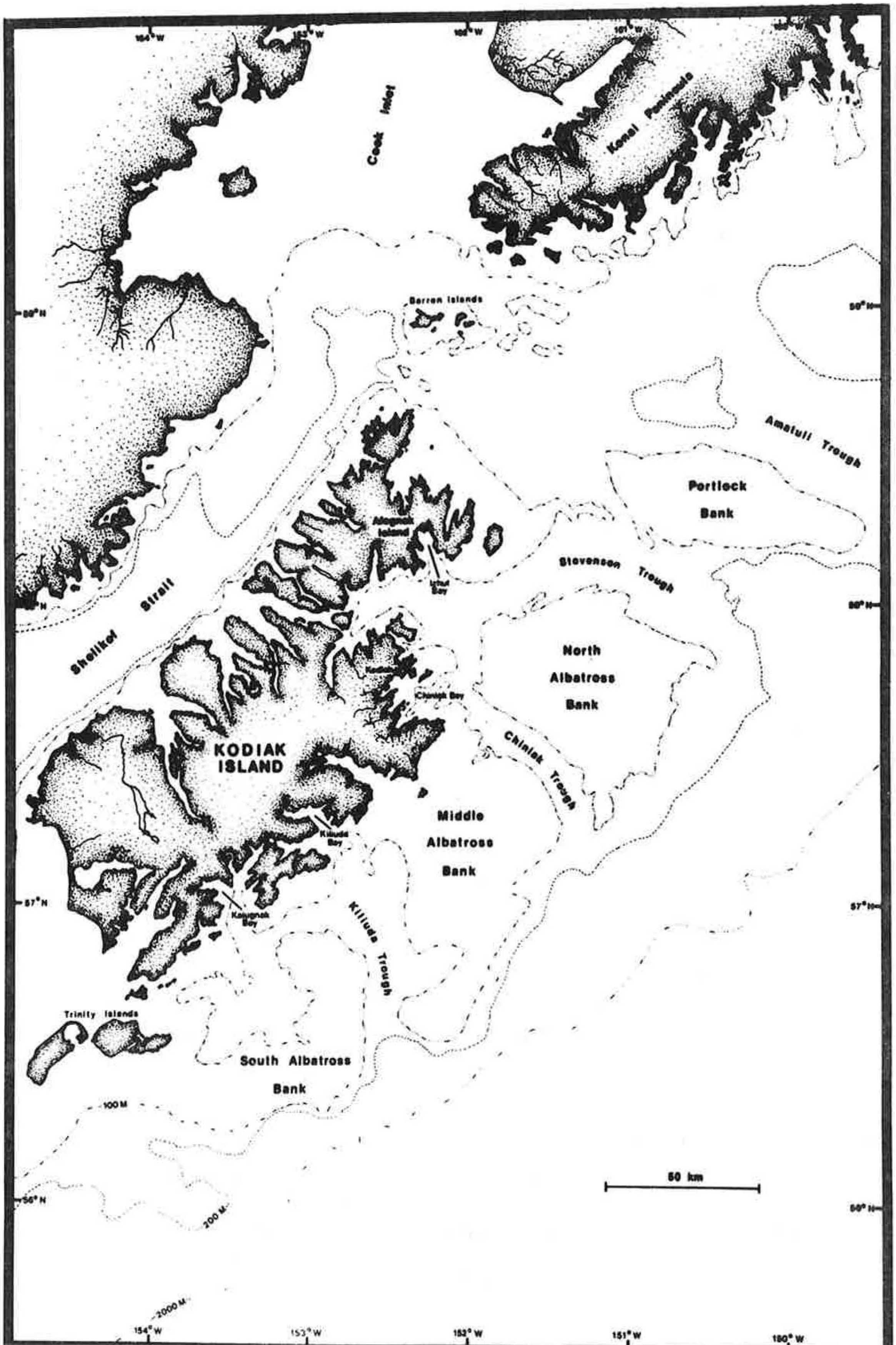


Figure I-1.--Kodiak Island study area showing general bathymetry and principal bays and inlets.

Portlock Bank to the Trinity Islands and include observations in Izhut, Chiniak, Kiliuda, and Kaiugnak Bays.

Shallow banks separated by troughs running to the continental shelf edge generally characterize the bathymetry east of Kodiak and Afognak Islands. Four major troughs; Amatuli, Stevenson, Chiniak, and Kiliuda (Figure I-1), traverse the rather wide shelf, which ranges from about 69-110 km in width. These troughs (except for Amatuli, the northern most) are offshore extensions of deep water trenches out of bays in the study area and have a depth range of about 110-140 m. Four banks separate the troughs, they are: Portlock, and North, Middle, and South Albatross Banks, and have depth ranges of about 49-91 m. In general, substrate composition changes rapidly within short distances on the rugged, uneven bottom and ranges from soft mud and sand to hard rock.

All four bays investigated during the study can be considered open systems with no sills or land masses to restrict interchange between the bay and ocean water masses.

Hydrography and Climate of the Study Area

The shelf area under investigation lies primarily between two surface current regimes: the Kenai current which flows through Shelikof Strait on the west side of the study area (Schumacher and Reed, MS 1979) and the Alaska stream on the east (Ingraham, 1979). Several authorities (Favorite and Ingraham, 1977; Royer, MS 1977; Schumacher et al. 1978; and others) indicate the continental shelf region around Kodiak Island is characterized by weak eddies and variable flow. On the shelf it is difficult to determine any basic order to flow other than that related to local winds and bathymetry (Kendall et al. 1980). If there is a general southwestward movement, it is, perhaps, only along the shelf edge.

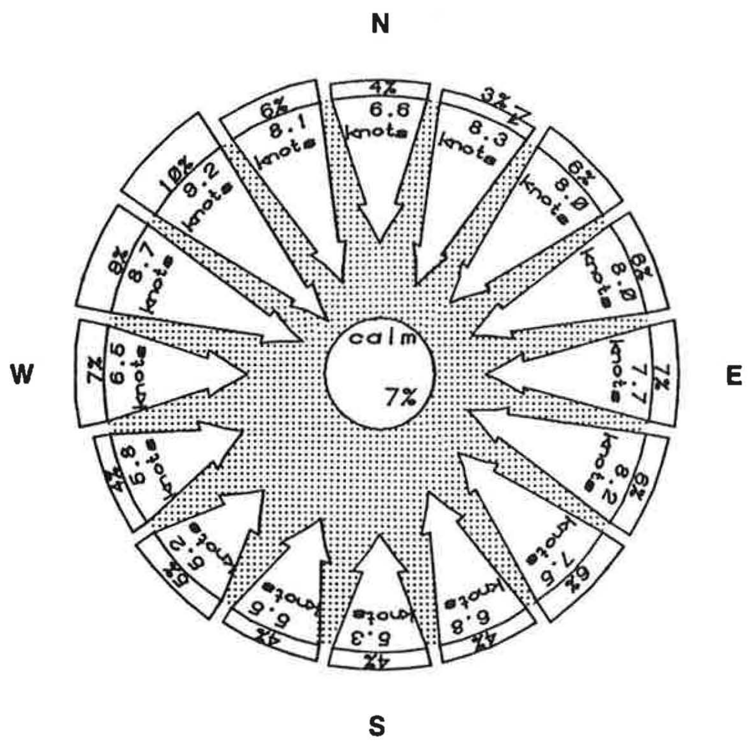
Mean monthly sea surface temperatures in offshore areas range between 0.5-12°C with frequent anomlies of $\pm$3°C for individual months (Ingraham, 1976).

Surface water temperatures in the inshore areas appear somewhat warmer than offshore and range from 0.5-14°C. Depths greater than 100 m generally have temperatures warmer than 5°C; however, during anomalously cold years temperatures may be as low as 1.5°C. Inshore temperatures at depths greater than 100 m apparently range between 1 and 7°C (ADF&G temperature data).

Surface salinity indicates inshore dilution as well as an extensive continuity of mid-shelf maxima. Shelf edge surface salinity minima are traceable to discharges from the Copper River in the eastern Gulf of Alaska outside Prince William Sound (Ingraham, 1979). Winter overturn in the offshore water column extends to depths of 75-100 m and therefore includes most of the study's bank areas (Kendall et al. 1980).

Marine influences dominate the climate of Kodiak Island's coastal regions. The range in air temperatures between an annual maxima and minima is small throughout the region with the greatest range being 8.2°C on the western coast (Buck et al. 1975). Maximum summer average temperatures are usually less than 16°C with winter average minima about -6°C. Average temperature differences between air and water are usually greatest during fall and winter. Then the air is as much as 7°C colder than the water. Long term average air temperature (1940-1970) for the northeast coast of Kodiak Island is 4.8°C (Buck et al. 1975).

Storm movements through the western Gulf of Alaska determine the pressure patterns that establish wind flow in the study area. Strongest winds in offshore areas come primarily from the northwest and secondarily from the east through southeast (Buck et al. 1975). Inshore surface winds are somewhat similar as high velocity winds come most frequently from the northwest (Figure I-2).



Arrows indicate the average wind velocity. Arrow tails indicate the percent frequency of occurrence of wind direction.

Figure I-2.--Long term (1945-1977) average wind velocity and percent frequency of occurrence of wind direction in the Kodiak Island study area (data from EDIS; plot design adapted from Buck et al., 1975).

SECTION II

MATERIALS AND METHODS

Survey designs

The data for this report were gathered in two discrete sets of surveys. Five offshore cruises were conducted by the Northwest and Alaska Fisheries Center and twelve inshore cruises were performed by the Fisheries Research Institute of the University of Washington.

An offshore cruise was conducted during each season from fall 1977 to winter 1979 (Table II-1). The sampling pattern was modified from a stratified design (Figure II-1) to a systematic centric design (Milne, 1959) (Figure II-2) after completion of the first two cruises. These patterns contained up to 88 stations and extended from the inshore region out to the continental slope. Occasionally, inclement weather or operational difficulties caused deletion of stations from planned sampling. Of the five offshore cruises conducted during the study (Table II-1), the first was not used in the analysis as it produced very little information.

The series of 12 cruises in the inshore region of the study area were conducted in: Izhut Bay on the south coast of Afognak Island, Chiniak Bay on the east coast of Kodiak Island, and Kiliuda and Kaiugnak Bays on the southeast coast of Kodiak Island (Figures II-3 and II-4). Sampling locations were initially limited to 5 stations within and closely adjacent to each of the four bays. Three (3) additional stations (stations 6, 7, and 8) were added to the inner portions of Izhut and Kiliuda Bays in May to increase sampling density in the inner portion of these bays. Consequently, 26 stations were sampled during each inshore cruise for the duration of the study (Figures II-3 and II-4). Ten (10) of these cruises were conducted in an almost continuous series on a bi-weekly basis from early spring through mid-summer (Table II-2). The remaining two surveys were conducted in November 1978 and early March 1979.

Table II-1.--Cruises and cruise dates for the 1977-1979 OCSEAP offshore plankton surveys.

Cruise	Season	Date
4MF77	Fall	31 OCT - 14 NOV 77
4DI78	Spring	28 MAR - 20 APR 78
2MF78	Summer	19 JUN - 9 JUL 78
1WE78	Fall	25 OCT - 17 NOV 78
1MF79	Winter	13 FEB - 11 MAR 79

Table II-2.--Cruises and cruise dates for the 1978-1979 OCSEAP inshore plankton surveys.

Cruise	Season	Date
I	Spring	29 MAR - 8 APR 78
II	"	10 APR - 17 APR 78
III	"	21 APR - 1 MAY 78
IV	"	3 MAY - 28 MAY 78
V	"	31 MAY - 6 JUN 78
VI	Summer	14 JUN - 26 JUN 78
VII	"	28 JUN - 18 JUL 78
VIII	"	21 JUL - 29 JUL 78
IX	"	1 AUG - 9 AUG 78
X	"	15 AUG - 21 AUG 78
XI	Fall	4 NOV - 13 NOV 78
XII	Winter	4 MAR - 16 MAR 79

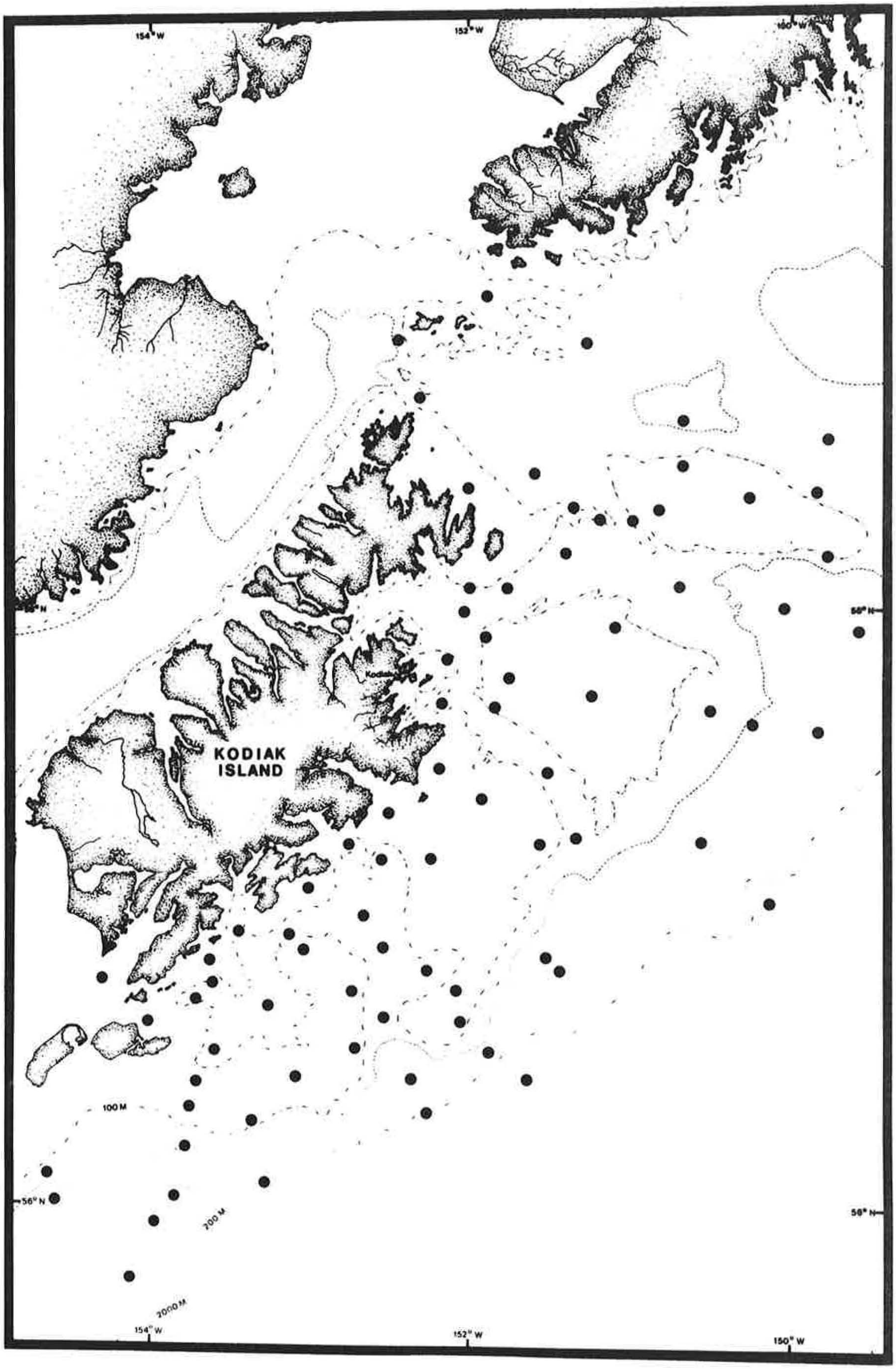


Figure II-1.--Stratified station pattern used for offshore cruise 4DI78; Spring 1978 (a similar pattern was used for 4MF77).

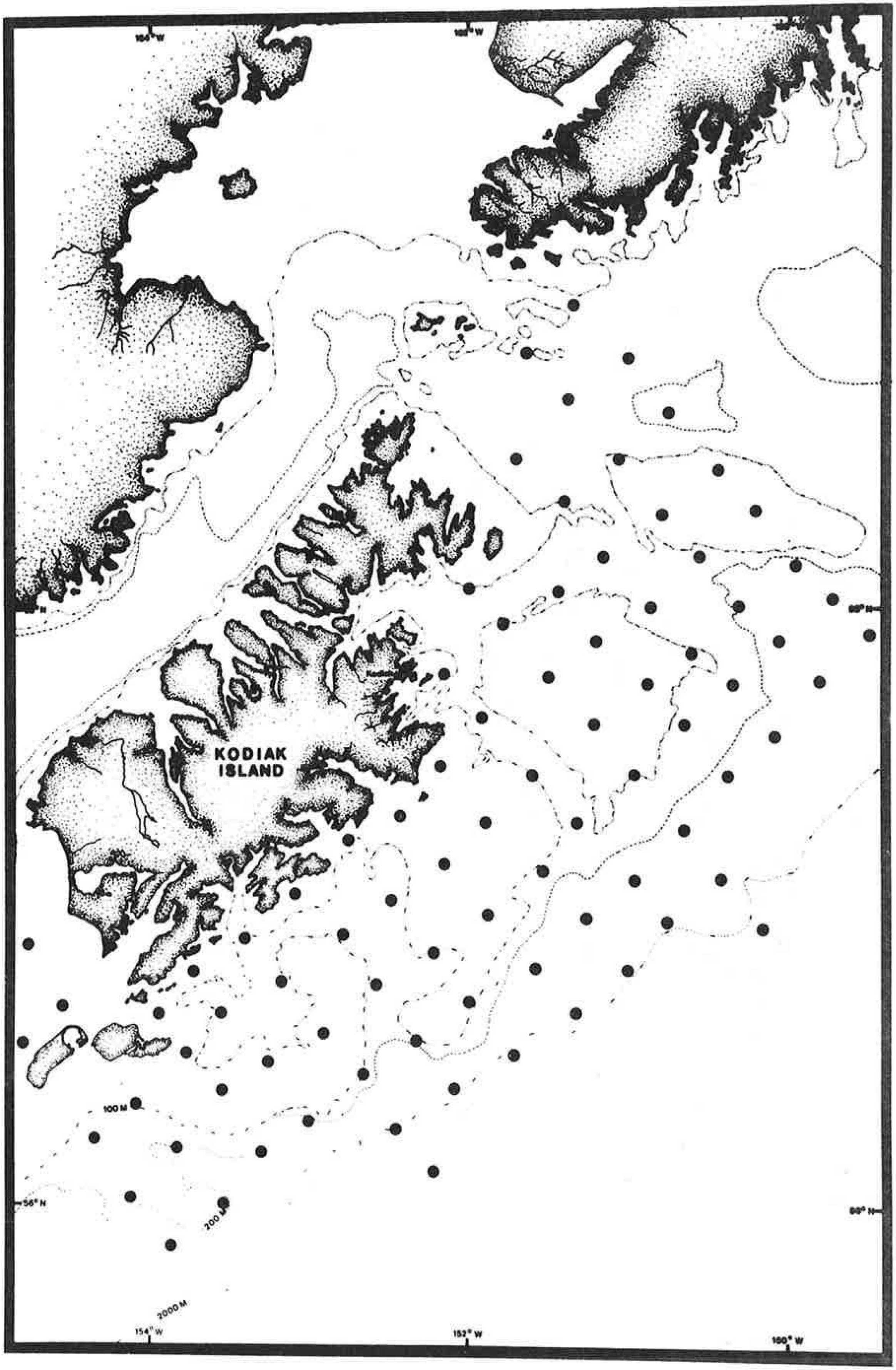


Figure II-2.--Systematic centric station pattern used for offshore cruises 2MF78, 1WE78, and 1MF79 (summer, fall, and winter).

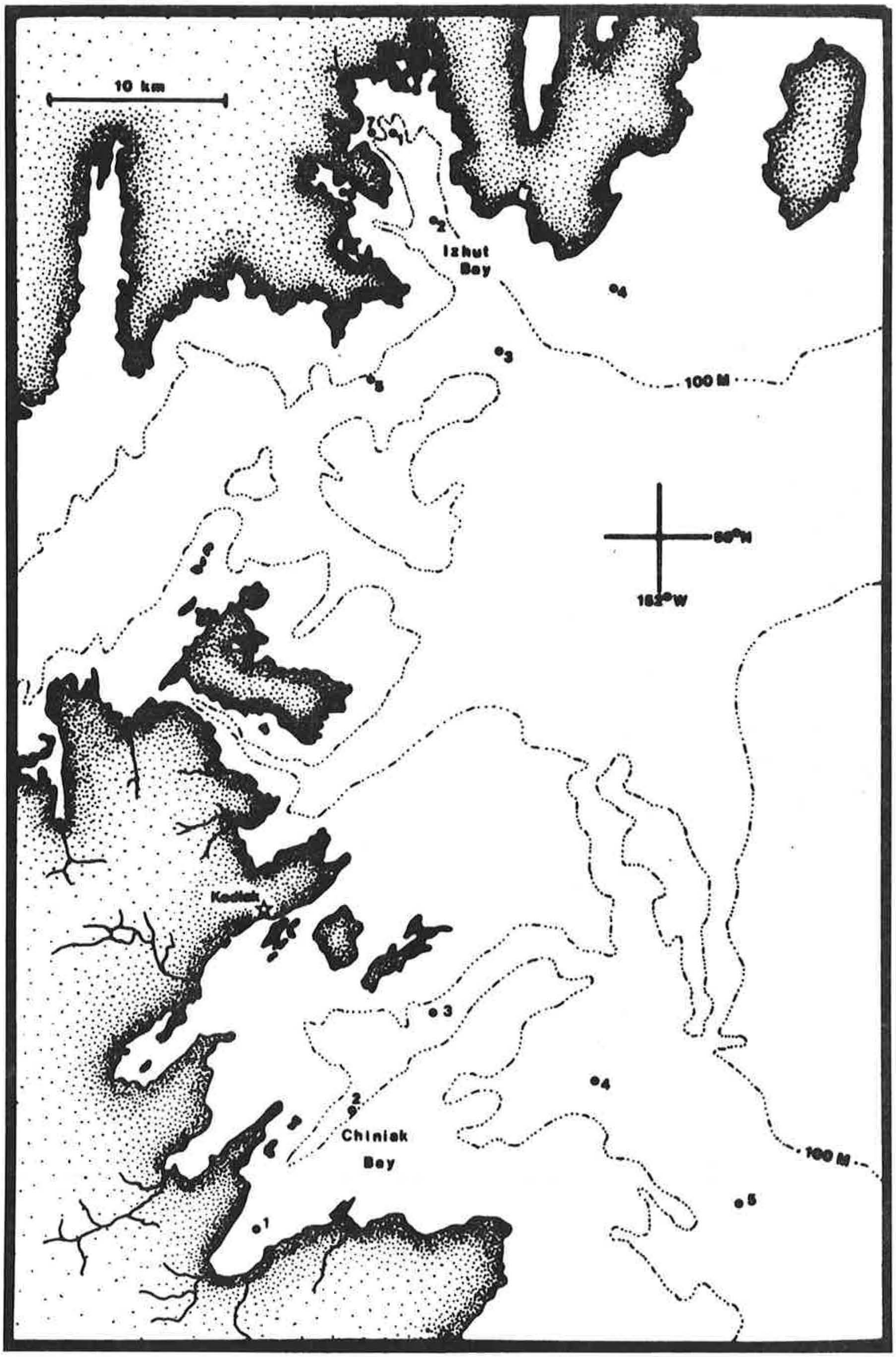


Figure II-3.--Inshore station locations in Izhut and Chiniak Bays.

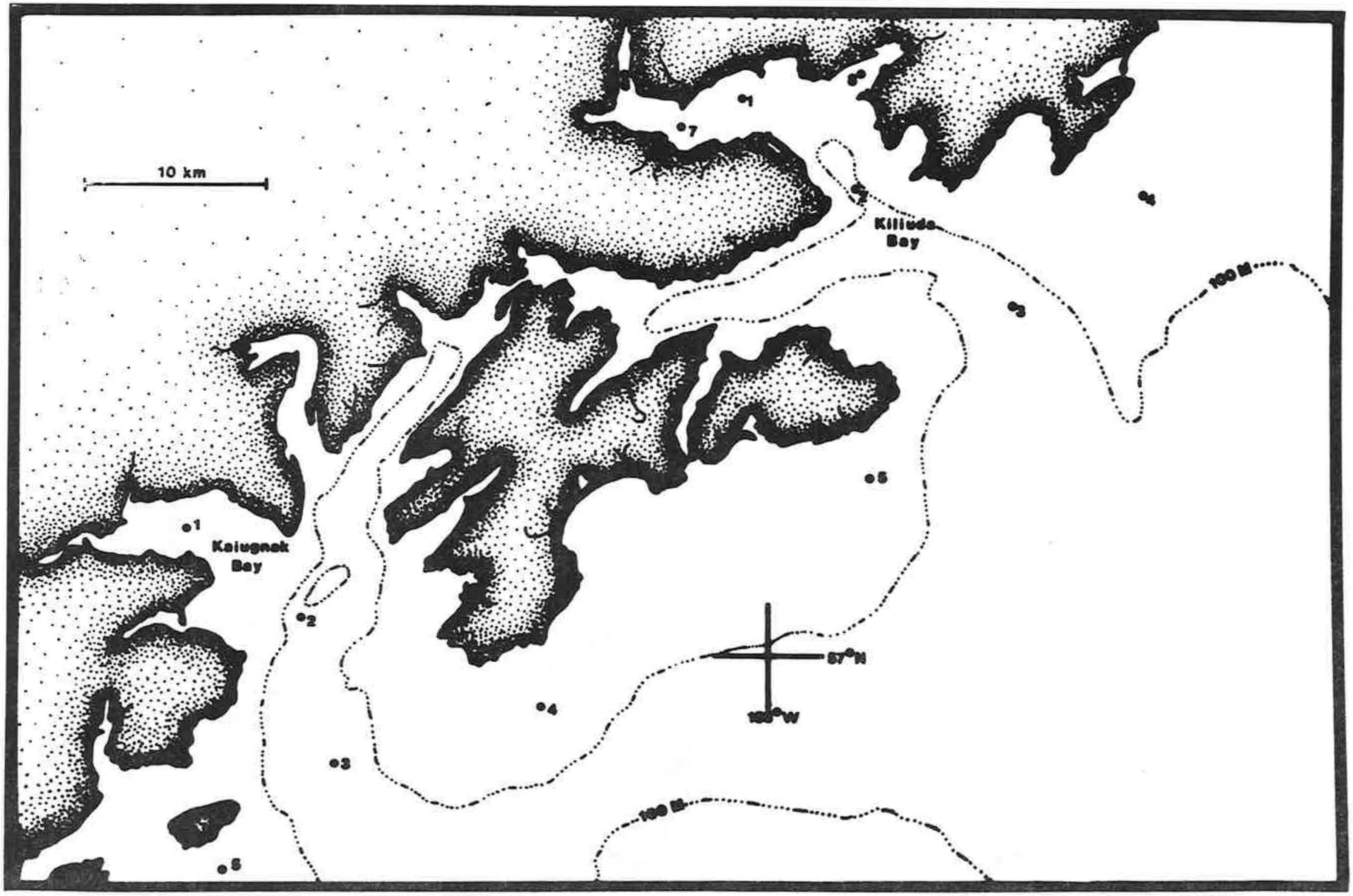


Figure II-4.--Inshore station locations in Kiliuda and Kaiugnak Bays.

Field Gear and Station Procedures

Samples analyzed in this report were obtained from three types of gear:

1) an aluminum MARMAP bongo sampler, 0.6 m inside diameter, with 0.505 and 0.333 mm mesh nets for collecting larvae from surface to near bottom;
2) a Sameoto neuston sampler (Sameoto and Jaroszynski, 1969) with a mouth opening of 0.3 m by 0.5 m and a 0.505 mm mesh net for collecting larvae at the air-sea interface; and,
3) a 1.0 m square mechanical opening-closing Tucker trawl (Clark, 1969) with three 0.505 mm mesh nets for sampling discrete depths.

Field sampling generally followed standard MARMAP procedures (Smith & Richardson, 1977).

A double oblique bongo tow was performed at every station during all cruises. The bongo nets were lowered at a rate of 50 m of wire per minute and retrieved at a rate of 20 m per minute, sampling from surface to within 5-10 m of the bottom, normally to a maximum depth of about 200 m. During lowering and retrieval, the ship's speed (approximately 2.0 knots, or 1.03 m/sec) was adjusted to maintain a 45° wire angle. Actual sampling depths varied depending on wire angles.

The air-sea interface was sampled with the Sameoto neuston sampler for 5 minutes at a speed of ca 2.0 knots (1.03 m/sec). This was done in conjunction with Tucker trawling at discrete depth sampling stations.

Discrete depth sampling via Tucker trawls was performed during both inshore and offshore surveys; however, sampling procedures varied substantially between surveys (Kendall et al. 1980, pages 8 and 28). The Tucker trawl and Sameoto samples from the inshore survey were used for analysis of vertical distribution and diel movement. This discrete depth sampling was conducted during day and night of each cruise at a station in both Izhut and Kiliuda Bays (Figure II-2). The surface and five depth intervals (5-20, 20-40, 40-60, 60-80, 80-100 m) were sampled during each diel series. The Tucker trawl was lowered to the desired depth, tripped open with a messenger and towed for 5 or 10 minutes. After the prescribed time, the net was closed with another messenger and retrieved. The desired depth interval was maintained by varying vessel speed with respect to wire angle.

Gear and procedures described in this section pertain only to those data sets which were addressed in this report.

Sample processing

Plankton samples were preserved in the field in a 5% Formalin-seawater mixture buffered with sodium tetraborate. These preserved samples were shipped to a sorting contractor (Texas Instruments, Inc., Dallas, Texas) for initial processing. The contractor determined the settled volume (Kramer et al., 1972) and removed all fish eggs and fish larvae (i.e., samples were not split).

An aliquot of approximately 500 organisms was then split from the remaining portion of the bulk samples of the 0.333 mm bongo net and Tucker trawl hauls. All organisms in these aliquots were sorted into major categories (e.g., phylum, class, or order). The resulting Natantia and Reptantia larvae were sent to NWAFC Kodiak Facility where they were identified to the most precise taxonomic category and life stage possible, and enumerated. Literature references used to identify the decapod larvae are presented in Appendix B.

Further processing of selected series of bulk plankton samples was done to: 1) evaluate the adequacy of the original 500-organism aliquots for indicating numbers of shrimp and crab zoeae present in the bulk samples (See Appendix A); and, 2) determine the larval decapod species composition in the inshore region's neuston samples. The original sorting contract had excluded neuston samples. The University of Washington, College of Fisheries and Oceanography did this work under contract, sorting from 35-85% (by volume) of the total plankton samples depending on sample type (See Appendix A).

Data Analysis

Numbers of shrimp and crab larvae in each life history stage for each taxon in the aliquots were recorded. These numbers were converted to biomass or density indicies as follows.

Bongo:

$$\text{biomass} = n \times d \times 10/(s \times (\text{aper})^2 \times \pi \times \ell)$$

Sameoto and Tucker:

$$\text{density} = n \times 1000/(s \times h \times w \times \ell)$$

Where:

biomass = number of organisms/10 m^2

density = number of organisms/1000 m^3

n = number of organisms in subsample

s = subsample fraction of bulk sample

aper = radius of net opening in meters (0.3 for bongo)

h = effective fishing height of net opening in meters (0.15 for Sameoto, 1.0 for Tucker)

w = width of net opening in meters (0.5 for Sameoto, 1.0 for Tucker)

ℓ = length of tow in meters (computed from flowmeter readings)

d = depth of water sampled

Biomass data for each taxon from the bongo catches were used to determine geographic distributions for comparisons of different areas and seasons. Density data from the neuston and Tucker catches were used to investigate the depth distribution of organisms as a function of time of day.

A comparative analysis of distribution, abundance, and time of occurrence was performed for each decapod species (or species group) of ecologic or economic importance. For these analyses, each sampled bay in the study's inshore region was defined as a separate inshore subarea while the offshore region was separated into the subareas shown in Figure II-5. They are described as follows:

Portlock subarea - continental shelf regions offshore Marmot Bay encompassed by the points 57°48', 151°55'; 58°13', 151°55'; 58°45', 150°32'; 57°53', 148°58'; 57°21', 150°09' including Portlock Bank, Stevenson Trough and North Albatross Bank.

Marmot subarea - continental shelf regions offshore Chiniak and Ugak Bays encompassed by 57°48', 151°55'; 57°13', 149°38'; 56°27', 151°20'; 57°13', 152°28'; 57°35', 151°55' including Chiniak Trough and Middle Albatross Bank.

Albatross subarea - continental shelf regions offshore Kiliuda and Kiaugnak Bays encompassed by 57°13', 152°28'; 56°27', 151°20'; 55°57', 152°41'; 56°46', 153°07' including Kiliuda Trough and the eastern arm of South Albatross Bank.

Sitkinak subarea - continental shelf regions south of any inshore sampling area encompassed by 56°46', 153°07'; 55°57', 152°41'; 55°39', 153°55'; 56°29', 155°20'; 56°46', 154°30' including South Albatross Bank and stations near the Trinity Islands.

The significance of differences in time of occurrence, distribution, and/or abundance of each taxon of interest was determined through a series of analyses of variance on the bongo net information. For each taxon, data for each cruise within a subarea was pooled. This was done because data from the contract-sorted bongo net aliquots were adequate to represent amounts present only in data sets where observations by larval stage and station were combined (see Appendix A). Additionally, since depths fished and volumes of water filtered at the stations differed between cruises, it was necessary to standardize the subarea summaries. A standardized biomass per subarea was determined from the relationship:

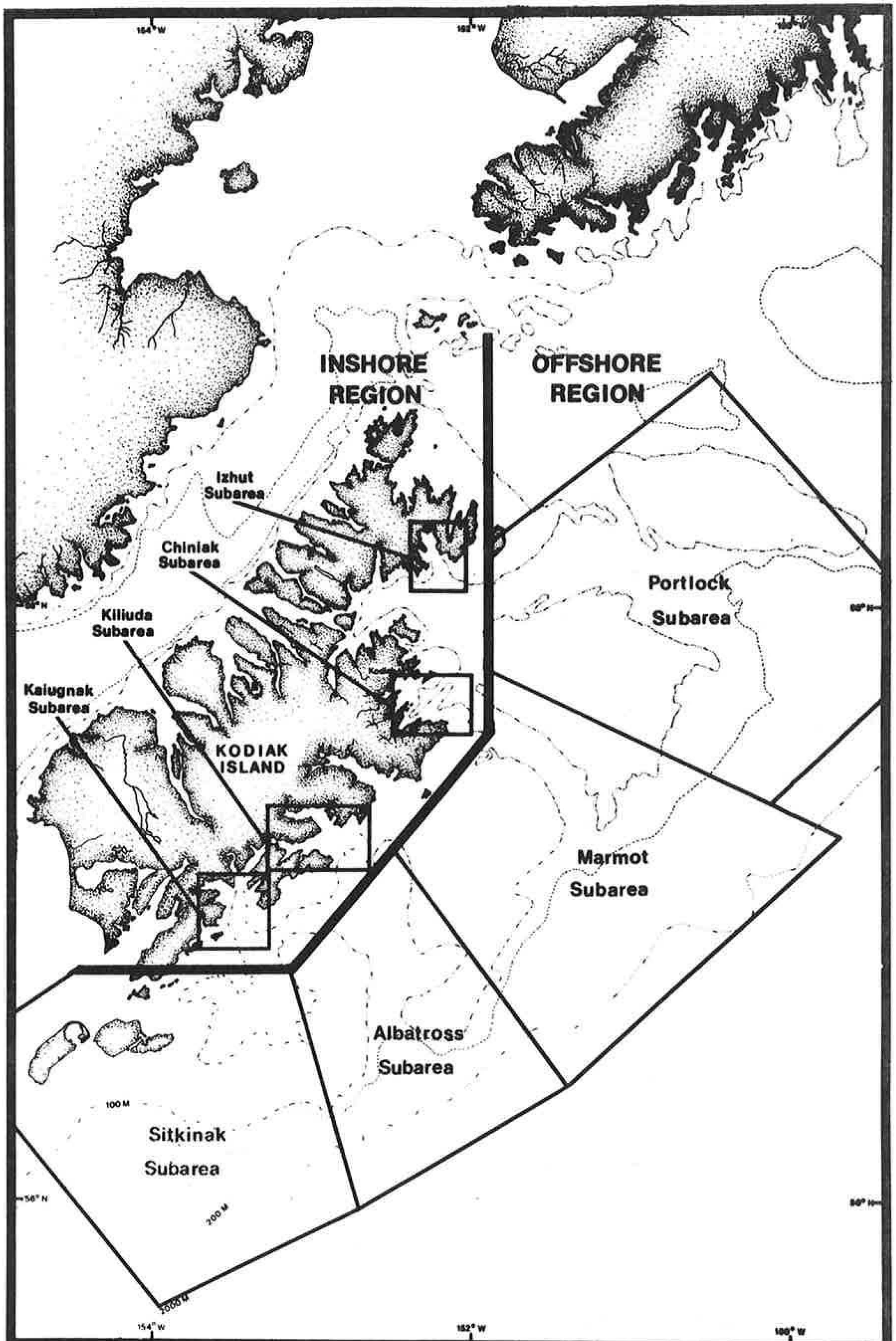


Figure II-5.--Kodiak Island study area showing the two regions and corresponding subareas used in the comparative analysis of distribution and abundance.

$$\hat{B}_{\bullet jkl} = \frac{\left(\sum_{i=1}^{t} n_{ijkl} \cdot \sum_{i=1}^{t} d_{ijkl/T}\right) 10}{\frac{\sum_{i=1}^{t} s_{ijkl}}{T} \cdot \frac{\sum_{i=1}^{t} V_{ijkl}}{T}}$$

where:

i = stations 1,2,...t;

j = cruise 1,2,...c;

k = subarea 1,2,3,4;

l = region 1,2;

n = the number of organisms of a taxon found in the aliquot at station "i", cruise "J", in subarea "k", of region "l";

s = the subsample fraction of bulksample associated with station "i";

V = volume of water filtered at station "i";

d = depth fished at station "i";

T = the total number of stations sampled during cruise "j", in sub-area "k", of region "l";

$\hat{B}$ = the standard biomass of a taxon during cruise "j" in sub-area "k", of region "l".

The ANOVA tests were performed on natural log transformations of these biomass data (ℓn ($\hat{B}_{ijkl}$ + 1)). Three main effects were considered: time (i.e. cruise), subarea, and region. Three separate factoral analyses of variance were performed for each taxon:

12(inshore cruises x 4(inshore bays);

4(offshore cruises) x 4(offshore subareas);

2 (regions) x 4 (cruise or seasons) x 4 (subareas).

The three separate tests were performed because of substantial differences in seasonal coverage for the inshore and offshore regions. The 10 inshore surveys conducted during spring and summer represented a level of detail for describing timing of occurrence and abundance that was not possible when these surveys were combined by season for the 2 x 4 x 4 factorial analysis. This latter ANOVA was performed to identify possible regional significance in larval abundance or interactions between regions, seasons and/or subareas.

The significance of main effects and interactions was tested at the a = 0.05 level. If a main effect was determined significant, a Scheffee's procedure (Steel and Torrie, 1960) was used to identify significant sub-sets of data.

Section III

RESULTS

OCSEAP plankton surveys of the Kodiak Island shelf found approximately 19 different taxa of Natantia and Reptantia larvae (Table III-1) which included several species of current economic importance and other non-commercial taxa. Some of these latter taxa were substantially more prevalent in samples than the species of economic importance (Figure III-1). Consequently, they were included in the taxa analyzed in this report. The taxa studied were:

Hippolytid shrimps (Hippolytidae)

Sand shrimps (Crangonidae)

Northern or pink shrimp (*Pandalus borealis*)

Humpy shrimp (*P. goniurus*)

Anomuran crabs (Anomura)

Red king crab (*Paralithodes camtschatica*)

Dungeness crab (*Cancer magister*)

Cancer crab (*Cancer* sp.)

Tanner or snow crab (*Chionoecetes bairdi*)

Pea Crabs (Pinnotheridae)

A summary of information follows for each decapod taxa of interest in the Kodiak Island study area. The limitations of the data base are analyzed and discussed in detail in Appendix A.

Table III-1.--Decapod crustacea larvae found during OCSEAP inshore and offshore plankton cruises.

Taxonomic Classification	Species or Groups Encountered
Suborder Natantia	
Family Hippolytidae	unidentified hippolytid shrimp
Family Crangonidae	unidentified crangonid shrimp
Family Pandalidae	*Pandalopsis dispar* *Pandalus borealis* *P. goniurus* *P. hypsinotus* *P. montagui tridens* *P. platyceros* *P. stenolepis*
Family Pasiphaeidae	*Pasiphaea* sp.
Suborder Reptantia	
Section Anomura	unidentified anomuran crabs
Family Lithodidae	*Paralithodes camtschatica*
Section Brachyura	
Family Atelecyclidae	*Telemessus cheiragonus*
Family Cancridae	*Cancer magister* *Cancer* sp.
Family Majidae	*Chionoecetes bairdi* *Hyas* sp. *Oregonia* sp.
Family Pinnotheridae	unidentified pinnotherid crabs

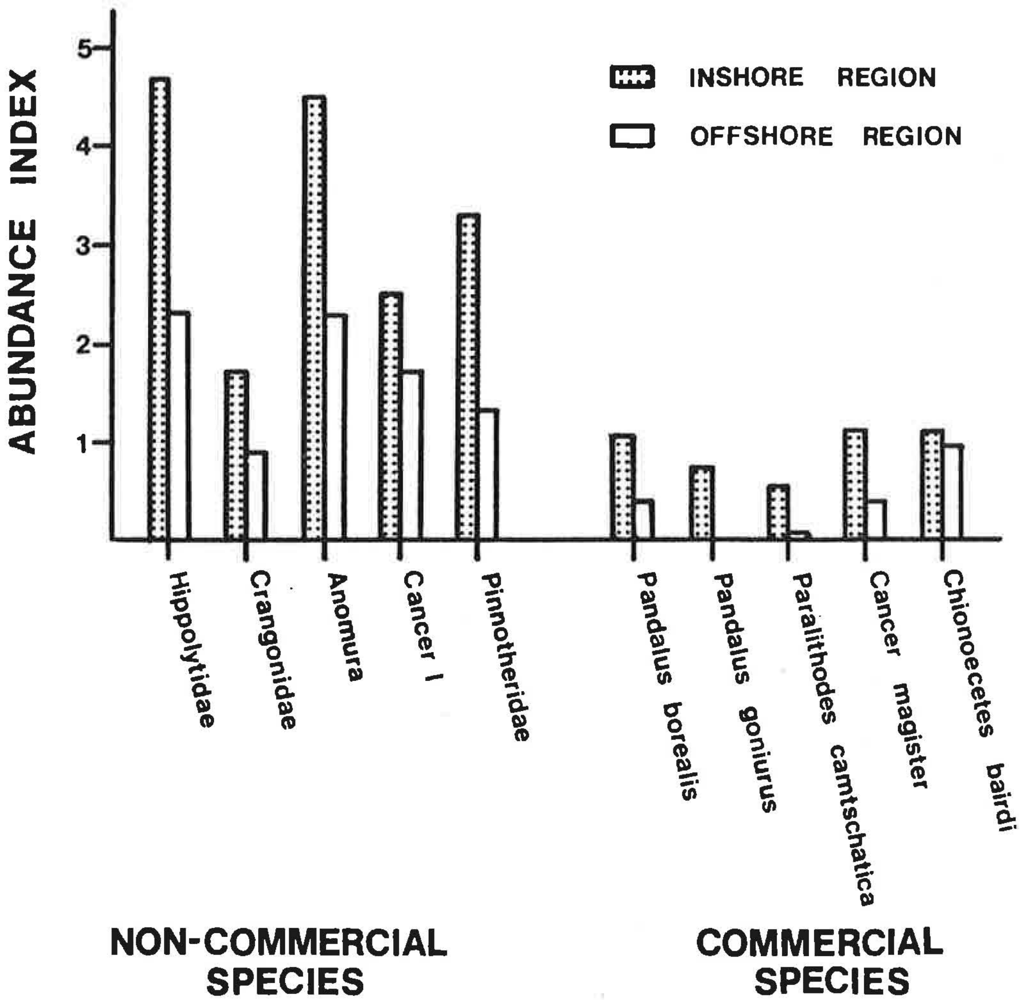


Figure III-1.--Index of abundance (ln(number per 10 m^2 + 1)) for commercial and non-commercial shellfish species found during OCSEAP inshore and offshore plankton cruises in the Kodiak Island area.

Results for Selected Taxa

Hippolytidae (hippolytid shrimps)

The hippolytid shrimp group comprises several species each with its own, often different, reproductive strategy. Because analysis could not be performed at the species level, the following reflects only gross aspects of larval distribution and abundance for this important and diverse group.

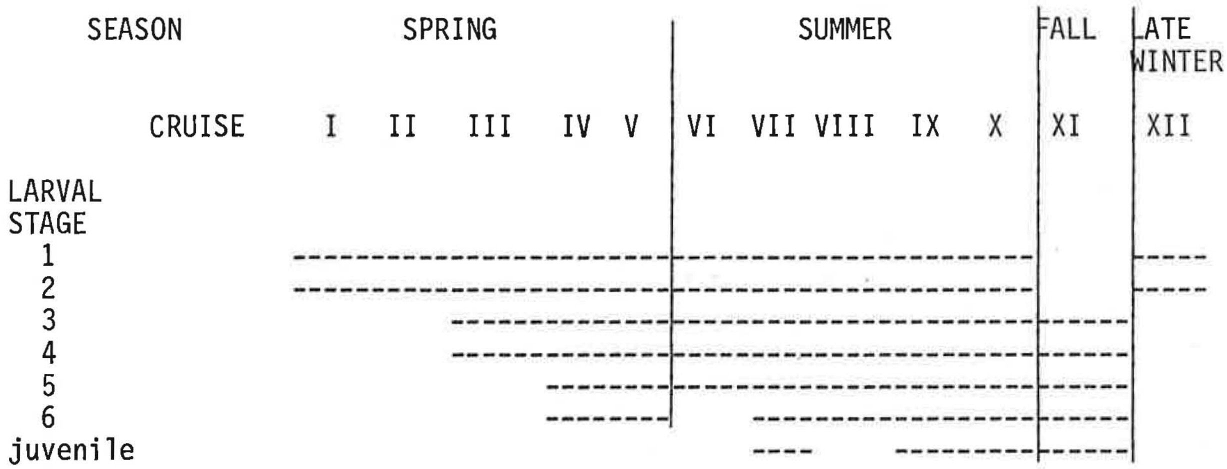
Larvae of hippolytid shrimp were found in the water column during all times of the year (Figure III-2) and in all areas sampled (Figure III-3). First stage zoeae were present from late winter through summer.

During the day, most hippolytid zoeae were found in the upper and mid-portions of the water column (5-60 m) (Figure III-4), while at night their vertical distribution appeared even shallower. Highest night-time concentrations were at the surface in both bays sampled and were greatest in Kiliuda Bay where neuston samples took over 90% of all zoeae.

Regions and seasons were identified in analysis of variance tests as having substantial effects on the distribution and abundance of hippolytid zoeae (Table III-2). This larval groups abundance was significantly greater in the inshore region and during spring and summer; however, a region x season interaction also was identified (Table III-2). Estimated abundance of larvae per unit area was nearly identical in both regions during fall (Tables III-3 and 4). During all other seasons, amounts in the inshore region were notably greater than amounts offshore (Figure III-3).

Separate tests of the inshore data determined that hippolytid larvae abundance in bays was significantly greater during June-August (Cruises VII-X) than during all other times surveyed. A significant bay effect was also identified but no individual bay could be determined to account for this significance.

Figure III-2.--Occurrence of larval stages of hippolytid shrimp, Hippolytidae, by cruise and season from the OCSEAP inshore plankton cruises. Data from all gear types.



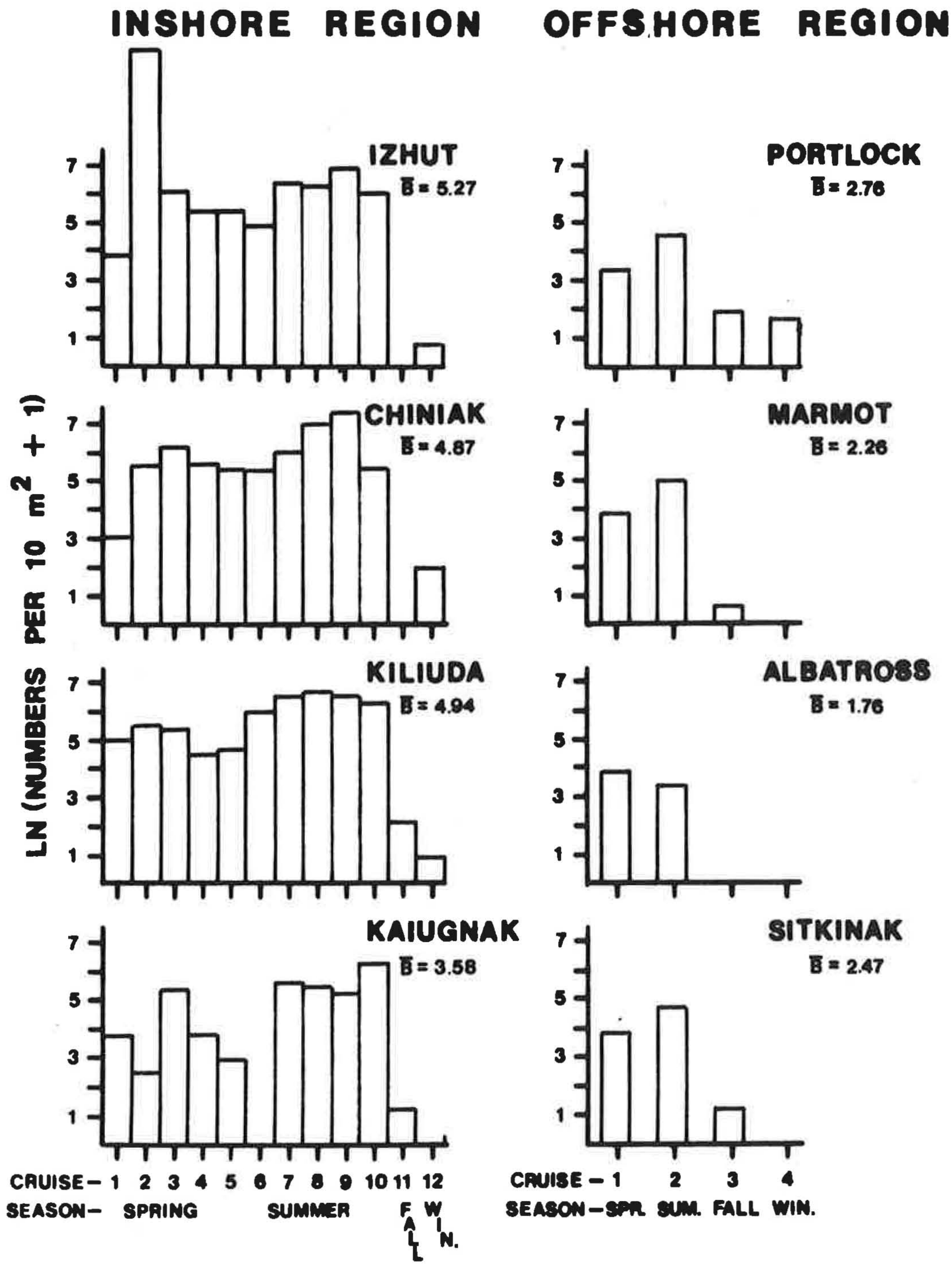


Figure III-3. Average biomass (ln(numbers per 10 m² + 1)) by cruise, season, bay, subarea and region for Hippolytidae in the Kodiak Island study area. Bongo net data.

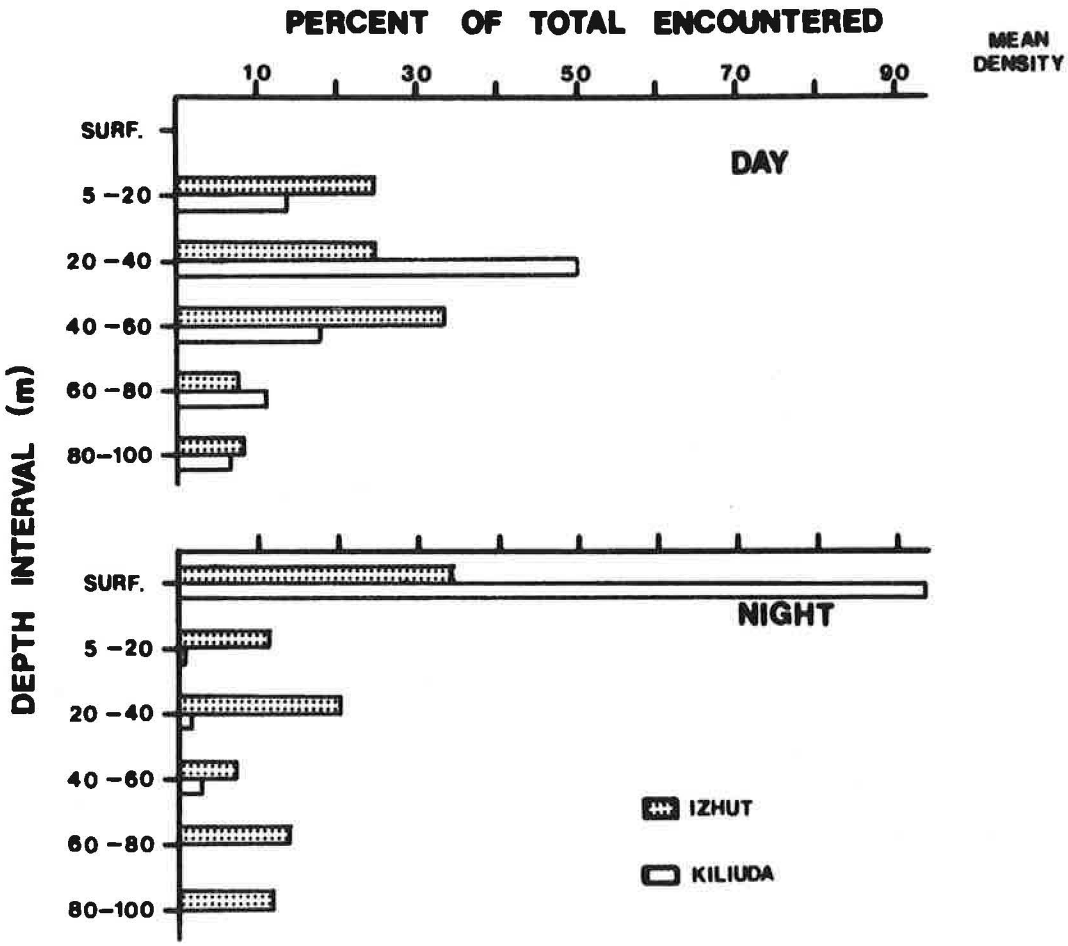


Figure III- 4. Percent of total Hippolytidae encountered during inshore OCSEAP plankton cruises by diel period and depth interval for Izhut and Kiliuda bays. Tucker trawl data.

Table III-2.-- Summary of information derived from analysis of variance tests of bongo net data (ln(numbers per $10m^2$ + 1)) for Hippolytid shrimp larvae.

TEST	SOURCE OF VARIABILITY	DEGREES OF FREEDOM	SUM OF SQUARES	VALUE OF F
Inshore and offshore combined	Total	63	467.80	--
	Main effects			
	Region (R)	1	114.96	50.79**
	Subarea (A)	3	19.24	2.84
	Season (S)	3	101.59	14.97**
	Interactions			
	R X A	3	0.86	0.13
	R X S	3	31.87	4.70**
	A X S	9	9.35	0.46
	R X A X S	9	11.60	0.57
	Residual	32	72.36	--
Inshore	Total	47	236.06	--
	Main effects			
	Bays	3	20.02	3.94*
	Cruise	11	160.13	8.59**
	Residual	33	55.91	--
Offshore	Total	15	51.50	--
	Main effects			
	Subarea	3	2.12	1.91
	Cruise	3	46.06	41.51**
	Residual	9	3.33	--

* denotes significance at = .05
** denotes significance at = .01

Table III-3.--Standardized biomass (ln(numbers per 10 m^2 + 1)) of hippolytid shrimp larvae, Hippolytidae, by season, cruise, and subarea in the inshore region of the Kodiak Island study area, March 1978 - March 1979. (Bongo net data).

SEASON			SPRING			SUMMER					FALL	WINTER	Mean Biomass All Cruises
CRUISE	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	
Subarea													
Izhut Bay	3.95*	11.06	6.21	5.42	5.38	4.85	6.44	6.34	6.76	5.97	0	.88	5.27
Chiniak Bay	2.97	5.52	6.16	5.48	5.40	5.27	6.02	6.92	7.31	5.45	0	1.98	4.87
Kiliuda Bay	4.91	5.41	5.20	4.30	4.53	5.69	6.28	6.55	6.40	6.17	2.08	1.74	4.94
Kiaugnak Bay	3.82	2.64	5.37	3.87	3.05	0	5.64	5.52	5.23	6.03	1.39	.38	3.58
Mean Biomass Bays Combined	3.91	6.16	5.73	4.77	4.59	3.95	6.09	6.33	6.42	5.90	.87	1.24	4.66

* ln of (standardized biomass (i.e. numbers per 10 m^2) +1)

Table III-4.--Standardized biomass (ln(numbers per 10 m^2 + 1)) of hippolytid shrimp larvae, Hippolytidae, by season, cruise and subarea in offshore region of the Kodiak Island study area, March 1978 - March 1979. (Bongo net data).

SEASON	SPRING	SUMMER	FALL	WINTER	Mean Biomass All Cruises
CRUISE	I	II	III	IV	
Subarea					
Portlock	3.21	4.49	1.68	1.67	2.76
Marmot	3.75	4.79	.51	0	2.26
Albatross	3.73	3.33	0	0	1.76
Sitkinak	3.89	4.70	1.28	0	2.47
Mean Biomass Subareas Combined	3.64	4.33	.87	.42	2.31

Crangonidae (sand shrimps)

Crangonid shrimp larvae were found in the water column at all times of the year sampled (Figure III-5). Similar to Hippolytidae, first stage zoeae of this group were present in samples throughout the time periods sampled except for fall.

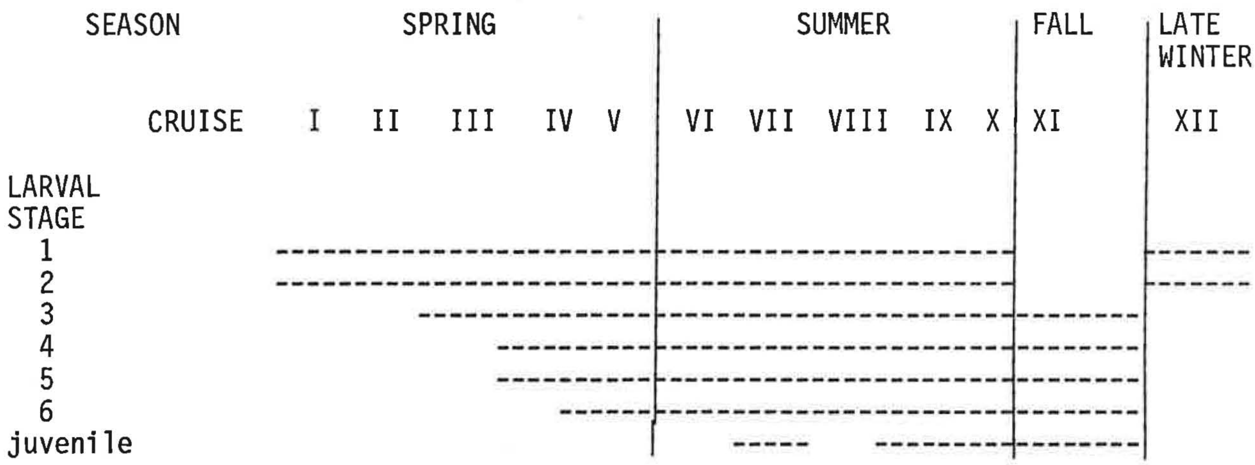
During daylight, most larvae of this species group were encountered in mid and upper portions of the water column (Figure III-6) but at night, a trend in vertical distribution was not apparent. Previous analysis of only the Tucker trawl data suggested these larvae were concentrated in 40-100 m during the night (Kendall et al., 1980). Inclusion of the neuston samples in the vertical distribution data indicates that about 40% of all larvae were encountered at or near the surface (Figure III-6). Relatively substantial numbers were also found at 20-60 m in Kiliuda Bay and at depths below 60 m in Izhut Bay.

Analyses of variance of the bongo net samples indicated that crangonid larvae were notably more abundant in summer than during other seasons (Figure III-7). There was no significant difference in abundance by region (Table III-5). Various bays seemed to contain significantly greater numbers of crangonid shrimp zoeae than others but the importance of a bay changed with time (Table III-6 and Figure III-7). This apparent bay x cruise interaction masked the importance of abundance within a bay during multiple comparison tests.

A separate analysis of the offshore region data also failed to identify significant abundance differences between subareas even though catches varied noticably. For example, all samples obtained in the Sitkinak subarea contained no crangonid zoeae while samples from all other offshore subareas contained measurable amounts, at least during summer (Table III-7).

The multi-species composition of the crangonid larvae group was a source of variation which could not be addressed in our sample analyses.

Figure III-5.--Occurrence of larval stages of crangonid shrimp, Crangonidae, by cruise and season from the OCSEAP inshore plankton cruises. Data from all gear types.



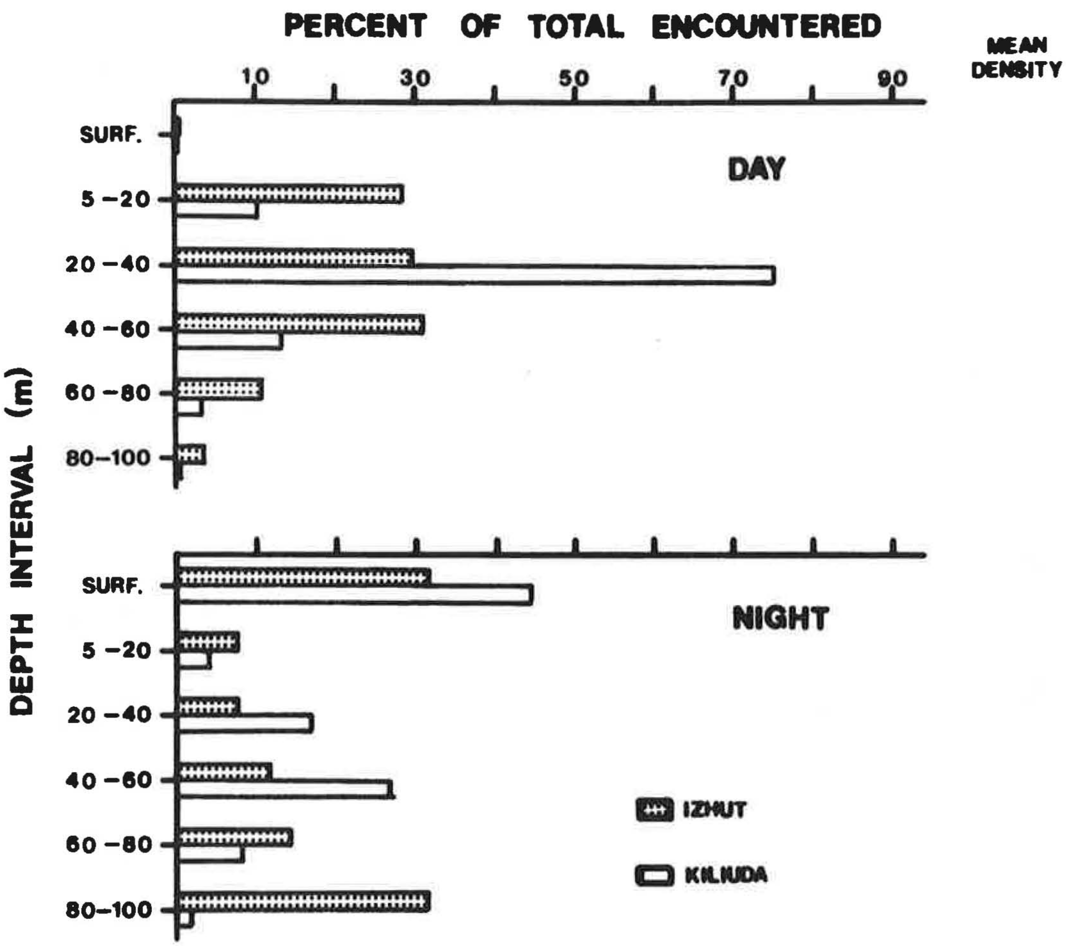


Figure III- 6. Percent of total Crangonidae encountered during inshore OCSEAP plankton cruises by diel period and depth interval for Izhut and Kiliuda bays. Tucker trawl data.

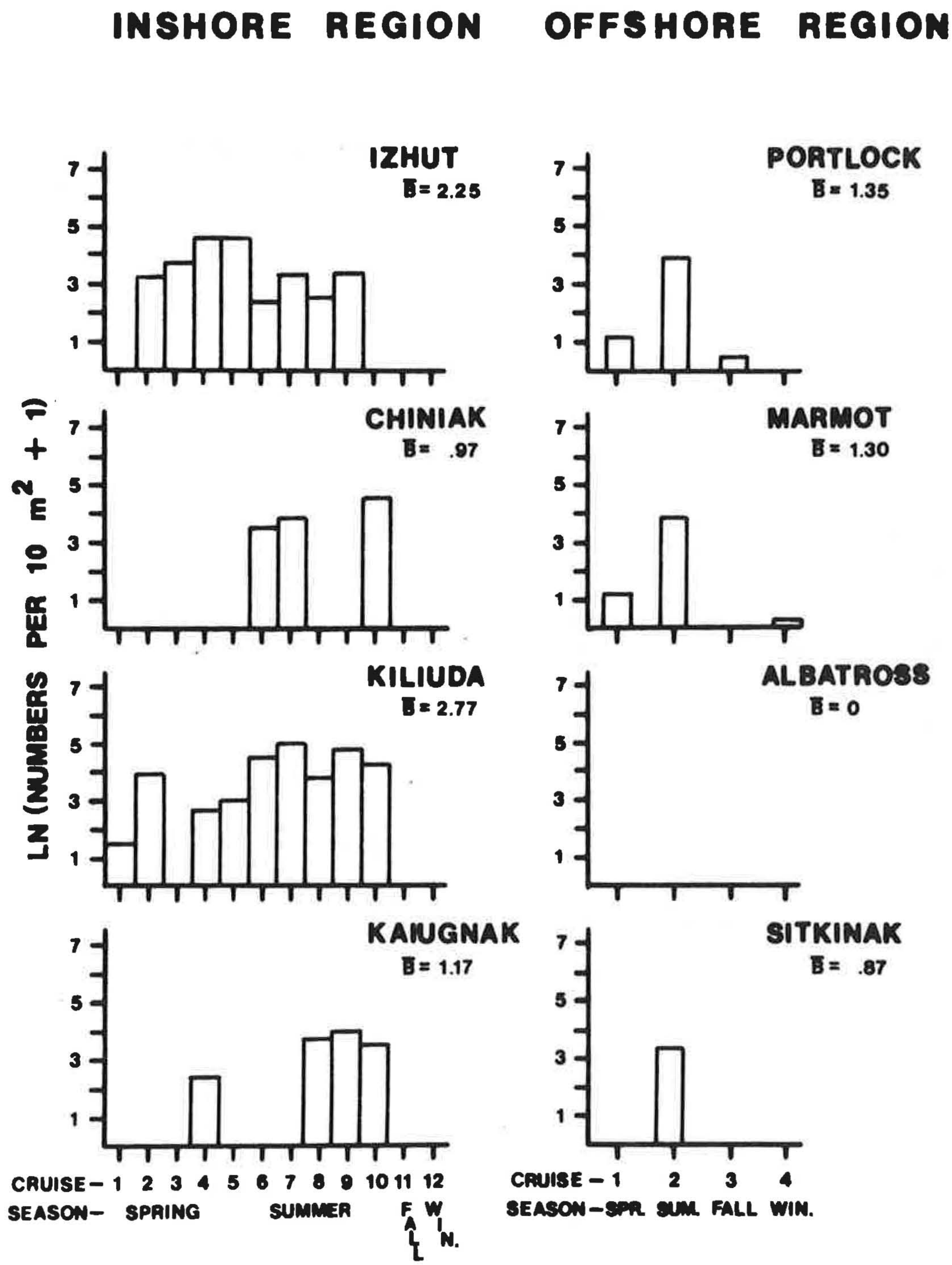


Figure III-7. Average biomass (ln(numbers per 10 m² + 1)) by cruise, season, bay, subarea and region for Crangonidae in the Kodiak Island study area. Bongo net data.

Table III-5.--Summary of information derived from analysis of variance tests of bongo net data (ln(numbers per 10 m^2 + 1)) for Crangonid shrimp larvae.

TEST	SOURCE OF VARIABILITY	DEGREES OF FREEDOM	SUM OF SQUARES	VALUE OF F
Inshore and offshore combined	Total	63	212.182	--
	Main effects			
	Region (R)	1	0.722	.32
	Subarea (A)	3	15.467	2.28
	Season (S)	3	66.963	9.88**
	Interactions			
	R X A	3	12.882	1.90
	R X S	3	1.811	0.27
	A X S	9	15.185	0.75
	R X A X S	9	14.536	0.71
	Residual	32	72.291	--
Inshore	Total	47	170.619	--
	Main effects			
	Bays	3	26.821	3.55*
	Cruise	11	60.788	2.20*
	Residual	33	83.010	--
Offshore	Total	15	31.709	--
	Main effects			
	Subarea	3	4.685	1.95
	Cruise	3	19.806	8.23**
	Residual	9	7.218	--

* denotes significance at = .05
** denotes significance at = .01

Table III-6.--Standardized biomass (ln(numbers per 10 m^2 + 1)) of crangonid shrimp larvae, Crangonidae, by season, cruise, and subarea in the inshore region of the Kodiak Island study area, March 1978 - March 1979. (Bongo net data).

SEASON			SPRING			SUMMER					FALL	WINTER	Mean Biomass All Cruises
CRUISE	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	
Subarea													
Izhut Bay	0*	3.12	3.59	4.52	4.47	2.27	3.22	2.43	3.34	0	0	0	2.25
Chiniak Bay	0	0	0	0	0	3.39	3.69	0	0	4.53	0	0	.97
Kiliuda Bay	1.59	3.94	0	2.60	3.01	4.54	4.92	3.71	4.74	4.21	0	0	2.77
Kiaugnak Bay	0	0	0	2.52	0	0	0	3.75	4.05	3.65	0	0	1.16
Mean Biomass Bays Combined	.40	1.76	.90	2.41	1.87	2.55	2.96	2.47	3.03	3.10	0	0	1.79

* ln of (standardized biomass (i.e. numbers per 10 m^2) + 1)

Table III-7.--Standardized biomass (ln(numbers per 10 m^2 + 1)) of Crangonid shrimp larvae, Crangonidae, by season, cruise and subarea in the offshore region of the Kodiak Island study area, March 1978 - March 1979. (Bongo net data).

SEASON	SPRING	SUMMER	FALL	WINTER	Mean Biomass All Cruises
CRUISE	I	II	III	IV	
Subarea					
Portlock	1.22	3.80	.43	0	1.36
Marmot	1.19	3.79	0	.16	1.28
Albatross	0	0	0	0	0
Sitkinak	0	3.49	0	0	.88
Mean Biomass Subareas Combined	.60	2.77	.11	.04	.88

Pandalus borealis (pink shrimp)

P. borealis zoeae were present in portions of the study area during all time periods sampled (Figure III-8). Stage I zoeae were found during late winter, spring, and early summer suggesting protracted larval release; however, peak abundance of Stage I larvae occurred during mid April (Cruise II).

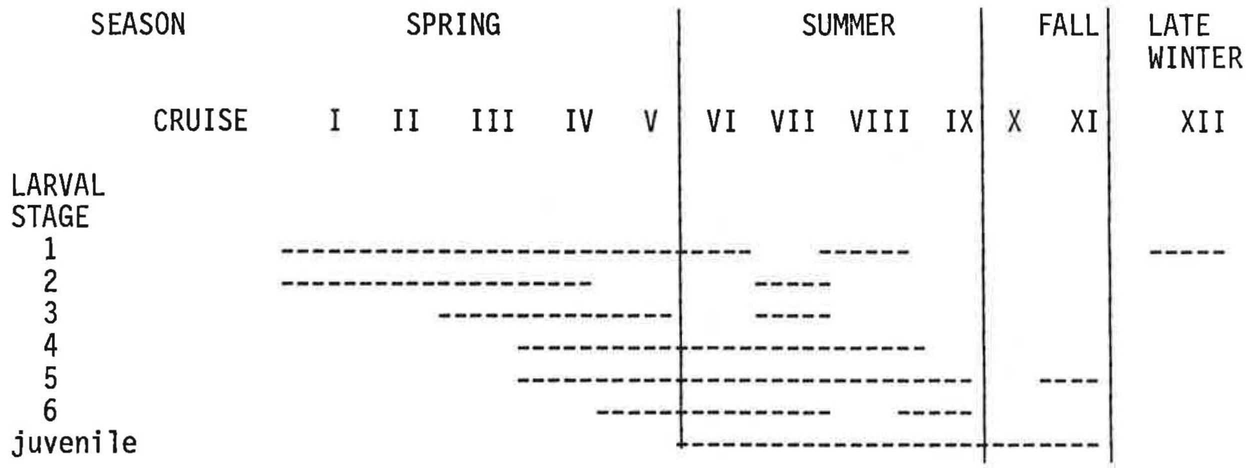
Information from the standard Tucker trawl aliquots, resorted samples, and neuston tows indicated that daytime vertical distribution differed between the two bays where these samples were taken. Highest concentrations in Kiliuda Bay were found in 5-20 m whereas zoeae found in Izhut Bay were concentrated in deeper waters in 60-80 m (Figure III-9). At night most zoeae were found in the deeper strata sampled in both bays with highest concentrations in 60-80 m. Very few P. borealis larvae were found in samples taken at the surface in both bays.

The detailed analyses of the daytime samples from Kiliuda Bay further suggests a change in vertical distribution of P. borealis zoeae with advancing stages of larval development. During Stages I-III, vertical distribution appeared associated with mid or upper portions of the water column with only Stage I zoeae found in surface samples (Figure III-10). Notable amounts of P. borealis larvae started occurring in the deepest depths sampled (80-100 m) as Stage IV while nearly all Stage VI and VII (juveniles) were found only in the deepest waters sampled.

No bays or offshore subareas displayed consistent trends in abundance for P. borealis larvae (Figure III-11 and Tables III-8 and III-9). Additionally, the ANOVA tests failed to identify any notable difference in abundance between the inshore and offshore regions of the Kodiak Island study area (Table III-10).

Analysis of bongo data indicated P. borealis zoeae were significantly more abundant in spring than during other times surveyed throughout the study area. Separate tests on the inshore data identified mid April through May (Cruises II-IV) as the period when inshore abundance was significantly higher than all other times sampled.

Figure III-8.--Occurrence of larval stages of pink shrimp, *Pandalus borealis*, by cruise and season from the OCSEAP inshore plankton cruises. Data from all gear types.



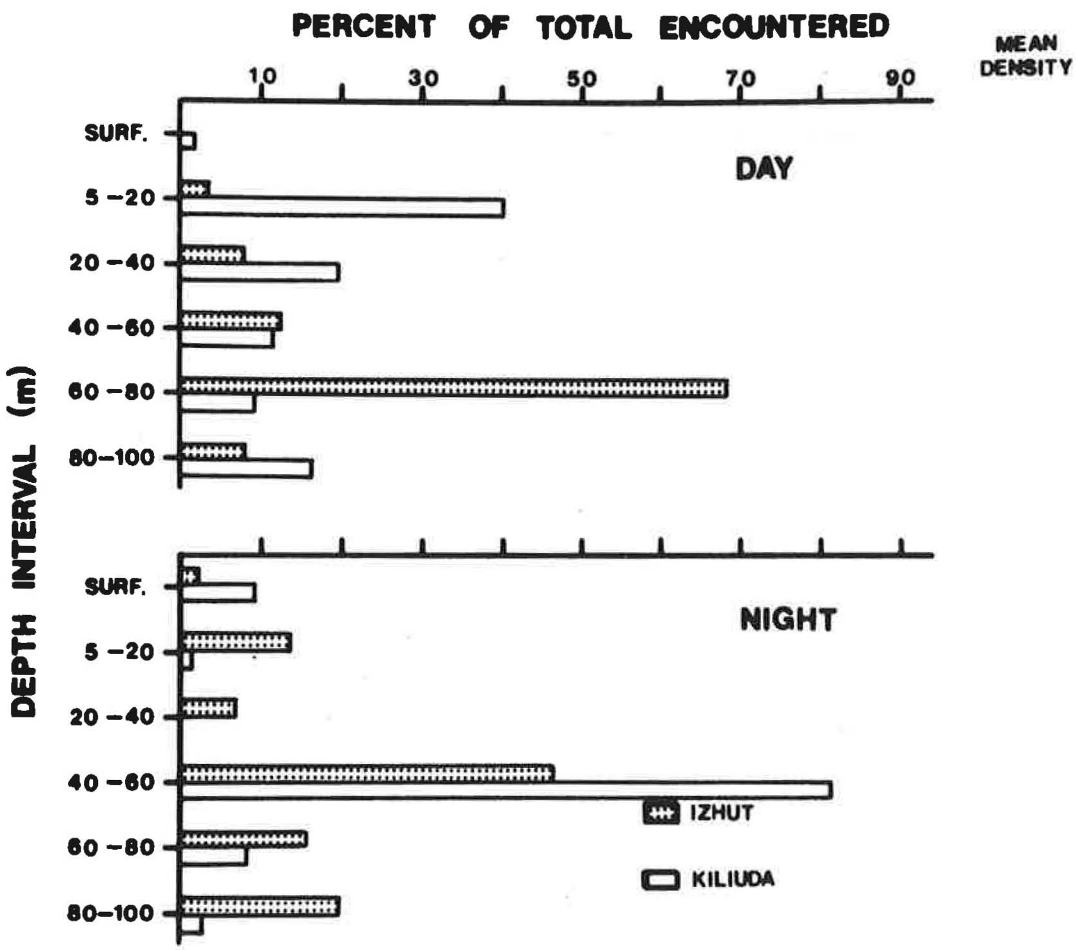


Figure III- 9. Percent of total Pandalus borealis encountered during inshore OCSEAP plankton cruises by diel period and depth interval for Izhut and Kiliuda bays. Tucker trawl data.

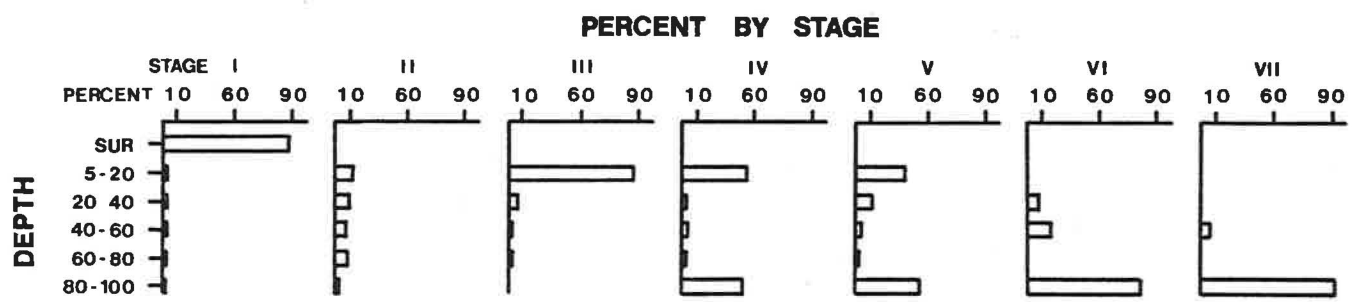


Figure III-10.--Percent of Pandalus borealis encountered per depth interval for each larval stage found during inshore sampling of the Kodiak Island study area. (neuston sampler and Tucker trawl data)

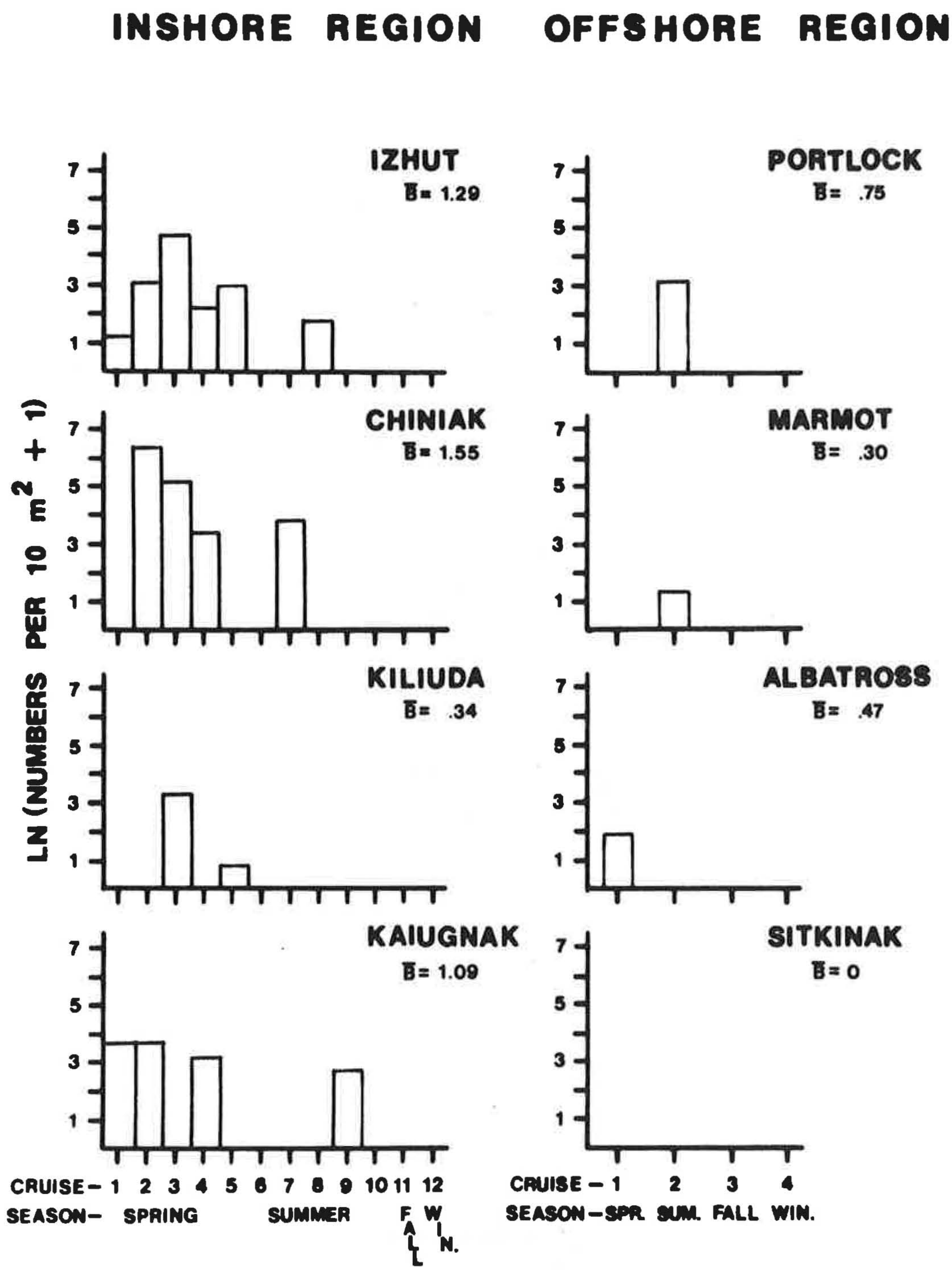


Figure III-11. Average biomass (ln(numbers per 10 m² + 1)) by cruise, season, bay, subarea and region for Pandalus borealis in the Kodiak Island study area. Bongo net data.

Table III-8.--Standardized biomass (ln(numbers per 10 m^2 + 1)) of pink shrimp larvae, *Pandalus borealis*, by season, cruise, and subarea in the inshore region of the Kodiak Island study area, March 1978 - March 1979. (Bongo net data).

SEASON			SPRING			SUMMER					FALL	WINTER	Mean Biomass All Cruises
CRUISE	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	
Subarea													
Izhut	1.12*	3.00	4.61	2.10	2.94	0	0	1.71	0	0	0	0	1.29
Chiniak	0	6.27	5.15	3.42	0	0	3.80	0	0	0	0	0	1.55
Kiliuda	0	0	3.22	0	.84	0	0	0	0	0	0	0	.34
Kiaugnak	3.64	3.59	0	3.18	0	0	0	0	2.68	0	0	0	1.09
Mean Biomass Bays Combined	1.19	3.21	3.24	2.17	.94	0	.95	.43	.67	0	0	0	1.07

*ln of (standardized biomass (i.e., numbers per 10 m^2) + 1)

Table III-9.--Standardized biomass (ln(numbers per 10 m^2 + 1)) of pandalid shrimp larvae, Pandalus borealis, by season, cruise and subarea in offshore region in the Kodiak Island study area, March 1978 - March 1979. (Bongo net data).

SEASON	SPRING	SUMMER	FALL	WINTER	Mean Biomass All Cruises
CRUISE	I	II	III	IV	
Subarea					
Portlock	0	3.04	0	0	.76
Marmot	0	1.25	0	0	.31
Albatross	1.87	0	0	0	.47
Sitkinak	0	0	0	0	0
Mean Biomass Subareas Combined	.47	1.07	0	0	.385

Table III-10.--Summary of information derived from analysis of variance tests of bongo net data (ln(numbers per 10 m^2 + 1)) for *P. borealis* larvae.

TEST	SOURCE OF VARIABILITY	DEGREES OF FREEDOM	SUM OF SQUARES	VALUE OF F
Inshore and offshore combined	Total	63	156.675	--
	Main effects			
	Region (R)	1	1.092	0.43
	Subarea (A)	3	7.518	0.98
	Season (S)	3	34.635	4.50**
	Interactions			
	R X A	3	2.589	0.34
	R X S	3	9.848	1.28
	A X S	9	2.324	0.10
	R X A X S	9	11.183	0.48
	Residual	32	82.080	--
Inshore	Total	47	139.139	--
	Main effects			
	Bays	3	9.795	1.62
	Cruise	11	62.946	2.84**
	Residual	33	66.397	--
Offshore	Total	15	11.929	--
	Main effects			
	Subarea	3	1.204	0.47
	Cruise	3	3.104	1.22
	Residual	9	7.622	--

* denotes significance at = .05
** denotes significance at = .01

Pandalus goniurus (humpy shrimp)

The analysis presented by Kendall et al. (1980) did not address this species due to its low incidence. Surveys found larvae of *P. goniurus* in Kodiak Island waters only during spring and summer (Figure III-12 and Table III-11) and Stage I zoeae only during spring.

Data resulting from the "extensive re-sort" subsamples (see Appendix A) were combined with the limited information previously available but this combination failed to show any consistent pattern in vertical distribution for *P. goniurus* zoeae. Larvae were found in only one daytime sample from Izhut Bay and those found in Kiliuda Bay appeared homogenously distributed at all depths (Figure III-13). During hours of darkness or low light levels, zoeae in Izhut Bay were heavily concentrated in depths shallower than 40 m but a ubiquitous vertical distribution was suggested in Kiliuda Bay. However, relatively few larvae were present at the surface in both bays.

Vertical distribution by stage of zoeal development was examined in the daytime Tucker samples from Kiliuda Bay. Nearly all *P. goniurus* Stage I larvae were found at the shallowest depths sampled (Figure III-14). No trends of depth preference were obvious for all other stages encountered. Stages II-V zoeae were present throughout the water column.

The analysis of variance tests on bongo samples for inshore, offshore, and combined regions failed to identify any significant region, area, or time effect on the distribution or abundance of *P. goniurus* zoeae (Table III-12). Although statistically these tests failed to identify significant differences, there was an obvious "solely inshore" distribution of these larvae during the study (Figure III-15). None were encountered in any offshore subarea during any season.

Figure III-12.--Occurrence of larval stages of humpy shrimp, Pandalus goniurus, by cruise and season from OCSEAP inshore plankton cruises. Data from all gear types.

```
SEASON             SPRING              |        SUMMER          |FALL | LATE
                                       |                        |     | WINTER

       CRUISE    I   II   III   IV   V | VI  VII  VIII  IX   X  | XI  |  XII

LARVAL                                 |                        |     |
STAGE                                  |                        |     |
  1            -----------------------  |                        |     |
  2                -----------------------                      |     |
  3                     -------------------------               |     |
  4                            -------|---                      |     |
  5                            -------|---------------          |     |
  6                                    |                        |     |
  7                                    |     ----               |     |
```

Table III-11.--Standardized biomass (ln(numbers per 10 m^2 + 1)) of Pandalus goniurus by season, cruise, and subarea in the inshore region of the Kodiak Island study area, March 1978 - March 1979. (Bongo net data).

SEASON			SPRING			SUMMER					FALL	WINTER	Mean Biomass All Cruises
CRUISE	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	
Subarea													
Izhut	0*	0	2.49	2.58	2.10	0	0	0	0	0	0	0	.60
Chiniak	0	2.22	4.50	4.10	0	3.06	0	0	0	0	0	0	1.16
Kiliuda	2.91	0	2.57	0	1.60	2.28	4.38	0	0	0	0	0	1.14
Kiaugnak	0	0	0	1.74	0	0	0	0	0	0	0	0	.14
Mean Biomass Bays Combined	.73	.55	2.39	2.10	.92	1.33	1.09	0	0	0	0	0	.76

*ln of (standardized biomass (i.e., numbers per 10 m^2) + 1)

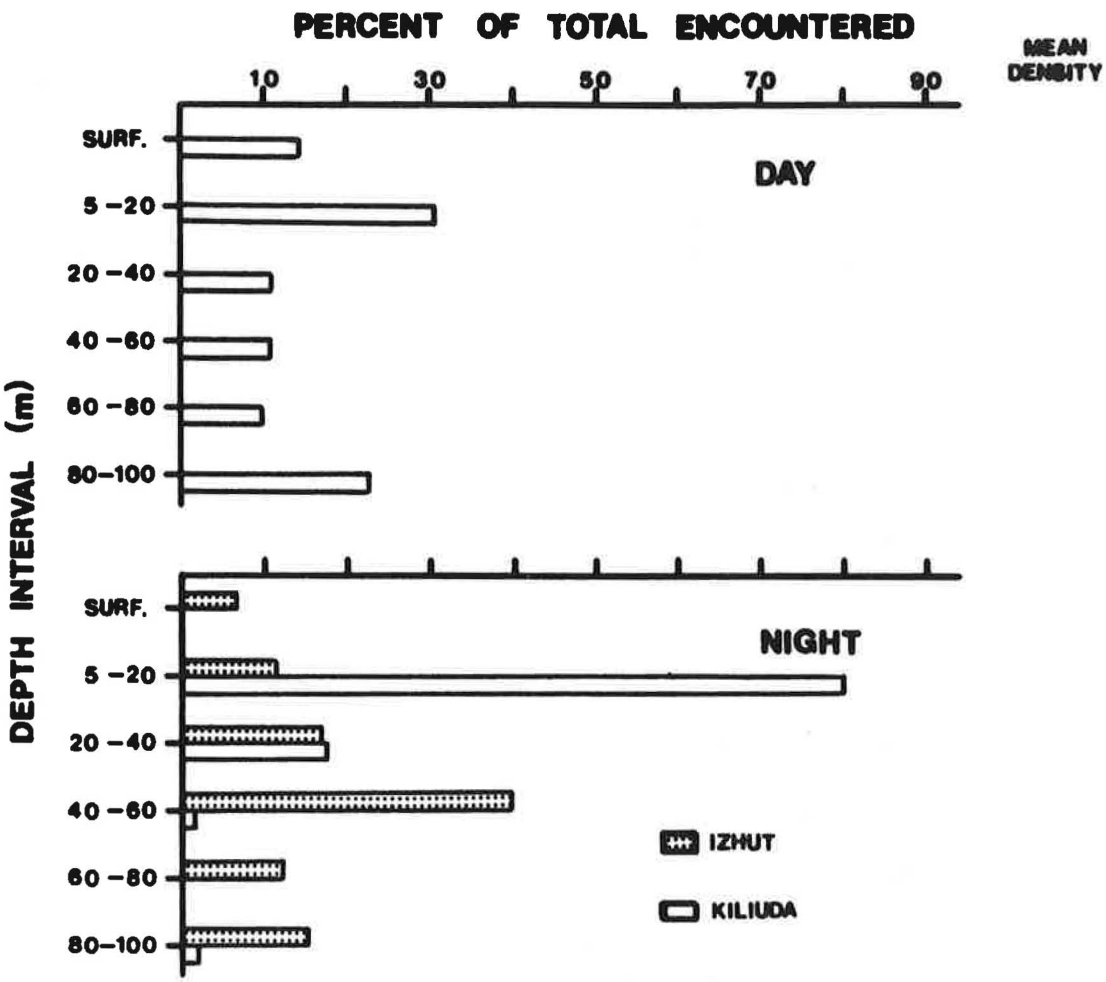


Figure III-13. Percent of total Pandalus goniurus encountered during inshore OCSEAP plankton cruises by diel period and depth interval for Izhut and Kiliuda bays. Tucker trawl data.

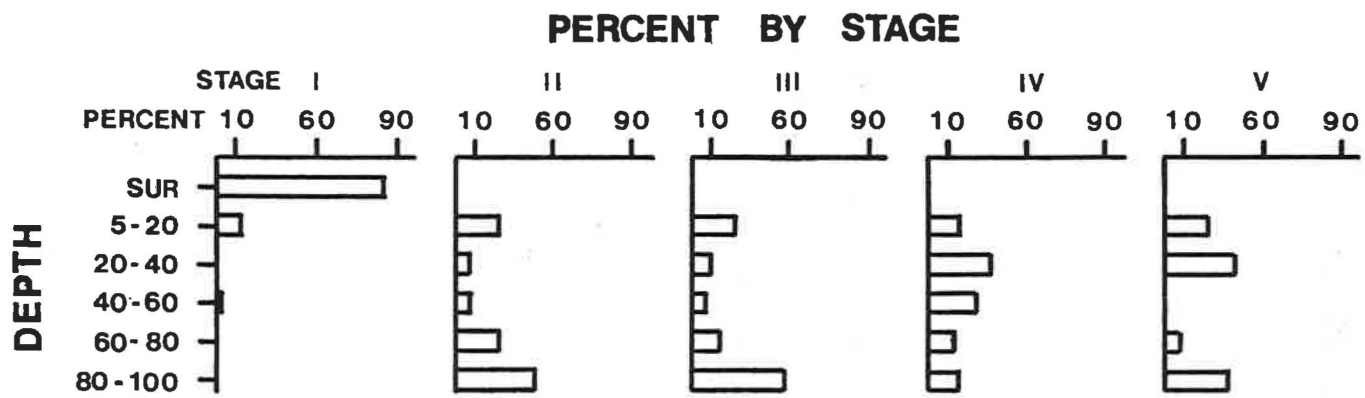


Figure III-14.--Percent of Pandalus goniurus encountered per depth interval for each larval stage found during inshore sampling of the Kodiak Island study area. (Neuston sampler and Tucker trawl data.)

Table III-12.--Summary of information derived from analysis of variance tests of bongo net data (ln(numbers per 10 m^2 + 1)) for *P. goniurus* larvae.

TEST	SOURCE OF VARIABILITY	DEGREES OF FREEDOM	SUM OF SQUARES	VALUE OF F
Inshore and offshore combined	Total	63	92.861	--
	Main effects			
	Region (R)	1	3.478	1.90
	Subarea (A)	3	6.392	1.16
	Season (S)	3	9.567	1.74
	Interactions			
	R X A	3	1.065	0.19
	R X S	3	3.305	0.60
	A X S	9	4.556	0.28
	R X A X S	9	1.337	0.08
	Residual	32	58.618	--
Inshore	Total	47	85.905	--
	Main effects			
	Bays	3	8.522	2.04
	Cruise	11	31.486	2.06
	Residual	33	45.897	--
Offshore	Total	15	0	--
	Main effects			
	Subarea	3	0	0
	Cruise	3	0	0
	Residual	9	0	--

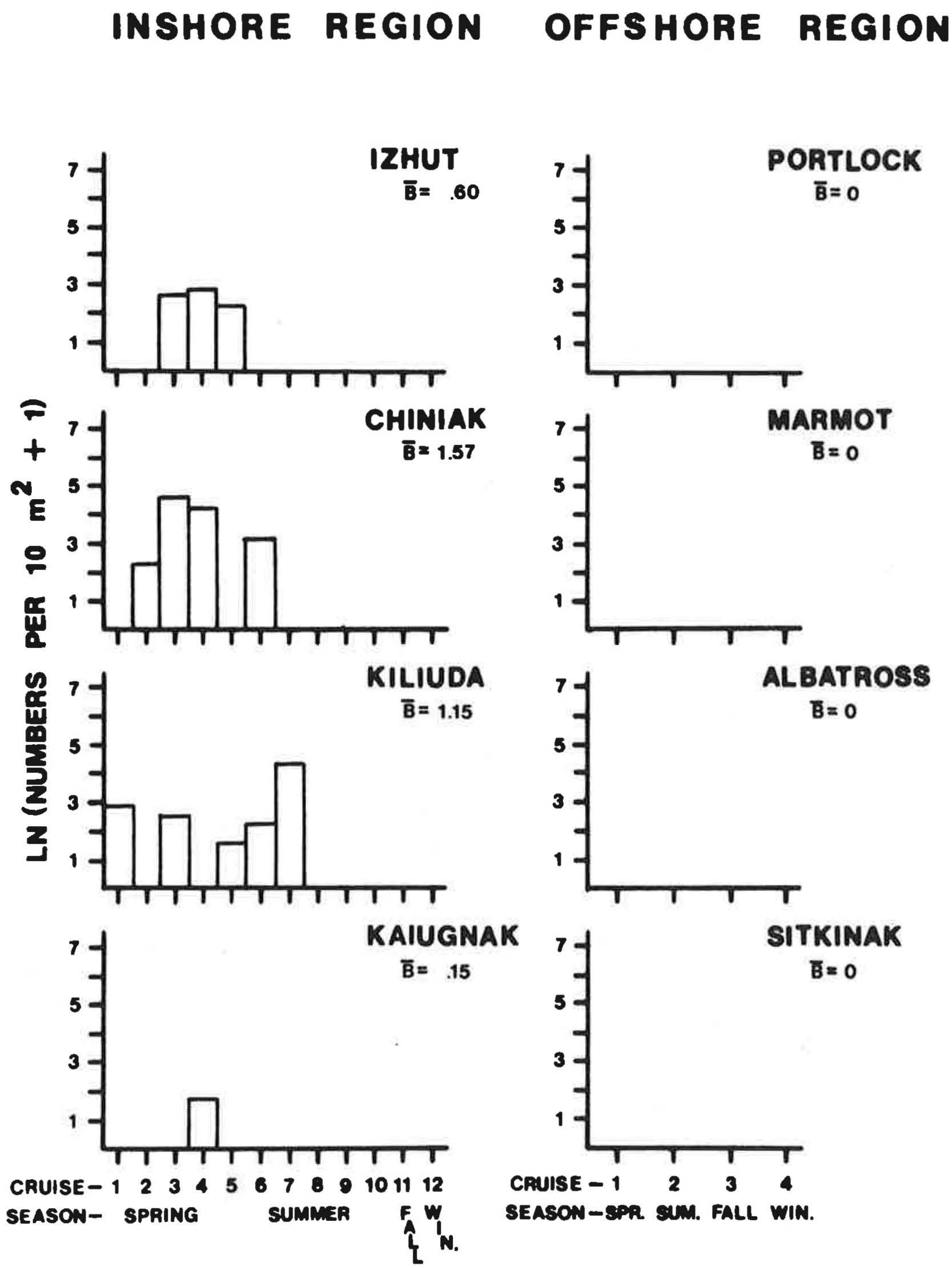


Figure III-15. Average biomass (ln(numbers per 10 m^2 + 1)) by cruise, season, bay, subarea and region for Pandalus goniurus in the Kodiak Island study area. Bongo net data.

Anomura (Anomuran crabs, except *Paralithodes camtschatica*)

Similar to the hippolytid and crangonid shrimps in this report, the anomuran crab group is a multi-species assemblage. Larval forms of anomuran crabs were found in most areas at all times of the year sampled (Figure III-16 and Tables III-13 and 14).

Analysis of vertical distribution data indicated that during the day most anomuran larvae concentrated at less than 40 m below the surface. Night-time data showed more larvae were present in the deeper intervals sampled than during the day. However, highest concentrations occurred at the surface in both bays (Figure III-17).

The abundance of anomuran crab zoeae was significantly effected by region and season (Table III-15). The inshore region contained significantly more of these larvae than offshore and spring/summer were more important than the other seasons. A region x season interaction was encountered implying that the abundance of anomuran zoeae in each region changed seasonally.

When the inshore data were analyzed separately, both bay and cruise (time) effects on abundance were identified (Table III-15). Significantly more anomuran larvae were present from early April through August (Cruises II-X) than during the remainder of the study period. Despite an apparent bay effect, no bay could be identified in multiple comparison tests as being more important than any other. All bays contained relatively substantial amounts of these zoeae (Figure III-18).

The separate analysis of the offshore data showed no significant subarea effect (Table III-15). There was a cruise effect, with spring and summer cruises encountering significantly greater numbers of larval anomurans than amounts encountered during fall or winter.

Figure III-16.--Occurrence of larval stages of anomuran crab, Anomura, by cruise and season from the OCSEAP inshore plankton cruises. Data from all gear types.

```
     SEASON                SPRING          |          SUMMER        |FALL | LATE
                                           |                        |     | WINTER
                                           |                        |     |
         CRUISE      I   II   III   IV   V | VI  VII  VIII  IX   X |  XI |    XII
LARVAL                                     |                        |     |
STAGE                                      |                        |     |
  1              --------------------------|-----------------       |-----|-------
  2              --------------------------|------------------------|     |
  3                           -------------|------------------------|     |
  4                                --------|------------------------|     |
                                           |                        |     |
glaucothe                                  |------------------------|-----|
                                           |                        |     |
```

Table III-13.--Standardized biomass (ln(numbers per 10 m^2 + 1)) of Anomuran crab larvae, Anomura, by season, cruise, and subarea in the inshore region of the Kodiak Island study area, March 1978 - March 1979. (Bongo net data).

SEASON			SPRING			SUMMER					FALL	WINTER	Mean Biomass All Cruises
CRUISE	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	
Subarea													
Izhut	5.56*	5.96	7.14	6.38	5.71	4.39	5.85	4.40	5.64	3.95	3.76	.40	4.93
Chiniak	4.01	4.20	5.79	3.81	4.10	5.33	5.76	4.57	5.49	5.22	2.83	.69	4.32
Kiliuda	5.11	5.14	5.49	6.56	6.21	6.34	4.70	4.21	5.04	5.34	4.45	1.20	4.98
Kiaugnak	0	4.94	3.49	5.78	4.84	5.89	2.41	5.24	5.44	3.99	2.20	.96	3.76
Mean Biomass Bays Combined	3.67	5.06	5.48	5.63	5.21	5.49	4.68	4.60	5.40	4.62	3.31	.81	4.50

*ln of (standardized biomass (i.e., numbers per 10 m^2) + 1)

Table III-14.--Standardized biomass (ln(numbers per 10 m^2 + 1)) of Anomuran crab larvae, Anomura, by season, cruise and subarea in the offshore region of the Kodiak Island study area, March 1978 - March 1979. (Bongo net data).

SEASON	SPRING	SUMMER	FALL	WINTER	Mean Biomass All Cruises
CRUISE	I	II	III	IV	
Subarea					
Portlock	3.96	5.35	.04	1.16	2.62
Marmot	2.38	4.81	0	.16	1.84
Albatross	3.69	4.10	.26	.21	2.06
Sitkinak	3.22	6.03	1.19	0	2.61
Mean Biomass Subareas Combined	3.31	5.07	.37	.38	2.28

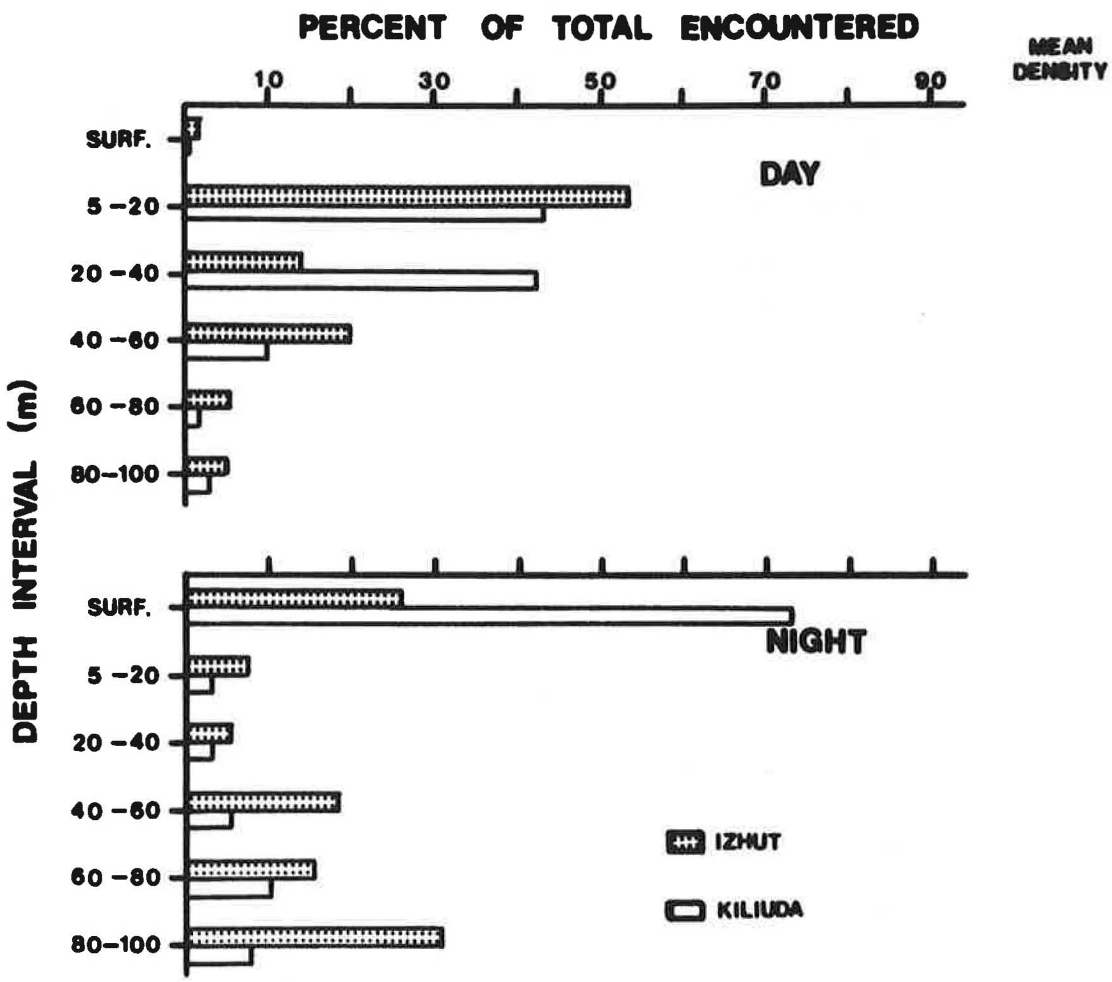


Figure III-17. Percent of total Anomura encountered during inshore OCSEAP plankton cruises by diel period and depth interval for Izhut and Kiliuda bays. Tucker trawl data.

Table III-15.--Summary of information derived from analysis of variance tests of bongo net data (ln(numbers per 10 m^2 + 1)) for Anomuran crab larvae.

TEST	SOURCE OF VARIABILITY	DEGREES OF FREEDOM	SUM OF SQUARES	VALUE OF F
Inshore and offshore combined	Total	63	261.543	--
	Main effects			
	Region (R)	1	13.546	10.60**
	Subarea (A)	3	8.684	2.26
	Season (S)	3	120.195	31.36**
	Interactions			
	R X A	3	4.665	1.22
	R X S	3	13.748	3.59*
	A X S	9	10.532	0.92
	R X A X S	9	3.638	0.32
	Residual	32	40.886	--
Inshore	Total	47	133.086	--
	Main effects			
	Bays	3	11.876	3.37*
	Cruise	11	82.461	6.38**
	Residual	33	38.749	--
Offshore	Total	15	69.621	--
	Main effects			
	Subarea	3	1.886	1.70
	Cruise	3	64.412	58.17**
	Residual	9	3.322	--

* denotes significance at = .05
** denotes significance at = .01

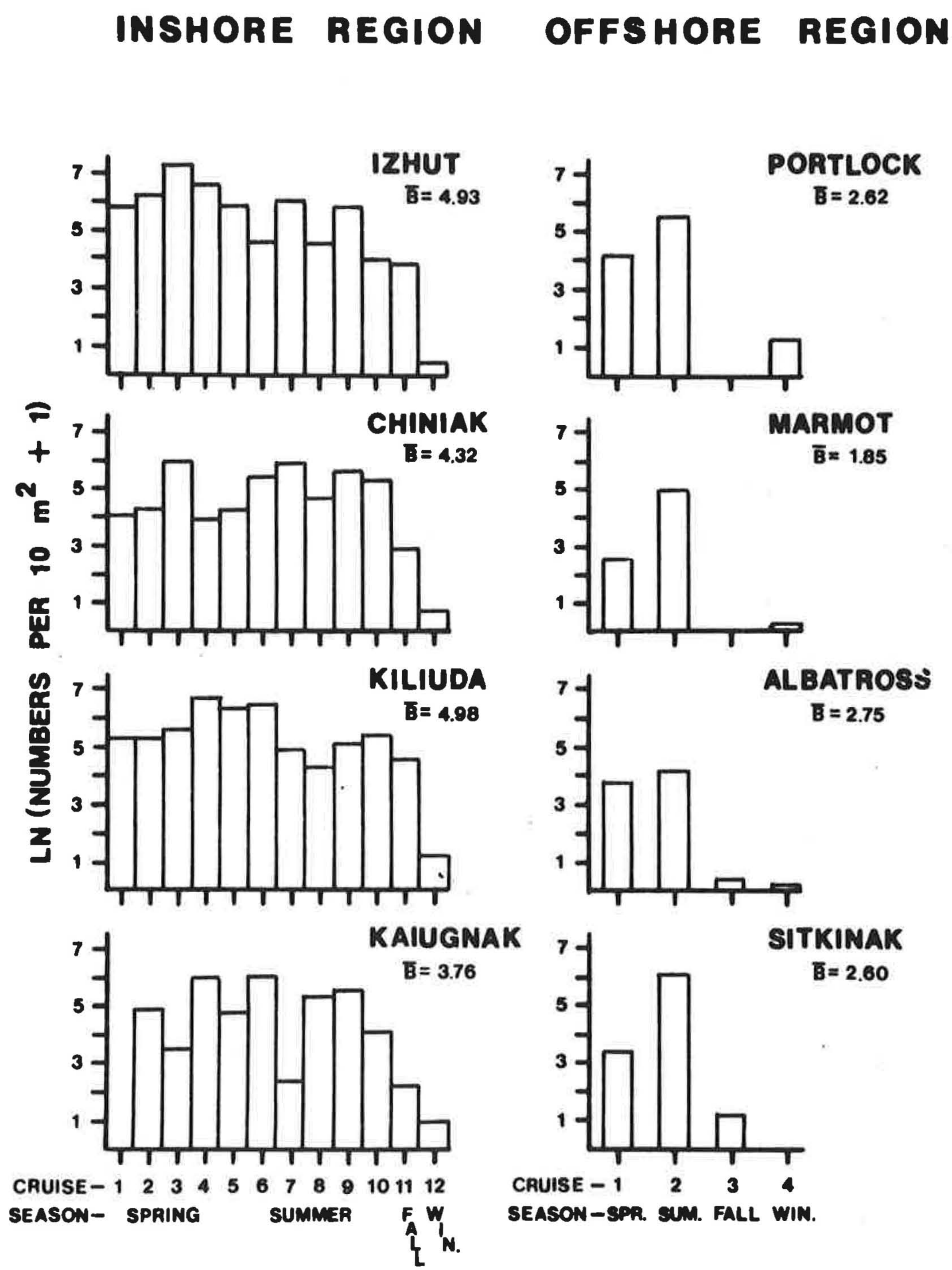


Figure III-18. Average biomass (ln(numbers per 10 m² + 1)) by cruise, season, bay, subarea and region for Anomura in the Kodiak Island study area. Bongo net data.

Paralithodes camtschatica (red king crab)

The zoeae of P. camtschatica were present in the study area from late winter (inshore only) through spring and early summer (Figure III-19 and Tables III-16 and 17) with stage I larvae occurring March through May.

During the day, most larvae were found in the stratum 5-20 m below the surface in Kiliuda Bay and in the upper 60 m of the water column in Izhut Bay (Figure III-20). Relatively small numbers remained at or near the surface at night and most zoeae appeared to move into deeper strata in both bays. P. camtschatica zoeae were concentrated in upper portions of the water column during daylight hours.

Detailed examination of the Kiliuda Bay daytime Tucker trawl samples indicated larval stages of P. camtschatica remain concentrated at very shallow depths until development into megalopae (Figure III-21). Stage I and II zoeae appeared somewhat dispersed throughout the upper 60 m but this observation is of questionable value because very few larvae were encountered in the samples. Highest concentration of megalopae were still encountered in shallow depth intervals and this stage was the only one found in measurable amounts at depths greater than 80 m.

There was no notable difference in abundance of P. camtschatica larvae by region or subarea during our study of the Kodiak Island shelf. Analysis of variance tests of the bongo data indicated that abundance differed significantly by season (Table III-18); however, multiple comparison tests failed to identify which season was the most important. Inability to attach significance to seasonal abundance differences probably resulted from the small amounts of larvae encountered in any area or time period (Tables III-16 and 17). Although the statistical tests failed to substantiate seasonal abundance trends, P. camtschatica larvae were encountered primarily in late winter and spring. Zoeae were found sporadically in all inshore bays but in only 2 of the 4 offshore subareas and in the offshore region only during spring and summer (Figure III-22).

Figure III-19.--Occurrence of larval stages of red king crab, Paralithodes camtschatica, by cruise and season from the OCSEAP inshore plankton cruises. Data from all gear types.

SEASON	SPRING					SUMMER					FALL	LATE WINTER
CRUISE	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
LARVAL STAGES												
1	----	----	----	----								----
2	----	----	----	----	----	----						
3	----	----	----	----	----	----						
4	----		----	----	----	----						
glaucothe				----	----							

Table III-16.--Standardized biomass (ln(numbers per 10 m^2 + 1)) of red king crab, *Paralithodes camtschatica*, by season, cruise, and subarea in the inshore region of the Kodiak Island study area, March 1978 - March 1979. (Bongo net data).

SEASON			SPRING			SUMMER					FALL	WINTER	Mean Biomass All Cruises
CRUISE	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	
Subarea													
Izhut	0*	2.00	0	0	1.63	0	0	0	0	0	0	.15	.31
Chiniak	3.51	0	0	3.42	0	0	0	0	0	0	0	3.04	.83
Kiliuda	0	2.08	3.11	2.90	1.44	0	0	0	0	0	0	0	.79
Kiaugnak	0	0	2.70	0	0	0	0	0	0	0	0	.80	.29
Mean Biomass Bays Combined	.88	1.02	.70	1.58	.77	0	0	0	0	0	0	1.00	.55

*ln of (standardized biomass (i.e., numbers per 10 m^2) + 1)

Table III-17.--Standardized biomass (ln(numbers per 10 m^2 + 1)) of red king crab larvae, Paralithodes camtschatica, by season, cruise and subarea in the offshore region of the Kodiak Island study area, March 1978 - March 1979. (Bongo net data).

SEASON	SPRING	SUMMER	FALL	WINTER	Mean Biomass All Cruises
CRUISE	I	II	III	IV	
Subarea					
Portlock	.50	0	0	0	.12
Marmot	0	0	0	0	0
Albatross	0	0	0	0	0
Sitkinak	0	.65	0	0	.16
Mean Biomass Subareas Combined	.12	.16	0	0	.07

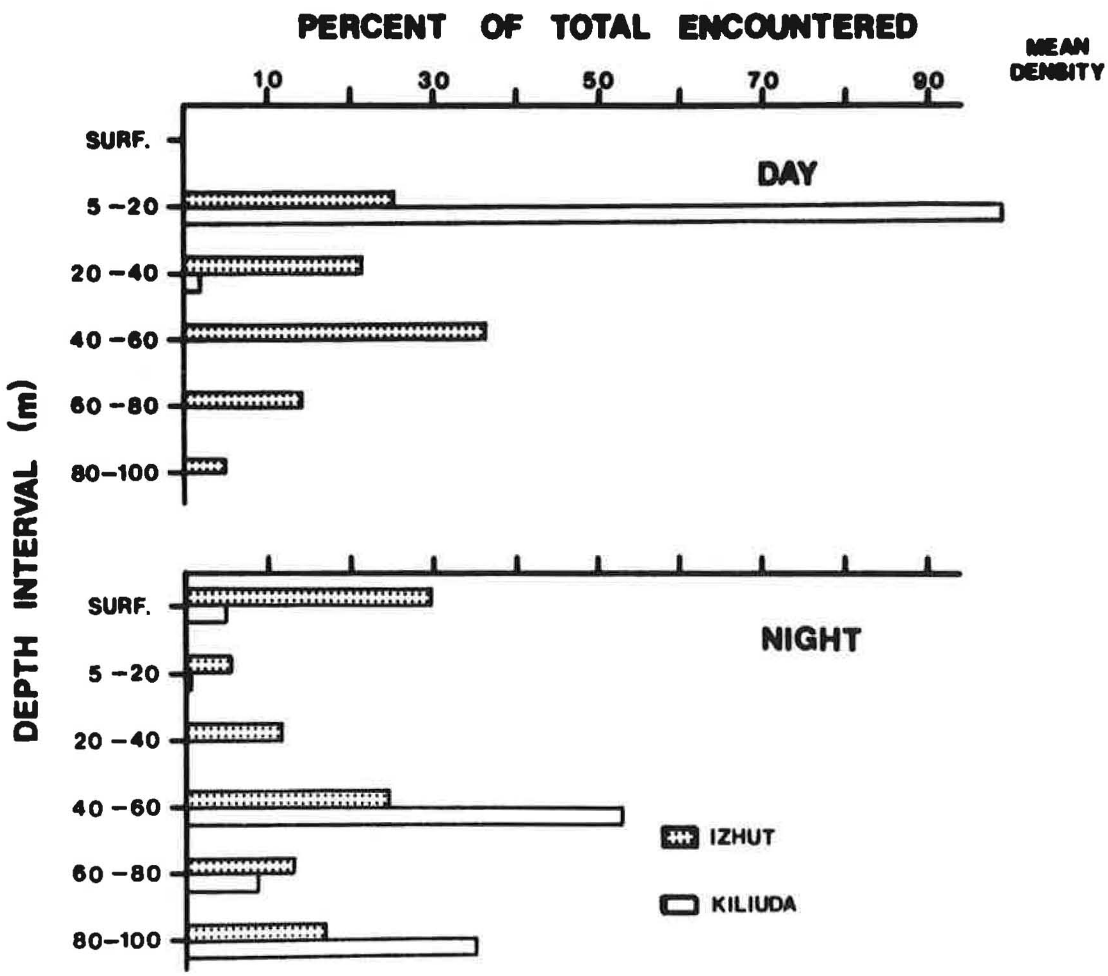


Figure III-20. Percent of total Paralithodes camtschatica encountered during inshore OCSEAP plankton cruises by diel period and depth interval for Izhut and Kiliuda bays. Tucker trawl data.

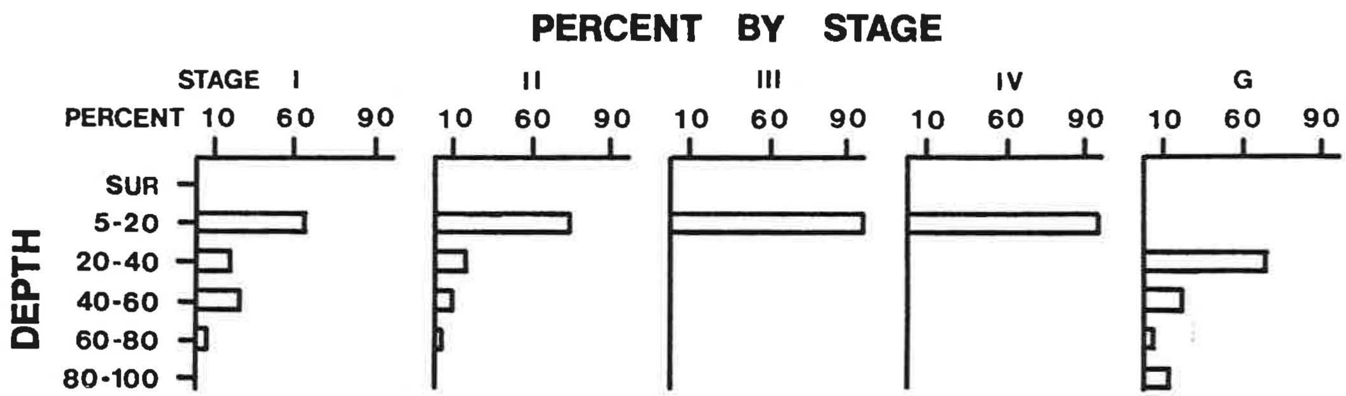


Figure III-21.--Percent of Paralithodes camtschatica encountered per depth interval for each larval stage found during inshore sampling of the Kodiak Island study area. (neuston sampler and Tucker trawl data)

Table III-18.--Summary of information derived from analysis of variance tests of bongo net data (ln(numbers per 10 m^2 + 1)) for P. camtschatica larvae.

TEST	SOURCE OF VARIABILITY	DEGREES OF FREEDOM	SUM OF SQUARES	VALUE OF F
Inshore and offshore combined	Total	63	60.793	--
	Main effects			
	Region (R)	1	2.186	2.29
	Subarea (A)	3	1.921	0.67
	Season (S)	3	11.780	4.11*
	Interactions			
	R X A	3	1.503	0.52
	R X S	3	3.304	1.15
	A X S	9	5.901	0.69
	R X A X S	9	3.213	0.37
	Residual	32	30.556	--
Inshore	Total	47	57.371	--
	Main effects			
	Bays	3	3.124	0.92
	Cruise	11	17.042	1.37
	Residual	33	37.205	--
Offshore	Total	15	0.590	--
	Main effects			
	Subarea	3	0.085	0.61
	Cruise	3	0.085	0.61
	Residual	9	0.419	--

* denotes significance at = .05

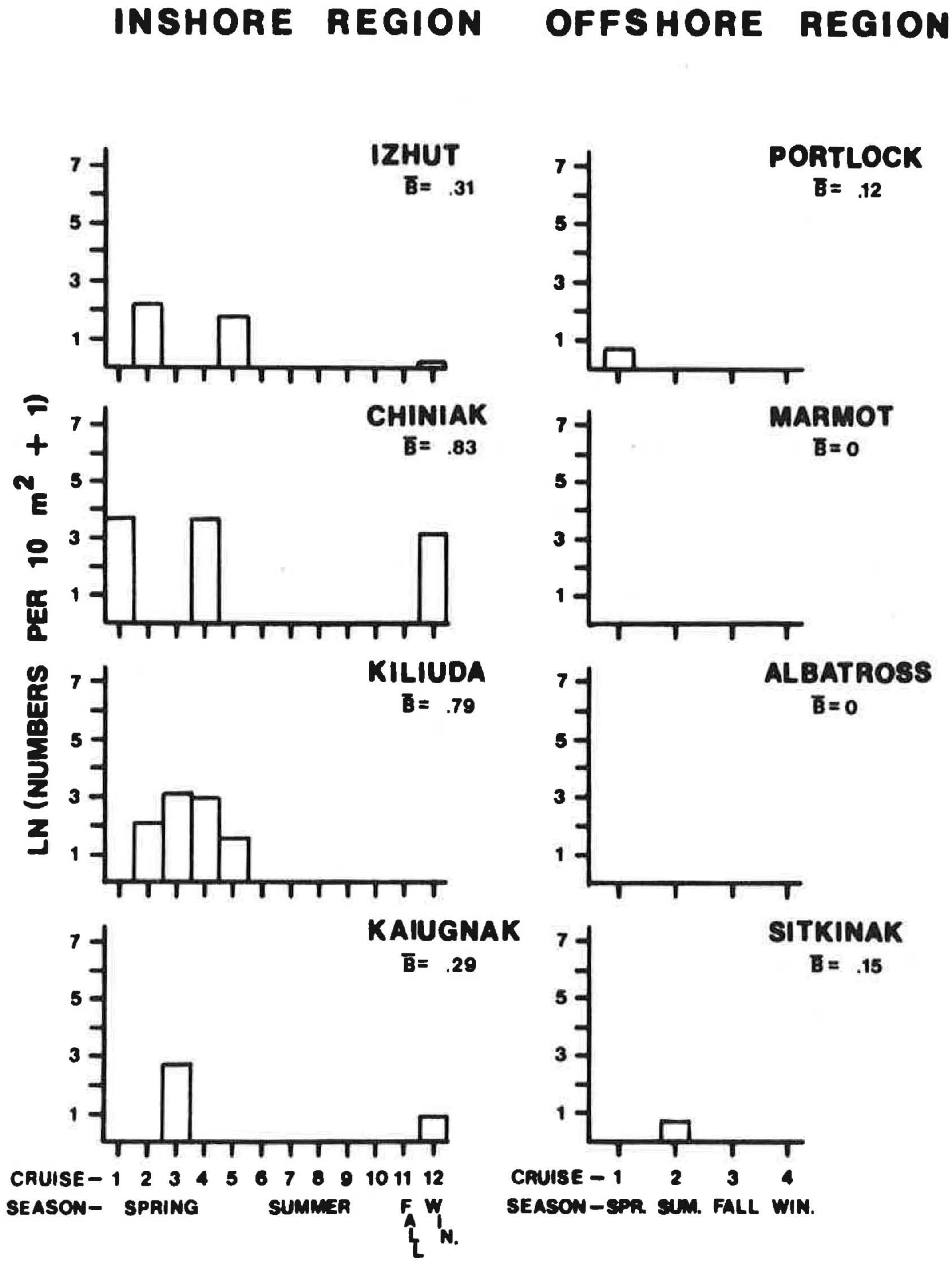


Figure III-22. Average biomass (ln(numbers per 10 m² + 1)) by cruise, season, bay, subarea and region for Paralithodes camtschatica in the Kodiak Island study area. Bongo net data.

Cancer magister (Dungeness crab)

Larvae of *C. magister* were present in the water column in late winter, spring and summer in the inshore region (Figure III-23 and Table III-19), but only during summer in the offshore region (Table III-20). Stage I zoeae were present inshore throughout most of the study period; however, a time of peak release could not be discerned from our data.

Information from the diel vertical distribution data indicated most *C. magister* zoeae were present from the surface to depths of 60 m during the day (Figure III-24). At night they were present throughout the water column but were found in highest concentrations from the surface down to 40 m. A high percentage of *C. magister* zoeae were present in 80-100 m in Izhut Bay but it should be noted that amounts found in samples from this bay were very low relative to concentrations encountered in Kiliuda Bay.

Analysis of variance tests of bongo net samples indicated no significant difference in the abundance of *C. magister* larvae between inshore and offshore regions of the study area (Table III-21). Separate tests by region also failed to identify notable differences in offshore distribution or abundance by subarea or season but significant differences were apparent inshore. Multiple comparison tests determined that the abundance of *C. magister* zoeae in Kiliuda Bay (Figure III-25) was significantly higher than in any other bay during the study. An inshore cruise effect was also indicated; however, the greater importance of any single cruise or group of cruises was not discerned.

Figure III-23.--Occurrence of larval stages of Dungeness crab, *Cancer magister*, by cruise and season from the OCSEAP inshore plankton cruises. Data from all gear types.

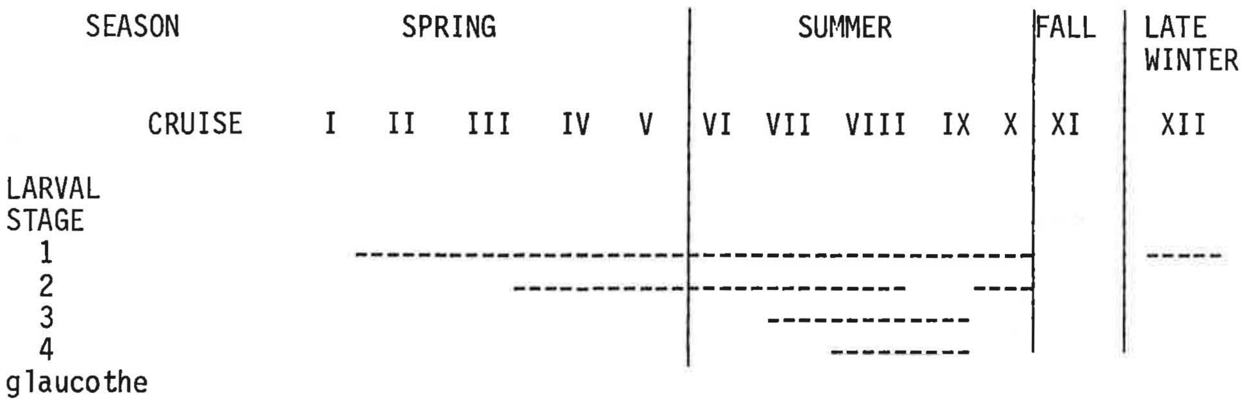


Table III-19.--Standardized biomass (ln(numbers per 10 m^2 + 1)) of Dungeness crab, Cancer magister, by season, cruise, and subarea in the inshore region of the Kodiak Island study area, March 1978 - March 1979. (Bongo net data).

SEASON			SPRING			SUMMER					FALL	WINTER	Mean Biomass All Cruises
CRUISE	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	
Subarea													
Izhut	0*	0	0	2.35	0	1.24	3.32	0	0	0	0	0	.56
Chiniak	0	0	0	0	0	3.96	0	0	0	0	0	0	.33
Kiliuda	0	4.26	0	3.78	4.75	4.02	3.93	4.04	2.84	0	0	0	2.30
Kiaugnak	0	0	2.33	1.92	2.74	4.64	0	3.05	0	0	0	.21	1.24
Mean Biomass Bays Combined	0	1.06	.58	2.01	1.87	3.46	1.81	1.77	.71	0	0	.05	1.11

*ln of (standardized biomass (i.e., numbers per 10 m^2) + 1

Table III-20.--Standardized biomass (ln(numbers per 10 m^2 + 1)) of Dungeness crab larvae, *Cancer magister*, by season, cruise and subarea in the offshore region of the Kodiak Island study area, March 1978 - March 1979. (Bongo net data).

SEASON	SPRING	SUMMER	FALL	WINTER	Mean Biomass All Cruises
CRUISE	I	II	III	IV	
Subarea					
Portlock	0	0	0	0	0
Marmot	0	2.60	0	0	.65
Albatross	0	0	0	0	0
Sitkinak	0	3.88	0	0	.97
Mean Biomass Subareas Combined	0	1.62	0	0	.40

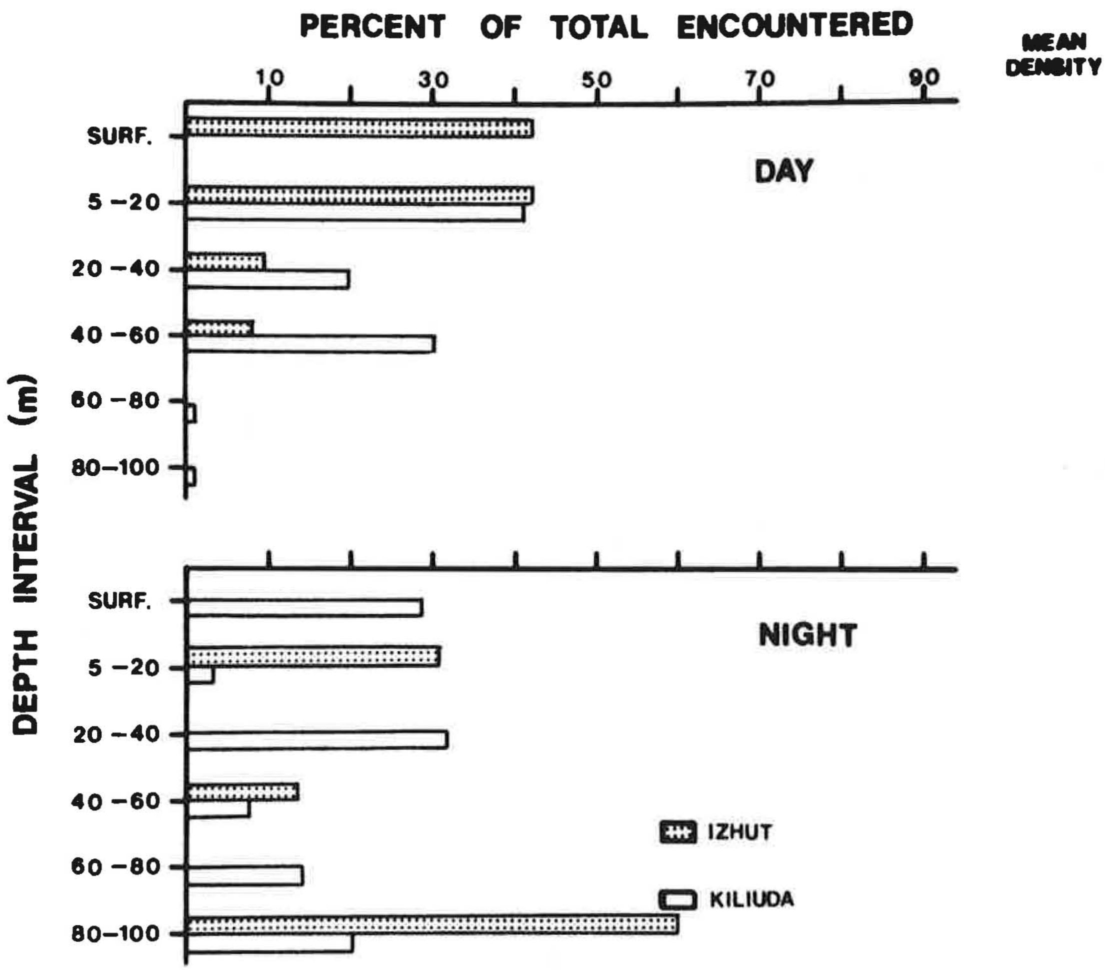


Figure III-24. Percent of total Cancer magister encountered during inshore OCSEAP plankton cruises by diel period and depth interval for Izhut and Kiliuda bays. Tucker trawl data.

Table III-21.--Summary of information derived from analysis of variance tests of bongo net data (ln(numbers per 10 m^2 + 1)) for C. magister larvae.

TEST	SOURCE OF VARIABILITY	DEGREES OF FREEDOM	SUM OF SQUARES	VALUE OF F
Inshore and offshore combined	Total	63	158.004	--
	Main effects			
	Region (R)	1	1.187	0.44
	Subarea (A)	3	19.350	2.41
	Season (S)	3	18.285	2.28
	Interactions			
	R X A	3	8.285	1.03
	R X S	3	2.911	0.36
	A X S	9	4.356	0.18
	R X A X S	9	10.232	0.43
	Residual	32	85.462	--
Inshore	Total	47	132.807	--
	Main effects			
	Bays	3	27.939	5.87**
	Cruise	11	52.508	3.01**
	Residual	33	52.361	--
Offshore	Total	15	19.190	--
	Main effects			
	Subarea	3	2.829	1.00
	Cruise	3	7.873	2.78
	Residual	9	8.488	--

** denotes significance at = .01

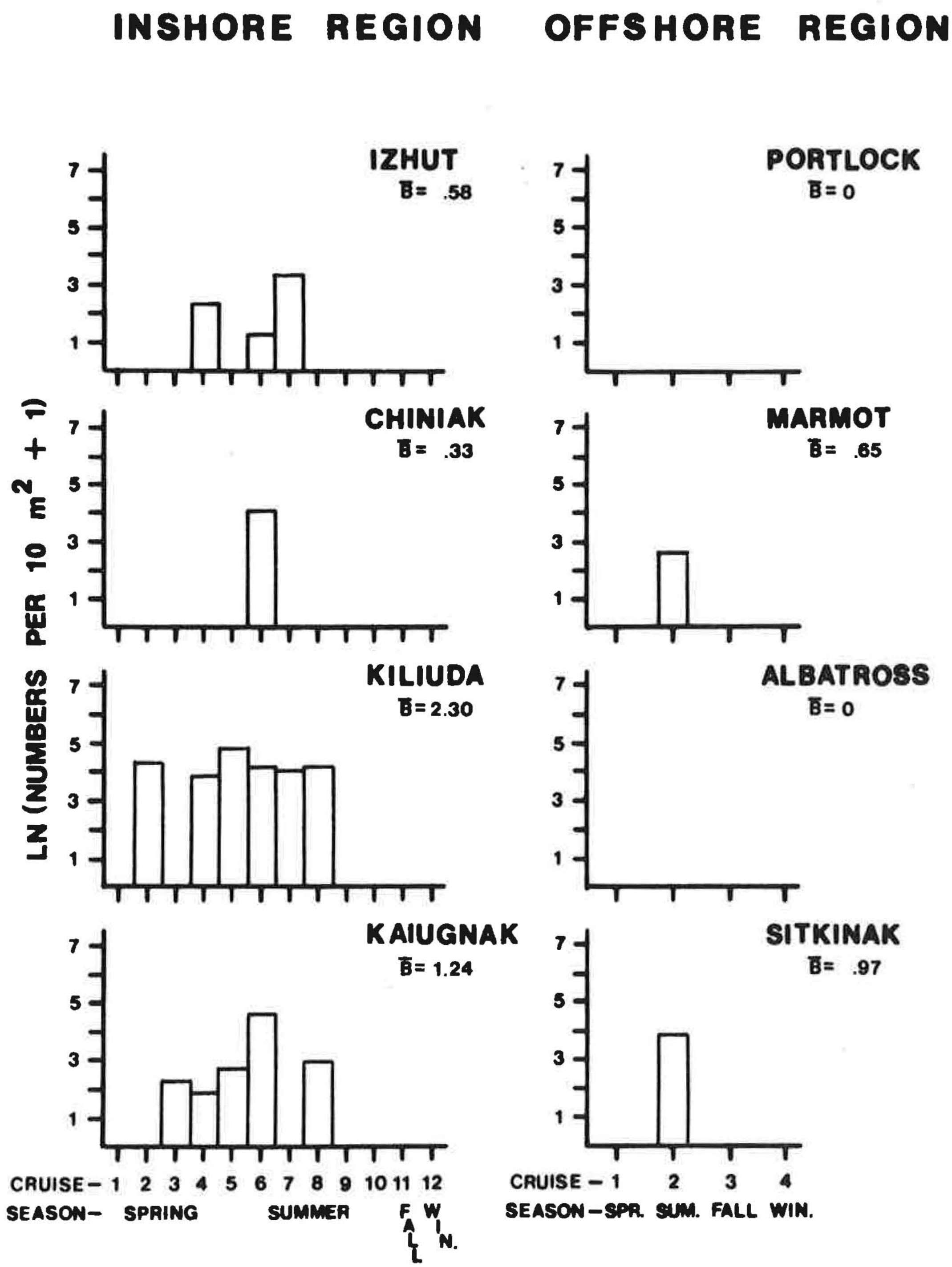


Figure III-25. Average biomass (ln(numbers per 10 m² + 1)) by cruise, season, bay, subarea and region for *Cancer magister* in the Kodiak Island study area. Bongo net data.

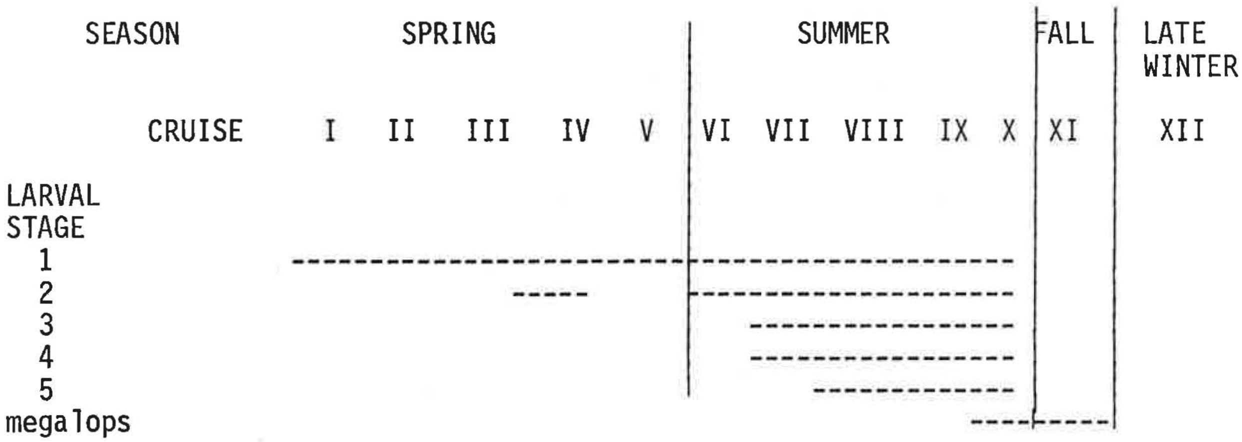
Cancer sp.

Occurrence of *Cancer* sp. larvae in the Kodiak Island study area was apparently limited to spring and summer (Figures III-26 and 27, and Tables III-22 and 23).

Nearly all larvae were found during the day in the 5-40 m interval and at or near the surface during the night (Figure III-28). It should be noted that the previous analysis by Kendall et al. (1980) suggested a deeper night-time distribution, however, that analysis did not include neuston samples.

The analysis of variance test of combined inshore and offshore data indicated no notable region or area effects on distribution or abundance of *Cancer* sp. larvae (Table III-24). There was a season effect with larval concentration in summer being significantly higher than amounts encountered during other times of the year. These results were mirrored by separate analyses for the inshore and offshore data. The period of mid June - early August (Cruises VI-IX) contained significantly greater amounts of *Cancer* sp. larvae inshore while in the offshore region peak abundance occurred during the summer cruise.

Figure III-26.--Occurrence of larval stages of cancer crab, Cancer sp. by cruise and season from the OCSEAP inshore plankton cruises. Data from all gear types.



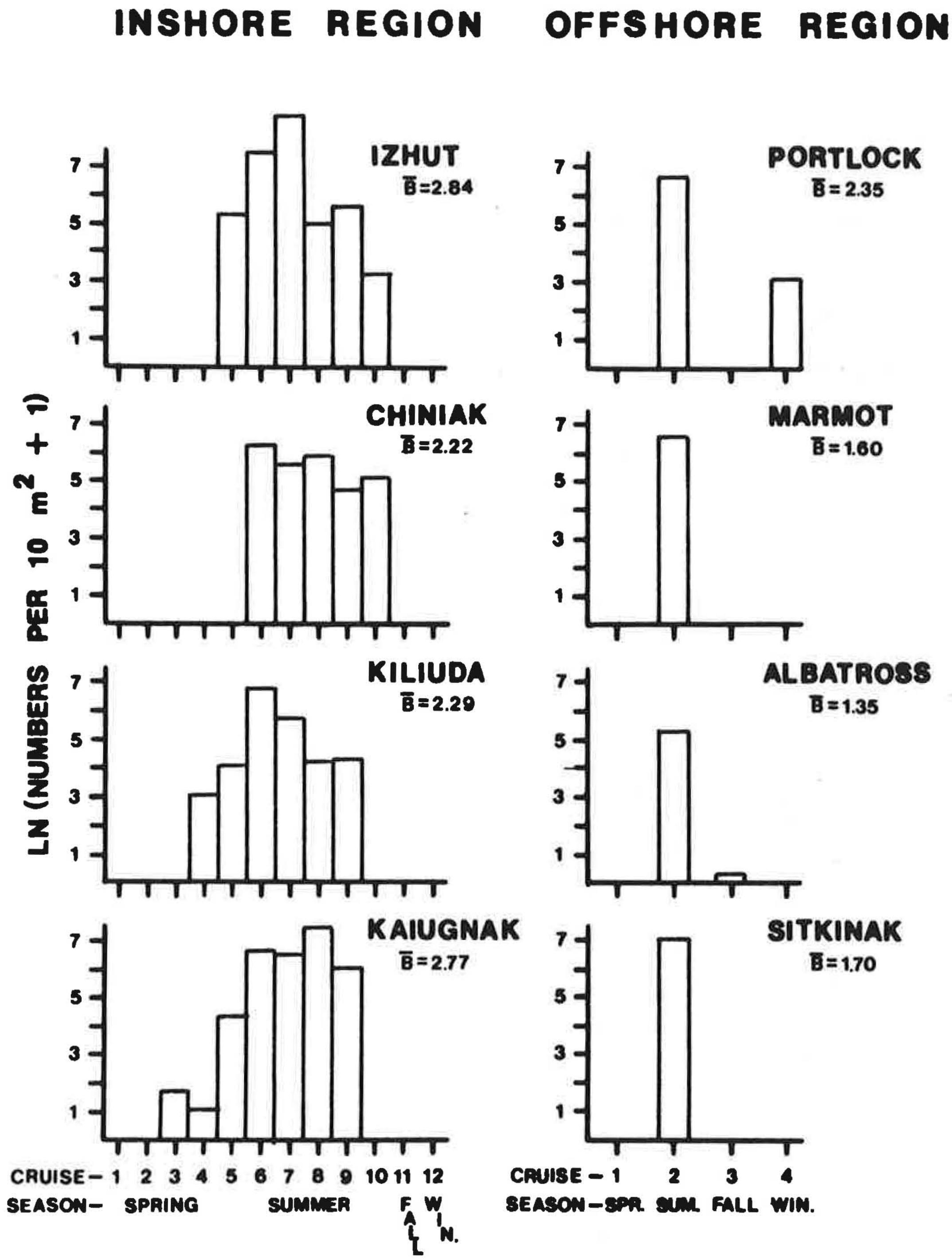


Figure III-27. Average biomass (ln(numbers per 10 m² + 1)) by cruise, season, bay, subarea and region for Cancer sp. in the Kodiak Island study area. Bongo net data.

Table III-22.--Standardized biomass (ln(numbers per 10 m^2 +1)) of Cancer crab, *Cancer* sp., by season, cruise, and subarea in the inshore region of the Kodiak Island study area, March 1978 - March 1979. (Bongo net data).

SEASON			SPRING			SUMMER					FALL	WINTER	Mean Biomass All Cruises
CRUISE	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	
Subarea													
Izhut	0*	0	0	0	5.09	7.25	8.46	4.83	5.37	3.12	0	0	2.84
Chiniak	0	0	0	0	0	6.10	5.36	5.65	4.58	5.00	0	0	2.22
Kiliuda	0	0	0	3.00	4.00	6.61	5.57	4.08	4.18	0	0	0	2.29
Kiaugnak	0	0	1.73	1.14	4.30	6.52	6.40	7.18	5.93	0	0	0	2.77
Mean Biomass Bays Combined	0	0	.43	1.03	3.35	6.62	6.45	5.43	5.01	2.03	0	0	2.53

*ln of (standardized biomass (i.e., nimbers per 10 m^2) + 1

Table III-23.--Standardized biomass (ln(numbers per 10 m^2 + 1)) of cancer crab larvae, Cancer sp., by season, cruise and subarea in the offshore region of the Kodiak Island study area, March 1978 - March 1979. (Bongo net data).

SEASON	SPRING	SUMMER	FALL	WINTER	Mean Biomass All Cruises
CRUISE	I	II	III	IV	
Subarea					
Portlock	0	6.37	0	3.02	2.35
Marmot	0	6.38	0	0	1.59
Albatross	0	5.08	.30	0	1.34
Sitkinak	0	6.83	0	0	1.71
Mean Biomass Subareas Combined	0	6.16	.07	.75	1.74

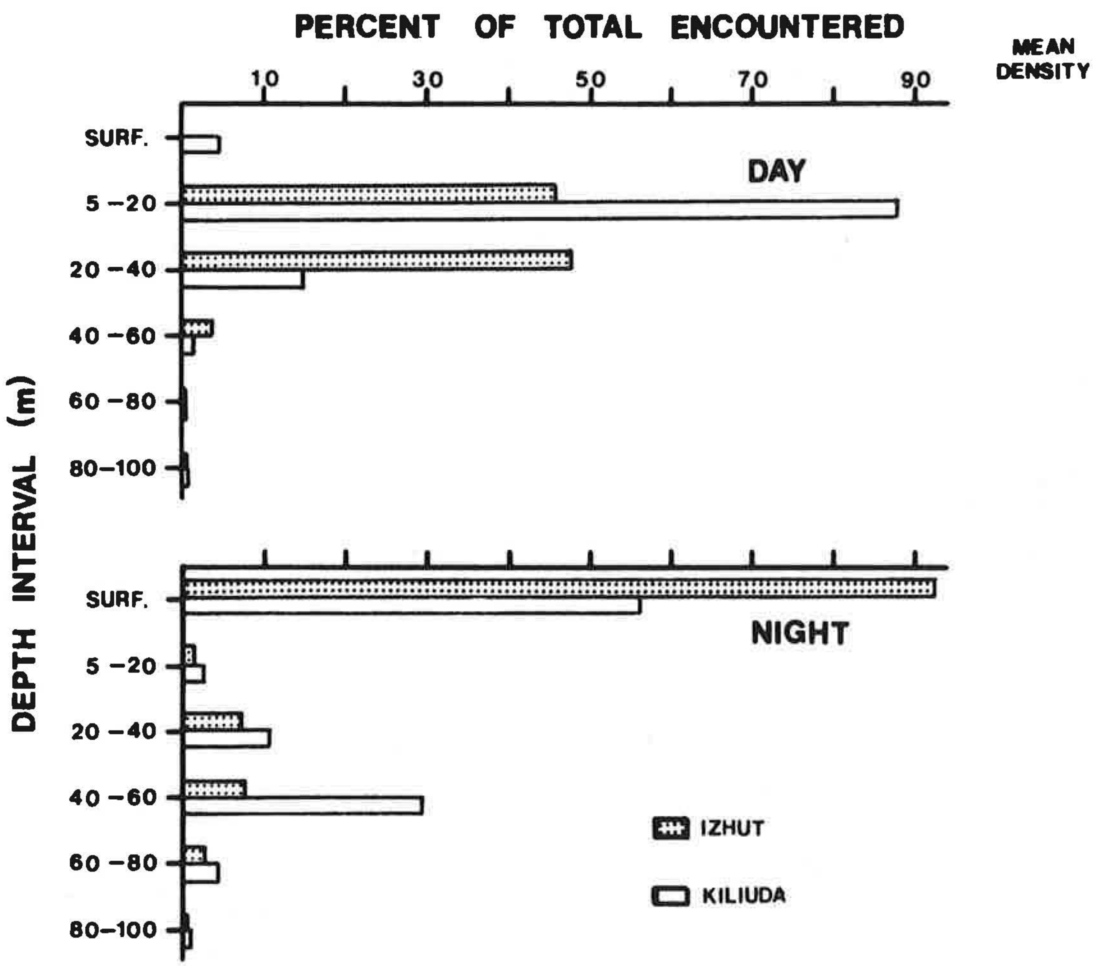


Figure III-28. Percent of total Cancer sp. encountered during inshore OCSEAP plankton cruises by diel period and depth interval for Izhut and Kiliuda bays. Tucker trawl data.

Table III-24.--Summary of information derived from analysis of variance tests of bongo net data (ln(numbers per 10 m^2 + 1)) for *Cancer* sp. larvae.

TEST	SOURCE OF VARIABILITY	DEGREES OF FREEDOM	SUM OF SQUARES	VALUE OF F
Inshore and offshore combined	Total	63	496.694	--
	Main effects			
	Region (R)	1	0.367	0.09
	Subarea (A)	3	5.250	0.44
	Season (S)	3	331.211	27.76**
	Interactions			
	R X A	3	0.425	0.04
	R X S	3	7.614	0.64
	A X S	9	12.799	0.36
	R X A X S	9	4.630	0.13
	Residual	32	127.252	--
Inshore	Total	47	575.260	--
	Main effects			
	Bays	3	3.679	0.77
	Cruise	11	319.351	18.34**
	Residual	33	52.229	--
Offshore	Total	15	114.017	--
	Main effects			
	Subarea	3	2.187	1.02
	Cruise	3	105.401	49.19**
	Residual	9	6.428	--

** denotes significance at = .01

Chionoecetes bairdi (Tanner crab)

C. bairdi zoeae were present in plankton samples throughout the year (Figure III-29, 30 and Tables III-25 and 26). Stage I larvae were encountered from late winter through mid-summer (28 March - 18 July 1978 and 4-16 March 1979) suggesting an asynchronous or a protracted period of larval release. However, the data from the extensively resorted bongo samples in Chiniak Bay and Tucker trawl tows in Kiliuda Bay indicated peak abundance of Stage I zoeae during late May-early June (Cruises IV and V) which implies that most hatching occurred during late spring.

Most larvae encountered during the day were in depths to 60 m. Vertical distribution at night could not be clearly explained. Large numbers of _C. bairdi_ zoeae were found near the surface, but equally substantial amounts were present from 40 m downward to 80-100 m. There was a notable lack of organisms at 20-40 m (Figure III-31).

Analysis of vertical distribution by larval stage indicated both Stage I and megalopae were present in highest concentrations in the upper portion of the water column (Kiliuda Bay, daytime data only). No Stage II larva were encountered in any of the 60 resorted samples used in this analysis (Figure III-32).

Analysis of variance tests failed to discern notable difference in the abundance of _C. bairdi_ larvae between inshore and offshore regions of the study area (Table III-27). Separate tests of each region identified significant time and area effects on amounts present. Multiple comparison tests determined that numbers of _C. bairdi_ zoeae found inshore in May to early June (Cruises IV and V) and offshore during the summer cruise were significantly greater than those found in any other period sampled. A bay effect was also identified inshore but an apparent bay x cruise interaction masked the importance of any bay.

Figure III-29.--Occurrence of larval stages of Tanner crab, *Chionoecetes bairdi*, by cruise and season from the OCSEAP inshore plankton cruises. Data from all gear types.

SEASON	SPRING					SUMMER					FALL	LATE WINTER
CRUISE	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
LARVAL STAGE												
1	----		----	----	----	----	----					----
2				----	----	----	----		----			
megalops		----	----	----	----	----	----	----		----	----	----

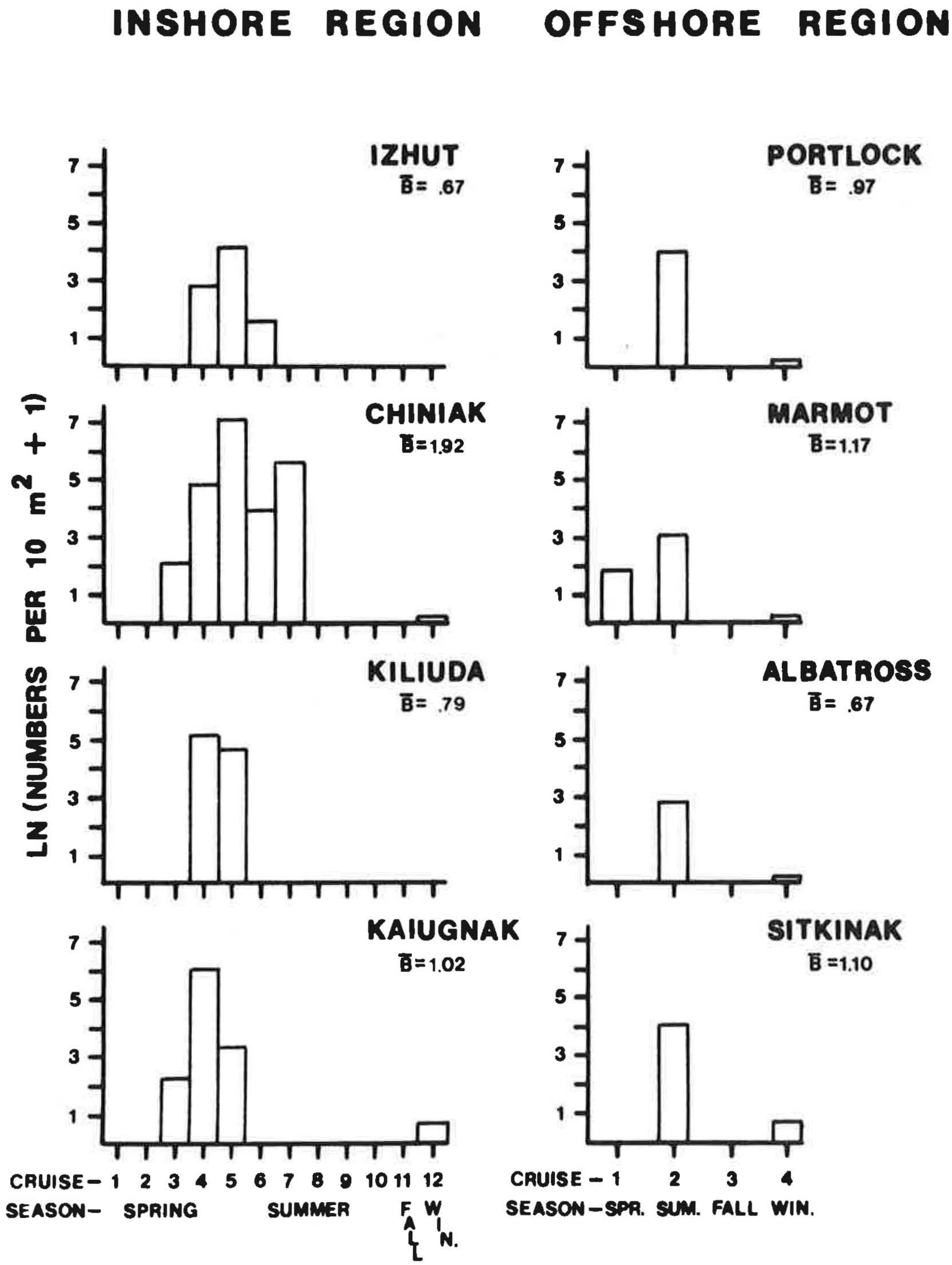


Figure III-30. Average biomass (ln(numbers per 10 m^2 + 1)) by cruise, season, bay, subarea and region for Chionoecetes bairdi in the Kodiak Island study area. Bongo net data.

Table III-25.--Standardized biomass (ln(numbers per 10 m^2 + 1)) of tanner crab, Chionoecetes bairdi, by season, cruise, and subarea in the inshore region of the Kodiak Island study area, March 1978 - March 1979. (Bongo net data).

SEASON			SPRING			SUMMER					FALL	WINTER	Mean Biomass All Cruises
CRUISE	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	
Subarea													
Izhut	0*	0	0	2.58	3.96	1.50	0	0	0	0	0	0	.67
Chiniak	0	0	1.99	4.66	6.99	3.78	5.53	0	0	0	0	.07	1.92
Kiliuda	0	0	0	4.97	4.46	0	0	0	0	0	0	0	.79
Kiaugnak	0	0	2.33	5.98	3.33	0	0	0	0	0	0	.66	1.02
Mean Biomass Bays Combined	0	0	1.08	4.55	4.68	1.32	1.38	0	0	0	0	.18	1.10

*ln of (standardized biomass (i.e., numbers per 10 m^2) + 1

Table III-26.--Standardized biomass (ln(numbers per 10 m^2 + 1)) of tanner crab larvae, *Chionoecetes bairdi*, by season, cruise and subarea in the offshore region of the Kodiak Island study area, March 1978 - March 1979. (Bongo net data).

SEASON	SPRING	SUMMER	FALL	WINTER	Mean Biomass All Cruises
CRUISE	I	II	III	IV	
Subarea					
Portlock	0	3.83	0	.10	.98
Marmot	1.73	2.89	0	.07	1.17
Albatross	0	2.65	0	.06	.68
Sitkinak	0	3.76	0	.63	1.10
Mean Biomass Subareas Combined	.43	3.28	0	.21	.98

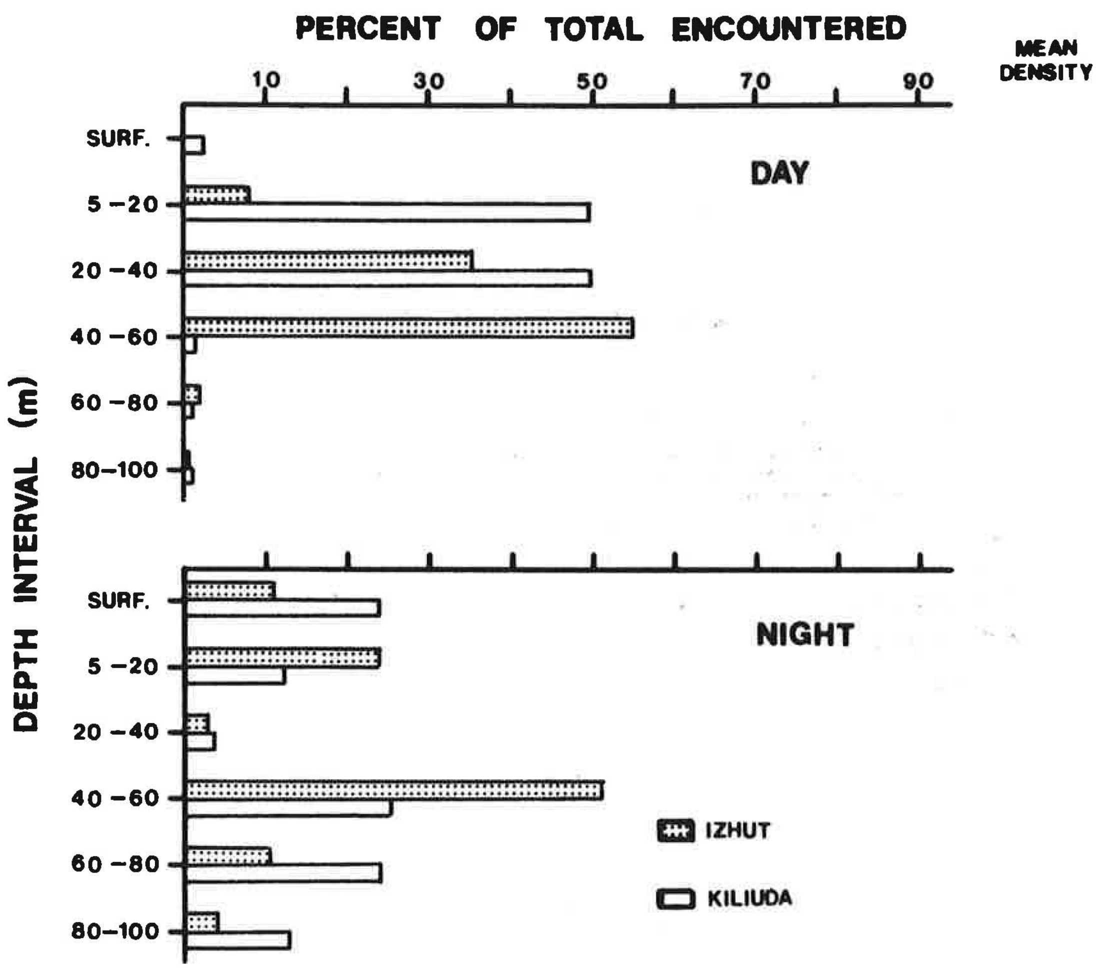


Figure III-31. Percent of total Chionoecetes bairdi encountered during inshore OCSEAP plankton cruises by diel period and depth interval for Izhut and Kiliuda bays. Tucker trawl data.

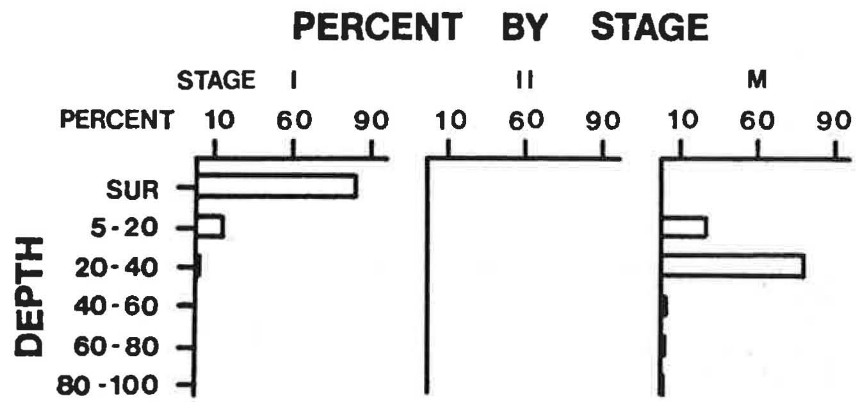


Figure III-32.--Percent of Chionoecetes bairdi encountered per depth interval for each larval stage found during inshore sampling of the Kodiak Island study area. (neuston sampler and Tucker trawl data)

Table III-27.--Summary of information derived from analysis of variance tests of bongo net data (ln(numbers per 10 m^2 + 1)) for C. bairdi larvae.

TEST	SOURCE OF VARIABILITY	DEGREES OF FREEDOM	SUM OF SQUARES	VALUE OF F
Inshore and offshore combined	Total	63	215.651	--
	Main effects			
	Region (R)	1	1.338	0.32
	Subarea (A)	3	10.212	0.82
	Season (S)	3	29.006	2.33
	Interactions			
	R X A	3	0.713	0.06
	R X S	3	32.619	2.63
	A X S	9	5.297	0.14
	R X A X S	9	3.998	0.11
	Residual	32	132.501	--
Inshore	Total	47	183.346	--
	Main effects			
	Bays	3	11.502	3.17*
	Cruise	11	131.980	9.93**
	Residual	33	39.865	--
Offshore	Total	15	32.144	--
	Main effects			
	Subarea	3	0.569	0.57
	Cruise	3	28.587	28.70**
	Residual	9	2.988	--

* denotes significance at = .05
** denotes significance at = .01

Pinnotheridae (pea crabs)

Pinnotherid crab larvae were found primarily from late spring through fall (Figures III-33 and 34 and Tables III-28 and 29). The presence of Stage I larvae from spring through summer suggests a fairly protracted period of larval release. Stages III through V were still prevalent in samples collected during the fall inshore cruise.

Pinnotherid zoeae were encountered mostly in mid-water depths (Figure III-35). During the day about 95% were found at 5-60 m while at night they appeared uniformly distributed throughout the water column. The largest proportion encountered during night time was in 60-80 m. Few pinnotherids were found at the surface and those only at night.

Analysis of variance tests for the combined inshore and offshore data identified a season effect on abundance of pinnotherid crab zoeae (Table III-30). Numbers encountered during summer were significantly greater than other times of the year throughout the study area. A separate ANOVA and multiple comparison test of the inshore region further identified May through August (Cruises IV-X) as being more important than other time periods. Although a bay effect was also identified inshore, no bay could be determined to be more important than any other.

Figure III-33.--Occurrence of larval stages of pea crabs, Pinnotheridae, by cruise and season from the OCSEAP inshore plankton cruises. Data from all gear types.

```
    SEASON              SPRING                 |           SUMMER          |FALL  | LATE
                                               |                           |      | WINTER
        CRUISE      I    II    III    IV    V  | VI   VII   VIII   IX   X | XI   |  XII
LARVAL                                         |                           |      |
STAGE                                          |                           |      |
  1                    ------------------------|---------------------------|      |
  2                          ------------------|---------------------------|      |
  3                                            |   ------------------------|----  |
  4                                            |   ------------------------|----  |
  5                                            |       --------------------|----  |
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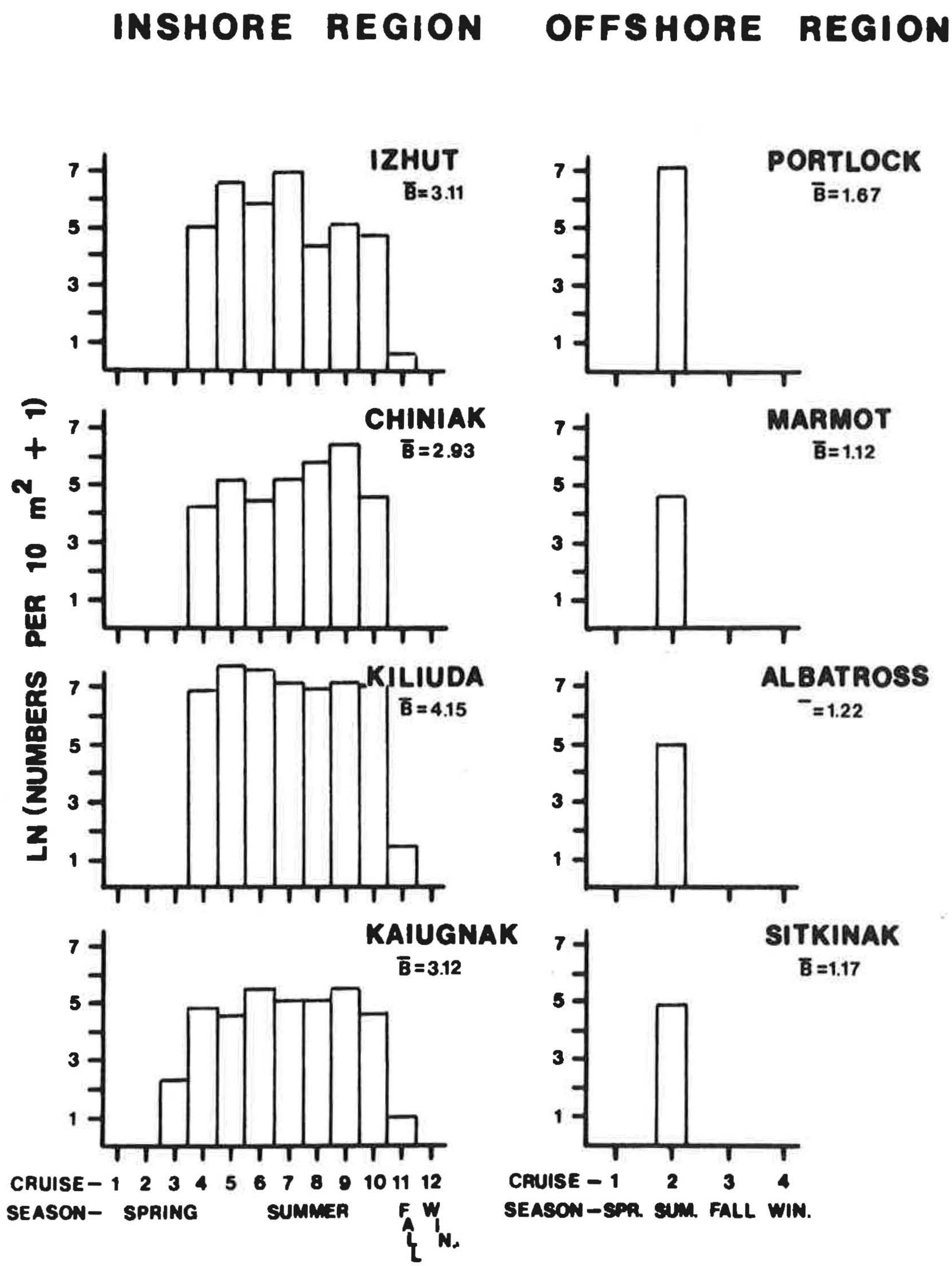

Figure III-34. Average biomass (ln(numbers per 10 m^2 + 1)) by cruise, season, bay, subarea and region for Pinnotheridae in the Kodiak Island study area. Bongo net data.

Table III-28.--Standardized biomass (ln(numbers per 10 m^2 + 1)) of peacrab, Pinnotheridae, by season, cruise, and subarea in the inshore region of the Kodiak Island study area, March 1978 - March 1979. (Bongo net data).

SEASON			SPRING			SUMMER					FALL	WINTER	Mean Biomass All Cruises
CRUISE	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	
Subarea													
Izhut	0*	0	0	4.77	6.26	5.57	6.75	4.17	4.94	4.47	.41	0	3.11
Chiniak	0	0	0	4.08	5.09	4.44	5.06	5.66	6.34	4.53	0	0	2.93
Kiliuda	0	0	0	6.66	7.53	7.42	6.87	6.57	6.76	6.76	1.29	0	4.15
Kiaugnak	0	0	2.33	4.71	4.44	5.37	4.98	4.97	5.27	4.52	.88	0	3.12
Mean Biomass Bays Combined	0	0	.58	5.05	5.83	5.70	5.91	5.34	5.83	5.07	.64	0	3.33

*ln of (standardized biomass (i.e., numbers per 10 m^2) + 1

Table III-29.--Standardized biomass (ln(numbers per 10 m^2 + 1)) of pea crab larvae, Pinnotheridae, by season, cruise and subarea in the offshore region of the Kodiak Island study area, March 1978 - March 1979. (Bongo net data).

SEASON	SPRING	SUMMER	FALL	WINTER	Mean Biomass All Cruises
CRUISE	I	II	III	IV	
Subarea					
Portlock	0	6.68	0	0	1.67
Marmot	0	4.52	0	0	1.13
Albatross	0	4.88	0	0	1.22
Sitkinak	0	4.74	0	0	1.81
Mean Biomass Subareas Combined	0	5.20	0	0	1.30

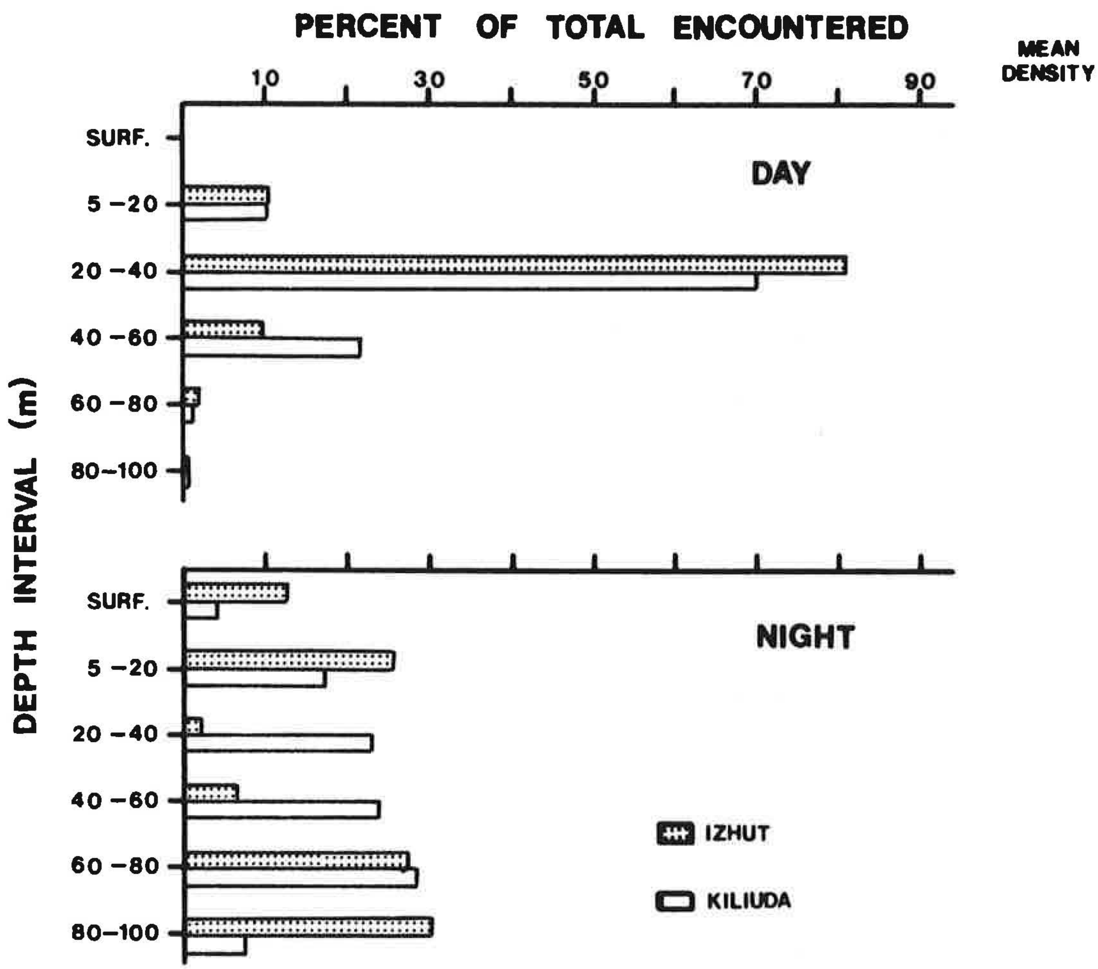

Figure III-35. Percent of total Pinnotheridae encountered during inshore OCSEAP plankton cruises by diel period and depth interval for Izhut and Kiliuda bays. Tucker trawl data.

Table III-30.--Summary of information derived from analysis of variance tests of bongo net data ($\ln$(numbers per 10 m^2 + 1)) for Pinnotherid crab larvae.

TEST	SOURCE OF VARIABILITY	DEGREES OF FREEDOM	SUM OF SQUARES	VALUE OF F
Inshore and offshore combined	Total	63	496.460	--
	Main effects			
	Region (R)	1	9.672	2.03
	Subarea (A)	3	8.200	0.57
	Season (S)	3	267.239	18.66**
	Interactions			
	R X A	3	2.920	0.20
	R X S	3	9.141	0.64
	A X S	9	2.868	0.07
	R X A X S	9	3.174	0.07
	Residual	32	152.730	--
Inshore	Total	47	362.855	--
	Main effects			
	Bays	3	11.128	6.07**
	Cruise	11	331.562	49.33**
	Residual	33	20.165	--
Offshore	Total	15	84.243	--
	Main effects			
	Subarea	3	0.742	1.00
	Cruise	3	81.276	109.59**
	Residual	9	2.225	--

** denotes significance at = .01

SECTION IV

DISCUSSION AND SUMMARY SECTION

This report describes results from the Kodiak Island region OCSEAP plankton surveys which were not previously available and statistically examines trends suggested by earlier analyses in Kendall et al. (1980). The OCSEAP plankton surveys were meant to increase our understanding of three general aspects of the distribution and abundance of decapod larvae: 1) the areas within the survey region where larvae of a given species are most abundant; 2) the depths within the water column they are found; and 3) the time of year they are present. An understanding of these parameters is necessary for a realistic assessment of the potential effects oil and gas related development would have upon the larval population.

Spatial Abundance

Distribution and abundance trends were suggested in the earlier report by Kendall et al. (1980), and an analysis of specific data sets was performed to substantiate or refute suggested trends. In most cases, statistical tests failed to identify significant abundance differences between subareas or between the regions. Significant regional abundance differences could only be determined for two taxa, Hippolytid shrimps and Anomuran crabs. For both, abundance in the inshore region (i.e. bays and along the coast of Kodiak and Afognak Islands) was significantly greater than offshore.

Statistical tests failed to identify several other regional differences in larval abundance as significant, however, supplemental information about adults indicates the inshore region to be more important than areas offshore for at least three additional taxa: *P. goniurus*, *P. camtschatica* and *C. magister*.

For example, adult *P. goniurus* are found only in shallow water areas such as nearshore along the coasts of the Kodiak Island Archipelago or in shallow portions of bays within the study area. Consequently, mating and larval release should occur in these shallow, nearshore areas with resulting larvae likewise in this region. Lack of a net offshore directed current in the study area should then retain *P. goniurus* larvae in the inshore region. Data from the surveys suggest this inshore distribution as no *goniurus* larvae were found anywhere offshore. Unfortunately, small sample sizes and low densities of larvae obscured this obvious regional abundance difference. This taxon was the least abundant decapod studied. The few larvae found in samples from the bays and numerous "no catch" samples (stations) resulted in a relatively high variability for the inshore region. As a result, the inshore presence of *P. goniurus* larvae could not be determined significantly different from that in the offshore region.

A similar situation of low overall abundance masking significant regional differences was evident for the larvae of *P. camtschatica*. Adults of this commercially important crab species migrate inshore during late winter - early spring for larval release, molting, and mating. This shoreward movement sometimes extends into intertidal areas. Again, extremely low abundance or patchiness of catches precluded the determination that nearshore or inshore concentrations of *P. camtschatica* larvae were significantly higher than amounts found offshore on the outer continental shelf.

A similar conclusion should be reached for *C. magister* larvae, but again, only very low concentrations of these zoeae were encountered.

While our statistical tests could not establish significant differences in regional abundance for most of the groups studied, summary averages for all 10 taxa (Table IV-1 and IV-2) indicated decapod larvae were roughly 3 times more prevalent inshore than offshore.

Table IV-1. Summary of average biomass (ln(numbers per 10 m^2 + 1)) for the taxa in the inshore bays and their averages over all taxa and all bays.

	Izhut Bay	Chiniak Bay	Kiliuda Bay	Kaiugnak Bay	Taxa averages
Hippolytidae	5.27	4.87	4.94	3.58	4.67
Crangonidae	2.25	0.97	2.77	1.17	1.79
P. borealis	1.29	1.55	0.34	1.09	1.07
P. goniurus	0.60	1.57	1.15	0.15	0.87
Anomura	4.93	4.32	4.98	3.76	4.50
P. camtschatica	0.31	0.83	0.79	0.29	0.55
C. magister	0.58	0.33	2.30	1.24	1.11
Cancer sp.	2.84	2.22	2.29	2.77	2.53
C. bairdi	0.67	1.92	0.79	1.02	1.10
Pinnotheridae	3.11	2.93	4.15	3.12	3.33
Bay Averages	2.19	2.15	2.45	1.82	2.15

Table IV-2. Summary of average biomass (ln(numbers per 10 m^2 + 1)) for the taxa in the offshore subareas and their averages over all taxa and all subareas.

	Portlock Subarea	Marmot Subarea	Albatross Subarea	Sitkinak Subarea	Taxa Averages
Hippolytidae	2.76	2.26	1.76	2.47	2.31
Crangonidae	1.35	1.30	0.00	0.87	0.88
P. borealis	0.75	0.30	0.47	0.00	0.38
P. goniurus	0.00	0.00	0.00	0.00	0.00
Anomura	2.62	1.85	2.75	2.60	2.45
P. camtschatica	0.12	0.00	0.00	0.15	0.07
C. magister	0.00	0.65	0.00	0.97	0.41
Cancer sp.	2.35	1.60	1.35	1.70	1.75
C. bairdi	0.97	1.17	0.67	1.10	0.98
Pinnotheridae	1.67	1.12	1.22	1.17	1.29
Subarea Averages	1.26	1.03	0.82	1.10	1.05

Vertical Distribution

The data used for study of vertical distribution and diel behavior of decapod larvae were only from the inshore surveys because sampling in the bays was more frequent and consistent than offshore. Limits imposed by subsample sizes (see Appendix A) caused diel observations from the twelve inshore cruises to be pooled. The resulting data set was not statistically analyzed. While a moderate degree of variability was noted between bays, we feel the averages presented reflect general depth preferences and day-night movements of the taxa studied.

The inclusion of neuston information into the data base studied by Kendall et al. (1980) noticeably altered vertical distribution trends suggested in their report. In their analysis many taxa, especially crabs, seemed positively phototaxic. Larvae appeared concentrated in shallow strata during the day and shifted downward into deeper water at night. Unfortunately, not knowing anything about larval presence in the near-surface regime complicated that interpretation. Our subsequent inclusion of neuston information indicates that although many taxa were present in upper portions of the water column during the day, their centers of abundance did not necessarily shift downward at night. Substantial amounts of larvae occurred during the night at the sea surface; up to 90% of the combined total from all samples for some taxa. Those larvae that were found extensively in the night neuston samples include: Hippolytidae, Crangonidae, Anomuran crabs, *P. camtschatica*, *C. magister*, *Cancer* sp. and *C. bairdi*. It should be mentioned that night-time concentrations at the surface are not wholly indicative of a negative phototaxis as considerable proportions of some taxa (e.g. Crangonidae, *C. magister*, Anomura and *P. camtschatica*) were still present in deeper strata at night.

The following is a revised general pattern of day-night vertical distribution for many taxa of decapod larvae studied in this report. During the day larvae appear concentrated at mid-depths (i.e. 10-50 m) and at night, these concentrations seem to shift both to the surface and to near the bottom. We do not know why this pattern occurs. It tends to lessen the apparent significance of light levels on diel movement and suggests other factors are involved. Unfortunately, we could not identify a correlation between larval vertical distribution and such factors as water temperature or salinity.

A possible reason for the above mentioned trend may be different depth or food preferences at various stages of larval development. An extensive resort of Kiliuda Bay vertical distribution samples resulted in enough larvae for several species (P. borealis, P. goniurus, P. camtschatica, and C. bairdi) to look at vertical distribution by stage on a combined day-night basis. For each species there was an observed shift in distribution from at or near surface downward into mid or bottom strata with progressive stages of development. An example is seen in Figure III-10 on page 41 depicting vertical distribution by larval stage of P. borealis. The early stages (I, II, III) were found primarily in the surface and 10 m strata; mid-stages (IV, V) had their largest numbers divided into near surface and near bottom modes; and later larval stages (VI, VII) were encountered almost entirely in the deepest depths sampled. The surface/near bottom pattern seen for stages IV and V is the same trend exhibited by a number of the other taxa at night. From the standpoint of a developing P. borealis larvae, stages IV and V might be considered transitional when they switch from feeding on one "type" of food to another (for example, phytoplankton to copepods). The food "types" might have different depth distributions which correspond to those chosen by the different stages of larvae.

Temporal Abundance

The bi-weekly cruises conducted in the inshore region during the spring and summer provided the best indication of changes in larval abundance with time. This sampling intensity, unfortunately, was not continued throughout the remainder of the year inshore, or at all offshore. Consequently, in the region and season analyses, all (4) offshore cruises and the latter two inshore (XI and XII) had to be considered representative of entire seasons. This is a very questionable assumption which must be considered when seasonal presence or absence of larvae is discussed.

A majority of the taxa tested showed significant differences in abundance by season. It is commonly accepted that decapod larvae are more abundant during certain gross times of the year (i.e. spring and summer); however, many of the cruise and seasonal effects were highly significant and further multiple comparison tests determined more precisely the times of the year that were most important. For instance, multiple comparison tests of a significant inshore cruise effect on P. borealis larvae identified Cruises II through IV (i.e. mid-April to late May) as having distinctly higher abundances of this taxon than during any other cruises. This period of peak abundance is similar to that determined by Haynes and Wing (1977) during their 1972 study of pandalid larvae in Kachemak Bay on the south central coast of Alaska. When no significant seasonal effect was identified it was most likely the result of low overall abundance (i.e. P. goniurus).

Temporal analysis of P. camtschatica was hampered by small numbers of this taxon in the samples and also by the timing of the cruises. Stage IV zoeae were present in the inshore Cruise I samples, indicating that in 1978, larval release had commenced previous to the first cruise. Furthermore, Cruise XII, which was the final inshore cruise of the 1978-79 study took place in very late winter and its samples contained Stage I P. camtschatica zoeae (see Figure III-19). This implies that Cruise XII actually represented initial observations for progeny of the following year (1979-80).

Study Limitations and Recommendations for Future Work

There were a number of points we considered in qualifying our data and results. These are: the atypical environmental conditions encountered during the surveys; insufficient subsample size; differences in the timing and amounts of sampling performed between the inshore and offshore regions; and the multispecies nature of some of the taxonomic groups analysed. A detailed analysis of some of these factors can be found in Appendix A, however, a discussion of the major conclusions as well as recommendations for future work are taken up here.

Environmental conditions during the time period of the study differed noticeably from a long term average. How changes in these environmental parameters (especially water temperature) effect hatching times and abundance of larval decapods is not adequately understood. Substantially more than one season would be necessary to evaluate the effect these parameters have on larval distribution and abundance. Given these limitations, we can only assume that conclusions derived from this study reflect aspects of larval decapod distribution and abundance during "warm weather" time periods.

Decapod larvae were not the only group targeted in the OCSEAP zooplankton surveys. Consequently, sort rules were not designed with the diversity and low relative abundance of this group in mind. The overall conclusion from the subsampling tests was that the 500-organism aliquots used as the standard subsample for the study were too small to provide detailed descriptions of larval abundance by time, area, and depth for the individual stages of zoeal development. The aliquots were sufficient, however, to describe vertical distributions or abundance with time in pooled data terms (i.e., all larval stages combined) for each species of decapod larvae tested. Future research directed at decapod larvae of commercially important species should have a subsampling intensity at least an order of magnitude larger (i.e., subsample aliquots averaging 40% of the bulk sample and not 4%) than that averaged in this study.

Sampling schemes for the two surveys differed substantially and restricted the comparisons which could be made between the inshore and offshore regions. Cruise intervals varied from 2 weeks to 3 months for inshore and offshore surveys, respectively. An average time in stage for some of the larval decapods encountered is 10 to 20 days. Scheduling of future cruises should take this into account if abundance by stage data is desired. Depending on the species of interest, sampling should be initiated earlier in the year. Cruise I of the inshore survey (29 March - 8 April) found stage II larvae of a majority of the species and Stage I-IV larvae of P. camtschatica which suggests that the onset of hatching is significantly earlier in the year.

The level of sampling attained during the surveys was also too limited to achieve the sample size necessary for testing relatively low larval concentrations. In many cases, statistical tests failed to identify significant abundance differences both within and between the inshore and offshore regions. However, failure to identify significant differences in inshore - offshore larval abundance should not imply uniform or random distribution.

One more limiting aspect of the study which would benefit from further work was the multispecies nature of some (of our) taxonomic groups. Of the ten taxa considered in our analysis, only five were individual species. The remaining (i.e., Hippolytidae, Crangonidae, Anomura, Cancer sp. and Pinnotheridae) were primarily comprised of a number of species. We were unable to differentiate species within these taxa because of the lack of descriptive literature regarding their larval morphology. Since individual species within these groups occupy different habitats and possess different "reproductive strategies", our gross taxonomic combinations masked species specific information in our samples. This was a probable reason for the region-season interactions observed in our ANOVA for Hippolytid shrimp and Anomuran crabs. A hypothetical example for this interaction would be one abundant inshore species spawning in spring and an abundant offshore species spawning during the summer.

Despite these limitations, it is our opinion that the OCSEAP-funded surveys still provided information which allows considerable insight into decapod larvae populations in the Kodiak Island region.

Oil Effects

The impact of toxic levels of oil on decapod larvae would be greatest from late winter through summer. The following list summarizes this study's findings on times of peak abundance for larvae of the five commercially important species:

Pandalus borealis	early April - early July
Pandalus goniurus	mid-April - early July
Paralithodes camtschatica	early March - early June
Cancer magister	late April - late July
Chionoecetes bairdi	late April - early July

A number of researchers have explored and documented the sensitivity of larval forms of various decapods to oil and its water soluble fraction (WSF). Caldwell et al. (1977) reported toxic effects to *Cancer magister* larvae to WSF (Cook Inlet crude) as low as .22 mg/l. Stage I larvae of *Pandalus hypsinotus* and *Paralithodes camtschatica* had 96 hr LC50's of 7.94 and 2.00 ppm (WCF Cook Inlet Crude), respectively (Mecklenburg et al., 1977). Besides being more succeptable to the toxic effects of oil than are juveniles and adults (Wells and Sprague, 1976), larval forms are also significantly more sensitive to exposure during the molting period (Mecklenburg et al., 1977). While the duration and number of larval stages vary between species, 5 molts over the course of 2 months might be considered an average for decapod larvae. This molting frequency and concurrent sensitivity makes the larval life stage particularly vulnerable.

Another factor which increases the succeptability of decapod larvae to the effects of water soluble fractions of surface borne oil is their proximity to the surface. The extent to which hydrocarbons dissolve into the water column is significantly effected by mixing (Gordon et al., 1973). Studies as well as measurements from actual spills (Boehm and Fiest, 1980) show that such wave related mixing can occur at toxic concentrations to a depth of 20-30 m in summer and 75-100 m in winter. The vertical distribution and diel movement portion of this study found that, day or night, substantial numbers of all the taxa studied were well within depths which would be mixed during spring.

While extent varied from group to group, all taxa exhibited some form of diel migration. Bigford (1977) showed that both geotactic and phototactic behavior for Cancer irroratus was significantly effected by exposure to WSF of fuel oil. It follows that exposure to either castastrophic or chronic levels of dissolved hydrocarbons would have a disabling effect on a decapod larva's ability for diel migration. Most likely, daily vertical migration is an important part of a larva's feeding behavior and disruption of it would further diminish an animal's survivability under adverse conditions. These same adverse conditions also affect the phytoplankton, copepods, etc., upon which decapod larvae most likely feed.

In summary, this study suggests that decapod larvae would suffer significant direct and indirect mortality from relatively low (WSF) oil concentrations, especially in areas and at times of peak abundance. Combining this study's information with our knowledge of life histories of commercially important decapods will provide an indication of the impact of oil development and/or accidents upon a year class and the subsequent potential reduction of recruitment to a fishery.

Appendix A

Appendix A

QUALIFICATION AND DATA LIMITATIONS

Three main questions must be considered regarding the analysis presented in this report. Were environmental conditions encountered during 1978 representative of normal or unusual occurrences? Was subsampling of the study's bulk plankton samples sufficient to accurately describe the number and types of organisms present? Was the level of sampling effort sufficient to accurately portray resource distribution and abundance?

Evaluation of environmental conditions

Seasonal weather information and water temperature data from the northeast coast of Kodiak Island were selected to show the study area's environment. Long term measurements of these parameters (c.f. pg. 4-6, Figure I-2) were compared with observations obtained during the study period to evaluate how conditions during 1978 related to an average.

Observations of temperature and wind (EDIS) during 1978 suggest that weather and environmental conditions during the study period differed from long term patterns. Surface winds were noticeably more frequent out of the east northeast to east southeast and the strongest average winds were associated with the northeast quadrant (Figure A-1). Sea and air temperatures suggested warmer than usual conditions, especially during winter-early spring (Figures A-2 and A-3). The most substantial of these temperature differences was observed for bottom water. February-April measurements at bottom were more than twice the levels averaged during several recent years (1971-1975).

Since this study focused on only one cycle of seasons, it is impossible to determine how apparent anomalous environmental conditions may have affected larval decapod populations. Also, a lack of other data sets for the study area

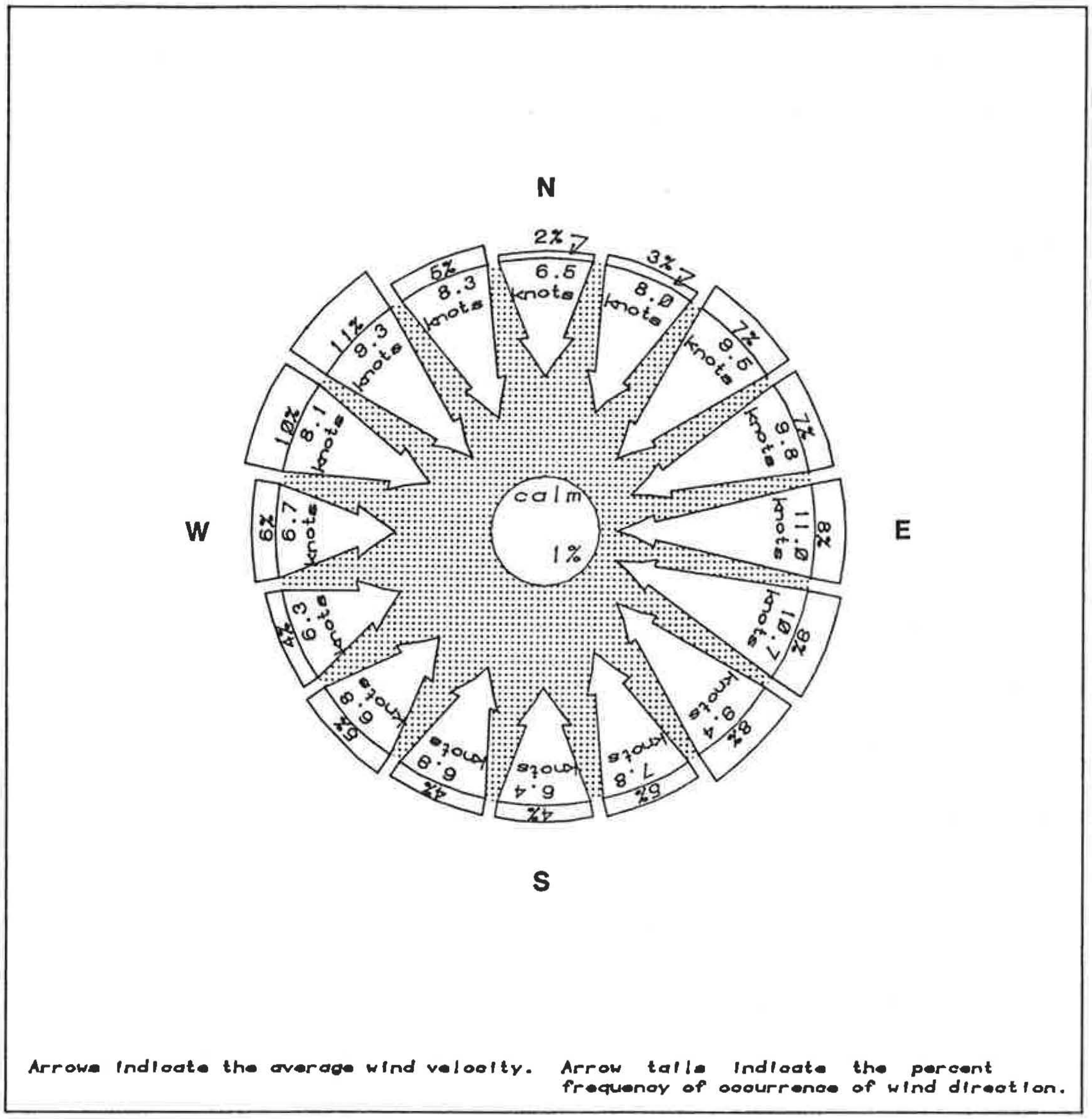

Figure A-1.--Average wind velocity and percent frequency of occurrence of wind direction during 1978 in the Kodiak Island study area (data from EDIS).

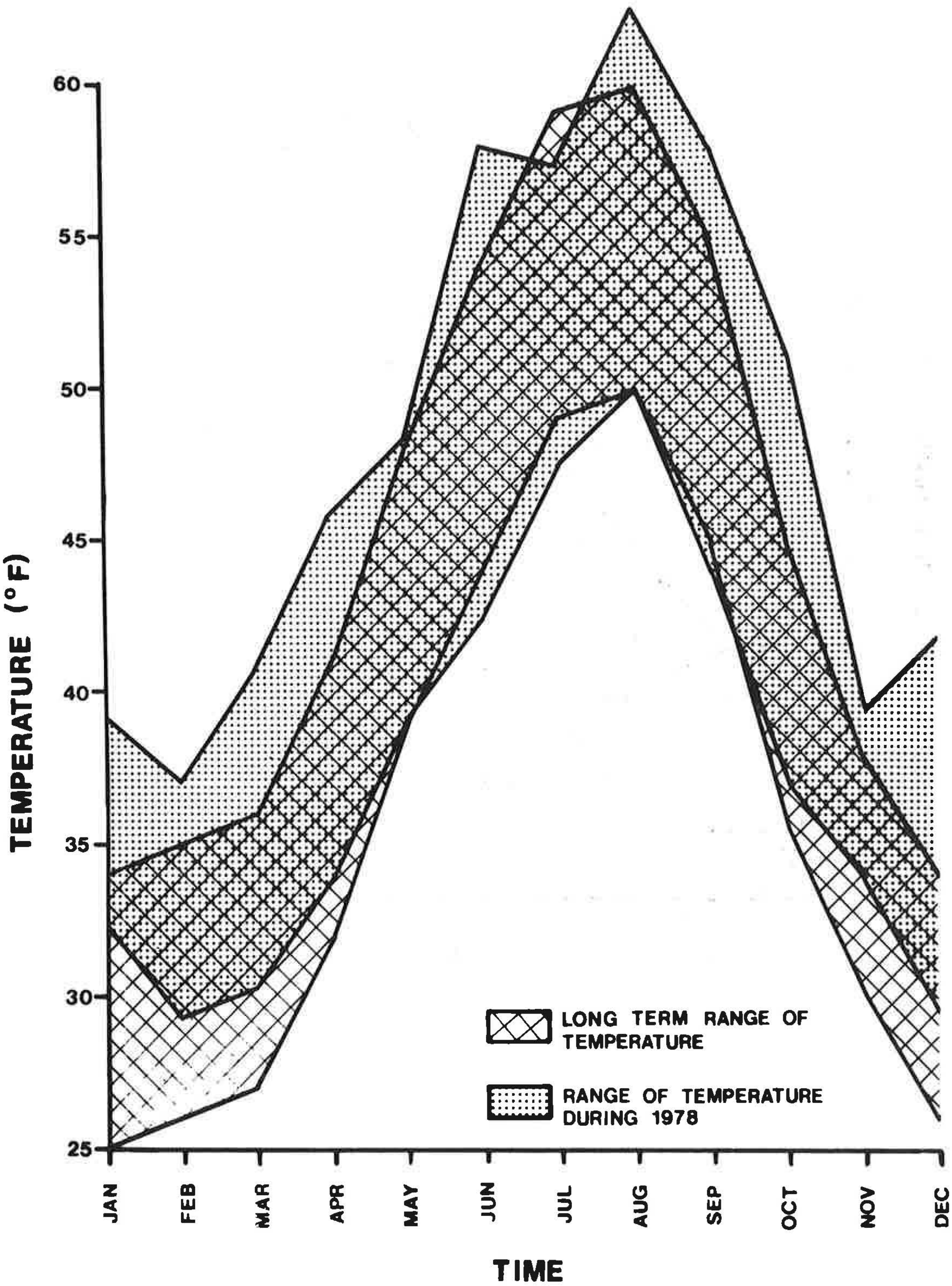

Figure A-2. -- Average long term minimum and maximum air temperatures by month for the Kodiak Island region and monthly temperature ranges for 1978 (Buck et al, 1975).

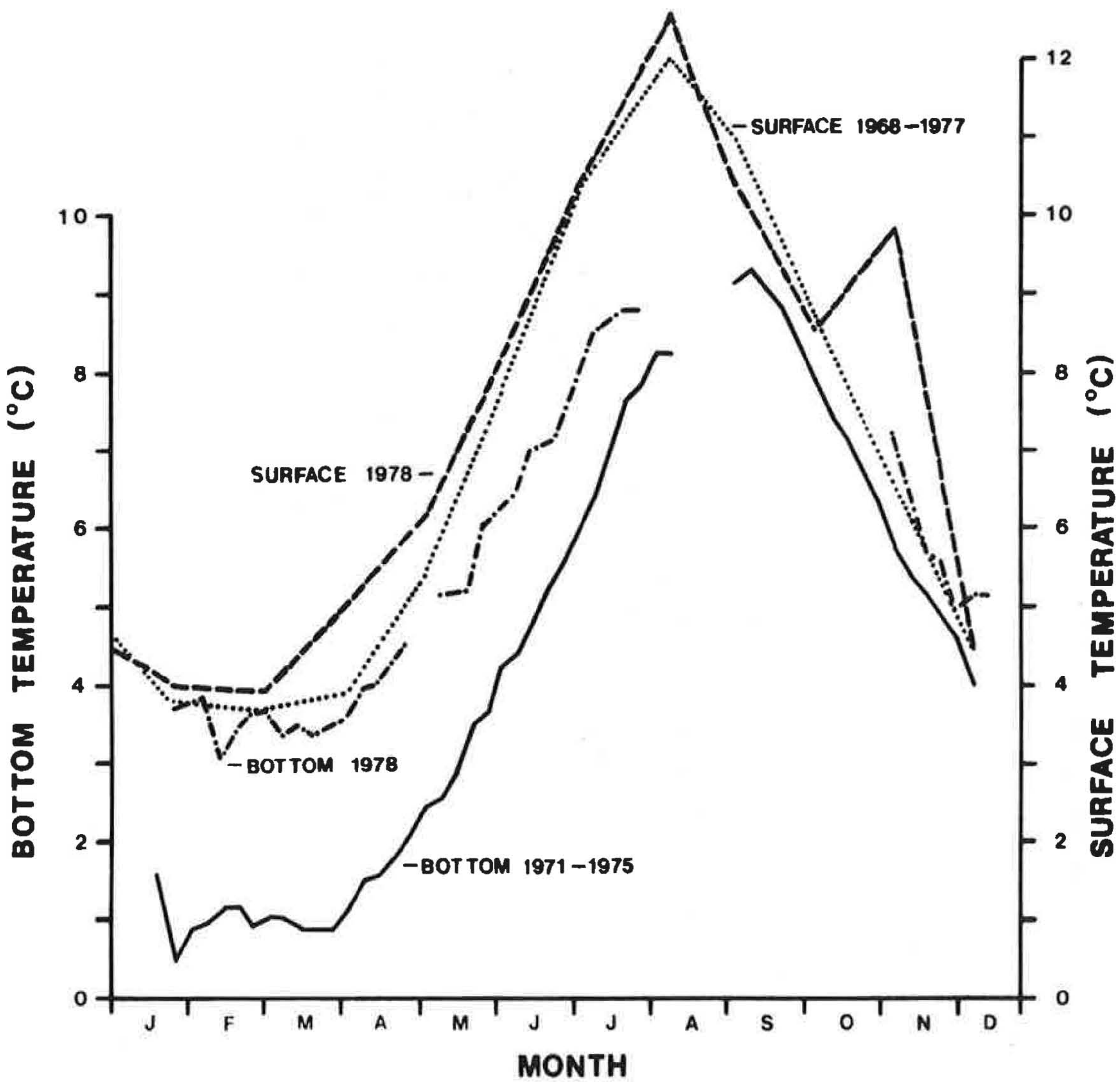

Figure A-3 -- Surface and bottom water temperature in the vicinity of Kodiak, long term averages and measurements for 1978.

inhibits interpretation of observations during the period studied. Given these limitations, we can only assume that conclusions derived from this study reflect aspects of larval decapod distribution and abundance which occur in the Kodiak Island region during "warm weather" time periods.

Evaluation of subsampling adequacy

This report's larval abundance data was derived primarily from analysis of 500-organism aliquots provided through the sorting contract with Texas Instruments Inc. These subsamples were assumed adequate for indicating numbers of shrimp and crab larvae present in the bulk samples; however, this was a substantial assumption. The 500-organism subsamples often represented less than 1% and averaged only 4% of organisms present in a bulk sample.

The adequacy of the study subsamples was examined through a series of nonparametric Spearman rank correlation tests (Seigel, 1956) on sets of inshore region bongo net and Tucker trawl information. Larval concentrations obtained from the aliquots of a selected set or series of bulk samples were ranked relative to each other and this ranking was compared to the ranks derived from extensive resampling of the same bulk samples. Calculations for each test are presented at the end of this appendix.

Data for four economically important decapod species were examined. These species were: pink shrimp (*Pandalus borealis*), humpy shrimp (*P. goniurus*), red king crab (*Paralithodes camtschatica*), and tanner crab (*Chionoecetes bairdi*).

Analysis of the bongo net samples for individual stages of *P. borealis* indicated that the original aliquots showed close association with the extensive subsamples for some zoeal stages but there was not a close correlation for every stage (Table A-1). When data for all larval stages were combined (by cruise for all stations in a bay) the test again indicated a high probability (P = .975) that the number of *P. borealis* zoeae derived from the original aliquot was closely correlated with the number present in the associated bulk sample. Similar results were obtained for all other species, except C. bairdi; however, a graph comparing data for this species from the different subsamples (Figure A-4d) showed notable similarity in depicting abundance with time. Our conclusion followed that the standard subsampling used for the study was sufficient to accurately describe over-all abundance of a species by time (i.e., all stages combined for all stations in a bay) but determining abundance by larval stage was not possible.

Spearman rank correlation tests on the vertical distribution information produced varying results. In general, there was a higher association between subsamples for larvae of crab species than shrimp. Aliquot data on C. bairdi zoeae was correlated closely with data produced from the extensive subsamples for nearly every cruise (Table A-2), but association between subsamples for P. camtschatica was not as extensive (Table A-3). For either species, however, there was a significant correlation between subsamples when data were combined for all cruises encountering larvae. High correlation coefficients (r_s = 0.98) for the pooled data suggests that the 500-organism aliquot of Tucker trawl catches was adequate to describe the vertical distribution of crab larvae (all stages combined) over the entire study period but not for specific time (cruise) intervals.

Subsamples for shrimp zoeae appeared less correlated. Comparisons by cruise and with cruises combined infrequently identified an association between numbers of shrimp larvae from the two types of subsamples (Tables A-4 and 5). Despite a lack of significant correlation, data from both subsamples displayed similar trends in describing general vertical distribution (Figures A-5a and b). Most P. borealis larvae in both data sets were found in samples from the upper 30 m of the water column, whereas the greatest proportion of P. goniurus larvae were observed for both subsample types in catches from near the surface.

Species	Larval Stage	Number of cruises encountering larvae	Number found in 500-organism aliquot	Number found in "extensive resort" subsamples	Spearman rank correlation data: Σd_i^2 1/	r_s 2/	correlation or association between subsamples at a=0.25
Pandalus borealis	1	12 3/	10	443	74.00	0.67	Yes
	2	4(1-4)	2	240	1.00	0.90	No
	3	6(1-6)	0	98	16.50	0.00	No
	4	6(1-6)	0	43	15.50	0.00	No
	5	7(1-7)	0	40	23.00	0.00	No
	6	7(1-7)	1	3	0.00	1.00	Yes
	7	7(1-7)	0	1	0.00	0.00	No
	All stages combined	12	13	868	99.00	0.60	Yes
P. goniurus	All stages combined	8(1-8)	8	186	40.00	0.92	Yes
Chionoecetes bairdi	All stages combined	10(1-10)	2	41	57.50	0.53	No
Paralithodes camtschatica	All stages combined	5(1-5)	13	179	2.00	0.90	Yes

1/ Sum of squares of the differences between rankings within subsample sets

2/ Spearman rank correlation co-efficient

3/ Number in parentheses indicates cruises included in testing.

Table A-1.--Summary of information on numbers of larvae removed from two different subsamples of bongo net catches obtained during larval distribution and abundance studies in the Chiniak Bay area of Kodiak Island, March - November, 1978 and February, 1979 (data for Stations 1-3 combined).

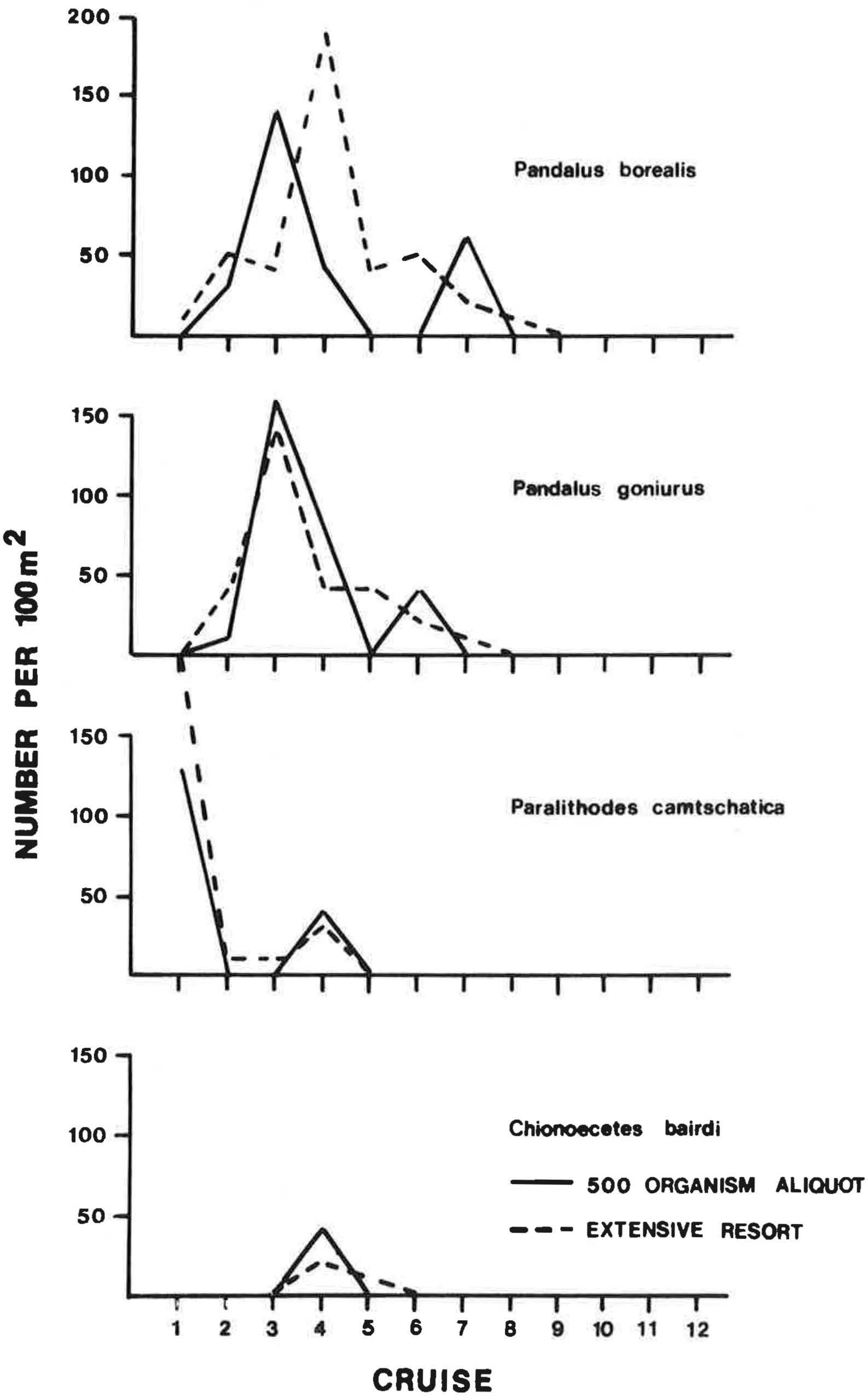

Figure A-4. Comparison of accuracy of sample sorting by number per 100 m² and cruise from the inshore region of the Kodiak Island study area. Bongo net data.

Table A-2.--Summary of information on estimated densities of bairdi Tanner crab larvae from two different subsamples of tucker trawl catches obtained during decapod larvae vertical distribution studies in the Kiliuda Bay area of Kodiak Island, March-November, 1978 and February, 1979.

Cruises	Average number of larvae per 1000 m^3 estimated present in Kiliuda Bay from original "500 organism" aliquot (all depths combined)	Average number of larvae per 1000 m^3 estimated present in Kiliuda Bay from the "estensive resort" subsamples (all depth combined)	Spearman Rank Correlation Information		
			d_i^2	r_s	Correlation of association between subsamples at = .025
1	0	0	0	1.00	yes
2	48	51	6.00	0.70	no
3	0	180	10.00	0.50	no
4	738	1,297	0.50	0.98	yes
5	38	363	2.00	0.90	yes
6-12	0	0	0	1.00	yes
2-5 combined	206	473	0.50	0.98	yes

Table A-3.--Summary of information on estimated densities of red king crab larvae from two different subsamples of tucker trawl catches obtained during decapod larvae vertical distribution studies in the Kiliuda Bay area of Kodiak Island, March-November, 1978 and February, 1979.

Cruises	Average number of larvae per 1000 m^3 estimated present in Kiliuda Bay from original "500 organism" aliquot (all depths combined)	Average number of larvae per 1000 m^3 estimated present in Kiliuda Bay from the "estensive resort" subsamples (all depth combined)	Spearman Rank Correlation Information		
			d_i^2	r_s	Correlation of association between subsamples at = .025
1	0	65	5.00	0.91	yes
2	76	41	2.00	0.90	yes
3	0	44	10.00	0.50	no
4	6	27	3.50	0.83	no
5	767	3,482	2.75	0.86	no
6-12	0	0	0	1.00	yes
1-5 combined	170	732	0.50	0.98	yes

Table A-4.--Summary of information on estimated densities of pink shrimp larvae from two different subsamples of tucker trawl catches obtained during decapod larvae vertical distribution studies in the Kiliuda Bay area of Kodiak Island, March-November, 1978 and February, 1979.

Cruises	Average number of larvae per 1000 m^3 estimated present in Kiliuda Bay from original "500 organism" aliquot (all depths combined)	Average number of larvae per 1000 m^3 estimated present in Kiliuda Bay from the "extensive resort" subsamples (all depth combined)	Spearman Rank Correlation Information d_i^2	r_s	Correlation of association between subsamples at = .025
1	521	83	14.00	0.30	no
2	0	337	10.00	0.50	no
3	1,481	164	2.00	0.90	yes
4	33	391	5.00	0.75	no
5	0	168	8.00	0.97	yes
6	0	20	13.50	0.71	no
7	0	9	10.00	0.92	yes
8	0	5	9.50	----	no
9	0	1	5.00	0.91	yes
10-12	0	0	0	1.00	yes
1-9 combined	226	131	20.00	0.00	no

Table A-5.--Summary of information on estimated densities of humpy shrimp larvae from two different subsamples of tucker trawl catches obtained during decapod larvae vertical distribution studies in the Kiliuda Bay area of Kodiak Island, March-November, 1978 and February, 1979.

Cruises	Average number of larvae per 1000 m^3 estimated present in Kiliuda Bay from original "500 organism" aliquot (all depths combined)	Average number of larvae per 1000 m^3 estimated present in Kiliuda Bay from the "estensive resort" subsamples (all depth combined)	Spearman Rank Correlation Information d_i^2	r_s	Correlation of association between subsamples at = .025
1	29	32	12.50	0.48	no
2	0	3	5.00	0.92	yes
3	0	5	8.00	0.97	yes
4	211	95	20.00	0.00	no
5	9	32	15.00	0.25	no
6	119	8	27.25	0.36	no
7-12	0	0	0	1.00	yes
1-6 combined	61	29	9.00	0.55	no

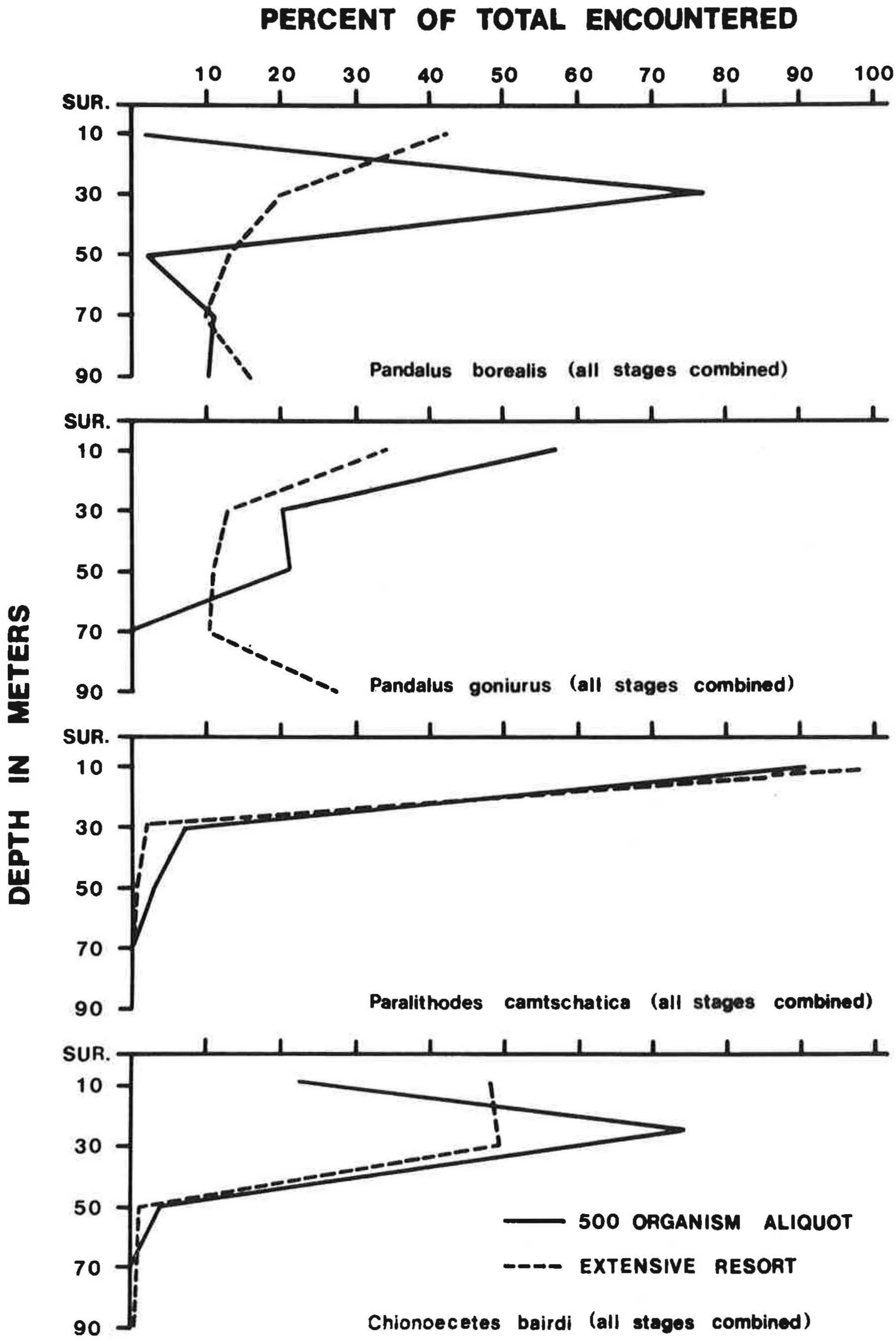

Figure A-5. Comparison of accuracy of sample sorting by percent of total organisms encountered and depth interval from the inshore region of the Kodiak Island study area. Neuston sampler and Tucker trawl data.

The overall conclusion from the subsampling tests was that the 500-organism aliquots used as the standard subsample for the study were too small to provide detailed descriptions of larval abundance by time, area, and depth for individual stages of zoeal development. The aliquots were sufficient, however, to describe vertical distributions or abundance with time in pooled-data terms (i.e., all larval stages combined) for each species of decapod larvae tested.

Evaluation of Sampling Adequacy

Detailed analysis of the adequacy of the study's sampling intensity by area or time was not attempted. There is no other data base for comparison. However, some comparisons were made between portions of the study's efforts. Larval populations in the offshore region were sampled once per season and station density never exceeded one station per 700 km^2. This coverage was limited in comparison to sampling of the inshore region. Inshore sampling density was as high as 5 cruises per season with station densities approaching one per 50 km^2. These regional sampling differences precluded integration of data from adjacent geographic areas and substantially complicated the analyses.

Summary of Report Limitations

This report presents a summary of data that was: 1) obtained during a year marked by weather conditions different from long term averages; 2) derived from subsamples adequate only to describe relatively general distribution and abundance; and, 3) gathered during two somewhat dissimilar sets of surveys.

It is most difficult to substantiate periods of larval occurrence or to assess the relative magnitude of larval resources from the study's approximately one year of information. Further, it is impossible to identify how timing of larval occurrence during a year of apparently anomolous climate conditions relates to other years. Despite these limitations, this report represents the most comprehensive analysis available for shrimp and crab larvae in the study area. Information presented in the report provides a general description of the seasonal abundance and distribution of decapod larvae in inshore and offshore regions of the Kodiak Island shelf.

Spearman Rank Non-parametric Correlation Tests

Bongo Sampling

Table A-6	*Pandalus borealis*	Stage I
Table A-7	" "	Stage II
Table A-8	" '	Stage III
Table A-9	" "	Stage IV
Table A-10	" "	Stage V
Table A-11	" "	Stage VI
Table A-12	" "	Stage VII
Table A-13	*Pandalus borealis*	all stages combined
Table A-14	*P. goniurus*	all stages combined
Table A-15	*Paralithodes camtschatica*	all stages combined
Table A-16	*Chionoecetes bairdi*	all stages combined

Vertical Distribution Sampling

Table A-17	*Pandalus borealis*	Cruise I
Table A-18	" "	Cruise II
Table A-19	" "	Cruise III
Table A-20	" "	Cruise IV
Table A-21	" "	Cruise V
Table A-22	" "	Cruise VI
Table A-23	" "	Cruise VII
Table A-24	" "	Cruise VIII
Table A-25	" "	Cruise IX
Table A-26	*Pandalus borealis*	Cruises I thru IX combined
Table A-27	*P. goniurus*	Cruise I
Table A-28	" "	Cruise II
Table A-29	" "	Cruise III
Table A-30	" "	Cruise IV
Table A-31	" "	Cruise V
Table A-32	" "	Cruise VI
Table A-33	*P. goniurus*	Cruises I thru VI combined
Table A-34	*Paralithodes camtschatica*	Cruise I
Table A-35	" "	Cruise II
Table A-36	" "	Cruise III
Table A-37	" "	Cruise IV
Table A-38	" "	Cruise V
Table A-39	*Paralithodes camtschatica*	Cruises I through V combined
Table A-40	*Chionoecetes bairdi*	Cruise II
Table A-41	" "	Cruise III
Table A-42	" "	Cruise IV
Table A-43	" "	Cruise V
Table A-44	" "	Cruises II through V combined
Table A-45	" "	Cruises VI through XII combined

Table A-6.--Spearman Rank Non-parametric Correlation Tests on bongo net information for pink shrimp larvae in the Chiniak Bay area of Kodiak Island, 1978 - 1979 (Stations C1, C2, and C3 combined).

Stage 1

Cruise	Number found in original "500-organism" aliquots (x_i)	Rank of x_i	Number found in "extensive resort" subsamples (y_i)	Rank of y_i	Difference in ranks (d_i)	Squares of differences (d_i^2)
1	0	5.5	17	10	4.5	20.25
2	2	11.0	226	12	1	1
3	8	12.0	179	11	1	1
4	0	5.5	12	9	3.5	12.25
5	0	5.5	1	6.5	1	1
6	0	5.5	0	3	2.5	6.25
7	0	5.5	0	3	2.5	6.25
8	0	5.5	7	8	2.5	6.25
9	0	5.5	0	3	2.5	6.25
10	0	5.5	0	3	2.5	6.25
11	0	5.5	0	3	2.5	6.25
12	0	5.5	1	6.5	1	1
						$\Sigma d_i^2 = 74$

Test: H_0: x and y are independent, i.e., there is no correlation between subsamples.
H_a: x and y are dependent, i.e., there is correlation or association.

Test Statistic: $t = r_s\sqrt{\frac{N-2}{1-(r_s)^2}}$ ~ student's "t" with N-2 degrees of freedom

Rejection Rule: Reject H_0 if $t > t_{N-2}^{.975}$; $t_{10}^{.975} = 2.228$

Calculations:

Correction for ties: $x = \frac{\Sigma T_x^3 - T_x}{12} = \frac{10^3-10}{12} = \frac{1000-10}{12} = 82.5$; $\Sigma x^2 = \frac{N^3-N}{12} - T_x = \frac{12^3-12}{12} - 82.5 = 60.5$

$y = \frac{\Sigma T_y^2 - T_y}{12} = \frac{5^3-5}{12} + \frac{2^3-2}{12} = 10.5$; $\Sigma y^2 = \frac{N^3-N}{12} - T_y = \frac{12^3-12}{12} - 10.5 = 132.5$

$$r_s = \frac{\Sigma x^2 + \Sigma y^2 - \Sigma d_i^2}{2\sqrt{\Sigma x^2 \cdot \Sigma y^2}} = \frac{60.5+132.5-74.0}{2\sqrt{60.5 \cdot 132.5}} = \frac{119.00}{179.07} = 0.665$$

$$t = r_s\sqrt{\frac{N-2}{1-r_s^2}} = 0.655\sqrt{\frac{12-2}{1-.665^2}} = 0.665\sqrt{\frac{10}{.558}} = 2.816 > 2.228$$

Conclusion: Reject H_0. The subsamples are correlated with respect to the numbers of stage I larvae present.

Table A-7.--Spearman Rank Non-parametric Correlation Tests on bongo net information for pink shrimp larvae in the Chiniak Bay area of Kodiak Island, 1978 (Stations C1, C2, and C3 combined).

Stage 2

Cruise 1/	Numbers found in original "500-organism aliquot (x_i)	Rank of x_i	Numbers found in "extensive resort" subsample (y_i)	Rank of y_i	Difference in ranks (d_i)	Squares of differences (d_i^2)
1	0	1.5	2	1	0.5	0.25
2	0	1.5	5	2	0.5	0.25
3	1	3.5	90	3	0.5	0.25
4	1	3.5	143	4	0.5	0.25
						$\Sigma d_i^2 = 1.00$

Test: H_0: x and y are independent, i.e., there is no correlation between subsamples.
H_a: x and y are dependent, i.e., there is correlation or association.

Test Statistic: $t = r_s\sqrt{\frac{N-2}{1-(r_s)^2}}$ ~ student's "t" with N-2 degrees of freedom

Rejection Rule: Reject H_0 if $t > t_{N-2}^{.975}$; $t_2^{.975} = 4.303$

Calculations:

$$r_s = 1 - \frac{6\Sigma d_i^2}{N^3-N} = 1 - \frac{6(1)}{64-4} = 0.900$$

$$t = r_s\sqrt{\frac{N-2}{1-r_s^2}} = 0.900\sqrt{\frac{2}{1-0.81}} = 2.920 \not> 4.303$$

Conclusion: Fail to reject H_0. The subsamples are not correlated.

1/ Cruises with zero catches in both subsamples (after occurrences) are omitted.

Table A-8.--Spearman Rank Non-parametric Correlation Tests on bongo net information for pink shrimp larvae in the Chiniak Bay area of Kodiak Island, 1978 (Stations C1, C2, and C3 combined).

Stage 3

Cruise 1/	Numbers found in original "500-organism aliquot (x_i)	Rank of x_i	Numbers found in "extensive resort" subsample (y_i)	Rank of y_i	Difference in ranks (d_i)	Squares of differences (d_i^2)
1	0	3.5	0	1.5	2	4.00
2	0	3.5	0	1.5	2	4.00
3	0	3.5	1	3	0.5	0.25
4	0	3.5	91	6	2.5	6.25
5	0	3.5	3	4.5	1	1.00
6	0	3.5	3	4.5	1	1.00
						Σd_i^2 = 16.50

Test: H_0: x and y are independent, i.e., there is no correlation between subsamples.
H_a: x and y are dependent, i.e., there is correlation or association.

Test Statistic: $t = r_s\sqrt{\frac{N-2}{1-(r_s)^2}}$ ~ student's "t" with N-2 degrees of freedom

Rejection Rule: Reject H_0 if $t > t_{N-2}^{.975}$; $t_4^{.975} = 2.776$

Calculations:

Correction for ties: $x = \Sigma\frac{T_x^3-T_x}{12} = \frac{6^3-6}{12} = 17.5$; $\Sigma x^2 = \frac{N^3-N}{12} - T_x = \frac{6^3-6}{12} - 17.5 = 17.5 - 17.5 = 0$

$y = \Sigma\frac{T_y^3-T_y}{12} = \frac{2^3-2}{12} + \frac{2^3-2}{12} = 0.5 + 0.5 = 1.0$; $\Sigma y^2 = \frac{N^3-N}{12} - T_y = 17.5 - 1.0 = 16.5$

$r_s = \frac{\Sigma x^2+\Sigma y^2-\Sigma d_i^2}{2\sqrt{\Sigma x^2\cdot\Sigma y^2}} = \frac{0+16.5-16.5}{2\sqrt{0\cdot 16.5}} = 0$ $t = 0\sqrt{\frac{4}{1-0}} = 0\cdot 2 = 0 \not> 2.776$

Conclusion: Fail to reject H_0. The subsamples are not correlated.

1/ Cruises with zero catches in both subsamples (after occurrences) are omitted, i.e., all cruises after occurrence of larvae are omitted from the analysis.

Table A-9.--Spearman Rank Non-parametric Correlation Tests on bongo net information for pink shrimp larvae in the Chiniak Bay area of Kodiak Island, 1978 (Stations C1, C2, and C3 combined).

Stage 4

Cruise 1/	Numbers found in original "500-organism aliquot (x_i)	Rank of x_i	Numbers found in "extensive resort" subsample (y_i)	Rank of y_i	Difference in ranks (d_i)	Squares of differences (d_i^2)
1	0	3.5	0	2	1.5	2.25
2	0	3.5	0	2	1.5	2.25
3	0	3.5	0	2	1.5	2.25
4	0	3.5	1	6	2.5	6.25
5	0	3.5	22	5	1.5	2.25
6	0	3.5	20	4	0.5	0.25
					$\Sigma d_i^2 =$	15.50

Test: H_0: x and y are independent, i.e., there is no correlation between subsamples.
H_a: x and y are dependent, i.e., there is correlation or association.

Test Statistic: $t = r_s\sqrt{\frac{N-2}{1-(r_s)^2}}$ ~ student's "t" with N-2 degrees of freedom

Rejection Rule: Reject H_0 if $t > t_{N-2}^{.975}$; $t_4^{.975} = 2.776$

Calculations:

Correction for ties: $x = \Sigma\frac{T_x^3-T_x}{12} = \frac{6^3-6}{12} = \frac{216-6}{12} = 17.5$; $\Sigma x^2 = \frac{N^3-N}{12} - T_x = \frac{6^3-6}{12} - 17.5 = 0$

$y = \Sigma\frac{T_y^3-T_y}{12} = \frac{3^3-3}{12} = \frac{27-3}{12} = 2.0$; $\Sigma y^2 = \frac{N^3-N}{12} - T_y = \frac{6^3-6}{12} - 2.0 = 15.5$

$r_s = \frac{\Sigma x^2+\Sigma y^2-\Sigma d_i^2}{2\sqrt{\Sigma x^2\cdot\Sigma y^2}} = \frac{0+15.5-15.5}{2\sqrt{0\cdot 15.5}} = 0$ $\qquad t = 0\sqrt{\frac{4}{1-0}} = 0\cdot 2 = 0 \not> 2.776$

Conclusion: Fail to reject H_0. The subsamples are not correlated.

1/ Cruises with zero catches in both subsamples (after occurrences) are omitted.

Table A-10.--Spearman Rank Non-parametric Correlation Tests on bongo net information for pink shrimp larvae in the Chiniak Bay area of Kodiak Island, 1978 (Stations C1, C2, and C3 combined).

Stage 5

Cruise 1/	Numbers found in original "500-organism aliquot (x_i)	Rank of x_i	Numbers found in "extensive resort" subsample (y_i)	Rank of y_i	Difference in ranks (d_i)	Squares of differences (d_i^2)
1	0	4	0	2.5	1.5	2.25
2	0	4	0	2.5	1.5	2.25
3	0	4	0	2.5	1.5	2.25
4	0	4	0	2.5	1.5	2.25
5	0	4	21	7	3.0	9.00
6	0	4	4	5	1.0	1.00
7	0	4	15	6	2.0	4.00
						$\Sigma d_i^2 = 23.00$

Test: H_0: x and y are independent, i.e., there is no correlation between subsamples.
H_a: x and y are dependent, i.e., there is correlation or association.

Test Statistic: $t = r_s\sqrt{\frac{N-2}{1-(r_s)^2}}$ ~ student's "t" with N-2 degrees of freedom

Rejection Rule: Reject H_0 if $t > t_{N-2}^{.975}$; $t_6^{.975} = 2.571$

Calculations:

Correction for ties: $x = \frac{T_x^3 - T_x}{12} = \frac{7^3-7}{12} = \frac{343-7}{12} = 28.0$; $\Sigma x^2 = \frac{N^3-N}{12} - T_x = \frac{7^3-7}{12} - 28.0 = 0$

$y = \frac{T_y^3 - T_y}{12} = \frac{4^3-4}{12} = \frac{64-4}{12} = 5.0$; $\Sigma y^2 = \frac{N^3-N}{12} - T_y = 28.0 - 5.0 = 23.0$

$r_s = \frac{\Sigma x^2 + \Sigma y^2 - \Sigma d^2}{2\sqrt{\Sigma x^2 \cdot \Sigma y^2}} = \frac{0+23-23}{2\sqrt{0 \cdot 23}} = 0$ $\quad t = 0\sqrt{\frac{5}{1-0}} = 0 \not> 2.571$

Conclusion: Fail to reject H_0. The subsamples are not correlated.

1/ Cruises with zero catches in both subsamples (after occurrences) are omitted.

Table A-11.--Spearman Rank Non-parametric Correlation Tests on bongo net information for pink shrimp larvae in the Chiniak Bay area of Kodiak Island, 1978 (Stations C1, C2, and C3 combined).

Stage 6

Cruise 1/	Numbers found in original "500-organism aliquot (x_i)	Rank of x_i	Numbers found in "extensive resort" subsample (y_i)	Rank of y_i	Difference in ranks (d_i)	Squares of differences (d_i^2)
1	0	3.5	0	3.5	0	0
2	0	3.5	0	3.5	0	0
3	0	3.5	0	3.5	0	0
4	0	3.5	0	3.5	0	0
5	0	3.5	0	3.5	0	0
6	0	3.5	0	3.5	0	0
7	1	7.0	3	7.0	0	0

$\Sigma d_i^2 = 0.00$

Test: H_0: x and y are independent, i.e., there is no correlation between subsamples.
H_a: x and y are dependent, i.e., there is correlation or association.

Test Statistic: $t = r_s\sqrt{\frac{N-2}{1-(r_s)^2}}$ ~ student's "t" with N-2 degrees of freedom

Rejection Rule: Reject H_0 if $t > t_{N-2}^{.975}$; $t_5^{.975} = 2.571$

Calculations:
Correction for ties:

$$x = \Sigma\frac{T_x^3-T_x}{12} = \frac{6^3-6}{12} = \frac{216-6}{12} = 17.5;\ \Sigma x^2 = \frac{N^3-N}{12} - T_x = \frac{7^3-7}{12} - 17.5 = 28.0 - 17.5 = 10.5$$

$$y = \Sigma\frac{T_y^3-T_y}{12} = \frac{6^3-6}{12} = \frac{216-6}{12} = 17.5;\ \Sigma y^2 = \frac{N^3-N}{12} - T_y = \frac{7^3-7}{12} - 17.5 = 28.0 - 17.5 = 10.5$$

$$r_s = \frac{\Sigma x^2+\Sigma y^2-\Sigma d_i^2}{2\sqrt{\Sigma x^2\cdot\Sigma y^2}} = \frac{10.5+10.5-0}{2\sqrt{10.5\cdot10.5}} = \frac{21.0}{21.0} = 1.00 = \text{complete correlation}$$

Conclusion: Reject H_0. The subsamples are correlated.

1/ Cruises with zero catches in both subsamples (after occurrences) are omitted.

Table A-12.--Spearman Rank Non-parametric Correlation Tests on bongo net information for pink shrimp larvae in the Chiniak Bay area of Kodiak Island, 1978 (Stations C1, C2, and C3 combined).

Stage 7

Cruise 1/	Numbers found in original "500-organism aliquot (x_i)	Rank of x_i	Numbers found in "extensive resort" subsample (y_i)	Rank of y_i	Difference in ranks (d_i)	Squares of differences (d_i^2)
1	0	4	0	3.5	0.5	0.25
2	0	4	0	3.5	0.5	0.25
3	0	4	0	3.5	0.5	0.25
4	0	4	0	3.5	0.5	0.25
5	0	4	0	3.5	0.5	0.25
6	0	4	0	3.5	0.5	0.25
7	0	4	1	7.0	3.0	9.00
						Σd_i^2 = 10.50

Test: H_0: x and y are independent, i.e., there is no correlation between subsamples.
H_a: x and y are dependent, i.e., there is correlation or association.

Test Statistic: $t = r_s\sqrt{\frac{N-2}{1-(r_s)^2}}$ ~ student's "t" with N-2 degrees of freedom

Rejection Rule: Reject H_0 if $t > t_{N-2}^{.975}$; $t_6^{.975} = 2.447$

Calculations:
Correction for ties:

$$x = \frac{T_x{}^3 - T_x}{12} = \frac{7^3-7}{12} = \frac{343-7}{12} = 28.0;\ \Sigma x^2 = \frac{N^3-N}{12} - T_x = \frac{343-7}{12} - 28.0 = 0$$

$$y = \frac{T\ \ -T}{12} = \frac{6^3-6}{12} = \frac{216-6}{12} = 17.5;\ \Sigma y^2 = \frac{N^3-N}{12} - T_y = \frac{343-7}{12} - 17.5 = 11.5$$

$$r_s = \frac{\Sigma x^2 + \Sigma y^2 - \Sigma d_i^2}{2\sqrt{\Sigma x^2 \cdot \Sigma y^2}} = \frac{0+11.5-10.5}{2\sqrt{0 \cdot 11.5}} = \frac{1}{\ } = 0 \qquad t = 0\sqrt{\frac{5}{1-0}} = 0 = 0 \not> 2.447$$

Conclusion: Fail to reject H_0. The subsamples are not correlated.

1/ Cruises with zero catches in both subsamples (after occurrences) are omitted.

Table A-13.--Spearman Rank Non-parametric Correlation Tests on bongo net information for pink shrimp larvae in the Chiniak Bay area of Kodiak Island, 1978 (Stations C1, C2, and C3 combined).

Stage 1-12 combined

Cruise	Numbers found in original "500-organism aliquot (x_i)	Rank of x_i	Numbers found in "extensive resort" subsample (y_i)	Rank of y_i	Difference in ranks (d_i)	Squares of differences (d_i^2)
1	0	4.5	2	5	1.5	2.25
2	33	9	49	11	2.0	4.00
3	138	12	42	9	3.0	9.00
4	38	10	185	12	2.0	4.00
5	0	4.5	35	8	3.5	12.25
6	0	4.5	46	10	5.5	30.25
7	65	11	20	7	4.0	16.00
8	0	4.5	5	6	1.5	2.25
9	0	4.5	0	2	2.5	6.25
10	0	4.5	0	2	2.5	6.25
11	0	4.5	0	2	2.5	6.25
12	0	4.5	1	4	0.5	0.25
					$\Sigma d_i^2 =$	99.00

Test: H_0: x and y are independent, i.e., there is no correlation between subsamples.
H_a: x and y are dependent, i.e., there is correlation or association.

Test Statistic: $t = r_s\sqrt{\frac{N-2}{1-(r_s)^2}}$ ~ student's "t" with N-2 degrees of freedom

Rejection Rule: Reject H_0 if $t > t_{N-2}^{.975}$; $t_{10}^{.975} = 2.228$

Calculations:
Correction for ties: $x = \Sigma\frac{T_x^3-T_x}{12} = \frac{8^3-8}{12} = \frac{512-8}{12} = 42.0$; $\Sigma x^2 = \frac{N^3-N}{12} - T_y = \frac{12^3-12}{12} - 42.0 = 143 - 42 = 101$

$y = \Sigma\frac{T_y^3-T_y}{12} = \frac{3^3-3}{12} = \frac{27-3}{12} = 2.0$; $\Sigma y^2 = \frac{N^3-N}{12} - T = \frac{12^3-12}{12} - 2 = 143-2 = 141$

$r_s = \frac{\Sigma x^2+\Sigma y^2-\Sigma d_i^2}{2\sqrt{\Sigma x^2 \cdot \Sigma y^2}} = \frac{101+141-99}{2\sqrt{101 \cdot 141}} = \frac{143}{238.67} = 0.599$ $\qquad t = 0.599\sqrt{\frac{10}{1-.359}} = 2.366 > 2.228$

Conclusion: Reject H_0. The subsamples are correlated.

Table A-14.--Spearman Rank Non-parametric Correlation Tests on bongo net information for *P. goniurus* in the Chiniak Bay area of Kodiak Island, 1978 (Stations C1, C2, and C3 combined).

Stage - All stages combined

Cruise 1/	Numbers found in original "500-organism aliquot (x_i)	Rank of x_i	Numbers found in "extensive resort" subsample (y_i)	Rank of y_i	Difference in ranks (d_i)	Squares of differences (d_i^2)
1	0	2.5	0	1	1.5	2.25
2	10 2/	5	3	2	3.0	9.00
3	164	8	41	5	3.0	9.00
4	77	7	129	8	1.0	1.00
5	0	2.5	44	6.5	4.0	16.00
6	44	6	44	6.5	0.5	0.25
7	0	2.5	21	4	1.5	2.25
8	0	2.5	7	3	0.5	0.25
						$\Sigma d_i^2 = 40.00$

Test: H_0: x and y are independent, i.e., there is no correlation between subsamples.
H_a: x and y are dependent, i.e., there is correlation or association.

Test Statistic: $t = r_s\sqrt{\frac{N-2}{1-(r_s)^2}}$ ~ student's "t" with N-2 degrees of freedom

Rejection Rule: Reject H_0 if $t > t_{N-2}^{.975} = t_6^{.975} = 2.447$

Calculations:

$$r_s = 1 - \frac{\Sigma d_i^2}{N^3-N} = 1 - \frac{40}{8^3-8} = 1 - \frac{40}{512-8} = 0.921$$

$$t = 0.921\sqrt{\frac{6}{1-.848}} = 5.778 > 2.447$$

Conclusion: Reject H_0. There is correlation between subsamples.

1/ Cruises with zero catches in both subsamples (after occurrences) are omitted.

2/ Mean biomass per 100 m^2

Table A-15.--Spearman Rank Non-parametric Correlation Tests on bongo net information for Paralithodes camtschatica in the Chiniak Bay area of Kodiak Island, 1978 (Stations C1, C2, and C3 combined).

Stage - All stages combined

Cruise 1/	Numbers found in original "500-organism aliquot (x_i)	Rank of x_i	Numbers found in "extensive resort" subsample (y_i)	Rank of y_i	Difference in ranks (d_i)	Squares of differences (d_i^2)
1	125 2/	5	209	5	0	0
2	0	2	9	2	0	0
3	0	2	13	3	1	1
4	38	4	36	4	0	0
5	0	2	5	1	1	1
						Σd_i^2 = 2.00

Test: H_0: x and y are independent, i.e., there is no correlation between subsamples.
H_a: x and y are dependent, i.e., there is correlation or association.

Test Statistic: $t = r_s\sqrt{\frac{N-2}{1-(r_s)^2}}$ ~ student's "t" with N-2 degrees of freedom

Rejection Rule: Reject H_0 if $t > t_{N-2}^{.975}$; $t_3^{.975} = 3.182$

Calculations:

$$r_s = 1 - \frac{6\Sigma d_i^2}{N^3-N} = 1 - \frac{6(2)}{5^3-5} = 1 - \frac{12}{120} = 0.900$$

$$t = 0.90\sqrt{\frac{3}{1-.81}} = 3.476 > 3.182$$

Conclusion: Reject H_0. The two sets of subsamples are correlated.

1/ Cruises with zero catches in both subsamples (after occurrences) are omitted.
2/ Mean biomass per 100 m².

Table A-16.--Spearman Rank Non-parametric Correlation Tests on bongo net information for Chionoecetes bairdi in the Chiniak Bay area of Kodiak Island, 1978 (Stations C1, C2, and C3 combined).

Stage - All stages combined

Cruise 1/	Numbers found in original "500 organism" aliquot (x_i)	Rank of x_i	Numbers found in "extensive resort" subsample (y_i)	Rank of Y_i	Difference in ranks (d_i)	Squares of differences (d_i^2)
1	0	5	1 2/	5	0.0	0
2	0	5	3	8	3.0	9.00
3	0	5	1	5	0.0	0
4	2	10	23	10	0.0	0
5	0	5	10	9	4.0	16.00
6	0	5	2	7	2.0	4.00
7	0	5	0	2	3.0	9.00
8	0	5	0	2	3.0	9.00
9	0	5	0	2	3.0	9.00
10	0	5	<1	5	0.0	0

$\Sigma d_i^2 = 56.00$

Test: H_0: x and y are independent, i.e., there is no correlation between subsamples.
H_a: x and y are dependent, i.e., there is correlation or association.

Test Statistic: $t = r_s\sqrt{\frac{N-2}{1-(r_s)^2}}$ ~ student's "t" with N-2 degrees of freedom

Rejection Rule: Reject H_0 if $t > t_{N-2}^{.975}$; $t_8^{.975} = 2.306$

Calculations:

Correction for ties: $x = \Sigma\frac{T_x^3-T_x}{12} = \frac{9^3-9}{12} = \frac{729-9}{12} = 60$; $\Sigma x^2 = \frac{N^3-N}{12} - T_x = \frac{10^3-10}{12} - 60 = \frac{1000-10}{12} - 60 = 22.5$

$y = \Sigma\frac{T_y^3-T_y}{12} = \left[\frac{3^3-3}{12} + \frac{3^3-3}{12}\right] = \left[\frac{27-3}{12} + \frac{27-3}{12}\right] = 4.0$; $\Sigma y^2 = \frac{N^3-N}{12} - T_y = \frac{10^3-10}{12} - 4.0 = \frac{1000-10}{12} - 4.0 = 78.5$

$r_s = \frac{\Sigma x^2+\Sigma y^2-\Sigma d_i^2}{2\sqrt{\Sigma x^2\cdot\Sigma y^2}} = \frac{22.5+78.5-56.0}{2\sqrt{78.5\cdot 22.5}} = \frac{45.00}{84.05} = 0.535$ $\quad t = r_s\sqrt{\frac{N-2}{1-r_s^2}} = 0.535\sqrt{\frac{8}{1-.281}} = 1.762 \not> 2.306$

Conclusion: Fail to reject H_0. There is no correlation between subsamples.

1/ Cruises with zero catches in both subsamples (after occurrences) are omitted.

2/ Mean biomass per 100 m².

Table A-17.--Spearman Rank Non-parametric Correlation Tests on vertical distribution for pink shrimp larvae in the Kiliuda Bay area of Kodiak Island, 1978.

Cruise 1

Sample Depth$_i$ (m)	Density estimated from original "500 organism" aliquot (x_i)	Rank of X_i	Density estimated from "extensive resort" subsample (y_i)	Rank of Y_i	Difference in ranks (d_i)	Squares of differences (d_i^2)
10	80 1/	2	378	5	3	9
30	366	3	12	3	0	0
50	0	1	0	1	0	0
70	1100	5	18	4	1	1
90	1059	4	9	2	2	4

$\Sigma d_i^2 = 14.00$

Test: H_0: x and y are independent, i.e., there is no correlation between subsamples.
H_a: x and y are dependent, i.e., there is correlation or association.

Test Statistic: $t = r_s\sqrt{\frac{N-2}{1-(r_s)^2}}$ ~ student's "t" with N-2 degrees of freedom

Rejection Rule: Reject H_0 if $t > t^{.975}_{N-2}$; $t_3^{.975} = 3.182$

Calculations:

$$r_s = 1 - \frac{6\sum_{i=10}^{90} d_i^2}{N^3-N}$$

$$= 1 - \frac{6(14)}{125-5}$$

$$= 1 - \frac{84}{120} = 0.30$$

$$t = 0.30\sqrt{\frac{N-2}{1-r_s^2}} = 0.30\sqrt{\frac{3}{1-.09}} = 0.544 \not> 3/182$$

Conclusion: Fail to reject H_0. These subsamples are not correlated.

1/ Number of larvae per 1000 m^3.

Table A-18.--Spearman Rank Non-parametric Correlation Tests on vertical distribution for pink shrimp larvae in the Kiliuda Bay area of Kodiak Island, 1978.

Cruise 2

Sample Depth$_i$ (m)	Density estimated from original "500 organism" aliquot (x_i)	Rank of X_i	Density estimated from "extensive resort" subsample (y_i)	Rank of Y_i	Difference in ranks (d_i)	Squares of differences (d_i^2)
10	0	3	160	2	1	1
30	0	3	361	3	0	0
50	0	3	566	5	2	4
70	0	3	468	4	1	1
90	0	3	140	1	2	4

$\Sigma d_i^2 = 10$

Test: H_0: x and y are independent, i.e., there is no correlation between subsamples.
H_a: x and y are dependent, i.e., there is correlation or association.

Test Statistic: $t = r_s\sqrt{\frac{N-2}{1-(r_s)^2}}$ ~ student's "t" with N-2 degrees of freedom

Rejection Rule: Reject H_0 if $t > t_{N-2}^{.975}$; $t_3^{.975} = 3.182$

Calculations:

$$r_s = 1 - \frac{6\sum_{i=10}^{90} d_i^2}{N^3-N}$$

$$= 1 - \frac{6(10)}{125-5}$$

$$= 1 - \frac{60}{120} = 0.500$$

$$t = 0.500\sqrt{\frac{3}{1-0.250}} = 1.00 \not> 3.182$$

Conclusion: Fail to reject H_0. These subsamples are not correlated.

Table A-19.--Spearman Rank Non-parametric Correlation Tests on vertical distribution for pink shrimp larvae in the Kiliuda Bay area of Kodiak Island, 1978.

Cruise 3

Sample Depth$_i$ (m)	Density estimated from original "500 organism" aliquot (x_i)	Rank of X_i	Density estimated from "extensive resort" subsample (y_i)	Rank of Y_i	Difference in ranks (d_i)	Squares of differences (d_i^2)
10	0	2	70	3	1	1
30	7246	5	632	5	0	0
50	158	4	90	4	0	0
70	0	2	30	2	0	0
90	0	2	10	1	1	1

Test: H_0: x and y are independent, i.e., there is no correlation between subsamples. $\Sigma d_i^2 = 2$
H_a: x and y are dependent, i.e., there is correlation or association.

Test Statistic: $t = r_s \sqrt{\frac{N-2}{1-(r_s)^2}}$ $\sim$ student's "t" with N-2 degrees of freedom

Rejection Rule: Reject H_0 if $t > t_{N-2}^{.975}$; $t_3^{.975} = 3.182$

Calculations:

$$r_s = 1 - 6\sum_{i=10}^{90} \frac{di^2}{N^3-N}$$

$$= 1 - \frac{6(2)}{125-5}$$

$$= 1 - \frac{12}{120} = 0.90$$

$$t = 0.90 \sqrt{\frac{3}{1-0.9^2}} = 3.576 > 3.182$$

Conclusion: Reject H_0. These subsamples are correlated.

Table A-20.--Spearman Rank Non-parametric Correlation Tests on vertical distribution for pink shrimp larvae in the Kiliuda Bay area of Kodiak Island, 1978.

Cruise 4

Sample $Depth_i$ (m)	Density estimated from original "500 organism" aliquot (x_i)	Rank of X_i	Density estimated from "extensive resort" subsample (y_i)	Rank of Y_i	Difference in ranks (d_i)	Squares of differences (d_i^2)
10	166	5	1760	5	0	0
30	0	2.5	130	4	1.5	2.25
50	0	2.5	27	2	0.5	0.25
70	0	2.5	4	1	1.5	2.25
90	0	2.5	33	3	0.5	0.25

$\Sigma d_i^2 = 5.00$

Test: H_0: x and y are independent, i.e., there is no correlation between subsamples.
H_a: x and y are dependent, i.e., there is correlation or association.

Test Statistic: $t = r_s\sqrt{\frac{N-2}{1-(r_s)^2}}$ ~ student's "t" with N-2 degrees of freedom

Rejection Rule: Reject H_0 if $t > t_{N-2}^{.975}$; $t_3^{.975} = 3.182$

Calculations:

$$r_s = 1 - \frac{6\sum_{i=10}^{90} di^2}{N^3-N}$$

$$= 1 - \frac{6(5)}{125-5}$$

$$= 1 - \frac{30}{120} = 0.750$$

$$t = 0.750\sqrt{\frac{3}{1-.75^2}} = 1.965 \not> 3.182$$

Conclusion: Fail to reject H_0. These subsamples are not correlated.

Table A-21.--Spearman Rank Non-parametric Correlation Tests on vertical distribution for pink shrimp larvae in the Kiliuda Bay area of Kodiak Island, 1978.

Cruise 5

Sample Depth$_i$ (m)	Density estimated from original "500 organism" aliquot (x_i)	Rank of X_i	Density estimated from "extensive resort" subsample (y_i)	Rank of Y_i	Difference in ranks (d_i)	Squares of differences (d_i^2)
10	0	3	64	4	1	1
30	0	3	20	2	1	1
50	0	3	20	2	1	1
70	0	3	20	2	1	1
90	0	3	718	5	2	4

Test: H_0: x and y are independent, i.e., there is no correlation between subsamples. $\Sigma d_i^2 = 8.00$
H_a: x and y are dependent, i.e., there is correlation or association.

Test Statistic: $t = r_s\sqrt{\frac{N-2}{1-(r_s)^2}}$ ~ student's "t" with N-2 degrees of freedom

Rejection Rule: Reject H_0 if $t > t^{.975}_{N-2}$; $t^{.975}_{3} = 3.182$

Calculations:

Correction for ties - $T_x = \frac{T_x^3 - T_x}{12} = \frac{5^3-5}{12} = \frac{125-5}{12} = 10;\ \Sigma x^2 = \frac{N^3-N}{12} - T_x = \frac{125-5}{12} - 10 = 0$

$T_y = \frac{T_y^3 - T_y}{12} = \frac{3^3-3}{12} = \frac{27-3}{12} = 2;\ \Sigma y^2 = \frac{N^3-N}{12} - T_y = \frac{125-5}{12} - 2 = 8$

$$r_s = \frac{\Sigma x^2 + \Sigma y^2 - \Sigma d_i^2}{2\sqrt{\Sigma x^2 \cdot \Sigma y^2}} = \frac{0+8-8}{2\sqrt{0 \cdot 8}} = 0$$

$$t = 0\sqrt{\frac{3}{1-0}} = 0 \not> 3.182$$

Conslusion: Fail to reject H_0. These subsamples are not significantly correlated.

Table A-22.--Spearman Rank Non-parametric Correlation Tests on vertical distribution for pink shrimp larvae in the Kiliuda Bay area of Kodiak Island, 1978.

Cruise 6

Sample Depth$_i$ (m)	Density estimated from original "500 organism" aliquot (x_i)	Rank of X_i	Density estimated from "extensive resort" subsample (y_i)	Rank of Y_i	Difference in ranks (d_i)	Squares of differences (d_i^2)
10	0	3	3	1	2	4
30	0	3	10	2.5	1.5	2.5
50	0	3	41	5	2	4
70	0	3	10	2.5	1.5	2.25
90	0	3	36	4	1	1

$\Sigma d_i^2 = 13.50$

Test: H_0: x and y are independent, i.e., there is no correlation between subsamples.
H_a: x and y are dependent, i.e., there is correlation or association.

Test Statistic: $t = r_s\sqrt{\frac{N-2}{1-(r_s)^2}}$ ~ student's "t" with N-2 degrees of freedom

Rejection Rule: Reject H_0 if $t > t^{.975}_{N-2}$; $t^{.975}_{3} = 3.182$

Calculations:

Correction for ties - $T_x = \frac{Tx^3-Tx}{12} = \frac{5^3-5}{12} = \frac{125-5}{12} = 10$; $\Sigma x^2 = \frac{N^3-N}{12} - T_x = \frac{125-5}{12} - 10 = 0$

$T_y = \frac{Ty^3-Ty}{12} = \frac{3^3-3}{12} = \frac{27-3}{12} = 2$; $\Sigma y^2 = \frac{N^3-N}{12} - T_y = \frac{125-5}{12} - 2 = 8$

$$r_s = \frac{\Sigma x^2+\Sigma y^2-\Sigma d_i^2}{2\sqrt{\Sigma x^2 \cdot \Sigma y^2}} = \frac{0+8-13.5}{2\sqrt{0 \cdot 8}} = 0$$

$$t = 0\sqrt{\frac{3}{1-0}} = 0 \not> 3.182$$

Conclusion: Fail to reject H_0. These subsamples are not correlated.

Table A-23.--Spearman Rank Non-parametric Correlation Tests on vertical distribution for pink shrimp larvae in the Kiliuda Bay area of Kodiak Island, 1978.

Cruise 7

Sample $Depth_i$ (m)	Density estimated from original "500 organism" aliquot (x_i)	Rank of X_i	Density estimated from "extensive resort" subsample (y_i)	Rank of Y_i	Difference in ranks (d_i)	Squares of differences (d_i^2)
10	1	3	16	5	2	4
30	0	3	4	2	1	1
50	0	2	14	4	1	1
70	0	3	12	3	0	0
90	0	3	--	1	2	4

$\Sigma d_i^2 = 10.00$

Test: H_0: x and y are independent, i.e., there is no correlation between subsamples.
H_a: x and y are dependent, i.e., there is correlation or association.

Test Statistic: $t = r_s\sqrt{\frac{N-2}{1-(r_s)^2}}$ ~ student's "t" with N-2 degrees of freedom

Rejection Rule: Reject H_0 if $t > t^{.975}_{N-2}$; $t^{.975}_{3} = 3.182$

Calculations:

$$r_s = \sum_{i-10}^{90} \frac{d_i^2}{N^3-N}$$

$$= 1 - \frac{10}{125-5}$$

$$= 0.917$$

$$t = 0.917\sqrt{\frac{3}{1-.917^2}} = 3.974 > 3.182$$

Conclusion: Reject H_0. There is correlation between these subsamples.

Table A-24.--Spearman Rank Non-parametric Correlation Tests on vertical distribution for pink shrimp larvae in the Kiliuda Bay area of Kodiak Island, 1978.

Cruise 8

Sample $Depth_i$ (m)	Density estimated from original "500 organism" aliquot (x_i)	Rank of X_i	Density estimated from "extensive resort" subsample (y_i)	Rank of Y_i	Difference in ranks (d_i)	Squares of differences (d_i^2)
10	0	3	0	1.5	1.5	2.25
30	0	3	0	1.5	1.5	2.25
50	0	3	3	3	0	0
70	0	3	13	5	2	4
90	0	3	7	4	1	1

$\Sigma d_i^2 = 9.50$

Test: H_0: x and y are independent, i.e., there is no correlation between subsamples.
H_a: x and y are dependent, i.e., there is correlation or association.

Test Statistic: $t = r_s\sqrt{\frac{N-2}{1-(r_s)^2}}$ ~ student's "t" with N-2 degrees of freedom

Rejection Rule: Reject H_0 if $t > t_{N-2}^{.975}$; $t_3^{.975} = 3.182$

Calculations:

Correction for ties - $T_x = \frac{T_x^3 - T_x}{12} = \frac{5^3-5}{12} = \frac{125-5}{12} = 10; \ \Sigma x^2 = \frac{N^3-N}{12} - T_x = \frac{125-5}{12} - 10 = 0$

$$T_y = \frac{T_y^3 - T_y}{12} = \frac{2^3-2}{12} = \frac{8-2}{12} = 0.5; \ \Sigma y^2 = \frac{N^3-N}{12} - T_y = 9.5$$

$$r_s = \frac{\Sigma x^2 + \Sigma y^2 - \Sigma d_i^2}{2\sqrt{\Sigma x^2 \cdot \Sigma y^2}} = \frac{0+9.5-9.5}{2\sqrt{0 \cdot 9.5}} = 0$$

$$t = 0\sqrt{\frac{3}{1-0}} = 0 \not> 3.182$$

Conclusion: Fail to reject H_0. There is no correlation between these subsamples.

Table A-25.--Spearman Rank Non-parametric Correlation Tests on vertical distribution for pink shrimp larvae in the Kiliuda Bay area of Kodiak Island, 1978.

Cruise 9

Sample Depth$_i$ (m)	Density estimated from original "500 organism" aliquot (x_i)	Rank of X_i	Density estimated from "extensive resort" subsample (y_i)	Rank of Y_i	Difference in ranks (d_i)	Squares of differences (d_i^2)
10	0	3	0	2.5	0.5	0.25
30	0	3	0	2.5	0.5	0.25
50	0	3	6	5	2	4.00
70	0	3	0	2.5	0.5	0.25
90	0	3	0	2.5	0.5	0.25

$\Sigma d_i^2 = 5.00$

Test: H_0: x and y are independent, i.e., there is no correlation between subsamples.
H_a: x and y are dependent, i.e., there is correlation or association.

Test Statistic: $t = r_s\sqrt{\frac{N-2}{1-(r_s)^2}}$ ~ student's "t" with N-2 degrees of freedom

Rejection Rule: Reject H_0 if $t > t_{N-2}^{.975}$; $t_3^{.975} = 3.182$

Calculations:

Correction for ties - $T_x = \frac{Tx^3-Tx}{12} = \frac{5^3-5}{12} = \frac{120}{12} = 10$; $\Sigma x^2 = \frac{N^3-N}{12} - T_x = \frac{125-5}{12} - 10 = 0$

$T_y = \frac{Ty^3-Ty}{12} = \frac{4^3-4}{12} = \frac{60}{12} = 5$; $\Sigma y^2 = \frac{N^3-N}{12} - T_y = \frac{125-5}{12} - 5 = 5$

$$r_s = \frac{\Sigma x^2 + \Sigma y^2 - \Sigma d_i^2}{2\sqrt{\Sigma x^2 \cdot \Sigma y^2}} = \frac{0+5-5}{2\sqrt{0 \cdot 5}} = 0$$

$$t = 0\sqrt{\frac{3}{1-0}} = 0 \not> 3.182$$

Conclusion: Fail to reject H_0. There is no significant correlation between these subsamples.

Table A-26.--Spearman Rank Non-parametric Correlation Tests on vertical distribution for pink shrimp larvae in the Kiliuda Bay area of Kodiak Island, 1978.

Cruise 1-9

Sample Depth$_i$ (m)	Density estimated from original "500 organism" aliquot (x_i)	Rank of X_i	Density estimated from "extensive resort" subsample (y_i)	Rank of Y_i	Difference in ranks (d_i)	Squares of differences (d_i^2)
10	27 1/	2	272	5	3	9
30	846	5	130	4	1	1
50	18	1	84	2	1	1
70	122	4	64	1	3	9
90	118	3	106	3	0	0

$\Sigma d_i^2 = 20.00$

Test: H_0: x and y are independent, i.e., there is no correlation between subsamples.
H_a: x and y are dependent, i.e., there is correlation or association.

Test Statistic: $t = r_s\sqrt{\frac{N-2}{1-(r_s)^2}}$ ~ student's "t" with N-2 degrees of freedom

Rejection Rule: Reject H_0 if $t > t_{N-2}^{.975}$; $t_3^{.975} = 3.182$

Calculations:

$$r_s = 1 - \frac{6\left(\sum_{i=10}^{90} d_i^2\right)}{N^3-N}$$

$$= 1 - \frac{6(20)}{125-5}$$

$$= 0$$

$$t = 0\sqrt{\frac{3}{1}} = 0 \not> 3.182$$

Conclusion: Fail to reject H_0. These subsamples are not correlated.

1/ Mean density per 1000 m³ for Cruises 1-9.

Table A-27.--Spearman Rank Non-parametric Correlation Tests on vertical distribution for humpy shrimp larvae in the Kiliuda Bay area of Kodiak Island, 1978.

Cruise 1

Depth (m)	Density estimated from original "500 organism" aliquot (x_i)	Rank of x_i	Density estimated from "extensive resort" subsample (y_i)	Rank of y_i	Difference in ranks (d_i)	Squares of differences (d_i^2)
10	0	2.5	156	5	2.5	6.25
30	0	2.5	0	2.5	0	0
50	145 1/	5	0	2.5	2.5	6.25
70	0	2.5	0	2.5	0	0
90	0	2.5	0	2.5	0	0
						$\Sigma d_i^2 = 12.50$

Test: H_0: x and y are independent, i.e., there is no correlation between subsamples.
H_a: x and y are dependent, i.e., there is correlation or association.

Test Statistic: $t = r_s\sqrt{\frac{N-2}{1-(r_s)^2}}$ ~ student's "t" with N-2 degrees of freedom

Rejection Rule: Reject H_0 if $t > t_{N-2}^{.975}$; $t_3^{.975} = 3.182$

Calculations:

Correction for ties - $T_x = \frac{Tx^3 - Tx}{12} = \frac{4^3-4}{12} = \frac{60}{12} = 5$; $\Sigma x^2 = \frac{N^3-N}{12} - T_x = \frac{125-5}{12} - 5 = 5$

$T_y = \frac{Ty^3 - Ty}{12} = \frac{4^3-4}{12} = \frac{60}{12} = 5$; $\Sigma y^2 = \frac{N^3-N}{12} - T_y = \frac{125-5}{12} - 5 = 5$

$$r_s = \frac{\Sigma x^2 + \Sigma y^2 - \Sigma d_i^2}{2\sqrt{\Sigma x^2 \cdot \Sigma y^2}} = \frac{5+5-12.5}{2\sqrt{25}} = \frac{-2.5}{10} = -0.250$$

$$t = -.250\sqrt{\frac{3}{1-.063}} = -0.447 \not> 3.182$$

Conclusion: Fail to reject H_0. These subsamples are not correlated.

1/ Number of larvae per 1000 m^3.

Table A-28.--Spearman Rank Non-parametric Correlation Tests on vertical distribution for humpy shrimp larvae in the Kiliuda Bay area of Kodiak Island, 1978.

Cruise 2

Depth (m)	Density estimated from original "500 organism" aliquot (x_i)	Rank of x_i	Density estimated from "extensive resort" subsample (y_i)	Rank of y_i	Difference in ranks (d_i)	Squares of differences (d_i^2)
10	0	3	0	2.5	0.5	0.25
30	0	3	0	2.5	0.5	0.25
50	0	3	16	5	2.0	4.00
70	0	3	0	2.5	0.5	0.25
90	0	3	0	2.5	0.5	0.25
						$\Sigma d_i^2 = 5.00$

Test: H_0: x and y are independent, i.e., there is no correlation between subsamples.
H_a: x and y are dependent, i.e., there is correlation or association.

Test Statistic: $t = r_s\sqrt{\frac{N-2}{1-(r_s)^2}}$ ~ student's "t" with N-2 degrees of freedom

Rejection Rule: Reject H_0 if $t > t_{N-2}^{.975}$; $t_3^{.975} = 3.182$

Calculations:

Correction for ties - $T_x = \Sigma \frac{Tx^3 - Tx}{12} = \frac{5^3-5}{12} = \frac{125-5}{12} = 10$; $\Sigma x = \frac{N^3-N}{12} - T_x = 10 - 10 = 0$

$T_y = \Sigma \frac{Ty^3 - Ty}{12} = \frac{4^3-4}{12} = \frac{60}{12} = 5$; $\Sigma y^2 = \frac{N^3-N}{12} - T_y = 10 - 5 = 5$

$$r_s = \frac{\Sigma x^2 + \Sigma y^2 - \Sigma d_i^2}{2\sqrt{\Sigma x^2 \cdot \Sigma y^2}} = \frac{0+5-5}{2\sqrt{0.5}} = 0$$

$$t = r_s\sqrt{\frac{N-3}{1-r_s^2}} = 0\sqrt{\frac{3}{0}} = 0 \not> 3.182$$

Conclusion: Fail to reject H_0. There is no correlation between the subsamples.

Table A-29.--Spearman Rank Non-parametric Correlation Tests on vertical distribution for humpy shrimp larvae in the Kiliuda Bay area of Kodiak Island, 1978.

Cruise 3

Depth (m)	Density estimated from original "500 organism" aliquot (x_i)	Rank of x_i	Density estimated from "extensive resort" subsample (y_i)	Rank of y_i	Difference in ranks (d_i)	Squares of differences (d_i^2)
10	0	3	20	5	2.00	4.00
30	0	3	0	2	1.00	1.00
50	0	3	0	2	1.00	1.00
70	0	3	4	4	1.00	1.00
90	0	3	0	2	1.00	1.00
						$\Sigma d_i^2 = 8.00$

Test: H_0: x and y are independent, i.e., there is no correlation between subsamples.
H_a: x and y are dependent, i.e., there is correlation or association.

Test Statistic: $t = r_s\sqrt{\frac{N-2}{1-(r_s)^2}}$ ~ student's "t" with N-2 degrees of freedom

Rejection Rule: Reject H_0 if $t > t_{N-2}^{.975}$; $t_3^{.975} = 3.182$

Calculations:

Correction for ties - $T_x = \Sigma \frac{Tx^3-Tx}{12} = \frac{5^3-5}{12} = \frac{120}{12} = 10; \; \Sigma x^2 = \frac{N^3-N}{12} - T_x = \frac{125-5}{12} - 10 = 10 - 10 = 0$

$T_y = \Sigma \frac{Ty^3-Ty}{12} = \frac{3^3-3}{12} = \frac{27-3}{12} = 2; \; \Sigma y^2 = \frac{N^3-N}{12} - T_y = 10 - 2 = 8$

$$r_s = \frac{\Sigma x^2 + \Sigma y^2 - \Sigma d}{2\sqrt{\Sigma x^2 \cdot \Sigma y^2}} = \frac{0+8-8}{2\sqrt{0 \cdot 8}} = 0$$

$$t = r_s\sqrt{\frac{N-3}{1-r_s^2}} = 0\sqrt{\frac{3}{1-0}} = 0 \ngtr 3.182$$

Conclusion: Fail to reject H_0. There is no correlation between subsamples.

Table A-30.--Spearman Rank Non-parametric Correlation Tests on vertical distribution for humpy shrimp larvae in the Kiliuda Bay area of Kodiak Island, 1978.

Cruise 4

Depth (m)	Density estimated from original "500 organism" aliquot (x_i)	Rank of x_i	Density estimated from "extensive resort" subsample (y_i)	Rank of y_i	Difference in ranks (d_i)	Squares of differences (d_i^2)
10	1055 1/	5	79	2	3	9.00
30	0	2.5	97	4	1.5	2.25
50	0	2.5	11	1	1.5	2.25
70	0	2.5	82	3	0.5	0.25
90	0	2.5	203	5	2.5	6.25
						$\Sigma d_i^2 = 20.00$

Test: H_0: x and y are independent, i.e., there is no correlation between subsamples.
H_a: x and y are dependent, i.e., there is correlation or association.

Test Statistic: $t = r_s\sqrt{\frac{N-2}{1-(r_s)^2}}$ ~ student's "t" with N-2 degrees of freedom

Rejection Rule: Reject H_0 if $t > t_{N-2}^{.975}$; $t_3^{.975} = 3.182$

Calculations:

$$r_s = 1 - \frac{6\sum_{i=10}^{N} d_i^2}{N^3-N}$$

$$= 1 - \frac{6(20)}{125-5}$$

$$= 1 - \frac{120}{120} = 0$$

$$t = 0\sqrt{\frac{3}{1}} = 0 \not> 3.182$$

Conclusion: Fail to reject H_0, there is no correlation.

1/ estimated number per 1000 m^3.

Table A-31.--Spearman Rank Non-parametric Correlation Tests on vertical distribution for humpy shrimp larvae in the Kiliuda Bay area of Kodiak Island, 1978.

Cruise 5

Depth (m)	Density estimated from original "500 organism" aliquot (x_i)	Rank of x_i	Density estimated from "extensive resort" subsample (y_i)	Rank of y_i	Difference in ranks (d_i)	Squares of differences (d_i^2)
10	0	2.5	51	4	1.5	2.25
30	47	5	21	3	2.0	4.00
50	0	2.5	82	5	2.5	6.25
70	0	2.5	8	2	0.5	0.25
90	0	2.5	0	1	1.5	2.25

$\Sigma d_i^2 = 15.00$

Test: H_0: x and y are independent, i.e., there is no correlation between subsamples.
H_a: x and y are dependent, i.e., there is correlation or association.

Test Statistic: $t = r_s\sqrt{\frac{N-2}{1-(r_s)^2}}$ ~ student's "t" with N-2 degrees of freedom

Rejection Rule: Reject H_0 if $t > t_{N-2}^{.975}$; $t_3^{.975}$ =3.182

Calculations:

$$r_s = 1 - \frac{6\sum_{i=10}^{N} d_i^2}{N^3-N}$$

$$= 1 - \frac{6(15)}{120}$$

$$= 1 - \frac{90}{120} = 0.250$$

$$t = 0.250\sqrt{\frac{3}{1-.25^2}} = 0.447 \ngtr 3.182$$

Conclusion: Fail to reject H_0. There is no correlation.

Table A-32.--Spearman Rank Non-parametric Correlation Tests on vertical distribution for humpy shrimp larvae in the Kiliuda Bay area of Kodiak Island, 1978.

Cruise 6

Depth (m)	Density estimated from original "500 organism" aliquot (x_i)	Rank of x_i	Density estimated from "extensive resort" subsample (y_i)	Rank of y_i	Difference in ranks (d_i)	Squares of differences (d_i^2)
10	0	25	6	3	0.5	0.25
30	334 1/	5	0	1.5	3.5	12.25
50	262	4	0	1.5	2.5	6.25
70	0	2.5	7	4	1.5	2.25
90	0	2.5	27	5	2.5	6.25

$\Sigma d_i^2 = 27.25$

Test: H_0: x and y are independent, i.e., there is no correlation between subsamples.
H_a: x and y are dependent, i.e., there is correlation or association.

Test Statistic: $t = r_s\sqrt{\frac{N-2}{1-(r_s)^2}}$ ~ student's "t" with N-2 degrees of freedom

Rejection Rule: Reject H_0 if $t > t_{N-2}^{.975}$; $t_3^{.975} = 3.182$

Calculations:

$$r_s = 1 - \frac{6\sum_{i=10}^{N} d_i^2}{N^3 - N}$$

$$= 1 - \frac{6(27.25)}{5^3-5} = 1 - \frac{163.5}{120} = -0.363$$

$$t = -0.363\sqrt{\frac{3}{1-(-0.363)^2}} = -0.591 \not> 3.182$$

Conclusion: Fail to reject H_0. There is no correlation.

1/ Number of organisms per 1000 m^3.

Table A-33.--Spearman Rank Non-parametric Correlation Tests on vertical distribution for humpy shrimp larvae in the Kiliuda Bay area of Kodiak Island, 1978.

Cruises 7-12 -- no organisms found at any depth in either subsamples.
Cruises 1-6 combined.

Depth (m)	Density estimated from original "500 organism" aliquot (x_i)	Rank of x_i	Density estimated from "extensive resort" subsample (y_i)	Rank of y_i	Difference in ranks (d_i)	Squares of differences (d_i^2)
10	176 1/	5	52	5	0	0
30	64	3.5	20	3	0.5	0.25
50	68	3.5	18	2	1.5	2.25
70	0	1.5	16	1	0.5	0.25
90	0	1.5	41	4	2.5	6.25
						$\Sigma d_i^2 = 9.00$

Test: H_0: x and y are independent, i.e., there is no correlation between subsamples.
H_a: x and y are dependent, i.e., there is correlation or association.

Test Statistic: $t = r_s\sqrt{\frac{N-2}{1-(r_s)^2}}$ ~ student's "t" with N-2 degrees of freedom

Rejection Rule: Reject H_0 if $t > t_{N-2}^{.975}$; $t_3^{.975} = 3.182$

Calculations:

$$r_s = 1 - \frac{6\sum_{i=10}^{N} d_i^2}{N^3-N}$$

$$= 1 - \frac{6(9)}{120} = 1 - \frac{54}{120} = .550$$

$$t = r_s \frac{N-2}{1-r_s^2} = .550\sqrt{\frac{3}{1-.303}} = 1.141 \not> 3.182$$

Conclusion: Fail to reject H_0. The subsamples are not correlated.

1/ Mean density per 1000 m^3 for cruises 1-6.

Table A-34.--Spearman Rank Non-parametric Correlation Tests on vertical distribution for red king crab larvae in the Kiliuda Bay area of Kodiak Island, 1978.

Cruise 1

Depth (m)	Density estimated from original "500 organism" aliquot (x_i)	Rank of x_i	Density estimated from "extensive resort" subsample (y_i)	Rank of y_i	Difference in ranks (d_i)	Squares of differences (d_i^2)
10	0	3	323 1/	5	2	4.00
30	0	3	0	2.5	0.5	0.25
50	0	3	0	2.5	0.5	0.25
70	0	3	0	2.5	0.5	0.25
90	0	3	0	2.5	0.5	0.25
						$\Sigma d_i^2 = 5.00$

Test: H_0: x and y are independent, i.e., there is no correlation between subsamples.
H_a: x and y are dependent, i.e., there is correlation or association.

Test Statistic: $t = r_s\sqrt{\frac{N-2}{1-(r_s)^2}}$ ~ student's "t" with N-2 degrees of freedom

Rejection Rule: Reject H_0 if $t > t_{N-2}^{.975}$; $t_3^{.975} = 3.182$

Calculations:

Correction for ties - $T_x = \Sigma \frac{Tx^3-Tx}{12} = \frac{5^3-5}{12} = \frac{125-5}{12} = 10$; $\Sigma x^2 = \frac{N^3-N}{12} - T_x = \frac{125-5}{12} - 10 = 0$

$$T_y = \Sigma \frac{Ty^3-Ty}{12} = \frac{4^3-4}{12} = \frac{60}{12} = 5;\ \Sigma y^2 = \frac{N^3-N}{12} - T_y = 10 - 5 = 5$$

$$r_s = \frac{\Sigma x^2+\Sigma y^2-\Sigma d}{2\sqrt{\Sigma x^2 \cdot \Sigma y^2}} = \frac{0+5-5}{2\sqrt{0.5}} = 0$$

$$t = 0\sqrt{\frac{3}{1-0}} = 0 \not> 3.182$$

Conclusion: Fail to reject H_0. The two types of subsamples are not correlated for king crab larvae during Cruise 1.

1/ Number of larvae per 1000 m^3.

Table A-35.--Spearman Rank Non-parametric Correlation Tests on vertical distribution for red king crab larvae in the Kiliuda Bay area of Kodiak Island, 1978.

Cruise 2

Depth (m)	Density estimated from original "500 organism" aliquot (x_i)	Rank of x_i	Density estimated from "extensive resort" subsample (y_i)	Rank of y_i	Difference in ranks (d_i)	Squares of differences (d_i^2)
10	0	2	23	3	1	1
30	286	5	100	5	0	0
50	95	4	65	4	0	0
70	0	2	19	2	0	0
90	0	2	0	1	1	1

$\Sigma d_i^2 = 2.00$

Test: H_0: x and y are independent, i.e., there is no correlation between subsamples.
H_a: x and y are dependent, i.e., there is correlation or association.

Test Statistic: $t = r_s\sqrt{\frac{N-2}{1-(r_s)^2}}$ ~ student's "t" with N-2 degrees of freedom

Rejection Rule: Reject H_0 if $t > t_{N-2}^{.975}$; $t_3^{.975}$ =3.182

Calculations:

$$r_s = 1 - \frac{6\Sigma(d_i^2)}{N^3-N} = 1 - \frac{6(2)}{120} = 1 - 0.10 = 0.90$$

$$t = .90\sqrt{3/1-0.81} = 3.576 > 3.182$$

Conclusion: There is correlation between two types of subsamples.
Reject H_0.

Table A-36.--Spearman Rank Non-parametric Correlation Tests on vertical distribution for red king crab larvae in the Kiliuda Bay area of Kodiak Island, 1978.

Cruise 3

Depth (m)	Density estimated from original "500 organism" aliquot (x_i)	Rank of x_i	Density estimated from "extensive resort" subsample (y_i)	Rank of y_i	Difference in ranks (d_i)	Squares of differences (d_i^2)
10	0	3	161	5	2	4
30	0	3	44	4	1	1
50	0	3	12	3	0	0
70	0	3	4	2	1	1
90	0	3	0	1	2	4

$\Sigma d_i^2 = 10.00$

Test: H_0: x and y are independent, i.e., there is no correlation between subsamples.
H_a: x and y are dependent, i.e., there is correlation or association.

Test Statistic: $t = r_s\sqrt{\frac{N-2}{1-(r_s)^2}}$ ~ student's "t" with N-2 degrees of freedom

Rejection Rule: Reject H_0 if $t > t_{N-2}^{.975}$; $t_3^{.975} = 3.182$

Calculations:

$$r_s = 1 - \frac{6\Sigma d_i^2}{N^3-N} = 1 - \frac{6(10)}{120} = 0.50$$

$$t = 0.50\sqrt{\frac{3}{1-.25}} = 1.00 \not> 3.182$$

Conclusion: Fail to reject H_0. There is no correlation between the two subsamples.

Table A-37.--Spearman Rank Non-parametric Correlation Tests on vertical distribution for red king crab larvae in the Kiliuda Bay area of Kodiak Island, 1978.

Cruise 4

Depth (m)	Density estimated from original "500 organism" aliquot (x_i)	Rank of x_i	Density estimated from "extensive resort" subsample (y_i)	Rank of y_i	Difference in ranks (d_i)	Squares of differences (d_i^2)
10	0	2.5	0	1	1.5	2.25
30	0	2.5	119	5	0.5	0.25
50	30	5	8	4	1.0	1.00
70	0	2.5	4	2.5	0	0
90	0	2.5	4	2.5	0	0
						$\Sigma d_i^2 = 3.50$

Test: H_0: x and y are independent, i.e., there is no correlation between subsamples.
H_a: x and y are dependent, i.e., there is correlation or association.

Test Statistic: $t = r_s\sqrt{\frac{N-2}{1-(r_s)^2}}$ ~ student's "t" with N-2 degrees of freedom

Rejection Rule: Reject H_0 if $t > t_{N-2}^{.975}$; $t_3^{.975} = 3.182$

Calculations:

Correction for ties - $T_x = \frac{T_x^3 - T_x}{12} = \frac{4^3-4}{12} = \frac{60}{12} = 5$; $\Sigma x^2 = \frac{N^3-N}{12} - T_x = 10 - 5 = 5$

$T_y = \frac{T_y^3 - T_y}{12} = \frac{2^3-2}{12} = \frac{6}{12} = 0.5$; $\Sigma y^2 = \frac{N^3-N}{12} - T_y = 10 - 0.5 = 9.5$

$$r_s = \frac{\Sigma x^2 + \Sigma y^2 - \Sigma d_i^2}{2\sqrt{\Sigma x^2 \cdot \Sigma y^2}} = \frac{5+9.5-3.5}{2\sqrt{47.5}} = 0.798$$

$$t = r_s\sqrt{\frac{N-2}{1-r_s^2}} = 0.80\sqrt{\frac{3}{1-(.80)^2}} = 2.294 \not> 3.182$$

Conclusion: Fail to reject H_0. No correlation for Cruise 4.

Table A-38.--Spearman Rank Non-parametric Correlation Tests on vertical distribution for red king crab larvae in the Kiliuda Bay area of Kodiak Island, 1978.

Cruise 5

Cruises 6-12 - No catches either subsample -- Correlation

Depth (m)	Density estimated from original "500 organism" aliquot (x_i)	Rank of x_i	Density estimated from "extensive resort" subsample (y_i)	Rank of y_i	Difference in ranks (d_i)	Squares of differences (d_i^2)
10	3813	5	17357	5	0	0
30	24	4	24	4	0	0
50	0	2.5	11	2	0.5	0.25
70	0	2.5	6	1	1.5	2.25
90	0	2.5	12	3	0.5	0.25
						$\Sigma d_i^2 = 2.75$

Test: H_0: x and y are independent, i.e., there is no correlation between subsamples.
H_a: x and y are dependent, i.e., there is correlation or association.

Test Statistic: $t = r_s\sqrt{\frac{N-2}{1-(r_s)^2}}$ ~ student's "t" with N-2 degrees of freedom

Rejection Rule: Reject H_0 if $t > t_{N-2}^{.975}$; $t_3^{.975} = 3.182$

Calculations:

$$r_s = 1 - \frac{6\Sigma d_i^2}{N^3-N} = 1 - \frac{6(2.75)}{120} = 0.863$$

$$t = r_s\sqrt{\frac{N-2}{1-r_s^2}} = 0.86\sqrt{\frac{3}{1-.74}} = 2.954 \not> 3.182$$

Conclusion: Fail to reject H_o. No correlation between subsamples for cruise 5.

Table A-39.--Spearman Rank Non-parametric Correlation Tests on vertical distribution for red king crab larvae in the Kiliuda Bay area of Kodiak Island, 1978.

Cruise 1-5 combined

Depth (m)	Density estimated from original "500 organism" aliquot (x_i)	Rank of x_i	Density estimated from "extensive resort" subsample (y_i)	Rank of y_i	Difference in ranks (d_i)	Squares of differences (d_i^2)
10	953 1/	5	4466	5	0	0
30	78	4	72	4	0	0
50	31	3	24	3	0	0
70	0	1.5	8	2	0.5	0.25
90	0	1.5	4	1	0.5	0.25
						$\Sigma d_i^2 = 0.50$

Test: H_0: x and y are independent, i.e., there is no correlation between subsamples.
H_a: x and y are dependent, i.e., there is correlation or association.

Test Statistic: $t = r_s\sqrt{\frac{N-2}{1-(r_s)^2}}$ ~ student's "t" with N-2 degrees of freedom

Rejection Rule: Reject H_0 if $t > t_{N-2}^{.975}$; $t_3^{.975} = 3.182$

Calculations:

$$r_s = 1 - \frac{6\Sigma d_i^2}{N^3-N} = 1 - \frac{6(.5)}{120} = 0.975$$

$$t = r_s\sqrt{\frac{N-2}{1-r_s^2}} = 0.975\sqrt{\frac{3}{1-.951}} = 7.600 > 3.182$$

Conclusion: Reject H_0. There is correlation between the subsamples when the data for several cruises are combined.

1/ Mean density per 1000 m^3 for cruises 1-5.

Table A-40.--Spearman Rank Non-parametric Correlation Tests on vertical distribution for *bairdi* tanner crab larvae in the Kiliuda Bay area of Kodiak Island, 1978.

Cruise 1 -- No catches in either subsample. Correlation--yes.

Cruise 2

Depth (m)	Density estimated from original "500 organism" aliquot (x_i)	Rank of x_i	Density estimated from "extensive resort" subsample (y_i)	Rank of y_i	Difference in ranks (d_i)	Squares of differences (d_i^2)
10	0	2	23	2	0	0
30	143 1/	5	133	5	0	0
50	95	4	33	3	1	1
70	0	2	19	1	1	1
90	0	2	47	4	2	4
						$\Sigma d_i^2 = 6$

Test: H_0: x and y are independent, i.e., there is no correlation between subsamples.
H_a: x and y are dependent, i.e., there is correlation or association.

Test Statistic: $t = r_s\sqrt{\frac{N-2}{1-(r_s)^2}}$ ~ student's "t" with N-2 degrees of freedom

Rejection Rule: Reject H_0 if $t > t_{N-2}^{.975}$; $t_3^{.975} = 3.182$

Calculations:

$$r_s = 1 - \frac{6\Sigma d_i^2}{N^3-N} = 1 - \frac{6(6)}{120} = 0.70$$

$$t = 0.70\sqrt{\frac{3}{1-0.49}} = 1.70 \not> 3.182$$

Conclusion: Fail to reject H_o. No correlation between subsamples.

1/ Number per 1000 m^3.

Table A-41.--Spearman Rank Non-parametric Correlation Tests on vertical distribution for *bairdi* tanner crab larvae in the Kiliuda Bay area of Kodiak Island, 1978.

Cruise 3

Depth (m)	Density estimated from original "500 organism" aliquot (x_i)	Rank of x_i	Density estimated from "extensive resort" subsample (y_i)	Rank of y_i	Difference in ranks (d_i)	Squares of differences (d_i^2)
10	0	3	723 1/	5	2	4
30	0	3	131	4	1	1
50	0	3	12	1	2	4
70	0	3	16	2	1	1
90	0	3	17	3	0	0
						$\Sigma d_i^2 = 10.00$

Test: H_0: x and y are independent, i.e., there is no correlation between subsamples.
H_a: x and y are dependent, i.e., there is correlation or association.

Test Statistic: $t = r_s\sqrt{\frac{N-2}{1-(r_s)^2}}$ ~ student's "t" with N-2 degrees of freedom

Rejection Rule: Reject H_0 if $t > t_{N-2}^{.975}$; $t_3^{.975}$ =3.182

Calculations:

$$r_s = 1 - \frac{6\Sigma d_i^2}{N^3-N} = 1 - \frac{6(10)}{120} = 0.50$$

$$t = 0.50\sqrt{\frac{3}{1-.25}} = 1.00 \ngtr 3.182$$

Conclusion: Fail to reject H_0. No correlation between subsamples.

1/ Number of larvae per 1000 m^3.

Table A-42.--Spearman Rank Non-parametric Correlation Tests on vertical distribution for bairdi tanner crab larvae in the Kiliuda Bay area of Kodiak Island, 1978.

Cruise 4

Depth (m)	Density estimated from original "500 organism" aliquot (x_i)	Rank of x_i	Density estimated from "extensive resort" subsample (y_i)	Rank of y_i	Difference in ranks (d_i)	Squares of differences (d_i^2)
10	792 1/	4	2101	4	0	0
30	2837	5	4337	5	0	0
50	60	3	30	3	0	0
70	0	1.5	16	2	.5	.25
90	0	1.5	1	1	.5	.25
						$\Sigma d_i^2 = 0.50$

Test: H_0: x and y are independent, i.e., there is no correlation between subsamples.
H_a: x and y are dependent, i.e., there is correlation or association.

Test Statistic: $t = r_s\sqrt{\frac{N-2}{1-(r_s)^2}}$ ~ student's "t" with N-2 degrees of freedom

Rejection Rule: Reject H_0 if $t > t_{N-2}^{.975}$; $t_3^{.975} = 3.182$

Calculations:

$$r_s = 1 - \frac{6\Sigma d_i^2}{N^3-N} = 1 - \frac{6(0.5)}{120} = 0.98$$

$$t = 0.98\sqrt{\frac{3}{1-.95}} = 7.65 > 3.182$$

Conclusion: Reject H_0. There is correlation between the subsamples.

1/ Number of larvae per 1000 m³.

Table A-43.--Spearman Rank Non-parametric Correlation Tests on vertical distribution for *bairdi* tanner crab larvae in the Kiliuda Bay area of Kodiak Island, 1978.

Cruise 5

Depth (m)	Density estimated from original "500 organism" aliquot (x_i)	Rank of x_i	Density estimated from "extensive resort" subsample (y_i)	Rank of y_i	Difference in ranks (d_i)	Squares of differences (d_i^2)
10	166 1/	5	1736	5	0	0
30	24	4	47	4	0	0
50	0	2	23	3	1	1
70	0	2	6	2	0	0
90	0	2	0	1	1	1
						$\Sigma d_i^2 = 2.0$

Test: H_0: x and y are independent, i.e., there is no correlation between subsamples.
H_a: x and y are dependent, i.e., there is correlation or association.

Test Statistic: $t = r_s\sqrt{\frac{N-2}{1-(r_s)^2}}$ ~ student's "t" with N-2 degrees of freedom

Rejection Rule: Reject H_0 if $t > t_{N-2}^{.975}$; $t_3^{.975} = 3.182$

Calculations:

$$r_s = 1 - \frac{6\Sigma d_i^2}{N^3-N} = 1 - \frac{6(2)}{120} = 0.90$$

$$t = 0.90\sqrt{\frac{3}{1-0.81}} = 3.674 > 3.182$$

Conclusion Reject H_0. There is correlation between subsamples.

1/ Number of larvae per 1000 m^3.

Table A-44.--Spearman Rank Non-parametric Correlation Tests on vertical distribution for _bairdi_ tanner crab larvae in the Kiliuda Bay area of Kodiak Island, 1978.

Cruise 6-12

Depth (m)	Density estimated from original "500 organism" aliquot (x_i)	Rank of x_i	Density estimated from "extensive resort" subsample (y_i)	Rank of y_i	Difference in ranks (d_i)	Squares of differences (d_i^2)
10	0	3	0	3	0	0
30	0	3	0	3	0	0
50	0	3	0	3	0	0
70	0	3	0	3	0	0
90	0	3	0	3	0	0

$\Sigma d_i^2 = 0$

Test: H_0: x and y are independent, i.e., there is no correlation between subsamples.
H_a: x and y are dependent, i.e., there is correlation or association.

Test Statistic: $t = r_s\sqrt{\frac{N-2}{1-(r_s)^2}}$ ~ student's "t" with N-2 degrees of freedom

Rejection Rule: Reject H_0 if $t > t_{N-2}^{.975}$; $t_3^{.975}$ =3.182

Calculations:

$$r_s = 1 - \frac{6\Sigma d_i^2}{N^3-N} = 1.0 = \text{correlation}$$

Table A-45.--Spearman Rank Non-parametric Correlation Tests on vertical distribution for *bairdi* tanner crab larvae in the Kiliuda Bay area of Kodiak Island, 1978.

Cruise 2-5 combined.

Depth (m)	Density estimated from original "500 organism" aliquot (x_i)	Rank of x_i	Density estimated from "extensive resort" subsample (y_i)	Rank of y_i	Difference in ranks (d_i)	Squares of differences (d_i^2)
10	240 1/	4	1146	4	0	0
30	751	5	1162	5	0	0
50	39	3	25	3	0	0
70	0	1.5	14	1	0.5	0.25
90	0	1.5	16	2	0.5	0.25
						$\Sigma d_i^2 = 0.50$

Test: H_0: x and y are independent, i.e., there is no correlation between subsamples.
H_a: x and y are dependent, i.e., there is correlation or association.

Test Statistic: $t = r_s\sqrt{\frac{N-2}{1-(r_s)^2}}$ ~ student's "t" with N-2 degrees of freedom

Rejection Rule: Reject H_0 if $t > t_{N-2}^{.975}$; $t_3^{.975} = 3.182$

Calculations:

$$r_s = 1 - \frac{6\Sigma d_i^2}{N^3 - N} = 1 - \frac{6(0.5)}{120} = 0.98$$

$$t = 0.98\sqrt{\frac{3}{1-0.95}} = 7.65 > 3.182$$

Conclusion: H_0 is rejected, correlation between subsamples.

1/ Mean density per 1000 m³ for cruises 2-5.

Appendix B

Appendix B

Literature References for Decapod Larvae Identification

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