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Plankton samples for this present study were collected from an area off the southern Oregon coast, extending westward to about 83 kilometers offshore. Over this sampling area, 41 species of adult copepods were identified, including representatives of 26 genera and 17 families. The total abundance averaged 550/m^3.

Population densities of copepods as a group were found higher inshore than offshore and this distribution was largely determined by four dominant species, that is, *Oithona similis*, *Pseudocalanus minutus*, *Acartia longiremis*, and *Acartia clausi*. They accounted for approximately 81% of the total copepod abundance.

Species diversity had a tendency to increase with distance from the coast. This could be due to the possibilities that the sampling depth was increased offshore, or that the living environment was more stable offshore than inshore.

Rank-correlation analysis of the four dominant species, fish eggs, copepod nauplii, euphausiids, and *Eucalanus bungii* suggest that the positively correlated category includes several pairs, *Oithona similis* to *Pseudocalanus minutus*, *O. similis* to *Acartia clausi*, *A. longiremis* to *P. minutus*, fish eggs to *O. similis*, *A. longiremis* to *A. clausi*, *O. similis* to copepod nauplii, and fish eggs to copepod nauplii. The negatively correlated category includes three pairs, euphausiids to copepod nauplii, euphausiids to fish eggs, and euphausiids to *O. similis*.

Results from the correlation analysis of the dominant species relative to temperature, salinity, and distance from shore show that no significant relationship was apparent except that the occurrence of *P. minutus* was negatively correlated to distance from shore.

The Copepods in a Collection from the Southern Coast of Oregon, 1963

by

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THE COPEPODS IN A COLLECTION FROM THE SOUTHERN COAST OF OREGON, 1963

INTRODUCTION

Objectives

Copepods, belonging to the class of Crustacea, are one of the most important links in a marine pyramid. They are very common in comparison to other plankton groups in the sea (Ackefors, 1965). In the old time they were known as sea-insects. Elton (1927) called copepods the key-industry animals, because they convert the energy produced by diatoms into animal substance. As it is well known, the copepods have long been considered to be an important food item for some commercial fishes; for example, *Calanus finmarchicus* and *Calanus tonsa* are the principal food for herring. Near the coast, it seems that where the *Calanus* are, the herring are almost sure to follow (Berrill, 1966). According to Lebour's (1918) study of the food of post-larval fish at Plymouth, *Pseudocalanus minutus*, *Acartia clausi*, *Temora longiremis* and *Calanus finmarchicus* were the four most common species of copepods eaten by the greater number of fish. Thus it is obvious that copepods not only provide food for fish but often serve as an indicator to the best fishing grounds (Marukawa, 1933). The abundance and distribution may also exert an important influence on the fishery, such as modifying the migration of fish or causing the decreases or increases in the quantity of fish caught (Clarke, 1934).

In a given copepod population, it appears that not all species are equally successful. The dominants in the population are represented by large numbers or large biomass. Odum (1963) pointed out that a few dominant species may exert a major controlling influence in the nature of a population by virtue of their numbers, distributional patterns, and activities. These dominant species may modify the environment in various ways for other species (Whittaker, 1965). A correlation analysis among dominant species shows if they tend to occur together or if they occur in opposite directions. As to the number of species, it is usually lower where the conditions of existence are unstable or severe (Odum, 1963). Therefore, the number of species in a population often shows the degree of stability of their living environment and the characteristics of dominant species.

Along the Oregon coast, the copepod population has been investigated since 1949, but observations off the southern Oregon coast are still far from complete. The purposes of this study are to 1) identify the dominant species, 2) search for correlations among the dominant species, 3) describe their horizontal distribution, 4) learn how species diversity is related to the distance from the coast and to some of the hydrographical features of these waters, and 5) compare the results to those from other areas, like the region off Newport.

Review of Literature

The earliest reference to the copepods of Oregon coastal water is that of Davis (1949), who reported 63 species in collections extending from San Francisco Bay on the south to the Aleutian Island on the north, including the inland waterways of the coasts of Washington and British Columbia. Frolander (1962) described the quantitative estimation of zooplankton off the coasts of Washington and British Columbia. In his plankton samples, *Pseudocalanus minutus* and *Oithona similis* were the most numerous zooplankters. Species of cyclopoid copepods occurring in the coastal waters of Oregon, California, and lower California were listed by Olson (1963). In the northeast Pacific albacore oceanography survey, Owen (1963) listed twenty-six species of copepod, of which *Eucalanus bungii californicus*, *Calanus finmarchicus* and *Microcalanus* sp. were the most common species. These species were different from those found by Frolander (1962) and Cross (1964); possibly due to the variation of station locations and of sampling season.

Several theses from Oregon State University deal with copepods from Oregon coastal waters. The seasonal and geographical distribution of pelagic species has been investigated by Cross (1964). He reported that *Pseudocalanus minutus*, *Oithona similis*, *Acartia longiremis*, *Acartia danae* and *Centropages abdominalis* (= *C.*

mcmurrichi)[1] were the most significant species off Brookings. The last two species were described as possible indicators of seasonal hydrographic change because they were not present at all times of the year. This was also noted by Frolander (1962) and Hebard (1966). During the summer time, from July through September, a southerly current was developed and A. danae was absent within 105 kilometers (65 miles) from the Oregon coast, while in the winter time the reappearance of A. danae was accompanied by the presence of the northerly flow of the Davidson current. The reverse was true of C. abdominalis, which occurred only from April to September. Since the periodic occurrence of A. danae and C. abdominalis appeared to correlate closely with the north-south seasonal changes of coastal water flow, Frolander (1962) considered A. danae as a species indicative of intrusion of near surface water from the south, Cross (1964) suggested that both species may be used as reciprocal indicators of seasonal change in surface current off Oregon.

Distribution of copepods in relation to oceanographic conditions were studied by Hebard (1966), who found 67 species of copepod from four stations off Newport, Oregon. Results from Hebard's association analysis of copepods and euphausiids revealed that Calanus

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[1] Although frequently called Centropages mcmurrichi Willey, 1920, this species was described by Sato (1913) under the name Centropages abdominalis. This name is used by Mori (1937).

finmarchicus and *Calanus pacificus* were the most closely associated group and the more loosely associated groups contained the copepods *Eucalanus bungii*, *Pareuchaeta japonica*, *Pleuromamma xiphias*, *Gaidius pungens*, and *Euchirella pulchra*, and the euphausiid, *Nematoscelis difficilis*.

Coastal upwelling and the ecology of lower trophic levels, such as copepods and euphausiids were described by Laurs (1967) off southern Oregon. For convenience, he divided the hydrographic conditions of Oregon coastal waters into four periods, that is, pre-upwelling, early upwelling, active upwelling and late upwelling. Active upwelling occurred from April to July, late upwelling from August to October. During the period of active upwelling, the isopleths of temperature, salinity, oxygen and phosphate were tilted sharply upward. In the late upwelling stages, all of these isopleths tend to flatten out near the surface. However, the distribution of temperature and salinity at the late upwelling stage indicated that upwelling was well developed north of latitude 42°30', but less developed to the south, including the C, D, E, and F sampling lines of this study.

Laurs (1967) also collected my samples and provided the hydrographic data (Appendix 5). He reported that the near-surface water observed from the U.S. Coast Guard Cutter MODOC 16-20 August 1963 was about 1 to 4 C colder inshore than offshore. The 10 C isotherm lay near the shore, while at the longitude of 125°15', the temperature increased to 12-14 C. The salinity of surface water was higher inshore than offshore, showing a difference of only 0.6 ‰. Laurs also reported that the standing stocks of trophic level 1 were also considerably higher inshore than they were offshore. However, he found the seasonal variation in the standing stock of phytoplankton at individual stations was large but that the differences between stations in the mean stocks were small.

MATERIALS AND METHODS

The materials for the present study were taken from about a 6,800 square kilometer area off the southern Oregon coast, extending from Cape Blanco south to the Oregon-California border and from the Oregon coastline westward about 83 kilometers to approximately 125°13.6'W (as shown in Table 1). These samples were collected by Dr. R. M. Laurs on a cruise of United States Coast Guard Cutter MODOC, August 16-20, 1963. In this square-like area, 25 samples were collected along six sampling lines, line A to F (Figure 1). Usually, five collections were made on each line and vertical hauls were taken from 270 meters to the surface, except in the shallower near-shore region. Hauls were taken with a one-half meter net (entrance 0.196 meter square) with 0.239 mm mesh. The plankton samples were preserved immediately in the field with ten percent buffered sea-water formalin.

In the laboratory, the larger forms such as fish larvae, amphipods, medusae, and chaetognaths were removed first. The larger copepods, such as Calanus finmarchicus, Eucalanus bungii, and Euchaeta japonica were also sorted out except when they were very numerous. Then, the rest of the sample was subdivided five or six times with a Folsom Plankton Splitter. The sub-samples were examined under the binocular microscope. The adult copepods were

Table 1. Sampling stations, MODOC cruise, 16-20 August, 1963.

Station no.	Date	Time	Wire out (M)	Latitude	Longitude
A-1	16 Aug.	1625-1630	40	42 49.8N	124 39.6W
A-2	"	1815-1825	178	42 49.6	124 48.0
A-4	"	2311-2320	270	42 47.8	125 16.1
B-2	17 Aug.	1700-	75	42 39.6	124 33.3
B-3	"	1435-1450	270	42 39.7	124 46.0
B-4	"	1120-1140	270	42 39.7	124 58.5
B-5	"	0813-	270	42 39.0	124 14.0
C-1	"	1910-1915	50	42 29.9	124 32.2
C-2	"	2132-2147	270	42 29.6	124 46.2
C-4	18 Aug.	0331-0344	270	42 29.9	125 15.0
D-1	19 Aug.	1003-1005	50	42 19.6	124 28.5
D-2	"	0842-0845	80	42 20.1	124 32.8
D-3	"	0620-0634	270	42 19.9	124 45.5
D-4	"	0320-0332	270	42 19.9	124 58.2
D-5	"	0016-0027	270	42 20.5	125 12.3
E-1	"	1202-1205	50	42 09.9	124 24.4
E-2	"	1345-1355	140	42 10.0	124 33.1
E-3	"	1558-1611	270	42 09.9	124 46.0
E-4	"	1838-1847	270	42 09.4	124 59.8
E-5	"	2054-2104	270	42 09.9	125 12.9
F-1	20 Aug.	1848-1851	35	41 59.0	124 19.5
F-2	"	1617-1625	140	41 59.1	124 32.1
F-3	"	1146-1202	270	41 59.2	124 45.6
F-4	"	0848-0857	270	41 59.4	124 59.4
F-5	"	0550-0600	270	41 59.7	124 13.6

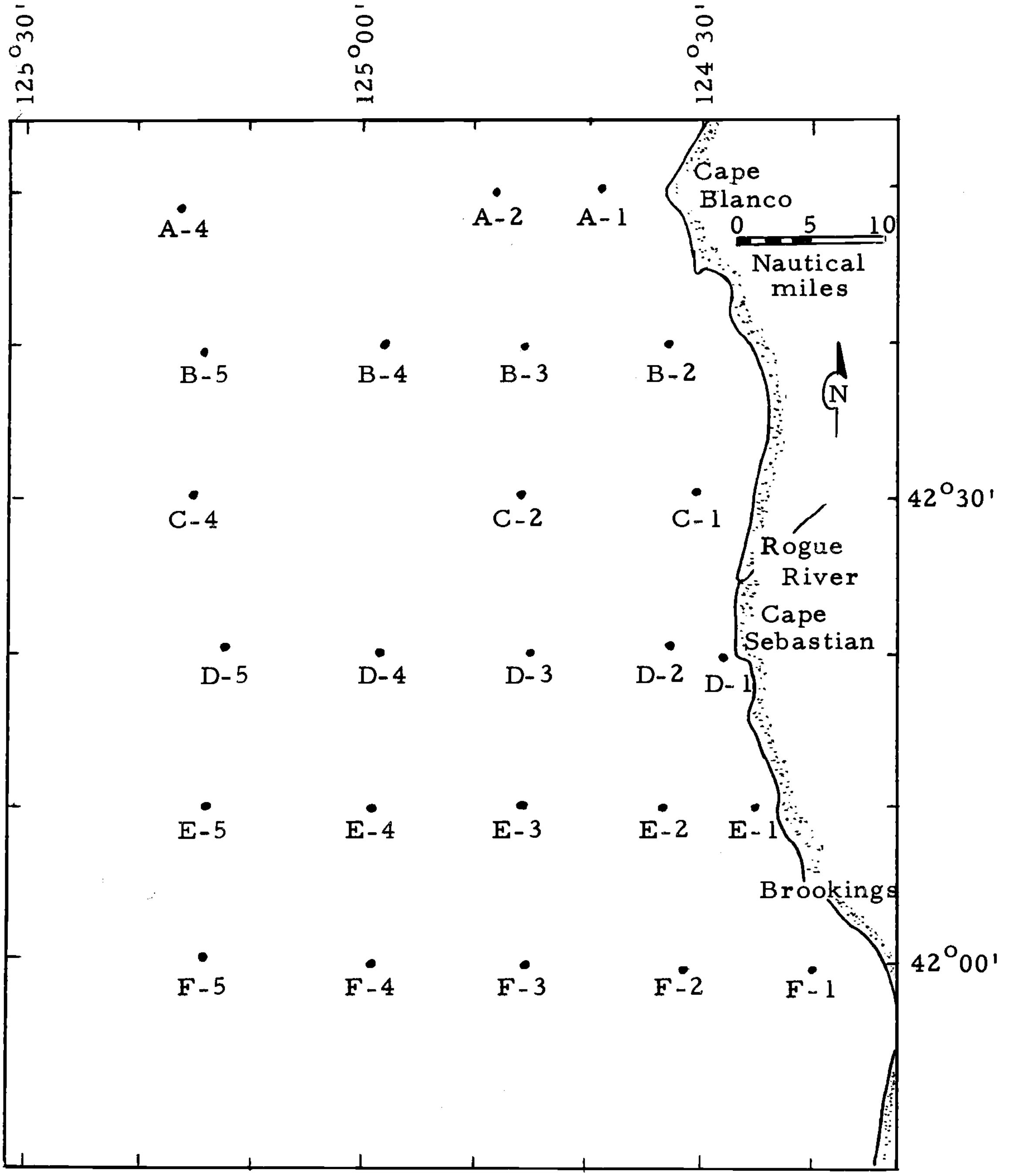


Figure 1. Station locations for MODOC cruise, 1963.

identified to species. The other zooplankton, including copepodites, were identified to genera only, or even to family or class.

The books used for copepod identification were by Brodskii (1967), Davis (1949), Grice (1961), Hardy (1965), Mori (1937), Newell (1963), Park (1968), Rose (1933) and Jespersen and Russell (1960).

The abundance of copepods is usually expressed as either number per cubic meter or number below one square meter of sea surface. The former is used in this study. No flow meter was used in making the MODOC-63 hauls. Since they were vertical tows, the amount of water filtered can be estimated by the following steps:

1) Assume the filtration efficiency of the plankton net was 100 percent.
2) Then, Volume of water filtered = (Depth of haul) x (Mouth area of net = 0.196 m^2) x 1.0 (= filtration efficiency).

The number of copepods per cubic meter is then calculated from the formula: $\text{no./m}^3 = [\text{subsample count} \times 2^{(\text{no. of splits})}] / \text{vol. of water filtered}$. After all calculations were made, the abundance of copepods was expressed by the number of organisms per cubic meter (Appendix 3).

RESULTS

Spatial Distribution of Copepods

Zooplankton Composition

In this study the zooplankton composition was divided into seven categories: copepods, copepodites, cladocerans, other crustacea, other larvae, amphipods, and other plankton (see Table 2). Copepod population contributed 85 percent of the total number. Forty-one species of adult copepods were identified, representing 26 genera and 17 families. All were typically marine species (see Appendix 3).

Because of their small size and incompletely developed appendages no attempt was made to identify the small copepodites or to count them. Other groups represented in the samples included cladocerans, polychaete larvae, fish eggs, oikopleurans, and cephalopods, of which fish eggs contributed significantly to the total number of zooplankters at stations of B-4, E-4, F-4, and F-5. Whether or not their distribution and occurrence was correlated with the abundance of copepods needs further investigation. There were only two species of Cladocera, *Podon leuckarti* and *Evadne nordmanni*. Their occurrence was sporadic and their numbers low.

Total Abundance of Copepods

Over the sampling area, the copepod population was very high

Table 2. Families, genera, and species of copepods and some other zooplankton in the samples.

Family	Genus	Species
COPEPODS		
Calanidae	Calanus	C. finmarchicus (Gunner)
		C. pacificus Brodsky
		C. cristatus Krøyer
Eucalanidae	Eucalanus	E. bungii Giesbrecht
		E. elongatus hyalinus Giesbrecht
	Rhincalanus	R. naustus Giesbrecht
Pseudocalanidae	Clausocalanus	C. arcuicornis (Dana)
	Pseudocalanus	P. minutus (Krøyer)
Aetideidae	Aetideus	A. armatus (Boeck)
	Gaidius	G. brevispinus (Sars)
		G. tenuispinus (Sars)
		G. pungens Giesbrecht
Euchirellinae	Euchirella	E. pulchra (Lubbock)
		E. curticauda Giesbrecht
	Chirundina	C. streetsi Giesbrecht
	Undeuchaeta	U. major Giesbrecht
		U. plumosa (Lubbock)
Euchaetidae	Euchaeta	E. japonica (Marukawa)
Phaennidae	Phaenna	P. spinifera Claus
Scolecithricidae	Scottocalanus	S. persecans (Giesbrecht)
	Lophothrix	L. frontalis Giesbrecht
	Scaphocalanus	S. brevicornis Sars
Metridiidae	Metridia	M. lucens Boeck
	Pleuromamma	P. abdominalis (Lubbock)
		P. xiphias (Giesbrecht)
		P. quadrungulata (Dahl)
		P. scutullata Brodsky
Centropagidae	Centropages	C. abdominalis Willey
Lucicutiidae	Lucicutia	L. flavicornis (Claus)

(Continued on next page)

Table 2. (Continued)

Family	Genus	Species
Heterorhabdidae	*Heterorhabdus*	*H. tanneri* (Giesbrecht)
	Heterostylites	*H. longicornis* (Giesbrecht) *H. major* (Dahl)
Candaciidae	*Candacia*	*C. columbiae* Campbell *C. bipinnata* Giesbrecht
Pontellidae	*Labidocera*	*L. amphitrites* (McMurrich)
Acartiidae	*Acartia*	*A. clausi* Giesbrecht *A. tonsa* Dana *A. longiremis* (Lilljeborg)
Oithonidae	*Oithona*	*O. similis* Claus *O. spinirostris* Claus
Oncaeidae	*Oncaea*	*O. conifera* Giesbrecht
Corycaeidae	*Corycaeus*	*Corycaeus* sp.

COPEPODITES

Calanus
Eucalanus
Pseudocalanus
Aetideus
Gaidius
Euchirella
Euchaeta
Scottocalanus
Lophothrix
Metridia
Pleuromamma
Lucicutia
Heterorhabdus
Acartia
Oithona

CLADOCERANS

Podon leuckarti Sars
Evadne nordmanni Loven

OTHER CRUSTACEANS

Copepod nauplius
Barnacle nauplius
Conchoecia sp.
Euphausiid
Cyprius

(Continued on next page)

Table 2. (Continued)

OTHER LARVAE

- Decapod larva
- Polychaeta larva
- Gastropoda larva
- Euphausiid larva
- Fish larva

AMPHIPODS

- *Primno abyssalis*
- *Phronima sedentaria*
- *Parathemisto* sp.
- *Tryphana* sp.
- *Streetsia* sp.

OTHER PLANKTON

- *Doliolum*
- Medusa
- Fish egg
- Radiolarian spp.
- Cephalopod
- Chaetognath
- *Oikopleura* sp.

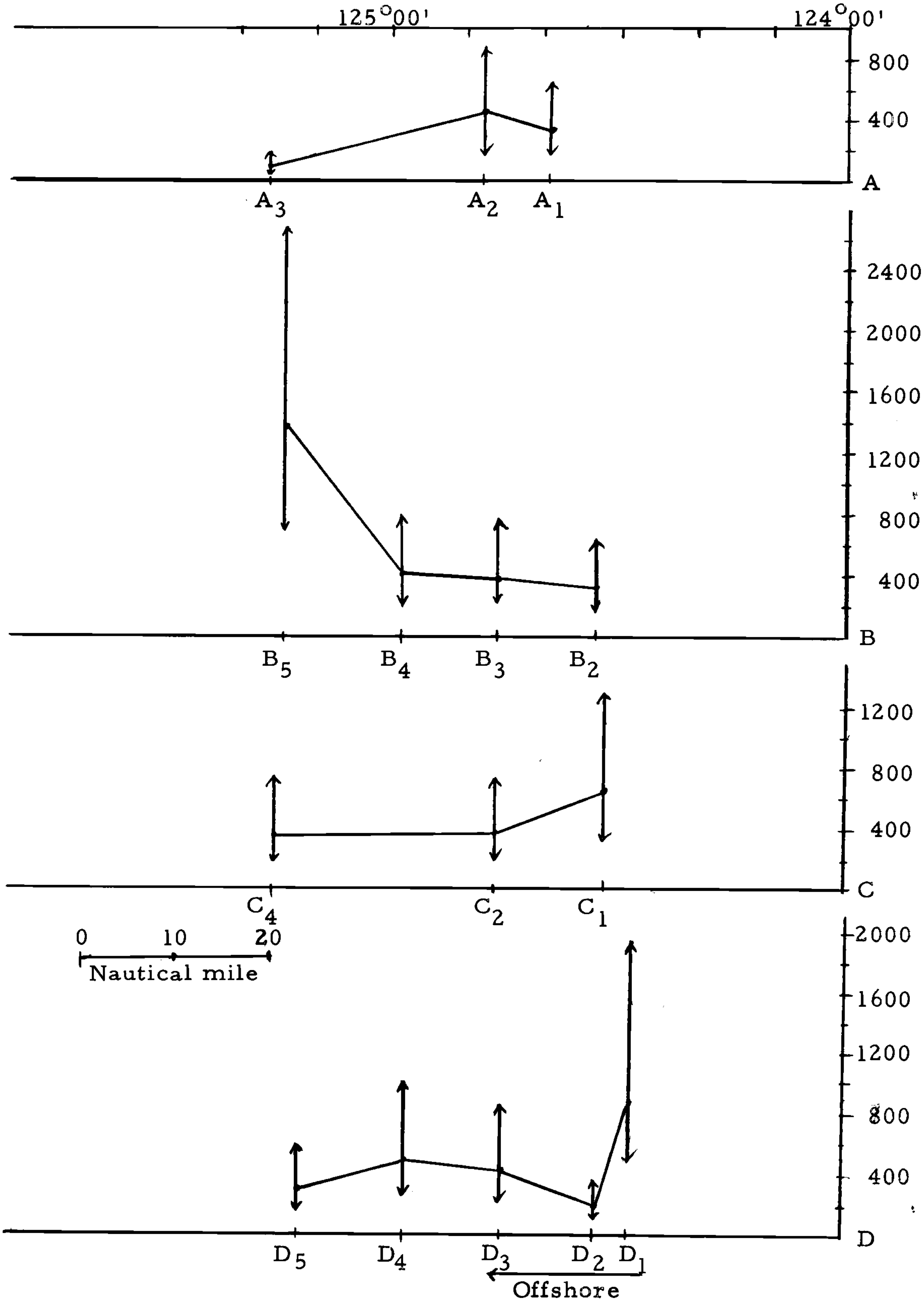
compared to the other six groups, ranging from 87/m^3 to 1626/m^3 with a mean abundance of 550/m^3 for these 25 observations during mid-August. Copepod abundance was found not to be positively related to its percentage in total zooplankton. For example, the highest density of copepods in the sample was 1626/m^3, which occurred at station F-1, where it composed about 72 percent of all zooplankton. While at station C-2, the abundance was 372.4/m^3, approximately 0.23 times that found in station F-1. Yet it represented over 98 percent of the entire zooplankton (see Table 3).

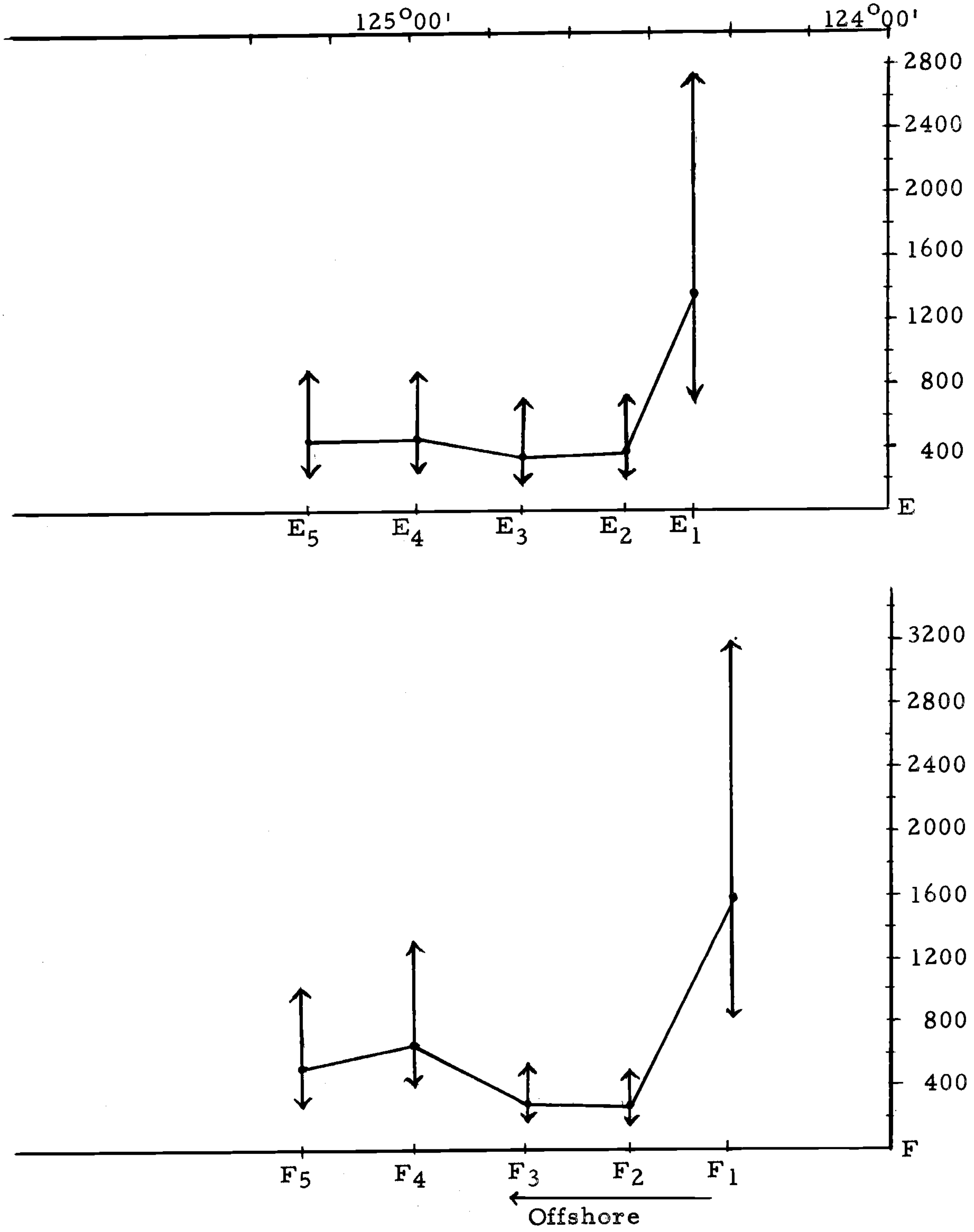
Figure 2 shows the relationship of total abundance of copepods to distance from the coast. No strong or consistent relationship is apparent. Nevertheless, it is possible to generalize to some degree and in the six sampling lines (from A to F) as a whole, two peaks occurred, one with an average number of 1311/m^3 was found nearest the coast, about 5.5 kilometers offshore, and the other was observed along the longitude of 125°00'W, with the average concentration of 603/m^3. The patterns of fluctuation along D, E, and F lines were similar to the extent that the abundance decreased first, then reached a secondary maximum. On the B line, the density increased seaward and the maximum abundance occurred at the farthest station B-5. The pattern of C line was the reverse of B line. On the A line, the greatest abundance was at the intermediate distance from the coast, approximately 21 kilometers off Cape Blanco.

Table 3. Total abundance, percentage of copepods, number of species and volume of water filtered at each station.

Station no.	Total abundance of zooplankton (no. /m^3)	Total abundance of copepods (no. /m^3)	Percentage of copepods (%)	Number of species	Volume of water filtered (m^3)
A-1	390.1	332.7	85.3	5	7.8
A-2	485.7	456.2	93.9	14	34.9
A-4	155.5	87.4	56.2	24	52.9
B-2	335.6	315.2	93.9	8	14.7
B-3	399.9	388.9	97.2	16	52.9
B-4	461.5	411.7	89.2	12	52.9
B-5	1416.7	1361.0	96.1	18	52.9
C-1	865.9	630.2	72.8	5	9.8
C-2	378.8	372.4	98.3	13	52.9
C-4	465.8	368.1	79.0	25	52.9
D-1	1452.2	948.2	65.3	11	9.8
D-2	223.3	198.3	89.2	9	15.7
D-3	500.8	418.2	83.5	21	52.9
D-4	561.4	490.2	87.3	22	52.9
D-5	340.5	307.1	90.2	18	52.9
E-1	2068.8	1360.4	65.8	6	9.8
E-2	407.1	373.8	91.8	11	27.4
E-3	453.7	325.5	71.7	18	52.9
E-4	1016.3	852.1	83.8	15	52.9
E-5	461.7	430.5	93.2	21	52.9
F-1	2260.3	1626.8	72.0	7	6.9
F-2	300.0	259.7	86.6	14	27.4
F-3	348.6	261.8	75.1	10	52.9
F-4	838.7	656.2	78.2	11	52.9
F-5	619.4	526.3	85.0	21	52.9

Figure 2. Total abundance of copepod in relation to the six sampling lines. Vertical arrows extend between confidence limits taken to be one-half to double the sample abundance estimate.


125°00'
124°00'
800
400
A
A_3
A_2
A_1
2400
2000
1600
1200
800
400
B
B_5
B_4
B_3
B_2
1200
800
400
C
C_4
C_2
C_1
0
10
20
Nautical mile
2000
1600
1200
800
400
D
D_5
D_4
D_3
D_2
D_1
Offshore


125°00'
124°00'
2800
2400
2000
1600
1200
800
400
E
E5
E4
E3
E2
E1
3200
2800
2400
2000
1600
1200
800
400
F
F5
F4
F3
F2
F1
Offshore

Copepod abundance increased from north to south, although relatively high mean catches appeared on the B line stations. Off Brookings, the average abundance reached 662/m^3, which showed little difference from that found in mid-August of 1962 by Cross (1964), who found 800/m^3. This was possibly related to some random variation between times of sampling, or to changes of environmental factors in different years.

As it will be seen later, the distribution of total abundance of copepods in this study is largely determined by the two most dominant species, Oithona similis and Pseudocalanus minutus. These two species dominated numerically the entire copepod population and particularly were found in most abundance near the coast (see Appendix 1). Brodskii (1950) has noted that P. minutus is characteristic of the neritic and northern cold water. Mori (1937) considered O. similis to be a species which was widely distributed in the water of the world and adapted to a somewhat low temperature. In the period of 16-20 August 1963, the near surface water temperature was 1 to 4 C warmer offshore than inshore. This perhaps is attributable to the coastal upwelling which lowers the surface temperature. The mean standing stock of chlorophyll "a" observed at the inshore stations was approximately 1.3 to 1.8 times higher than the mean value found at offshore stations (Laurs, 1967). Thus the profusion of copepod population at the inshore stations may be due to the combined effects of

1) distributional characteristics of dominant species, 2) lower inshore surface water temperature, and 3) higher inshore chlorophyll "a".

On the B line, the highest abundance appearing at the offshore station B-5 may be due to the nonrandom spatial distribution of copepods, since zooplankton patchiness can be an important component of zooplankton sampling error (Wiebe and Holland, 1968).

Wiebe and Holland (1968) summarized field estimates of the total sampling error from 13 studies and found that the 95 percent confidence limits usually exceed half or double the observed value regardless of the type of net, the method used in towing, or the organisms used in calculations. If one-half and double field variability limits are considered to apply in the present study (see graphical presentation of confidence limits in Figure 2), field error makes the abundance of copepod at station B-4 and B-5 hardly distinguishable. It seems that the secondary maximum of D, E, and F lines found at the longitude of about 125°00'W, may also be sampling artifacts. However, despite the use of field error estimates, the abundance at station D-1, E-1, and F-1 was higher than the next stations offshore.

Some Important Species and Their Distribution

In the present study, the most important species among the forty-one species identified were *Oithona similis*, *Pseudocalanus minutus*, *Acartia clausi*, and *A. longiremis*. These four species dominated the entire population of copepods over the 25 sampling stations, where they accounted for approximately 81 percent of the total copepod abundance (see Appendix 1). One species, *Centropages abdominalis*, is thought to be associated with changes of hydrographic conditions (Cross, 1964; Hebard, 1966), although its exact role in the Oregon coastal waters remains uncertain. This species was recorded only in three samples of my collection, B-3, B-4 and D-2, and their number was low, not more than 5/m^3. Cameron (1957) reported that *Aetideus armaratus*, *Oithona spinirostris*, and *Eucalanus bungii* were associated with subsurface forms. The last species was previously recorded only from the northern Pacific and the adjacent Arctic near Japan (Davis, 1949). In my study, its occurrence was frequent but in low numbers (see Appendix 2).

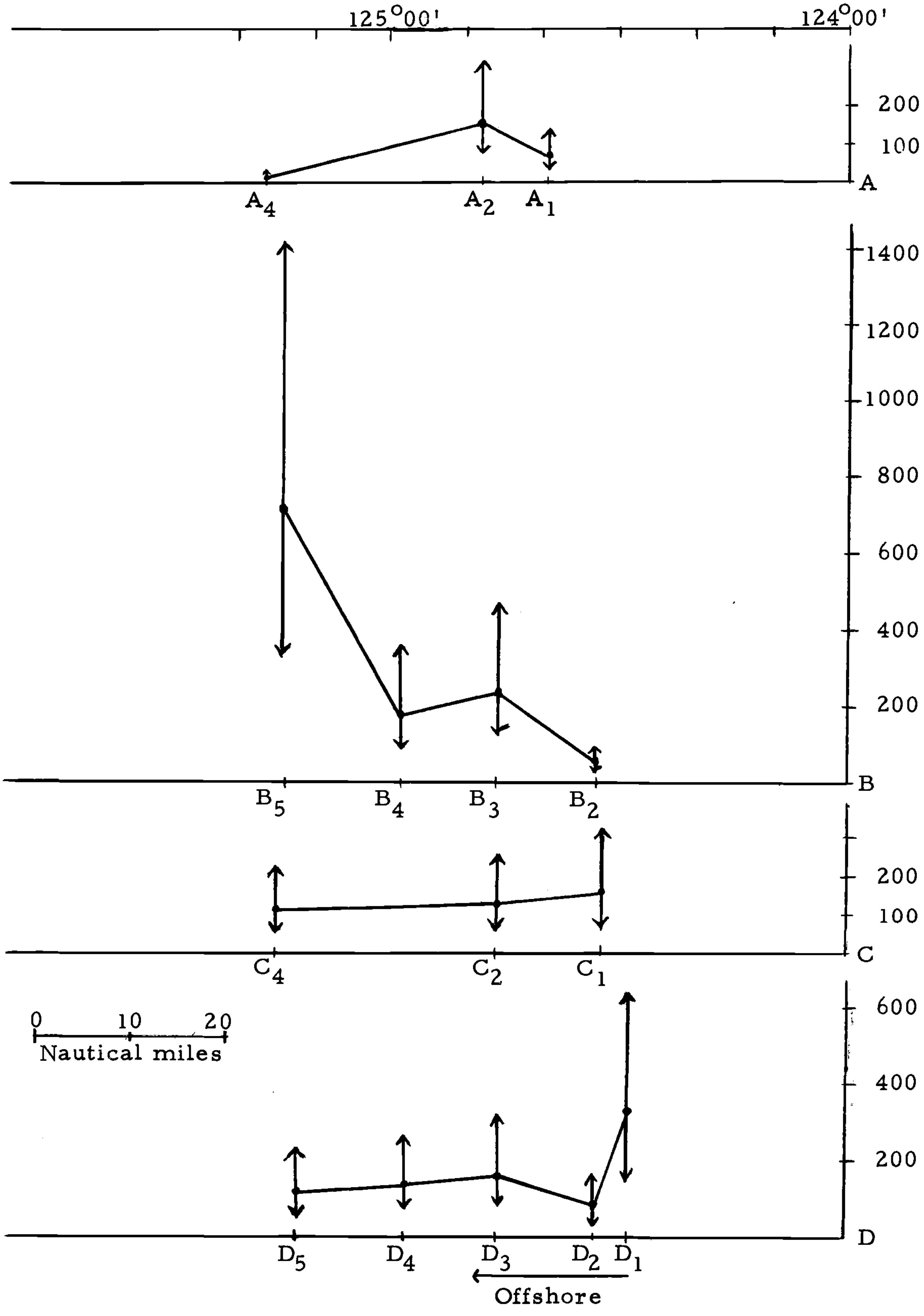
Oithona similis. Information on abundance and seasonal fluctuation of *Oithona similis* has been reported by Cross (1964), but his survey was largely confined to the regions off Astoria, Newport, Coos Bay, and Brookings, and the plankton collections were made only during June and late July. Hebard (1966), in his study off Newport, did not report this species. His plankton data were collected between May, 1963 and July, 1964.

In the present study, *O. similis* was the most abundant species from the 25 stations, comprising about 35.3 percent of the total copepod population. Comparison of distribution of *O. similis* and the total copepod population revealed several similarities in the change of abundance with distance off the coast. Along the D, E, and F lines (Figure 3), *O. similis* had one peak on the stations of D-3, E-4, and F-4 and generally low numbers offshore. An offshore station B-5 showed maximum number of $715/m^3$. This was opposite to the distributional patterns of other five sampling lines. As already mentioned, it might be due to local variation of sampling.

Pseudocalanus minutus. This species was found both in the open ocean and near shore. In the present study, it made up 34.5 percent of the copepod population, and is probably not significantly less than *O. similis*. *Pseudocalanus minutus* was found at all stations. Its variation of abundance (Figure 4) with the distance off the shore was closely parallel to that of *O. similis*, although some discrepancies existed. A major distinction between these two species was that the secondary maximum, which occurred in the D, E, and F lines for *O. similis* was almost absent for *P. minutus*. As a whole, this species followed a decreasing trend in abundance at offshore stations, confirming earlier work by Cross (1964) in Oregon coastal waters.

Acartia clausi. This species was the third most important species (Figure 5). Although its abundance was great inshore, it did not contribute greatly to the total copepod population. The average percentage was 5.7 percent, just a little higher than that of *A. longiremis*. Its abundance varied among stations, in general, the

Figure 3. Abundance of *Oithona similis* in relation to the six sampling lines. Vertical arrows extend between confidence limits taken to be one-half to double the sample abundance estimate.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A
A_4
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B
B_5
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B_3
B_2
200
100
C
C_4
C_2
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Nautical miles
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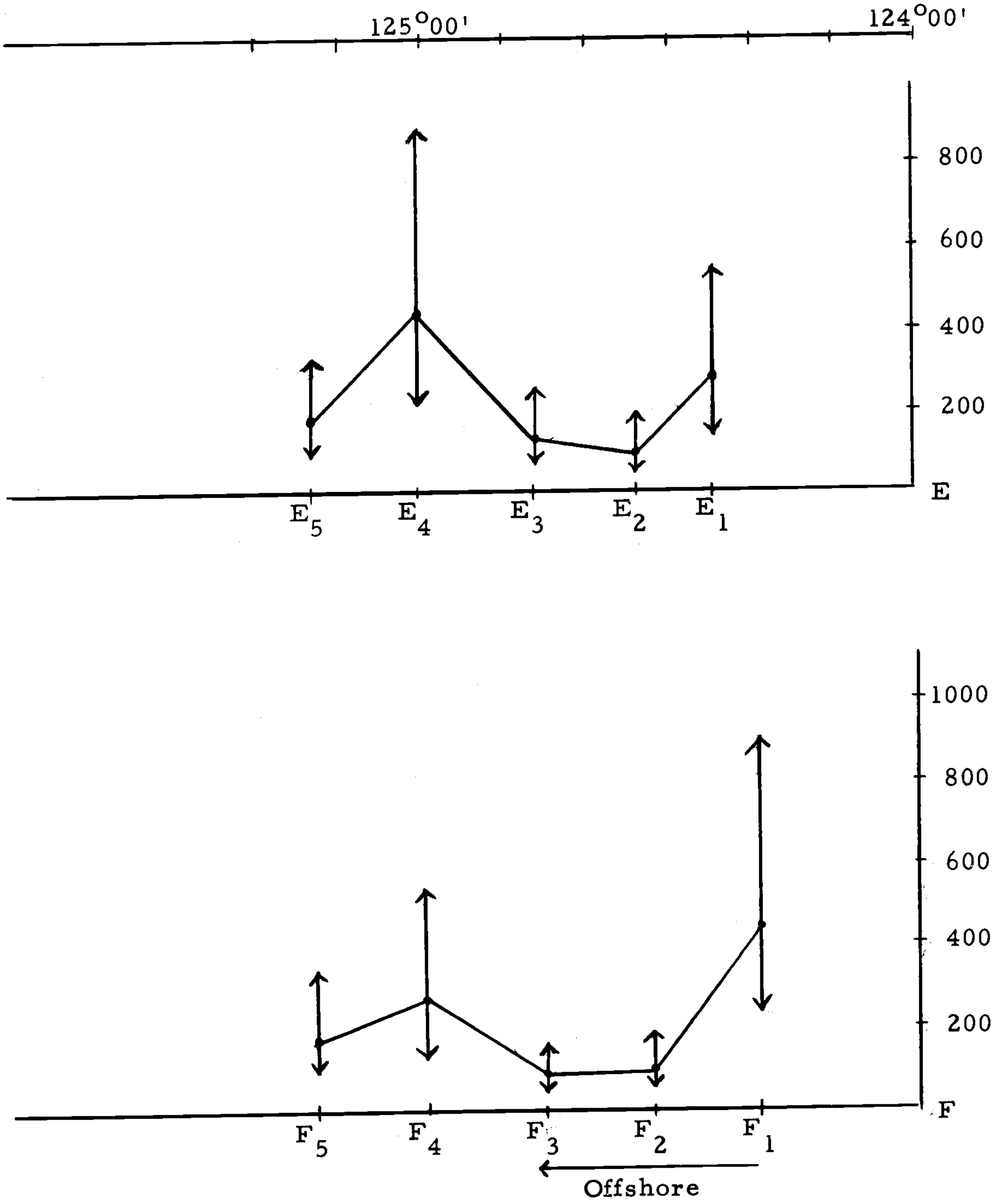
D_1
Offshore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F
F5
F4
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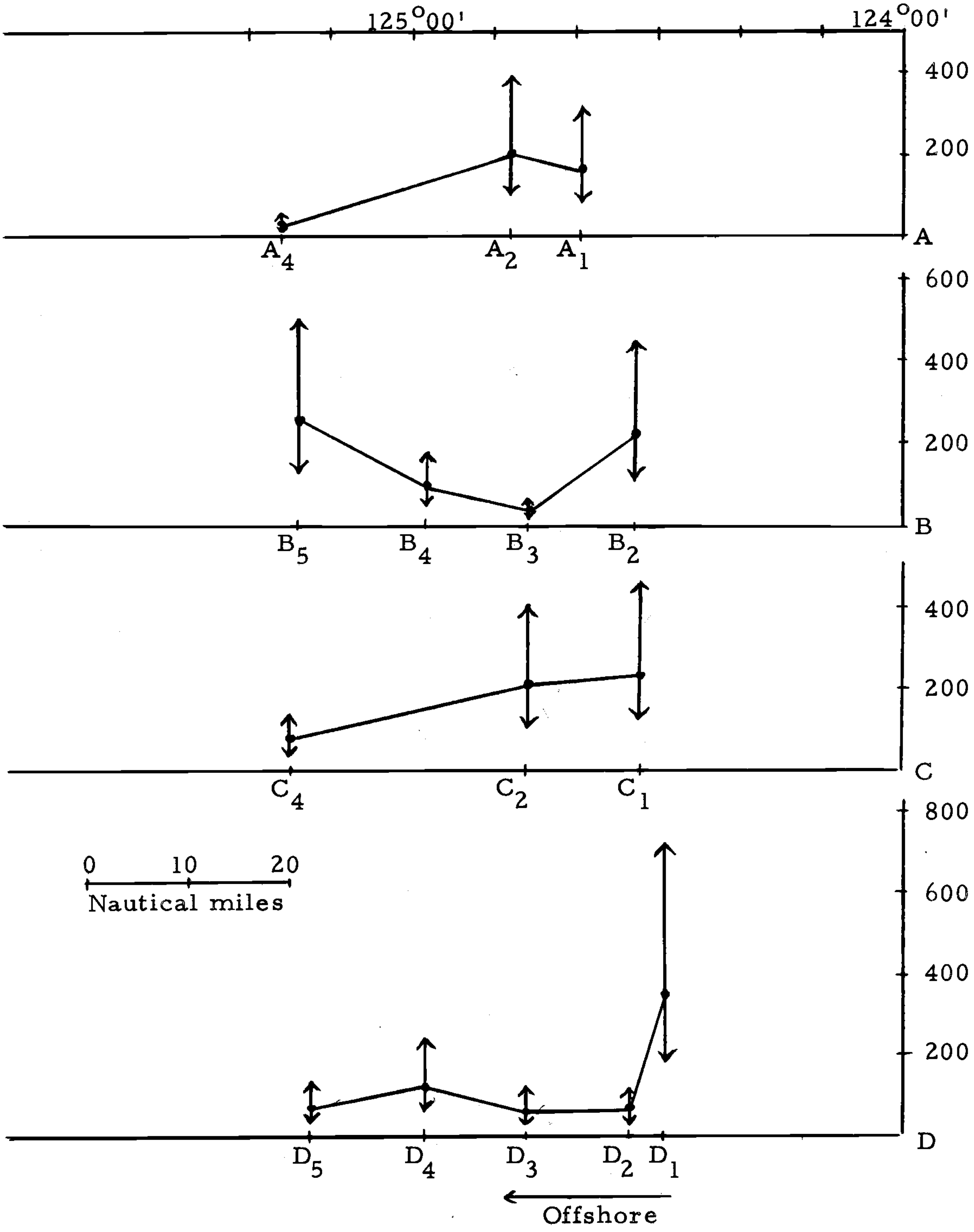
F1
Offshore

Figure 4. Abundance of _Pseudocalanus minutus_ in relation to the six sampling lines. Vertical arrows extend between confidence limits taken to be one-half to double the sample abundance estimate.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C
C4
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Nautical miles
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D2
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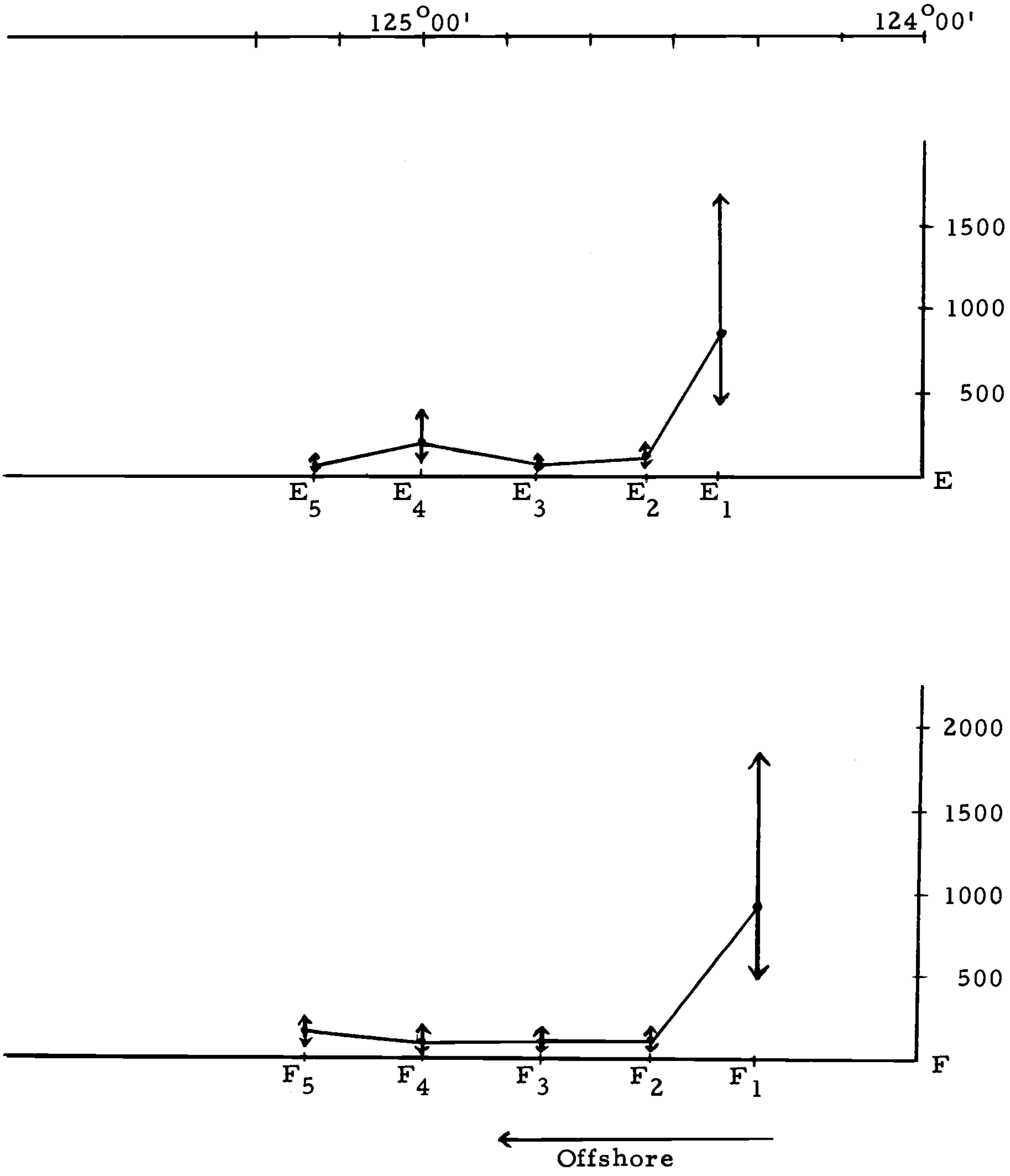
Offshore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F4
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F2
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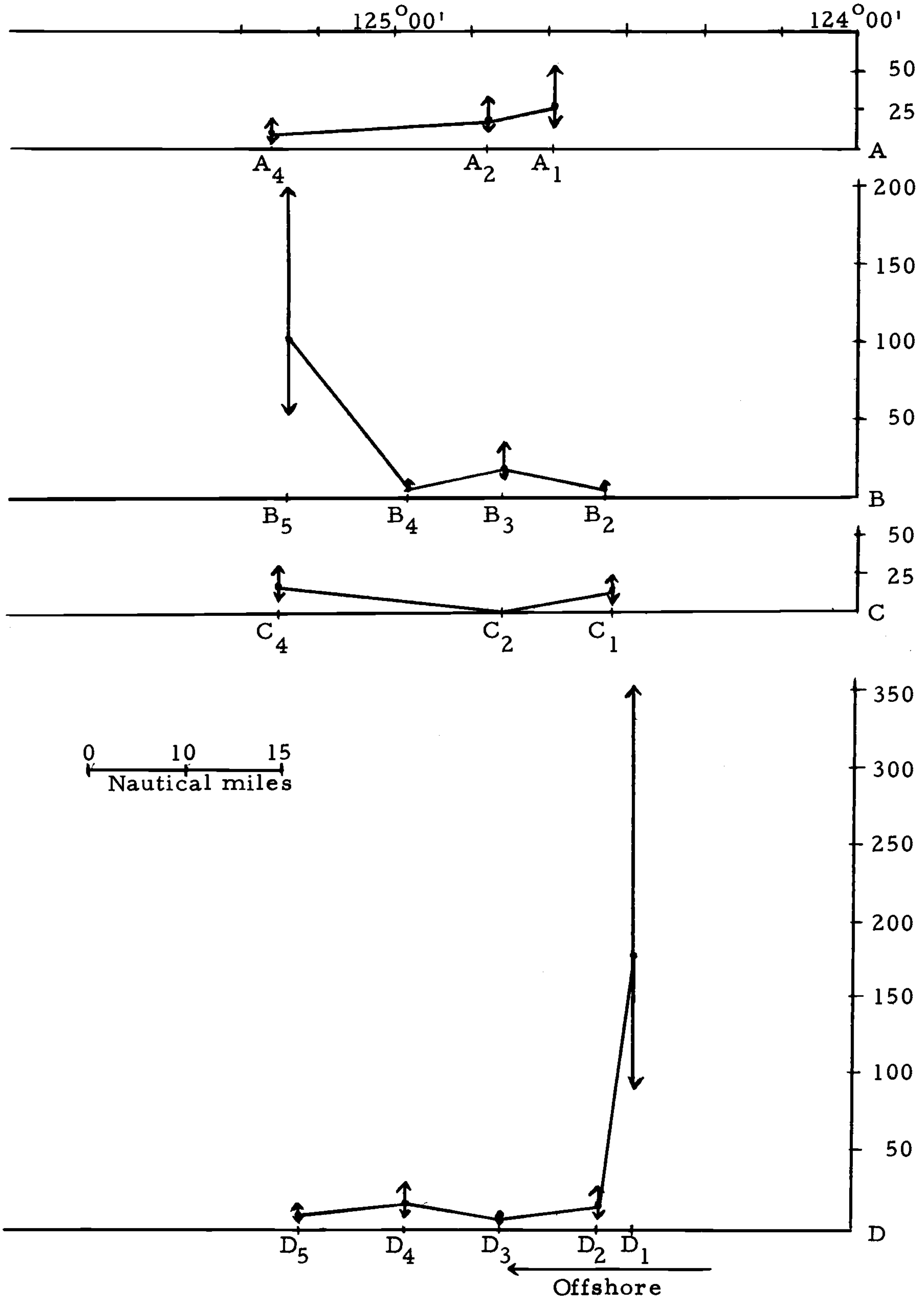
Offshore

Figure 5. Abundance of _Acartia clausi_ in relation to the six sampling lines. Vertical arrows extend between confidence limits taken to be one-half to double the sample abundance estimate.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B5
B4
B3
B2
50
25
C
C4
C2
C1
350
300
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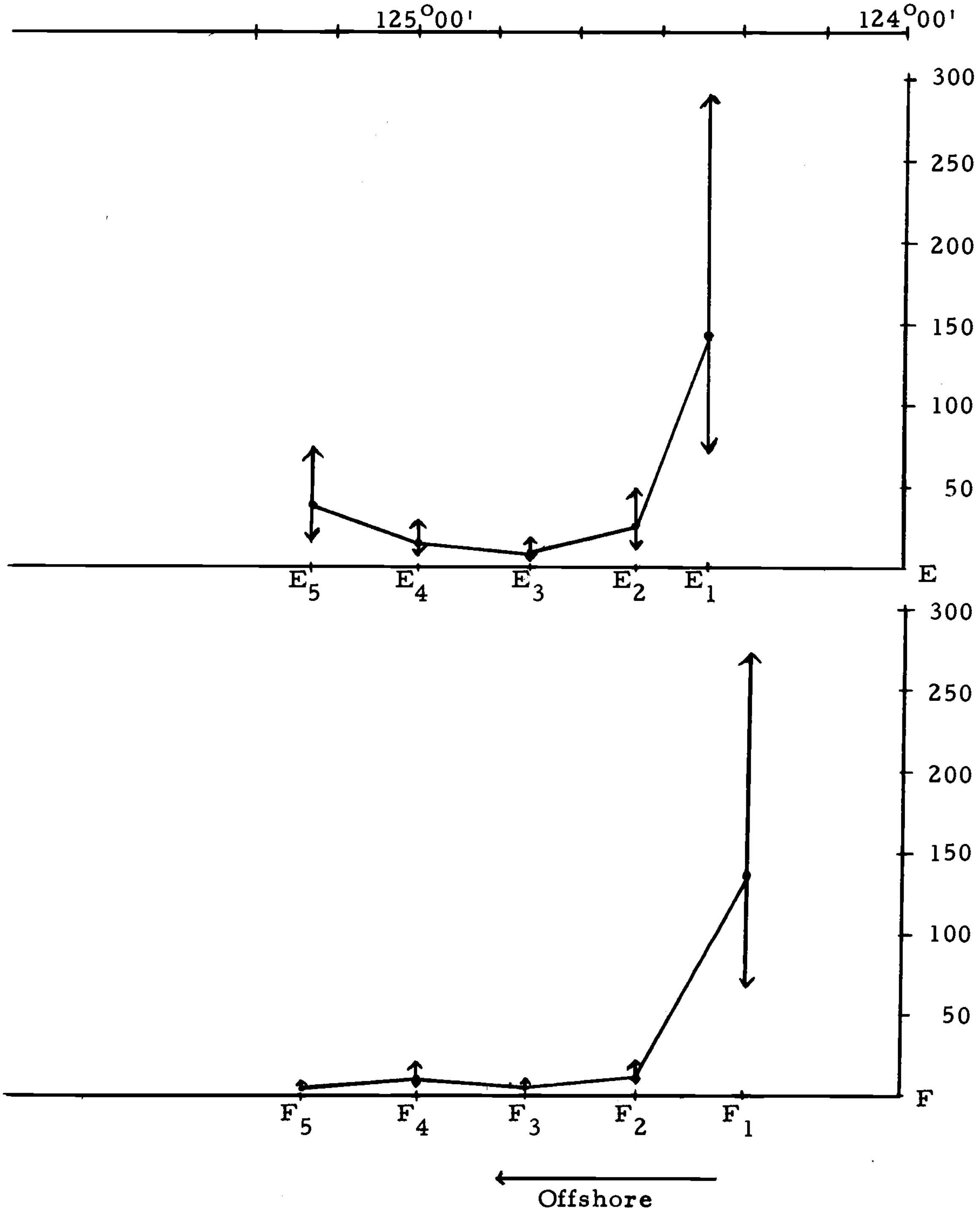
50
D
0
10
15
Nautical miles
D5
D4
D3
D2
D1
Offshore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F5
F4
F3
F2
F1
Offshore

highest abundance occurred adjacent to the coast, with the average concentration of 84.2/m^3, then decreased progressively offshore. Again, the reverse trend was noted along stations of line B.

Acartia longiremis. Although Brodskii (1950) noted that this species is more limited and northern in distribution than A. clausi, it was widespread for the area of this study. It occurred at all stations, but its distribution (Figure 6) varied greatly among the six sampling lines. The average percentage of A. longiremis was five percent.

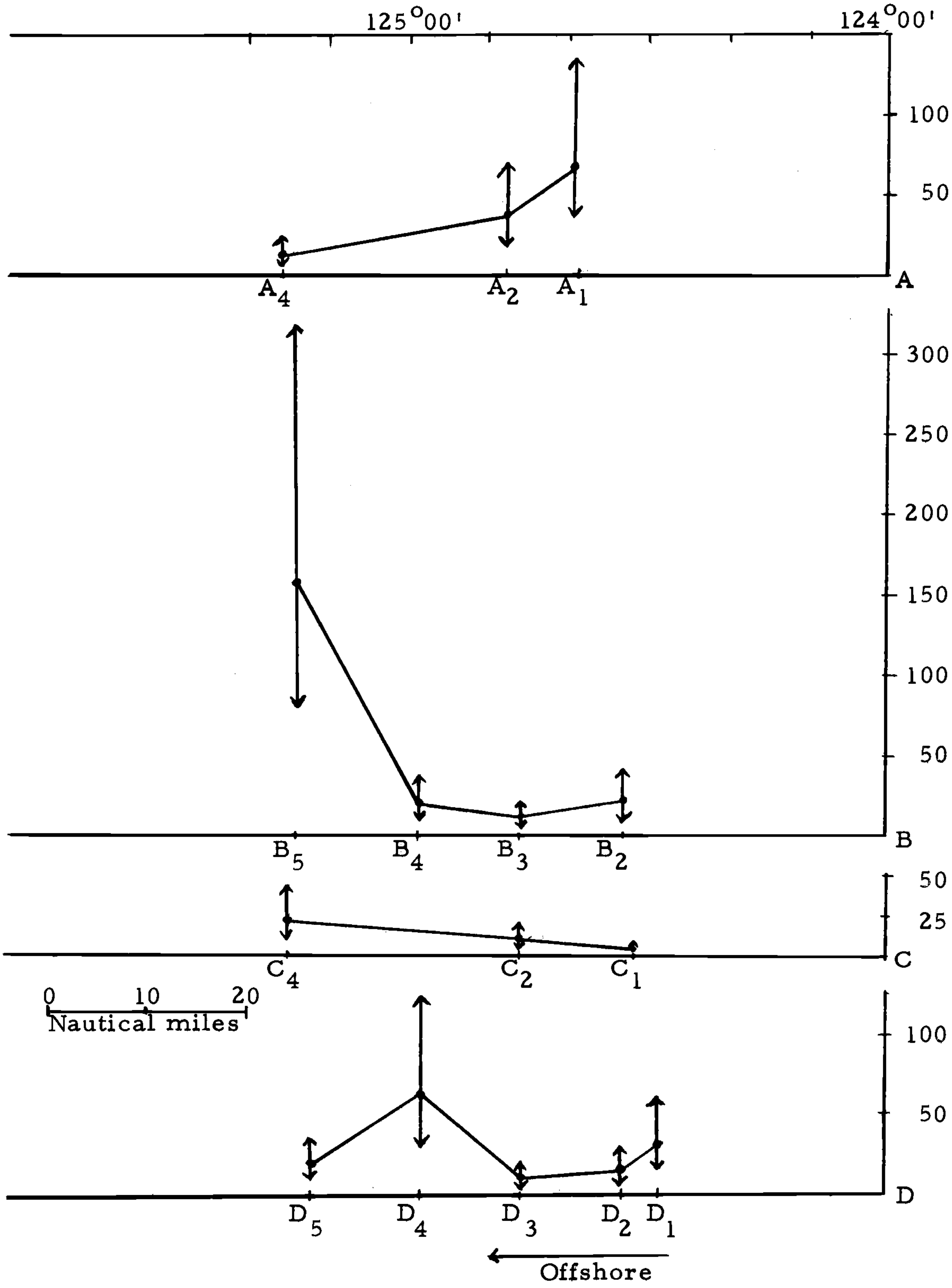
Miscellaneous

Copepod nauplii (Appendix 2) averaged 59/m^3. They were frequently found in higher abundance at offshore stations. Fish eggs occurred in high abundance at offshore stations, such as B-4, B-5, E-4, and F-4. If these were considered as members of the zooplankton, they would contribute significantly to the total zooplankton population (see Appendix 2).

Patterns of Species Diversity

"Patterns of species diversity exist" (MacArthur, 1965, p. 510). "The simplest measure of species diversity is a count of the number of species" (p. 511). "Local variations in the species diversity of small uniform habitats can usually be predicted in terms of the structure and productivity of the habitat" (p. 531). However, if diversity was from an area of complex and often obscure relationships,

Figure 5. Abundance of Acartia clausi in relation to the six sampling lines. Vertical arrows extend between confidence limits taken to be one-half to double the sample abundance estimate.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B4
B3
B2
50
25
C
C4
C2
C1
0
10
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Nautical miles
100
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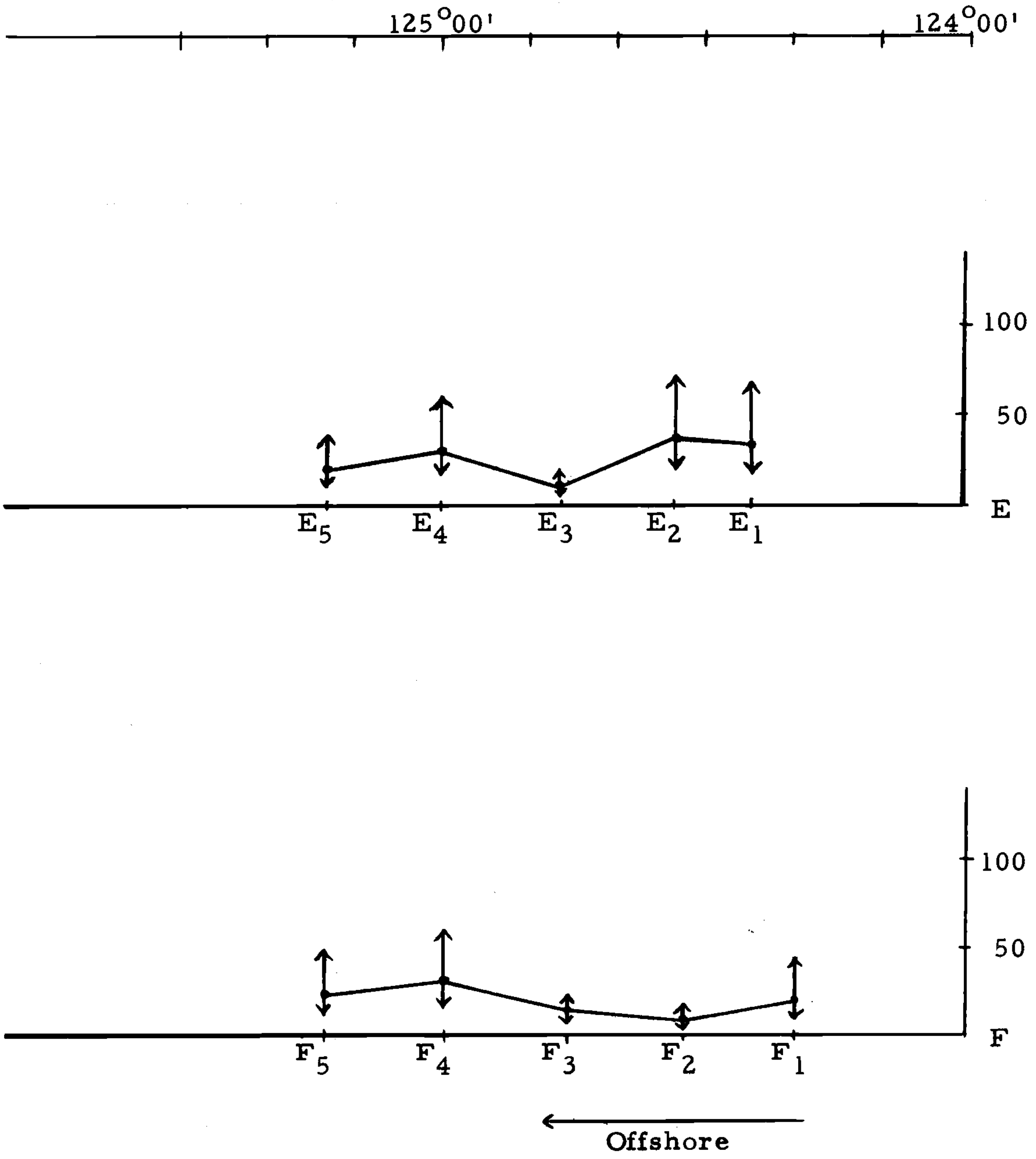
D5
D4
D3
D2
D1
Offshore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F$_4$
F$_3$
F$_2$
F$_1$
Offshore

it is often not subject to a neat simplification.

> Species-diversity of a community is a resultant of at least three interrelated determinants--characteristics of environment, time during which species have evolved niche differentiation in relation to one another, and characteristics of the particular species which have evolved to form communities in that environment, especially characteristics of the dominants which affect environmental conditions for subordinate species (Whittaker, 1965, p. 257-258).

The spatial patterns of species diversity in this study are shown in Figure 7, in which the number of species ranges from five, found in stations of A-1 and C-1, to 25, found in station C-5. Species diversity shows no clear relation to the variation of latitude but varies with distance from the coast. In all sampling lines, copepod diversity generally increased with distance from the shore, although at the most offshore station in line D diversity was slightly less than at the next inshore station. The stations with least species were near the coast with numbers varying from 5 to 11, while at the offshore stations, the number of species was at least 18. There are three possible explanations for this kind of distribution of species diversity.

1) Near the coast, wave action and a large degree of turbulence make the environment unstable. This limits the number of species which have evolved to maintain themselves in this sort of living environment, while in the more stable offshore environment, a larger number of species thrive in the more uniform, less hostile environmental conditions.

2) The sampling depth changed with distance from shore. Along

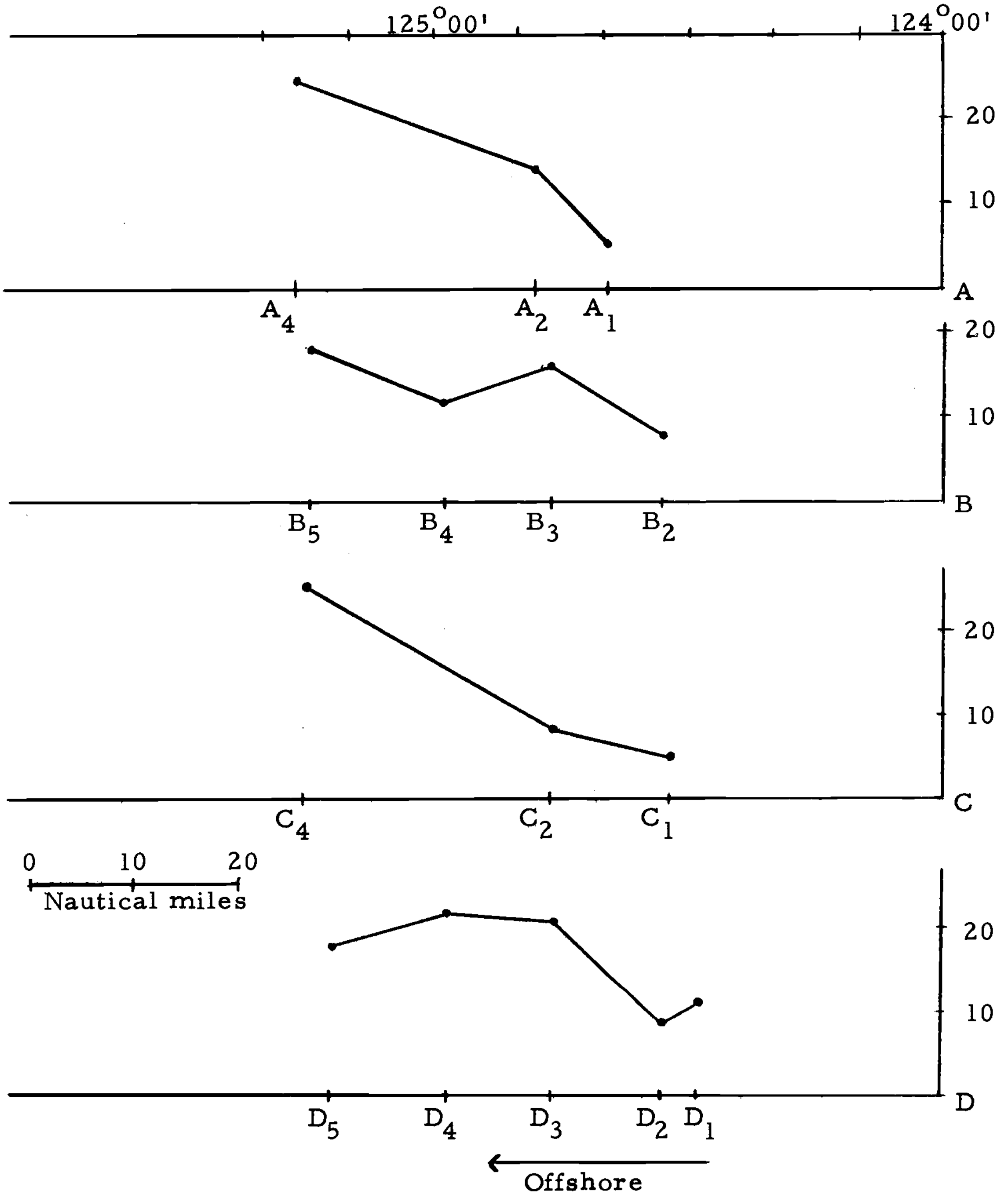
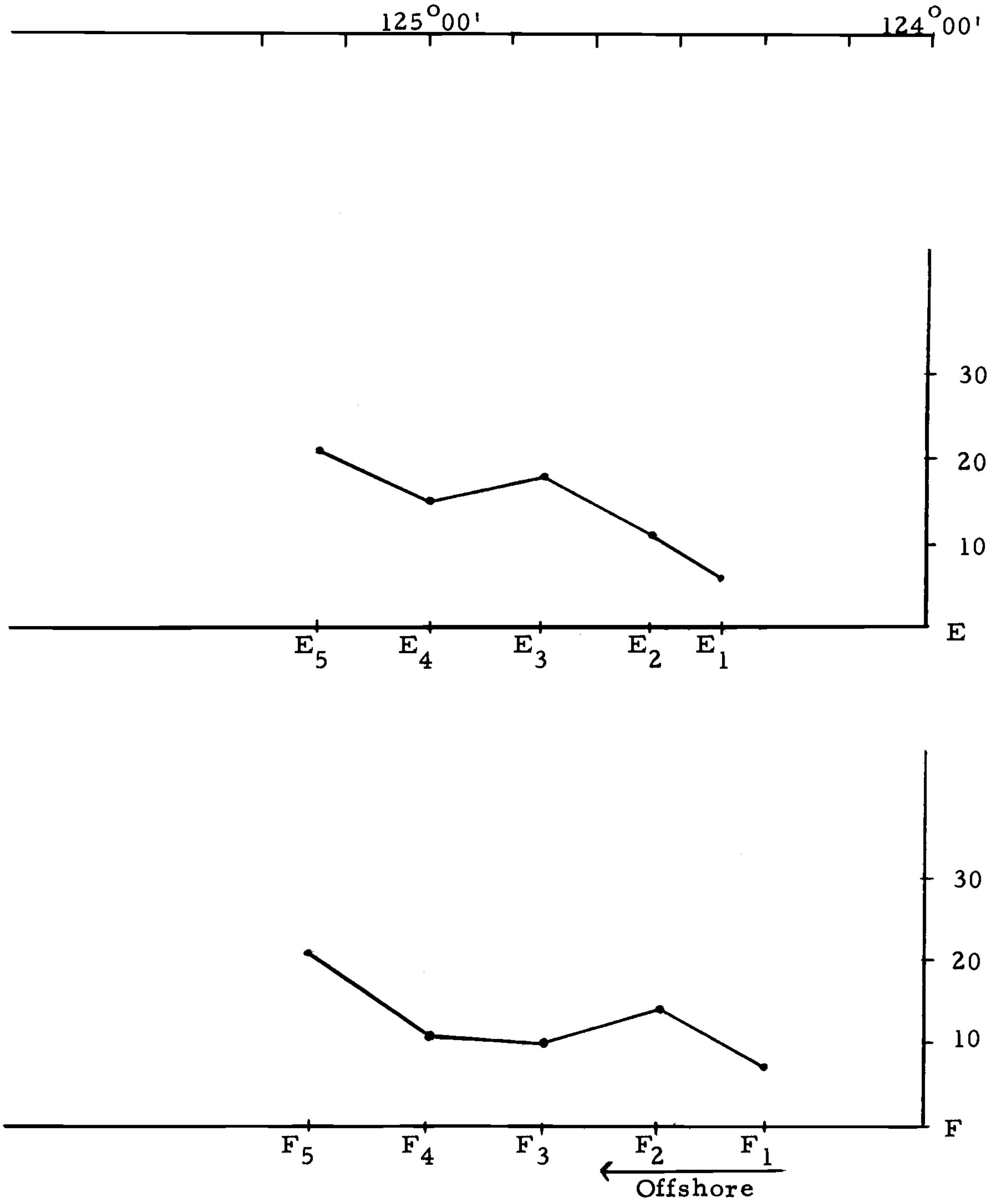


Figure 7. Species diversity of copepod population in relation to the six sampling lines.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F2
F1
Offshore

the stations numbered 1 and 2, samples were collected from the depth of 50 to 170 meters, but farther offshore, the depth was increased to 270 meters. Thus, more species could be obtained from this greater sampling range and consequent greater volume of water filtered.

3) The pattern of few species with large number of individuals associated with many species with few individual is characteristic of most population structures (Odum, 1959). That is, rich population usually contains a few species and a population which contains many species is usually represented by low abundance. In the present study, the copepod population was found higher inshore than offshore. Thus, more species would be expected offshore than inshore.

Correlation Analysis of Dominant Species

Correlation between dominant species will be tested by the rank-correlation method. The rank-correlation coefficient (Spearman, 1904) is usually denoted by r_s. The r_s for two species is given by:

$$r_s = 1 - \frac{6\Sigma di^2}{N(N^2-1)}$$

where

di = Difference in rank of a sample in orderings based on the abundance of the two species.

N = Size of sample. That is, the total number of stations.

Like the product-moment correlation coefficient, r_s, the rank correlation can range from -1 (complete discordance) to +1 (complete concordance) (Snedecor and Cochran, 1967). It is also a pure number without unit and dimension.

In addition to the four dominant species, fish eggs, copepod nauplii, euphausiids, and *Eucalanus bungii* were also included in the correlation analysis. These were included because they occurred in large numbers at some stations (like fish eggs, found in stations of B-4, E-4, and F-4), or because of their biological importance. Most of the eight organisms were found at all stations, except that copepod nauplii were not found in station A-1 and F-2, *Acartia clausi* not at station C-2, and *Eucalanus bungii* not at stations A-1 and C-1. Table 4 shows the ranking of 25 stations for each of these eight groups. The rank-correlation coefficients between each pairing of the eight organisms are given in Table 5.

For the sample size of 25, the significance level of r_s at five percent and one percent are 0.396 and 0.505, respectively. Thus, at the five percent level, the values of the r_s listed in Table 5 can be divided into three categories: 1) The first consisted of 18 pairs (Appendix 4), in which the value of r_s was between +0.396 and -0.396 (i.e., the null hypothesis that there was no relationship was not rejected), 2) the second (Table 6) included seven pairs, where r_s was greater than 0.396, and 3) The remaining three pairs formed the third category (Table 7), for which the value of r_s was less than

Table 4. Ranking of 25 sampling stations, based on the abundance of each of the eight organisms.

Station no.	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
A-1	13	17	23	24.5	2	6	10	24.5
A-2	10	7	13	17	4	9	8	22
A-4	2	21	25	22	20	17.5	25	10
B-2	3	22	24	19.5	11.5	24	6	18
B-3	21	15	7	16	20	8	24	19
B-4	18	4	8	9	13.5	23	15	20
B-5	20	2	1	7	1	4	4	16
C-1	7	20	12	19.5	25	13	5	24.5
C-2	5	25	15	23	22	25	7	14
C-4	23.5	16	18	5	10	10.5	18	9
D-1	9	23	4	14.5	6.5	1	3	13
D-2	15	24	22	21	17	14	19	12
D-3	22	5	11	3	20	22	21	8
D-4	25	10	14	8	3	12	12	16
D-5	19	9	17	11	16	19	20	21
E-1	11	18	5	14.5	6.5	2	2	4
E-2	6	12	20	18	5	7	13	7
E-3	12	19	16	12	24	17.5	22	2
E-4	23.5	3	3	2	8.5	10.5	9	6
E-5	16	13	10	6	13.5	5	23	11
F-1	8	8	2	10	15	3	1	3
F-2	1	14	19	24.5	23	15	17	1
F-3	4	6	21	13	18	21	14	5
F-4	14	1	6	1	8.5	16	16	16
F-5	17	11	9	4	11.5	20	11	23

(1) Euphausiid	(3) *O. similis*	(5) *A. longiremis*	(7) *P. minutus*
(2) Fish eggs	(4) Copepod nauplii	(6) *A. clausi*	(8) *E. bungii*

Table 5. The rank-correlation coefficients between each pairing of the eight organisms.

		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Euphausiids	(1)	1	-0.421	-0.702	-0.317	-0.133	0.223	-0.446	0.215
O. similis	(2)		1	-0.601	0.247	0.440	0.401	0.466	0.016
Copepod nauplii	(3)			1	0.257	0.027	-0.083	0.695	0.077
A. longiremis	(4)				1	0.530	0.443	0.330	-0.232
A. clausi	(5)					1	0.341	0.011	0.131
P. minutus	(6)						1	-0.014	-0.113
Fish eggs	(7)							1	0.001
E. bungii	(8)								1

Table 6. Category-2, which shows positive correlation and has a value of r_s greater than 0.396.

Paired species	Rank-correlation coefficient
1) Oithona similis-Pseudocalanus minutus	0.401
2) Oithona similis-Acartia clausi	0.440
3) Acartia longiremis-Pseudocalanus minutus	0.443
4) Fish eggs-Oithona similis	0.466
5) Acartia longiremis-Acartia clausi	0.530
6) Oithona similis-Copepod nauplii	0.601
7) Fish eggs-Copepod nauplii	0.695

Table 7. Category-3, negatively correlated group, having the conditions for r_s less than -0.396.

Paired species	Rank-correlation coefficient
1) Euphausiids-Copepod nauplii	-0.702
2) Euphausiids-Fish eggs	-0.446
3) Euphausiids-Oithona similis	-0.421

-0.396.

Examination of coefficients in the second category shows there are two groups of mutually correlated species (see Figure 8):

1) The species, found in the first positively correlated group (group 1), were Oithona similis, Acartia clausi, Acartia longiremis, and Pseudocalanus minutus. These four species were found most abundantly near the coastal region. That is perhaps why they are positively correlated.

2) The second positively associated group included copepod nauplii, fish eggs and Oithon similis. Since there are no data available on the ecology of copepod nauplii and fish eggs along the Oregon coast, it is difficult to make a conclusion or suggestion for this group.

The significantly negative correlations are between the abundance of euphausiid larvae and the abundance of Oithona similis, fish eggs, and copepod nauplii. At those stations where euphausiid larvae occurred in high abundance, the other three organisms were in low numbers. This could be related to the following possibility--the predator-prey relation: The food of euphausiids can be roughly grouped into three classes. That is, phytoplankton, zoöplankton, and detritus materials. The stomach contents of euphausiids in this present collection revealed that some stomachs were empty and some contained a few fragments of crustacean exoskeleton, but none of the identifiable contents was found to be that of Oithona similis. Ponomareva (1954)

Table 8. List of species which comprised category-2 and category-3.

Number	Species
1	Euphausiids
2	<u>Oithona</u> <u>similis</u>
3	Copepod nauplii
4	<u>Acartia</u> <u>longiremis</u>
5	<u>Acartia</u> <u>clausi</u>
6	<u>Pseudocalanus</u> <u>minutus</u>
7	Fish eggs

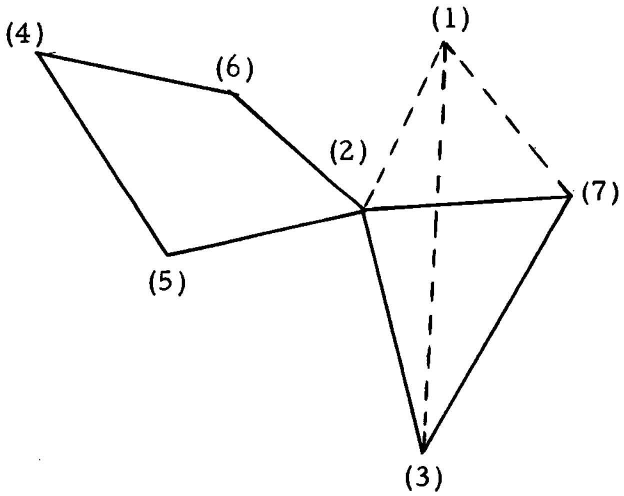

Figure 8. Correlation of species between category-2 and category-3. Solid lines indicate positive correlation and dotted lines indicate negative correlation. Numbers refer to species listed in Table 8.

described the way in which euphausiids feed on the copepods. Once the copepod has been captured, it is held by the mouth parts and its integument pierced. The juices are then sucked from the body of the copepod leaving an empty husk. The remains are rejected from the food basket and only a small quantity of unidentifiable fragments of the exoskeleton enter the stomach of the euphausiids. Her results have been confirmed by observation on *Thysanoessa raschii* and *Meganyctiphanes norvegica* by Mauchline and Fisher (1969). Therefore, the possibility of a predator-prey relationship between euphausiid larvae and *Oithona similis*, or copepod nauplii cannot be disproved until more work on the feeding of euphausiids in the Oregon coastal waters has been done.

Table 9 shows the ranking of 25 stations, based on the numerical value of temperature, salinity, and distance from shore. Rank-correlation analysis (see Table 10) of those factors relative to the four dominant species, total abundance of copepods and percentage of copepod indicated that no significant relation was apparent except one pair, *Pseudocalanus minutus* to distance from shore. The r_s for this pair was -0.453. Therefore, their occurrence was in the opposite direction.

Table 9. Ranking of 25 sampling stations by the total abundance of copepod, percentage of copepod, temperature, salinity, and distance from shore.

Station no.	(1)	(2)	(3)	(4)	(5)
A-1	18	14	23	11	23
A-2	10	4.5	21	19	17
A-4	25	25	1	24	7
B-2	20	4.5	25	1	19
B-3	14	2	20	4	13
B-4	13	9.5	18	6	9
B-5	2	3	5	25	3
C-1	7	20	24	2	21
C-2	16	1	19	3	14
C-4	17	17	16	23	6
D-1	4	24	15	8.5	25
D-2	24	9.5	22	5	22
D-3	12	16	12	18	15
D-4	9	11	9	20	11
D-5	21	8	10	21	5
E-1	3	23	6	14	24
E-2	15	7	14	12	18
E-3	19	22	7	15	12
E-4	5	15	3	10	8
E-5	11	6	2	22	2
F-1	1	21	17	7	20
F-2	23	12	13	8.5	16
F-3	22	19	11	13	10
F-4	6	18	8	17	4
F-5	8	13	4	16	1

(1) Total abundance of copepod
(2) Percentage of copepod
(3) Temperature
(4) Salinity
(5) Distance from shore

Table 10. The rank-correlation coefficients of these four dominant species, total abundance of copepod and percentage of copepod relative to temperature, salinity, and distance from shore.

	(1)	(2)	(3)	(4)	(5)	(6)
Temperature	0.285	-0.256	0.087	0.103	-0.191	0.255
Salinity	-0.033	0.326	-0.165	-0.345	0.055	-0.114
Distance from shore	0.141	-0.453	-0.295	-0.007	0.018	-0.201

(1) *O. similis*
(2) *P. minutus*
(3) *A. clausi*
(4) *A. longiremis*
(5) Total abundance of copepod
(6) Percentage of copepod

DISCUSSION

The total abundance of copepods differed greatly between inshore and offshore stations. Greater abundance was found inshore, with the number approximately two times that found offshore. This was possibly related to the distribution of phytoplankton which Laurs (1967) noted to be more abundant near shore. During periods of upwelling, higher standing stock of primary producers occurred inshore than offshore, supporting a larger copepod population. When a comparison was made between the spatial distribution of total abundance and the four dominant species, it revealed that both had peaks in those stations adjacent to the coast and decreased in a seaward direction.

The four dominant species have been considered as neritic species and often occur in considerable abundance in the neritic zone. This appears to be the case in the southern Oregon coastal waters.

Species diversity during mid-August, 1963 resembled that described by Hebard (1966) for the coastal waters off Newport. Cross (1964) used a diversity index dependent upon relative diversity and showed that the species diversity off Newport was greatest inshore during all seasons of the year, and that offshore waters were usually characterized by one or two species making up a very large percentage of the total population during the winter, spring and autumn months. In my present study, the highest number of species was consistently found in the offshore stations.

However, when comparing the inshore and offshore copepod populations, several differences are readily apparent. The inshore copepod population has 1) a higher average abundance, 2) a lower number of species, 3) and the four dominant species occur in relatively large numbers per cubic meter.

Cross (1964) considered *Acartia danae* and *Centropages abdominalis* to be important species and possible indicators of seasonal hydrographic changes. He thought that *C. abdominalis*, absent from Oregon coastal waters during the winter months may closely correlate with the presence of the northerly flow of Davidson current. In the summer period, from April through September, when a southerly current was developed, *C. abdominalis* reappeared. Cross found that the occurrence of *A. danae* contrasted to that of *C. abdominalis*. That is, *A. danae* was found in Oregon coastal waters only from October through May. In the present study, no specimen of *A. danae* was present and *C. abdominalis* was recorded only at three stations, B-3, B-4 and D-2 and was in small numbers.

SUMMARY

1) Plankton samples were collected during the cruise of U.S. Coast Guard Cutter MODOC in mid-August of 1963. On the cruise vertical hauls were made at 25 stations along six lines, extending westward from the southern Oregon coast to about 83 kilometers offshore.

2) Forty-one species of adult copepod were identified, including representatives of 26 genera and 17 families. The total abundance averaged 550/m^3, a little lower than that found by Cross during 1962. This was possibly related to some random variation between times of sampling, to methods used in collecting plankton, or to differences in environmental factors in different years.

3) Higher population densities of copepods as a group were found inshore than offshore. This distribution was largely determined by the four dominant species. Rank-correlation analysis of those four dominant species, total abundance of copepod, and percentage of copepod relative to temperature, salinity and distance from shore shows that no significant relationship was apparent except one pair, Psuedocalanus minutus to distance from shore. They occurred in opposite directions.

4) The dominant species were Oithona similis, Psuedocalanus minutus, Acartia clausi, and Acartia longiremis. These four species often dominate the entire copepod population over the 25

sampling stations, where they accounted for approximately 81 percent of the total copepod abundance.

5) The patterns of species diversity, in general, are a result of at least three interrelated determinants: 1) characteristics of environment, 2) time, and 3) characteristics of some important (dominant) species. In all sampling lines, except D, copepod diversity had a tendency to increase with distance from the coast. That is, the lowest number of species was near the coast with five to 11 species, while at offshore stations there were at least 18. The reason for this could be mainly due to their environments. Near the coast, the wave action and large degree of turbulence probably limit the number of species which have evolved an adaption to the near shore environment, while in the more stable offshore environment, large numbers of species can tolerate the environmental conditions.

6) Results from the correlation analysis of the dominant species suggest that the first positively correlated group included Oithona similis, Pseudocalanus minutus, Acartia clausi, and Acartia longiremis. These species were believed to be mainly neritic species. The second positively correlated species consisted of fish eggs, copepod nauplii and O. similis. Since there were no available data concerned with their ecology off Oregon coast, it is difficult to come to an independent conclusion. The

third negatively correlated category included Oithona similis, fish eggs, copepod nauplii, and euphausiids. When euphausiids were in high abundance, the other three groups of organisms were in low abundance. Alternatively, the reverse was true.

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APPENDICES

APPENDIX 1

Abundance of four dominant species at each station.

Station no.	O. similis (no. /m^3)	P. minutus (no. /m^3)	A. clausi (no. /m^3)	A. longiremis (no. /m^3)	(1) %
A-1	67.4	159.2	26.5	67.3	96.3
A-2	154.1	199.0	16.5	36.7	89.0
A-4	13.3	29.0	8.5	10.9	70.6
B-2	50.1	224.2	2.2	21.8	94.5
B-3	244.3	35.1	16.9	10.9	78.9
B-4	181.4	93.1	3.6	19.4	72.2
B-5	715.9	256.4	101.6	154.8	89.8
C-1	158.4	233.5	13.1	1.6	64.4
C-2	129.4	209.2	-	10.1	93.6
C-4	118.5	72.6	14.5	24.2	62.4
D-1	320.0	365.7	150.2	32.7	91.5
D-2	77.6	71.4	12.2	16.3	89.5
D-3	159.6	60.5	4.8	10.9	56.2
D-4	135.4	118.5	14.5	64.1	67.9
D-5	120.9	70.1	7.3	18.1	70.4
E-1	293.9	842.5	143.6	32.7	96.5
E-2	93.3	96.8	24.5	38.5	67.7
E-3	128.2	54.4	8.5	8.5	61.3
E-4	440.2	165.7	14.5	29.0	76.2
E-5	169.3	50.8	36.3	19.4	64.0
F-1	457.1	914.3	111.9	18.7	92.3
F-2	95.6	90.9	11.7	9.3	79.9
F-3	82.2	94.3	2.4	12.1	73.0
F-4	270.9	91.6	9.7	29.0	61.2
F-5	177.6	147.5	2.4	21.8	66.0
Average	194.1	189.9	31.6	28.7	
(2) %	35.3	34.5	5.7	5.0	

(1) Percentages in total abundance of copepod, if four species combined.

(2) Percentage of each dominant species in the total abundance of copepod.

APPENDIX 2

Abundance of euphausiids, fish eggs, copepod nauplii, and Eucalanus bungii.

Station no.	Euphausiids (no. /m^3)	Fish eggs (no. /m^3)	Copepod nauplii (no. /m^3)	Eucalanus bungii (no. /m^3)
A-1	1.3	40.8	-	-
A-2	1.8	117.4	25.7	0.20
A-4	11.3	14.5	6.1	0.80
B-2	10.3	10.9	6.5	0.54
B-3	0.5	45.9	30.2	0.50
B-4	0.8	319.3	66.5	0.31
B-5	0.6	914.3	82.3	0.60
C-1	5.3	17.9	6.5	-
C-2	8.8	2.4	2.4	0.60
C-4	0.4	41.1	94.8	0.90
D-1	2.2	6.5	39.2	0.61
D-2	1.0	6.1	6.1	0.64
D-3	0.5	151.2	137.9	1.10
D-4	0.3	70.1	81.0	0.60
D-5	0.6	71.4	61.7	0.22
E-1	1.6	26.1	39.2	2.04
E-2	6.9	59.5	15.2	1.16
E-3	1.3	25.4	60.5	3.02
E-4	0.4	350.7	142.7	1.32
E-5	0.8	55.6	91.9	0.76
F-1	5.2	74.6	65.3	2.92
F-2	11.8	51.3	-	11.66
F-3	10.3	130.6	53.2	1.74
F-4	1.3	1232.5	145.1	0.57
F-5	0.8	67.7	96.8	0.04

APPENDIX 3

Species of copepods other than four dominant species and their abundance at each station.

Station no.	(1)	(2)	(3)	(4)	(5)	(6)	(7)
A-1	0.22	-	-	-	-	-	-
A-2	1.72	0.17	-	-	-	-	-
A-4	0.45	0.08	-	-	-	-	-
B-2	1.22	-	-	-	-	-	-
B-3	0.07	0.03	-	-	-	-	-
B-4	0.03	-	-	-	-	-	-
B-5	0.53	0.11	0.03	-	-	0.04	-
C-1	-	-	-	-	-	-	-
C-2	3.10	0.15	-	0.04	0.03	-	3.62
C-4	0.45	-	-	0.04	0.04	-	-
D-1	0.20	0.20	-	0.20	-	-	-
D-2	1.53	0.25	-	-	-	-	-
D-3	0.19	0.03	-	0.13	-	-	4.84
D-4	0.26	0.03	-	0.03	0.03	-	6.05
D-5	0.16	0.07	-	-	-	0.08	-
E-1	-	-	-	-	-	-	-
E-2	0.51	0.15	-	-	-	-	-
E-3	0.19	0.03	-	-	-	-	-
E-4	0.11	-	-	0.08	-	-	12.09
E-5	0.30	0.15	-	-	-	-	-
F-1	0.58	0.29	-	-	-	-	-
F-2	0.44	0.14	-	0.07	-	-	2.41
F-3	-	0.07	-	-	-	-	1.21
F-4	-	-	-	-	-	-	4.84
F-5	0.23	-	0.03	-	-	-	0.11
Frequency	21	16	2	7	3	2	8

(1) *Calanus finmarchicus*

(2) *Calanus pacificus*

(3) *Calanus cristatus*

(4) *Eucalanus elongatus hyalinus*

(5) *Rhincalanus nasutus*

(6) *Clausocalanus arcuicornis*

(7) *Aetideus armatus*

Appendix 3 (Continued).

Station no.	(8)	(9)	(10)	(11)	(12)	(13)
A-1	-	-	-	-	-	-
A-2	-	-	-	0.06	-	-
A-4	-	-	0.08	0.15	-	0.07
B-2	-	-	-	-	-	-
B-3	-	-	-	0.03	-	-
B-4	-	-	-	0.07	-	-
B-5	-	-	-	0.07	-	-
C-1	-	-	-	-	-	-
C-2	-	-	-	-	-	-
C-4	0.03	-	0.30	-	-	0.03
D-1	-	-	-	-	-	-
D-2	-	-	-	-	-	-
D-3	-	-	0.11	0.19	-	-
D-4	-	-	0.07	0.30	0.07	-
D-5	-	-	0.04	-	0.04	-
E-1	-	-	-	-	-	-
E-2	-	-	-	-	-	-
E-3	-	-	-	0.03	-	-
E-4	-	-	0.08	0.03	-	-
E-5	-	-	0.11	0.18	-	-
F-1	-	-	-	-	-	-
F-2	-	-	-	0.07	-	-
F-3	-	-	-	-	-	-
F-4	-	-	-	0.11	-	-
F-5	-	0.19	0.07	0.22	0.04	-
Frequency	1	1	8	13	3	2

(8) *Gaidius brevispinus*

(9) *Gaidius tenuispinus*

(10) *Gaidius pungens*

(11) *Euchirella pulchra*

(12) *Euchirella curticauda*

(13) *Chirundina streetsi*

Appendix 3 (Continued).

Station no.	(14)	(15)	(16)	(17)	(18)	(19)
A-1	-	-	-	-	-	-
A-2	-	-	0.05	-	-	-
A-4	0.08	-	0.03	0.03	-	-
B-2	-	-	0.02	-	-	-
B-3	-	-	0.07	-	0.03	-
B-4	-	-	0.18	-	-	-
B-5	-	-	0.23	-	0.03	-
C-1	-	-	-	-	-	-
C-2	-	-	-	-	-	-
C-4	0.03	0.04	0.03	-	0.03	-
D-1	-	-	-	-	-	-
D-2	-	-	-	-	-	-
D-3	-	0.03	0.15	0.03	0.03	0.03
D-4	-	0.03	0.11	-	-	-
D-5	-	0.03	0.23	-	-	-
E-1	-	-	-	-	-	-
E-2	-	-	-	-	-	-
E-3	-	-	0.23	-	0.03	-
E-4	-	-	0.22	-	-	-
E-5	-	-	0.03	0.03	0.04	-
F-1	-	-	-	-	-	-
F-2	-	-	-	-	-	-
F-3	-	-	0.03	-	-	-
F-4	-	-	0.07	-	-	-
F-5	-	-	0.26	0.03	-	-
Frequency	2	4	16	4	6	1

(14) *Undeuchaeta major*

(15) *Undeuchaeta plumosa*

(16) *Euchaeta japonica*

(17) *Phaenna spinifera*

(18) *Scottocalanus persecans*

(19) *Lophothrix frontalis*

Appendix 3 (Continued).

Station no.	(20)	(21)	(22)	(23)	(24)	(25)
A-1	-	-	-	-	-	-
A-2	-	7.28	0.05	0.05	-	-
A-4	-	-	0.03	0.11	0.03	0.03
B-2	-	-	-	-	-	-
B-3	-	7.86	-	0.03	-	-
B-4	-	3.63	-	-	-	-
B-5	-	4.72	0.03	0.03	-	-
C-1	-	-	-	-	-	-
C-2	-	0.07	-	-	-	-
C-4	-	0.22	0.03	0.03	0.03	-
D-1	-	-	-	-	-	-
D-2	-	-	-	-	-	-
D-3	-	9.75	-	0.03	0.03	-
D-4	-	19.35	-	0.04	0.03	0.03
D-5	-	-	0.04	-	0.16	0.04
E-1	-	-	-	-	-	-
E-2	-	75.80	-	-	-	-
E-3	-	9.70	0.03	0.03	0.04	-
E-4	-	3.70	-	-	-	-
E-5	0.03	0.38	0.03	-	0.07	-
F-1	-	-	-	-	-	-
F-2	-	0.07	-	-	-	-
F-3	-	-	-	-	-	-
F-4	-	-	-	-	-	-
F-5	-	24.18	-	-	0.03	0.04
Frequency	1	14	7	8	8	4

(20) *Scaphocalanus brevicornis*

(21) *Metridia lucens*

(22) *Pleuromamma abdominalis*

(23) *Pleuromamma xiphias*

(24) *Pleuromamma quadrungulata*

(25) *Pleuromamma scutullata*

Appendix 3 (Continued).

Station no.	(26)	(27)	(28)	(29)	(30)	(31)
A-1	-	-	-	-	-	-
A-2	-	-	-	-	-	-
A-4	-	0.03	0.08	0.08	-	-
B-2	-	-	-	-	-	-
B-3	0.60	-	-	-	-	-
B-4	1.21	-	-	-	-	-
B-5	-	-	0.03	-	-	-
C-1	-	-	-	-	-	-
C-2	-	-	-	-	-	-
C-4	-	0.22	0.18	0.11	-	-
D-1	-	-	-	-	-	-
D-2	4.08	-	-	-	-	-
D-3	-	-	-	-	-	-
D-4	-	-	0.03	-	-	-
D-5	-	-	0.03	-	-	-
E-1	-	-	-	-	-	-
E-2	-	-	-	-	-	-
E-3	-	-	0.04	-	-	-
E-4	-	-	-	-	-	-
E-5	-	-	0.11	0.08	0.03	-
F-1	-	-	-	-	-	-
F-2	-	-	-	-	-	-
F-3	-	-	-	-	-	-
F-4	-	-	-	-	-	-
F-5	-	-	0.08	-	-	0.03
Frequency	3	2	8	3	1	1

(26) *Centropages abdominalis*

(27) *Lucicutia flavicornis*

(28) *Heterorhabdus tanneri*

(29) *Heterostylites longicornis*

(30) *Heterostylites major*

(31) *Candacia columbiae*

Appendix 3 (Continued).

Station no.	(32)	(33)	(34)	(35)	(36)	(37)
A-1	-	-	-	-	-	-
A-2	-	-	-	1.83	10.09	-
A-4	0.32	-	-	3.63	7.26	4.84
B-2	-	-	-	-	-	2.17
B-3	-	-	-	3.02	26.00	3.02
B-4	-	-	-	9.68	31.44	-
B-5	-	-	-	9.68	24.19	-
C-1	-	-	-	1.63	-	-
C-2	-	0.03	-	6.05	1.20	-
C-4	0.03	-	-	9.68	29.03	-
D-1	-	-	19.59	6.53	-	6.53
D-2	-	-	4.08	-	-	-
D-3	-	-	-	4.84	18.39	-
D-4	-	-	-	12.09	26.61	-
D-5	-	-	-	8.47	18.14	-
E-1	-	-	-	6.53	-	-
E-2	-	-	10.49	9.33	1.20	-
E-3	-	-	-	8.47	41.12	2.42
E-4	-	-	-	12.09	24.19	3.68
E-5	-	-	-	2.42	24.19	-
F-1	-	-	-	-	-	-
F-2	-	-	6.98	9.33	18.66	-
F-3	-	-	-	3.63	9.68	-
F-4	-	-	9.67	16.93	70.14	-
F-5	-	-	-	4.84	50.79	-
Frequency	2	1	5	21	18	6

(32) *Candacia bipinnata*

(33) *Labidocera amphitrites*

(34) *Acartia tonsa*

(35) *Oithona spinirostris*

(36) *Oncaea conifera*

(37) *Corycaeus* sp.

APPENDIX 4

The least associated group which had value of r_s between +0.396 and -0.396.

	Paired species	Rank-correlation coefficient
1)	Euphausiids-Acartia longiremis	-0.317
2)	Acartia longiremis-Eucalanus bungii	-0.232
3)	Euphausiids-Acartia clausi	-0.133
4)	Eucalanus bungii-Pseudocalanus minutus	-0.113
5)	Copepod nauplii-Pseudocalanus minutus	-0.083
6)	Fish eggs-Pseudocalanus minutus	-0.014
7)	Fish eggs-Eucalanus bungii	0.001
8)	Fish eggs-Acartia clausi	0.011
9)	Oithona similis-Eucalanus bungii	0.016
10)	Copepod nauplii-Acartia clausi	0.027
11)	Copepod nauplii-Eucalanus bungii	0.077
12)	Acartia clausi-Eucalanus bungii	0.131
13)	Euphausiids-Eucalanus bungii	0.215
14)	Euphausiids-Pseudocalanus minutus	0.223
15)	Oithona similis-Acartia longiremis	0.247
16)	Copepod nauplii-Acartia longiremis	0.257
17)	Fish eggs-Acartia longiremis	0.330
18)	Acartia clausi-Pseudocalanus minutus	0.341

APPENDIX 5

Observed surface temperature, salinity and concentration of oxygen at each station.

Station no.	Temperature (^oC)	Salinity (‰)	Concentration of oxygen (ml/l)
A-1	9.77	33.682	5.82
A-2	10.15	33.345	6.96
A-4	15.24	32.232	5.99
B-2	9.52	33.863	4.55
B-3	10.20	33.781	4.95
B-4	10.73	33.735	5.83
B-5	13.33	32.163	6.76
C-1	9.62	33.853	4.85
C-2	10.42	33.799	5.53
C-4	10.96	33.061	7.07
D-1	11.14	33.701	6.63
D-2	9.91	33.772	5.05
D-3	12.04	33.465	6.57
D-4	12.63	33.125	8.71
D-5	12.56	33.116	8.42
E-1	12.99	33.612	8.27
E-2	11.15	33.658	5.95
E-3	12.84	33.565	6.83
E-4	13.46	33.369	7.83
E-5	14.51	33.110	8.14
F-1	10.91	33.716	5.70
F-2	11.27	33.701	6.57
F-3	12.49	33.634	8.03
F-4	12.70	33.511	8.23
F-5	13.40	33.546	8.36