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Title SEASONAL AND GEOGRAPHICAL DISTRIBUTION OF PELAGIC COPEPODS IN OREGON COASTAL WATERS

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(Major Professor)

The copepod population in Oregon coastal waters was examined from 116 oblique plankton tows taken during 1962. Quantitative Clarke-Bumpus samplers were used and stations ranged from 5-105 miles from shore along four hydrographic lines. Forty-six species of copepods were identified.

The total adult population varied according to distance from shore, season and hydrographic line sampled. Populations in neritic regions reached highest abundance during the spring and summer months while offshore populations reached peaks only during April and May. Two unusually high populations recorded during July appeared to be linked to the effects of upwelling and/or discharge from the Columbia River. Population diversity indices were calculated to show temporal and spatial change in percent species composition. The seasonal and spatial abundance of the total copepodite population was very similar to that of the adult population. *Oithona similis* Claus was the dominant cyclopoid species, and often the most abundant of all species. *Pseudocalanus minutus* (Krøyer) was the most abundant calanoid

copepod. *Acartia longiremis* (Lilljeborg) was an important member of the copepod community during the summer months, and only in neritic areas. It is suggested that *Acartia danae* Giesbrecht and *Centropages mcmurrichi* Willey may be used as reciprocal indicators of seasonal change in surface current movement off Oregon. Their distributions appeared to correlate closely with surface water characteristics during different seasons of the year.

SEASONAL AND GEOGRAPHICAL DISTRIBUTION OF PELAGIC COPEPODS IN OREGON COASTAL WATERS

by

FORD A CROSS

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APPROVED:

Assistant Professor, Department of Oceanography

In Charge of Major

Chairman, Department of Oceanography

Chairman of School Graduate Committee

Dean of Graduate School

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Typed by Joan Stevens

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SEASONAL AND GEOGRAPHICAL DISTRIBUTION OF PELAGIC COPEPODS IN OREGON COASTAL WATERS

Introduction

A quantitative investigation of the seasonal and geographical distribution of pelagic copepods in Oregon coastal waters in 1962 was undertaken to extend existing knowledge of copepod distribution in the northeast Pacific. Previous quantitative studies are rather limited for this region. Frolander (15 p.657-675) gives quantitative estimations of the dominant copepod species as well as the seasonal variation of zooplankton volumes off the coast of Washington and British Columbia. Hebard (19, p.1-64) conducted a similar study in Puget Sound, while LeBrasseur (22, p.19-21) recorded settling volumes of copepods in several British Columbia inlets.

The remaining copepod studies in the northeast Pacific have been largely taxonomic. Davis (11, p.1-118) recorded 67 copepod species in the northeastern Pacific from San Francisco Bay to the Aleutian Islands. In addition to this, he listed another 24 species which had previously been found by other workers, although they did not appear in his collections.

Cameron (8, p.165-202) identified 32 copepod species in the Queen Charlotte Island region and discussed factors influencing the horizontal distribution of the more common ones. Campbell (9, p.303-332) recorded 25 species of calanoid and cyclopoid copepods from the Vancouver Island region, and Willey (39, p.1k-46k) listed the copepod species found in the Alaskan and Bering Seas. Copepods taken in the north Pacific during the CARNEGIE and ALBATROSS expeditions were recorded by Wilson (40, p.1-237 and 41, p.141-441). Olson (25, p.1-208) in a study of the cyclopoid population in the coastal waters of Oregon, California and Lower California, examined collections from 12 stations off the Oregon coast during a cruise of the E. W. SCRIPPS in 1938. Owen (26, p.33) in the Northeast Pacific Albacore Oceanography Survey for 1961 collected 26 species in tows taken off the Washington and Oregon coasts.

Extrapolation of laboratory data on copepod grazing, reproduction, growth, metabolism, vertical migration, etc., to field conditions requires thorough knowledge of distributional patterns. The quantitative evaluation of seasonal and geographic distributions of pelagic Copepoda off the Oregon coast will provide the framework for such extrapolation.

Sampling Area and Methods

The area in which copepod collections were made in this study extended from the mouth of the Columbia River (Lat. 46°14.4'N) south to the Oregon-California border (Lat. 42°00'N), and from the Oregon coastline west to 105 miles offshore (approximately Long. 126°35'W, varying somewhat because of the configuration of the coastline). The sampling pattern followed the regular hydrographic cruise pattern of the R/V ACONA, research vessel of the Department of Oceanography at Oregon State University, with the exception that the copepod collections were examined only as far offshore as 105 miles (Fig. 1). Four sampling lines were followed off the coastal towns of Astoria, Newport, Coos Bay and Brookings. Seven stations were sampled along each line as often as ship time permitted during 1962. The stations were 5, 15, 25, 35, 45, 65, and 105 miles from shore and were given designations identical to the hydrographic stations; i.e., the 15 mile station off Newport was NH-15, the 65 mile station off Brookings was BH-65, and so on.

The collecting procedure at each station consisted of oblique tows taken from approximately 150 meter depth (depth permitting) to the surface. Modified Clarke-Bumpus quantitative samplers (27, p.284-288) were used with No. 6 mesh nets (0.239 mm mesh openings). The mouth diameter of the samplers was 12.7 cm. Towing speeds varied from one to two knots and towing time was 15 minutes. Samples were removed from the collecting bucket of the sampler after each tow and preserved with 10% neutralized formalin. As these collections were taken during hydrographic cruises, physical data such as temperature, salinity, dissolved oxygen and surface weather conditions were obtained at each station. Also, 12 drift bottles were released at each station in an effort to determine direction of surface current movement.

The laboratory procedure consisted of examining each sample under a dissecting microscope, removing all larger zooplankton forms

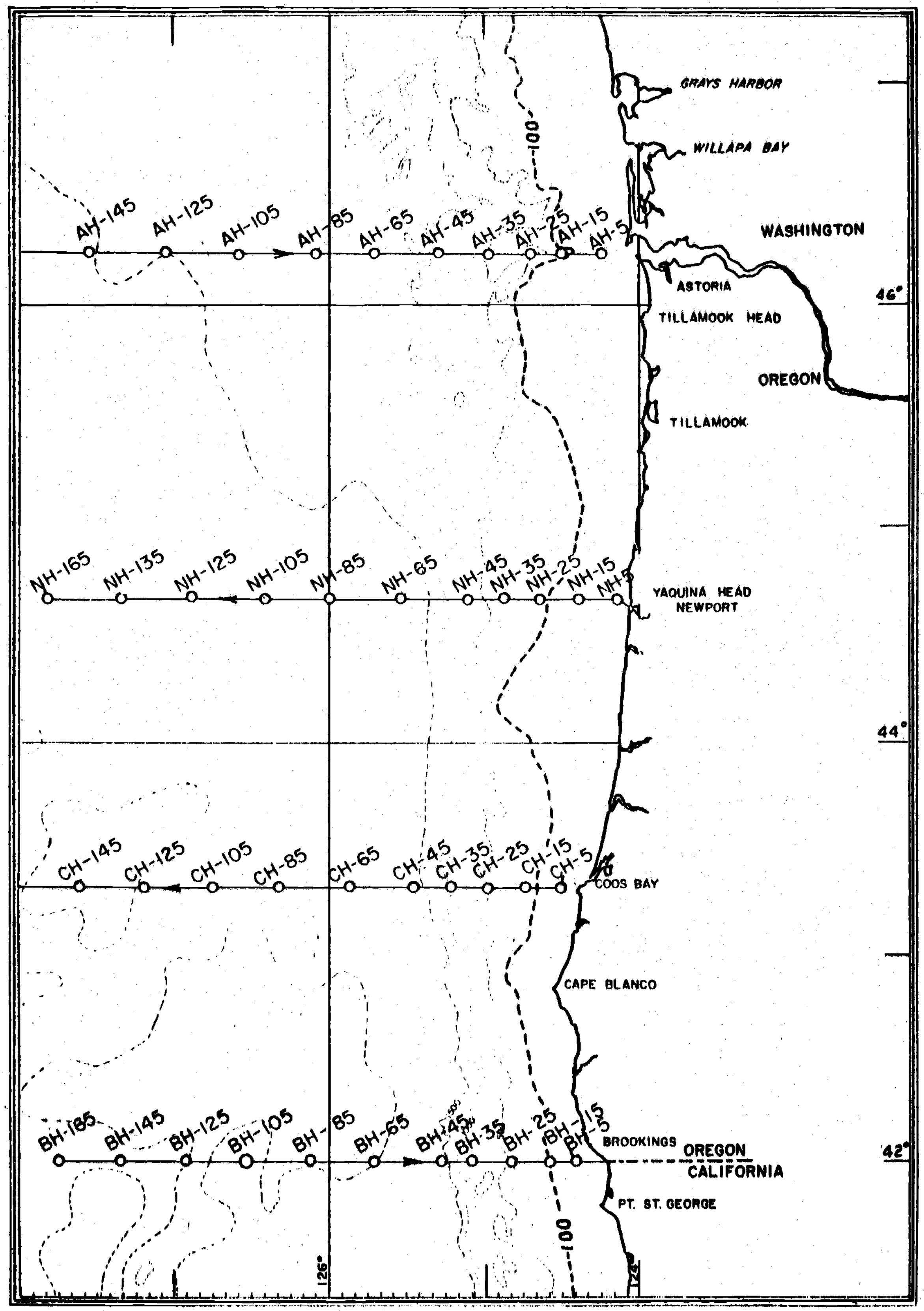

Figure 1. Hydrographic Stations off Oregon (AH-165 and CH-165 not shown).

such as chaetognaths, euphausiids, amphipods, etc., counting and removing all copepods over 4 mm in length (except when very abundant), and sub-sampling the remainder of the sampler. The sub-sampling was done by diluting the sample approximately five times with the settled volume and extracting a 1 cc aliquot with a Stempel pipette (14, p.5-6). This aliquot was then placed in a gridded petri dish and adult copepods were identified to species and counted. All copepodites were lumped into one category during counting, regardless of species or stage of maturity.

In all, 116 samples were examined. However, because of the small mouth diameter of the Clarke-Bumpus sampler, the larger copepods, which occurred in very small numbers in many samples (often less than five in a whole sample), may not have been collected quantitatively. Thus, these species were merely listed as present. The texts used for identification were Brodsky (6, p.1-441), Olson (25, p.1-208), Giesbrecht (16, p.1-831), and Tanaka (33, p.251-272, 34, p.367-406, 35, p.31-68, 36, p.169-207, and 37, p.327-367). Forty-six species of copepods were identified (Table 1).

After all identifications and counts were made, the data were processed in an IBM 1620 computer. Number per cubic meter of total adult copepods, individual species, and copepodites were calculated for each sample along with percentages of the total population represented by each species.

Table 1. List of Copepod Species Identified in This Study.

Calanus finmarchicus (Gunnerus)

Calanus plumchrus Marukawa

Calanus cristatus Krøyer

Calanus tenuicornis Dana

Eucalanus bungii Giesbrecht

Eucalanus elongatus hyalinus Giesbrecht

Rhincalanus nasutus Giesbrecht

Paracalanus parvus (Claus)

Pseudocalanus minutus (Krøyer)

Clausocalanus arcuicornis (Dana)

Aetideus armatus (Boeck)

Gaidius pungens Giesbrecht

Gaetanus simplex Brodsky

Euchirella rostrata (Claus)

Euchirella pulchra (Lubbock)

Chirundina streetsi Giesbrecht

Pareuchaeta japonica (Marukawa)

Scottocalanus persecans (Giesbrecht)

Scaphocalanus brevicornis Sars

Racovitzanus porrectus (Giesbrecht)

Scolecithricella minor v. *orientalis* Brodsky

Metridia lucens Boeck

Pleuromamma abdominalis (Lubbock)

Pleuromamma xiphias (Giesbrecht)

Pleuromamma quadrungulata (Dahl)

Pleuromamma scutullata Brodsky

Centropages mcmurrichi Willey

Lucicutia flavicornis (Claus)

Heterorhabdus tanneri (Giesbrecht) (= *Heterorhabdus proximus* Davis)

Heterorhabdus sp.

Heterostylites longicornis (Giesbrecht)

Candacia columbiae Campbell

Candacia bipinnata Giesbrecht

Epilabidocera amphitrites (McMurrich)

Acartia clausi Giesbrecht

Acartia longiremis (Lilljeborg)

Acartia danae Giesbrecht

Tortanus discaudatus (Thompson and Scott)

Microstella sp.

Clytemnestra rostrata (Brady)

Aegisthus mucronatus Giesbrecht

Oithona similis Claus

Oithona spinirostris Claus

Corycaeus sp.

Oncaea conifera Giesbrecht

Physical Factors Influencing the Distribution and Abundance of Copepods in the Surface Layers

Oregon coastal waters offer an excellent environment in which to study the influence of physical factors upon the distribution and abundance of copepods in the top 200 meters. Upwelling, Columbia River discharge, coastal regions of high runoff and precipitation, and seasonal changes in the direction of flow of the surface current all influence the copepod population during some part of the year.

In general, from April to September the movement of surface waters in the region studied is in a southerly direction. Maughan (23, p.33) has shown that these southward flowing waters have a weak onshore component during April and May and a moderate offshore component during July. Due to prevailing northwest winds, surface water is moved offshore during the summer months and is replaced along the coast by colder, more saline water upwelled from greater depths. It is not uncommon in regions of upwelling off the Oregon coast to have temperatures at 10 meters depth 6-8°C lower and salinities as much as one part per thousand higher than the surrounding water.

Pattullo and Denner (29) found that upwelling influenced surface temperatures and salinities to a greater extent south of Lat. 44°N along the Oregon coast. Of the four hydrographic lines sampled for copepods in this study, Brookings showed the most intense upwelling within five miles of shore. Upwelling, of course, brings nutrients to the surface and consequently relatively more biomass can be produced and maintained in the general area where this is taking place.

Also during the summer months, the prevailing northwest winds and southerly currents push Columbia River water to the southwest off the Oregon coast. If Columbia River water is defined as surface water having a salinity of 32.5 $^{o}/oo$ or less (2, p.3) the so-called "plume" extends as far south as lat. 40^{o}N and westward to 250 miles from shore (1, p.6). The plume is best developed during late summer and early fall, as greatest discharge from the Columbia River occurs during June (2, p.5-6).

From October through March, the northward flowing Davidson Current is found off the coast, varying in width to over 165 miles from shore. Its presence appears to be due to prevailing southerly winds (7) at this time of year. Maughan (23, p.33) lists a moderate to strong onshore component from November to February for the Davidson Current. This onshore movement of water, in regions of high precipitation and runoff, creates a narrow band of relatively low salinity water along the coast.

The bathymetry of the continental shelf may, at times, affect the distribution and abundance of the copepod population. The 100 fathom contour, which is usually considered to be the outer edge of the neritic environment, is found between the 5 and 15 mile station at Astoria, but extends out to about the 25 mile station off Newport (Fig. 1). At Coos Bay and Brookings it is present in the vicinity of the 15 mile station again. The extension of the 100 fathom contour off Newport to about 25 miles may influence the abundance of certain species of copepods.

Distribution Patterns of the Total Copepod Population

Total Adult Population

The total adult copepod population off Oregon in 1962 varied according to distance from shore, season, and hydrographic line sampled. The Newport line offered the best available data, as collections were made in January, February, April, May, July, September and October. Data were not available during all of these months on the other three lines, and therefore seasonal comparison between lines becomes somewhat difficult.

Off Newport, spring and late summer were seasons of maximum abundance at the 5, 15, 25, and 35 mile stations (Fig. 3). At the remaining stations (45, 65 and 105 miles), high numbers were found only during April and May, with greatest numbers appearing in May, both inshore and offshore. By late July numbers were still high inshore, but a marked depletion of the population was evident at the offshore stations. September was similar to July, although the inshore population was somewhat smaller. October showed even a lesser population inshore than September, but it appeared that the October offshore population may have increased relative to July and September. The Newport line was not completely sampled in October, however. January data indicated that the winter populations were low and relatively uniform at all stations.

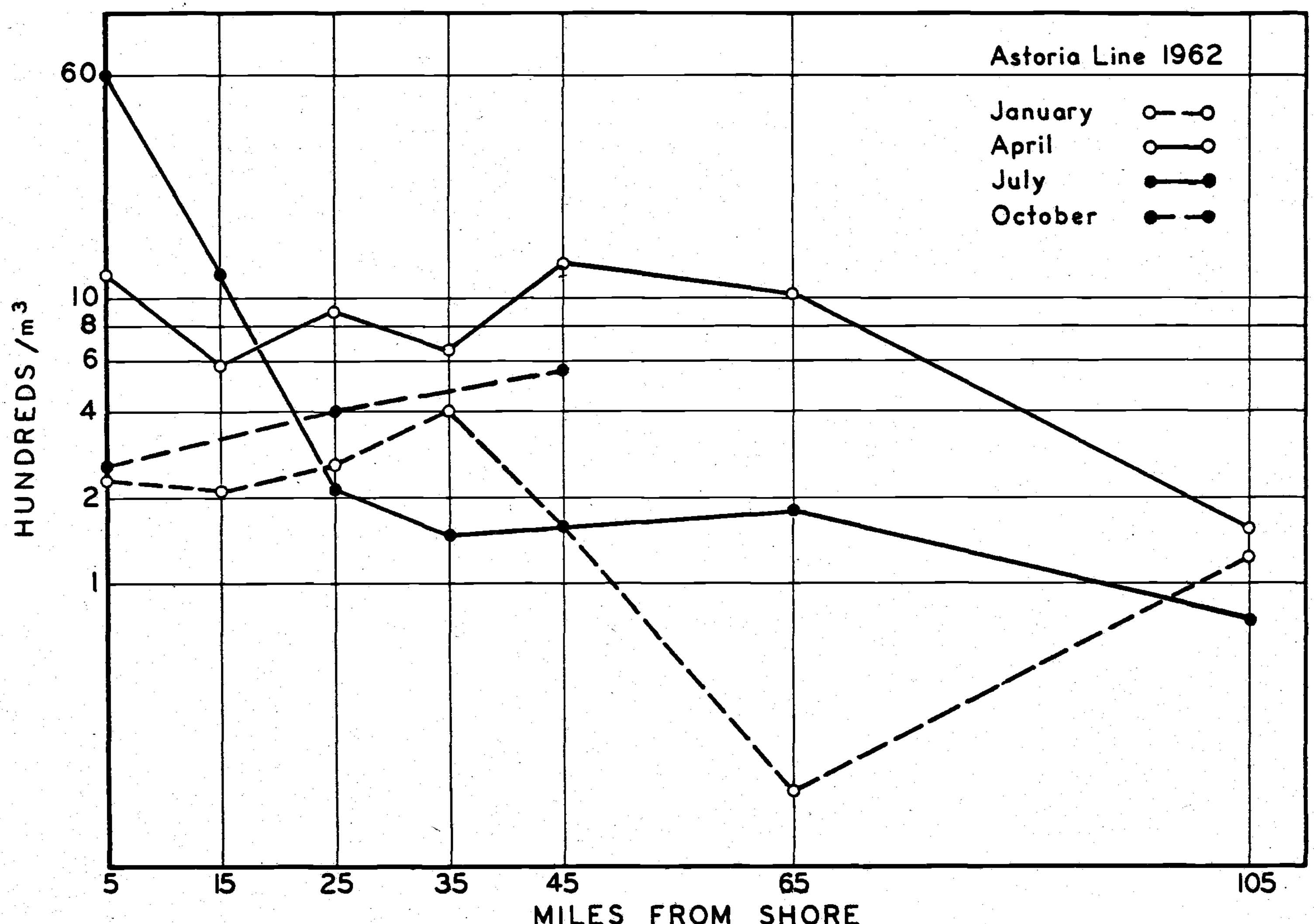

Figure 2. Total Adult Population - Astoria Line (Note semi-log scale).

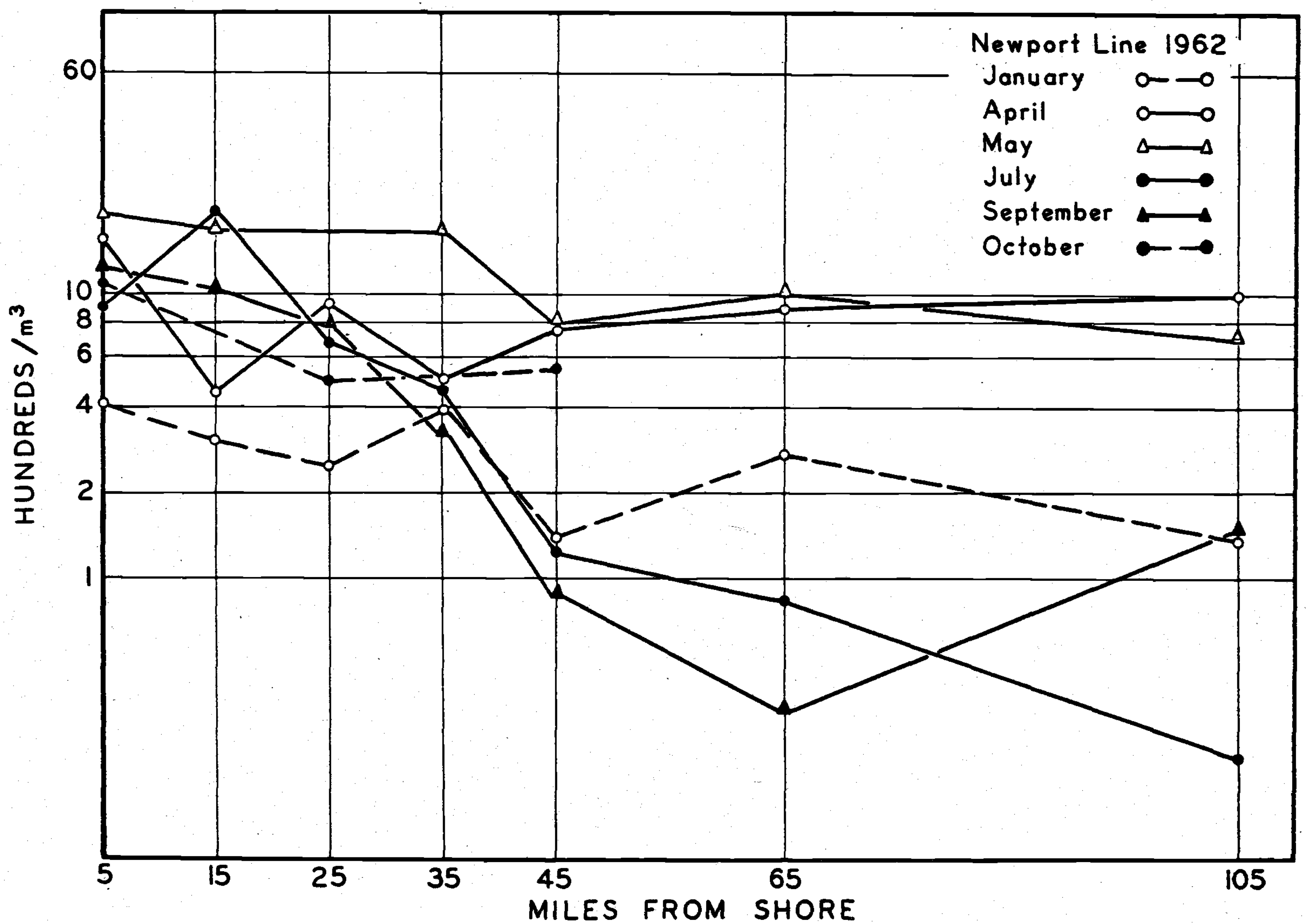

Figure 3. Total Adult Population - Newport Line (Note semi-log scale).

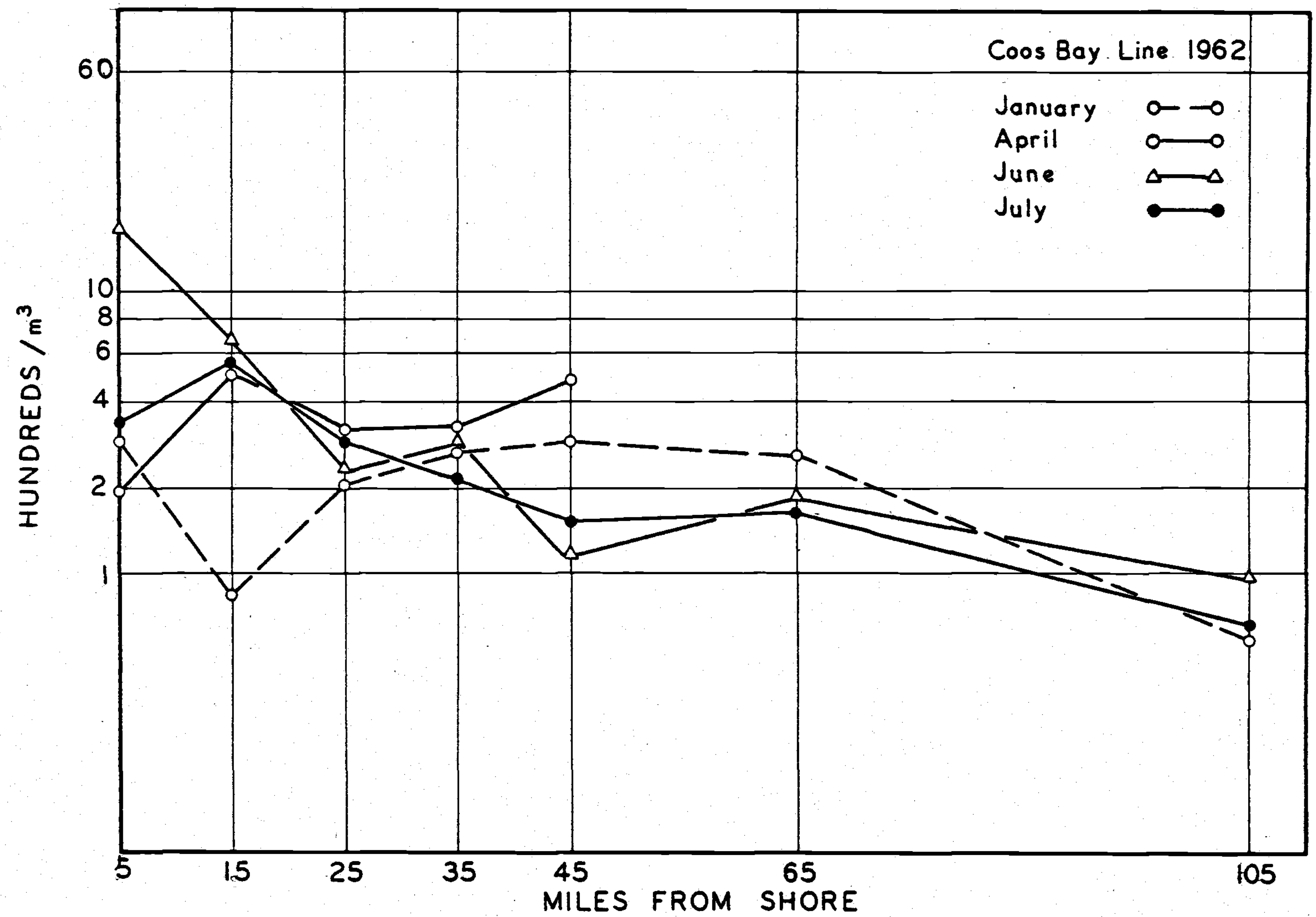

Figure 4. Total Adult Population - Coos Bay Line (Note semi-log scale).

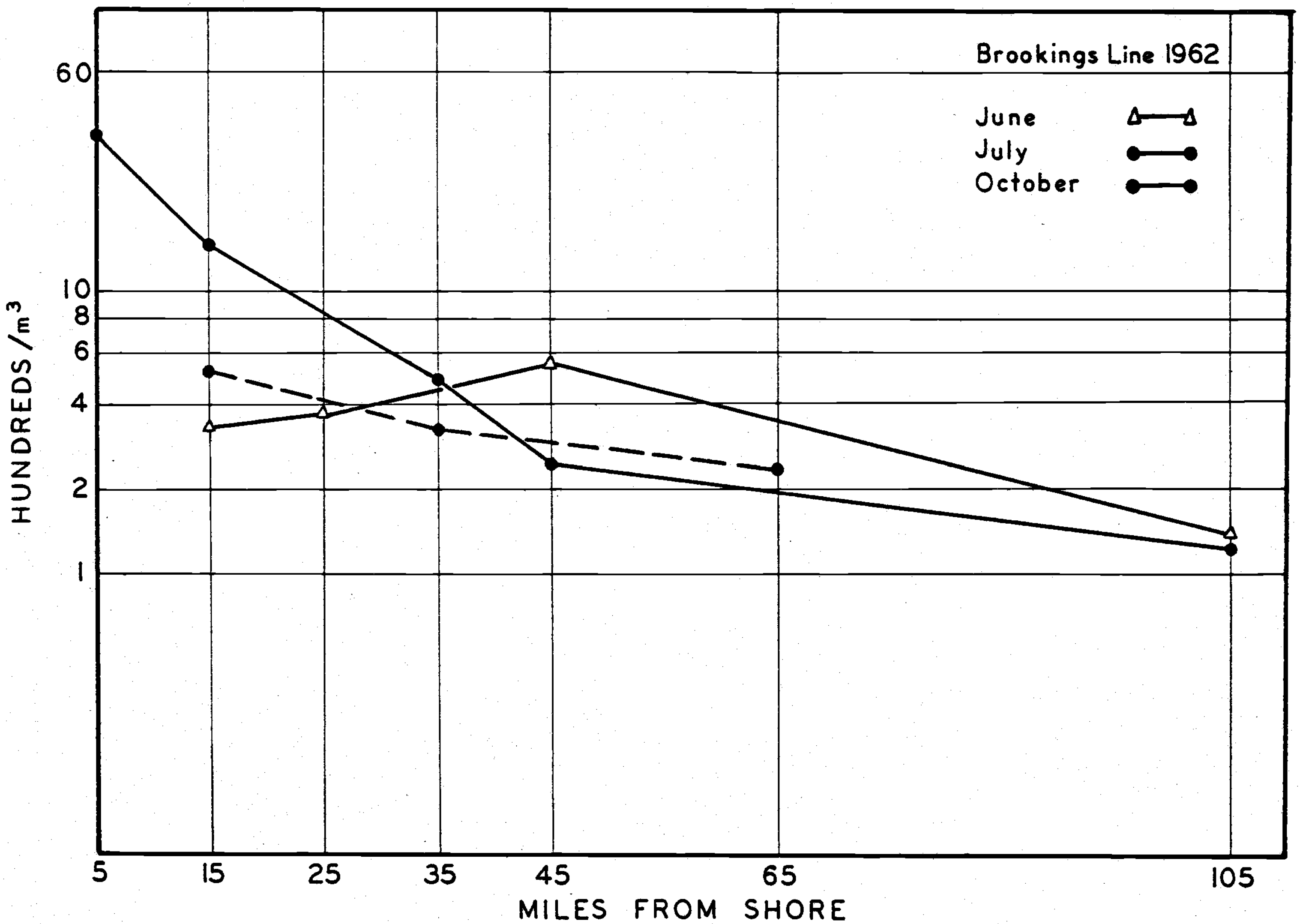

Figure 5. Total Adult Population - Brookings Line (Note semi-log scale).

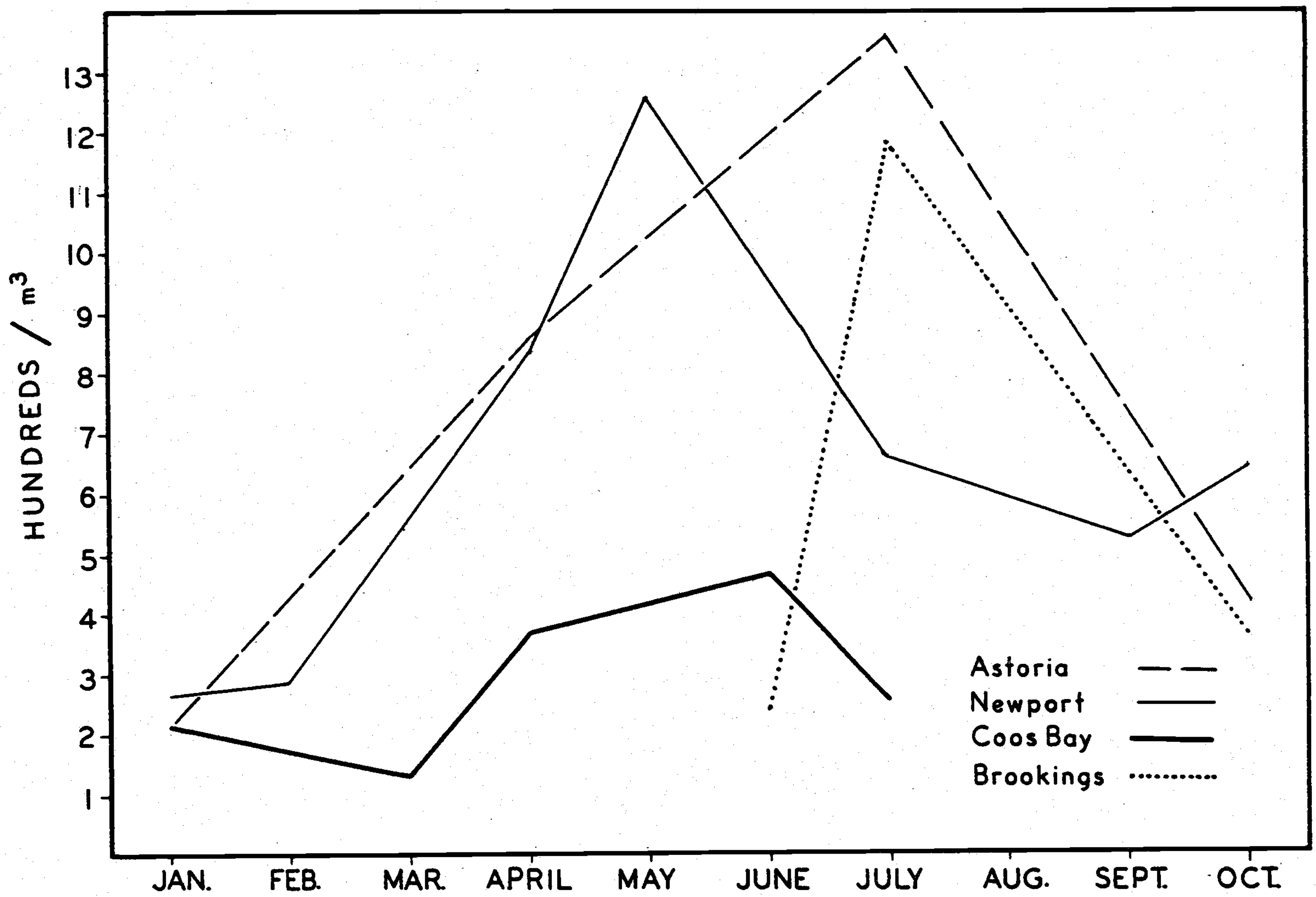

Figure 6. Monthly Average of the Adult Copepod Population for all Stations Sampled.

The Astoria line (Fig. 2) was sampled only four times during 1962 (January, April, July and October). However, the seasonal and spatial distribution of adult copepods appeared similar to that on the Newport line. Highest numbers generally were found in April, though July populations exceeded the April populations at AH-5 and AH-15. The highest adult population found in this study was at AH-5 in July (6326/m^3). This was exceptional in that only one other collection in 1962 yielded number exceeding 2000 copepods/m^3 (BH-5 in July with 3581/m^3). This extremely high Astoria population was possibly a result of two factors. First, the fertility of the water in this area probably was quite high at this time of year due to great discharge from the Columbia River. Anderson, et al (2, p.5-6) have shown that the Columbia River reaches its maximum discharge about the middle of June. The fact that high river discharge often enhances the basic fertility of water bodies receiving the discharge has been noted in the literature. Curl (10) found that high phosphate concentrations were introduced into the western basin of Lake Erie via the Maumee River during periods of highest discharge. These high phosphate concentrations enhanced the growth of phytoplankton, which presumably could have supported a substantial zooplankton population. It seems reasonable to suppose that high discharge from the Columbia River may have indirectly aided in the establishment of the high AH-5 copepod population in this study. Water samples collected from the top 50 meters at the inshore station off Astoria in June 1962, had phosphate concentrations ranging from 0.69-2.80 µM

PO_4-P/l. In comparison to this, phosphate concentrations from top 100 meters at AH-65 on the same date ranged from 0.62-1.83 µM PO_4-P/l. In late July, at the time of the exceedingly high copepod population at AH-5, phosphate concentrations were still high (1.30-2.54 µM PO_4-P/l in the top 50 meters).

A second factor perhaps contributing to the high AH-5 population in July was upwelling. Relatively low temperatures and high salinities characterized the water below 20 meters at AH-5 in June and were also apparent in July. This upwelled water was not, however, detectable at the surface because of the presence of Columbia River water.

The adult population at Coos Bay (Fig. 4) varied somewhat from patterns found at Astoria and Newport. Samples were collected only during January, April, June, and July, however. The magnitude of the April population did not approach that of the other two lines, although no data were available for CH-65 or CH-105. A June peak appeared inshore at Coos Bay, which possibly can be compared to the May and July inshore populations at Newport and possibly the July population at AH-5.

Off Brookings, collections were made during June, late July, and October (Fig. 5). A marked inshore high occurred in July, where concentrations of $3580/m^3$ and $1466/m^3$ were present at the 5 and 15 mile stations, respectively. At this time of year off Brookings intense coastal upwelling had been in effect for approximately two months. Surface salinities at BH-5 were 34.06 ‰ in June and

and 33.84 ‰ in July, while farther offshore they were always lower than 33.00 ‰. Chlorophyll "a" concentrations averaged about 10 mg/m^3 in the top 25 meters in July at BH-5, but were consistently lower than 1 mg/m^3 at the offshore stations (32). This indicated that the primary standing crop was high in the area of upwelling, and subsequently high zooplankton concentrations might be expected.

The total adult copepod populations on each of the four sampling lines can be compared seasonally by averaging the station data on each line for each cruise and plotting these averages against time of year. Several points become evident when this is done (Fig. 6). First, the average numbers of copepods per cubic meter off Astoria, Newport, and Coos Bay in January were strikingly similar. This similarity was also evident in April off Newport and Astoria. The high peak off Astoria in July was due primarily to the extremely large AH-5 population.

The average populations off Coos Bay were decidedly smaller than those off the two northern lines during the spring and summer. *Pseudocalanus minutus*, *Oithona similis* and *Acartia longiremis* were substantially more abundant off Newport and Astoria than off Coos Bay during this time. The small numbers of these three organisms on the Coos Bay line had a marked effect in reducing the total population there.

Though no data were available, it was expected that the average numbers of copepods off Brookings during the winter and spring months might be similar to those off Coos Bay, as Brookings populations in

June and October fell well within the range of the Coos Bay populations. The high population peak off Brookings in July was due mainly to the large population recorded at the five mile station.

The seasonal maxima along the Oregon coast from April through July are in close agreement with those summarized by Raymont (30, p.371-418) from the north Atlantic. In the northeast Pacific, Frolander (15, p.661) reported maximum displacement volumes in May off the Washington coast, and Hebard (19, p.40) recorded greatest displacement volumes from May to September in Puget Sound.

Oithona similis and Pseudocalanus minutus were the dominant species at all stations throughout the year. They consistently made up 65-90% of the adult copepod population. During January, O. similis was the predominant copepod at most stations sampled. In the spring (April and May) both O. similis and P. minutus were present in great numbers, P. minutus at the inshore stations (5, 15 and 25 miles) and O. similis at the offshore stations (45, 65 and 105 miles). The spring populations were also bolstered by large numbers of young Calanus cristatus and Calanus plumchrus. Populations remained high through late summer at the inshore stations, with Pseudocalanus minutus and Acartia longiremis contributing most significantly. Oithona similis again became the dominant copepod in October.

Other copepods which were not abundant but occurred consistently included Oithona spinirostris, Calanus finmarchicus, Clausocalanus arcuicornis, Eucalanus bungii, Scolecithricella minor, Metridia lucens, Lucicutia flavicornis, Oncaea conifera, and, during the winter months, *Acartia danae*. Species which appeared almost exclusively at the 5 and 15 mile stations in small numbers were *Paracalanus parvus*, *Epilabidocera amphitrites*, *Acartia clausi*, and *Tortanus discaudatus*.

Total Copepodite Population

All stages of copepodites, regardless of species, were lumped into one category. The distribution of this copepodite population resembled that of the total adult population very closely and the factors affecting copepodite distribution were probably similar to those governing the adult population. Only general trends will be pointed out.

The highest overall concentrations occurred during April and May off Astoria, Newport and Coos Bay (Figs. 7-9). No data were available off Brookings during these months, but summer and fall populations are shown in figure 10. Inshore populations were high in July along all sampling lines, but declined rapidly seaward. October populations appeared to be slightly higher offshore than those in July, though the lines were not completely sampled in October.

The monthly averages for all stations (Fig. 11) were strikingly similar to the averages shown for the total adult population (Fig. 6). Off Astoria and Newport, numbers were low in January, increased markedly over the spring and summer months, then declined during late summer and early autumn. Populations of copepodites never developed off Coos Bay as they did off the two northern sampling lines, though January concentrations were very similar to those of the northern

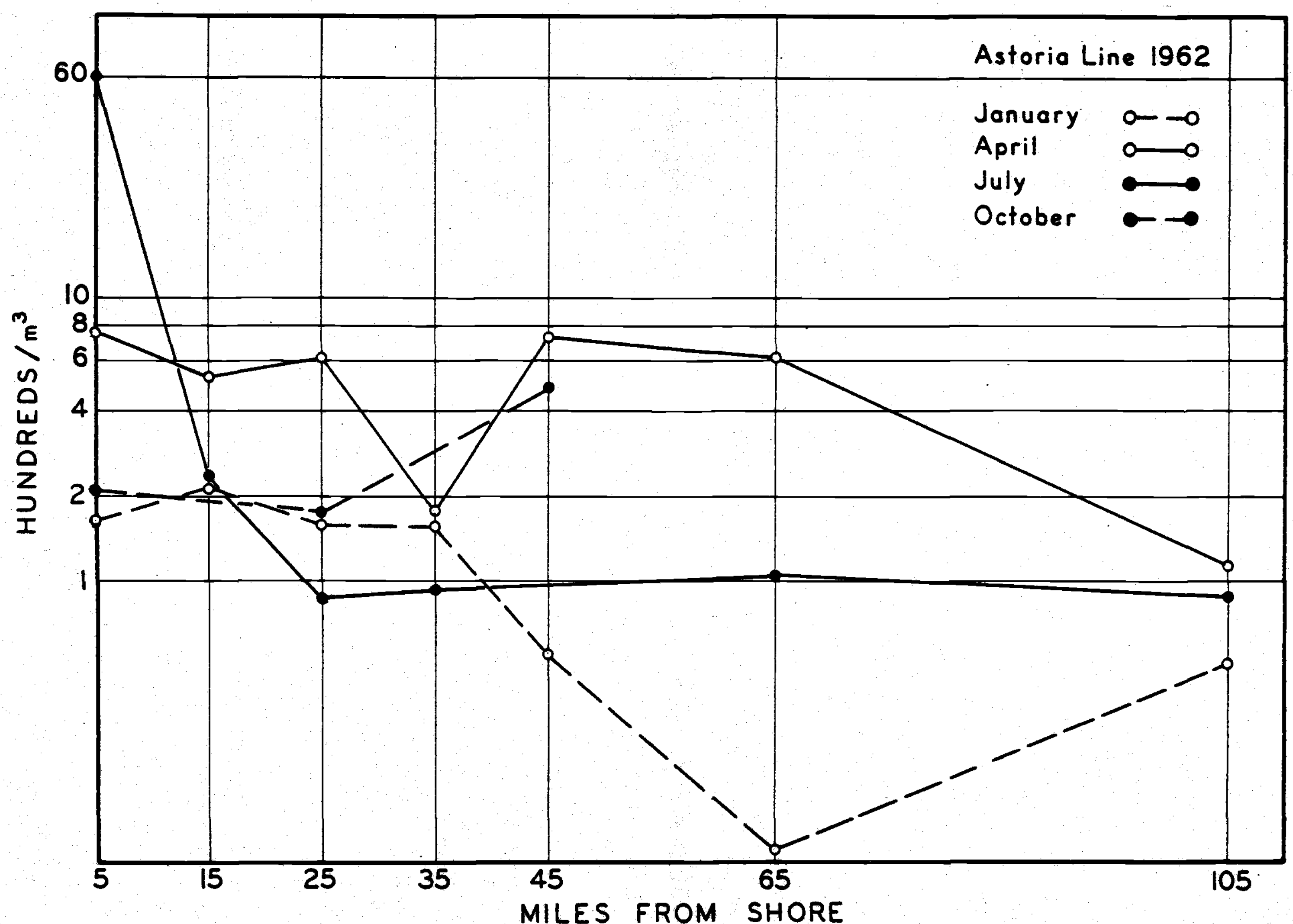

Figure 7. Total Copepodite Population - Astoria Line (Note semi-log scale).

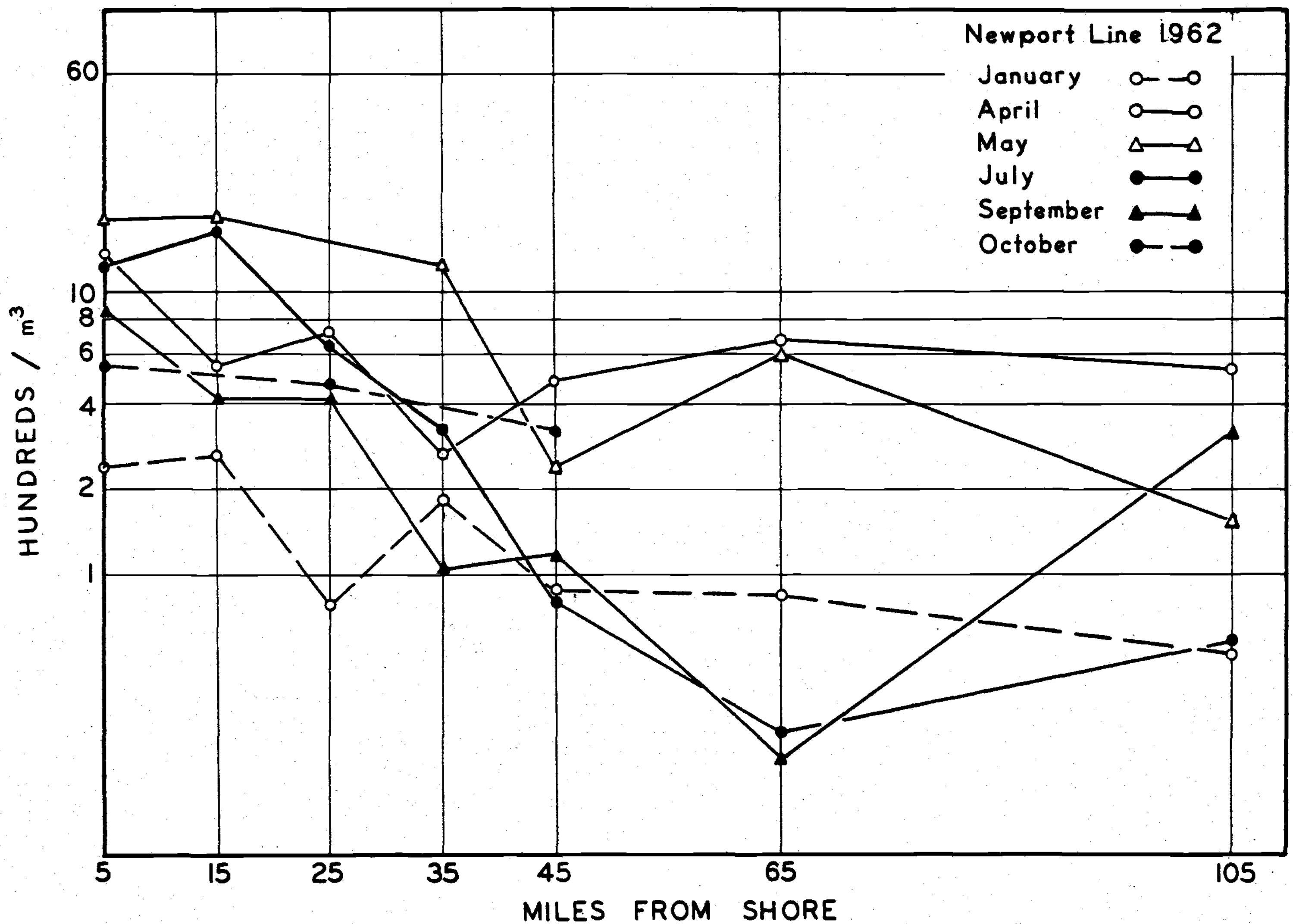

Figure 8. Total Copepodite Population - Newport Line (Note semi-log scale).

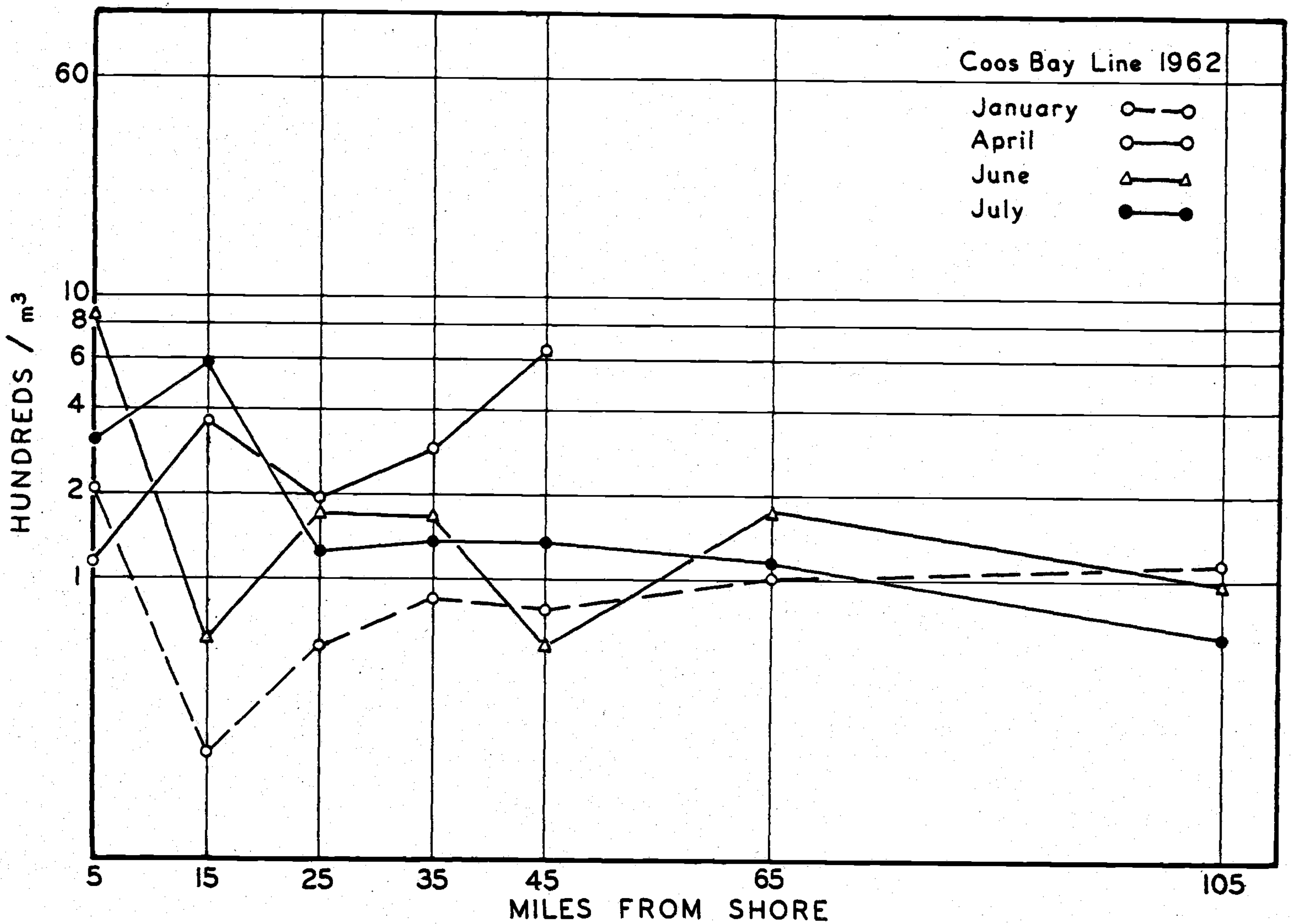

Figure 9. Total Copepodite Population - Coos Bay Line (Note semi-log scale).

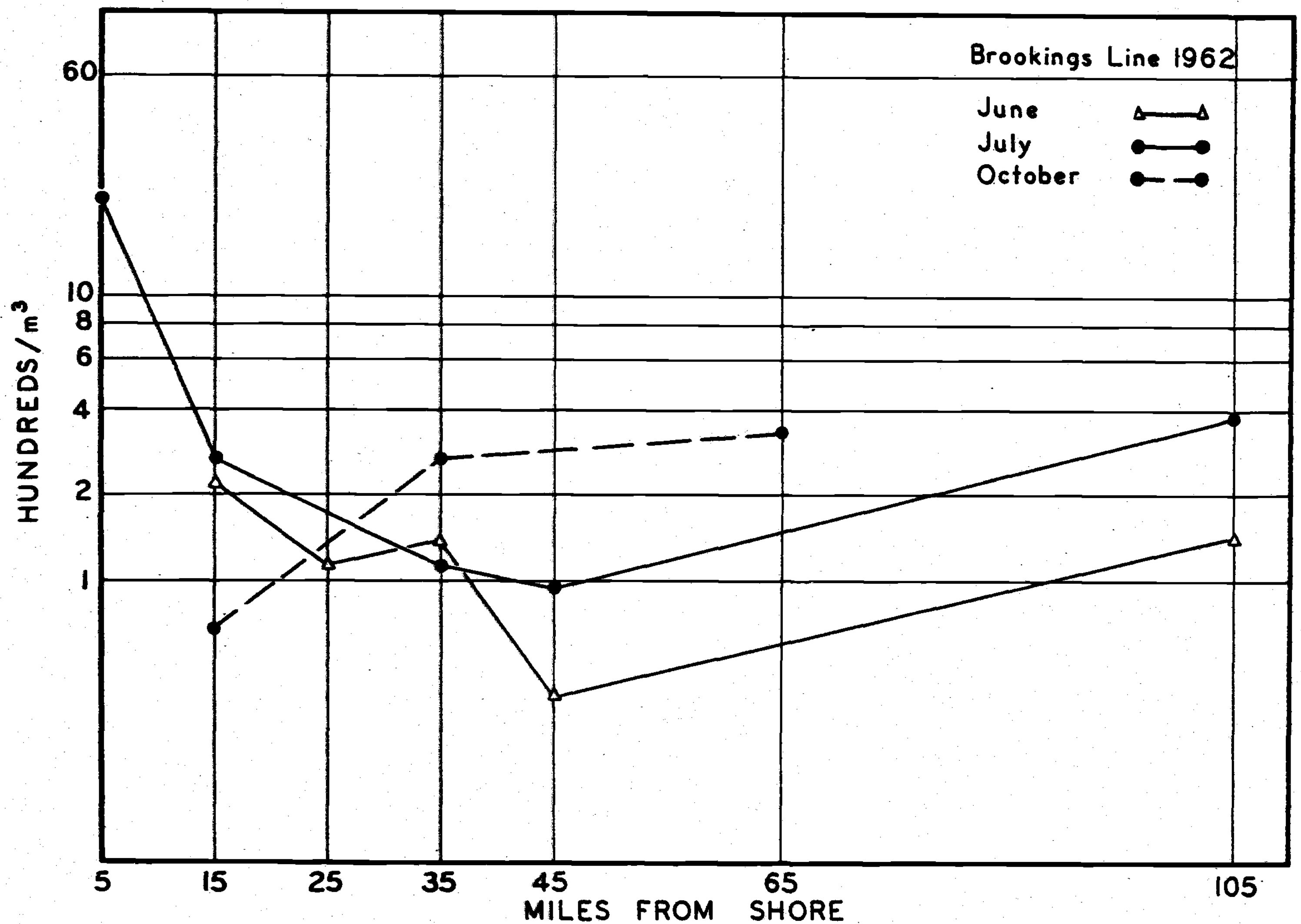

Figure 10. Total Copepodite Population - Brookings Line (Note semi-log scale).

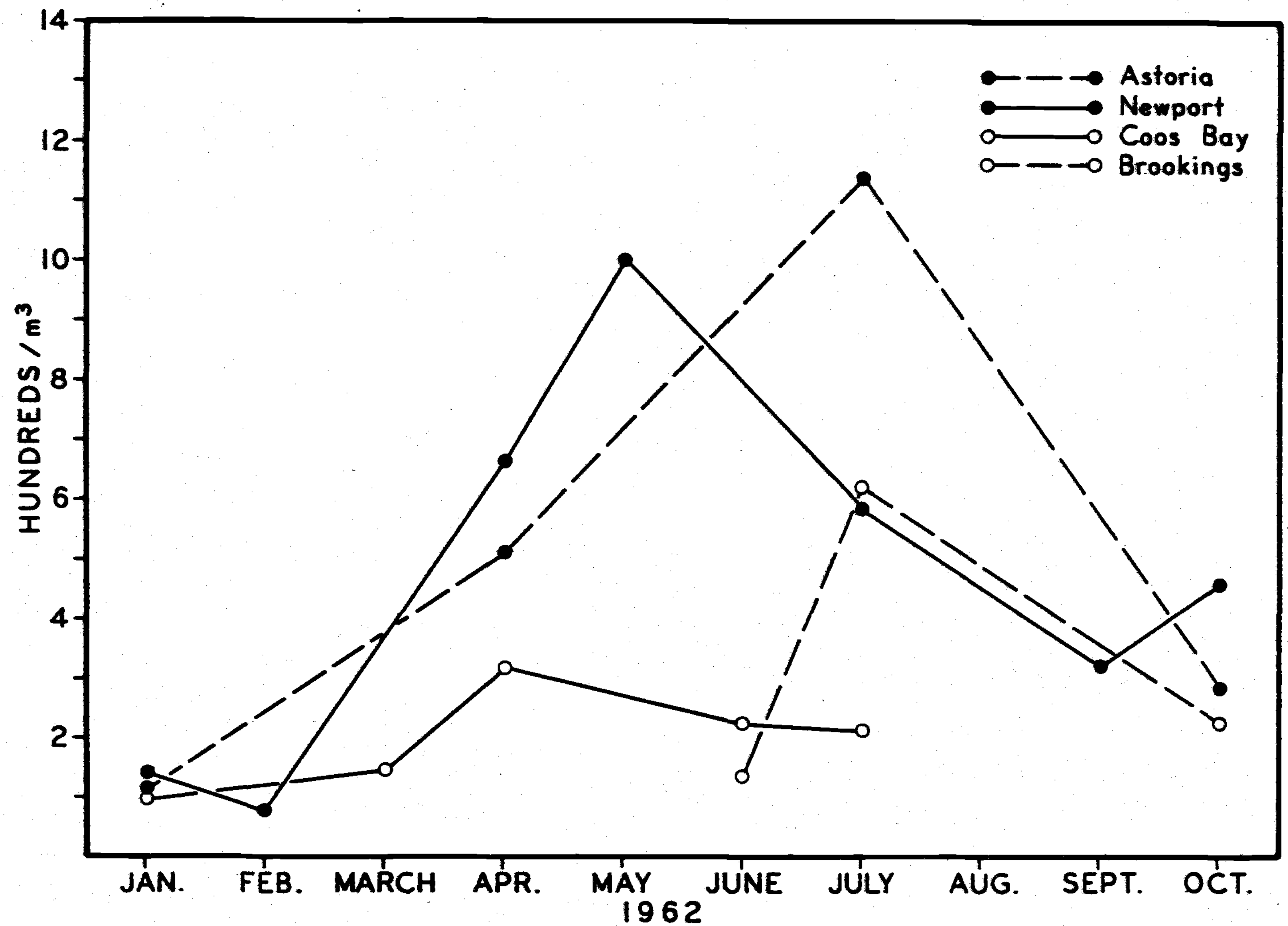

Figure 11. Monthly Average of the Copepodite Population for all Stations Sampled.

lines. This same relationship was evident with the average adult populations.

No winter and spring data were available off Brookings, but a July copepodite peak coincided with a similar peak in the adult population along this sampling line. As with the adult population, the high average concentration of copepodites at this time was caused by the high population at BH-5, which in turn probably was due to the intense upwelling conditions at this station during this time of year.

Distribution Patterns of the Most Significant Species

Pseudocalanus minutus (Krøyer)

Pseudocalanus minutus was found in greatest numbers in neritic waters. On the Newport line it was consistently more abundant out to NH-25 than further offshore (Fig. 13). The population was relatively low during the winter months, but increased by April to 200-650 individuals/m^3 at the coastal stations and 125-300/m^3 at the offshore stations. Maximum numbers occurred in May, where highs of 1424/m^3 were found at NH-5, 1478/m^3 at NH-15, and 1002/m^3 at NH-35. No data were available for NH-25 in May. The population remained high in July in the coastal area, but declined markedly from NH-25 to NH-105. In September it was still relatively high in the coastal region and continued in low numbers offshore.

On the Astoria line the distribution was similar to that off

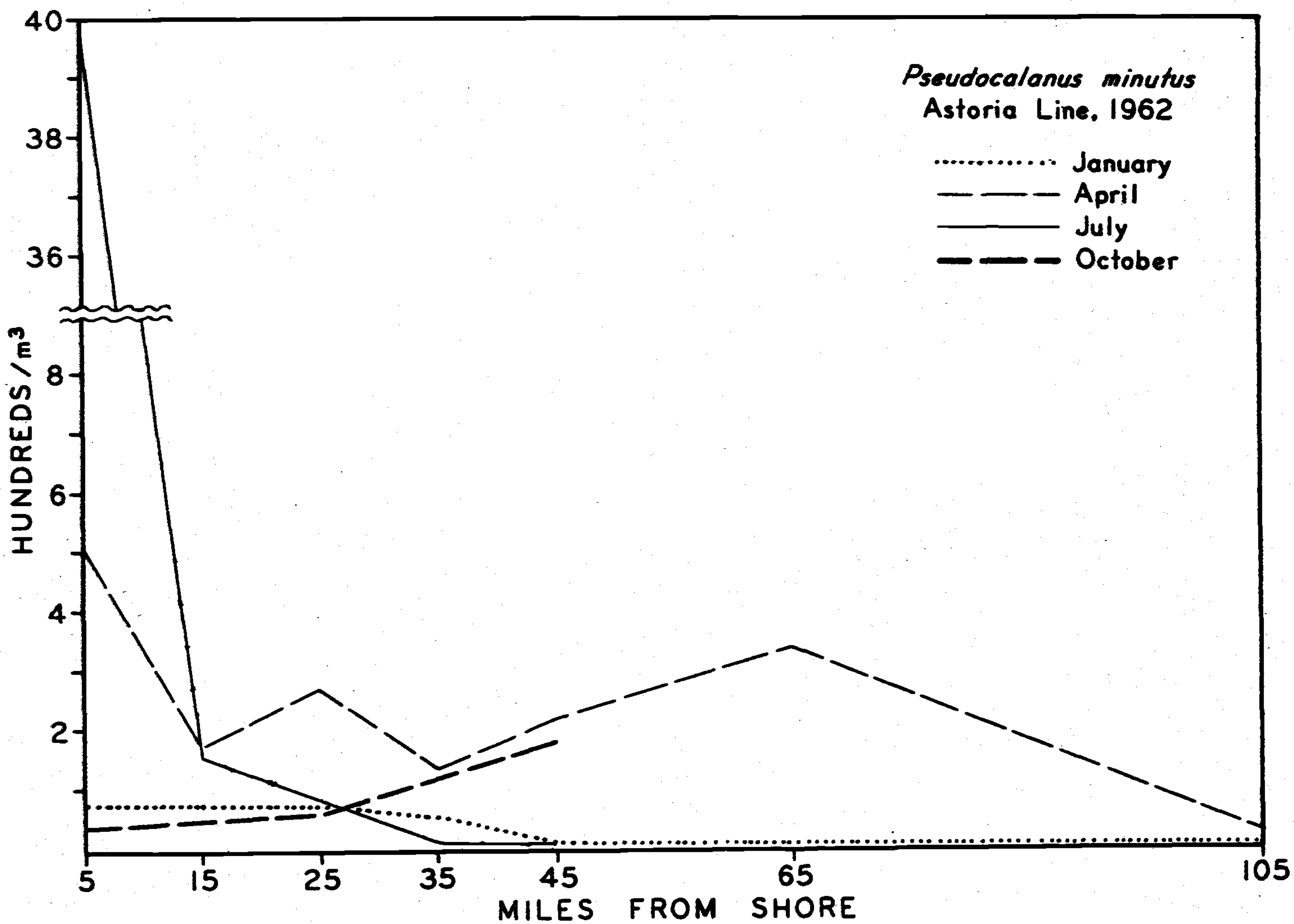

Figure 12. Seasonal Distribution of Pseudocalanus minutus - Astoria line.

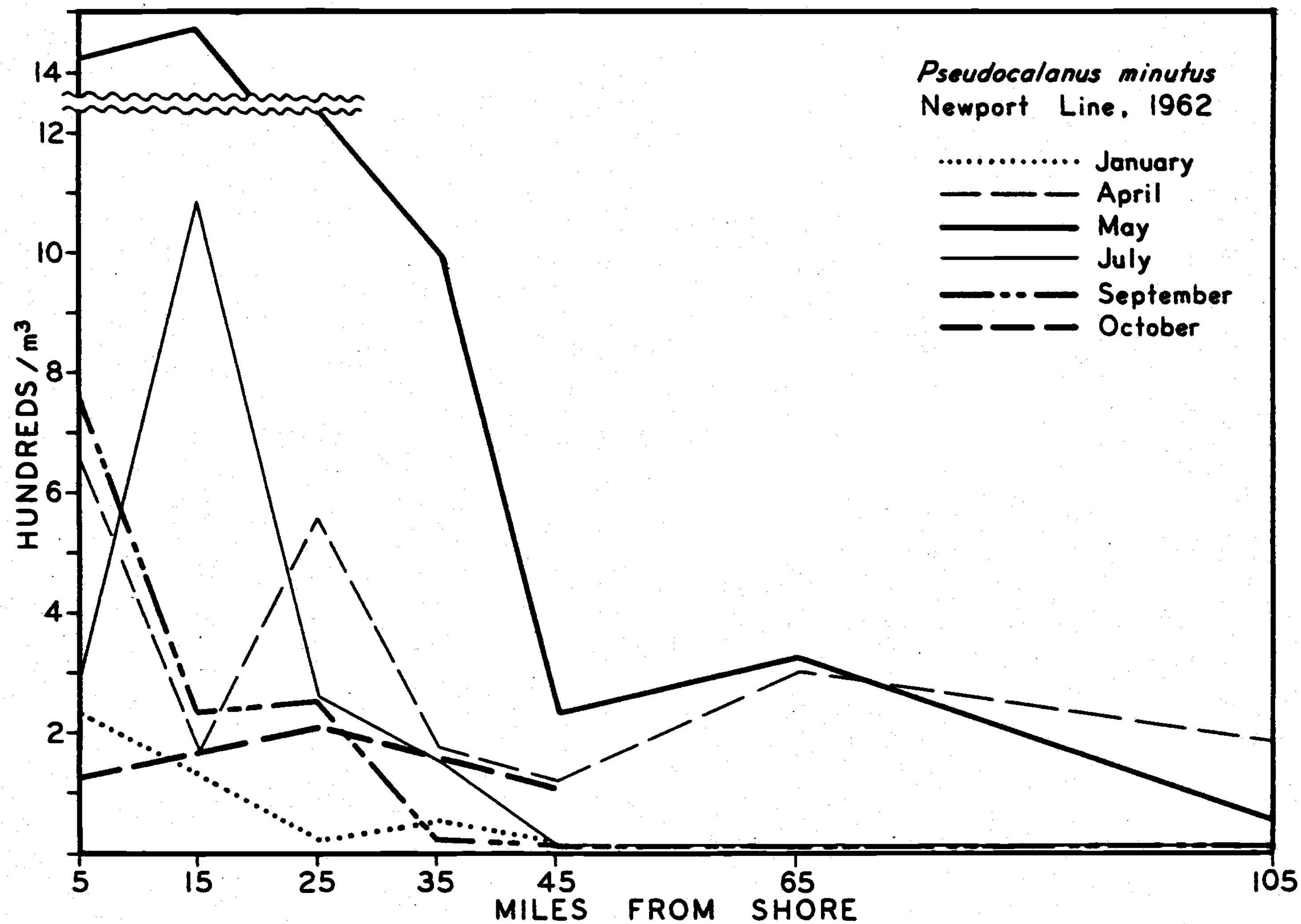

Figure 13. Seasonal Distribution of Pseudocalanus minutus - Newport line.

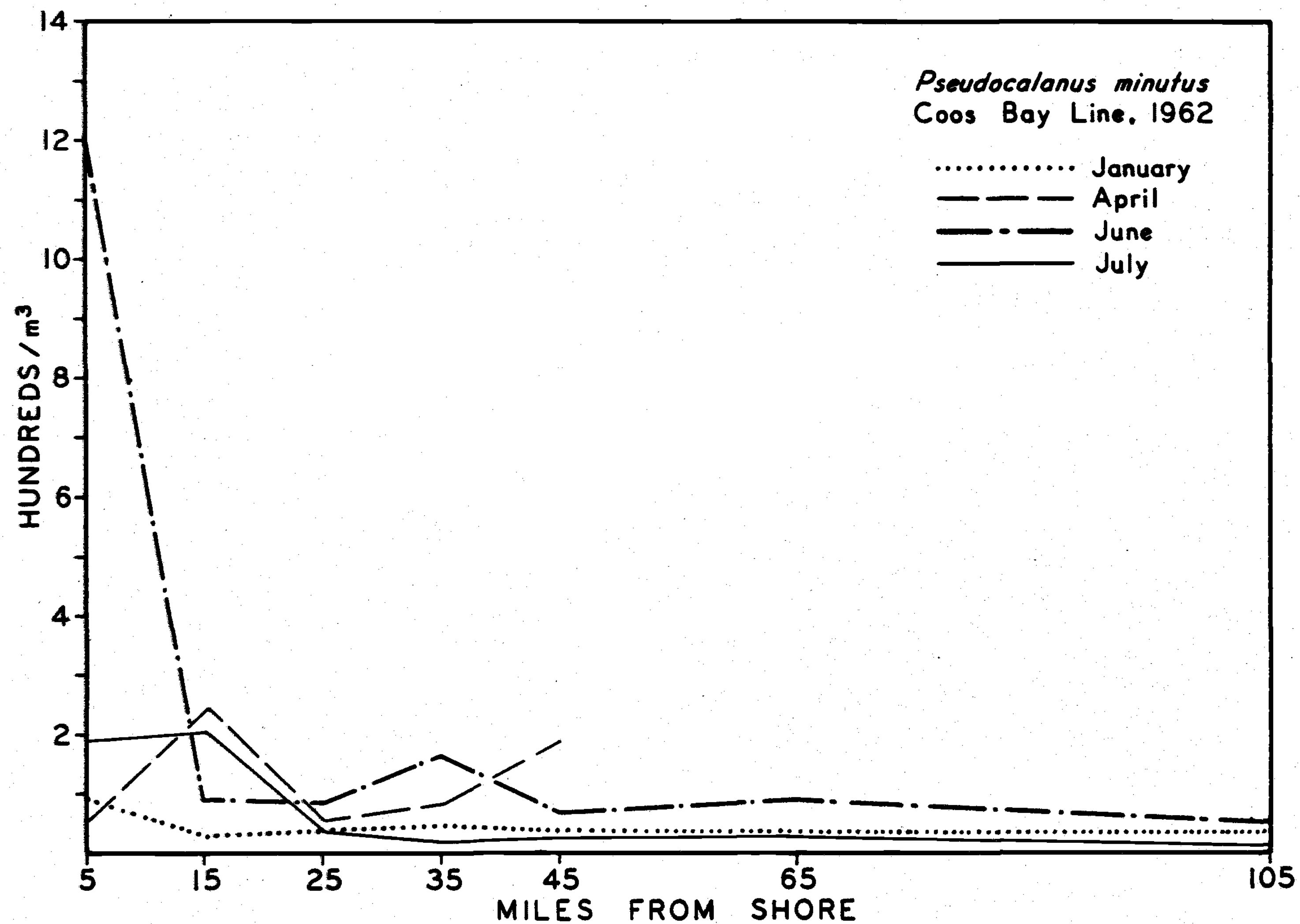

Figure 14. Seasonal Distribution of Pseudocalanus minutus - Coos Bay line.

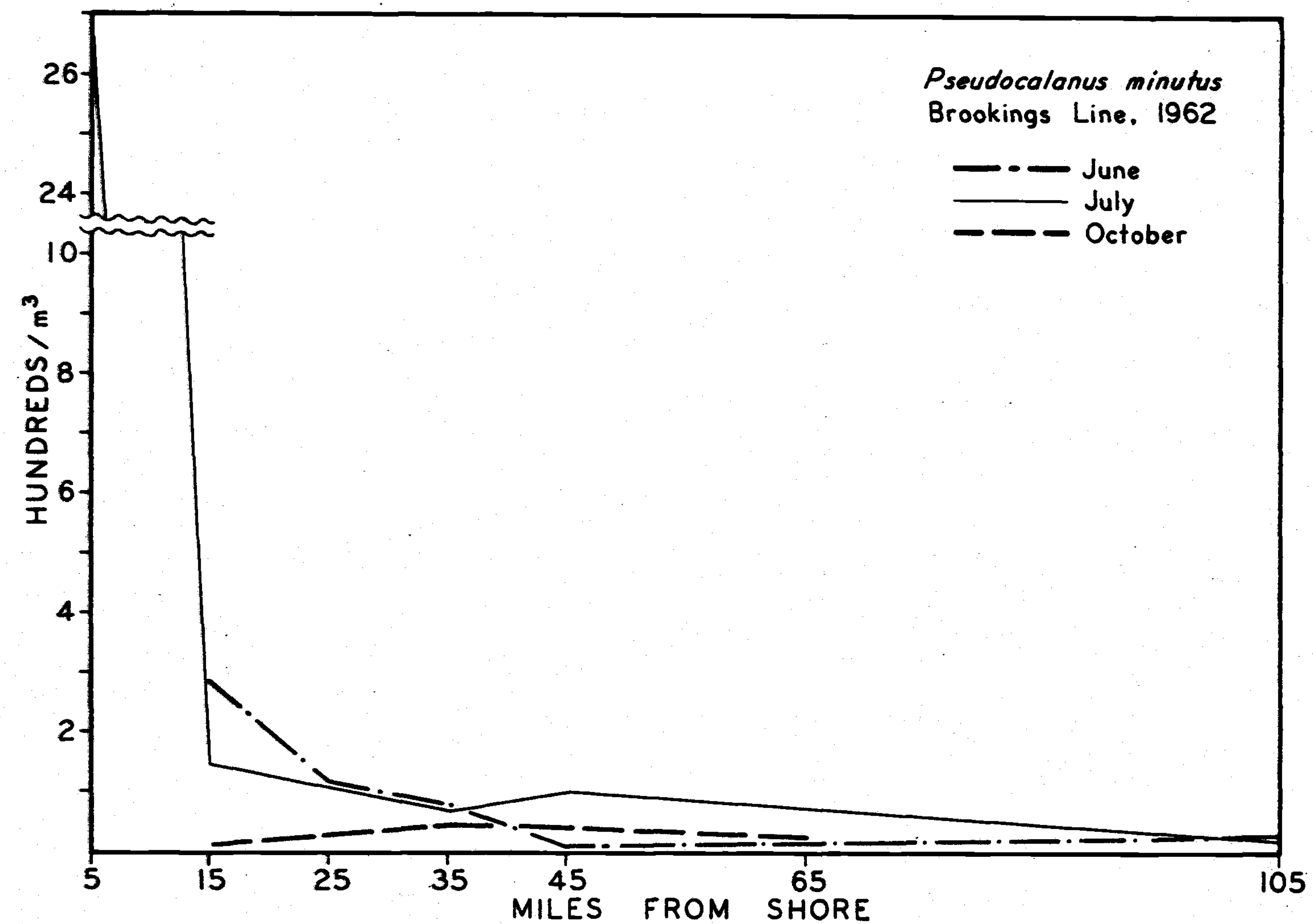

Figure 15. Seasonal Distribution of Pseudocalanus minutus - Brookings line.

Newport for much of the year (Fig. 12). Data were not available for May, however, when the population reached its maximum peak off Newport. The highest concentration of this copepod recorded off Oregon for 1962 occurred in July at AH-5 ($3970/m^3$). This was possibly related to both Columbia River discharge and upwelling, as discussed in the section on total adult populations. At AH-15 on the same date the population dropped to $157/m^3$, and was below $100/m^3$ at the remaining stations. The population from AH-25 seaward was quite similar to the corresponding population off Newport.

The Coos Bay population was generally much lower and more consistent than either the Astoria or Newport populations (Fig. 14). A peak in June at CH-5 reached $1192/m^3$, however. At no other time during the months sampled did the population exceed $250/m^3$. Off Brookings one exceptional population was noted (Fig. 15). This occurred at BH-5 in July, where $2662/m^3$ were found. As discussed in the section on total adult copepod populations, the great abundance of copepods in this region might be attributed to upwelling. The population at the remaining stations were quite low and comparable to those off Coos Bay. Data were available only for June, July and October.

Because samples were not available at frequent intervals, it was difficult to pinpoint the seasonal maximum of this species in Oregon coastal waters. However, the data point to May, June and July as periods of marked abundance. This agrees with earlier quantitative work by Frolander (15, p.663) off Washington and British

Columbia, and Hebard (19, p.16) in Puget Sound.

The spatial distribution of P. minutus may possibly be related to the bathymetry of the continental shelf off Oregon. It has been shown that the 100 fathom (200 meter) contour line (the approximate seaward boundary of the shelf off Oregon) extends approximately 25 miles off Newport, but only about 15 miles off Astoria, Coos Bay and Brookings (Fig. 1). P. minutus occurred farther from shore in somewhat greater numbers off Newport than off the other three sampling lines (Figs. 12, 13, 14 and 15). Thus, the regions of maximum abundance of the P. minutus population seemed to be generally limited to the relatively shallow waters over the continental shelf.

Pseudocalanus minutus apparently inhabits the boreal and Arctic waters of the North Pacific Ocean, as it has been reported from the coast of Japan (24, p.36), Aleutian waters (4, p.124), Arctic waters (39, p.8k-9k and 5, p.154), the Vancouver Island region (9 , p.308), the Queen Charlotte Island region (8, p.169) off the Washington coast (15, p.657), Puget Sound (19, p.16), Friday Harbor (20, p.23), and from the north central Pacific (40, p.205 and 41, p.316-317). It has not been reported from San Francisco Bay (12, p.81-110), or from Pacific equatorial waters (17, p.173-174). P. minutus does not appear to be synonomous with its namesake from the east coast of the United States (15, p.663).

Oithona similis Claus

Oithona similis averaged 51% of the adult copepod population in this study. Off Newport it exhibited two periods of abundance, the first in April and May at NH-35, 45, 65 and 105, and the second at the inshore stations in September and October (Fig. 17). Work by Wiborg (38, p.169) off the coast of Norway and Fish (13, p.186) in the Gulf of Maine indicates that late summer and early fall are periods of maximum concentrations in the Atlantic for this organism. Frolander (15, p.663) reported O. similis to be most abundant off Washington and British Columbia during November.

On the Astoria line highest concentrations were present in April, both inshore and offshore (Fig. 16). January and July numbers were low, but the October population appeared to be somewhat higher. The seasonal pattern off Astoria thus tended to be similar to that off Newport, with periods of abundance in spring and fall. Only three collections were examined off Astoria during the fall months, however (AH-5, 25 and 45 in October), indicating that more data are needed to verify the apparent similarity to Newport.

The lowest overall concentrations were found off Coos Bay (Fig. 18). June was the period of maximum abundance at the most inshore stations (CH-5 and 15), while no pronounced seasonal peak was found at the offshore stations. The greatest concentrations offshore (CH-35, 45 and 65) were found in January, although April data were not available beyond CH-45. Since no September or October data were available, it was not known whether an autumn peak developed on the Coos Bay line.

The Brookings line was sampled only in June, late July, and October (Fig. 19). The July and October populations were much

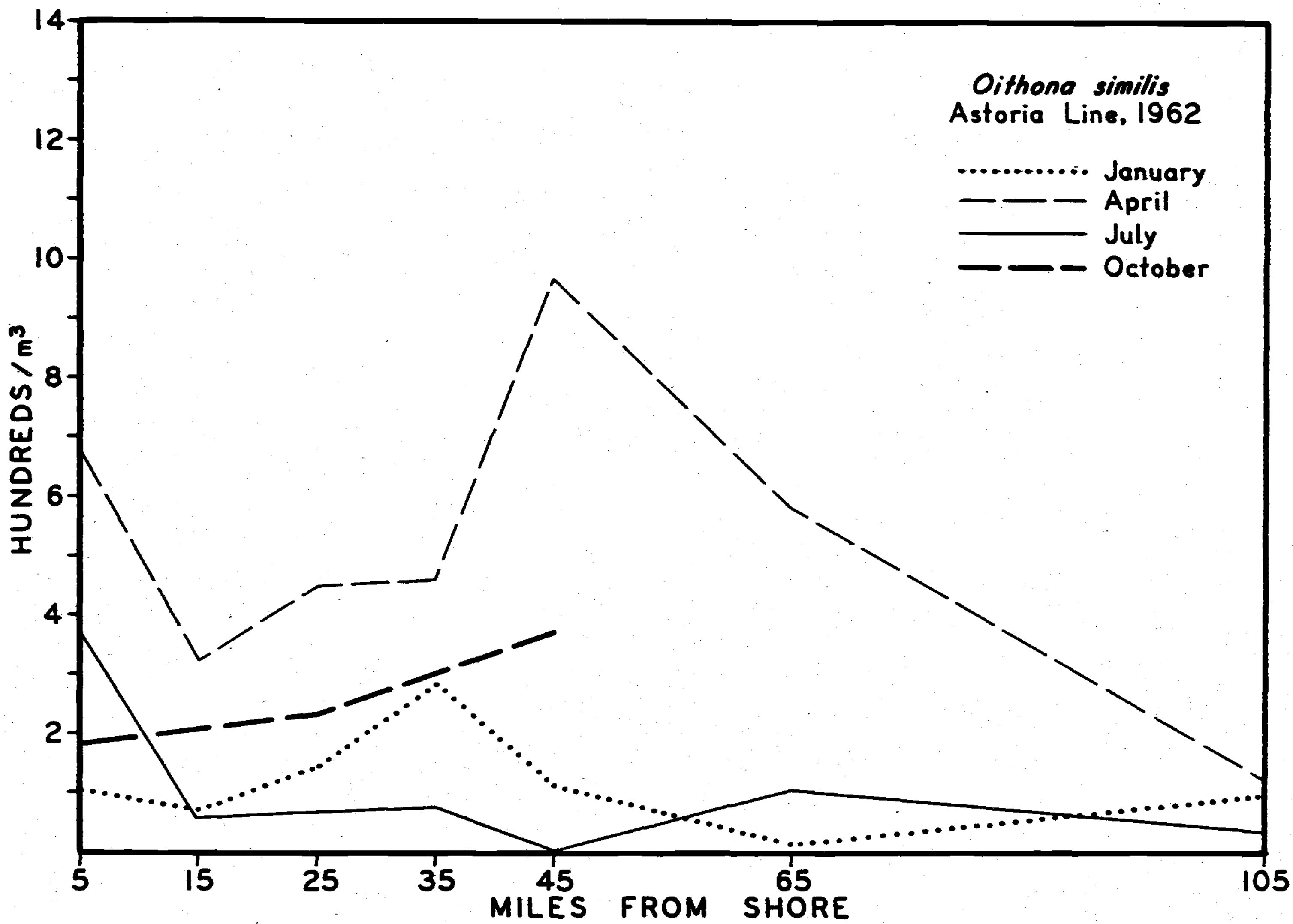

Figure 16. Seasonal Distribution of Oithona similis - Astoria line.

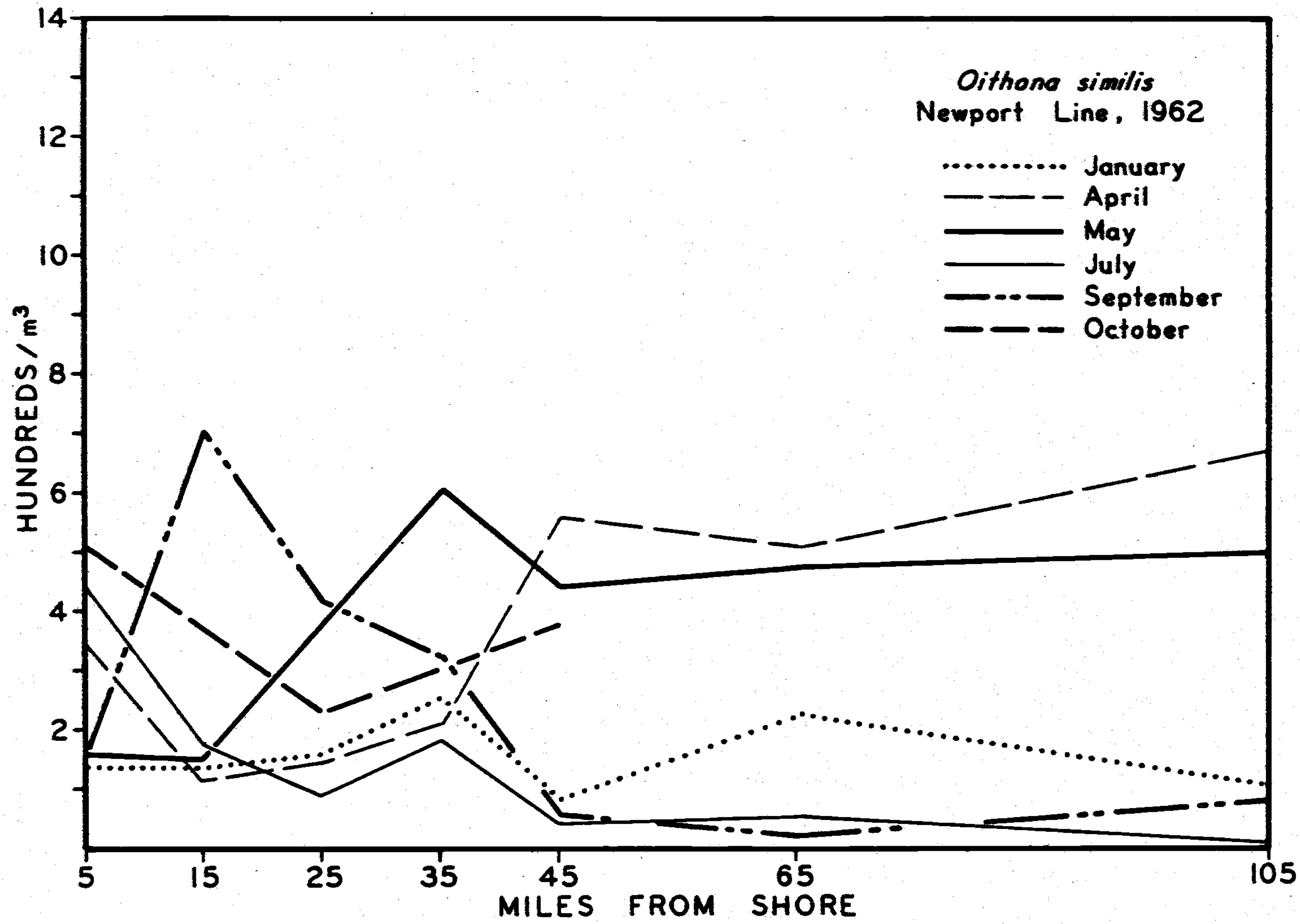

Figure 17. Seasonal Distribution of Oithona similis - Newport line.

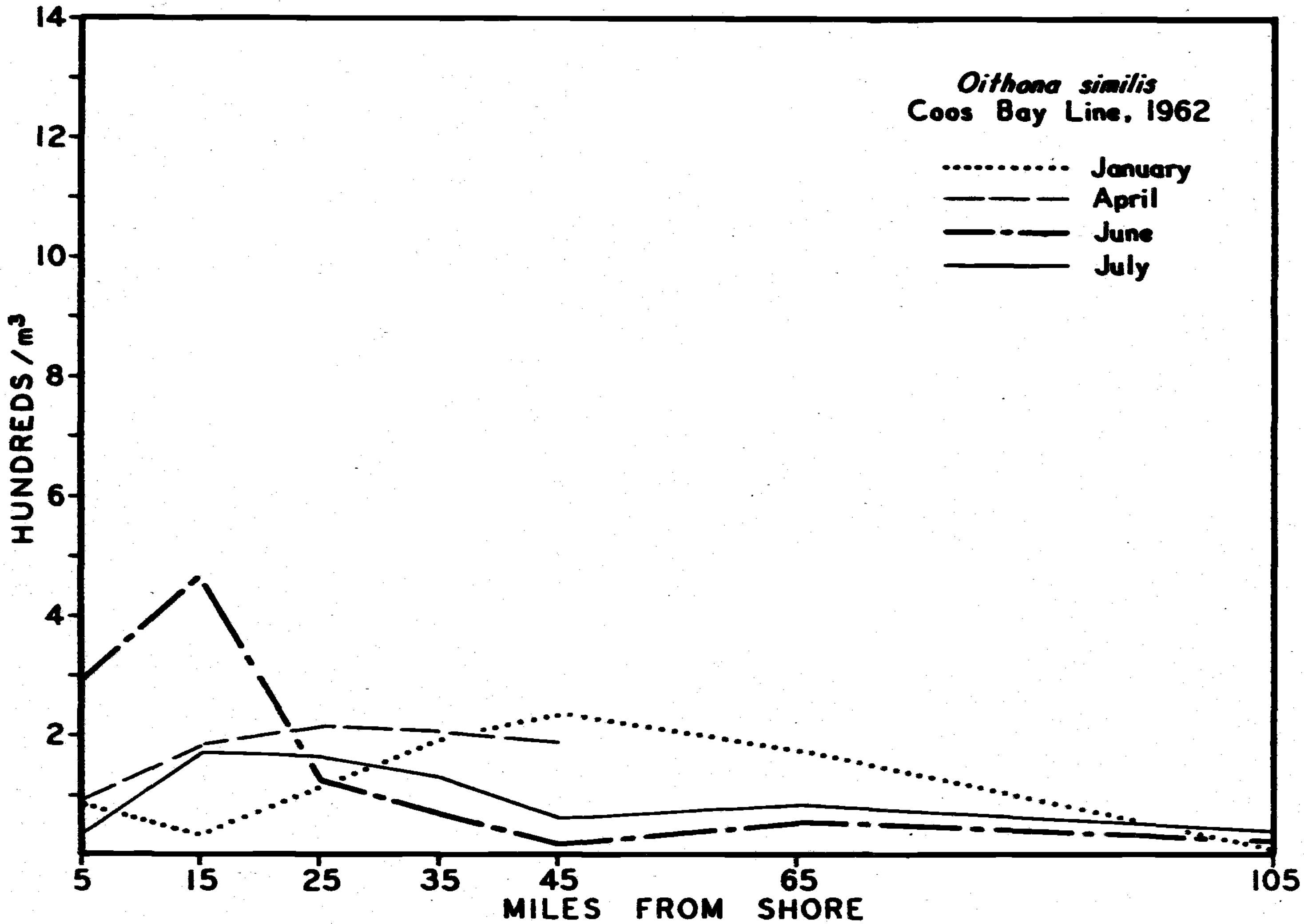

Figure 18. Seasonal Distribution of Oithona similis - Coos Bay line.

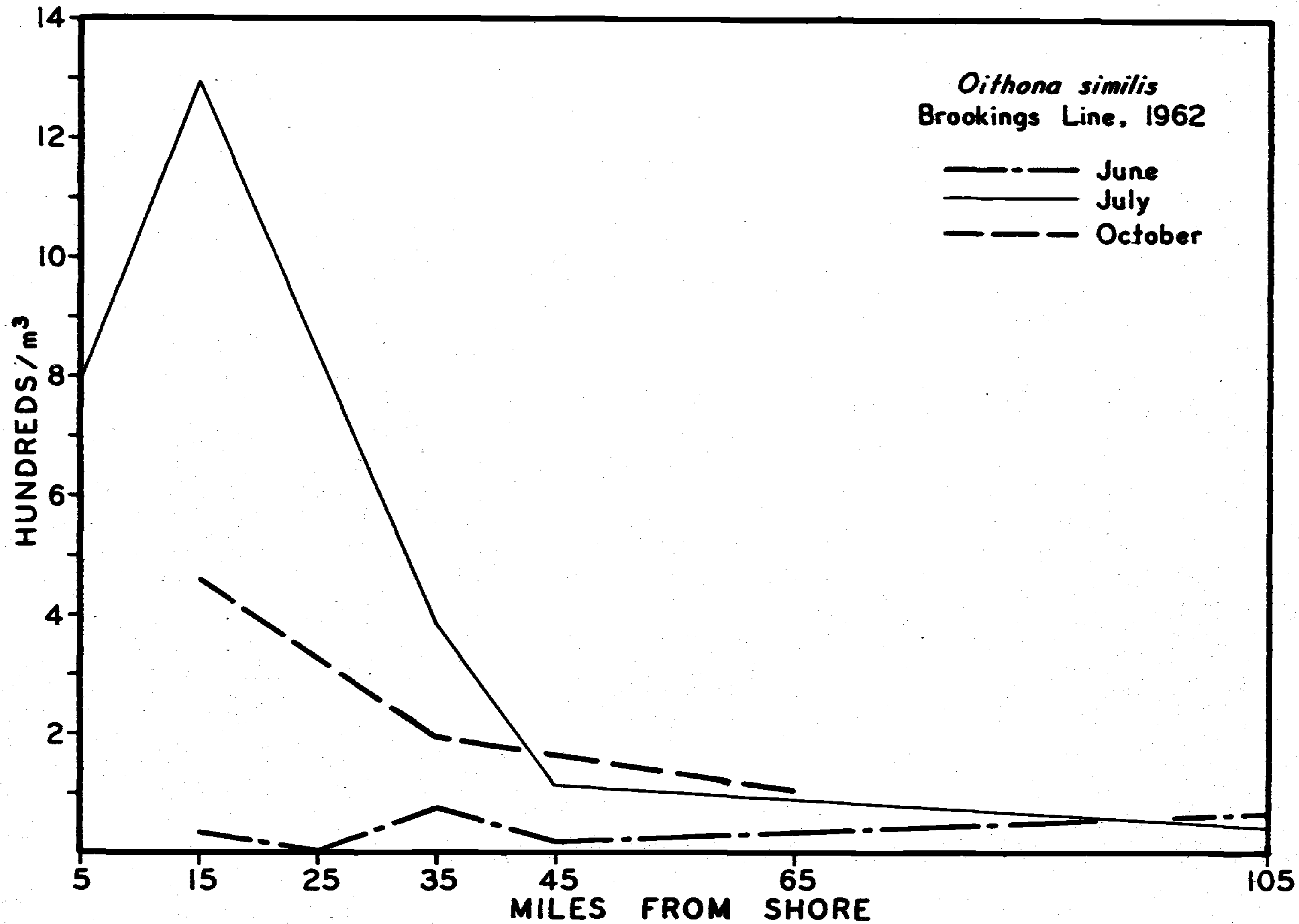

Figure 19. Seasonal Distribution of Oithona similis - Brookings line.

higher inshore than those found during June, with the 5 and 15 mile stations in July exhibiting particularly high concentrations. These July stations have been shown earlier to fall within an area of intense upwelling (and associated high chlorophyll "a" concentrations) at this time of year. The high numbers of O. similis might have been correlated with this phenomenon.

The high numbers of O. similis found off Oregon, particularly on the two northern lines, was not surprising. Frolander (15, p.657) listed this species and Pseudocalanus minutus as the two dominant copepods off the coast of Washington and British Columbia. Wilson (40, p.196-197) named this copepod as the most abundant and widely distributed species of all plankton copepods.

Acartia longiremis (Lilljeborg)

Acartia longiremis was distributed similarly to Pseudocalanus minutus along the two northern lines, as it was present in greatest numbers at the most inshore stations and decreased markedly seaward (Figs. 20 and 21). This feature was also found by Frolander off Washington and British Columbia (15, p.664). Only during the late summer months did A. longiremis contribute significantly to the adult copepod population, however. This late summer peak agrees with earlier work in Puget Sound by Hebard (19, p.28).

July populations of $1615/m^3$ and $747/m^3$ were found at AH-5 and 15, and $345/m^3$ and $704/m^3$ were recorded at NH-5 and 15 (Figs. 20 and 21). Populations of less than $120/m^3$ occurred at the same time off Coos Bay and Brookings (Figs. 22 and 23). During these peaks at

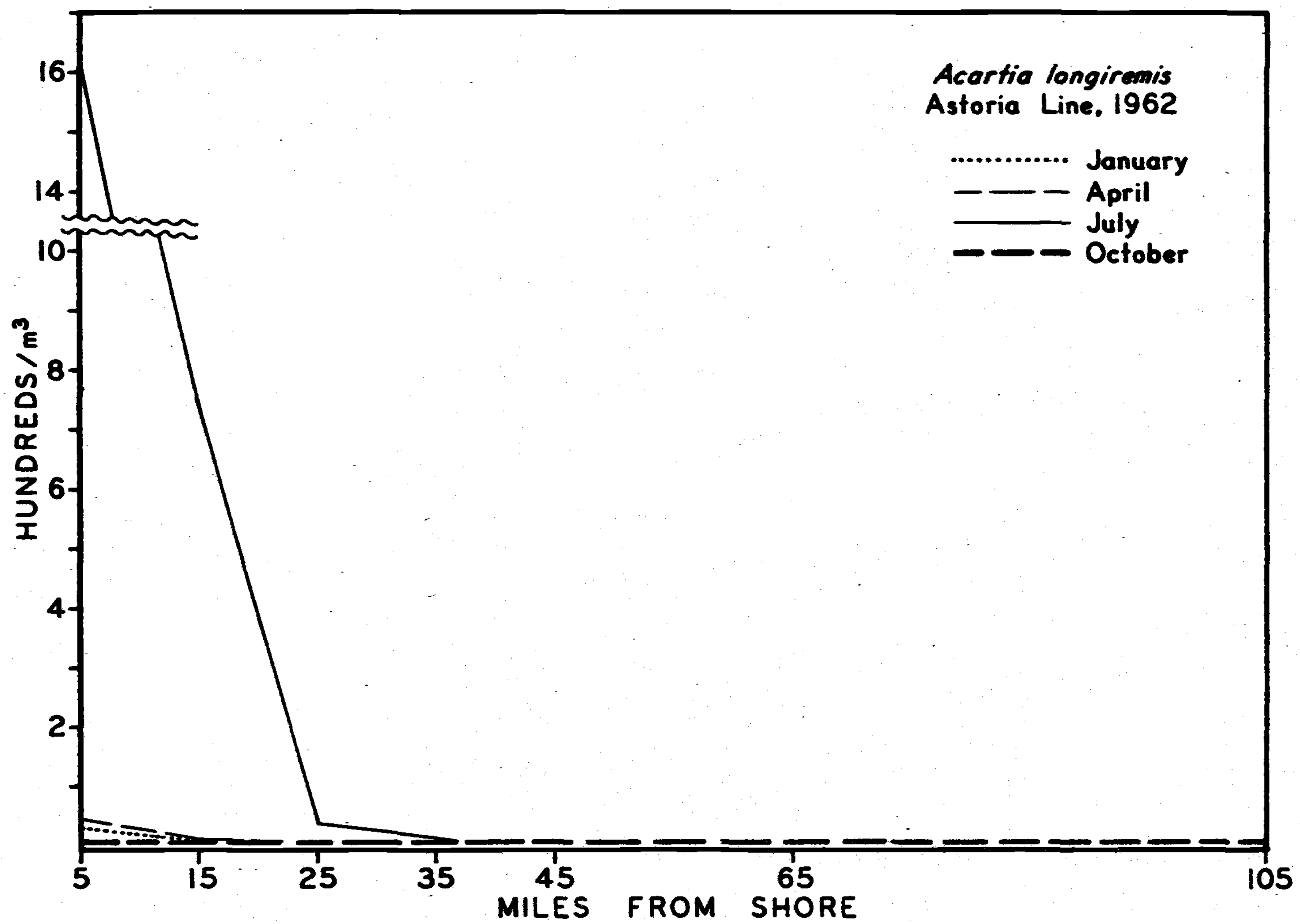

Figure 20. Seasonal Distribution of Acartia longiremis - Astoria line.

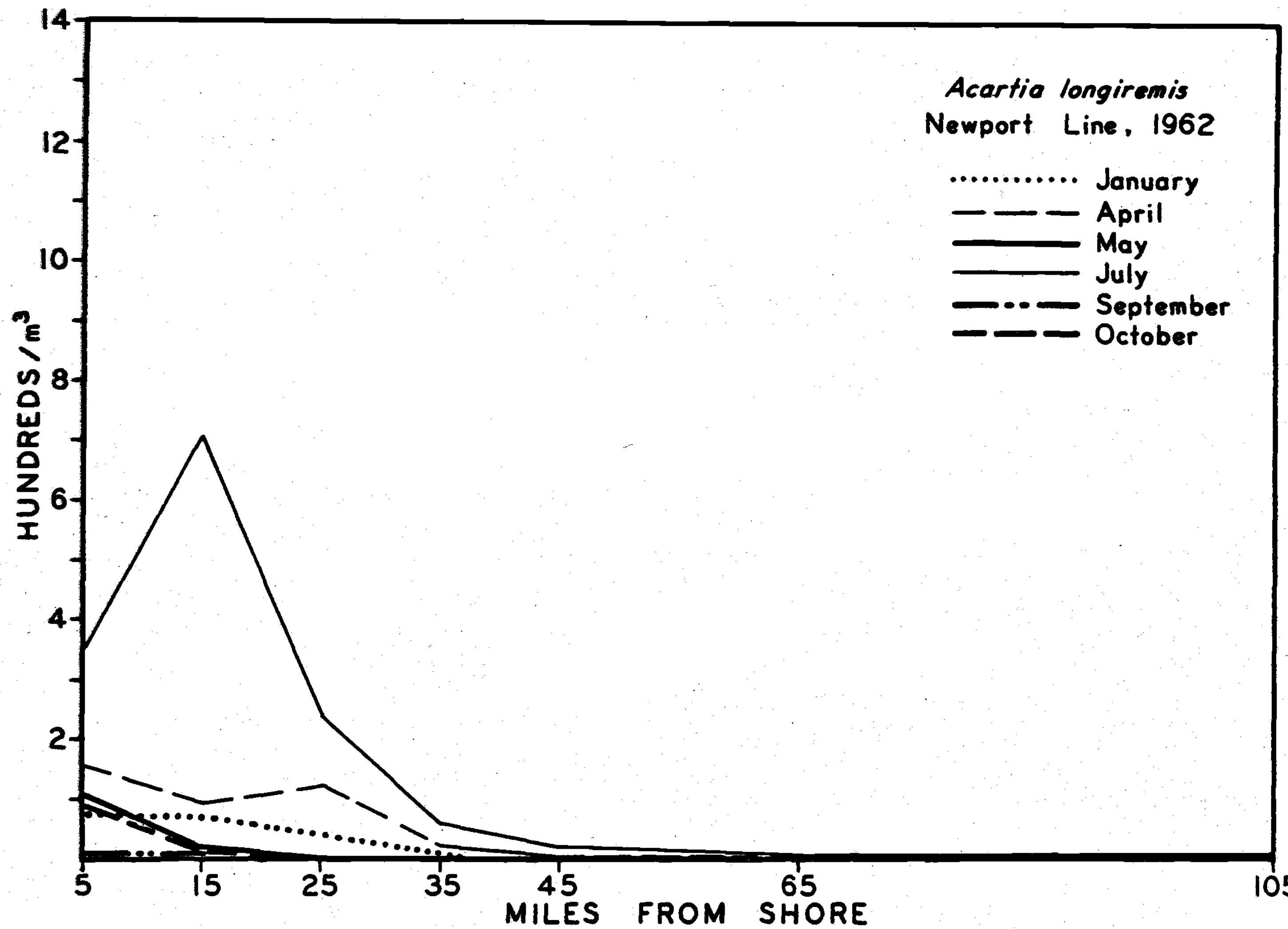

Figure 21. Seasonal Distribution of Acartia longiremis - Newport line.

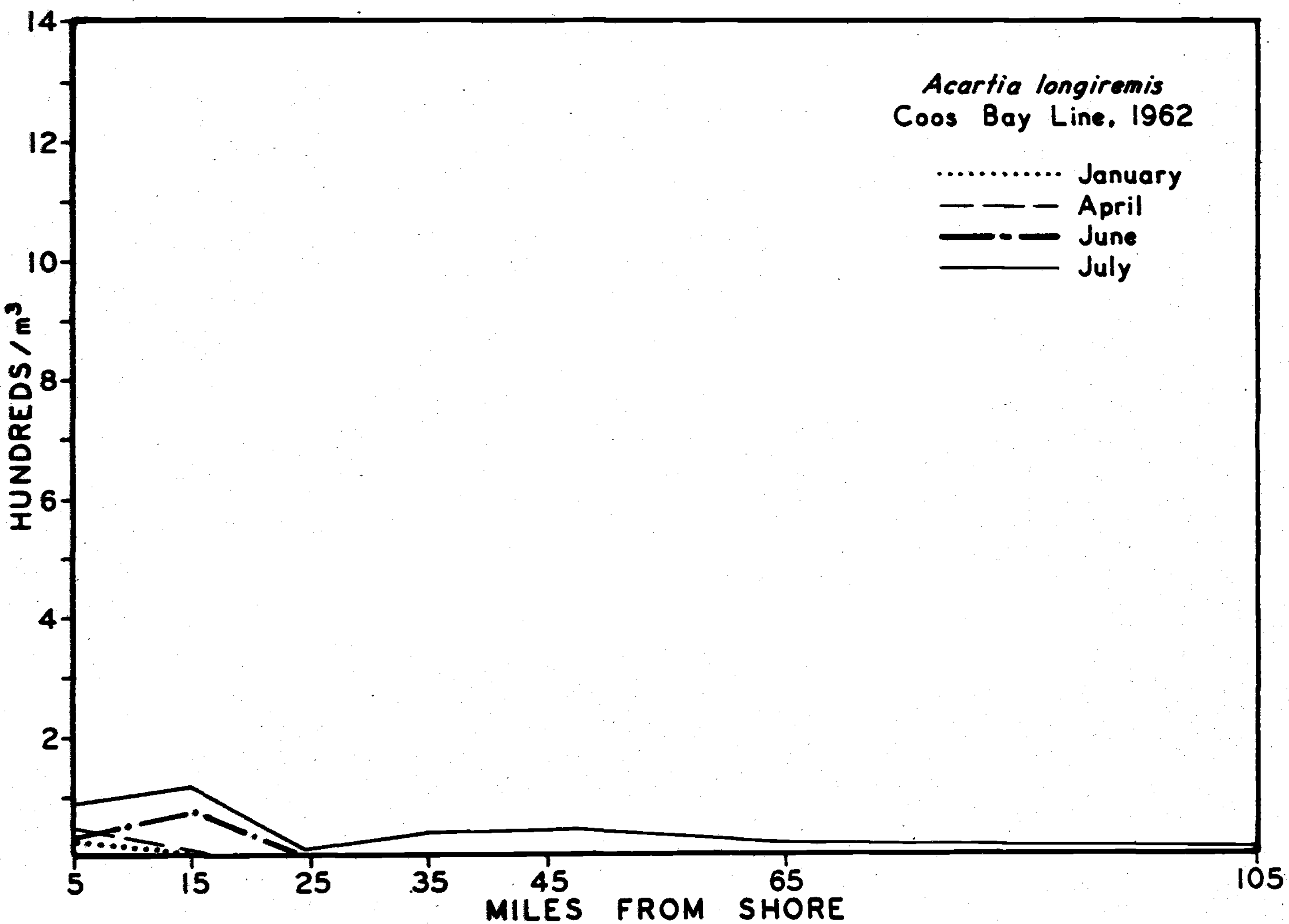

Figure 22. Seasonal Distribution of <u>Acartia longiremis</u> - Coos Bay line.

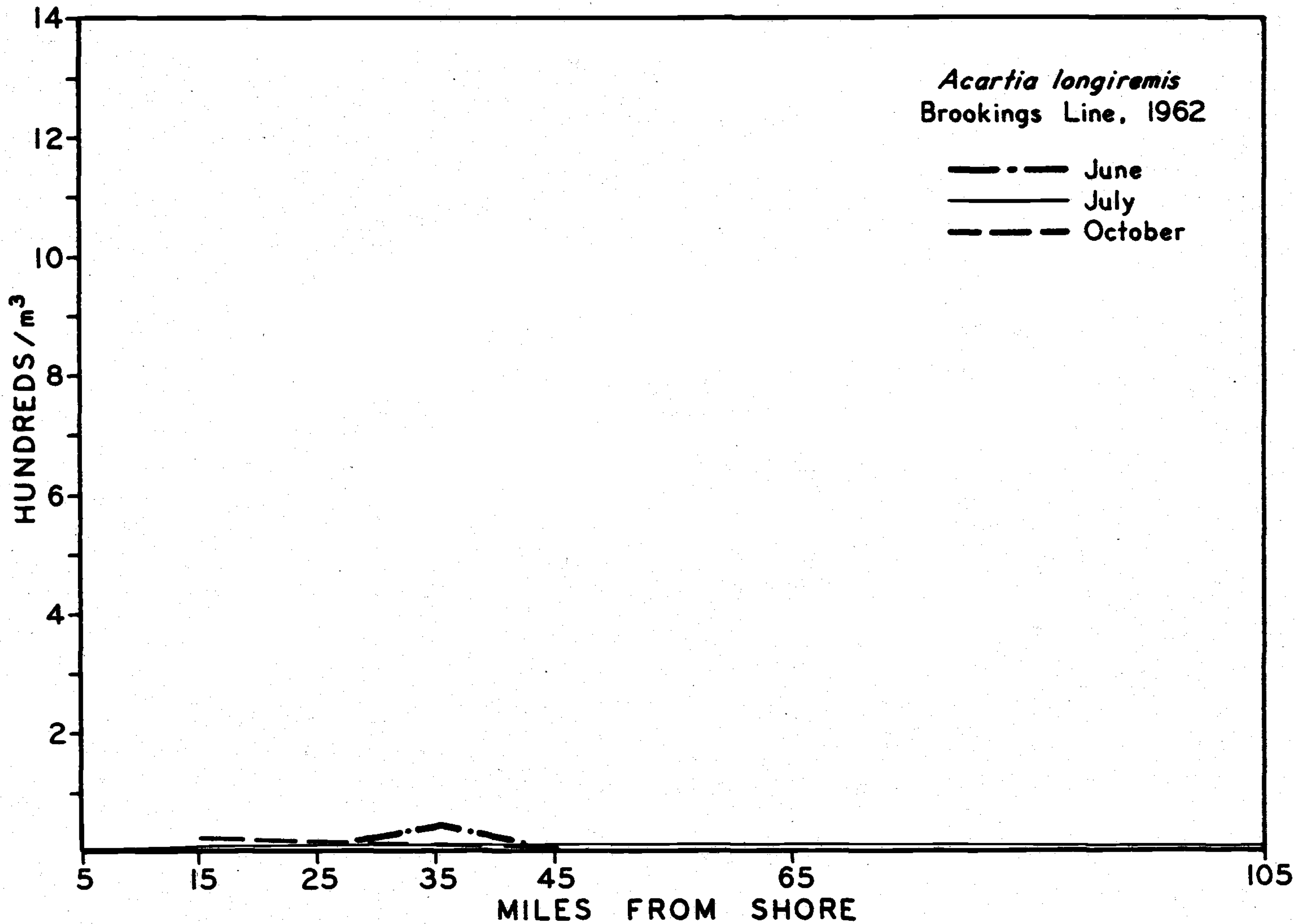

Figure 23. Seasonal Distribution of Acartia longiremis - Brookings line.

the northern stations, *A. longiremis* represented from 20-62% of the adult copepod population, depending upon the locality. Off Newport, *A. longiremis* populations extended farther seaward in somewhat greater numbers than on the other lines, indicating, as with *P. minutus*, a more seaward extension of the coastal environment over the continental shelf.

During its period of maximum abundance in July, numbers decreased progressively from north to south. The highest concentrations were found off Astoria, followed in order by Newport, Coos Bay and Brookings. Brodsky (6, p.421), recorded *A. longiremis* as a northern neritic species, found predominantly in the upper layers. Davis (11, p.65) reported it from the Gulf of Alaska, Queen Charlotte Islands, west and east coasts of Vancouver Island and Friday Harbor, Washington. Significantly, Esterly (12, p.81-110) did not report *A. longiremis* from the San Francisco Bay area, and Johnson (21) did not find it along the coast of southern California. Grice (18, p.104) lists the southern boundary of *A. longiremis* in the north Pacific as approximately lat. 42°00'N. The progressive decrease in abundance in a southerly direction off the Oregon coast may be due to encroachment of this species on its southern distributional boundary. A second explanation might be that the summer maxima at the two southern hydrographic lines characteristically lag behind those of the two northern stations and consequently had not developed by July, when the last series of collections for the summer months were available at Coos Bay and

Brookings. However, it is felt that the problem cannot be resolved until further sampling is done.

<u>Acartia</u> <u>danae</u> Giesbrecht

<u>Acartia</u> <u>danae</u> was present at nearly all stations sampled in January on the Newport line (Fig. 24), although in very low numbers (less than $5/m^3$). During April and May, when the surface currents may vary from both north and south (7), <u>A.</u> <u>danae</u> showed a very sporadic distribution as it had a tendency to be displaced farther offshore than during January. From July through September it was absent, with one exception, from stations less than 65 miles from shore on all sampling lines. Qualitative examination of July samples taken well offshore showed <u>A.</u> <u>danae</u> to be present in very low numbers 165 miles off Astoria, Coos Bay and Brookings and 105 miles off Newport. Therefore, although <u>A.</u> <u>danae</u> was excluded from the coastal regions during the summer months, it was present in waters farther than 100 miles from shore during all seasons of the year in this study.

Other workers have indicated that this species is excluded from coastal waters in summer but is present in offshore waters during this time of year. Frolander (15, p.658) did not find it in samples taken east of long. 128°W during July 1957 off northern Washington and British Columbia. Davis (11, p.66), however, found it in September 1935 at lat. 46°32'N and long. 125°57'W. Johnson (21) did not report this species from April to December 1938 in coastal samples taken off California from lat. 31-35°N. He did, however,

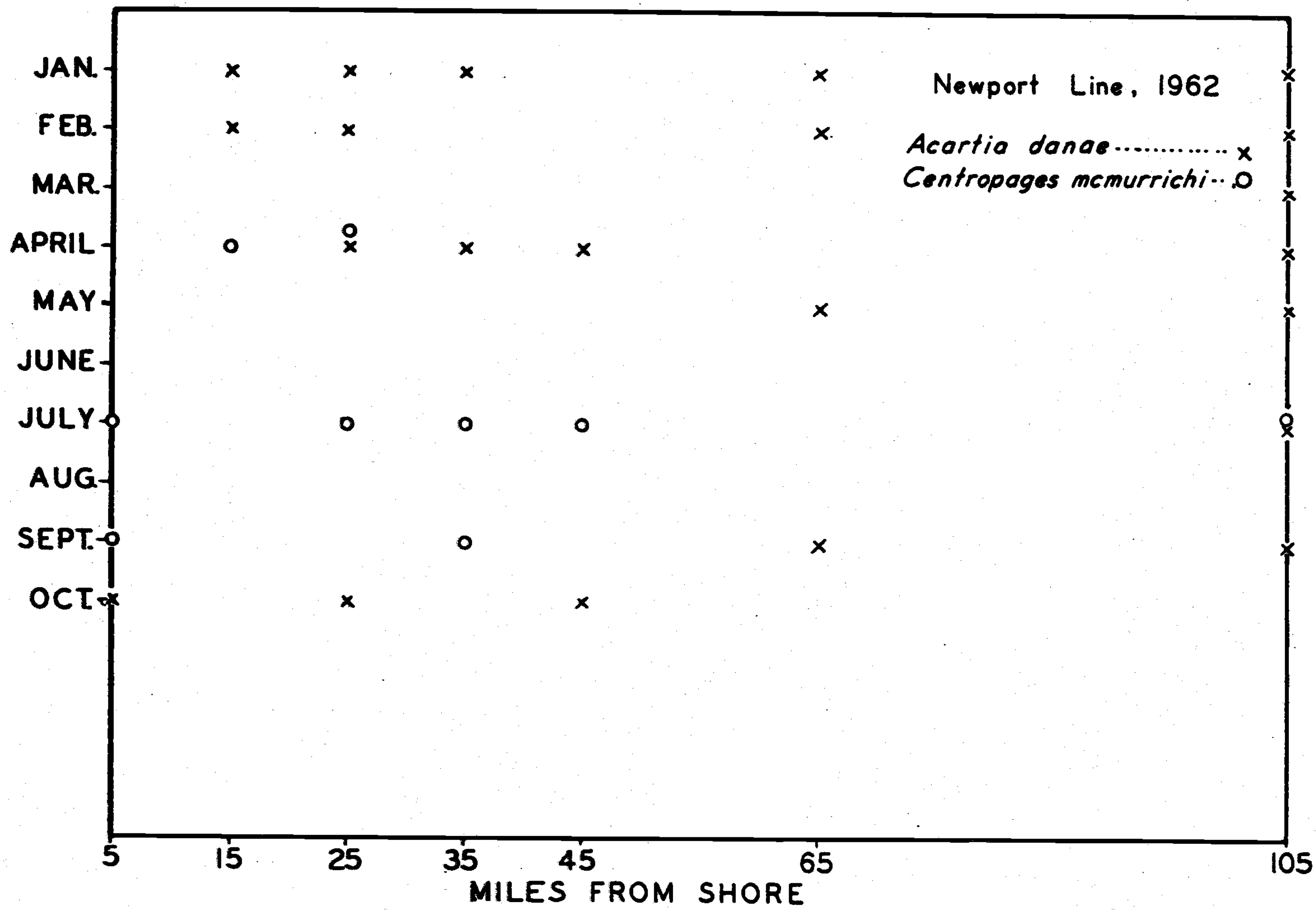

Figure 24. Seasonal Distribution of Acartia danae and Centropages mcmurrichi - Newport line.

record it as an oceanic species at these latitudes. Frolander (15, p.671) reported it in August 1956 at 40°01'N, 127°34'W. Thus, it appears that A. danae is excluded during the summer months, from coastal waters off Washington, Oregon and California but is present in offshore waters.

Acartia danae reappeared along the Oregon coast in October in this study. The greatest concentrations at this time appeared off Brookings, with 18, 15, 66 and 25 animals/m^3 at the 15, 35, 65 and 105 mile stations, respectively. At the same time, less than 15/m^3 were present off Newport. Of the three stations samples off Astoria in October (AH-5, 25 and 45), A. danae was present only at the 25 mile station (9/m^3). This rather steady decrease in numbers from south to north may indicate that this organism arrived from the south or southwest in the warm Davidson Current, which flows north along the Oregon coast from October through March. The steadily decreasing numbers might possibly reflect both predation and increased mixing and dilution of Davidson Current waters toward the north. Lower numbers in January on all lines (less than 5/m^3) may be caused by unfavorable winter temperatures, as this species characteristically inhabits the warmer surface waters to the south (15, p.670-672). The relatively high numbers found off Brookings in October, when the Davidson Current begins flowing northward, suggests that A. danae populations reaching Oregon coastal waters were endemic to a region not too far south or southwest of the Brookings sampling line.

The appearance of Acartia danae in conjunction with the Davidson Current was first noted by Frolander (15, p.670-672) who suggested the use of this species as a possible indicator of the periodic flow of southerly waters along the northwest coast of the North American continent. He reported the presence of A. danae off the coast of northern Washington and British Columbia from December through May (1956-57). The distribution of A. danae off the Oregon coast in 1962 correlated closely with these dates, except for the earlier appearance in Oregon waters. This would be expected if populations were being moved from south to north in the Davidson Current.

Centropages mcmurrichi Willey

The distribution of Centropages mcmurrichi off the Oregon coast was in direct contrast to that of Acartia danae (Fig. 24). Centropages mcmurrichi appeared off the Newport, Coos Bay and Brookings lines only from April to September, when the general movement of the surface water was in a southerly direction. The populations were consistently higher near shore, decreasing steadily seaward.

Off Astoria, C. mcmurrichi was found in all samples taken five miles from shore, regardless of season. At AH-15 it occurred only during April and July and at AH-25 only during July. It did not appear at any other station on this line.

Off Newport this species first appeared in April at the 15 and 25 mile stations. By July it was found at various stations ranging over the entire sampling line. In September its distribution was limited to the 5 and 35 mile stations, and it did not appear in any of the October samples.

The distribution of C. mcmurrichi off Coos Bay appeared rather limited, as it was found only at CH-5 in June and CH-25 in July. On the Brookings line the only appearance of this copepod was at BH-35 in June.

Davis (11, p.54) reported C. mcmurrichi from the Arctic Ocean; Bering Sea; Grantly Harbor, Alaska; Dixon Entrance, British Columbia; and the east and west coasts of Vancouver Island. Cameron (8, p.169) listed it in the Queen Charlotte Island region, predominantly in the surface waters. There appears to be no record of this copepod south of the Oregon coast in the eastern Pacific. Brodsky (6, p.316) listed C. mcmurrichi as synonymous with Centropages abdominalis Sato, and found it to be a neritic species peculiar to shallow coasts and bays.

Other Species

Certain species were not as abundant as those discussed earlier in some detail, but nevertheless are worth noting because of characteristic distributional patterns.

Calanus plumchrus Marukawa was present in the surface layer at nearly all stations during April and May (Fig. 25), with the highest concentration appearing in May (91/m^3 at NH-65). The majority of individuals were stage V copepodites. Because the distributional patterns were similar on all sampling lines, only Newport data are

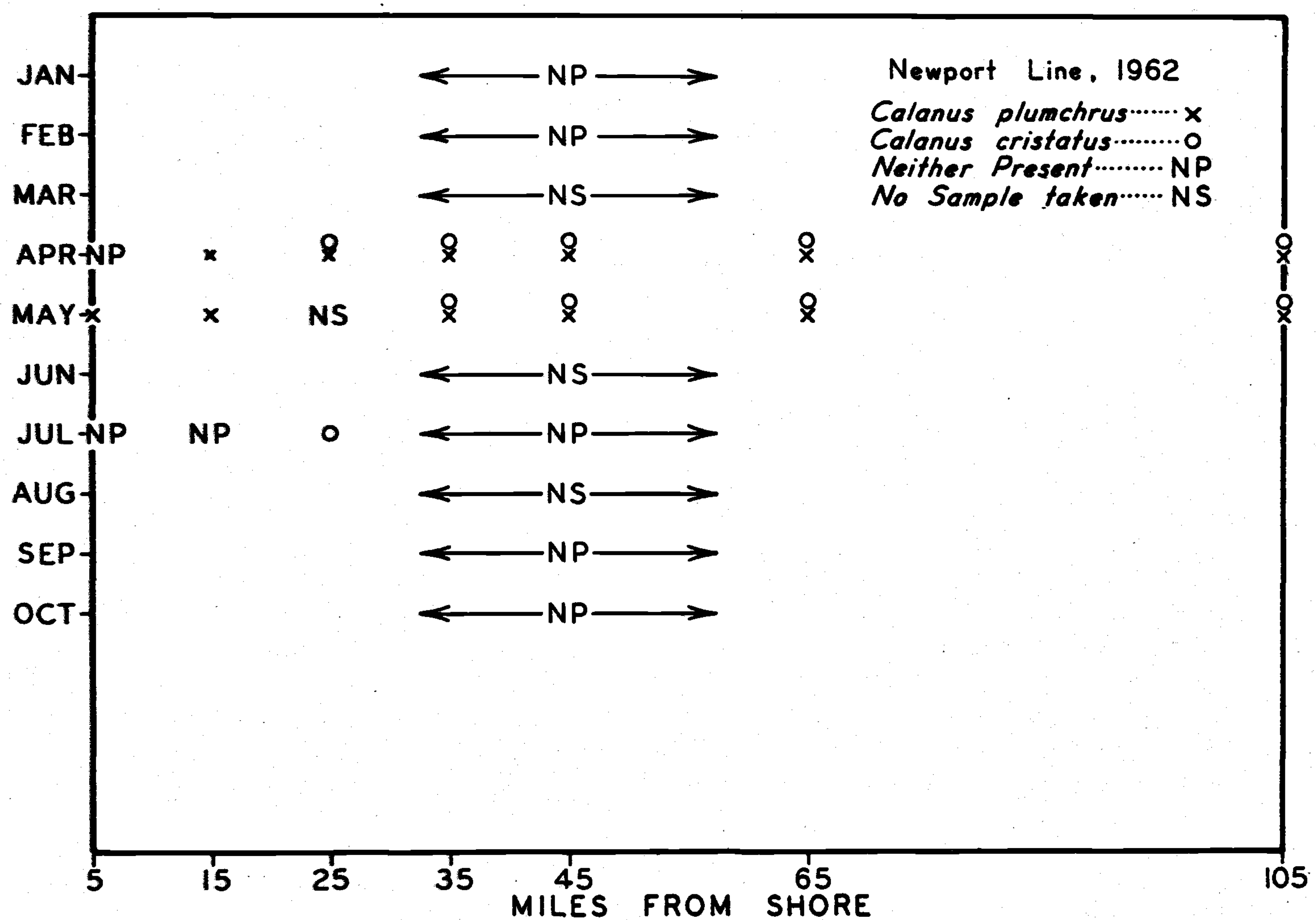

Figure 25. Seasonal Distribution of Calanus plumchrus and Calanus cristatus in the surface layers.

considered here. This species was found only sporadically during the summer months, as it apparently moved deeper into the water column, beyond the collecting depths in this study. Seasonal vertical migration by C. plumchrus was noted by Brodsky (6, p.91-93). He listed this organism as one which appears in the surface layers during April and May in the late copepodite stages. However, with the warming of the surface waters in early summer, it gradually descends into deeper water, remaining there until the following spring.

Calanus cristatus Krøyer was distributed similarily to C. plumchrus in this study, as it also appeared in the surface layers predominantly in April and May (Fig. 25). A few individuals were taken in July. This species was not recorded less than 25 miles from shore.

On rare occasions, Calanus finmarchicus (Gunnerus) represented a significant percentage of the total population. At AH-15 in July $220/m^3$ were found, which represented 21% of the adult copepod population. This species also made up 18% of the population at NH-15 in April ($318/m^3$). At other times it did not number more than $55/m^3$ and often considerably less. It was present in greatest numbers close to shore and decreased seaward.

Oithona spinirostris Claus appeared in greatest numbers between April and July. Also, it was most abundant in waters beyond 100 fathoms depth. The highest concentration obtained was $56/m^3$ at NH-105 in April.

Racovitzanus porrectus (Giesbrecht) is usually considered to be a deep-dwelling copepod (6, p.274). In this study it did not appear less than 45 miles from shore, and never contributed significantly to the total population in the surface waters. At no time did it number more than $2/m^3$. Vervoort[1] feels that this species is closely allied to, if not identical with, Racovitzanus antarcticus Giesbrecht, which has been reported from the northwest Pacific by Brodsky (6, p.266-267).

Scolecithricella minor v. orientalis Brodsky was a common, though never abundant, member of the copepod population ($15/m^3$ maximum). It appeared no closer to shore than 15 mile stations off Astoria, Coos Bay and Brookings, and 25 miles off Newport. This suggested that the continental shelf may delineate the shoreward distributional boundary for this species. Anraku (3, p.250) also found S. minor to be an oceanic species, not occurring in coastal waters. Brodsky (6, p.268-269) listed S. minor as most abundant at depths from 50 to 100-200 meters.

The extension of the continental shelf farther offshore at Newport not only tends to delineate the seaward distributional boundaries of P. minutus and A. longiremis during periods of maximum abundance, but also apparently affects the shoreward distribution of several deeper dwelling copepods. Scolecithricella minor is one of these, as noted above. Lucicutia flavicornis, Euchirella pulchra,

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[1] Personal Communication with Dr. W. Vervoort, Leiden, The Netherlands

Pleuromamma sp., Scaphocalanus brevicornis, and Heterorhabdus sp. also appeared at stations closer to shore off Astoria and Coos Bay than off Newport (Table 2). The Brookings line was not listed, as relatively few collections were made during 1962.

Acartia danae and Centropages mcmurrichi as Possible Indicator Species

The appearance of Acartia danae and Centropages mcmurrichi at different times of the year (Fig. 24) suggested close relationships between the distributions of these two copepods and changing hydrographic conditions. These relationships can be shown by plotting the distributions of these two organisms on a temperature-salinity diagram (Fig. 26). Each circle on the diagram represents the average temperature and salinity for the top ten meters on a designated date. For example, the circle A-15, 6201 refers to station AH-15, sampled in January 1962. The average 0-10 meter salinity for this sample was 30.5 ^{o}/oo. The average temperature was 8.6^{o}C. A cruise begun in late July and terminated in early August is designated 6207-8.

The presence of A. danae and/or C. mcmurrichi is indicated in figure 26 by the code in each circle. Thus, a closed circle indicates neither species is present at the designated station and date, a circle with the right half open indicates the presence of A. danae, a circle with the left half open indicates the presence of

Table 2. Shoreward Distributional Boundaries of Several Deeper Dwelling Copepods

	First station a species appeared moving seaward		
Scolecithricella minor	AH-15	NH-25	CH-15
Lucicutia flavicornis	AH-25	NH-25	CH-15
Scaphocalanus brevicornis	AH-25	NH-35	CH-25
Heterorhabdus sp.	AH-25	NH-25	CH-15
Euchirella pulchra	AH-25	NH-35	CH-15
Pleuromamma sp.	AH-25	NH-35	CH-15

C. mcmurrichi, and a circle completely open indicates the presence of both species.

The shaded rectangle or "central cell" represents the temperature-salinity regime for nearly all stations sampled from January through May 1962 (9.0-10.1°C and 32.35-32.65 ^{o}/oo). Only a few stations have been plotted during this time of the year in order to avoid overlap. Upwelling, precipitation and runoff, and the Columbia River plume have modifying effects on the temperature and salinity of this "central cell" water (29), and these effects are indicated by the directional arrows in the diagram. Upwelling contributes cold, saline water to the surface layers in the summer, precipitation and runoff lowers the salinity without any appreciable change in temperature (most evident inshore in winter), and the Columbia River plume yields warm fresh water in the summer.

Most of the stations showing the presence of *A. danae* in January (6201) and April (6204) fall within the T-S range indicated by the shaded rectangle. This rectangle does not necessarily delineate the T-S tolerances of this organism, but rather characterizes the surface water of the Davidson Current during winter and spring. The feasibility of using *Acartia danae* and *Centropages mcmurrichi* as indicators of seasonal hydrographic changes can be shown by comparing the distributions of these two copepods with the Astoria, Newport and Coos Bay T-S data and with surface current movement. Beginning with the first directional flag (1▷) the exclusion of *A. danae* from the 5, 15 and 25 mile stations on the

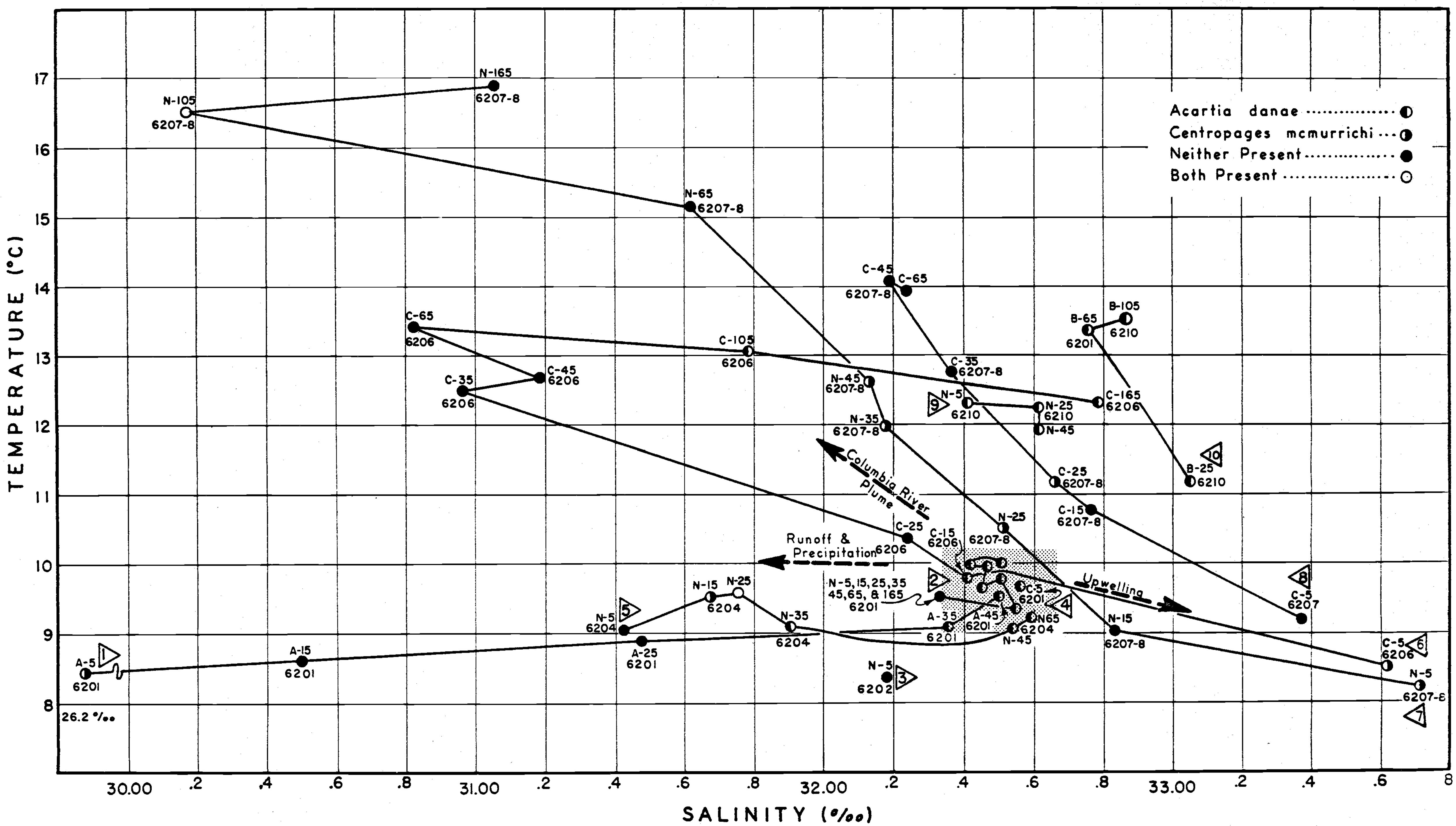

Figure 26. Relationship of Acartia danae and Centropages mcmurrichi to surface water characteristics.

Astoria line in January is shown. This exclusion was probably due to lower salinities resulting from precipitation and Columbia River runoff. At AH-35 and 45 the effects of precipitation and runoff were reduced and *A. danae* was present (within the shaded rectangle). It is evident from the diagram that *Acartia danae*, in most cases, was excluded from stations with salinities less than 32.00 ^{o}/oo.

On the Newport line in January (▷2) this organism appeared as close to shore as NH-15, where the salinity was greater than 32.00 ^{o}/oo. *A. danae* was not found at NH-5, even though T-S values were within the proper range. Water off Newport in February (▷3) showed a T-S distribution similar to that in January, and again *A. danae* was excluded from the 5 mile station. CH-5 in January, however, falls well within the shaded rectangle and *A. danae* is present (▷4). The remaining stations along the Coos Bay line in January and along the Newport line in February are not shown. However, like the Newport offshore stations in January, they fell within the shaded cell and *A. danae* was present, with one exception, in every case.

The exclusion of *A. danae* in winter from inshore stations not included within the shaded cell suggests that the influence of the Davidson Current is not the predominant influence along the coast in regions of high runoff and precipitation. As stated earlier in the section on hydrography, the prevailing southerly winds tend to drive the surface water onshore in these regions, which results in a narrow band of low salinity water along the coast. It is from these regions that *A. danae* appears to be absent. Frolander (15, p.671), collecting to 200 meters depth off the Washington coast, recorded *A. danae* only at stations with salinities ranging from 32.24 °/oo to 33.96 °/oo.

Burt and Wyatt (7) have shown that March and April is a period of transition between the north and southward movement of water. *Centropages mcmurrichi* was present at the 15 and 25 mile stations off Newport in early April (5). *Acartia danae*, on the other hand, was present from NH-25 seaward at this time. This situation suggests the possibility that *C. mcmurrichi* had been carried along the coast from a more northerly location to the Newport line, and the area around the 25 mile station, where *C. mcmurrichi* and *A. danae* occur together, represented a zone of mixing between Davidson Current water and southward flowing water. The assumption that *C. mcmurrichi* was carried southward along the Oregon coast during the spring and summer months is supported by two other observations. First, this copepod appeared off Newport and Coos Bay only during the period April to September, when the surface currents are moving in a southerly direction. Secondly, *C. mcmurrichi* appeared in April samples off Newport, but not off Coos Bay and Brookings until June.

Upwelling, indicated by low temperature, high salinity surface water, was present at CH-5 in June (6). *C. mcmurrichi* was recorded at this station. Upwelling was not evident at CH-15 and *A. danae* appeared here (note this is within the characteristic winter-spring T-S ranges of this organism). At CH-35, 45 and 65, neither *C. mcmurrichi* nor *A. danae* was present, and the influence of the Columbia River plume was quite noticeable (warm, low salinity water). However, at CH-105 and 165 the salinity increased (reduced influence of Columbia River plume) and *A. danae* reappeared. Thus, the presence of *A. danae* at the 15 mile station (within the characteristic T-S range of winter and spring stations) and its absence on either side of CH-15, indicated that waters both to the east and west of this station had been modified by physical processes which may have excluded this species from the environment.

The distributions of both *A. danae* and *C. mcmurrichi* were modified significantly in July off Newport (7). The salinity ranges in which the 15, 25, 35 and 45 mile stations fell were those in which *A. danae* was most prevalent during the winter months. In July, however, *A. danae* was absent from these stations, and *C. mcmurrichi* was present. The absence of *A. danae* indicated that the water off Newport at this time of the year came from a region in which this species was not an endemic member of the zooplankton population. The presence of *C. mcmurrichi*, normally a more neritic species, suggested that the water may have moved in from coastal regions somewhere north of the Columbia River.

The presence of *C. mcmurrichi* 105 miles off Newport but only 25 miles off Astoria in July suggested the offshore movement of water from coastal regions between Astoria and Newport. This was supported by Maughan's statement (23, p.33) that surface currents off the Oregon coast in July are southerly with a moderate offshore component. *C. mcmurrichi* was present only out to the 25 mile station on the Coos Bay line in July, however (8). This may mean that the offshore movement of water in this region was not as pronounced as it was farther north.

Samples collected in October off Newport (9) and Brookings (10) showed the presence of *A. danae* and the absence of *C. mcmurrichi*. October marks the beginning of the northward flow of the Davidson Current, which brings with it *Acartia danae* and replaces the more northerly water type characterized by the presence of *Centropages mcmurrichi*.

Population Diversity

Diversity of copepod populations throughout the year may be correlated with seasonal changes in water characteristics off the Oregon coast. Several indices to describe population diversity have been developed, most of which depend upon a knowledge of information theory (28). A graphical method of comparing diversities of different populations, proposed by Sanders (31, p.87-90), precludes any rigid knowledge of this special branch of statistics and was used in this study to derive relative numerical indices.

Basically, the method involves the calculation of the diversity of any sample population relative to maximum possible diversity. Maximum diversity in a population occurs when all species making up the population are found in exactly the same numbers; i.e., the percentages of the total population represented by any one species is exactly the same as the percentages of the population represented by each of the other species. In this situation, if the cumulative percentage of the population is plotted against cumulative percentage of the species, a straight line is developed which passes through the origin and bisects the total area of the graph (A, Fig. 27). The triangular area bounded by the ordinate, abscissa and this straight line (X, Y, A) represents the "area of maximum diversity."

If each species does not make up exactly the same percentage of the population, diversity is somewhat less than maximum. If cumulative percent of the population is plotted against cumulative percent of the species in this situation (B, Fig. 27), a curvilinear line is achieved, the degree of curvilinearity depending upon the percentage of the total population represented by each species. The area bounded by the ordinate, abscissa, and curvilinear line (X, Y, B) represents the "area of sample diversity." The ratio "area of sampled diversity"/"area of maximum diversity" is used as the diversity index. The limits of the index are zero to unity, with a zero index signifying no diversity (a single-species population) and an index of unity designating maximum diversity.

Population diversity was calculated for the 5, 25, 45 and 105 mile stations on all four sampling lines during January, April, July and October (Table 3). These four months were selected to establish a seasonal picture of diversity off the Oregon coast during 1962. The general trend was for the copepod populations to show relatively

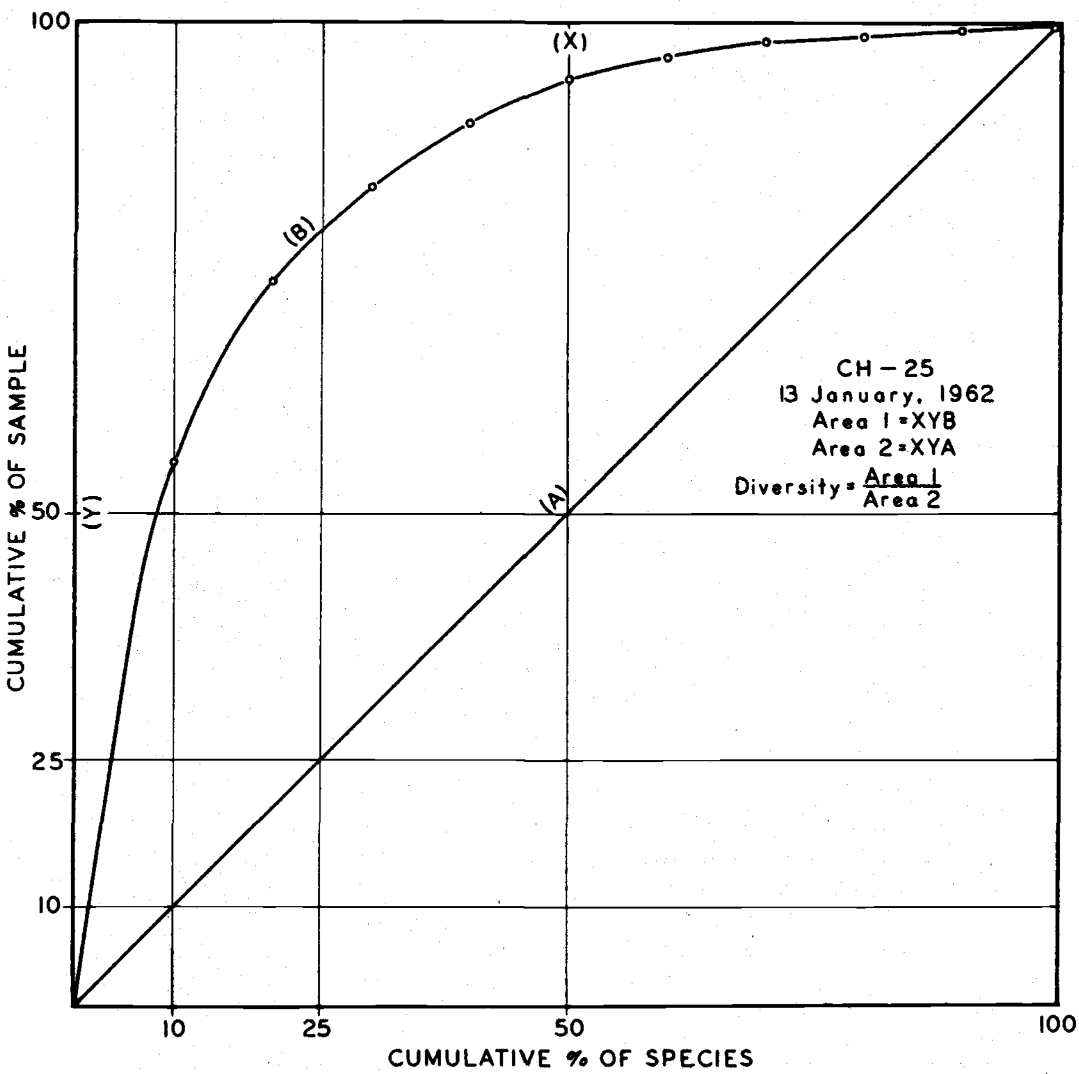

Figure 27. Cumulative Frequency Curve Used to Measure Population Diversity.

Table 3. Seasonal Change in Population Diversity off the Oregon Coast During 1962.

STATION	JAN.	APRIL	JULY	OCT.
		Astoria Line		
AH-5	0.275	0.263	0.336	0.363
AH-25	0.296	0.295	0.268	0.243
AH-45	0.180	0.150	0.223	0.246
AH-105	0.210	0.168	0.334	NO SAMPLE
		Newport Line		
NH-5	0.274	0.434	0.475	0.320
NH-25	0.260	0.241	0.355	0.235
NH-45	0.185	0.132	0.323	0.157
NH-105	0.185	0.174	0.523	NO SAMPLE
		Coos Bay Line		
CH-5	0.431	0.257	0.348	
CH-25	0.308	0.178	0.266	NO
CH-45	0.160	0.241	0.336	SAMPLE
CH-105	0.349	NO SAMPLE	0.324	
		Brookings Line		
BH-5			0.360	
BH-25	NO	NO	NO SAMPLE	NO
BH-45	SAMPLE	SAMPLE	0.228	SAMPLE
BH-105			0.428	

little diversity in winter (both inshore and offshore), increased diversity inshore in spring and fall, and the greatest diversity at all stations in summer. The southern sampling lines (Coos Bay and Brookings) may show exception to this, though little data were available for Brookings. January populations at Coos Bay were more diverse than those at Astoria or Newport, and seemed to be as diverse as the summer populations at most stations. For example, the higher diversity at CH-5 in January was due to greater relative abundance of two unusually less abundant copepods, *Calanus finmarchicus* and *Metridia lucens*. The two normally dominant organisms, *Pseudocalanus minutus* and *Oithona similis*, thus were lower in percent composition of the sample. This caused the diversity index to rise.

Graphical representation of population diversity off Newport (Fig. 28) showed that greatest diversity was found inshore during all seasons of the year (with the exception of NH-105 in July). The offshore waters were usually characterized by one or two species which made up a very large percentage of the total population during the winter, spring and autumn months. It should be emphasized here that diversity indices bear no relation to total numbers of copepods present at any station or any time of year. It is possible to have a low numerical population with a high diversity; for example, a total population of only ten copepods/100m^3, but with, say, five different species represented. It is just as possible to have a

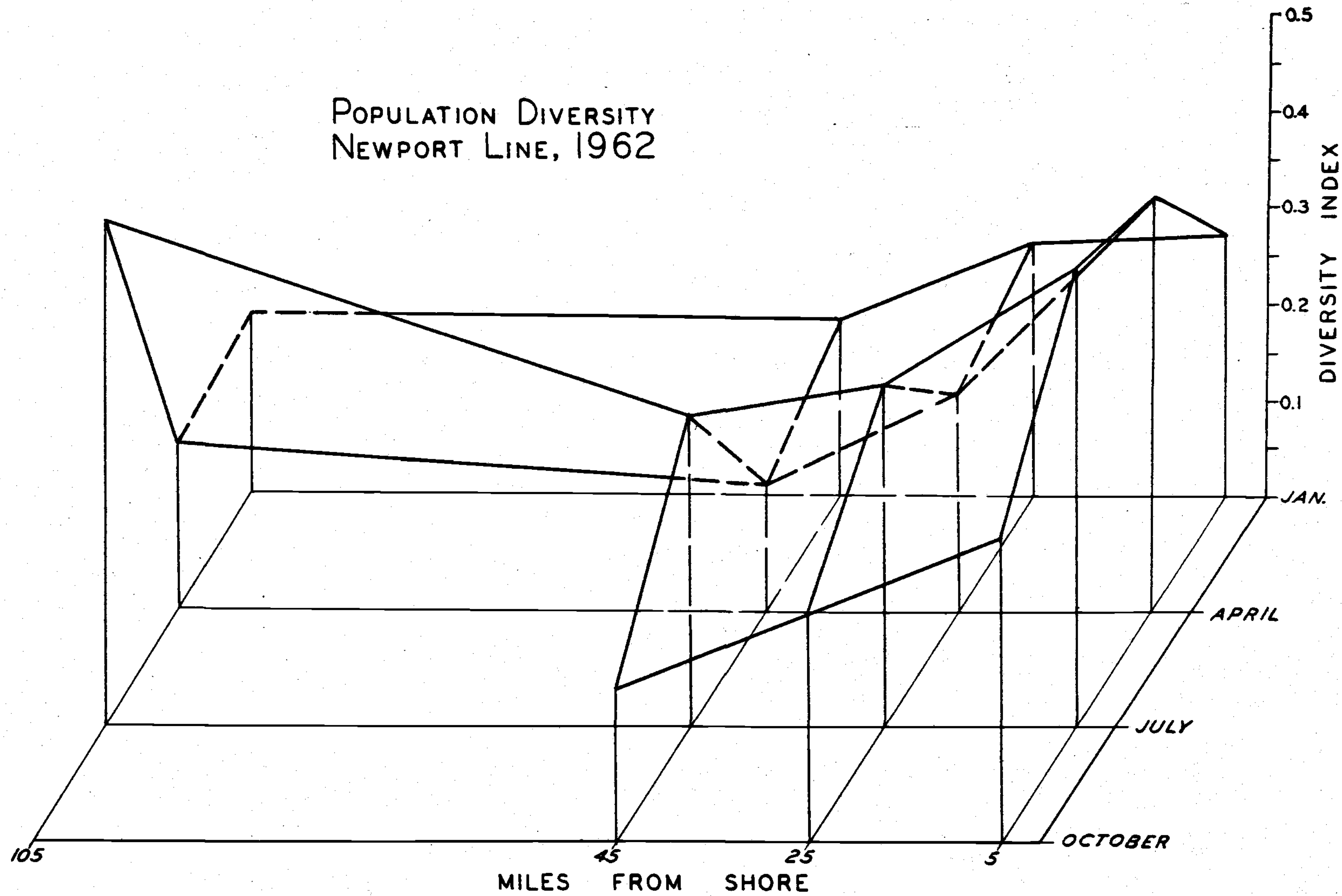

Figure 28. Seasonal Change in Population Diversity off Newport.

large population with a very low diversity. Equal population diversities do not necessarily mean equal population numbers. For example, equal diversity indices in, say, January and July give no information on the total numbers of copepods present during these two months. They do indicate that species (not necessarily the same ones) are found in the same cumulative percentages in January and July.

Diversity indices may be directly related to species composition. In this study, indices lower than 0.2 showed that, in most cases, Oithona similis represented more than 70% of the sample. Indices falling between 0.2 and 0.3 tended to indicate O. similis and Pseudocalanus minutus were the dominant organisms. Indices greater than 0.3 indicated an increase in percent composition of the less common copepods, such as Calanus finmarchicus and Metridia lucens. The January CH-5 population mentioned earlier is a good example of a population with an index greater than 0.3. Likewise, the increase in diversity at NH-5 in April was due to a greater percentage of Calanus finmarchicus and Acartia longiremis. The higher indices at NH-5 and 25 in July were due mainly to Acartia longiremis, which reached its seasonal maximum at the inshore stations during this time.

Copepod population diversity indices may possibly offer rough criteria for distinguishing different waters seasonally and on an areal basis. In this study, for example, indices of less than 0.2 were generally characteristic of offshore water on the two northern lines in winter, spring, and possible fall. Indices falling between

0.2 and 0.3 generally specified inshore waters at all seasons. Indices between 0.3 and 0.5 for the most part were associated with summer populations, both inshore and offshore.

Summary

The copepod population in Oregon coastal waters was examined from 116 oblique plankton tows taken during 1962. Quantitative Clarke-Bumpus samplers were used and stations ranged from 5-105 miles from shore off four hydrographic lines. Collection depth was to 150 meters. Forty-six species of copepods were identified.

The total adult copepod population varied according to distance from shore, season and hydrographic line sampled. During January, populations were low and relatively constant over all stations. Population peaks appeared at nearshore stations in spring and summer, while populations at the offshore stations reached peaks only during April and May. Two extremely high inshore summer populations may be linked in one case to the combined influence of the Columbia River and upwelling, and in the other case to upwelling alone. The temporal and spatial abundance of the total copepodite population followed the adult population very closely.

The Astoria and Newport hydrographic line had substantially higher populations during the spring and summer months than the more southerly Coos Bay line. The most apparent reason for this was the higher concentration of three copepod species on the two northern lines (*Pseudocalanus minutus*, *Oithona similis* and *Acartia longiremis*). *Pseudocalanus minutus* (Krøyer) was the most abundant calanoid copepod with periods of greatest abundance occurring in neritic waters. *Acartia longiremis* (Lilljeborg) was an important member of the copepod community during the mid-summer months, and only in neritic areas.

The presence of P. minutus and A. longiremis in somewhat higher numbers offshore on the Newport line suggests an extension of the coastal environment in this region. Oithona similis Claus was the dominant cyclopoid species, and often the most abundant of all species in Oregon coastal waters. April and May were periods of maximum abundance for this species at the offshore stations, while late summer and early fall appeared to be months of greatest abundance at the inshore stations.

Acartia danae Giesbrecht occurred at stations less than 65 miles from shore from October through May, even though it appeared to be endemic to waters farther than 100 miles from shore. Its seasonal appearance in coastal waters appears to be linked with the northward-flowing Davidson Current. Centropages mcmurrichi Willey, on the other hand, was collected in samples taken only between April and September when the surface current movement off the Oregon coast is in a southerly direction. It is suggested that A. danae and C. mcmurrichi may be used as reciprocal indicators of seasonal change in surface current movement off Oregon. Their distributions appeared to correlate closely with surface water characteristics during different seasons.

Diversity indices were calculated for selected stations at different seasons of the year to show temporal and spatial change in percent species composition. Inshore populations were, in general, more diverse than offshore populations. Inshore populations were also more diverse during spring and summer, while offshore populations showed high diversity only during the summer months.

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A P P E N D I X

Example of IBM Tabulation Sheet for NH-5, 15 October 1962

A B	C	D	E	F	G	H	I	J	K	L	M
NH005	15	10	1217	.00443	25	3	19	65	812	132.99	14.77
NH005	15	10	1217	.00443	25	3	79	250	3125	511.51	56.81
NH005	15	10	1217	.00443	25	3	81	1	12	2.04	.22
NH005	15	10	1217	.00443	25	3	67	46	575	94.11	10.45
NH005	15	10	1217	.00443	25	3	17	70	875	143.22	15.90
NH005	15	10	1217	.00443	25	3	69	6	75	12.27	1.36
NH005	15	10	1217	.00443	25	3	7	1	12	2.04	.22
NH005	15	10	1217	.00443	25	3	63	1	12	2.04	.22
NH005	15	10	1217	.00443	25	3	3	0	0	0.00	0.00
NH005	15	10	1217	.00443	25	3	87	271	3387	554.47	0.00
NH005	15	10	1217	.00443	25	3	91	13	162	26.59	0.00
NH005	15	10	TOTAL = 9.0026091E + 02								

A = Hydrographic line (in this case the Newport line)
B = Station sampled in miles from shore
C = Day of sampling
D = Month of sampling
E = Total revolutions of Clarke-Bumpus sampler
F = Calibration factor for C-B sampler (units = revolutions/m^3)
G = Diluted volume of sample
H = Number of 1 cc aliquots extracted for count
I = Species code
J = Number of each species counted
K = Total number of each species in sample (calculated)
L = Number per cubic meter (calculated)
M = Percent composition of adult population (calculated)

TOTAL = Sum of individual species

ZERO = the presence of a species in a sample even though it did not appear in the aliquot count.