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Seasonal and Areal Distributions of Zooplankton in Coastal Waters of the Gulf of Maine, 1967 and 1968

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Sampling for zooplankton in 1967 and 1968 was similar to the earlier coastal surveys of 1963 to 1966 (Sherman, 1968). Four stations were sampled seasonally in each of three Gulf of Maine coastal areas -- western (Cape Ann to Cape Elizabeth) central (Cape Elizabeth to Mt. Desert) and eastern (Mt. Desert to Machias Bay). Collections were made between the coastal headlands and the 100 m isobath. Oblique tows of 30 minutes were made with a Gulf III sampler fitted with metal netting of 0.37 mm apertures.

The abundant zooplankters included 13 taxa: 6 were holoplanktonic (copepods, appendicularians, chaetognaths, cladocerans, euphausiids, and pteropods) and 7 were meroplanktonic (brachyuran larvae, cirriped larvae, crustacean eggs, crustacean nauplii, decapod larvae, fish eggs and gastropod larvae). Copepods were the dominant taxa in both years, with numbers ranging from 98 percent of the total zooplankton in winter to 41 percent in summer. Nineteen copepod species were in the samples. The most numerous species were Calanus finmarchicus in winter, spring and summer, and Centropages typicus in autumn.

Seasonal Changes in Zooplankton Abundance

The seasons of maximal abundance of the zooplankton taxa varied between years. The holoplankters were most numerous in spring in 1968, when all except the cladocerans were at their annual peak in abundance. In 1967 in contrast, four of the six taxa -- appendicularians, chaetognaths, cladocerans, and euphausiids -- were most abundant in summer. Among the meroplankters, cirriped larvae were most numerous in spring of both years, and decapod larvae in peak numbers in spring, 1968. The remaining groups were at an annual maximum in summer.

Zooplankton Volumes

Seasonal trends in zooplankton volumes were similar in the 2 years with one exception. Volumes increased from winter to a spring peak and declined in summer in both years; from summer to autumn, however, they decreased in 1967 and increased in 1968. Differences in station volumes among the areas were significant ($P < 0.05$) in winter, spring, and autumn, 1967, and in spring, 1968. Volumes generally decreased from west to east. Differences among the areas were not significant in autumn and winter 1968, and in the summer of both years (table 1).

Trends in zooplankton abundance were similar along the coast in 1967 and 1968; mean annual volumes for each of the areas declined from a high in the west to a low in the east (fig. 1).

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Surface temperatures and salinities in each of the areas varied seasonally. In the western and central areas temperatures increased from a winter low to a summer high and decreased in autumn; in the eastern area the annual maximum was reached in autumn. The salinity maximum occurred in autumn in the eastern area and during winter in the central and western sections. Surface conditions were similar in all three areas in winter. In other seasons temperatures decreased and salinities increased from west to east along the coast (fig. 2).

Variations in Temperature and Zooplankton Abundance

Thermal stratification of coastal waters begins in spring and is most pronounced in summer. With the onset of vernal warming, the overwintering populations of adult zooplankters produce swarms of nauplii, copepodites, and other young forms. The timing of the spring swarming, however, varies with temperature. In spring 1967, when sampling was earlier (March 28 to April 13) than in 1968 (May 15-22) the coastal waters were cool (< 3° C.) and vertically mixed from Cape Ann to Machias Bay. In spring 1968, the waters were warmer and a thermocline was developed in the western and central areas; eastern waters were also warmer, although vertically mixed because of tidal stirring. Zooplankton volumes in spring were not significantly different between the two years ($U = 56$, $P > 0.05$), but the size composition of the dominant zooplankter -- Calanus finmarchicus -- showed the effects of the earlier sampling in 1967; the adult overwintering form was dominant in 1967, whereas copepodite stages three and four predominated in 1968. The displacement volume of individuals is considerably less for copepodites than for adults but since the copepodites were more numerous in 1968 than the adults in 1967, the standing crop estimates in spring were not significantly different in the 2 years.

The between-year difference in the timing of the spring sampling was also reflected in the abundance of other zooplankton commonly eaten by juvenile herring. Decapod larvae, cladocerans, and cirriped larvae were more numerous in the spring samples in 1968 than in 1967.

The annual differences in the abundance of zooplankton from west to east along the coast corroborate similar differences found both in the early decades of the century, and more recently in each year in 1963-68. Although the annual trend in zooplankton abundance is well established, the seasonal differences among the three coastal areas are more variable. Significant variations in abundance can occur between 2 years at the same season of the year, depending on the timing of sampling -- as evidenced by the differences in the spring abundance estimates of 1967 and 1968. In addition, local differences in circulation can affect the areal abundance of zooplankton; in 1968 anomalous concentrations of four copepod species -- C. finmarchicus, Pseudocalanus minutus, Tortanus discaudatus and Temora longicornis were observed in the eastern area of the coast. The holoplankters found in coastal waters are widely distributed.-- particularly the dominant copepods. Concentrations of the predominant species, Calanus finmarchicus and Centropages typicus occur in offshore waters, and offshore waters are advected periodically into the coastal region to compensate for estuarine discharge. The influence of the offshore populations on the abundance of zooplankters along the coast is being investigated.

LITERATURE CITED

Sherman, K. 1968. Seasonal and areal distributions of zooplankton in coastal waters of the Gulf of Maine, 1965 and 1966. U.S. Fish Wildl. Serv., Spec. Sci. Rep. Fish. 562, 11 pp.

Table 1. Sample volumes per 100 $m.^3$ of water strained at each sampling station in three areas along the coast of the Gulf of Maine, 1967 and 1968. [Kruskal-Wallis H and probability values are listed for each area by season. See figure 1 for location of stations and areas].

Year, area, and station number	Winter	Spring	Summer	Autumn
1967				
West				
1	0.91	9.08	3.73	5.81
3	2.44	63.28	1.42	2.87
4	4.34	5.69	12.45	2.67
5	1/33.56	21.81	5.21	1.47
Central				
9	0.57	9.91	1.26	0.19
12	0.28	4.36	8.00	1.98
13	0.70	11.22	1.49	0.87
14	2/	10.72	0.09	2.59
East				
17	0.15	1.48	0.89	0.38
18	0.01	0.88	0.48	0.24
19	0.62	0.39	2.94	0.11
21	0.29	2.73	0.57	0.16
H value	7.48	7.94	3.96	7.54
P value	< 0.010	< 0.008	>0.104	< 0.011
1968				
West				
1	10.32	42.18	1.31	2.92
3	4.12	22.10	1.98	2.55
4	9.94	9.80	3.07	7.77
5	7.71	16.05	2.43	3.99
Central				
9	0.55	8.94	4.22	6.43
12	4.33	4.11	4.40	5.29
13	10.12	1.11	2.74	1.66
14	1.72	1.13	0.90	6.23
East				
17	1.33	0.45	0.93	2/
18	3.06	0.40	2.43	0.83
19	9.75	0.31	1.97	2/
21	3.62	0.48	0.97	0.76
H value	2.88	9.84	2.19	4.42
P value	>0.104	< 0.008	>0.104	>0.103

1/ Mostly euphausiids
2/ No sample obtained

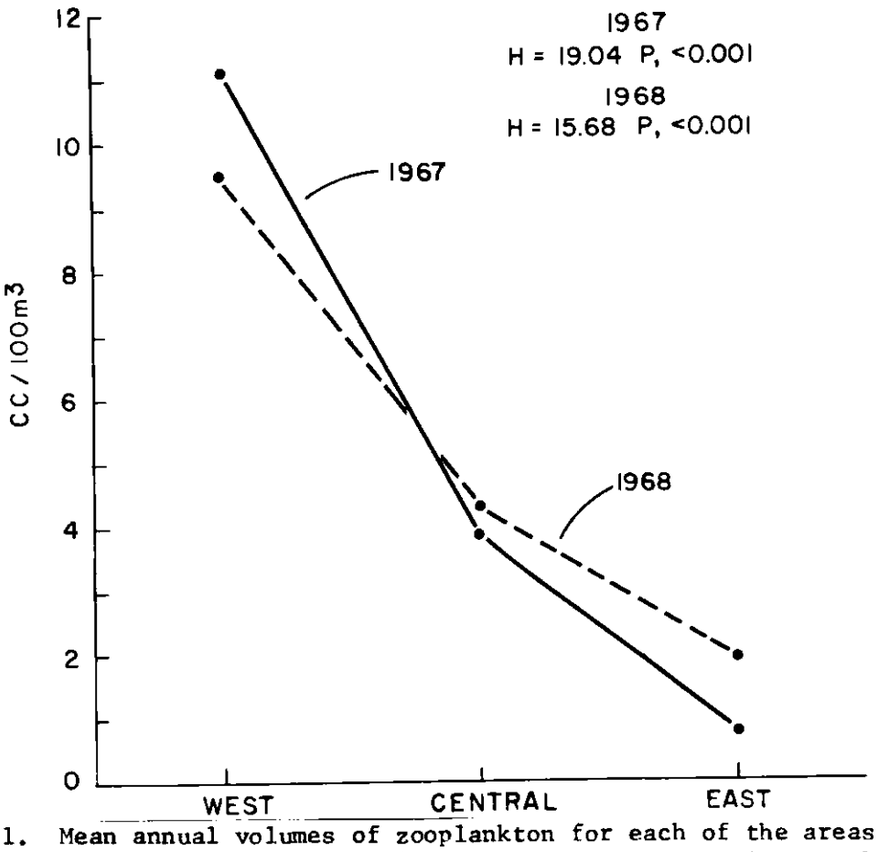

Figure 1. Mean annual volumes of zooplankton for each of the areas investigated in Gulf of Maine coastal waters in 1967 and 1968. Kruskal-Wallis H values are given for among area comparisons. Solid line is for 1967 and dotted line for 1968.

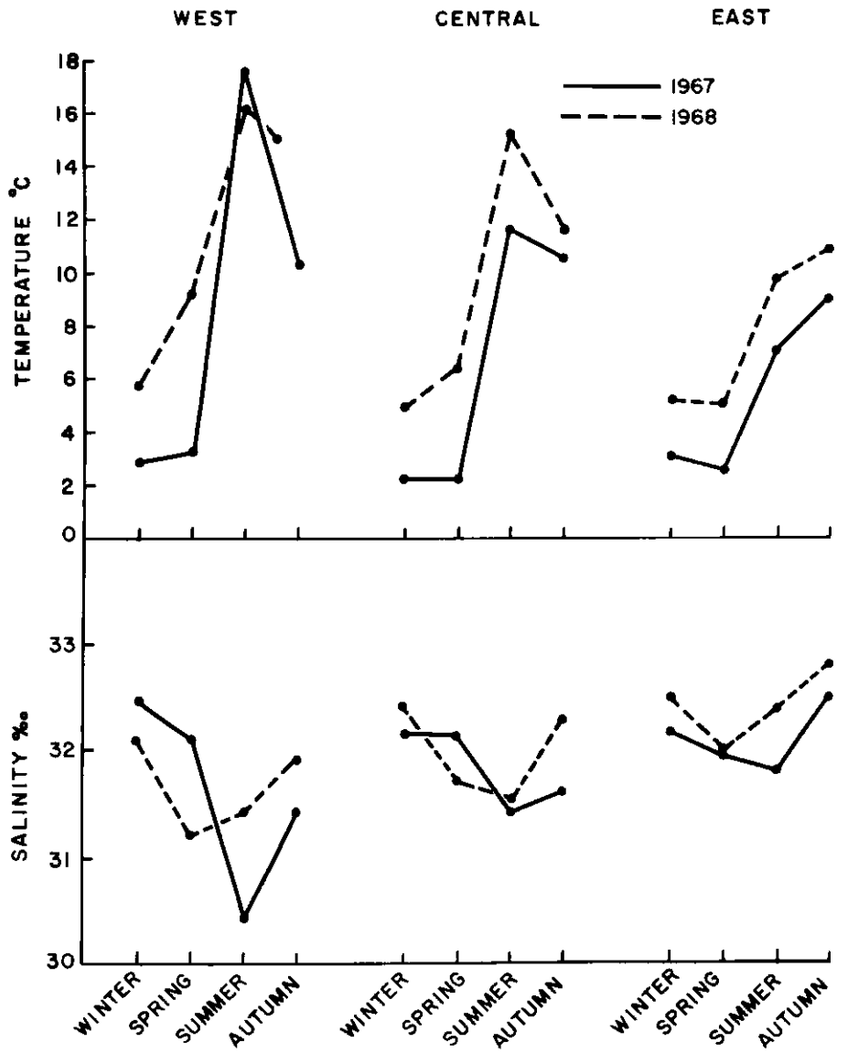

Figure 2. Mean seasonal surface temperature and salinity for the western, central, and eastern areas of the coastal Gulf of Maine in 1967 and 1968.