562

Seasonal and Areal Distribution of Zooplankton in Coastal Waters of the Gulf of Maine, 1965 and 1966

SPECIAL SCIENTIFIC REPORT–FISHERIES No. 562

UNITED STATES DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE
BUREAU OF COMMERCIAL FISHERIES

UNITED STATES DEPARTMENT OF THE INTERIOR
Stewart L. Udall, *Secretary*
David S. Black, *Under Secretary*
Stanley A. Cain, *Assistant Secretary for Fish and Wildlife and Parks*
FISH AND WILDLIFE SERVICE, Clarence F. Pautzke, *Commissioner*
BUREAU OF COMMERCIAL FISHERIES, H. E. Crowther, *Director*

Seasonal and Areal Distribution of Zooplankton in Coastal Waters of the Gulf of Maine, 1965 and 1966

By

KENNETH SHERMAN

United States Fish and Wildlife Service
Special Scientific Report--Fisheries No. 562

Washington, D.C.
March 1968

CONTENTS

Seasonal and Areal Distribution of Zooplankton in Coastal Waters of the Gulf of Maine, 1965 and 1966

By

KENNETH SHERMAN, Fishery Biologist

Bureau of Commercial Fisheries Biological Laboratory
West Boothbay Harbor, Maine 04575

ABSTRACT

A description is given of the abundance, composition, and seasonal variations in distribution of zooplankton. Eleven major taxa were represented in the samples. Six were holoplanktonic, and five were meroplanktonic. Copepods were the dominant zooplankters during all seasons in both years. Zooplankton volumes in both years followed similar areal trends. Mean annual volumes were highest in the western area (Cape Ann to Cape Elizabeth), moderate in the central area (Cape Elizabeth to Mt. Desert Island), and low in the eastern sector (Mt. Desert Island to Machias Bay). Zooplankton volumes were generally lower in 1966 than in 1965. Areal and annual variations in the abundance of zooplankters are discussed in relation to hydrography.

INTRODUCTION

The Bureau of Commercial Fisheries in 1963 began an investigation of the effects of the environment on the availability and abundance of herring, Clupea harengus harengus L., in coastal waters of the Gulf of Maine. Studies of zooplankton were undertaken as part of this investigation. Sampling was designed to measure variations in composition, distribution, and abundance of the larger zooplankters, particularly calanoid copepods, an important food of herring. This is the third in a series of reports (see Sherman, 1965 and 1966) on the coastal zooplankton assemblage in the Gulf of Maine.

METHODS

Sampling in 1965 and 1966 was similar to that in the earlier surveys of 1963 and 1964. Four stations 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)--were sampled seasonally on cruises of the research vessel Rorqual (fig. 1). Samples were collected with a Gulf III sampler fitted with a 20.4-cm. nose cone and metal netting (aperture width, 0.37 mm.). Step-oblique tows of 30 minutes--10 minutes each at 20 m., 10 m., and the surface--were made during daylight. The amount of water strained was determined from a calibrated flow meter mounted on the tail section of the sampler. Each tow covered about 5.6 km. (3 nautical miles) and filtered about 200 m.^{3} of water. The towing speed was 308 cm./sec. (6 knots).

Volumes of the samples of zooplankton were measured in the laboratory by the mercury-immersion method (Yentsch and Hebard, 1957). Ctenophores, large coelenterate remains (>2 cm. long), and all fish larvae were excluded. Zooplankton samples were divided into aliquots ranging from a half to a sixty-fourth, depending on the mass of the sample, and sorted into major taxonomic groups. Copepods were identified to species, and numbers of copepods and other zooplankters per 100 m.^{3} of water were calculated.

ABUNDANCE, COMPOSITION, AND DISTRIBUTION OF ZOOPLANKTON

Zooplankton Volumes

Seasonal trends in zooplankton volumes in 1965 and 1966 were similar in the western area of the Gulf (Fig. 2). Volumes increased from a winter low to a summer high and decreased in the fall. In the eastern area volumes were low (<2.5 cc./100 m.^{3}) in all seasons during both years. Seasonal variations were greatest in the central area. In 1965 volumes were high in the winter, but

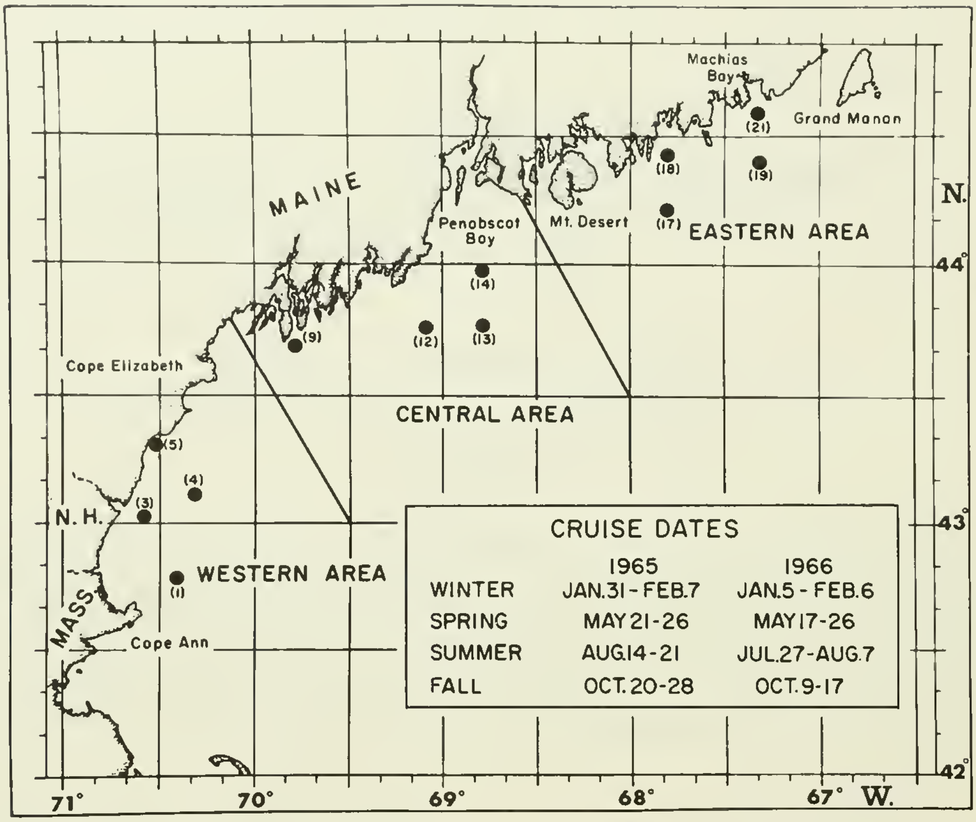

Figure 1.--Zooplankton sampling stations, Gulf of Maine coastal waters, 1965 and 1966. Station numbers are shown in parentheses.

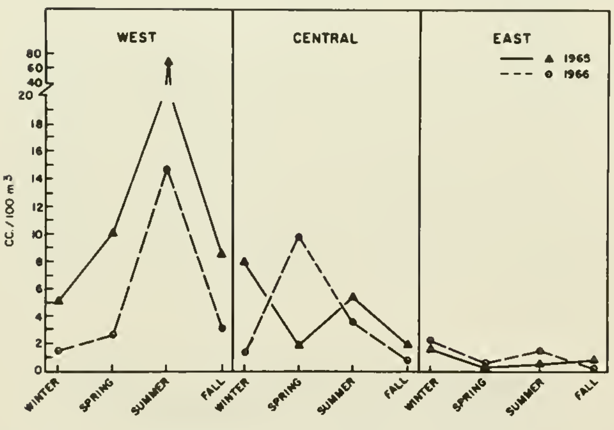

Figure 2.--Mean seasonal volumes of zooplankton by Gulf of Maine coastal areas in 1965 and 1966.

decreased in the spring, whereas in 1966 they increased from a low in winter to an annual high in spring. Volumes decreased from summer to fall in both years. These values are considered as minimal estimates of zooplankton abundance because sampling was done only in daylight in the upper 20 m. of water, and the netting had relatively large apertures (used to obtain the larger zooplankton, particularly calanoid copepods).

Volumes at each sampling location were examined for differen~es among the areas with the Kruskal-Wallis analysis of variance (Siegel, 1956). Differences in station values among the areas were significant ($P < 0.05$) in spring, summer, and fall. Volumes generally decreased from west to east; the notable exception was in the high volumes in the central area in the spring of 1966. In winter, volumes were higher in 1965 than in 1966, but differences among the areas in both years were not statistically significant (table 1).

Annual trends in zooplankton abundance along the coast were similar in 1965 and 1966; mean annual volumes for each of the areas declined from a high in the west to a low in the east (fig. 3). Differences in volumes between years and between areas were tested with the Mann-Whitney U test (Siegel, 1956). Volumes were significantly higher in the west than in the east ($P < 0.001$). Volumes in the central area were between the western and eastern extremes. Between-year volumes in the central and eastern area were similar, but in the west were about four times greater in 1965 than in 1966 ($P < 0.01$).

Table 1.--Sample volumes (cc./100 m.^{3}) at each sampling station in three areas along the coast of the Gulf of Maine, 1965 and 1966

[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	Season			
	Winter	Spring	Summer	Fall
1965				
West				
1.........	7.70	7.04	104.52	14.87
3.........	3.76	3.42	100.36	6.07
4.........	5.44	24.25	58.07	6.60
5.........	3.36	5.29	7.81	6.26
Central				
9.........	1.55	2.17	3.04	4.57
12.........	26.39	3.51	12.08	2.78
13.........	2.31	0.67	4.17	0.59
14.........	1.89	0.90	2.48	0.50
East				
17.........	2.77	0.07	0.85	0.68
18.........	0.67	0.49	0.39	0.85
19.........	1.95	0.27	0.03	0.59
21.........	1.19	0.28	0.52	0.90
H value......	5.10	9.25	9.25	7.40
P value......	<.097	<.008	< .008	<.049
1966				
West				
1.........	1.53	2.26	9.82	1.09
3.........	1.06	4.09	9.29	2.85
4.........	1.63	0.90	33.57	6.08
5.........	1.57	2.64	6.23	2.12
Central				
9.........	1.04	3.83	2.41	0.94
12.........	1.09	19.05	5.43	0.57
13.........	0.53	8.62	4.06	0.57
14.........	2.56	8.28	1.96	1.05
East				
17.........	1.88	0.88	2.89	0.13
18.........	1.48	0.31	1.45	([1])
19.........	2.23	0.71	1.10	0.08
21.........	2.92	0.67	0.89	0.35
H value......	3.23	9.25	8.75	7.84
P value......	<.020	<.008	<.008	<.010

[1] Phytoplankton clogged net; sample not suitable for measurement.

Group and Species Composition

Copepods were the dominant zooplankters in the samples. In different seasons and years, their contribution to the total zooplankton ranged from about 97 percent (winter of both years) to 35 percent (summer of 1966). Ten other groups (taxa) constituted more than 1 percent of the zooplankton in each year (table 2); five were holoplanktonic (appendicularians, pteropods, euphausiids, cladocerans, and chaetognaths) and five were meroplanktonic (fish eggs, crustacean eggs, and larval cirripeds, decapods, and brachyurans).

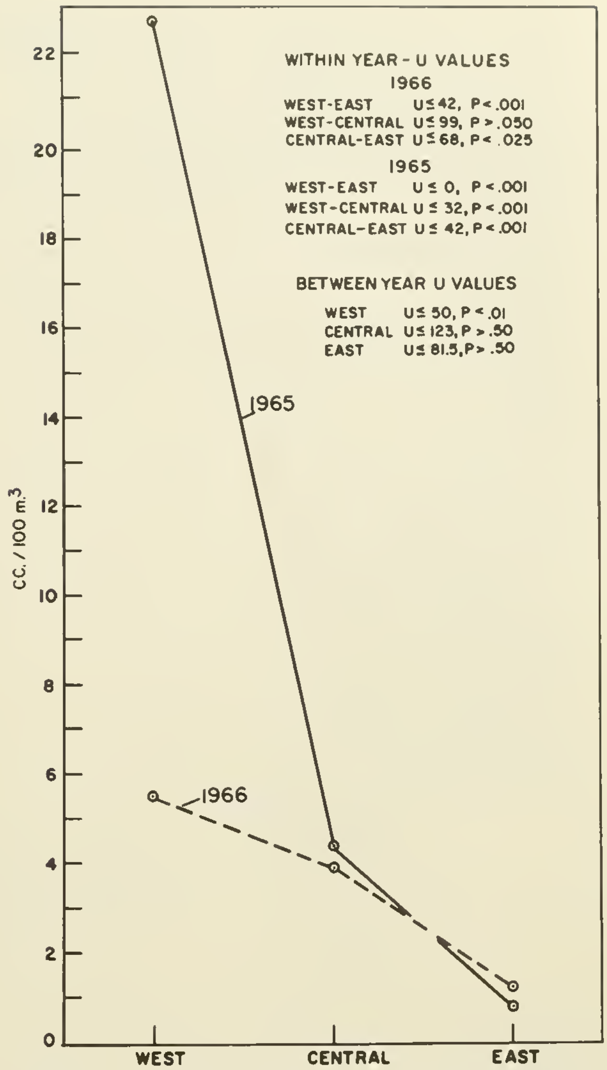

Figure 3.--Mean annual volumes of zooplankton in Gulf of Maine coastal areas in 1965 and 1966. Mann-Whitney U values are given for between-years and within year comparisons.

Seasonal abundance, expressed as mean numbers of zooplankters per unit volume per season, was similar among three of the holoplanktonic groups--copepods, appendicularians, and euphausiids. They increased from a winter low to a summer maximum, and declined in the fall (table 3). Chaetognaths

Table 2.--Percentage composition of zooplankton groups in coastal waters of the Gulf of Maine, 1965 and 1966

Group	1965				1966			
	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
Holoplankton	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
Amphipoda.............	P[1]	P	--	P	P	P	P	--
Appendicularia.........	--	2.1	1.6	P	--	3.7	27.4	1.4
Chaetognatha...........	1.3	P	1.1	2.1	1.9	--	P	1.5
Cladocera..............	P	2.6	P	2.1	P	1.6	1.9	12.1
Copepoda...............	96.9	74.4	71.4	91.6	97.3	72.4	35.4	76.8
Euphausiacea...........	1.3	4.6	6.2	P	P	4.6	3.4	1.5
Isopoda................	P	--	--	--	--	--	--	--
Medusae................	P	P	P	--	--	P	P	P
Pteropoda..............	P	--	P	1.0	P	P	P	P
Meroplankton								
Annelida larvae........	P	P	P	P	P	P	P	P
Brachyura larvae.......	--	P	1.5	1.4	--	P	1.8	--
Cirripedia larvae......	P	12.3	P	--	P	13.3	P	--
Crustacean eggs........	--	P	10.9	P	P	P	15.1	3.5
Crustacean nauplii.....	--	--	--	P	--	P	P	P
Decapoda larvae........	P	P	P	P	--	P	4.8	P
Echinodermata larvae...	--	--	--	--	--	--	P	P
Fish eggs..............	P	1.1	6.1	P	P	1.7	8.1	P
Gastropoda larvae......	--	P	P	--	--	P	P	P
Pelecypoda larvae......	--	--	P	P	P	--	P	--
Pycnogonoida...........	--	P	--	--	--	--	--	--

[1] (P) Present, but representing less than one percent of the zooplankton in each season.

Table 3.--Mean numbers of dominant zooplankton groups per 100 $m.^3$ of water in each season, Gulf of Maine coastal waters, 1965 and 1966

Group	Year	Season			
		Winter	Spring	Summer	Fall
Holoplankton					
Copepoda..........................	1965	2,496	5,733	26,008	20,397
	1966	1,233	7,058	8,725	3,664
Euphausiacea......................	1965	31	353	2,259	45
	1966	3	444	846	72
Chaetognatha......................	1965	34	13	380	157
	1966	24	1	81	70
Appendicularia....................	1965	--	164	598	15
	1966	--	363	6,755	67
Cladocera.........................	1965	1	203	113	157
	1966	2	155	467	579
Pteropoda.........................	1965	5	--	9	66
	1966	1	15	2	1
Meroplankton					
Fish eggs.........................	1965	5	146	2,210	25
	1966	1	163	1,993	7
Crustacean eggs...................	1965	--	1	4,004	25
	1966	1	84	3,717	166
Cirripedia larvae.................	1965	--	949	31	--
	1966	1	1,295	129	--
Decapoda larvae...................	1965	2	41	201	35
	1966	--	61	1,184	21
Brachyura larvae..................	1965	--	19	543	107
	1966	--	55	452	60

were most numerous in summer and fall. Cladocerans were at an annual low in winter, and numbers of pteropods were low in all seasons (<100/100 m.^{3}). Among the meroplankton, larval cirripeds were most numerous in spring. In summer, crustacean eggs, fish eggs, decapod larvae, and brachyuran larvae, were in peak abundance.

Group and Species Composition by Season and Area

Areal distributions of the abundant zooplankton groups (seasonal mean >100/100 m.^{3}) were determined by season for each of the Gulf areas (table 4). In 1965 copepods decreased in abundance from west to east in

Table 4.--Mean number of the dominant zooplankton groups per 100 m.^{3} of water in each area and season, Gulf of Maine coastal waters, 1965 and 1966

Group and area	1965				1966			
	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
Holoplankton								
Copepoda								
West.................	1,760	15,550	73,726	17,255	1,035	6,559	18,257	9,405
Central..............	4,560	1,605	4,007	2,974	1,340	14,414	3,833	1,415
East.................	1,168	42	292	168	1,326	202	4,086	171
Euphausiacea								
West.................	93	1,048	6,571	--	--	1,234	2,262	29
Central..............	--	10	207	136	1	91	235	145
East.................	--	2	--	--	8	8	41	41
Chaetognatha								
West.................	47	38	798	339	34	--	138	148
Central..............	20	--	344	124	13	--	48	55
East.................	35	1	1	7	27	1	57	7
Appendicularia								
West.................	--	312	--	--	--	26	2,071	201
Central..............	--	175	1,563	19	--	951	15,913	--
East.................	--	4	231	25	--	111	2,281	1
Cladocera								
West.................	--	560	29	412	--	446	337	1,674
Central..............	--	48	221	60	--	19	917	59
East.................	--	2	89	1	5	--	148	4
Pteropoda								
West.................	--	--	--	182	1	4	--	1
Central..............	2	--	--	12	3	42	7	--
East.................	12	--	10	3	--	1	--	--
Meroplankton								
Fish eggs								
West.................	5	254	1,078	72	--	310	4,258	14
Central..............	1	142	4,785	--	--	132	1,548	5
East.................	1	43	767	3	1	47	174	2
Crustacean eggs								
West.................	--	--	--	17	--	26	16	--
Central..............	--	1	--	27	--	224	6,612	471
East.................	--	1	10,709	15	4	2	4,522	27
Cirripedia larvae								
West.................	--	1,786	29	--	1	295	8	--
Central..............	--	281	221	--	--	1,830	44	--
East.................	1	780	89	--	2	1,761	334	--
Decapoda larvae								
West.................	2	45	798	84	--	125	2,728	47
Central..............	2	61	343	6	--	40	627	11
East.................	2	16	1	14	--	19	197	4
Brachyura larvae								
West.................	--	33	1,076	18	--	151	300	5
Central..............	--	18	485	157	--	12	775	153
East.................	--	6	68	148	--	3	280	24

spring, summer, and fall; maximum numbers were in the central area in winter. In 1966 distributions of copepods were more variable: numbers generally declined from west to east in summer and fall; peak abundance was in the central area in spring; and mean numbers in the three areas were similar in winter. Among the other holoplanktonic forms, numbers of euphausiids and chaetognaths generally decreased from west to east. Distributions of the meroplanktonic groups were variable; of the abundant forms, crustacean eggs occurred most frequently in summer in the central and eastern areas. Numbers of fish eggs decreased from west to east in the spring of 1965 and the spring and summer of 1966, but were highest in the central area in the summer of 1965. Swarming of cirriped larvae was most pronounced in the west in the spring of 1965, and in the central and eastern areas in the spring of 1966.

The samples included 19 copepod species. Of this number, five were classifed as common (>50/100 m.^{3}/station) in 1965, and six in 1966 (table 5). The dominant species in both years was Calanus finmarchicus. In addition to C. finmarchicus, three species occurred commonly in 1965 and 1966--Temora longicornis, Centropages typicus, and Pseudocalanus minutus. The abundance of the other principal species varied annually; Metridia lucens was classified "common" in 1965, and Oithona similis and Acartia longiremis in 1966.

Numbers of copepods generally decreased eastward in spring, summer, and fall (fig. 4). Notable exceptions were the concentrations of C. finmarchicus in the central area in the spring of 1966, and of T. longicornis in the eastern area in the summer of 1966. In winter, numbers of copepods were at an annual low and distributions were variable. The greatest concentration in winter was of C. finmarchicus in the central area in 1965.

The west-to-east decline in volumes reflects the general decrease in abundance of copepods along the coast from Cape Ann to Machias Bay. Variations in the abundance of C. finmarchicus, the dominant zooplankter, were responsible for the large between-year differences in volumes in the western Gulf. In summer, when the annual zooplankton volumes were highest, C. finmarchicus was about four times more numerous in 1965 (ca 71,000/100 m.^{3}/station) than in 1966

Table 5.--Copepod species in zooplankton samples, Gulf of Maine coastal waters, 1965 and 1966

1965		1966	
Species	Mean number/ 100 m.^{3}/ station	Species	Mean number/ 100 m.^{3}/ station
Common species (>50/100 m.^{3})		Common species (>50/100 m.^{3})	
Calanus finmarchicus (Gunnerus)..	8,934	Calanus finmarchicus (Gunnerus)..	3,749
Temora longicornis (Muller)......	600	Centropages typicus Kroyer.......	680
Centropages typicus Kroyer.......	257	Pseudocalanus minutus (Kroyer)...	182
Pseudocalanus minutus (Kroyer)...	204	Temora longicornis (Muller)......	114
Metridia lucens Boeck...........	88	Oithona similis Claus............	110
		Acartia longiremis (Lilljeborg)..	60
Less numerous species (<50/100 m.^{3})		Less numerous species (<50/100 m.^{3})	
Oithona similis Claus............	49	Tortanus discaudatus (Thompson and Scott)	20
Centropages hamatus (Lilljeborg).	40	Centropages hamatus (Lilljeborg)	18
Acartia longiremis (Lilljeborg)..	39	Calanoid sp. immature............	8
Eurytemora herdmani Thompson and Scott....	15	Metridia lucens Boeck............	8
Tortanus discaudatus (Thompson and Scott)..	14	Oithona spinirostris Claus.......	7
Acartia clausi Giesbrecht........	12	Acartia clausi Giesbrecht........	5
Euchaeta norvegica Boeck.........	2	Eurytemora herdmani Thompson and Scott....	4
Eurytemora sp....................	1	Calanus hyperboreus Kroyer.......	2
Oithona spinirostris Claus.......	1	Acartia sp. immature.............	1
Calanus hyperboreus Kroyer.......	([1])	Harpacticoid sp..................	1
Harpacticoid sp..................	([1])	Metridia longa (Lubbock).........	([1])
Calanoid sp. immature............	([1])	Euchaeta norvegica Boeck.........	([1])
Cyclopoid sp.....................	([1])	Anomalocera pattersoni Templeton.	([1])
Undinopsis similis Sars..........	([1])		

[1] Less than 1.

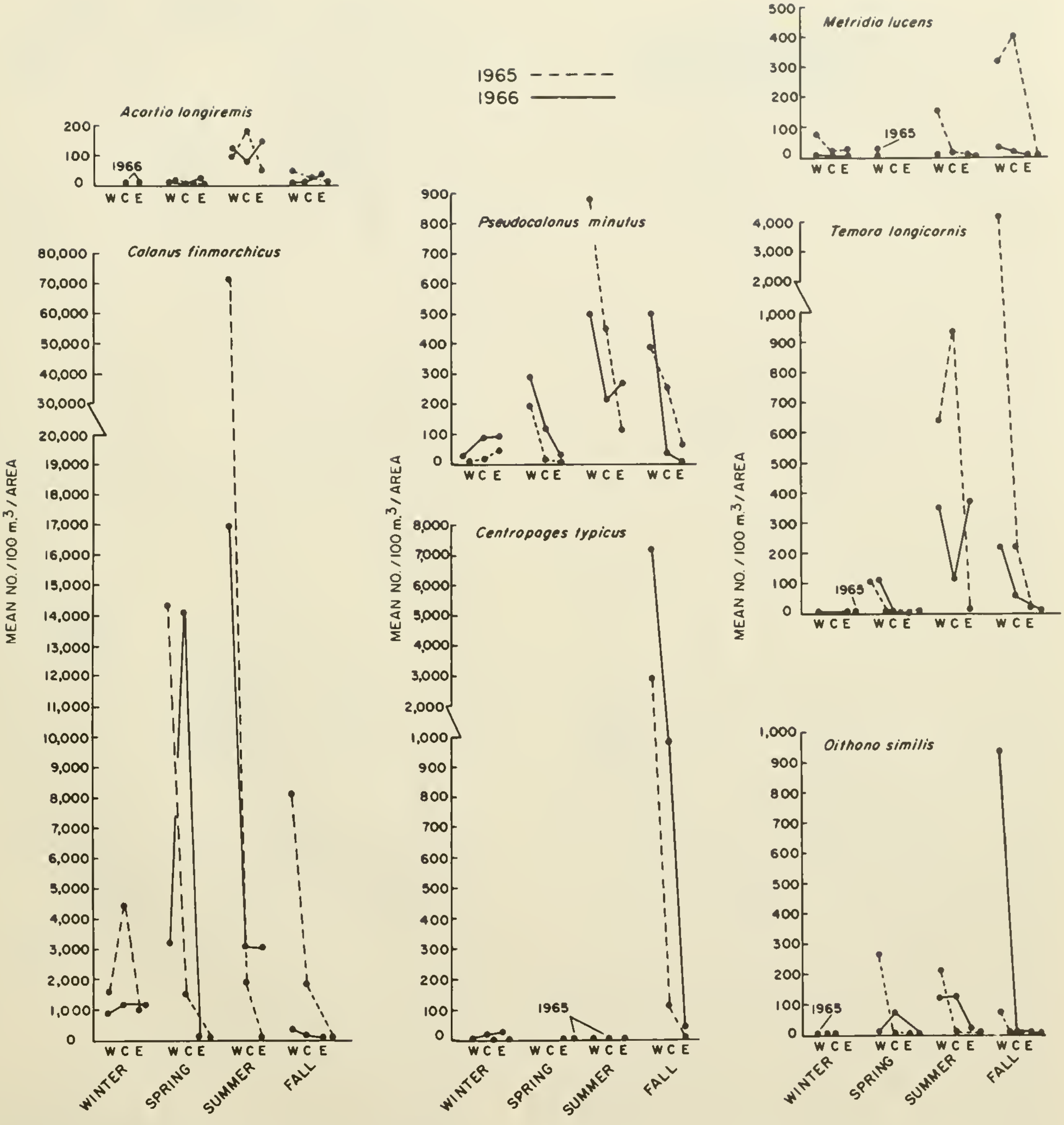

Figure 4.--Mean number of dominant copepod species per 100 m.^{3} of water in different seasons in each of the coastal Gulf of Maine areas, (W) western, (C) central, and (E) eastern, in 1965 and 1966.

(ca. 17,000/100 m.^{3}/station). The seasonal differences in volumes in the central area were also the result of fluctuations in the abundance of C. finmarchicus: this species was about four times more numerous in winter in 1965 than in 1966, but about seven times more numerous in the spring in 1966 than in 1965.

HYDROGRAPHY AND ZOOPLANKTON

Observations were made of temperature, salinity, and zooplankton by season in each of the areas for 1965 and 1966.

Surface Temperature and Salinity

Surface temperatures and salinities varied seasonally among the coastal areas; the seasonal trends within each area were similar, however. Mean temperatures in 1965 and 1966 generally increased from an annual low in winter to a summer high and declined in the fall (fig. 5). The single exception was in the eastern area in 1966; mean temperatures increased slightly from summer (8.7° C.) to fall (9.0° C.). Temperatures in winter were low in each of the areas (<3.0° C.). Temperatures decreased from west to east in spring, summer, and fall. The range in temperature from winter to summer was greatest in the western area--about 5° C. greater than the difference in the eastern region.

Seasonal changes in salinity (measured in parts per thousand) were similar in both years (fig. 5). In the western and central areas mean salinities decreased from an annual high in winter to a low in spring, and subsequently rose in summer and fall. Salinities in the east decreased from winter to a low in spring, and increased progressively to the annual high in the fall. Spring and summer salinities were lower in the western and central areas in 1966 than in 1965; in the eastern area values were higher in 1965.

Areal differences in temperature and salinity along the Gulf coast result from local environmental conditions rather than from large-scale advection of waters. The low temperatures and high salinities of the eastern area from spring through fall are the products of vertical mixing through the water column induced by tidal stirring, and minimal river drainage; higher temperatures and lower salinities of the western region result from increased stability of the water column, reduced tidal mixing, and large-scale runoff from rivers (Bigelow, 1914, 1915, 1917, 1927; Sherman, 1966). Profiles of temperature and salinity based on observations made in 1966 corroborate earlier reports of vertical mixing in the eastern Gulf and stratification of water in the western area during the warmer months (fig. 6); inshore to offshore observations of temperature and salinity were made from the mouths of three rivers--the Merrimack, Penobscot, and Machias--to approximately 28 km. offshore. The relatively low temperatures and high salinities in the western and central areas in winter result from wind-induced mixing of the water column, and the movement of cold air over the Gulf from the adjacent land mass by the prevailing northwest winds of the season (Bigelow, 1927).

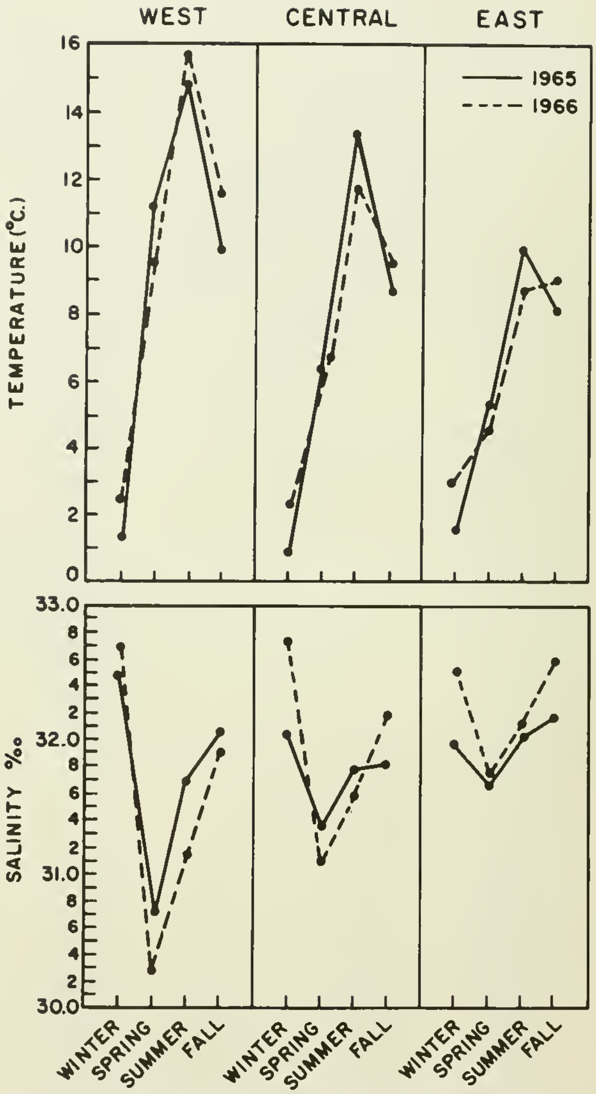

Figure 5.--Mean seasonal surface temperature and salinity for the western, central, and eastern areas of the coastal Gulf of Maine in 1965 and 1966.

Areal Distribution of Zooplankton and Hydrography

The general decrease in zooplankton volumes from west to east along the coast is similar to the areal decline in abundance observed in earlier investigations (Bigelow, 1926; Fish and Johnson, 1937; Sherman, 1966). This decrease appears to be caused by dissimilar hydrography in the different areas. In the eastern Gulf the unstable water column, low

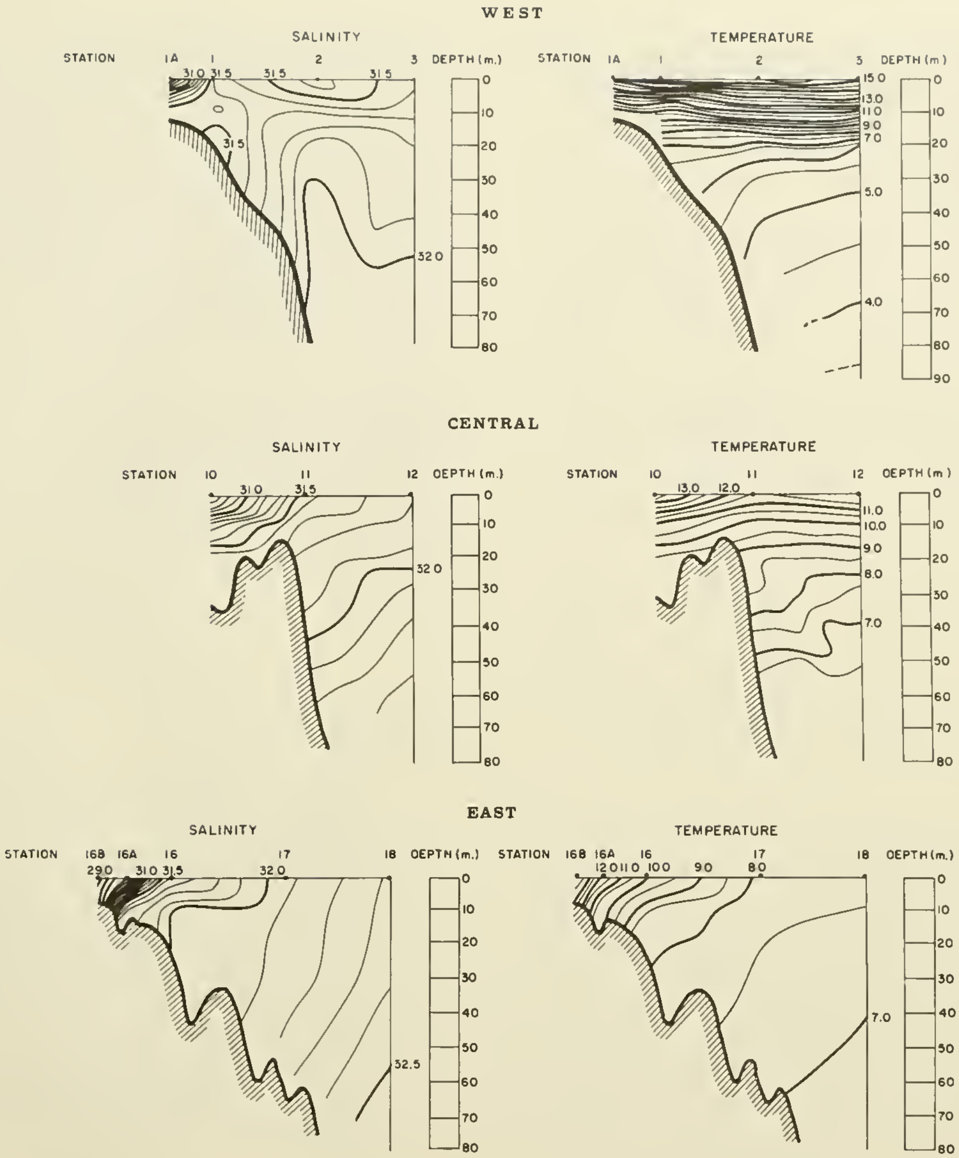

Figure 6.--Inshore-offshore vertical profiles of temperature (°C.) and salinity (p.p.t.), Gulf of Maine coastal waters, summer 1966.

temperatures depressing the growth of crustacean eggs and larvae (Fish and Johnson, 1937), and lack of appreciable influx of zooplankton from the north and east (Bigelow, 1926; Redfield, 1941) lead to minimal conditions for population growth. In contrast, the increased stability of the water column, and higher spring and summer temperatures westward provide an increasingly favorable environment for growth and development of zooplankton from Mt. Desert to Cape Ann (Sherman, 1966).

Circulation and Between-Year Differences in Zooplankton

The intensity and duration of river discharge have a dominant influence on the annual development of the nontidal drift in the Gulf of Maine (Bigelow, 1927; Bumpus, 1960; Bumpus and Lauzier, 1965). Spring runoff for major rivers emptying into the central and western Gulf was higher in 1966 than in 1965 (table 6). This increase was apparently responsible for

Table 6.--Total monthly discharge (in cubic feet per second) of the major rivers emptying into the Gulf of Maine, March, April, and May (spring) 1965 and 1966 [1]

Coastal area and river	Year	
	1965	1966
East		
St. Croix..........	238,020	245,987
Machias............	109,396	103,745
Central		
Penobscot..........	1,244,890	1,543,700
Sheepscot..........	29,710	44,115
Kennebec...........	246,140	442,070
Androscoggin.......	533,488	916,440
West		
Saco...............	249,090	364,140
Piscataqua.........	22,147	30,072
Merrimack..........	600,400	874,500
Total................	3,273,281	4,564,769

[1] Data from the U.S. Geological Survey, Water Resources Division, Augusta, Maine, and Boston, Mass.

the lower salinities in the western and central areas in the spring and summer of 1966. The dominant zooplankter, C. finmarchicus, was more numerous in the western Gulf in 1965 than in 1966. Between-year differences in the abundance of C. finmarchicus, and consequently in volumes of zooplankton as well, appear to be related to variations in development of the dominant nontidal drift along the coast. In periods of low runoff, circulation along the western north Atlantic coast is weak; less water is lost to the offshore system, and less water is drawn into the coastal system (Bumpus, 1966[1]). In late spring and summer the dominant drift from Cape Elizabeth to Cape Ann is southwesterly (Bumpus and Lauzier, 1965). The lower runoff in 1965 than in 1966 weakened the flow of nontidal drift. The resulting decreased loss of C. finmarchicus from the western area in 1965 most probably contributed to the between-year differences in zooplankton abundance. A similar difference in the abundance of C. finmarchicus occurred in 1963 and 1964; C. finmarchicus was more numerous in 1964, when spring runoff was lower than in 1963 (Sherman, 1966).

[1] Bumpus, Dean F. 1966. Investigations of climate and oceanographic factors influencing the environment of fish. Woods Hole Oceanographic Institution. Technical Report 66-59, 7 pp. Unpublished manuscript.

Distributions of copepod species in 1965 and 1966 generally decreased from west to east along the coast (fig. 4). The concentrations of C. finmarchicus in the central area in the spring of 1966 may have resulted from an indraft of offshore water to compensate for water displaced by the spring increase in runoff of the Penobscot, Sheepscot, and Kennebec Rivers. Incursions of C. finmarchicus and other copepods from offshore to inshore areas are known to occur periodically in the Gulf (Bigelow, 1926; Fish, 1936a, 1936b, 1936c), and one of the chief centers of abundance of C. finmarchicus is in the eastern basin of the Gulf beyond the 100-m. isobath in the offing of Penobscot Bay (Bigelow, 1926). Incursions of zooplankters to the central region could contribute to the standing-crop values of the western area if the plankters are carried along the coast in the dominant nontidal drift. The constancy and magnitude of this contribution to the coastal zooplankton of the Gulf, however, is not presently known.

LITERATURE CITED

BIGELOW, HENRY B.
1914. Explorations in the Gulf of Maine, July and August, 1912, by the United States fisheries schooner Grampus. Oceanography and notes on the plankton. Mus. Comp. Zool., Bull. 58: 29-147.
1915. Exploration of the coast between Nova Scotia and Chesapeake Bay, July and August, 1913, by the United States fisheries schooner Grampus. Oceanography and plankton. Mus. Comp. Zool., Bull. 59: 152-359.
1917. Explorations of the coast water between Cape Cod and Halifax in 1914 and 1915 by the United States fisheries schooner Grampus. Oceanography and plankton. Mus. Comp. Zool., Bull. 61: 164-357.
1926. Plankton of the offshore waters of the Gulf of Maine. U.S. Bur. Fish., Bull. 40: 1-509.
1927. Physical oceanography of the Gulf of Maine. U.S. Bur. Fish., Bull. 40: 511-1027.

BUMPUS, DEAN F.
1960. Sources of water contributed to the Bay of Fundy by surface circulation. J. Fish. Res. Bd. Can. 17: 181-197.

BUMPUS, DEAN F., and LOUIS M. LAUZIER.
1965. Surface circulation on the continental shelf off eastern North America between Newfoundland and Florida. In Serial atlas of the marine environment. Folio 7, Amer. Geogr. Soc., 24 pp.

FISH, CHARLES J.
1936a. The biology of Calanus finmarchicus in the Gulf of Maine and Bay of Fundy. Biol. Bull. (Woods Hole) 70: 118-141.

1936b. The biology of Pseudocalanus minutus in the Gulf of Maine and Bay of Fundy. Biol. Bull. (Woods Hole) 70: 193-216.

1936c. The biology of Oithona similis in the Gulf of Maine and Bay of Fundy. Biol. Bull. (Woods Hole) 71: 168-186.

FISH, CHARLES J., and MARTIN W. JOHNSON.
1937. The biology of the zooplankton population in the Bay of Fundy and Gulf of Maine with special reference to production and distribution. J. Biol. Bd. Can. 3: 189-322.

REDFIELD, ALFRED C.
1941. The effect of the circulation of water on the distribution of the calanoid community in the Gulf of Maine. Biol. Bull. (Woods Hole) 80: 86-110.

SHERMAN, KENNETH.
1965. Seasonal and areal distribution of Maine coastal zooplankton, 1963. Int. Comm. Northwest Atl., Fish., Spec. Publ. 6: 611-624.

1966. Seasonal and areal distribution of zooplankton in coastal waters of the Gulf of Maine, 1964. U.S. Fish Wildlife Serv., Spec. Sci. Rep. Fish. 530, 11 pp.

SIEGEL, SIDNEY.
1956. Nonparametric statistics. McGraw-Hill Co., New York, 312 pp.

YENTSCH, CHARLES S., and J. FRANK HEBARD.
1957. A gauge for determining plankton volume by the mercury immersion method. J. Cons. 22: 184-190.

MS. #1701

GPO 930-409

Created in 1849, the Department of the Interior--a department of conservation--is concerned with the management, conservation, and development of the Nation's water, fish, wildlife, mineral, forest, and park and recreational resources. It also has major responsibilities for Indian and Territorial affairs.

As the Nation's principal conservation agency, the Department works to assure that nonrenewable resources are developed and used wisely, that park and recreational resources are conserved for the future, and that renewable resources make their full contribution to the progress, prosperity, and security of the United States--now and in the future.

UNITED STATES
DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE
BUREAU OF COMMERCIAL FISHERIES
WASHINGTON, D.C. 20240

POSTAGE AND FEES PAID
U.S. DEPARTMENT OF THE INTERIOR

OFFICIAL BUSINESS

Return this sheet to above address, if you do NOT wish to receive this material ☐, or if change of address is needed ☐ (indicate change).

SSR 7

Librarian
Marine Biological Lab.,
Woods Hole, Mass. 02543