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Seasonal Abundance and Distribution of Zooplankton, Fish Eggs, and Fish Larvae in the Eastern Gulf of Mexico, 1972-74

EDWARD D. HOUDE and NICHOLAS CHITTY

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DEPARTMENT OF COMMERCE
Elliot L. Richardson, Secretary

NATIONAL OCEANIC AND
ATMOSPHERIC ADMINISTRATION
Robert M. White, Administrator

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Seasonal Abundance and Distribution of Zooplankton, Fish Eggs, and Fish Larvae in the Eastern Gulf of Mexico, 1972-74[1]

EDWARD D. HOUDE and NICHOLAS CHITTY[2]

ABSTRACT

Zooplankton volumes and abundance of fish eggs and fish larvae were determined for stations on 12 cruises to the western Florida continental shelf. Contour charts of zooplankton volumes and of ichthyoplankton abundance are presented. A marked seasonality was observed for zooplankton and ichthyoplankton, highest zooplankton volumes and ichthyoplankton abundance occurring during May through September. Zooplankton volumes were highest and spawning by fishes most intense in the northern half of the study area (north of lat. 27°15'N). Fish larvae abundance (number under 10 m^2 of sea surface) was highest at stations deeper than 50 m. Simple correlations among biological variables showed fish egg abundance-zooplankton volumes and fish egg abundance-fish larvae abundance to be positively correlated on most cruises. No clear relationships were observed between abundance or concentration of biological variables and temperature or salinity.

INTRODUCTION

A fisheries assessment survey of sardinelike fishes in the eastern Gulf of Mexico was carried out from 1971 to 1974 to estimate spawning biomass from the seasonal abundance and distribution of planktonic eggs and larvae (Houde 1973, 1974, in press). A total of 12 cruises was completed during 1972-74 from which both plankton samples and hydrographic data were collected. Zooplankton abundance and the abundance of both fish eggs and fish larvae were examined to determine which areas of the western Florida continental shelf (Fig. 1) were highly productive with respect to plankton and which areas might be important spawning areas for fishes. Abundance of these organisms was examined seasonally and in relation to temperature and salinity in the eastern Gulf.

Most previous reports on plankton abundance from the western Florida shelf area included few sampling stations or were not carried out long enough to determine seasonality of production. Hopkins (1973) recently has reviewed plankton investigations in the eastern Gulf. Plankton abundance from shelf waters on a transect west of Charlotte Harbor (lat. 26°30'N) in 1946-47 was reported by King (1949). Arnold (1958) summarized results of plankton-ichthyoplankton collections made throughout the Gulf of Mexico in 1951-53. His collections included 63 stations from the western Florida shelf that were sampled quantitatively. Soviet-Cuban fishery investigations in 1963-64 included some determinations of total plankton biomass from most parts of the Gulf of Mexico. These data were summarized by Bogdanov et al. (1968) and Khromov (1969). Recently, Austin and Jones (1974) reported on the physical oceanography and plankton biomass relationship on the Florida Middle Ground, a productive shelf area located northwest of Tampa Bay. Their data represented monthly observations from June 1969 through August 1970 and included a single fixed station at lat. 28°30'N, long. 84°14'W, as well as three to five stations on a transect along lat. 28°30'N. Although earlier reports are incomplete in many respects, and sometimes incomparable due to collecting gear differences, they do offer a basis for comparison with our plankton distribution data which give more complete seasonal and areal coverage of the eastern Gulf.

Identification of organisms was limited to the broad categories of zooplankton, fish eggs, and fish larvae. Thus, our results were used only in a relative sense, to define areas of high or low productivity on the western Florida shelf. The eggs and larvae of clupeid fishes were identified and future papers will describe their distribution and abundance, as well as estimates of stock abundance based on them (Houde in press). Results published here will be useful when considering possible effects of man's activities in the

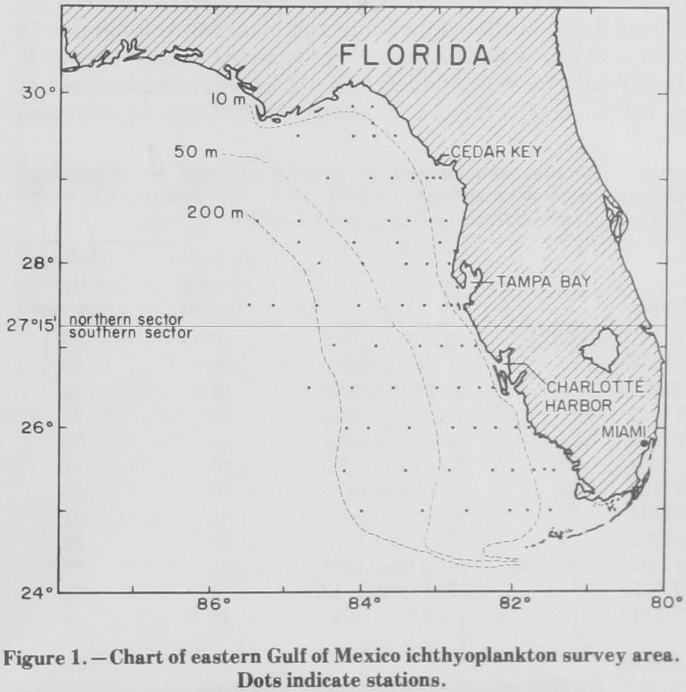


Figure 1.—Chart of eastern Gulf of Mexico ichthyoplankton survey area. Dots indicate stations.

[1] Contribution from the Rosenstiel School of Marine and Atmospheric Science, University of Miami, Miami, FL 33149.

[2] Division of Biology and Living Resources, Rosenstiel School of Marine and Atmospheric Science, University of Miami, 4600 Rickenbacker Causeway, Miami, FL 33149.

eastern Gulf of Mexico, because the area has important commercial fisheries and is presently a focus of oil exploration.

METHODS

Data based on 12 cruises during 1972-74 are included in this report (Table 1). Plankton volumes were determined from a total of 482 stations and fish eggs and larvae were collected at 483 stations. Stations were located on a grid extending from lat. 24°30'N to lat. 29°30'N and from the 10-m contour near the west Florida coast to approximately the 200-m contour at the edge of the continental shelf (Fig. 1). The two cruises in 1974 included some stations in water as shallow as 4 m to compare plankton biomass and fish spawning there with offshore areas. The number of stations occupied on cruises ranged from 13 to 51 (Table 1).

Plankton collections were made with the paired 61 cm Bongo net plankton sampler (Posgay et al. 1968). One net was fitted with 505-μm Nitex mesh from which fish eggs and larvae were sorted. The second net was 333-μm Nitex mesh and it was used to provide zooplankton for volume determinations; this net meets the specifications of a reference net prescribed by the National Academy of Sciences (1969) for determining zooplankton biomass. A TSK (Tsurumi-Seiki Kosakusho) flowmeter was secured in the mouth of the 505-μm mesh net to determine volume filtered during each tow. Tows were double oblique from within 5 m of bottom to surface, or from 200-m depth to surface at deep stations. Towing speed was 2 to 3 knots and winch speeds were controlled to ensure that all depths were sampled proportionately. A Benthos time-depth recorder was attached to the plankton sampler to record tow characteristics. Tow times varied from 1 min at stations shallower than 50 m to 20 min at the deepest stations. Volumes filtered during a tow varied from approximately 100 m^3 at shallow stations to 400 m^3 at the deepest stations.

All plankton collected by the nets was retained and preserved in 10% buffered seawater Formalin. In the laboratory all fish eggs and larvae were sorted from the 505-μm mesh net samples. After samples had been stored for at least 2 mo to allow for changes in plankton volume due to preservation, volumes were determined using methods similar to those described by Thrailkill (1969) and Kramer et al. (1972). Zooplankton volumes are displacement volumes, reported as cubic centimeters per 1,000 m^3 of seawater filtered by the collecting net. Contour charts (Fig. 2) illustrate zooplankton concentrations for each cruise. These are mean values for the whole water column at a location since discrete depth strata were not sampled.

Table 1.—Cruises and number of stations analyzed for zooplankton volumes and ichthyoplankton, 1972-74. 8B = RV *Bellows*, GE = RV *Gerda*, IS = RV *Columbus Iselin*, and CL = RV *Calanus*.

Cruise	Dates	Plankton volume stations	Fish egg and larvae stations
8B 7201 & GE 7202	1-11 Feb. 1972	26	30
GE 7208	1-10 May 1972	28	30
GE 7210	12-18 June 1972	13	13
IS 7205	9-17 Sept. 1972	34	34
IS 7209	8-16 Nov. 1972	49	50
IS 7303	19-27 Jan. 1973	50	51
IS 7308	9-17 May 1973	49	49
IS 7311	27 June-6 July 1973	51	51
IS 7313	3-13 Aug. 1973	50	50
IS 7320	6-14 Nov. 1973	51	51
CL 7405	28 Feb.-9 Mar. 1974	36	32
CL 7412	1-9 May 1974	45	42
Totals		482	483

Zooplankton displacement volumes were determined after removing nonplanktonic organisms (e.g., seaweeds, large fish) and large planktonic organisms (>5 cc; mostly coelenterates). The remaining zooplankton organisms were of 5 cc or less in volume. This fraction of the plankton sampled was aspirated onto a 35-μm plankton mesh filter in a Buchner funnel under a 22 psi vacuum until less than one drop of water per 15 s was drawn from the sample. Samples with large numbers of jellylike organisms were aspirated for shorter times to avoid reduction in plankton volume due to body fluid loss. Volume was then determined by water displacement in a graduated cylinder. The zooplankton volumes given in this report, therefore, are for organisms less than 5 cc. The most numerous organisms were crustaceans, molluscs, and chaetognaths, all of which are important in food webs that sustain pelagic fish resources.

Numbers of fish eggs and larvae were reported as numbers under 10 m^2 of sea surface, giving an estimate of abundance for each station. Contour charts of the abundance of fish eggs and larvae (Figs. 3, 4) show the distribution based on this method. Mean concentrations of fish eggs and larvae at a station also can provide useful information. These values are not illustrated or reported here but can be obtained from our abundance charts and a bathymetric chart of the eastern Gulf by multiplying our contoured abundance values by 10/d (where d equals depth of tow in meters), to give numbers per 100 m^3. Tow depths and volumes filtered for stations on each cruise are available in a comprehensive data report (Houde et al. 1976). If calculated, concentrations of fish eggs or larvae at a given station represent the mean concentration over the tow depth of that station because discrete depths were not sampled.

Contour charts for zooplankton, fish eggs, and fish larvae were produced using the method proposed by Simpson (1959). Isopleths of zooplankton concentrations were drawn for the 25, 50, 100, 400, and 800 cc/1,000 m^3 contours (Fig. 2). Those for fish eggs and larvae were drawn at 50, 100, 400, 800, and 1,600 under 10 m^2 of sea surface (Figs. 3, 4).

Temperatures and salinities were obtained at each station by casts of 1.7 liter Niskin bottles equipped with reversing thermometers. A mechanical bathythermograph also was dropped at each station. An STD (salinity-temperature-depth) recorder was used on some cruises. Salinities from Niskin bottle samples were determined on a salinity bridge.

Analyses of hydrographic data and contour plots of these data were provided us by physical oceanographers at the State University System of Florida Institute of Oceanography and the Rosenstiel School of Marine and Atmospheric Science.[3, 4]

[3]State University System of Florida, Institute of Oceanography, St. Petersburg, Fla. 1975. Final Report to Bureau of Land Management. Contract No. 08550-CT4-16. Compilation and summation of historical and existing physical oceanographic data from the eastern Gulf of Mexico, 97 p. plus 7 appendices.

[4]Hydrographic data from cruises discussed in our report are available through the National Oceanographic Data Center, Washington, D. C. Data can be retrieved from the MAFLA (Mississippi-Alabama-Florida) file.

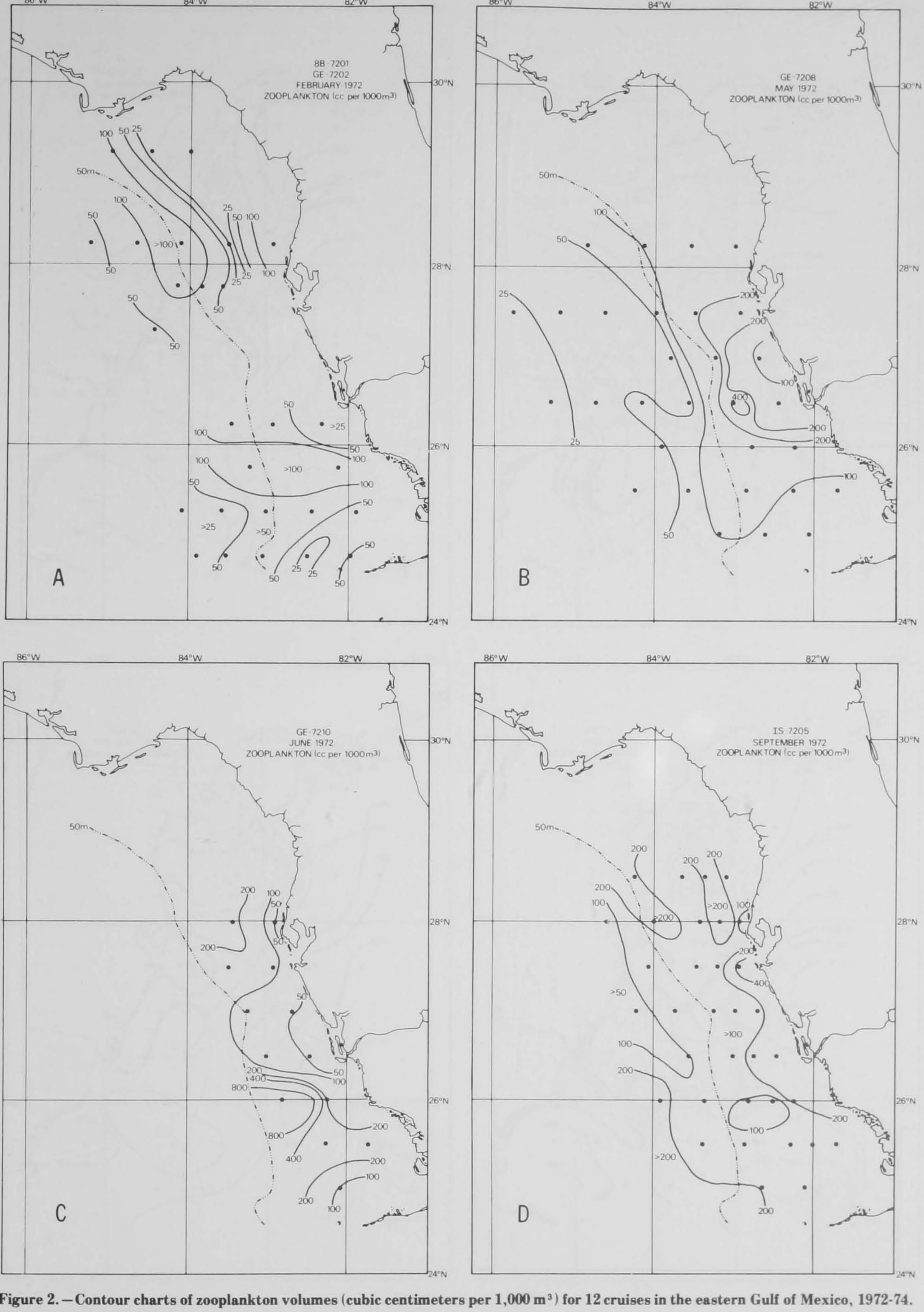
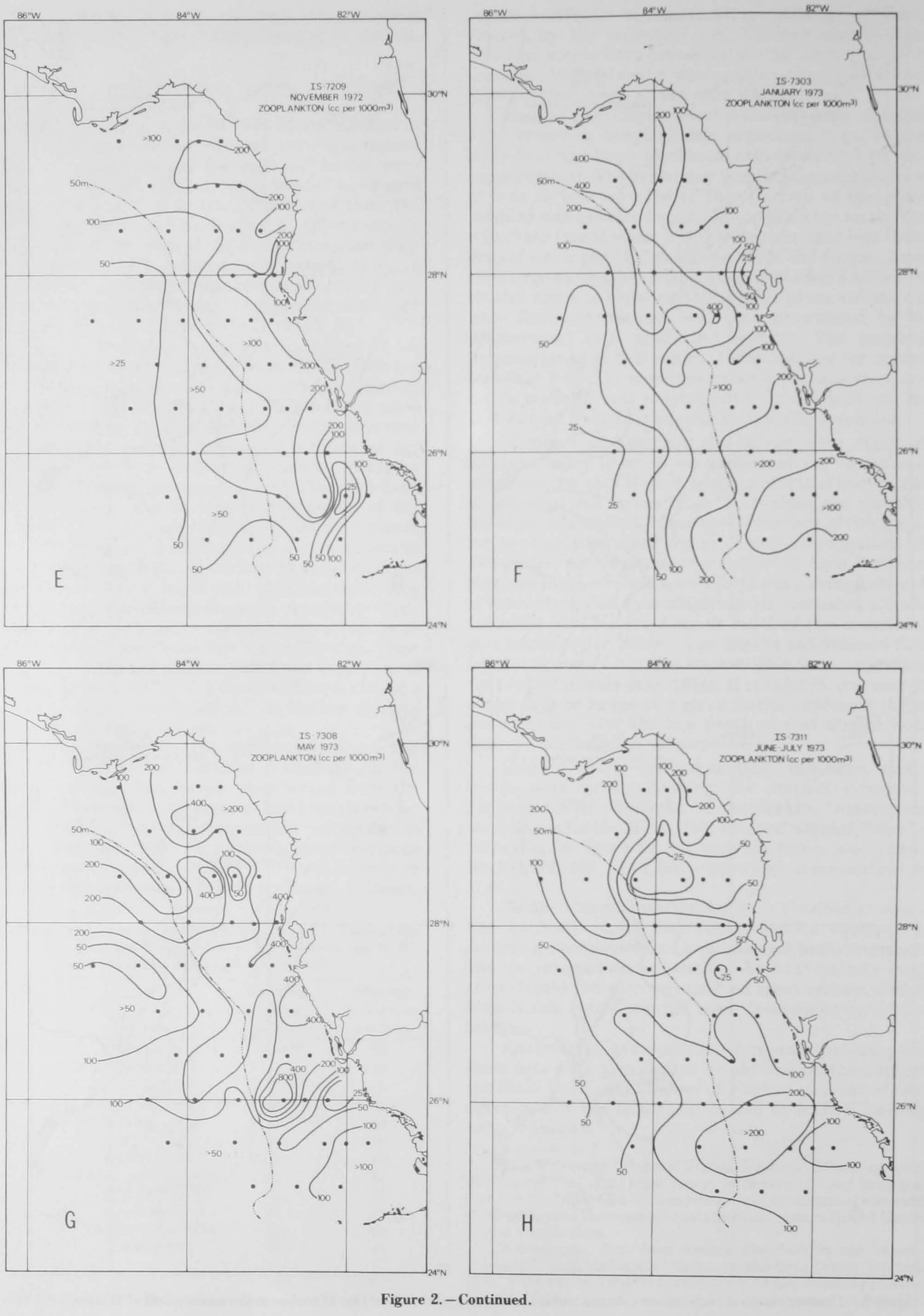


Figure 2. — Contour charts of zooplankton volumes (cubic centimeters per 1,000 m^3) for 12 cruises in the eastern Gulf of Mexico, 1972-74.



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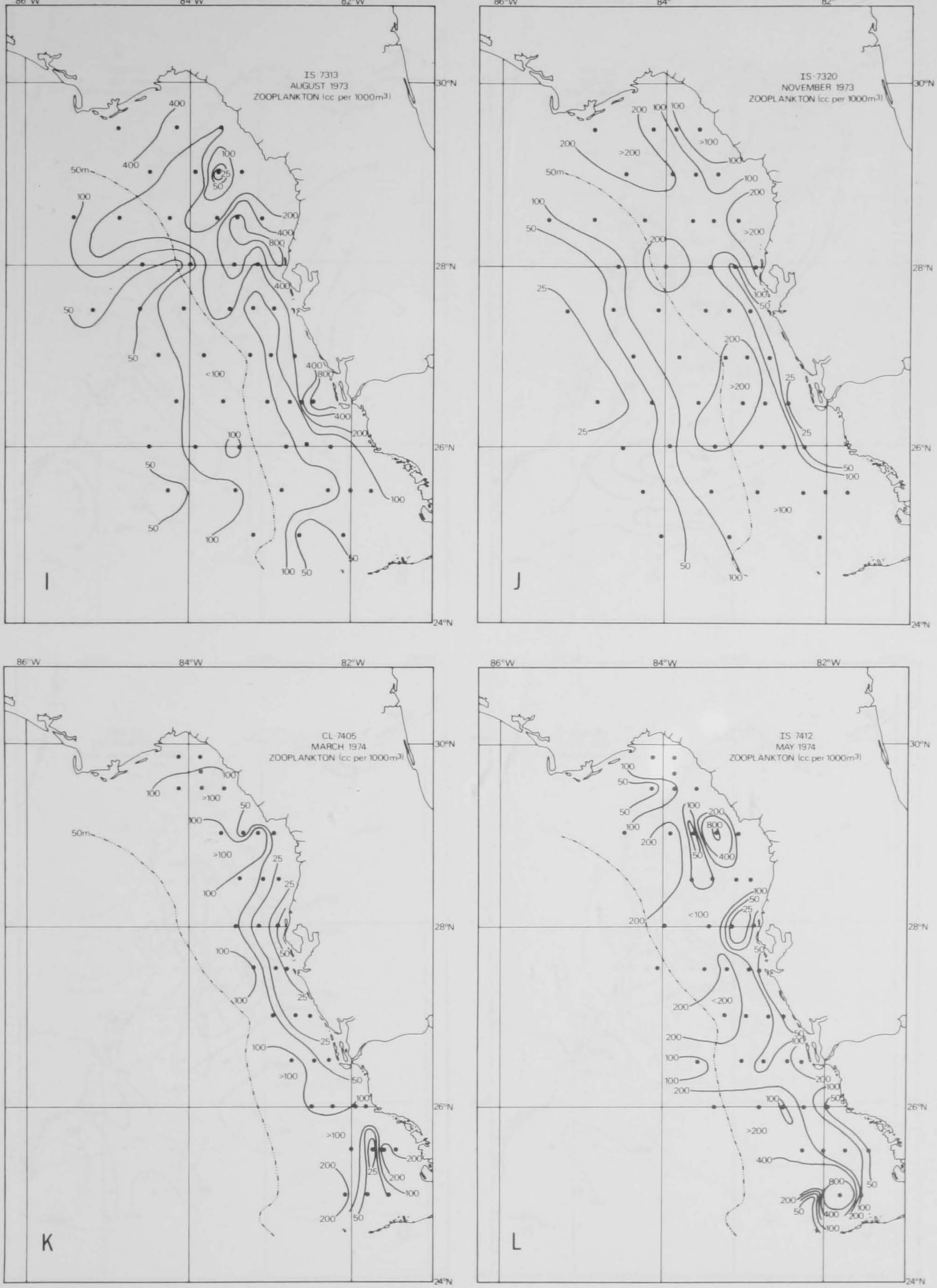

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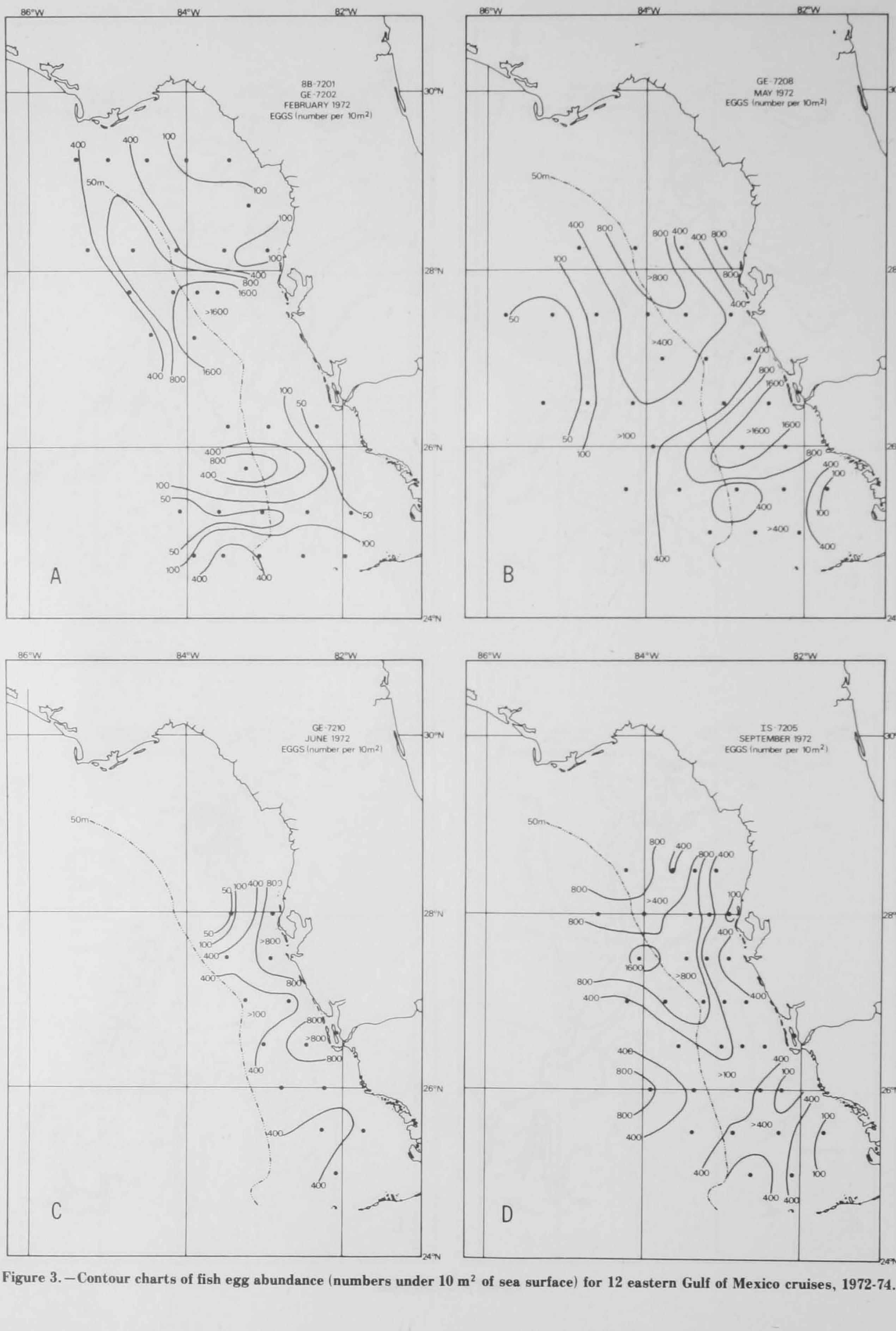
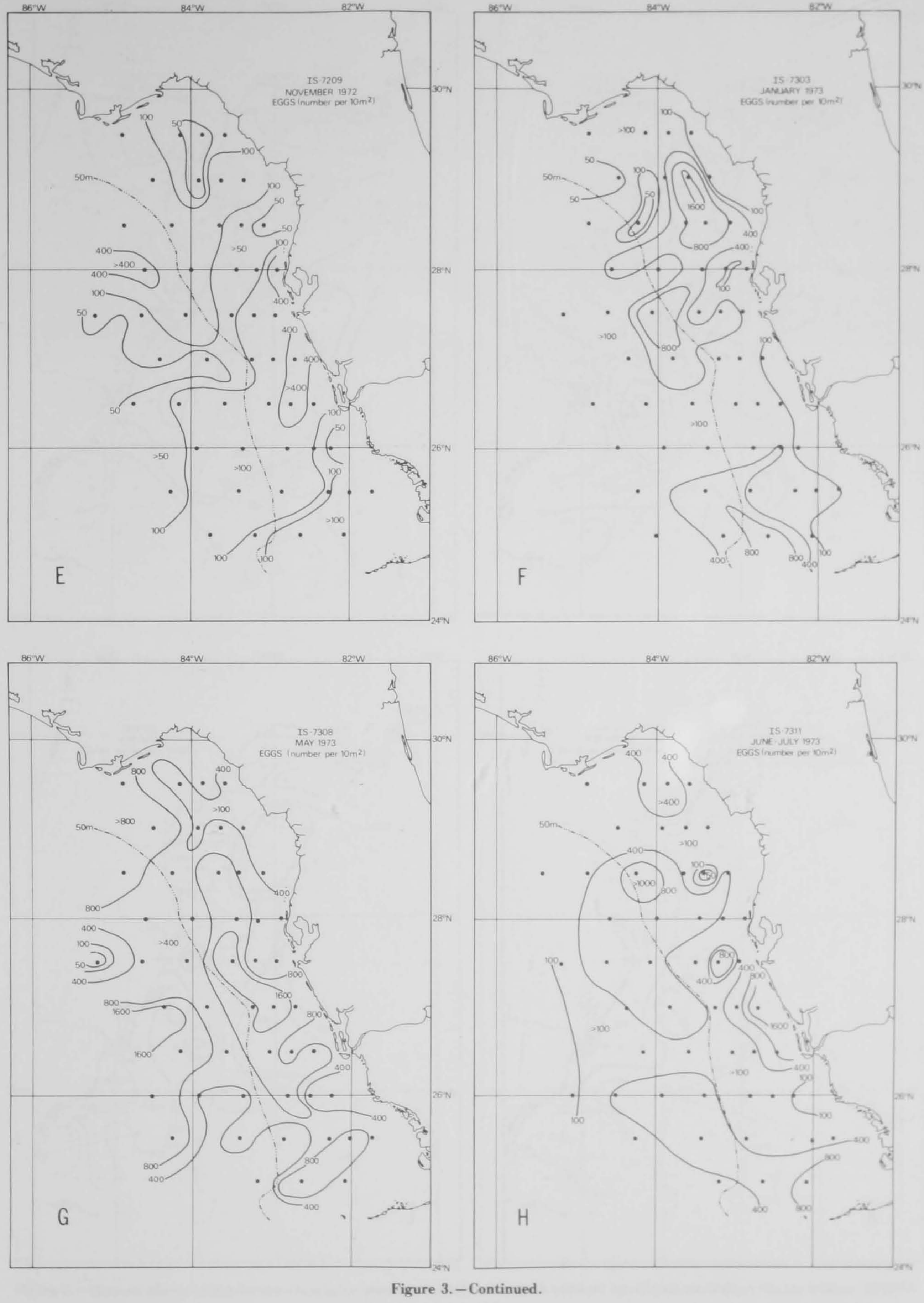


Figure 3.—Contour charts of fish egg abundance (numbers under 10 m^2 of sea surface) for 12 eastern Gulf of Mexico cruises, 1972-74.



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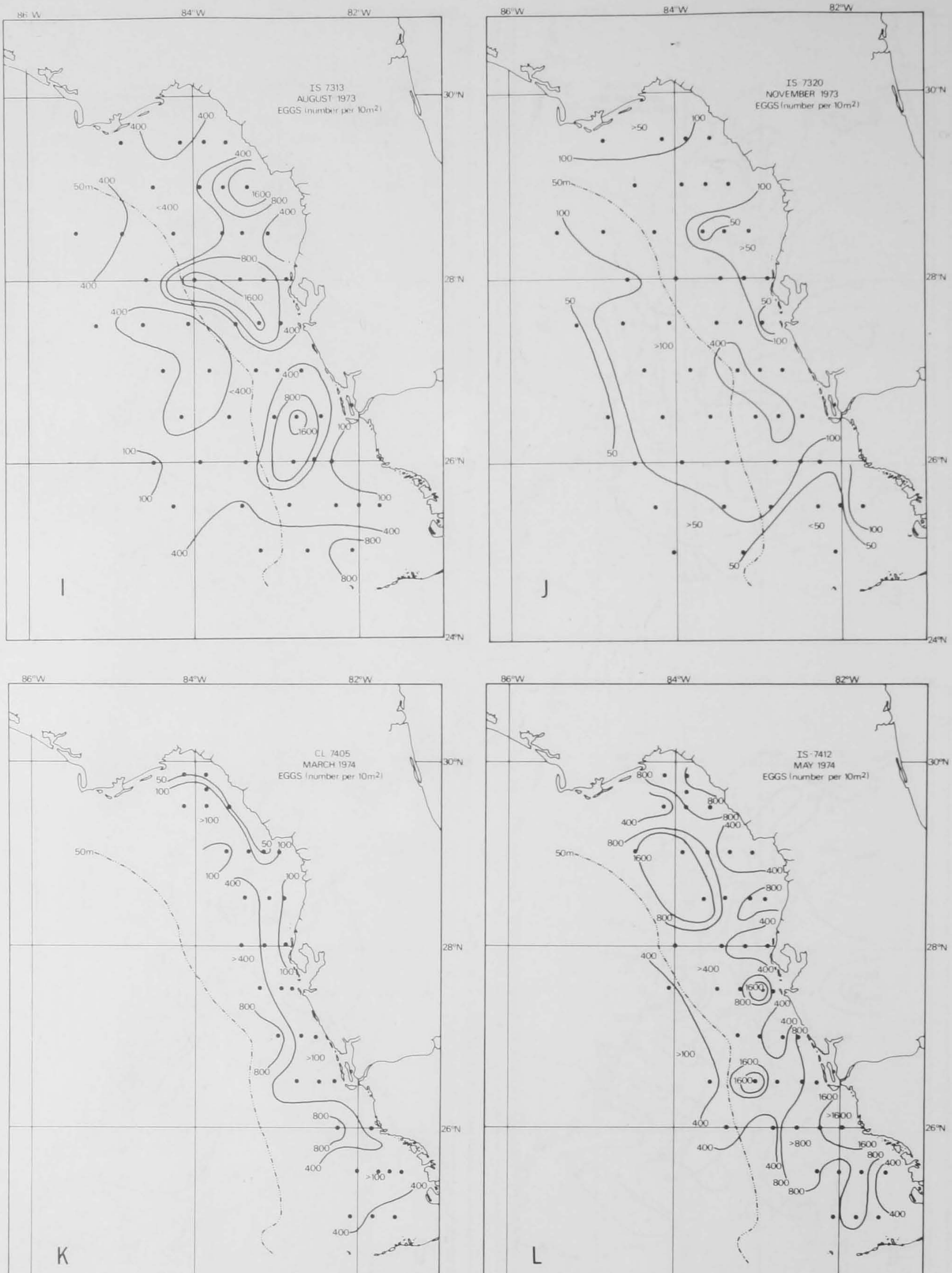

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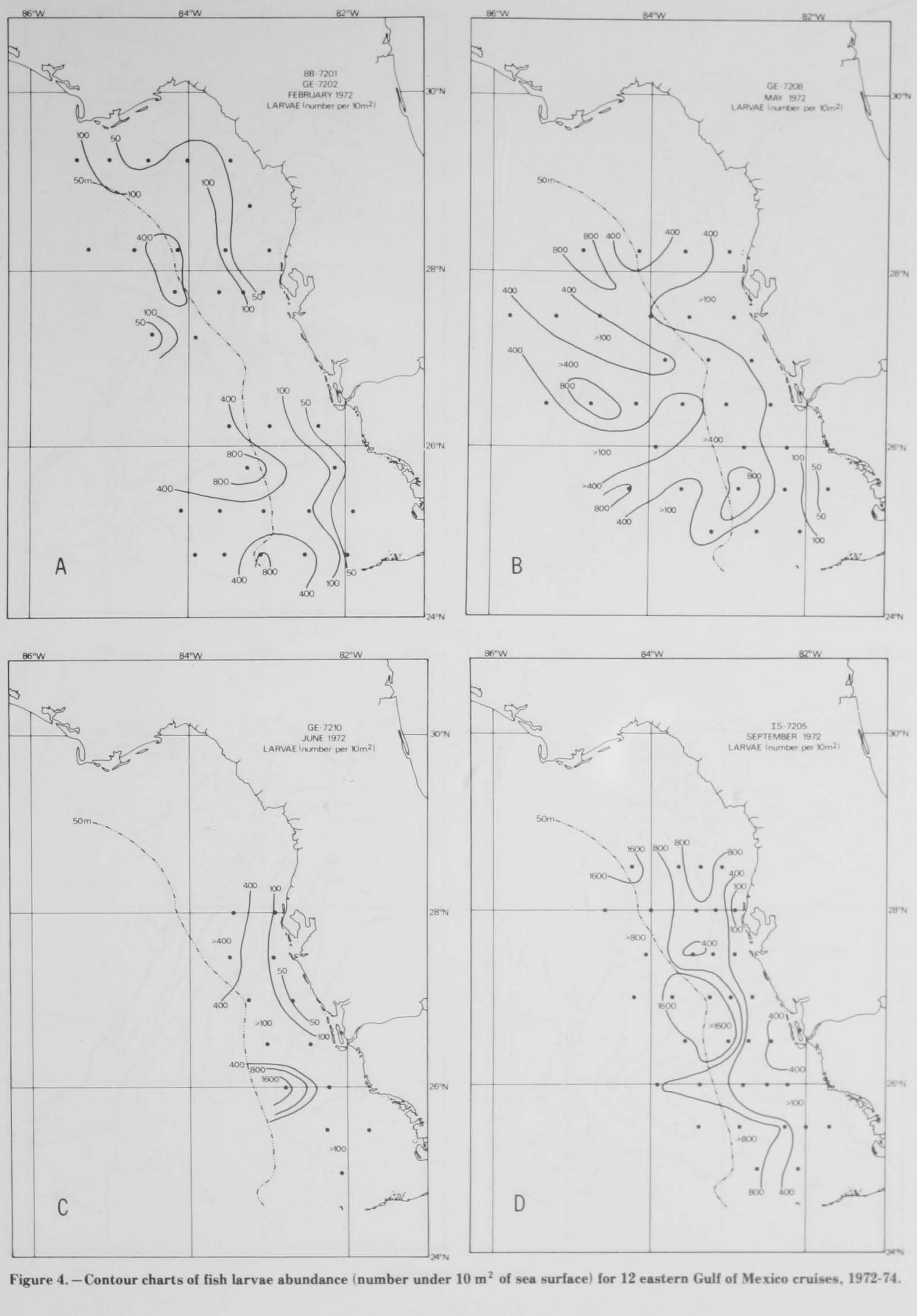
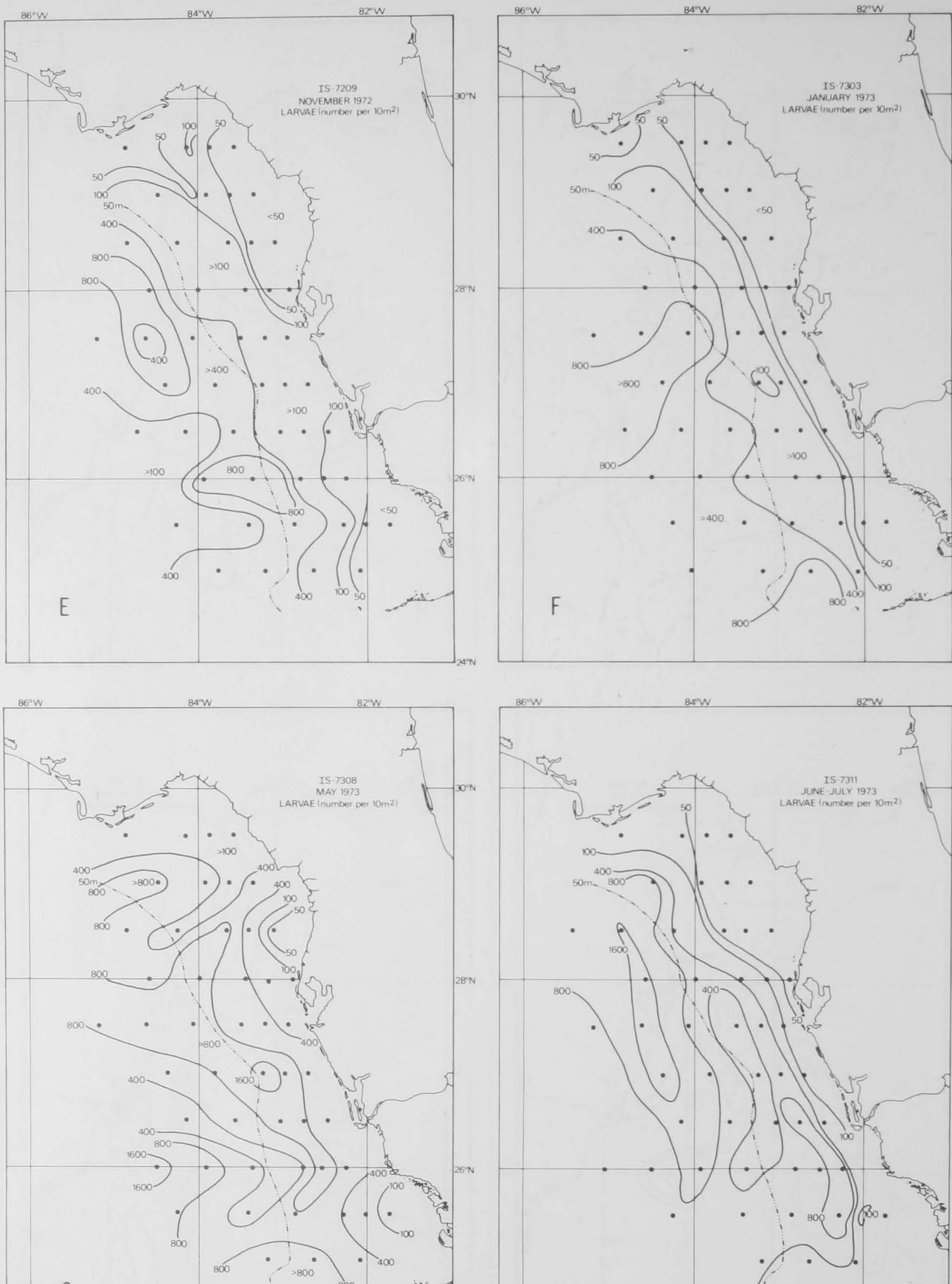


Figure 4.—Contour charts of fish larvae abundance (number under 10 m² of sea surface) for 12 eastern Gulf of Mexico cruises, 1972-74.



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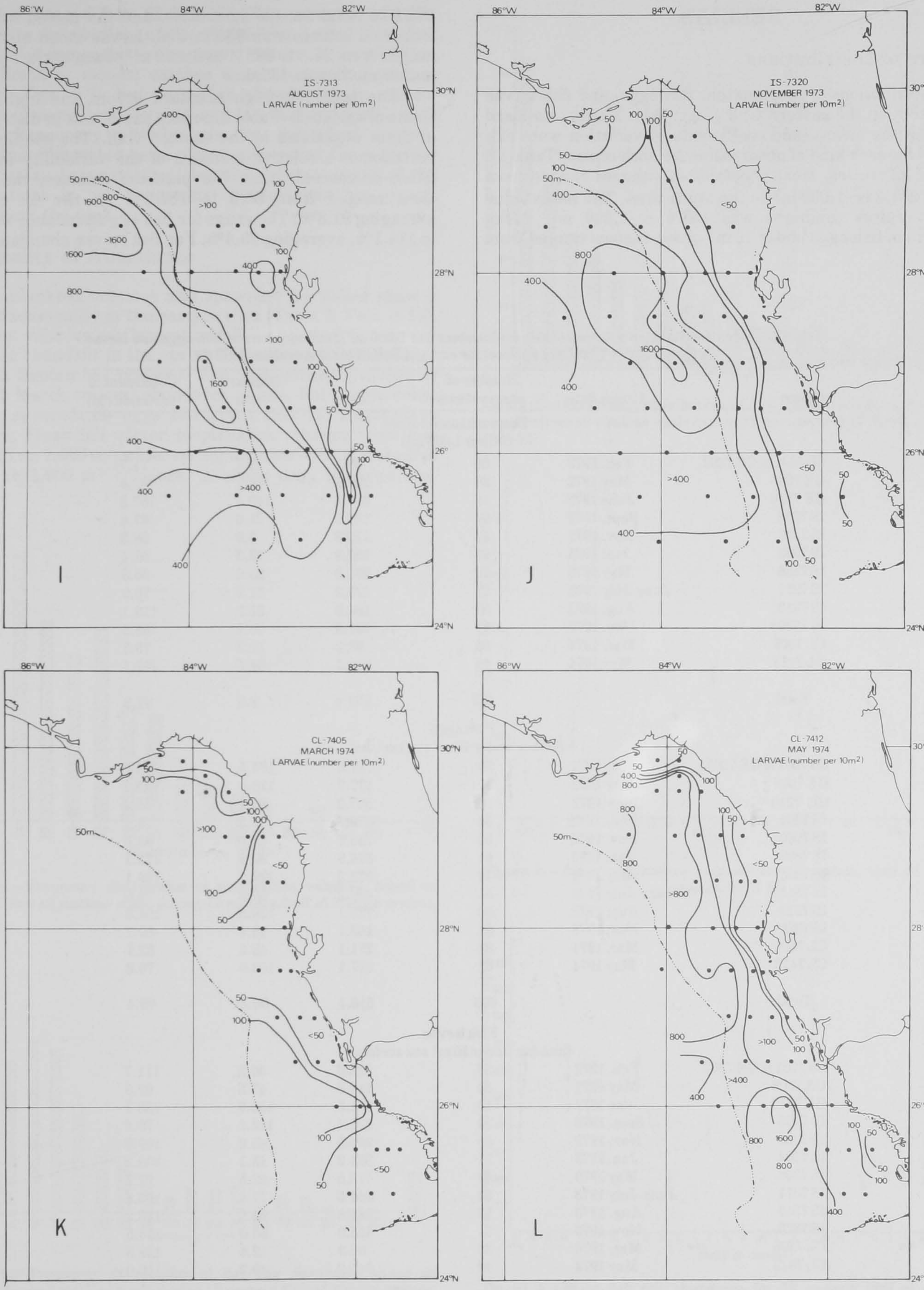

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RESULTS

Nature of Distributions

Distributions of zooplankton, fish eggs, and fish larvae are patchy in the eastern Gulf (Figs. 2-4). Means, standard errors of the means, and coefficients of variation were calculated for each kind of observation for each cruise (Table 2). For the 12 cruises, mean zooplankton volumes ranged from 69.1 to 287.8 cc/1,000 m^3 in the study area. The mean value for all cruises combined was 153.4 cc/1,000 m^3. Mean numbers of fish eggs under 10 m^2 of sea surface ranged from 163.1 to 927.1 for the 12 cruises, and the pooled mean for combined cruises was 510.1. Fish larvae mean abundance ranged from 55.3 to 825.4 under 10 m^2 of sea surface and the pooled mean was 435.5.

The relatively high standard errors and high coefficients of variation (Table 2) reflect patchiness in distribution of these organisms in the eastern Gulf. The coefficient of variation is a relative measure of the variability in abundance or concentration. For plankton volumes, the coefficient ranged from 56.3 to 187.2% on the 12 cruises, averaging 91.8%. The range for fish egg abundance was 58.4 to 174.1%, averaging 99.4%. For fish larvae abundance, the

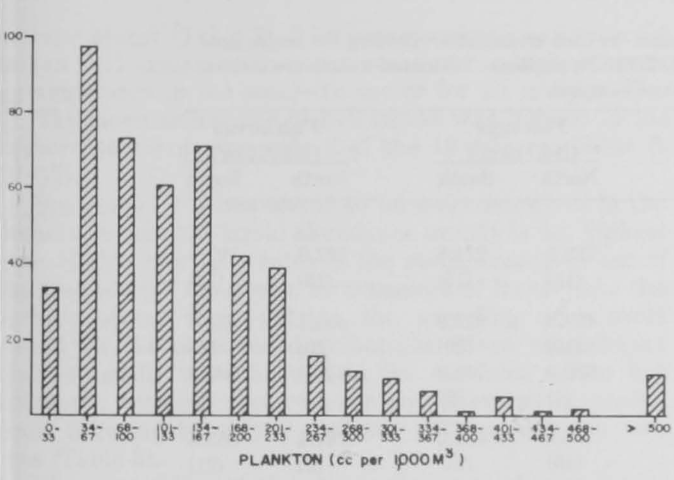
Table 2.—Mean zooplankton volumes (cubic centimeters per 1,000 m^3), and numbers of fish eggs and larvae (numbers under 10 m^2 sea surface) for eastern Gulf of Mexico cruises, 1972-74.

Cruise	Cruise date	Number of observations	Mean	Standard error	Coefficient of variation (%)
		Zooplankton volumes (cc per 1,000 m^3)			
8B 7201 & GE 7202	Feb. 1972	26	69.1	9.7	71.7
GE 7208	May 1972	28	107.1	16.7	82.4
GE 7210	June 1972	13	287.8	149.4	187.2
IS 7205	Sept. 1972	34	181.0	21.0	67.8
IS 7209	Nov. 1972	49	119.3	9.9	58.3
IS 7303	Jan. 1973	50	152.9	13.3	61.4
IS 7308	May 1973	49	204.3	25.0	85.8
IS 7311	June-July 1973	51	120.2	11.9	70.9
IS 7313	Aug. 1973	50	194.9	31.2	113.1
IS 7320	Nov. 1973	51	131.3	10.4	56.3
CL 7405	Mar. 1974	36	92.2	12.2	79.3
CL 7412	May 1974	45	219.1	54.6	167.1
Total		482	153.4	8.5	91.8
		Fish eggs (number under 10 m^2 sea surface)			
8B 7201 & GE 7202	Feb. 1972	30	517.6	164.5	174.1
GE 7208	May 1972	30	577.7	119.9	113.7
GE 7210	June 1972	13	527.2	85.4	58.4
IS 7205	Sept. 1972	34	578.8	72.5	73.1
IS 7209	Nov. 1972	50	186.5	21.9	83.0
IS 7303	Jan. 1973	51	374.9	58.8	112.1
IS 7308	May 1973	49	872.2	129.7	104.1
IS 7311	June-July 1973	51	450.2	50.2	79.6
IS 7313	Aug. 1973	50	725.1	158.5	154.6
IS 7320	Nov. 1973	51	163.1	18.4	80.7
CL 7405	Mar. 1974	32	291.1	42.6	82.7
CL 7412	May 1974	42	927.1	109.0	76.2
Total		483	510.1	30.3	99.4
		Fish larvae (number under 10 m^2 sea surface)			
8B 7201 & GE 7202	Feb. 1972	30	226.6	46.2	111.7
GE 7208	May 1972	30	414.3	47.5	62.8
GE 7210	June 1972	13	341.5	130.9	138.1
IS 7205	Sept. 1972	34	825.4	112.1	79.2
IS 7209	Nov. 1972	50	295.5	45.6	109.0
IS 7303	Jan. 1973	51	301.2	45.1	106.9
IS 7308	May 1973	49	613.5	62.5	71.3
IS 7311	June-July 1973	51	551.5	77.8	100.8
IS 7313	Aug. 1973	50	581.6	94.8	115.2
IS 7320	Nov. 1973	51	346.0	55.5	114.5
CL 7405	Mar. 1974	32	55.3	12.6	129.3
CL 7412	May 1974	42	519.2	89.7	112.0
Total		483	435.5	19.5	104.2

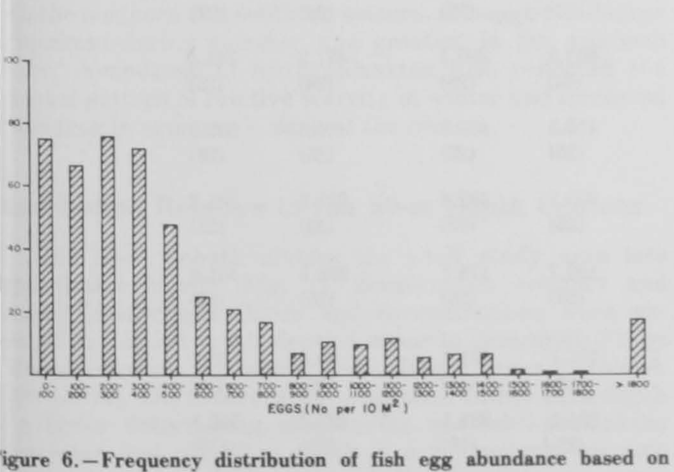
oefficient ranged from 62.8 to 138.1%, averaging 104.2%. 'requency distributions of abundance from pooled data of all ruises also demonstrate the patchy nature of the distribu- ions. Small or modest catches were observed most fre- uently (Figs. 5-7), but very high abundances or concen- rations of organisms occurred at a few stations during each ruise. Frequency distributions for individual cruises, hough not illustrated here, closely resembled those for the ooled data, demonstrating that the patchy nature of the istributions is not a seasonal phenomenon but occurs hroughout the year.

easonality of Abundance

Zooplankton volumes and spawning by fishes show a istinct seasonality in the eastern Gulf (Table 2; Figs. 8-10). lankton volumes are largest and fish eggs and fish larvae re most abundant in the spring and summer months (May hrough September cruises). Fall and winter (November hrough March cruises) abundance is less, but the decrease more apparent for eggs and larvae than for zooplankton olumes. Mean fall-winter zooplankton volumes were less han 125 cc/1,000 m³ while spring-summer means increased 200 cc/1,000 m³ or more. A sharp drop in mean zoo-



igure 5.—Frequency distribution of zooplankton volumes, based on amples from all stations made during 12 eastern Gulf of Mexico cruises, 972-74.



igure 6.—Frequency distribution of fish egg abundance based on amples from all stations made during 12 eastern Gulf of Mexico cruises, 972-74.

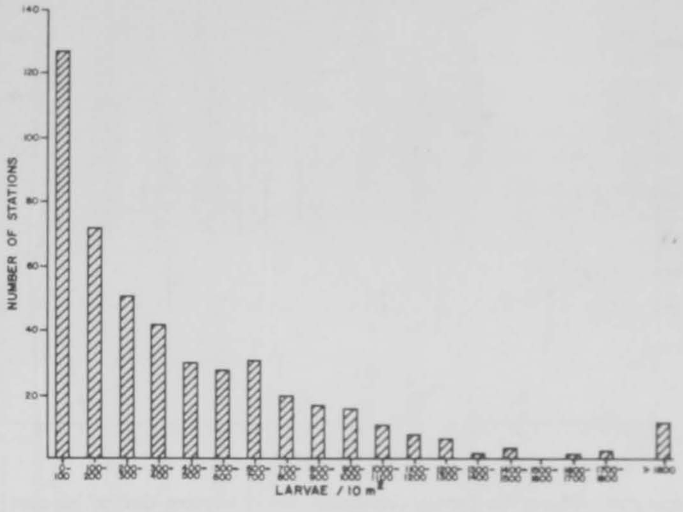


Figure 7.—Frequency distribution of fish larvae abundance based on samples from all stations made during 12 eastern Gulf of Mexico cruises, 1972-74.

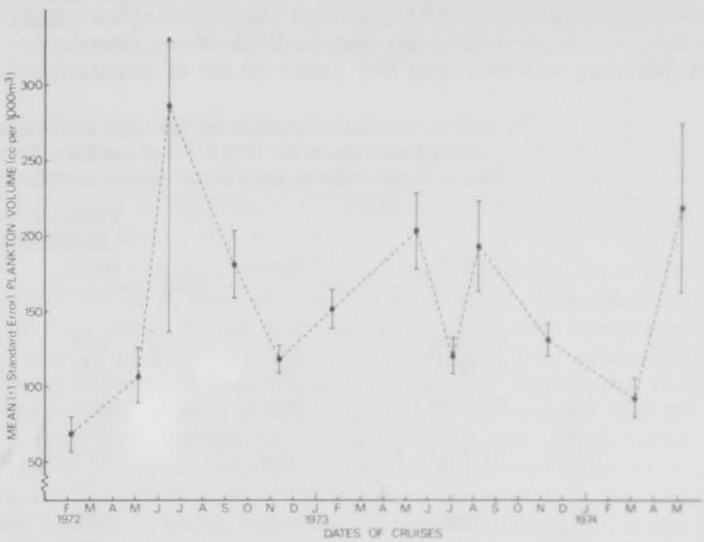


Figure 8.—Mean zooplankton volumes for 12 eastern Gulf of Mexico cruises, 1972-74.

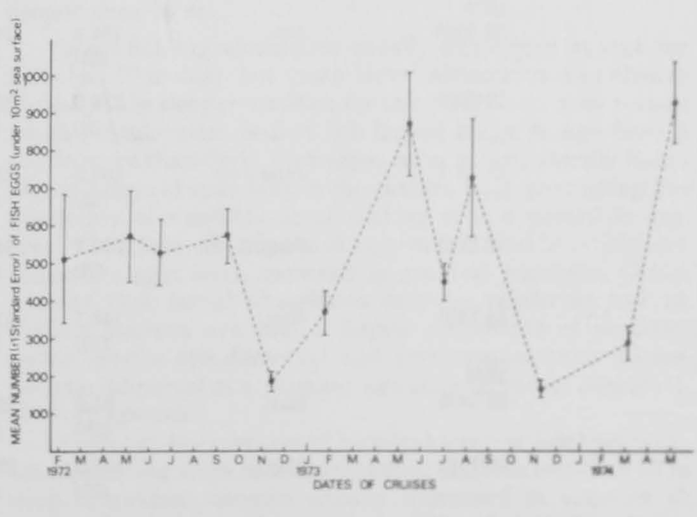


Figure 9.—Mean fish egg abundance for 12 eastern Gulf of Mexico cruises, 1972-74.

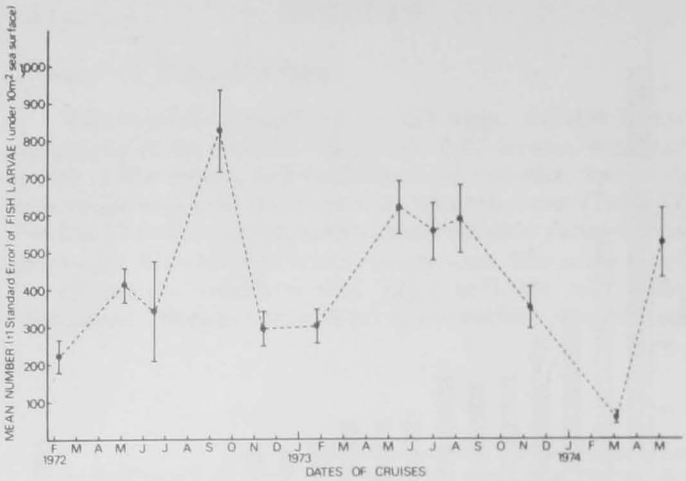


Figure 10.—Mean fish larvae abundance for 12 eastern Gulf of Mexico cruises, 1972-74.

plankton volume was observed in June-July 1973, along with similar decreases in ichthyoplankton abundance. There was a recovery in abundance by August 1973. Mean abundance of fish eggs was less than 300 under 10 m² of sea surface during fall-winter but exceeded 550 during the spring-summer months. Fish larvae mean abundance was less than 350 under 10 m² in fall-winter, increasing to more than 500 in spring-summer.

North-South Distribution

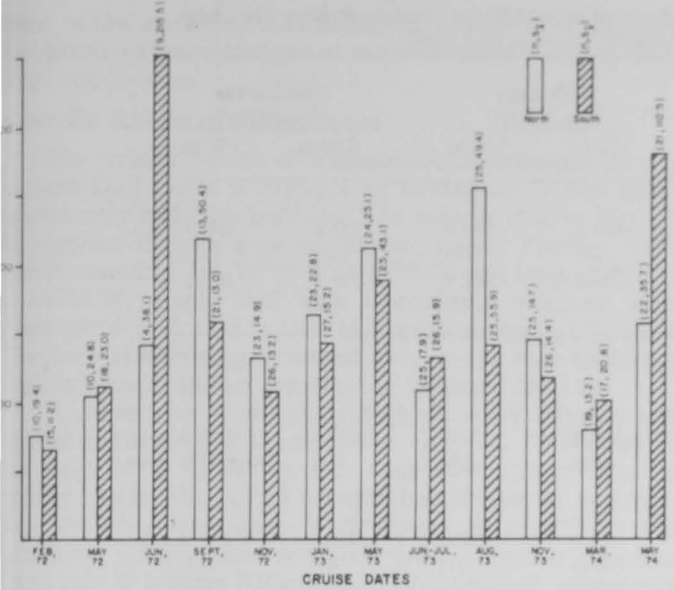
Zooplankton and ichthyoplankton were examined for each cruise in relation to latitude. The study area was arbitrarily divided into halves at lat. 27°15′N (Fig. 1). Catches north and south of this line were compared to determine if abundance differed greatly between the two areas.

Mean abundance of eggs and larvae and zooplankton volumes usually were greatest north of lat. 27°15′N (Table 3; Figs. 11, 12). Only fish larvae had a higher pooled mean abundance (number under 10 m²) in the southern half of the area for all cruises combined. The contour charts of organism distribution (Figs. 2-4) do not readily show that mean abundance tended to be higher north of lat. 27°15′N because of the patchy nature of the distributions.

Mean zooplankton volumes were highest in the northern sector for 7 of the 12 cruises (Table 3; Fig. 11). Four of the five exceptions occurred during spring and summer cruises. Mean fish egg abundance was highest in the north during 6 of the 12 cruises (Table 3; Fig. 12). The pooled mean abundance of eggs for all cruises was highest for the

Table 3.—Summary of plankton, fish eggs, and fish larvae data for each cruise, after dividing the cruise area into northern (above lat. 27°15′N) and southern (below lat. 27°15′N) portions. Tabulated values are means. Values in parentheses are the numbers of stations that were sampled.

Cruise	Month	Plankton volume (cc/1,000 m³) North	Plankton volume (cc/1,000 m³) South	Fish eggs (No./10 m²) North	Fish eggs (No./10 m²) South	Fish larvae (No./10 m²) North	Fish larvae (No./10 m²) South
1972							
GE 7202 & 8B 7201	Feb.	76.9 (10)	65.9 (15)	722.3 (13)	221.8 (15)	162.9 (13)	297.1 (15)
GE 7208	May	103.6 (10)	111.0 (18)	497.2 (10)	617.8 (20)	406.7 (10)	418.1 (20)
GE 7210	June	142.2 (4)	352.5 (9)	656.4 (4)	469.8 (9)	340.3 (4)	342.1 (9)
IS 7205	Sept.	218.1 (13)	158.1 (21)	764.2 (13)	464.0 (21)	764.4 (13)	863.2 (21)
IS 7209	Nov.	132.1 (23)	108.0 (26)	166.2 (24)	205.2 (26)	206.6 (24)	377.9 (26)
1973							
IS 7303	Jan.	164.4 (23)	143.1 (27)	451.3 (24)	307.0 (27)	219.3 (24)	374.3 (27)
IS 7308	May	220.9 (24)	188.4 (25)	845.2 (24)	898.1 (25)	477.2 (24)	744.4 (25)
IS 7311	June-July	108.2 (25)	131.9 (26)	415.5 (25)	481.4 (25)	466.6 (25)	633.0 (26)
IS 7313	Aug.	255.9 (25)	141.5 (25)	909.2 (25)	492.4 (25)	621.9 (25)	541.2 (25)
IS 7320	Nov.	145.1 (25)	118.1 (26)	150.7 (25)	175.1 (26)	288.9 (25)	401.0 (26)
1974							
IS 7405	Mar.	80.0 (19)	101.5 (17)	191.1 (16)	391.1 (16)	60.4 (16)	50.2 (16)
IS 7412	May	157.3 (22)	278.8 (21)	926.1 (23)	384.5 (19)	497.2 (23)	545.8 (19)
Pooled means		157.1 (223)	150.3 (256)	545.4 (226)	463.4 (225)	380.5 (226)	486.9 (255)



gure 11.—Comparison of mean zooplankton volumes for stations mpled north of lat. 27°15′N and stations south of that latitude for 12 stern Gulf of Mexico cruises, 1972-74. Numbers of stations and andard errors of the mean are given in parentheses above bar graphs.

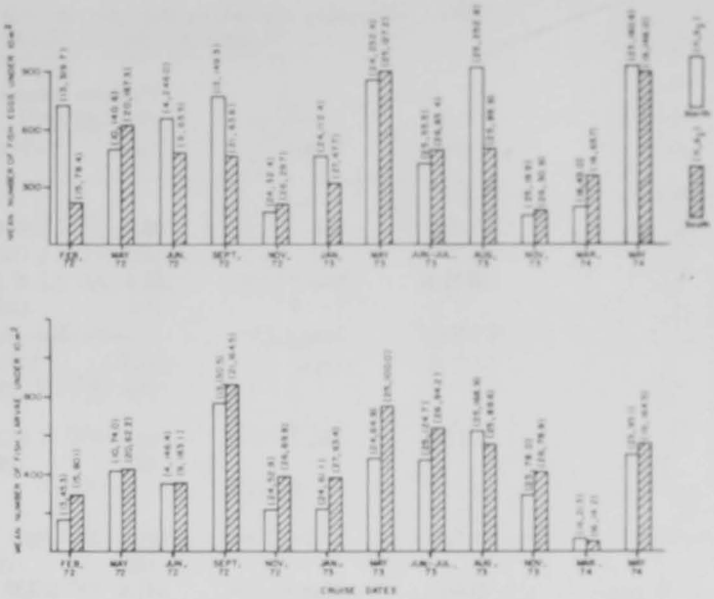


Figure 12.—Mean fish egg and fish larvae abundance. Comparisons are made for stations sampled north of lat. 27°15′N and stations south of that latitude for 12 eastern Gulf of Mexico cruises, 1972-74. Numbers of stations and standard errors of the mean are given in parentheses above bar graphs.

orthern sector (Table 3). There was no apparent seasonal attern that explained the occurrence of the highest mean gg abundance in the southern sector for six cruises (Fig. 2). The mean abundance of fish larvae was highest in the orthern sector during only 2 of the 12 cruises (Table 3; ig. 12).

Spawning by fishes seems to be more intensive in the orthern sector, but larval abundance usually is not highest ere. Higher mortality rates in the north, transport out of at area toward the south, or transport of larvae into the outhern sector from outside the sampling area could ccount for the observed distributions. Mean zooplankton olumes usually were highest in the northern sector but fferences between sectors were not often great, pooled eans differing by only 7 cc/1,000 m³ between the two eas (Table 3).

The seasonality of abundance that was observed pre- ously, when the whole shelf area was considered, also was pparent in each of the sectors (Figs. 11, 12). Zooplankton olumes were lowest in winter and highest in summer for oth the northern and southern sectors, although the degree increase during summer was greatest in the southern ector. Abundance of ichthyoplankton also reflected the asonal pattern of relative scarcity in winter and increased oundance in summer in each of the sectors.

istribution Relative to the 50-m Depth Contour

The 50-m isobath divides the shelf study area into pproximate halves (Fig. 1). Zooplankton volumes and hthyoplankton abundance and concentrations were ex- mined in relation to this depth contour to determine if they ffered between nearshore and offshore areas (Table 4; igs. 13, 14). The nature of water masses, rather than depth a factor determining zooplankton and ichthyoplankton oundance, but the 50-m depth is a convenient, common ontour for comparing cruises. Gulf Loop Current water ay occasionally intrude onto the west Florida continental shelf where depths range from 50 to 200 m (Maul 1974) and the character of zooplankton and ichthyoplankton could be influenced by such intrusions (Austin 1974). We did not determine if differences in plankton species composition occurred during this study.

Mean volumes of zooplankton were greatest at stations less than 50 m deep on 8 of the 10 cruises where stations in both depth zones were sampled. The two exceptions occurred in February 1972 and June-July 1973 when the mean volumes of zooplankton were slightly higher over the outer shelf. Pooled mean zooplankton volumes for the 10 cruises were calculated for each of the two depth zones (Table 4). Mean volume at depths shallower than 50 m exceeded that at deeper stations by a factor of 1.78. For the 10 cruises in which both depth zones were sampled, mean zooplankton volumes at stations shallower than 50 m exceeded 150 cc/1,000 m³ seven times, but mean plankton volume exceeded that amount on only one cruise at stations deeper than 50 m.

Mean fish egg abundance usually was higher at stations less than 50 m deep but mean larval abundance was always higher at the deeper stations for the 10 cruises. One reason for this observation is that fish larvae range in age from 1 day to more than 3 wk. Fish eggs, by contrast, usually hatch within 2 days of spawning in the eastern Gulf, precluding the possibility of numbers accumulating over a period in any area. Therefore, abundance of eggs would tend to be highest where the eggs were spawned in greatest numbers. Other reasons that larval abundance may be relatively low at shallow stations are that a higher proportion of shallow-water species are demersal and furthermore their larvae become demersal at a younger age than larvae of demersal, offshore species.

Seasonal fluctuations of zooplankton and ichthyoplankton abundance were most apparent at stations less than 50 m deep. Plankton volumes usually increased in summer at stations located over deeper water (Fig. 13) but the relative increase in zooplankton was less than at shallower stations.

Table 4.—Summary of plankton, fish eggs, and fish larvae mean catches for each cruise, dividing the cruise into portions greater than 50 m depth and less than 50 m depth.

Cruise	Month	Plankton volume (cc/1,000 m³)		Fish Eggs (No./10 m²)		Fish Larvae (No./10 m²)	
		<50 m	>50 m	<50 m	>50 m	<50 m	>50 m
1972							
8B 7201 & GE 7202	Feb.	68.8 (15)	69.6 (12)	420.1 (18)	880.3 (12)	153.2 (18)	336.7 (12)
GE 7208	May	158.2 (15)	48.2 (13)	820.0 (16)	300.6 (14)	348.8 (16)	489.1 (14)
GE 7210	June	No stations were greater than 50 m deep					
IS 7205	Sept.	195.7 (26)	120.7 (8)	559.9 (26)	640.1 (8)	742.9 (26)	1,093.7 (8)
IS 7209	Nov.	144.6 (33)	67.1 (16)	198.4 (34)	161.0 (16)	134.8 (34)	638.0 (16)
1973							
IS 7303	Jan.	181.1 (33)	107.1 (17)	419.0 (34)	362.2 (17)	146.1 (34)	645.3 (17)
IS 7308	May	237.6 (34)	128.9 (15)	955.2 (34)	684.0 (15)	545.8 (34)	767.0 (15)
IS 7311	June-July	118.2 (34)	124.2 (17)	483.8 (34)	379.7 (17)	328.7 (34)	997.0 (17)
IS 7313	Aug.	232.6 (34)	114.9 (16)	857.2 (34)	368.4 (16)	363.1 (34)	1,045.8 (16)
IS 7320	Nov.	158.3 (32)	100.6 (18)	364.3 (32)	138.1 (18)	121.5 (32)	698.2 (18)
1974							
CL 7405	Mar.	No stations were greater than 50 m deep					
CL 7412	May	215.1 (41)	191.7 (3)	937.4 (39)	354.9 (3)	508.7 (39)	655.5 (3)
Pooled means		178.9 (297)	100.7 (135)	606.4 (301)	402.8 (136)	342.2 (301)	739.2 (136)

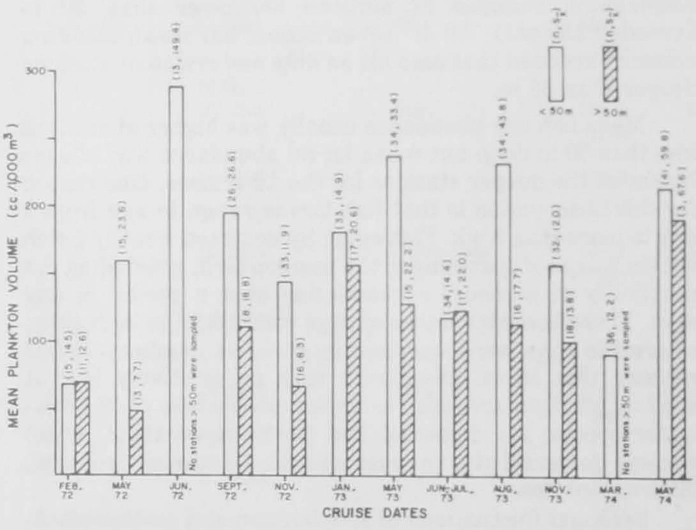


Figure 13.—Comparison of mean zooplankton volumes between stations less than 50 m deep and those more than 50 m deep for 12 eastern Gulf of Mexico cruises, 1972-74. Numbers of stations and standard errors of the means are given in parentheses above bar graphs.

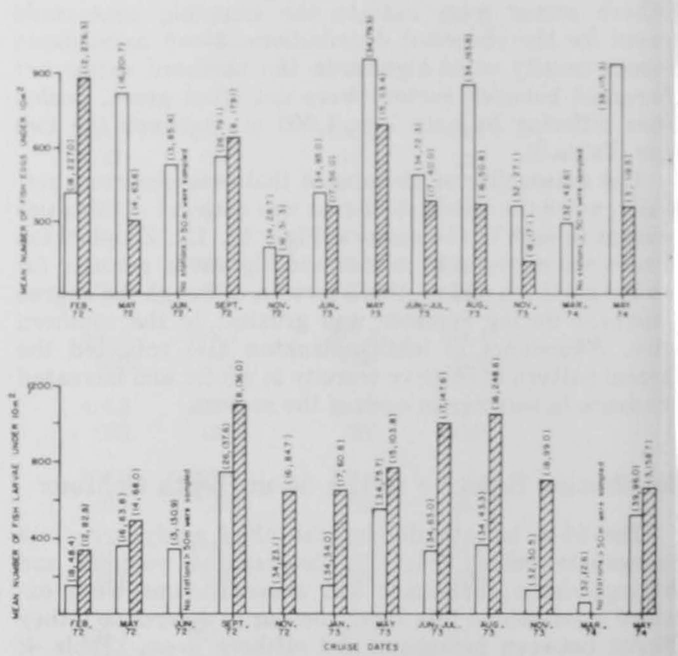


Figure 14.—Mean fish egg and fish larvae abundance. Comparisons are made between stations less than 50 m deep and those more than 50 m deep for 12 eastern Gulf of Mexico cruises, 1972-74. Numbers of stations and standard errors of the means are given in parentheses above bar graphs.

Most of the observed seasonality in larval fish abundance was attributable to changes at stations shallower than 50 m (Fig. 14).

Specific Areas of Abundance

The patchy nature of zooplankton distribution in the eastern Gulf made it difficult to determine if any areas consistently had high biomass. The contour charts (Fig. 2) do suggest that an area on the southwest Florida shelf, encompassed by lat. 25°30′N to 27°30′N and long. 82°30′W to 84°00′W, usually had high zooplankton volumes. This observation is similar to that of Bogdanov et al. (1968) and Khromov (1969) who observed year-round high plankton standing stocks in this area during 1963 and 1964.

Another area of relatively high plankton volumes was located on the shelf in the northeast Gulf (lat. 28°N to 29°N and long. 84°W to 85°W). Our data show this area to be rich in zooplankton at all seasons but richest in summer, thus differing from data of Bogdanov et al. (1968) and Khromov (1969), who reported high plankton biomass there only in winter. Because their observations apparently included phytoplankton biomass, as well as zooplankton, our data may not be directly comparable. Austin and Jones (1974) also reported a high zooplankton biomass in this region and cited possible influences of the Loop Current and shelf circulation on production. Their data, based on monthly collections from June 1969 through August 1970, showed plankton biomass for this area of the Gulf to be lowest in February and March, then increasing rapidly through May and June, and reaching a peak in fall.

Zooplankton volumes frequently were high in small areas near the coast, but none of these areas had consistently high volumes. Such areas included coastal stations west of Charlotte Harbor (lat. 26°30′N), Tampa Bay (lat. 27°30′N) and Cedar Key (lat. 29°00′N). Nutrients from local terrestrial runoff may have a major influence on plankton production in these areas.

Contour charts of fish egg abundance (Fig. 3) show less uniformity than those for zooplankton volumes. Egg abundance was low during fall and winter; the only area that had relatively high numbers of eggs at those seasons was located between Charlotte Harbor and Tampa Bay at depths of 20 to 100 m. During spring and summer, spawning is intense but no areas of unusually great spawning activity were located. Patches of high abundance (>1,600 eggs under 10 m²) often occurred and these usually were found where depths ranged from 20 to 50 m.

Abundance of fish larvae (number under 10 m²) was greatest at depths from 50 to 100 m (Fig. 4). Contour lines of larval fish abundance tended to lie parallel to isobaths. Greatest abundance of larvae occurred between lat. 26°30′N and 28°30′N. Localized patches of great abundance sometimes were observed for larvae, but these were less common than for fish eggs.

Relationships Among Biological Variables

Complex statistical analyses were not undertaken to examine relationships among the plankton and ichthyoplankton categories. Simple correlation coefficients among pairs of variables for each cruise were calculated, however, to determine if any of them had a significant linear association (Table 5). All of the correlations were calculated using $\log_{10}$-transformed data because most of the cruise frequency distributions for abundance or concentrations were nearly normally distributed after transformation.

Table 5.—Summary of simple correlations among biological variables. All correlation coefficients were calculated using $\log_{10}$-transformed data.

Cruise	Plankton (cc/1,000 m³) by fish eggs (No./10 m²)	Plankton (cc/1,000 m³) by fish larvae (No./10 m²)	Fish eggs (No./10 m²) by fish larvae (No./10 m²)
8B 7201 & GE 7202	+0.281	+0.218	+0.389*
GE 7208	+0.631**	+0.097	+0.087
GE 7210	-0.172	+0.727**	-0.329
IS 7205	+0.283	+0.109	+0.610**
IS 7209	+0.038	-0.179	+0.021
IS 7303	+0.022	-0.118	+0.172
IS 7308	+0.205	-0.056	+0.070
IS 7311	-0.074	+0.347*	+0.252
IS 7313	+0.171	-0.241	-0.012
IS 7320	+0.211	-0.000	+0.376**
CL 7405	-0.044	+0.450**	+0.346
CL 7412	+0.309*	+0.359*	+0.258

* Significant; $P<0.05$

** Highly significant; $P<0.01$

The correlations between zooplankton volumes and fish egg abundance were positive for nine cruises, but significantly so ($P<0.05$) for only two of these. This suggests that there is a relationship between areas of intense spawning and high zooplankton abundance at some times. The correlations between fish egg abundance and fish larvae abundance, though positive on 10 of the 12 cruises, were significant in only three cases. The fact that only positive correlation coefficients were significant among those that were calculated (Table 5) supports the belief that there is at times a real association among these variables in the eastern Gulf.

Relationships of Biological Variables to Temperature and Salinity

There were no obvious associations among temperature and salinity conditions and the distribution of organisms. Such associations almost certainly would be species dependent; because we did not identify organisms to the species level or sample discrete depth strata, these associations were not observed. Even in summer 1973, when a lens of low salinity water (<30‰) was located over part of the shelf study area, predominantly from Mississippi flood runoff, the effects on the plankton were not obvious. Zooplankton volumes, fish egg abundance, and larval fish abundance were all reduced during the June-July 1973 cruise (Figs. 8-10), but had recovered by August 1973, although surface salinities remained low in the area. Because this low salinity water was present only from the surface to 15-m depth, it is possible that many planktonic organisms that remained below that depth were not seriously affected. It is not known what effects this low salinity lens had on spawning, egg development, or larval survival for those species that normally are found near the sea surface.

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