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Distribution Patterns of Fish Eggs in the U.S. Northeast Continental Shelf Ecosystem, 1977–1987

Peter Berrien and John Sibunka

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Distribution Patterns of Fish Eggs in the U.S. Northeast Continental Shelf Ecosystem, 1977–1987

PETER BERRIEN and JOHN SIBUNKA

James J. Howard Marine Sciences Laboratory at Sandy Hook
Northeast Fisheries Science Center
National Marine Fisheries Service, NOAA
74 Magruder Road
Highlands, New Jersey 07732

ABSTRACT

This atlas presents information on fish eggs and temperature data collected from broadscale ichthyoplankton surveys conducted off the U.S. northeast coast from 1977 to 1987. Distribution and abundance information is provided for 33 taxa in the form of graphs and contoured egg-density maps by month and survey. Comments are included on interannual and interseasonal trends in spawning intensity. Data on 14 additional but less numerous taxa are provided in tabular form.

Introduction

The Northeast Fisheries Science Center (NEFSC) conducted a comprehensive fisheries ecosystem study in coastal waters off the northeastern United States from 1977 through 1987. Known as MARMAP (Marine Resource Monitoring Assessment and Prediction), the study included standardized year-round collections of fish eggs and larvae that provide baseline information on the distribution of eggs to determine spawning times and locations, as well as the abundance and variety of fish eggs and larvae (Sherman, 1980). Since these results are based on nine, and for some species, as many as eleven years of data, generalizations based on these collections are robust.

The distribution and abundance data of pelagic fish eggs provide the best available information on spawning areas, times, and intensities; long-term data can provide information on seasonal and annual changes in spawning intensity and areas. Correlation of such data with environmental parameters will lead to definition of essential habitat for early life stages. It will also improve our understanding of those factors contributing to fluctuations in year-class strength and, when compared with the relative abundance of larval and juvenile fish, will lead to more knowledge about early life-stage survival. The purpose of our atlas is to describe distribution patterns of fish eggs for the 33 principal taxa collected, and to provide summary notes on an additional 14 taxa. This atlas is the fourth in a series of publications which summarize data from the MARMAP program. Previous atlases have reported on survey design and methodology (Sibunka and Silverman, 1984, 1989) and larval fish distributions (Morse et al., 1987).

Methods

MARMAP surveys were conducted at monthly to bimonthly intervals from 1977 through 1987 (Table 1). The study area included continental shelf waters from the northern Gulf of Maine and western Scotian Shelf to Cape Hatteras, North Carolina—an area of approximately 260,000 km^2. Based on ecological considerations described by Sherman (1980), the survey area was divided into four subareas: the estuarine-influenced waters of the Middle Atlantic Bight, the broad continental shelf waters over a gently sloping bottom off southern New England, the relatively shallow, well-mixed waters of Georges Bank, and the deep, seasonally-stratified waters of the Gulf of Maine (Fig. 1). Data for this study were collected on standardized MARMAP surveys and on those dedicated to assessing the status of juvenile and adult fish or molluscan populations. The latter were only secondarily concerned with plankton collections. Station locations for standardized MARMAP surveys varied little between surveys except that a few deep-water sites occupied during the first two years were subsequently omitted. Additional stations were added to increase sampling intensity at selected sites, mostly in 1987 as part of

Table 1

List of surveys, sampling dates, and numbers of plankton-tow collections examined for fish eggs collected from 1977–87 in continental shelf waters off the U.S. east coast. Surveys 1–5 were examined for eggs of *Pleuronectes ferrugineus* and *Scomber scombrus* only; eggs from surveys 6–11, 51, and 52 were not identified.

Survey number	Year	Sampling dates	Number of tows	Survey number	Year	Sampling dates	Number of tows
1	1977	Mar 19 – Apr 08	69	44	1983	Jul 27 – Aug 30	116
2		Mar 04 – Apr 22	188	45		Aug 16 – Sep 04	62
3		Apr 14 – May 13	189	46		Sep 14 – Nov 09	160
4		May 18 – Jun 22	205	47		Nov 16 – Dec 19	149
5		Jul 31 – Aug 30	147	48	1984	Jan 10 – Feb 08	159
12	1978	Oct 06 – Nov 11	149	49		Mar 02 – Apr 25	151
13		Nov 16 – Nov 29	70	50		May 09 – Jun 02	177
14	1979	Feb 25 – Mar 14	102	53		Jul 10 – Jul 30	106
15		Apr 01 – May 07	102	54		Jul 25 – Aug 30	119
16		May 06 – May 29	170	55		Sep 17 – Nov 03	158
17		Jun 17 – Jul 13	123	56		Nov 01 – Dec 05	144
18		Aug 11 – Sep 02	145	57	1985	Jan 08 – Feb 06	125
19		Oct 04 – Oct 28	158	58		Feb 27 – Apr 12	120
20		Nov 15 – Dec 20	102	59		Apr 02 – Apr 22	130
21	1980	Feb 20 – Apr 04	170	60		May 09 – May 30	134
22		Apr 16 – May 12	174	61		Jul 17 – Aug 29	150
23		May 23 – Jun 29	148	62		Aug 30 – Sep 22	173
24		Jul 16 – Aug 09	153	63		Sep 10 – Nov 15	140
25		Sep 26 – Oct 29	174	64		Nov 07 – Dec 12	179
26		Nov 19 – Dec 21	137	65	1986	Jan 10 – Feb 12	173
27	1981	Feb 18 – Mar 24	151	66		Mar 04 – Apr 27	145
28		Mar 19 – Apr 08	99	67		May 08 – Jun 06	161
29		Mar 19 – May 12	143	68		Jun 17 – Jul 17	105
30		May 21 – Jun 17	143	69		Jul 29 – Aug 29	116
31		Jun 27 – Jul 19	78	70		Aug 27 – Sep 24	155
32		Aug 04 – Sep 02	94	71		Sep 14 – Nov 06	147
33		Sep 17 – Nov 08	169	72		Nov 05 – Dec 11	159
34		Nov 18 – Dec 21	88	73	1987	Jan 07 – Feb 08	132
35	1982	Feb 14 – Mar 23	145	74		Mar 24 – Apr 28	152
36		Mar 11 – May 08	166	75		Apr 13 – Apr 22	91
37		May 18 – Jun 11	132	76		May 07 – Jun 07	193
38		Jul 13 – Aug 07	123	77		May 31 – Jun 30	129
39		Sep 15 – Nov 09	149	78		Jul 07 – Aug 10	155
40		Nov 17 – Dec 20	152	79		Aug 19 – Sep 20	179
41	1983	Jan 18 – Mar 01	148	80		Sep 11 – Oct 30	144
42		Mar 09 – May 01	139	81		Nov 04 – Dec 10	124
43		May 26 – Jun 21	170				

an intensive study to assess Atlantic mackerel spawning. There were 214 standard station locations visited during all 81 surveys over the 11-year period. Nine deep-water locations sampled during the first two years and four non-transect locations in close proximity to others (<12 km distant) were omitted, leaving a total of 201 standard locations to be considered here. Stations were located along and between 7 transects. Those along the transects were spaced at 8 to 18-km intervals, others at 25 to 35-km intervals (Fig. 1). Plankton sampling locations on trawl and dredge surveys were selected from stratified random station plans that changed with each survey (Grosslein, 1969). Ichthyoplankton sampling intensity on trawl and dredge surveys was similar to that on dedicated plankton surveys, i.e. stations were approximately 25 to 35 km apart.

Plankton was sampled with a 61-cm bongo fitted with 0.505 and 0.333-mm mesh nets and weighted with a 45-kg lead ball. The 0.505-mm side was used for most ichthyoplankton collections, while the 0.333-mm side was used primarily for zooplankton collections; it also provided replacement samples of ichthyoplankton in

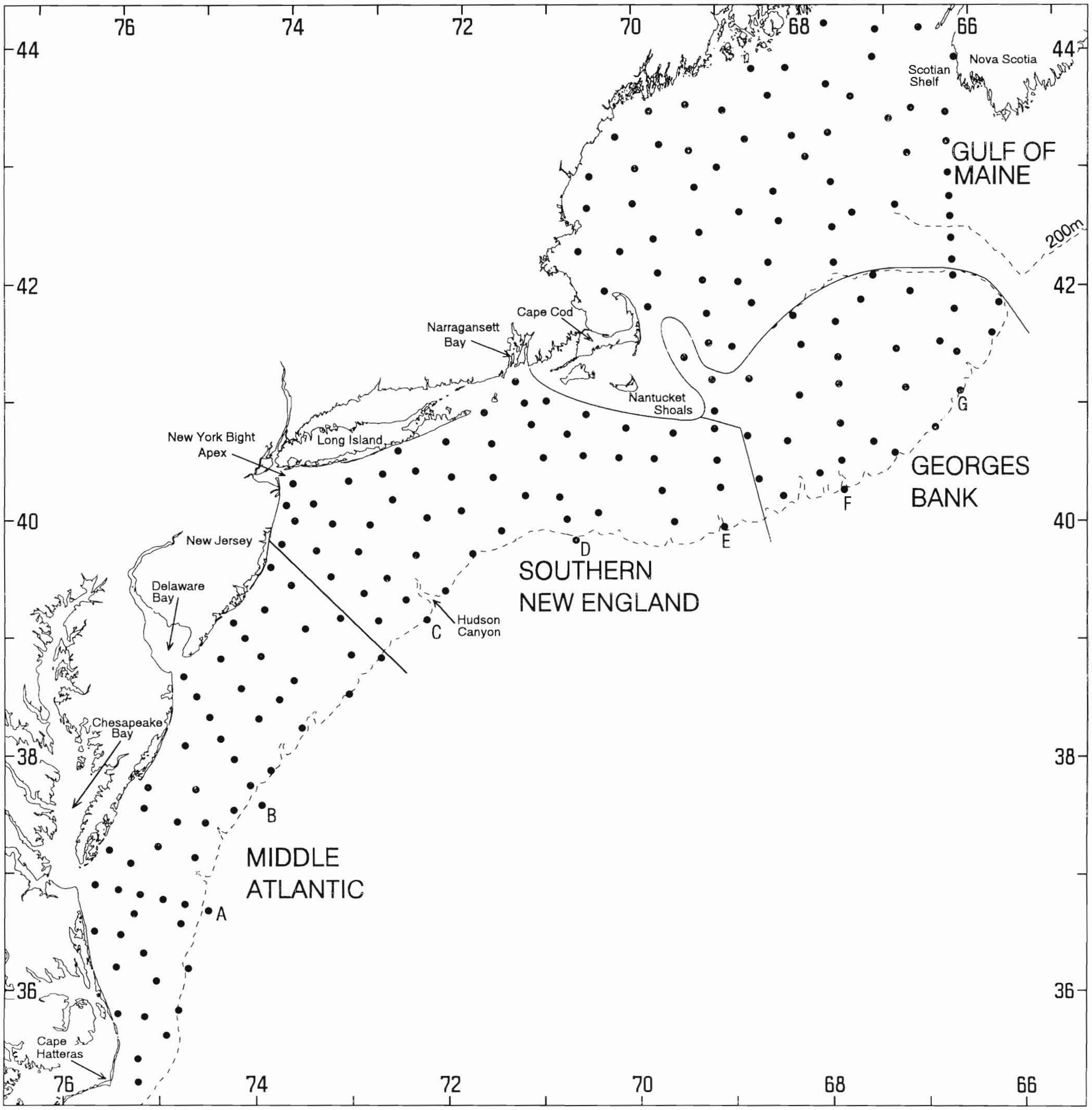


Figure 1

MARMAP survey area, 1977–87, including 201 standard sampling locations, four subareas, seven transects (A to G), and various geographic features referred to in text.

cases where a 0.505-mm sample was lost. Of 10,273 egg samples analyzed, 927 were replacements provided by the 0.333-mm side; of these, 123 were necessitated by breakage (primarily in transit) or preservation failure, and 804 were used to replace samples lost in a laboratory fire. A digital flowmeter suspended in the mouth of each net was used to measure water volume filtered, and a bathykymograph attached to the towing wire 0.5 m above the bongo frame recorded tow profile and maximum depth sampled. Plankton tows were smooth double-oblique and made by adjusting vessel speed to maintain a 45° wire angle throughout the haul. Sampling was conducted to within 5 m of the bottom to a maximum of 200 m. Vessel speed was maintained about 2.8 km/hr (1.5 kt).

Plankton samples were fixed and preserved (5% formalin seawater solution). All fish eggs were removed from the 0.505-mm mesh samples, identified, and separated into developmental stages. Three stages were used: 1) from just spawned to just before blastopore closure, 2) from blastopore closure to just before the tail bud lifts free from the yolk surface, and 3) from tail bud free to just before hatching. When large numbers of eggs were collected, subsamples were taken for staging purposes. We used two levels of subsampling that allowed for more precise estimates of egg stages for targeted species, and which were to be considered for future analysis. A maximum of 500 eggs were staged if the taxon was *Cynoscion regalis*, *Gadus morhua*, *Pleuronectes ferrugineus*, *Melanogrammus aeglefinus*, *Merluccius bilinearis*, *Paralichthys dentatus*, *Pomatomus saltatrix*, *Peprilus triacanthus*, *Pollachius virens*, or *Scomber scombrus*. Approximately 100 eggs were staged for other taxa.

Identification of fish eggs is difficult because there are fewer morphometric and meristic features available for identification than there are for larvae and juveniles. Some identifications can only be made to genus or family level because of the absence of distinguishing features. While several features are relatively constant throughout egg development, there can be some degree of overlap or commonality among unrelated taxa with respect to these features. These features include egg diameter and shape; number and size of oil globules; size of perivitelline space; nature of yolk, whether homogeneous or segmented; and nature of chorion surface, whether smooth, pitted, or sculptured. Certain taxa with similar size eggs could not be distinguished at certain developmental stages (Table 2). To identify eggs within these groupings we applied proportions noted among later, identifiable stages to the numbers of earlier, inseparable stages at the same or neighboring station. All catches were standardized to number of eggs sampled per 10 m² of sea surface area (Smith and Richardson, 1977).

Table 2

Taxonomic groupings of potentially co-occurring fish eggs, collected from 1977–87 in continental shelf waters off the U.S. northeast coast. These groupings are indistinguishable for identification purposes, within stated developmental stages, and at some seasons and egg sizes; see text for pertinent data handling.

Taxonomic groupings	Developmental stage(s)
Urophycis sp., *P. triacanthus*, and *M. undulatus*	1
T. adspersus and *P. ferrugineus*	1 and 2
T. adspersus and *T. onitis*	1 and 2
G. morhua, *M. aeglefinus*, *G. cynoglossus*	1
G. morhua, and *M. aeglefinus*	1, 2 and 3 (part)[1]
P. saltatrix and *Auxis* sp.	1
P. saltatrix, *M. bilinearis*, and *C. regalis*	1
C. striata and *P. oblongus*	1
P. dentatus and *S. aquosus*	1 (part)
S. aquosus and *P. oblongus*	1 (part)
Urophycis sp. and *E. cimbrius*	1 (part)

[1] *G. morhua* and *M. aeglefinus* eggs are indistinguishable within stage 3 only before tail twisting and flexion.

Maps depicting contoured egg densities (no./10 m² of sea surface area) were computer generated using Surface III software (Sampson, 1988) and interpreted and enhanced by a Fortran program that produced bitmap (PCX-format) output files for printing purposes. Monthly egg-density contour maps were created by averaging tow densities (no./10 m²) at each standard station, then plotting the resulting mean density at the weighted mean location. These locations were weighted by individual tow densities.

Mean egg densities (no./10 m²), by month and by survey, were graphed for each of 33 taxa. Delta-means (Pennington, 1983; Berrien et al., 1984) were used to summarize data for these graphs. Monthly egg densities were composites of data across all years. Survey mean densities were based on all tows in a given survey and did not attempt to compensate for variability in sampling coverage between surveys. Surveys failing to sample the entire MARMAP area, either by design or due to severe weather or vessel breakdowns, can introduce bias in the resulting mean egg density data, and graphs based on these surveys should be viewed with this in mind. There are a few instances where the calculated mean dates of occurrence for two adjacent surveys are so close in time that one of the histogram bars is obscured by the other member of the pair. There are several instances where the calculated mean density is such a low value (relative to the maximum displayed) that it is not visible; it is not displayed by the graphing software. And, similarly, there are many low-density values which are displayed but appear as very small dots. In both of these cases of low density, survey maps are included which show the areal occurrence of the species in question, even if densities are not visible on the histogram.

Temperature observations at plankton stations were obtained from surface waters by bucket thermometer and, at depth, from expendable bathythermograph (XBT) drops, conductivity-temperature-depth (CTD) casts, or reversing-thermometers on Niskin-bottle casts. Mean values for 0–15 m and 0–200 m depth intervals were calculated for each station. These were weighted means; each observation at depth was weighted by the depth interval extending halfway to adjacent observations. Survey mean values were calculated for three depth regimes (surface, 0–15 m, and 0–200 m). Expected mean values were derived for the 11-year series using methods described by Mountain (1989) and deviations from the long-term mean were calculated for each survey.

Results

There were 81 MARMAP surveys in all, conducted between February 1977 and December 1987, however, a lesser number of surveys were analyzed for fish eggs. Plankton samples from several surveys, both unexamined and partially examined, were lost in a laboratory fire. For most species considered here, samples from 68 surveys (nos. 12 to 50 and 53 to 81) were examined. In addition, egg samples from surveys 1 to 5 were examined for *Scomber scombrus* and *Pleuronectes ferrugineus* eggs. A total of 9,478 plankton samples collected during 68 surveys were examined for fish eggs; these numbers change to 10,273 samples and 73 surveys when samples partially sorted and identified are included. All identified taxa are listed along with additional information including numbers caught, frequency of occurrence, and seasonal and areal summaries of occurrence (Table 3). More than 1.8 million fish eggs, belonging to 47 known taxa, 67 unknown but distinct types, and the category "unidentified," were collected during MARMAP surveys. Information for 33 selected taxa is shown in graph and map form, accompanied by brief statements summarizing seasonal distribution and abundance. These 33 taxa comprise 97.8% of all eggs collected. Four taxa were clearly dominant: *Anchoa mitchilli, Scomber scombrus, Urophycis* spp., and *Merluccius bilinearis.* Together they comprised 60% of all eggs collected during the 68 surveys fully sorted and identified. Maps of contoured egg densities are given for all surveys on which a given taxon was caught. These data are also summarized by monthly plots which illustrate seasonal changes in geographic distribution of eggs during a composite average year. Monthly plots of sampling effort (number of tows per location) are given to aid interpretation of monthly distribution maps (Fig. 2). An additional 14 taxa appear only in Table 3. These were not sufficiently abundant or adequately sampled to warrant a more detailed presentation.

Temperature data associated with plankton tows are presented in graph and tabular form (Fig. 3–5; Append. Table 1). Graphs summarize survey means, ±1 standard deviation (SD), and anomalies of sea surface, 0–15 m, and 0–200 m depth ranges. Interannual trends illustrated by anomalies show that shelf waters tended to be lower in temperature during 1977 to 1982 than the long-term average, were above average from 1983 to 1986, and below average in 1987. These trends were evident in data from the three depth regimes noted above. Similar trends are evident in data from a study by Mountain and Manning (1994—Fig. 8) covering the same years (1977–87) at four sites in shelf waters between Georges Bank and Virginia, although they are not evident for sites within the Gulf of Maine. These authors noted that sites southwest of Georges Bank exhibit a higher degree of correlation in temperature anomalies than sites in the Gulf of Maine, implying regional scale influences.

Differences in "N", the total number of catches examined for fish eggs (Table 1) vs. the number of temperature observations (Append. Table 1), the number of stations sampled (Sibunka and Silverman, 1984, 1989), or the number of catches examined for fish larvae (Morse et al., 1987), are due to loss of egg or larva samples, or lack of temperature data at given stations.

The following are summaries of data on individual species (taxa).

Table 3

List of fish-egg taxa collected in continental shelf waters off the U.S. northeast coast, from 1977–87. Symbol (+ or –) following taxon name indicates presence (+) or absence (–) of maps and summary graphs in this paper.

Taxon	Total catch of eggs	Maximum per tow: Catch	Maximum per tow: No. per 10 m²	Non-zero tows[1]	Percent occurence	Non-zero Surveys[1]	Months occurred	Occurred in subareas[2]: GoM	GB	SNE	MA
Ophichthus cruentifer+	1,549	150	950	278	2.9	30	Jan–Nov		X	X	X
Brevoortia tyrannus+	1,806	321	1,287	135	1.4	26	May–Nov, Jan	X		X	X
Clupea harengus–	787	721	4,636	5	0.1	4	Sep, Oct, Apr	X	X		
Anchoa hepsetus+	5,530	557	1,477	105	1.1	22	Apr–Sep			X	X
Anchoa mitchilli+	466,382	142,898	257,931	231	2.4	26	Apr–Oct			X	X
Engraulis eurystole–	707	342	451	27	0.3	9	May, Jul–Oct			X	X
Argentina silus–	28	16	125	4	<0.1	3	Apr, May	X			
Maurolicus muelleri+	3,138	439	2,463	238	2.5	40	Jan–Dec	X	X	X	X
Synodontidae– (incl. 3 types)	227	30	105	42	0.4	26	Feb–May, Jul–Nov	X		X	X
Brosme brosme+	1,967	122	718	394	4.2	40	Mar–Nov	X	X	X	X
Enchelyopus cimbrius+	22,773	1,644	9,782	1,143	12.1	63	Jan–Dec	X	X	X	X
Gadus morhua+	60,322	27,785	150,039	1,354	14.3	60	Jan–Dec	X	X	X	X
Melanogrammus aeglefinus+	22,025	1,535	8,289	559	5.9	32	Jan–Aug	X	X	X	X
Merluccius albidus+	6,656	264	1,470	509	5.4	61	Jan–Dec	X	X	X	X
Merluccius bilinearis+	110,176	4,510	24,264	1,897	20.0	64	Jan–Dec	X	X	X	X
Pollachius virens+	17,900	2,830	14,886	588	6.2	43	Oct–Jun	X	X	X	X
Urophycis sp.+	199,514	5,570	29,227	2,974	31.4	66	Jan–Dec	X	X	X	X
Ophidiidae– (incl. 3 types)	22,862	3,400	8,949	350	3.7	38	Mar–Oct	X	X	X	X
Lophius americanus–	28	4	22	14	0.1	9	Mar, May, Jun, Sep, Oct	X	X	X	X
Trachipteridae–	1	1	7	1	<0.1	1	May		X		
Prionotus sp.+	68,405	1,949	4,198	767	8.1	48	Mar–Nov, Jan		X	X	X
Myoxocephalus aeneus–	1	1	3	1	<0.1	1	Apr			X	
Centropristis striata+	5,245	221	535	375	4.0	36	Apr–Oct, Jan			X	X
Lopholatilus chamaeleonticeps+	553	50	361	140	1.5	38	Mar–Nov		X	X	X
Pomatomus saltatrix+	13,775	1,272	4,533	215	2.3	19	May–Aug			X	X
Rachycentron canadum–	16	8	8	8	0.1	4	Jun, Jul				X
Stenotomus chrysops–	94	47	149	12	0.1	8	May–Aug			X	X
Cynoscion regalis+	14,523	1,976	3,122	151	1.6	22	Mar–Aug			X	X
Micropogonias undulatus+	14,102	1,606	3,334	132	1.4	20	Jul–Nov			X	X
Tautoga onitis+	3,139	800	2,584	158	1.7	25	Apr–Sep	X		X	X
Tautogolabrus adspersus+	58,671	18,844	60,866	561	5.9	28	May–Nov	X	X	X	X
Uranoscopidae+	1,215	50	92	262	2.8	36	Apr–Oct				X
Ammodytes sp.–	31	9	31	12	0.1	9	Nov, Dec, Feb		X	X	X
Auxis sp.+	1,564	186	916	89	0.9	19	May–Sep			X	X
Sarda sarda+	2,780	316	791	218	2.3	20	May–Aug			X	X
Scomber scombrus+[3]	239,352	20,159	53,220	1,030	10.0	30	Apr–Aug	X	X	X	X
Peprilus triacanthus+	29,148	2,150	13,223	688	7.3	30	Mar–Sep	X	X	X	X
Citharichthys/Etropus+	56,420	837	3,714	1,963	20.7	52	Jan–Nov	X	X	X	X
Paralichthys dentatus+	3,176	85	296	389	4.1	26	Sep–Jan, Apr, May		X	X	X
Paralichthys oblongus+	44,267	948	3,062	1,984	20.9	42	Apr–Nov	X	X	X	X
Scophthalmus aquosus+	37,540	1,013	3,890	1,341	14.1	58	Feb–Nov	X	X	X	X
Glyptocephalus cynoglossus+	3,428	165	904	623	6.6	44	Feb–Oct	X	X	X	X
Hippoglossoides platessoides+	4,977	258	1,703	416	4.4	40	Jan–Dec	X	X	X	
Pleuronectes americanus–	527	30	124	110	1.2	24	Feb–Jun	X	X	X	X
Pleuronectes ferrugineus+[3]	58,533	982	4,979	1,495	14.5	44	Feb–Sep	X	X	X	X
Symphurus sp.–	1,070	254	351	36	0.4	15	Feb, May–Sep				X
Trinectes maculatus–	39	18	30	6	0.1	4	Jul, Aug			X	X

[1] Total number of tows examined for most species was 9,478, from a total of 68 surveys.
[2] GoM = Gulf of Maine, GB = Georges Bank, SNE = Southern New England, MA = Mid-Atlantic (waters)
[3] *P. ferrugineus* and *S. scombrus* identified from a possible maximum of 10,273 tows (not 9,478) from 73 surveys (not 68).

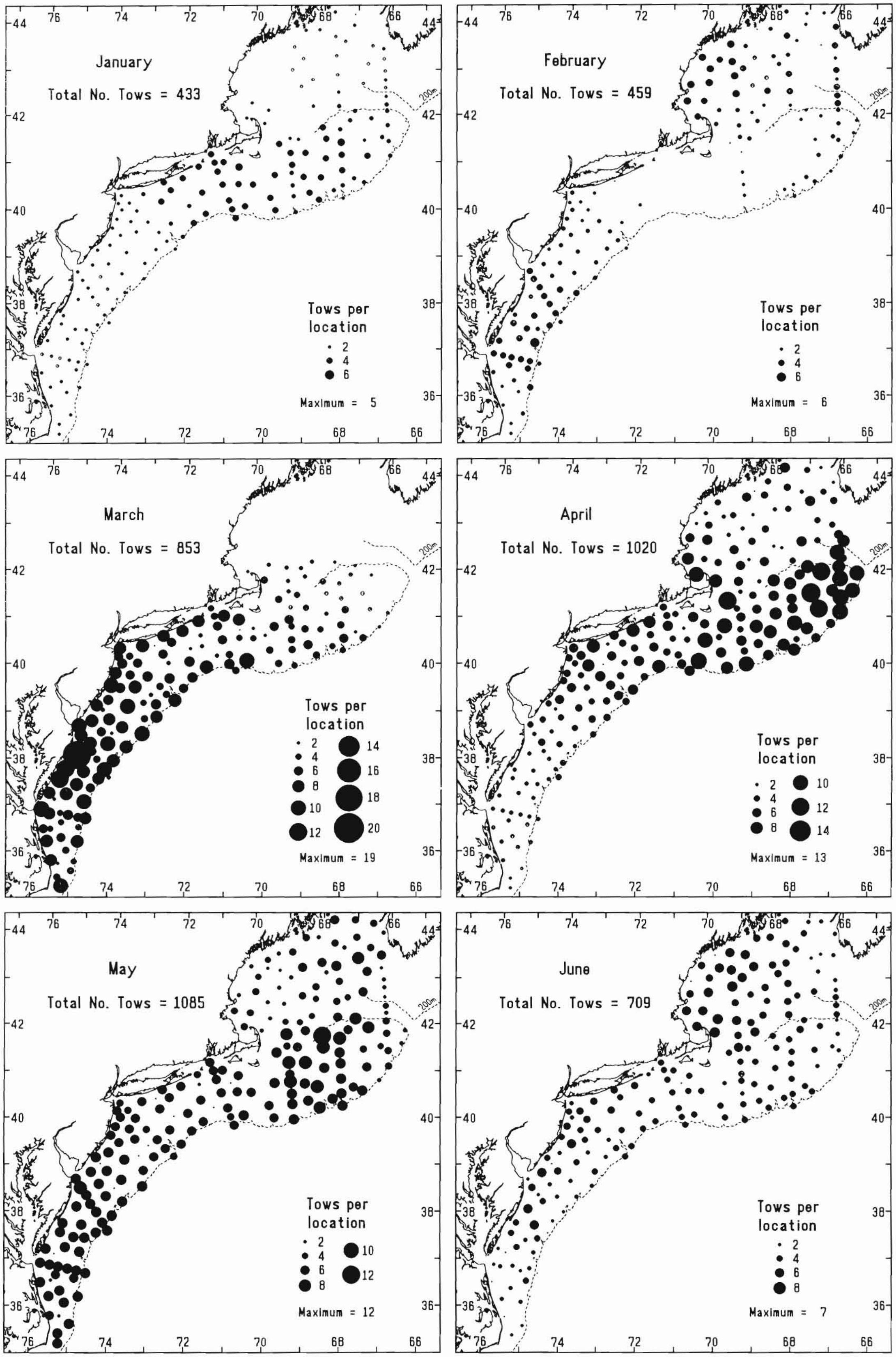


Figure 2

Monthly numbers of plankton samples examined for fish eggs from MARMAP surveys nos. 12–81 during 1978–87. Survey nos. 1–5, during March to August, are not included here and were examined only for eggs of *Scomber scombrus* and *Pleuronectes ferrugineus*.

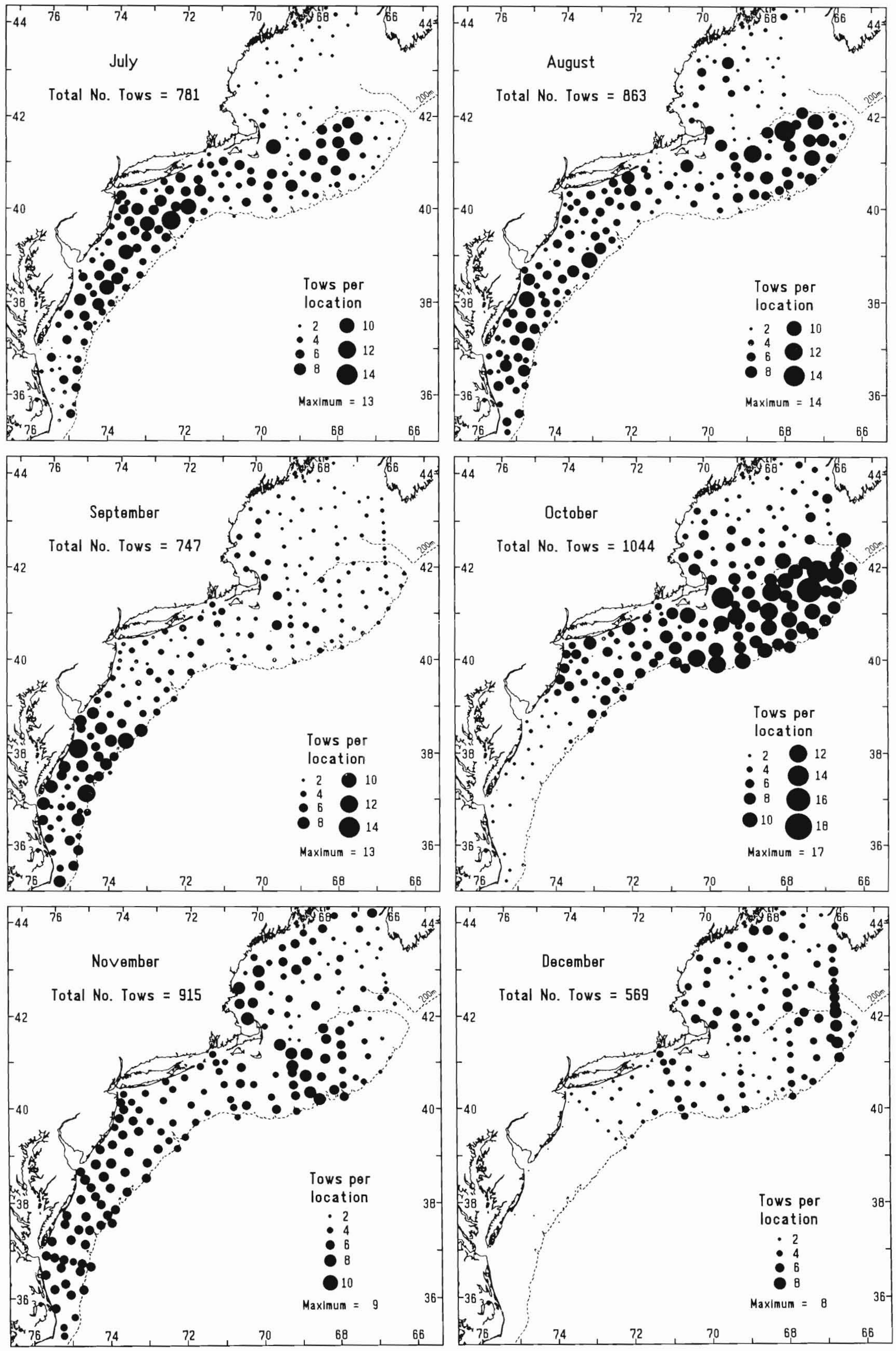


Figure 2 (continued)

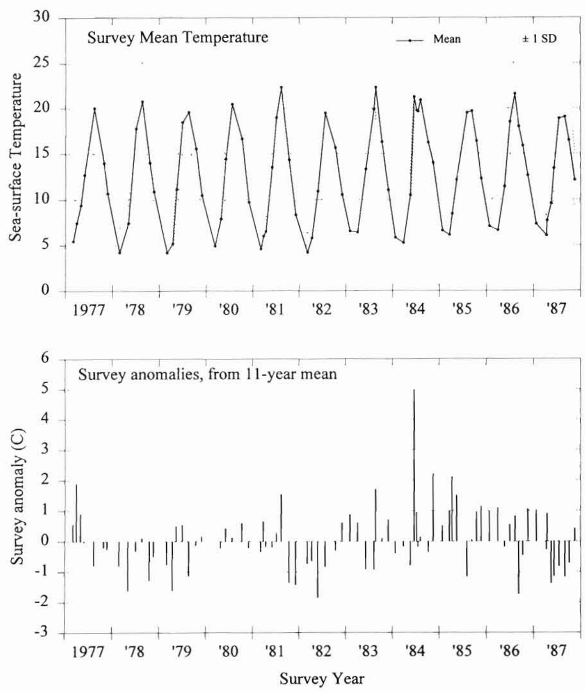


Figure 3
Mean sea-surface temperature (± SD) by survey (top) and survey anomalies from 11-year mean temperatures (bottom) for the total MARMAP area.

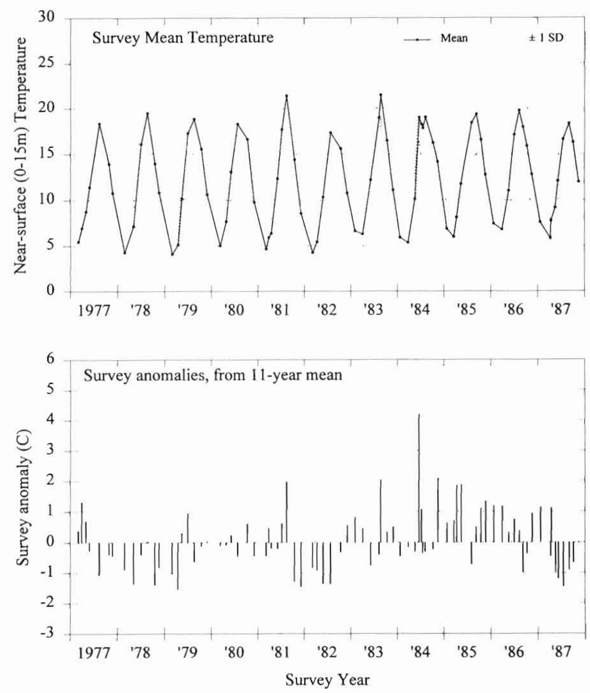


Figure 4
Mean near-surface (0–15 m) temperature (± SD) by survey (top) and survey anomalies from 11-year mean temperatures (bottom) for the total MARMAP area.

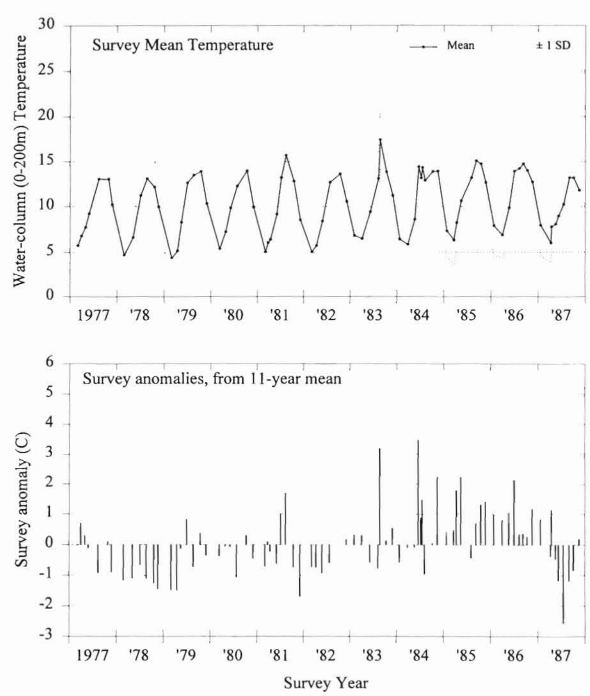


Figure 5
Mean water-column (0–200 m) temperature (± SD) by survey (top) and survey anomalies from 11-year mean temperatures (bottom) for the total MARMAP area.

Ophichthus cruentifer, margined snake eel (Figs. 6–8)

Ophichthus cruentifer eggs were caught during 11 months of the year, January to November, but were most abundant in July to September, indicating predominantly summer spawning (Fig. 6). Most were collected in outer, deeper portions of shelf waters between Cape Hatteras and southern Georges Bank.

There was an extended period of minimal spawning (October to May) followed by increased spawning in June of some years and by July in all years (Fig. 7). Eggs were first collected in isolated patches, usually in the extreme southern part of the Middle Atlantic subarea, followed by collections encompassing a broad area of outer shelf waters, from Cape Hatteras to southern Georges Bank. This increased spawning continued into August then rapidly reverted back to minimal activity by October.

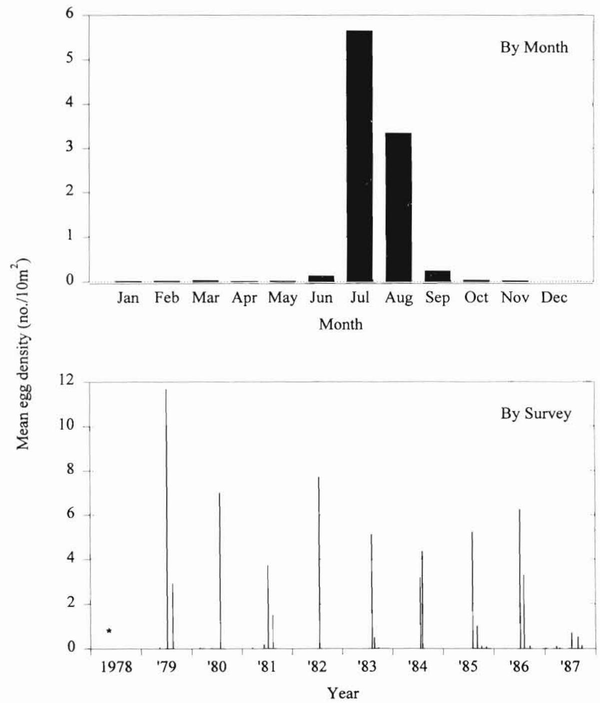


Figure 6
Ophichthus cruentifer; mean-egg-density graphs by month (top) and by survey (bottom) for the total MARMAP area. (*Samples from the first four surveys in 1978 were not analyzed for *O. cruentifer* eggs.)

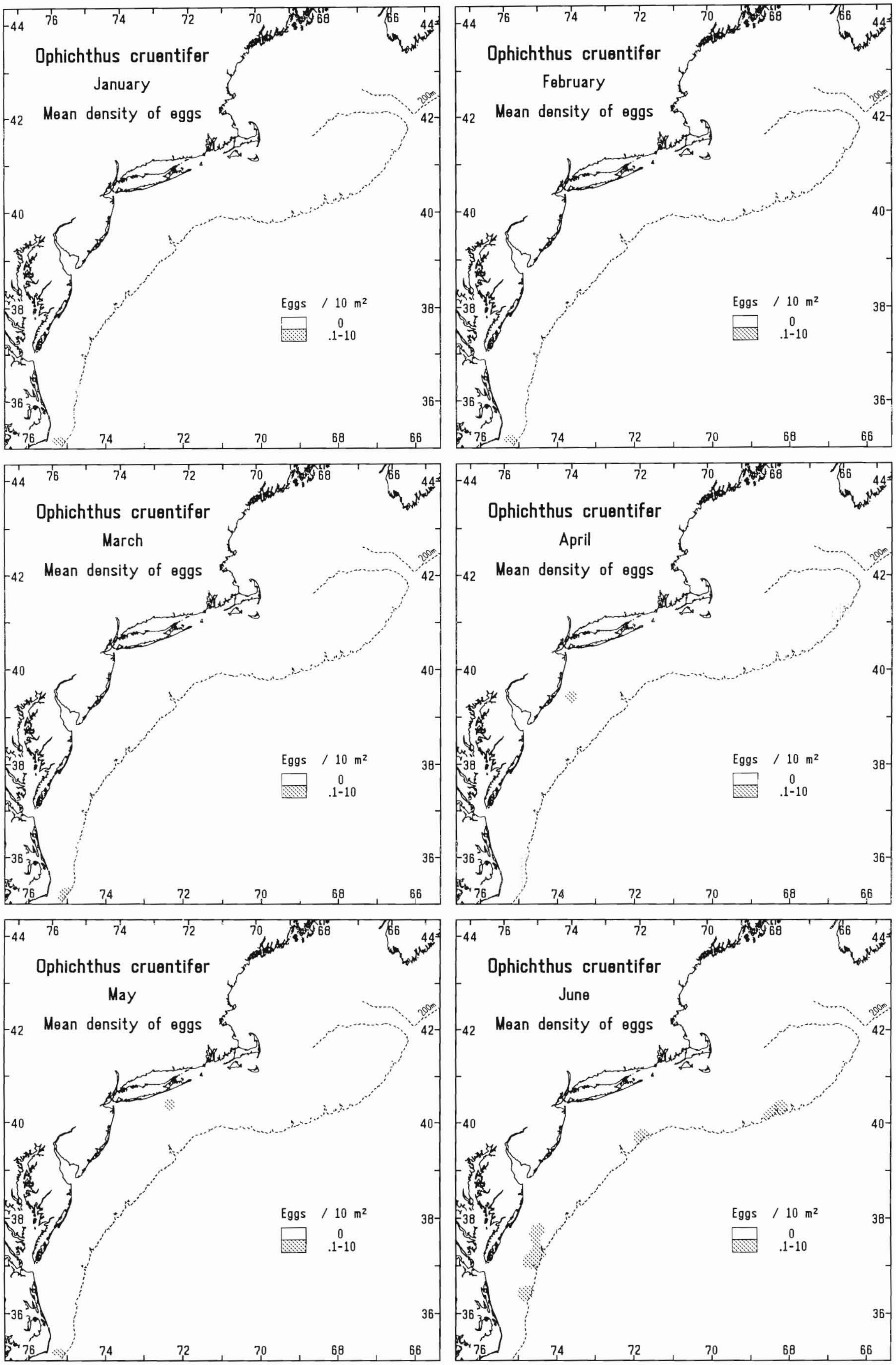
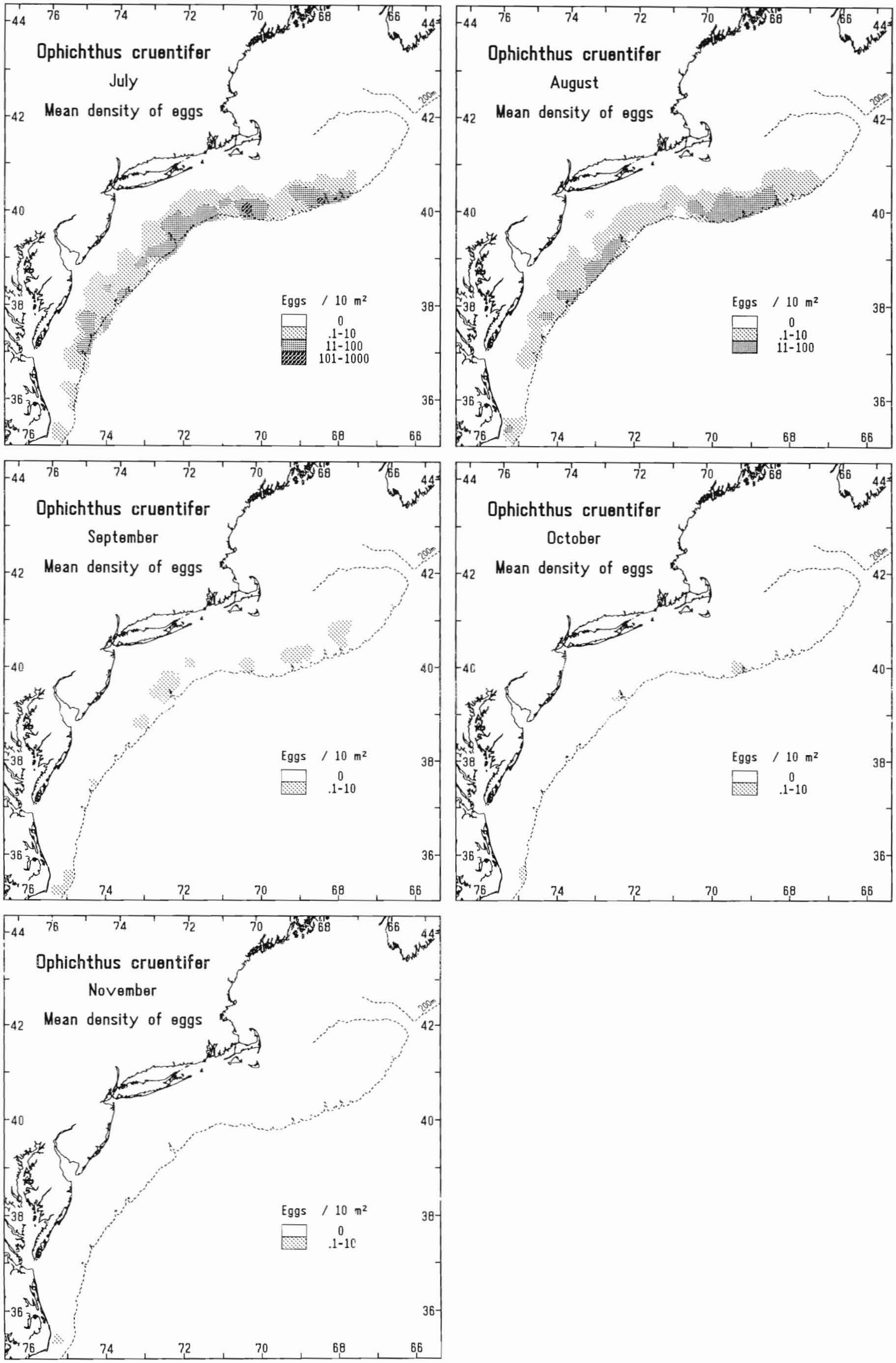


Figure 7

Ophichthus cruentifer; composite monthly areal plots of mean egg densities (no./10 m²).



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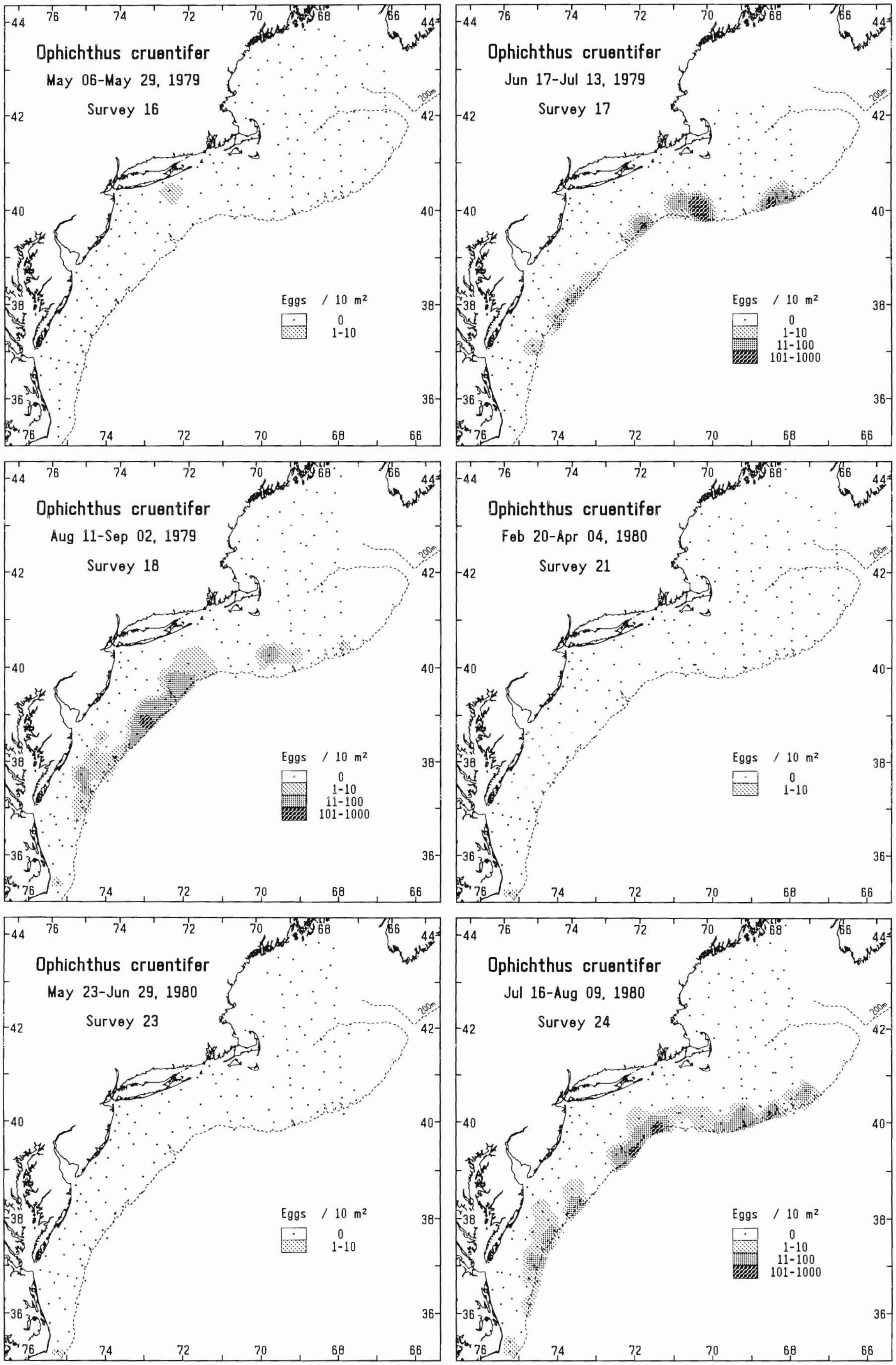
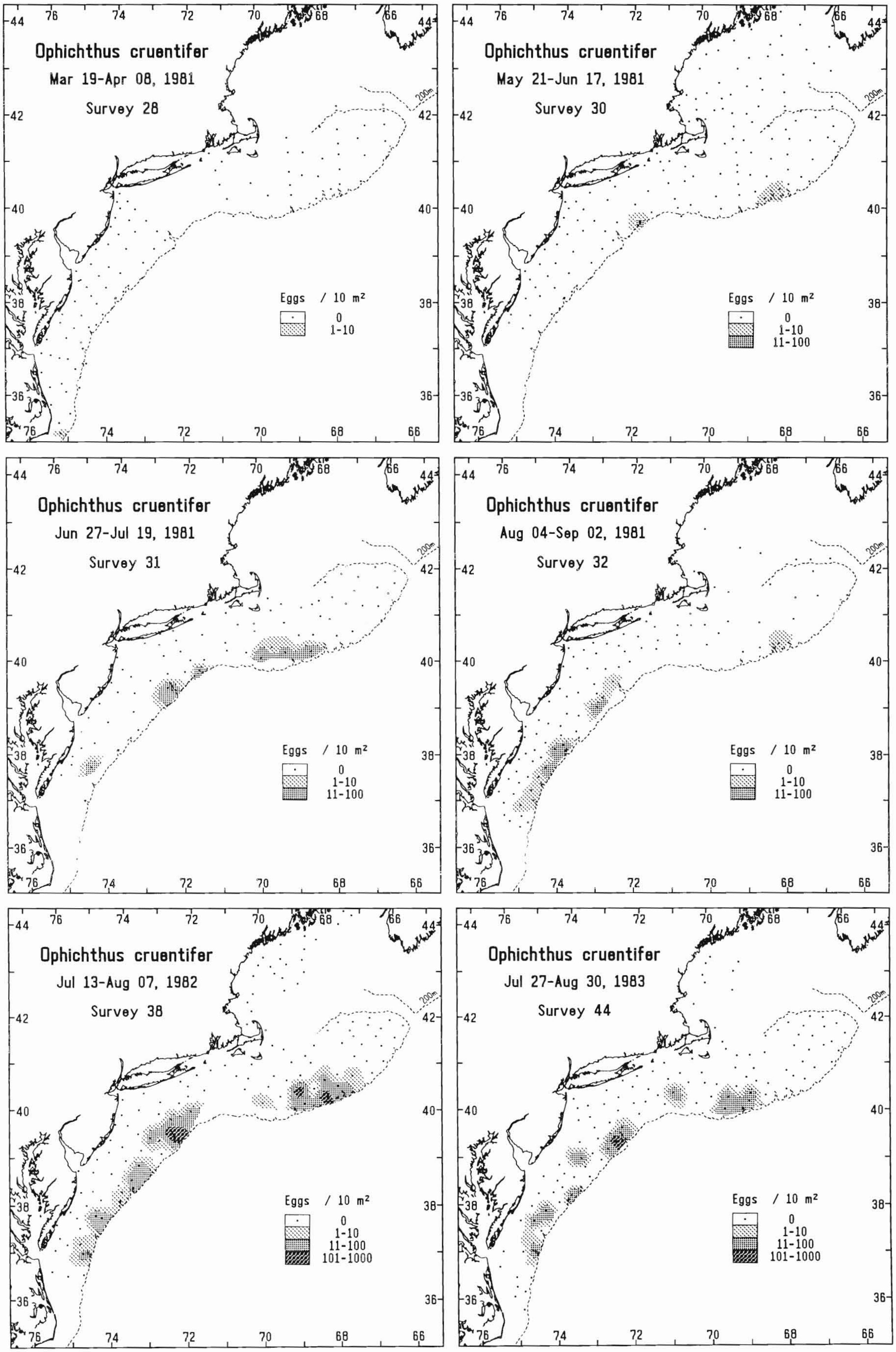


Figure 8

Ophichthus cruentifer; survey areal plots of egg densities (no./10 m^2).



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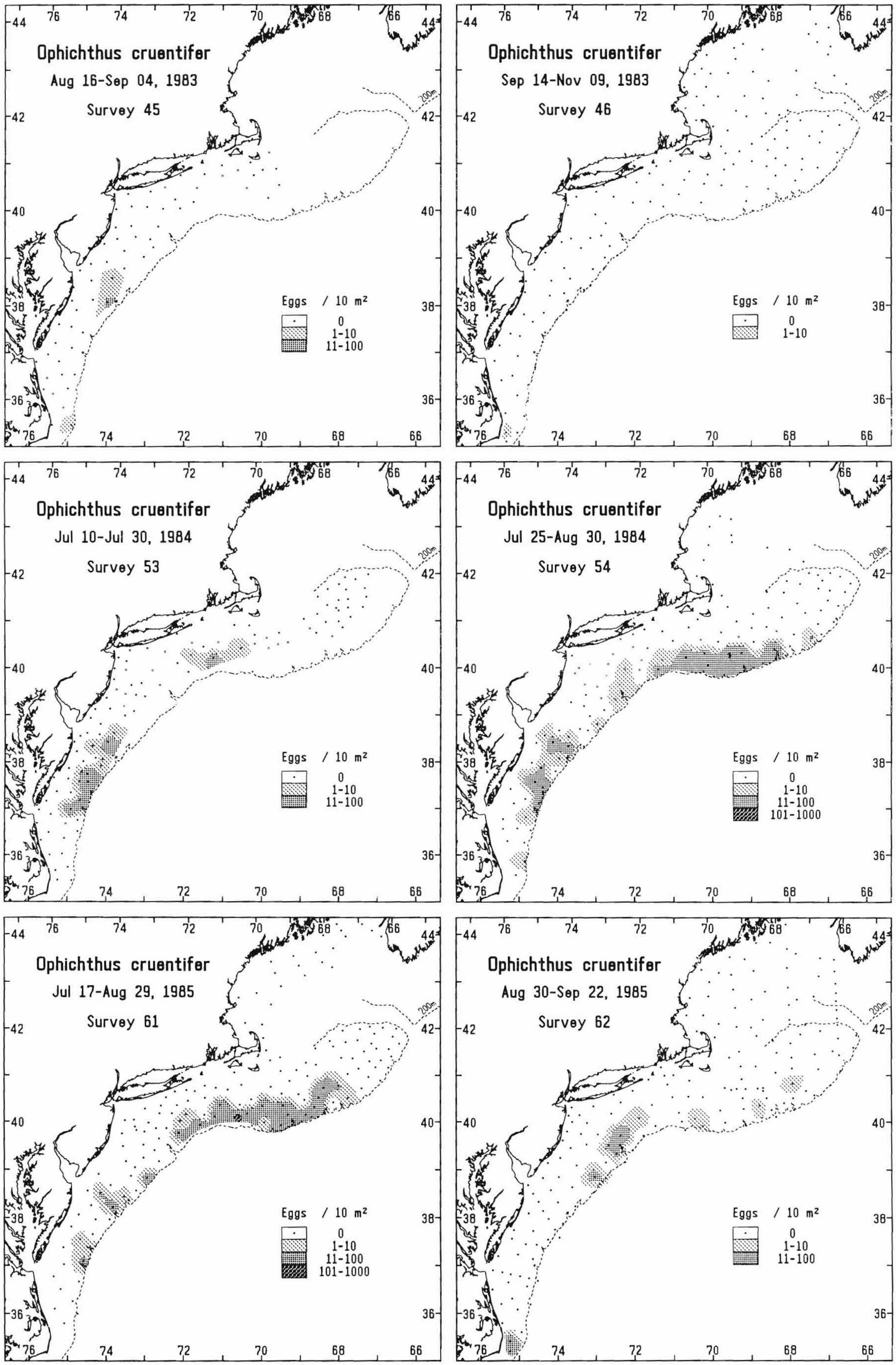

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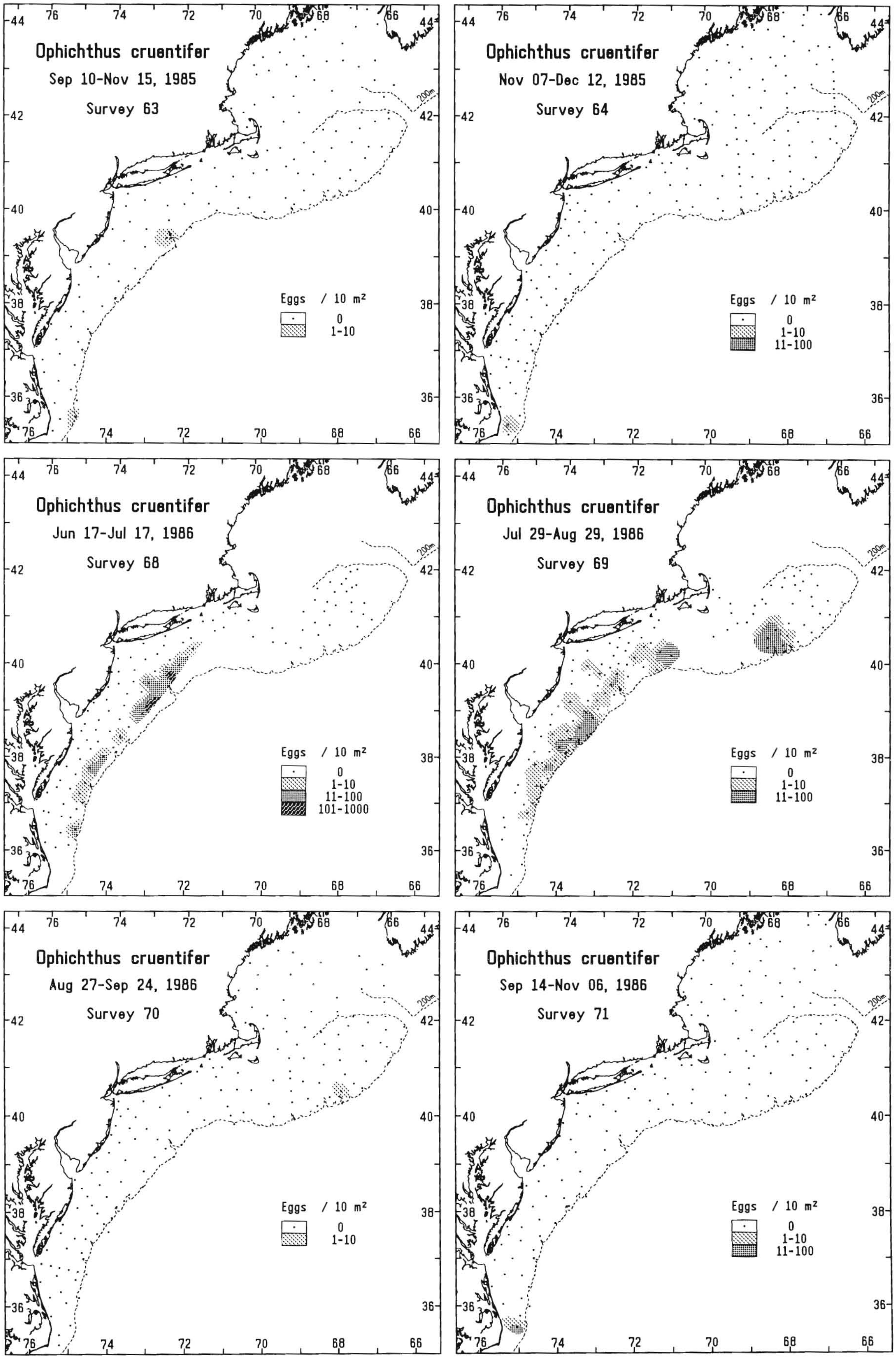

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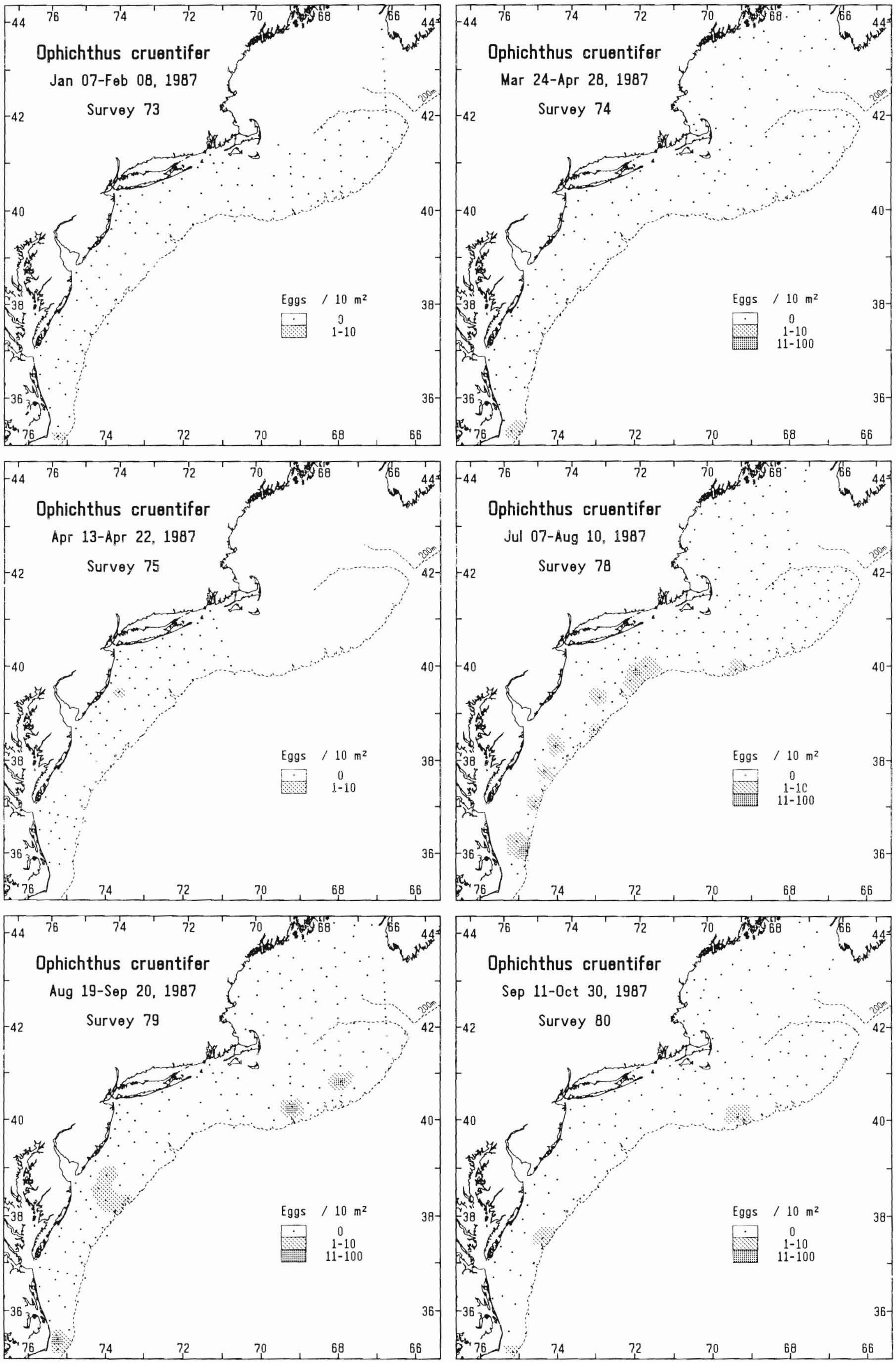


Figure 8 (continued)

Brevoortia tyrannus, Atlantic menhaden (Figs. 9–11)

Brevoortia tyrannus eggs were collected from May to November and in January. The frequency distribution of mean egg abundance was distinctly bi-modal, with peaks in spring and autumn (Fig. 9). Most *B. tyrannus* eggs were taken in nearshore continental shelf waters.

The peak in spring (May to July) indicates spawning began in southern New England waters, then rapidly spread into western Gulf of Maine during June, and subsided in July. The second and more protracted spawning period occurred from late summer to early winter in southern New England and Middle Atlantic areas. This spawning began in central Middle Atlantic waters in August and spread during September to November throughout inshore waters from Nantucket Shoals to Chesapeake Bay and southward. Spawning rapidly subsided and ended by January in southern Middle Atlantic waters (Fig. 10). The lack of *B. tyrannus* eggs in December probably reflects a lack of sampling in southern Middle Atlantic waters during that month (Fig. 2).

Egg abundance increased over the 9 years of MARMAP egg surveys (Fig. 9). *Brevoortia tyrannus* eggs were most abundant from 1984 to 1987 in both northern and southern spawning areas noted above (Fig. 11).

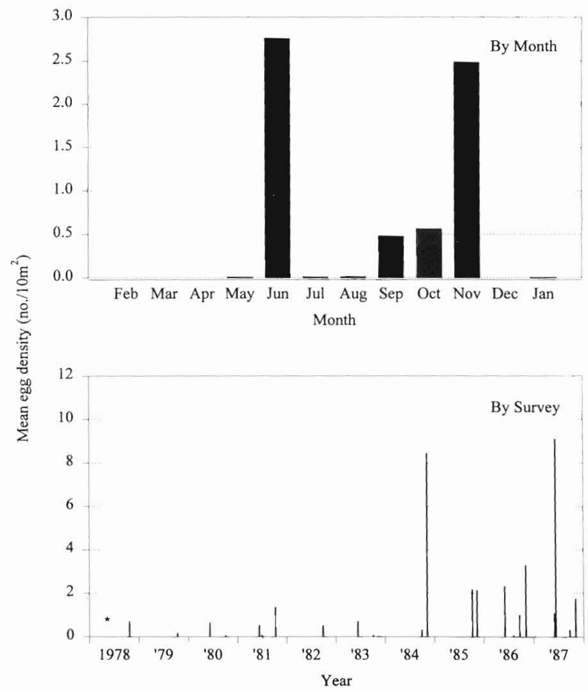


Figure 9
Brevoortia tyrannus; mean-egg-density graphs by month (top) and by survey (bottom) for the total MARMAP area. (*Samples from the first four surveys in 1978 were not analyzed for *B. tyrannus* eggs.)

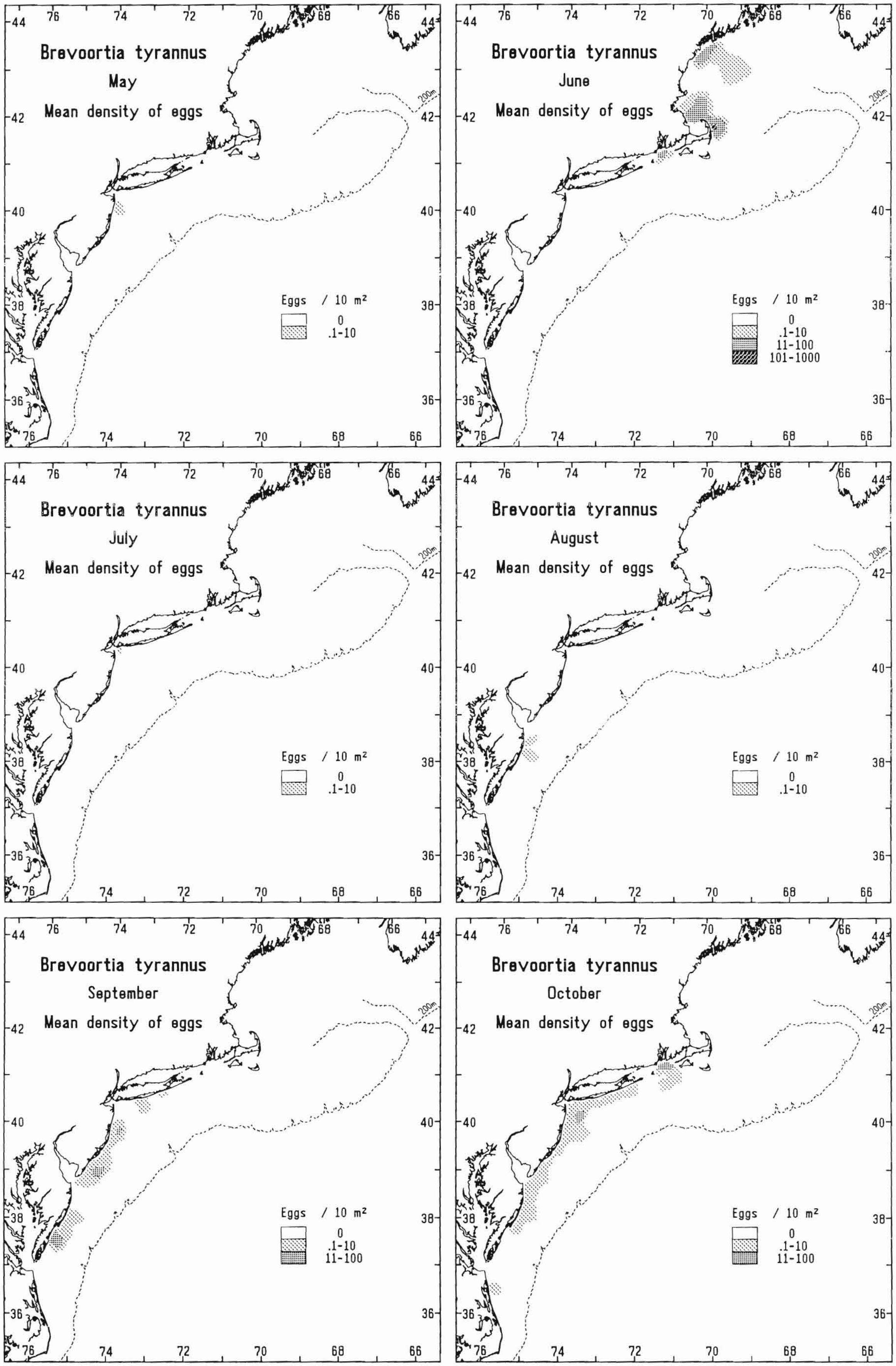
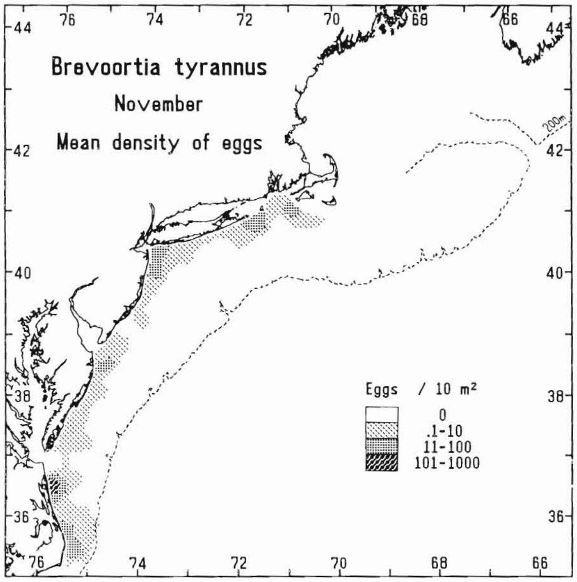


Figure 10

Brevoortia tyrannus; composite monthly areal plots of mean egg densities (no./10 m²).



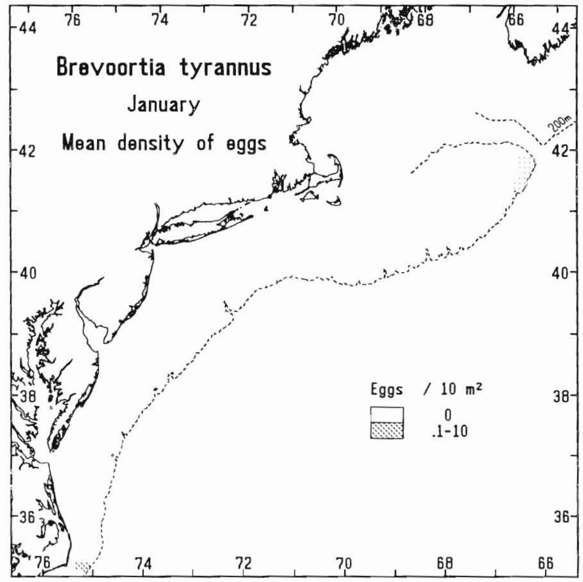


Figure 10 (continued)

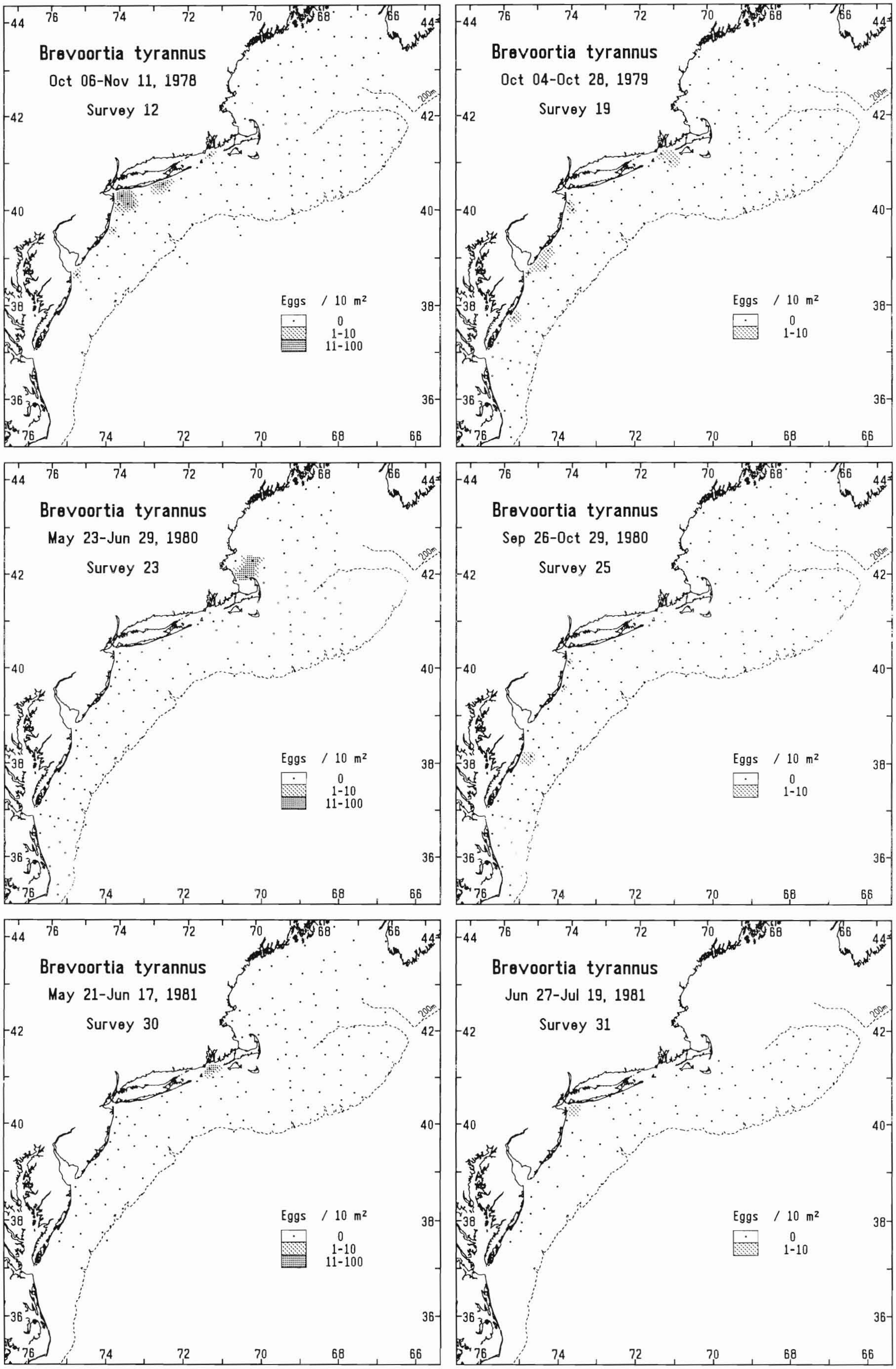
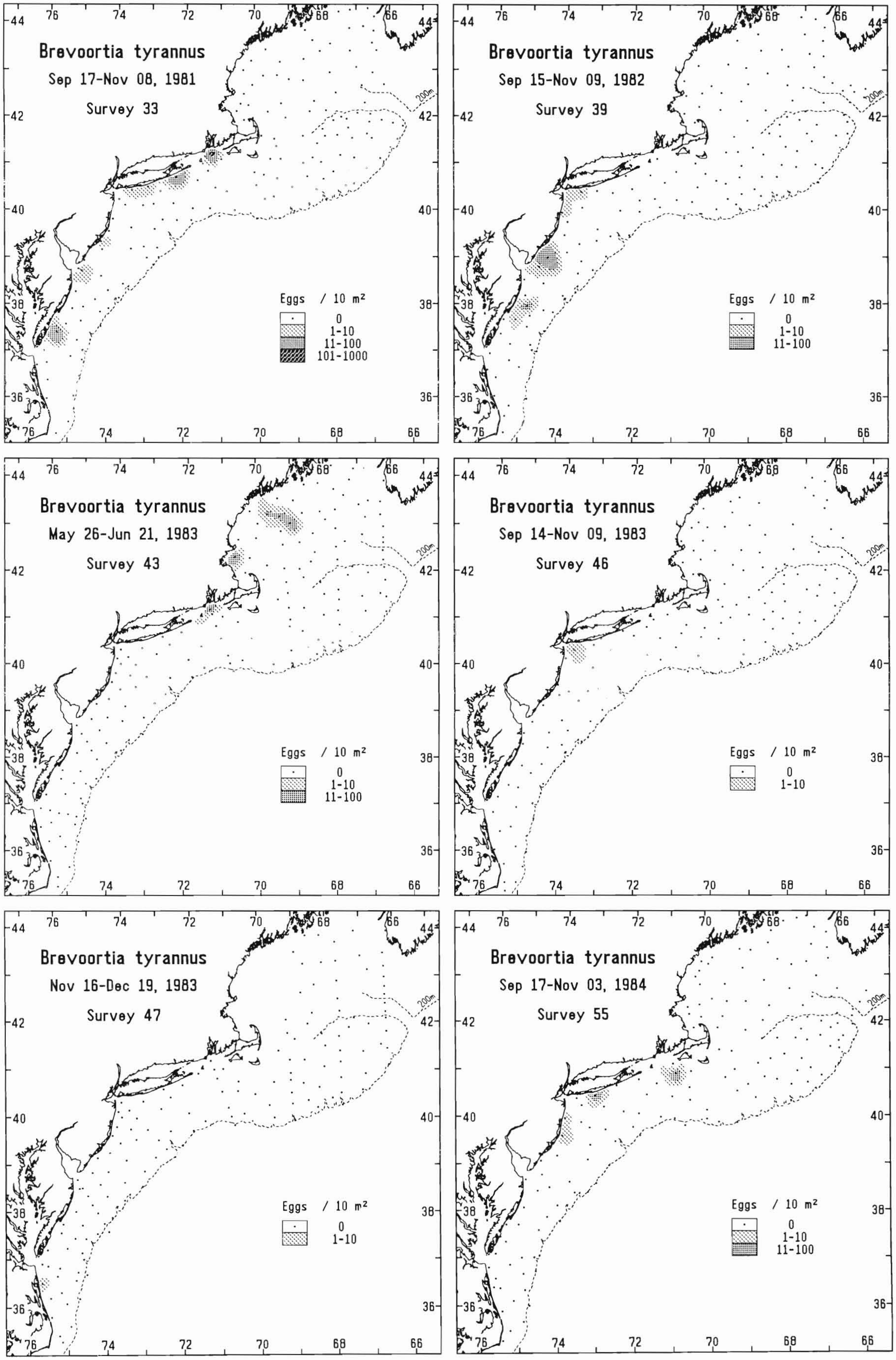


Figure 11

Brevoortia tyrannus; survey areal plots of egg densities (no./10 m^2).



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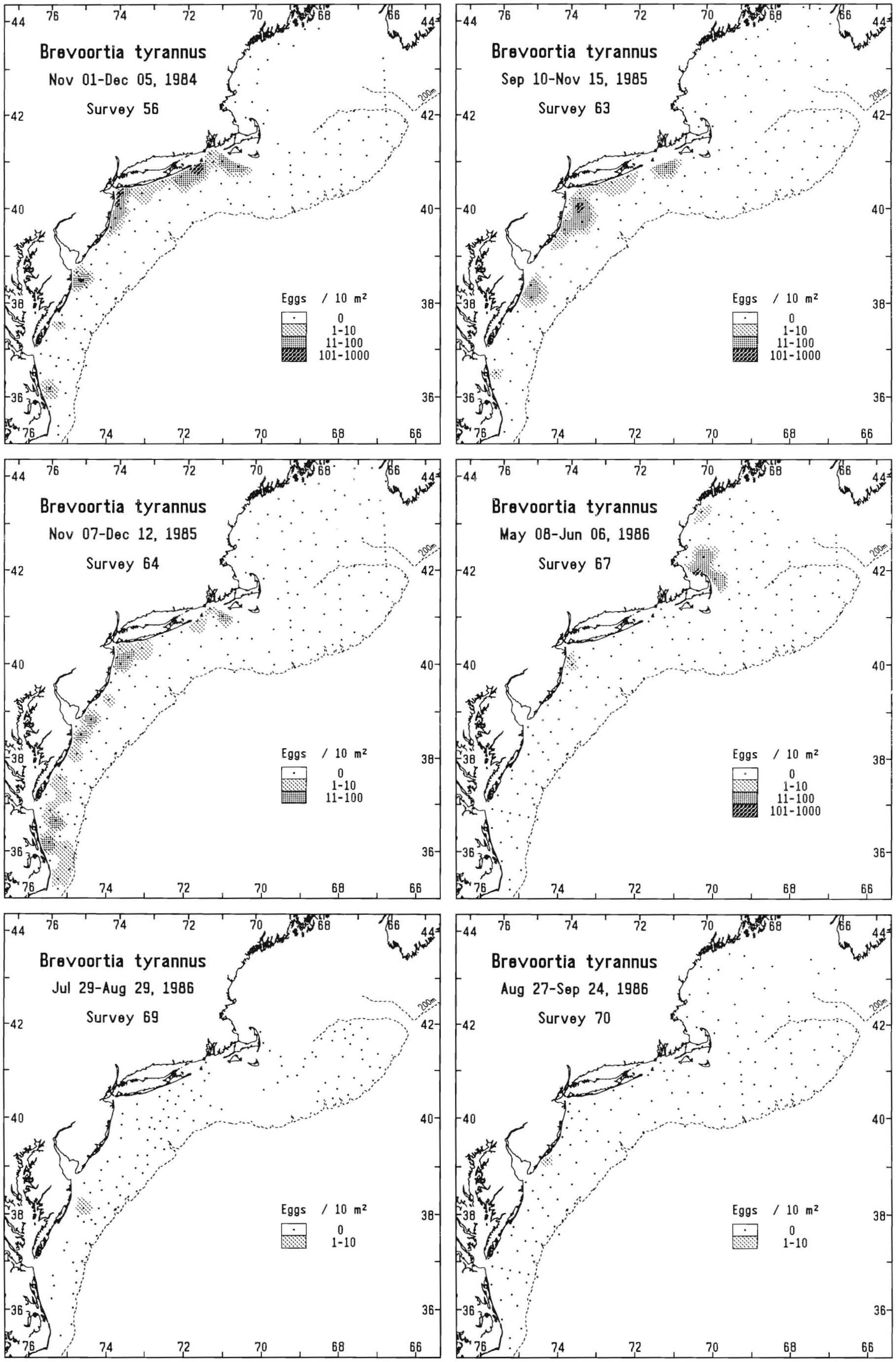

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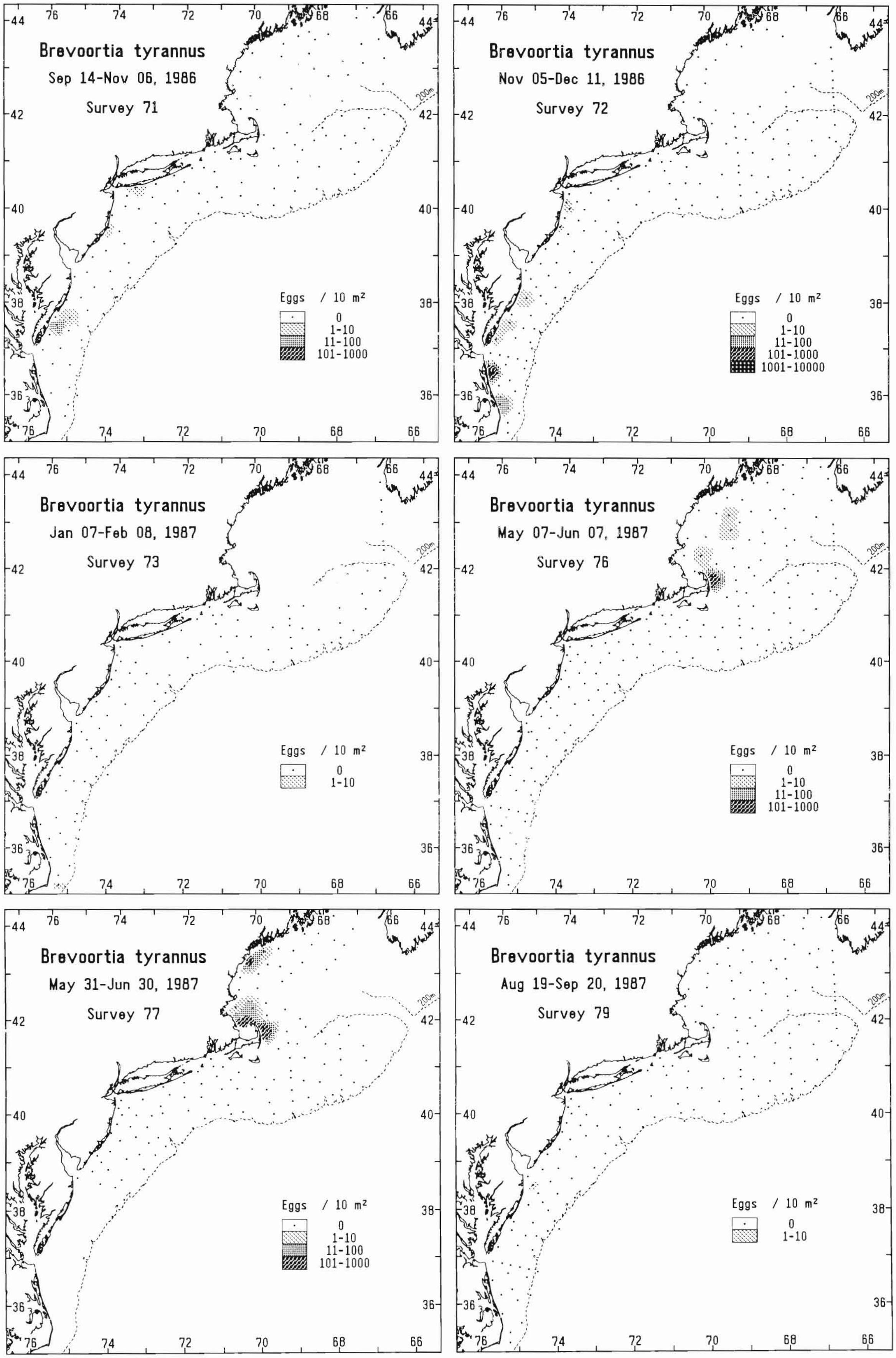

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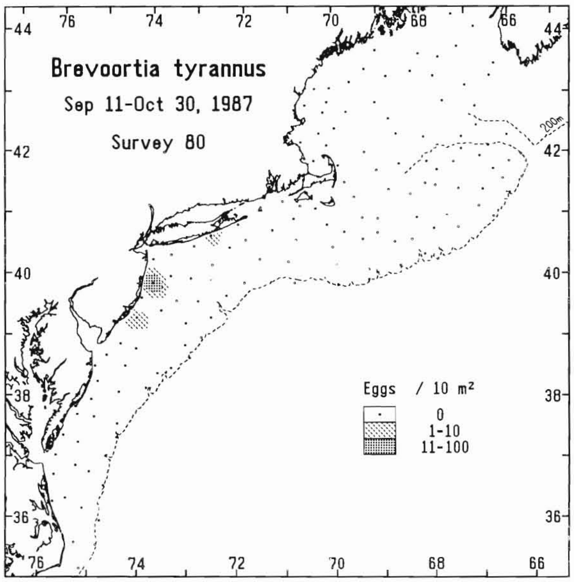


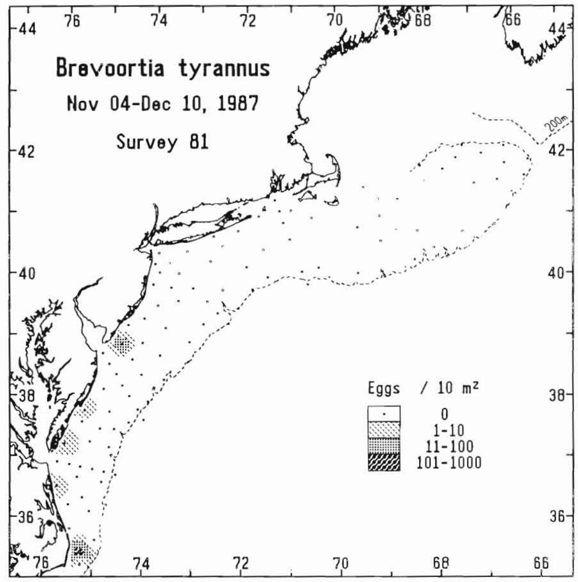


Figure 11 (continued)

Anchoa hepsetus, striped anchovy (Figs. 12–14)

Anchoa hepsetus eggs were collected from April through September, with peak abundance occurring in May and June (Fig. 12). Although eggs of this species were not as abundant as eggs of the congener *A. mitchilli* (Figs. 15–17), these species shared similar spatial and temporal spawning habits. Eggs occurred predominantly inshore from Cape Hatteras to New Jersey, but ranged north and east to inner shelf waters off Narragansett Bay (Figs. 13 and 14).

Spawning began as early as April near Cape Hatteras, then progressed northward as far as Delaware Bay during May and to inshore southern New England waters in July. Thereafter eggs were found in relatively restricted areas into September.

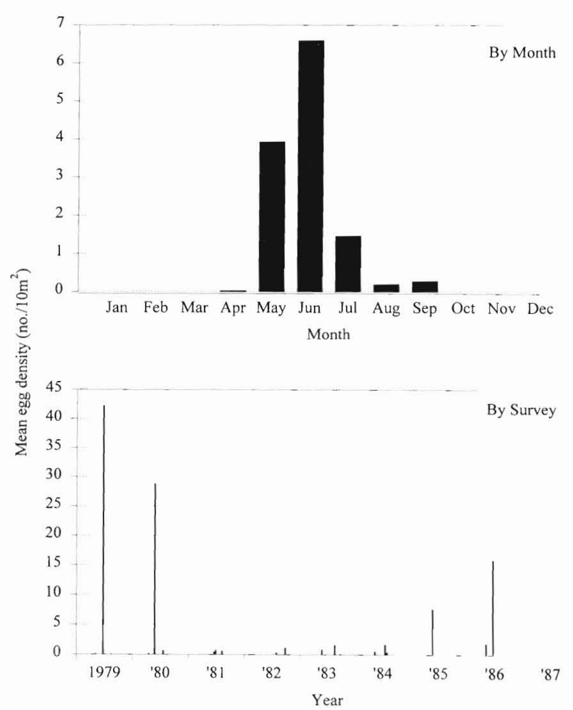


Figure 12
Anchoa hepsetus; mean-egg-density graphs by month (top) and by survey (bottom) for the total MARMAP area.

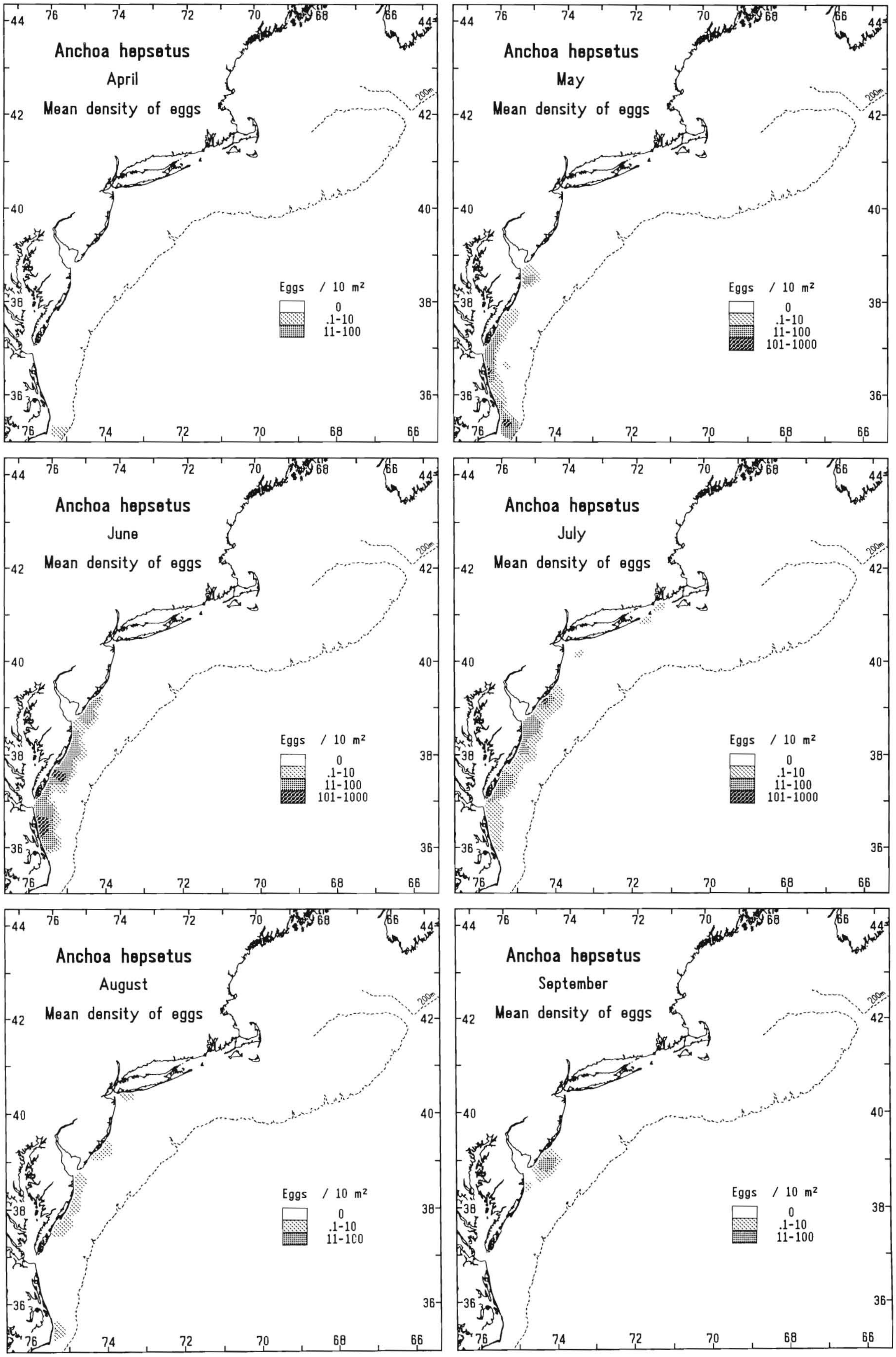


Figure 13

Anchoa hepsetus; composite monthly areal plots of mean egg densities (no./10 m²).

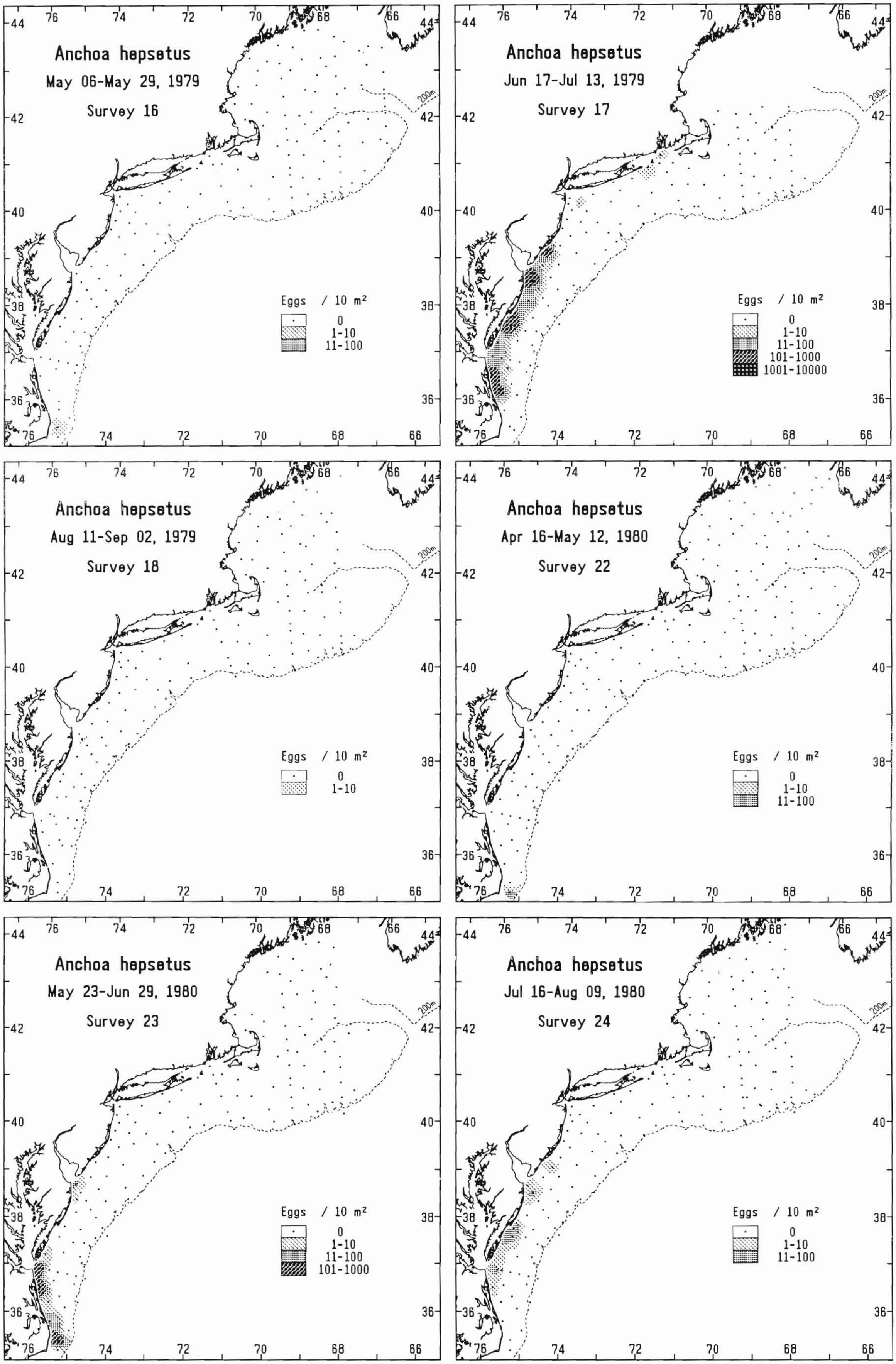
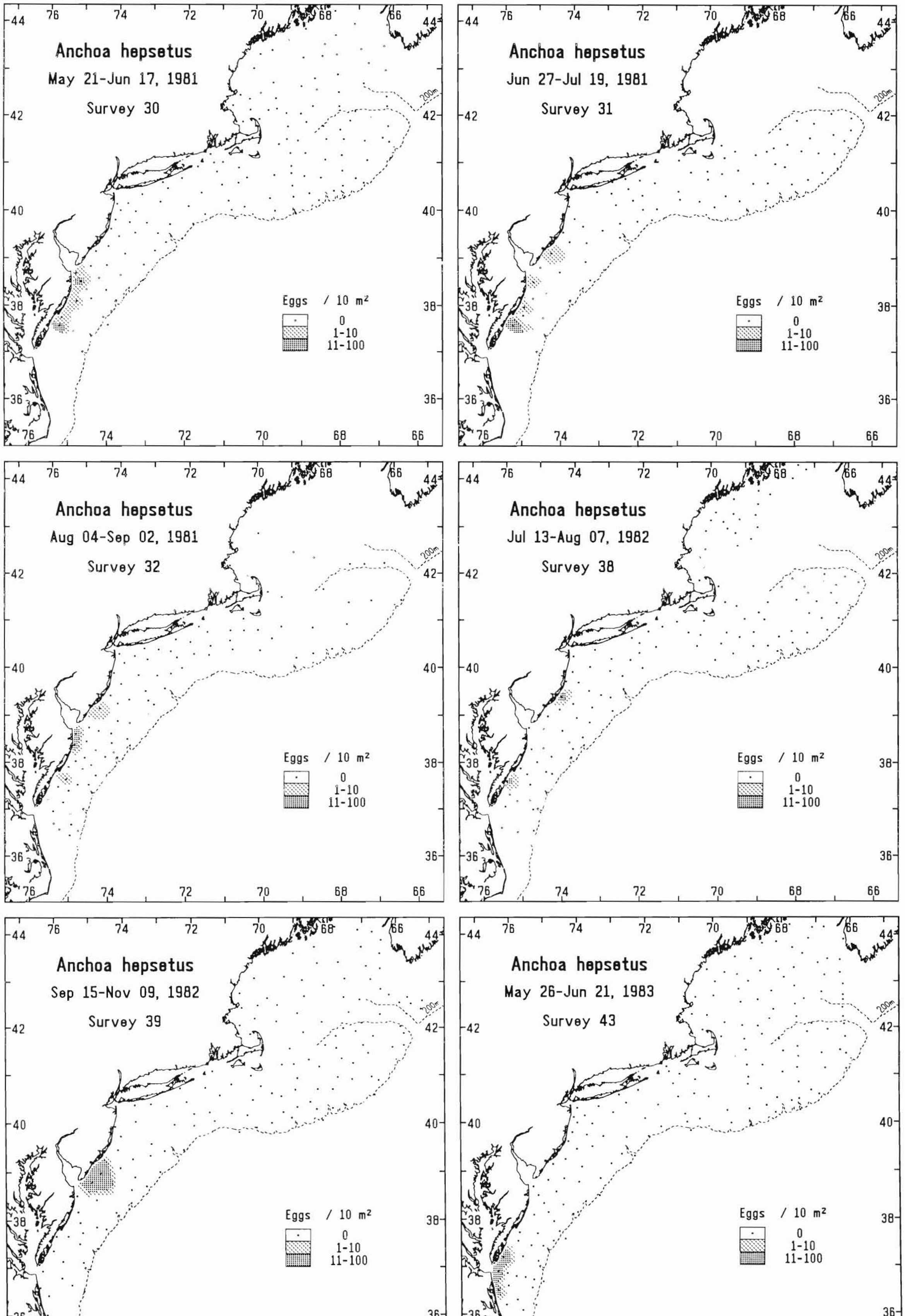


Figure 14

Anchoa hepsetus; survey areal plots of egg densities (no./10 m²).



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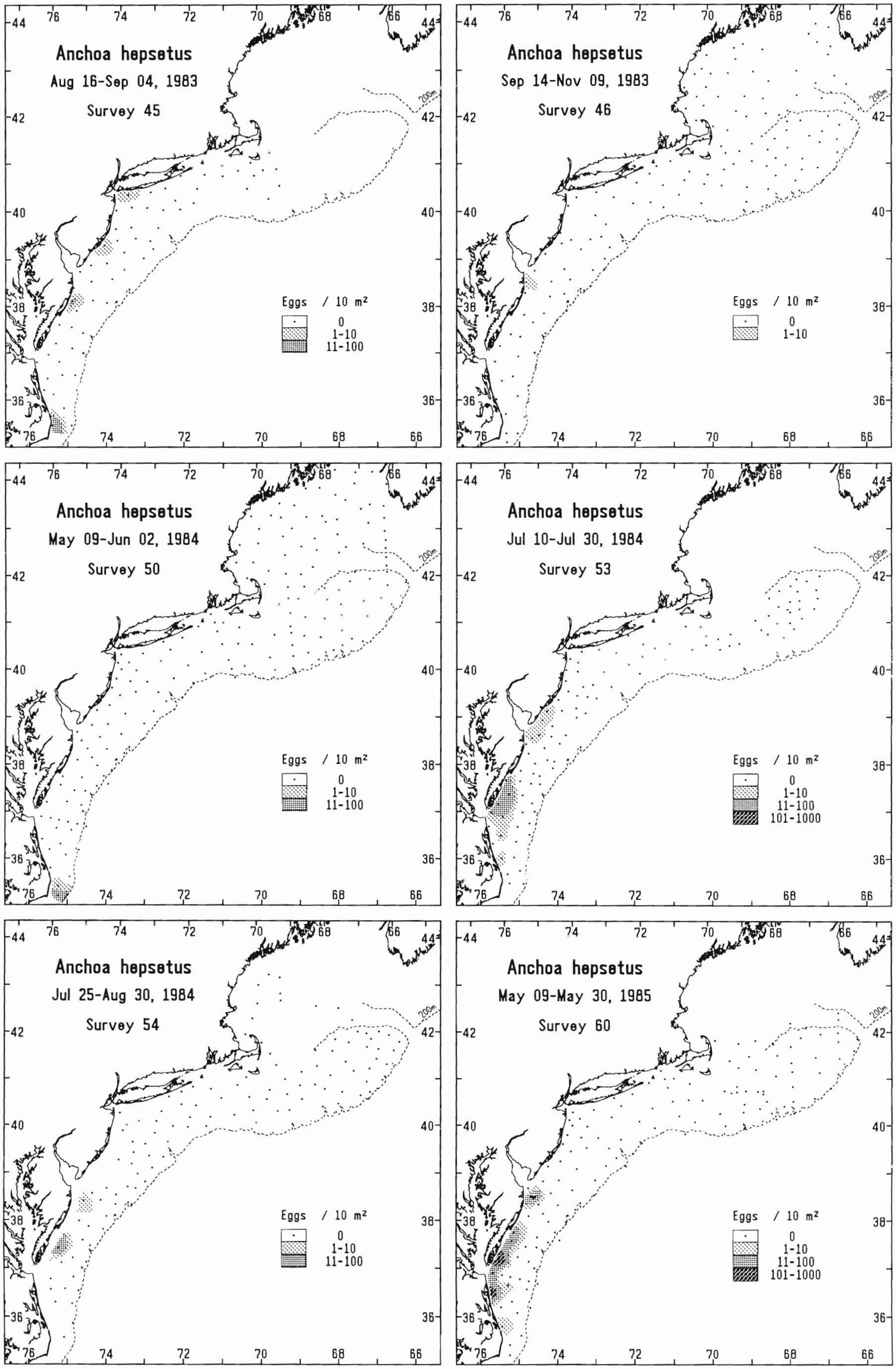

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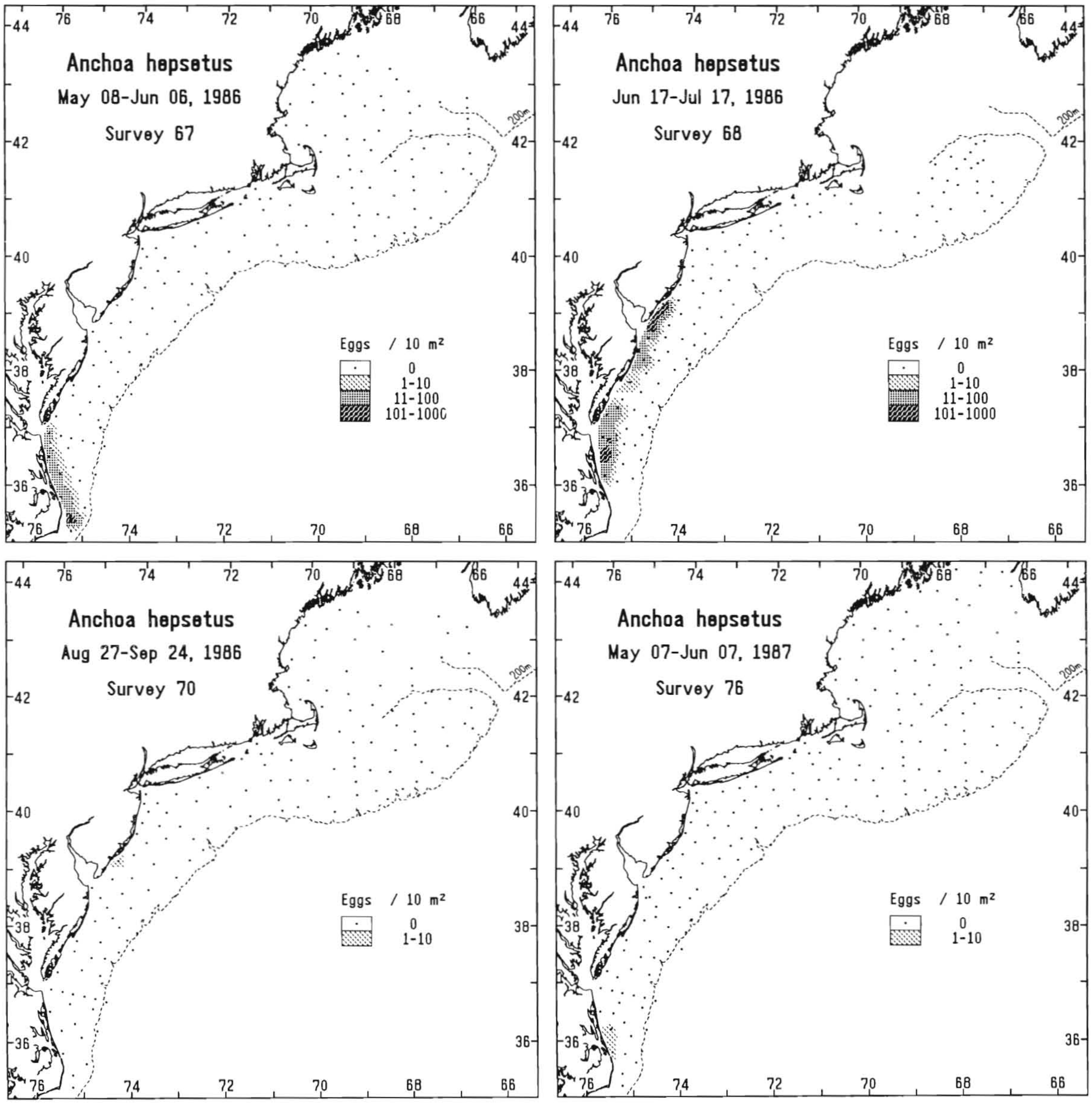


Figure 14 (continued)

Anchoa mitchilli, bay anchovy (Figs. 15–17)

Anchoa mitchilli eggs, the most abundant taxon collected, occurred predominantly in inner shelf waters of the Middle Atlantic and southern New England subareas during April through October, with peak abundances occurring in June or July (Fig. 15). The highest densities occurred close to shore, as would be expected for this estuarine species. Eggs were not collected east or north of Nantucket Shoals. Although the peak density in June (Fig. 15) was influenced strongly by collections from one survey in 1979 (no. 17), several tows contributed to this peak. If 1979 data were omitted, peak mean egg density would change to the month of July.

Based on occurrences of *A. mitchilli* eggs, spawning starts as early as April near Cape Hatteras, then rapidly expands northward in inner shelf waters through May and June, occurring as far north and east as Long Island, and occasionally to Narragansett Bay in July (Figs. 16 and 17). Between September and October spawning declined and appeared sporadic.

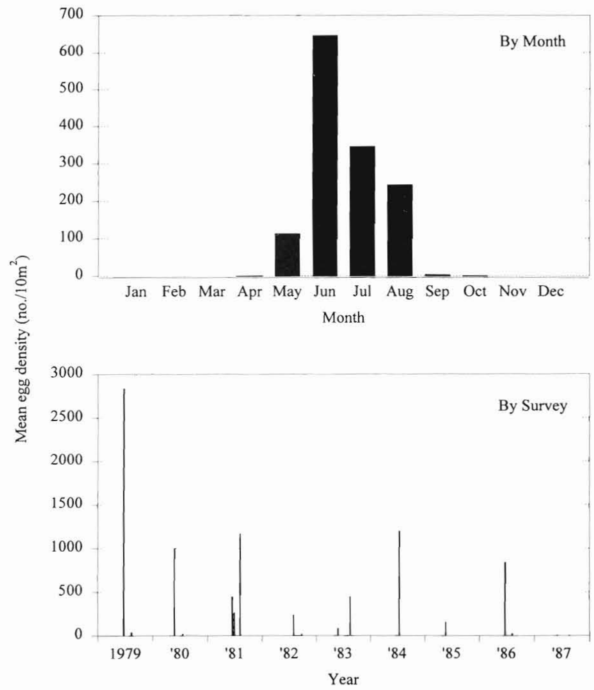


Figure 15
Anchoa mitchilli; mean-egg-density graphs by month (top) and by survey (bottom) for the total MARMAP area.

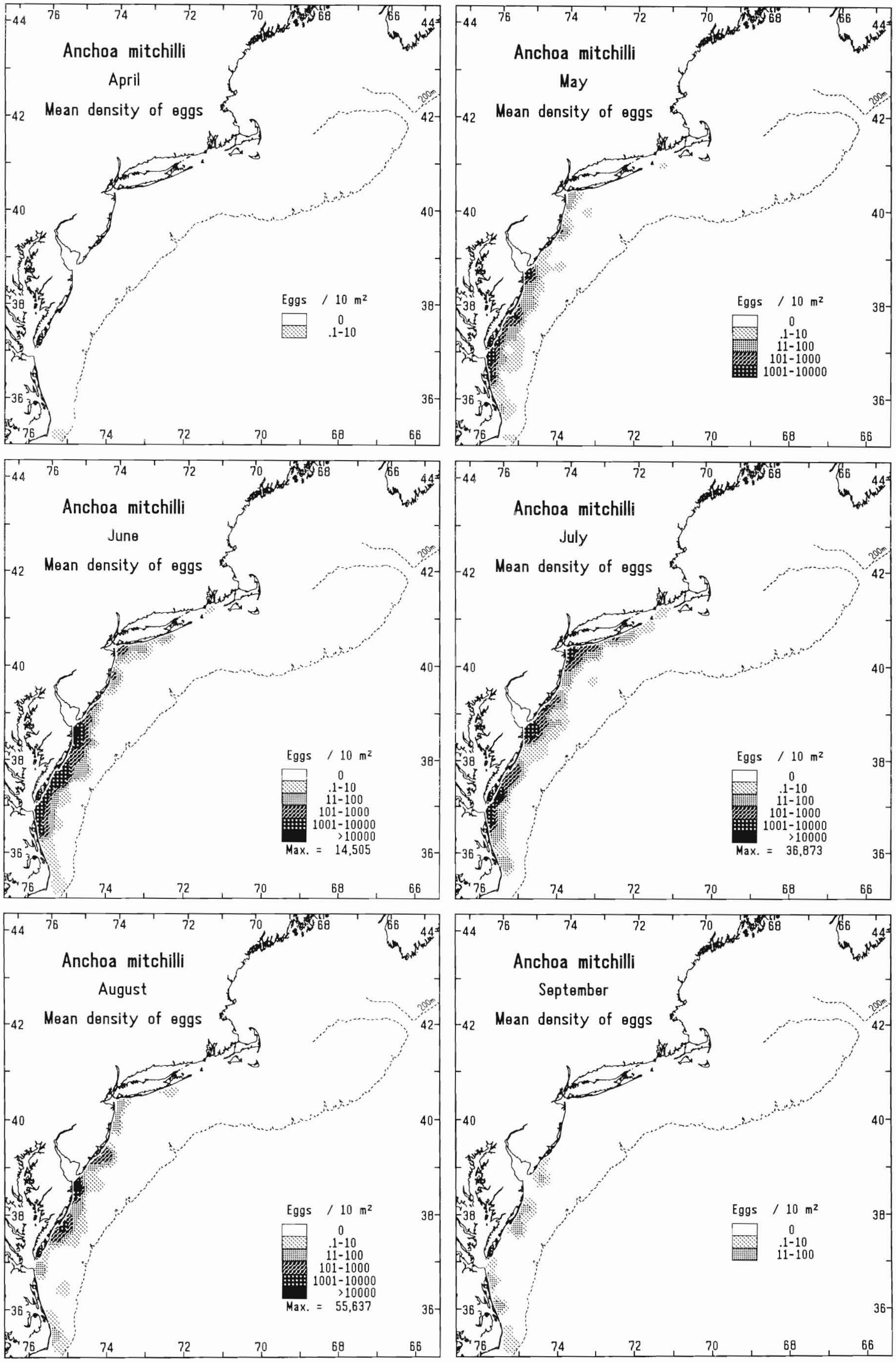


Figure 16

Anchoa mitchilli; composite monthly areal plots of mean egg densities (no./10 m²).

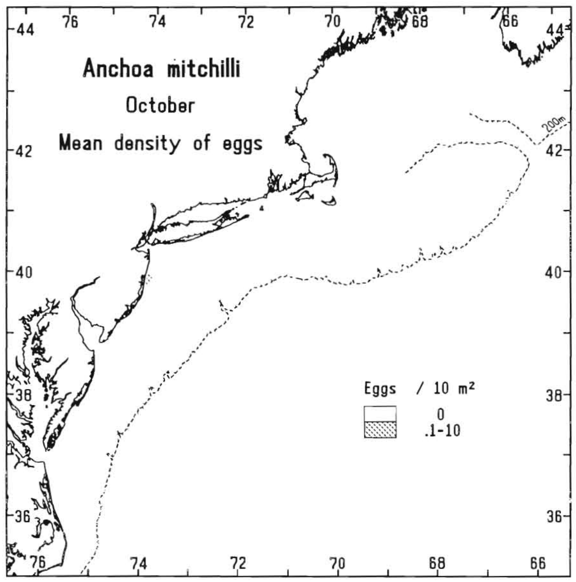


Figure 16 (continued)

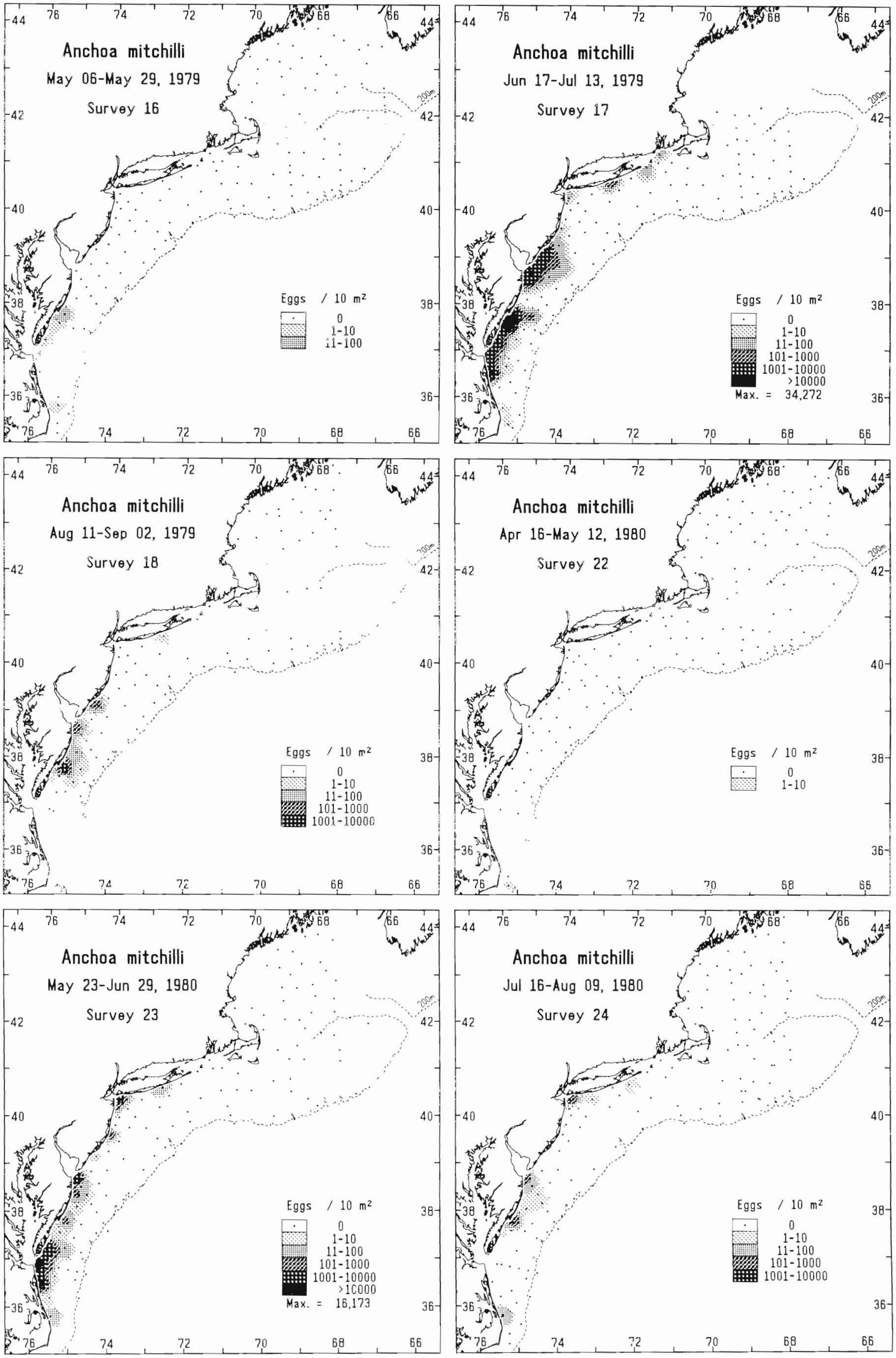
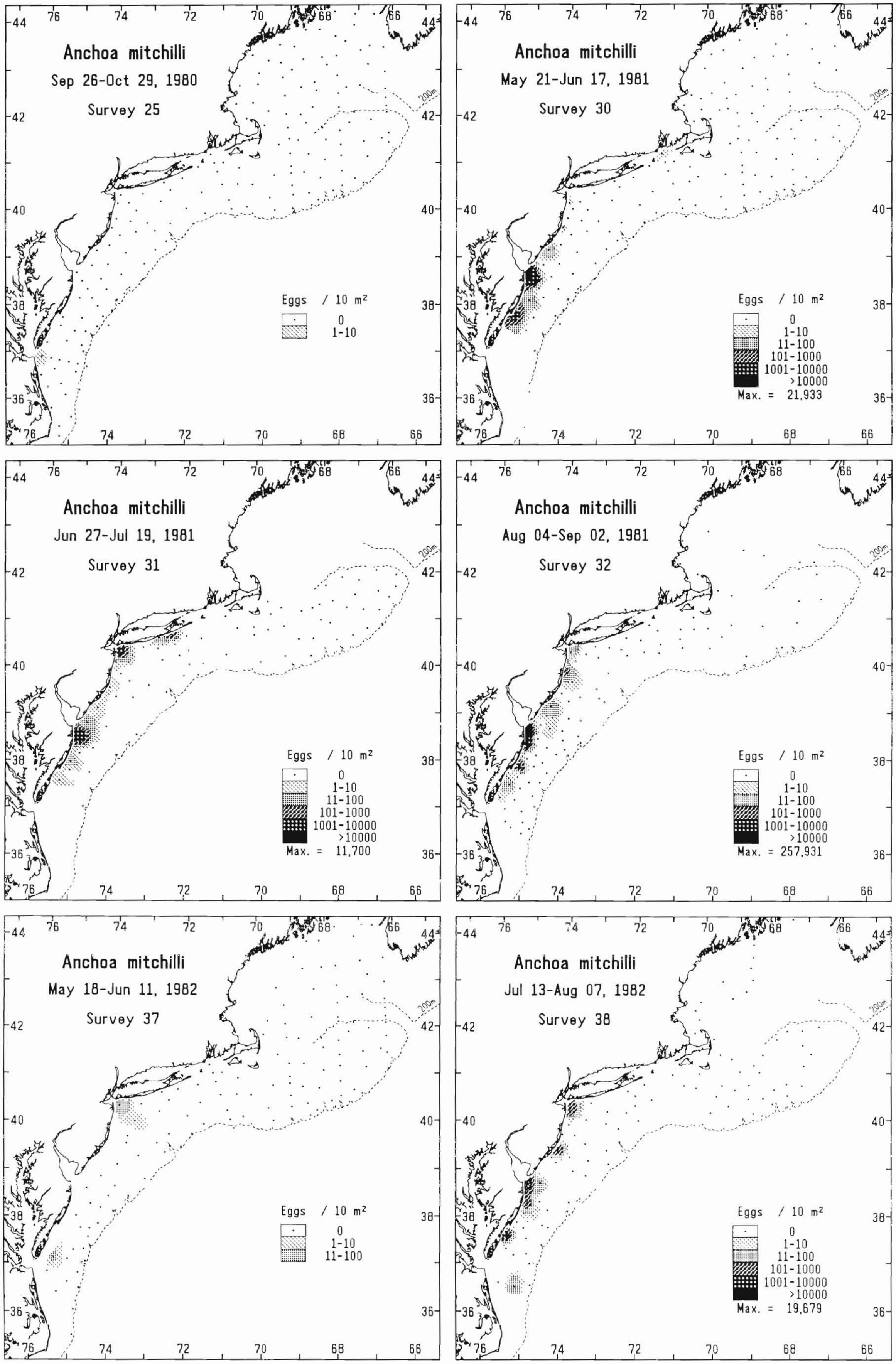


Figure 17

Anchoa mitchilli; survey areal plots of egg densities (no./10 m²).



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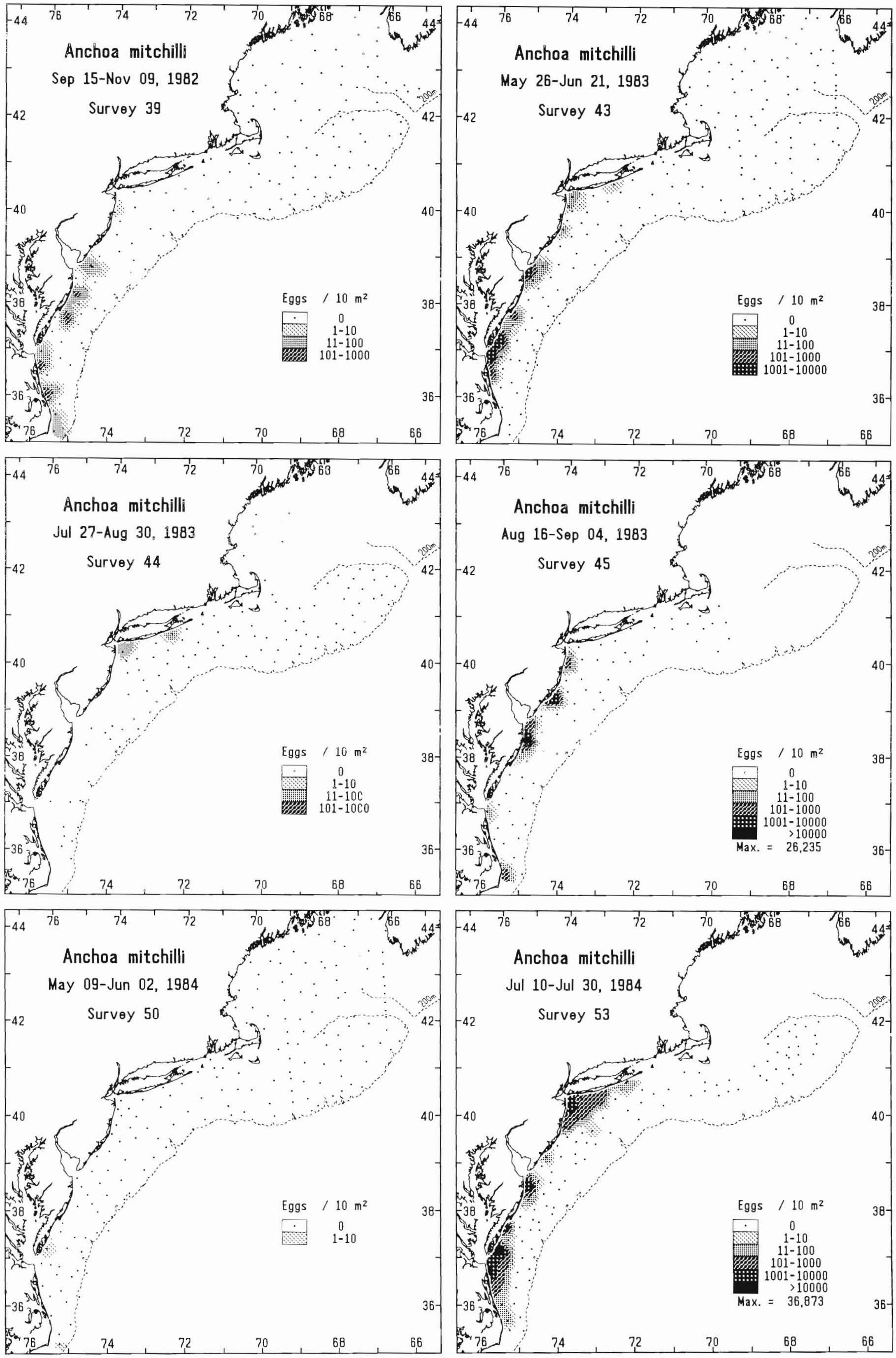

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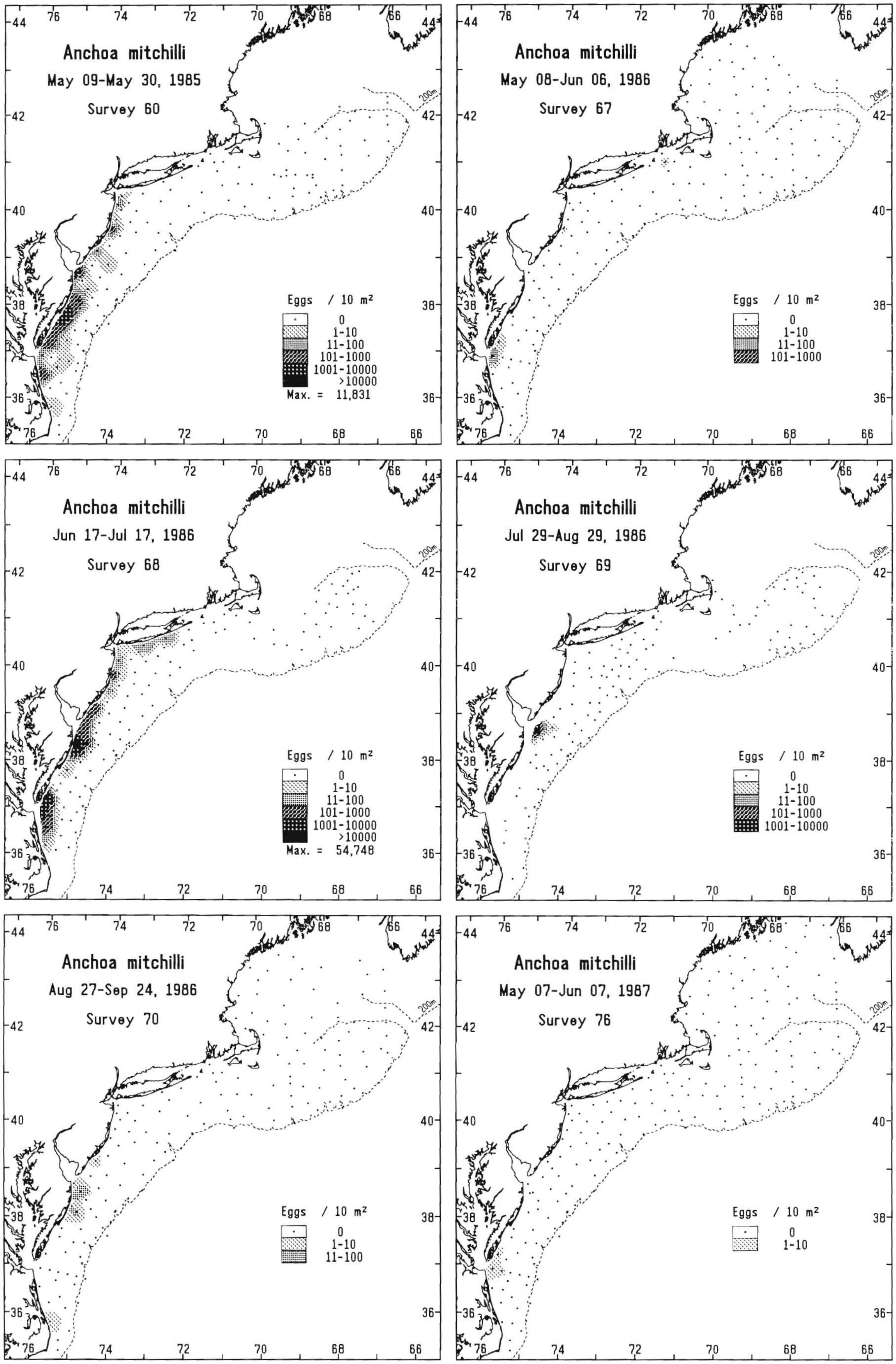

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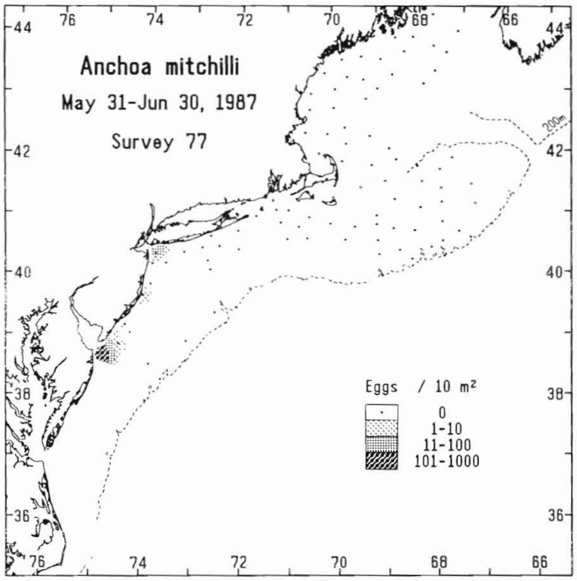
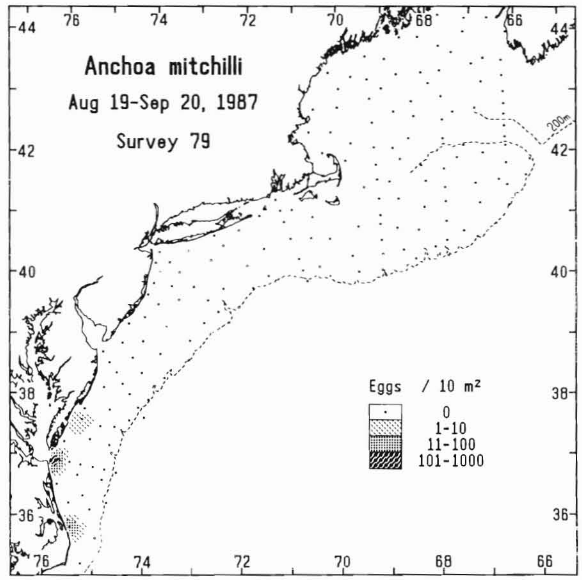




Maurolicus muelleri, Müller's pearlsides (Figs. 18–20)

Maurolicus muelleri eggs were collected throughout the year. A seasonal cycle in egg abundance was apparent with a minimum from February to April and a maximum from September to November (Fig. 18). Eggs of this mesopelagic species occurred primarily in shelf edge waters. Occasionally, during September to December, eggs were collected in isolated locations in western Gulf of Maine, northwestern Georges Bank, and southern New England waters (Fig. 19).

Eggs occurred in isolated locations along the shelf edge of Middle Atlantic, southern New England, and Georges Bank subareas during the period of minimal spawning from February to April. As spawning gradually increased from May to August, eggs occurred in these same areas, but more frequently and in somewhat greater numbers. With highest egg densities in September, egg distribution was almost continuous along the shelf edge from off Cape Hatteras to southeastern Georges Bank, and in scattered locations in Georges Bank and Gulf of Maine subareas (Fig. 19). Thereafter, mean monthly egg densities decreased while spawning diminished in intensity along the shelf edge. Mean egg densities during August, October, and December were probably underestimated due to incomplete coverage of shelf edge waters.

There appeared to be an upward trend in *M. muelleri* spawning levels over the years sampled (Fig. 18). However, only the inner portion of the apparent spawning area was sampled.

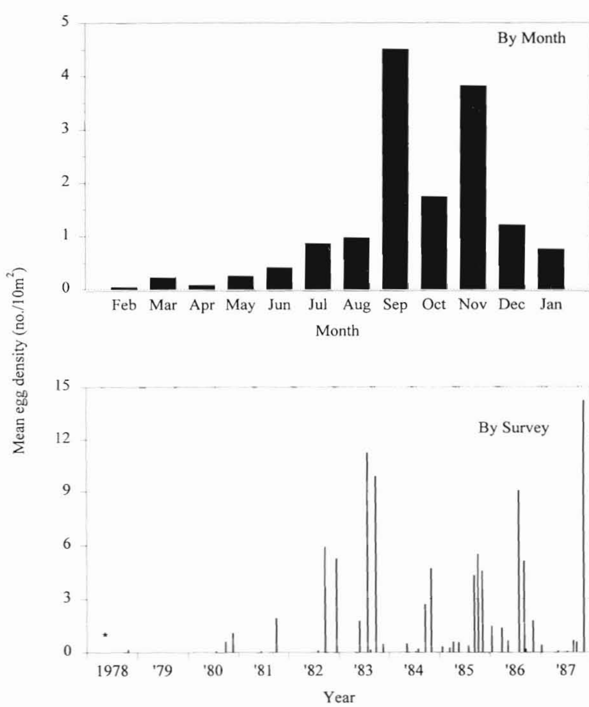


Figure 18
Maurolicus muelleri; mean-egg-density graphs by month (top) and by survey (bottom) for the total MARMAP area. (*Samples from the first four surveys in 1978 were not analyzed for *M. muelleri* eggs.)

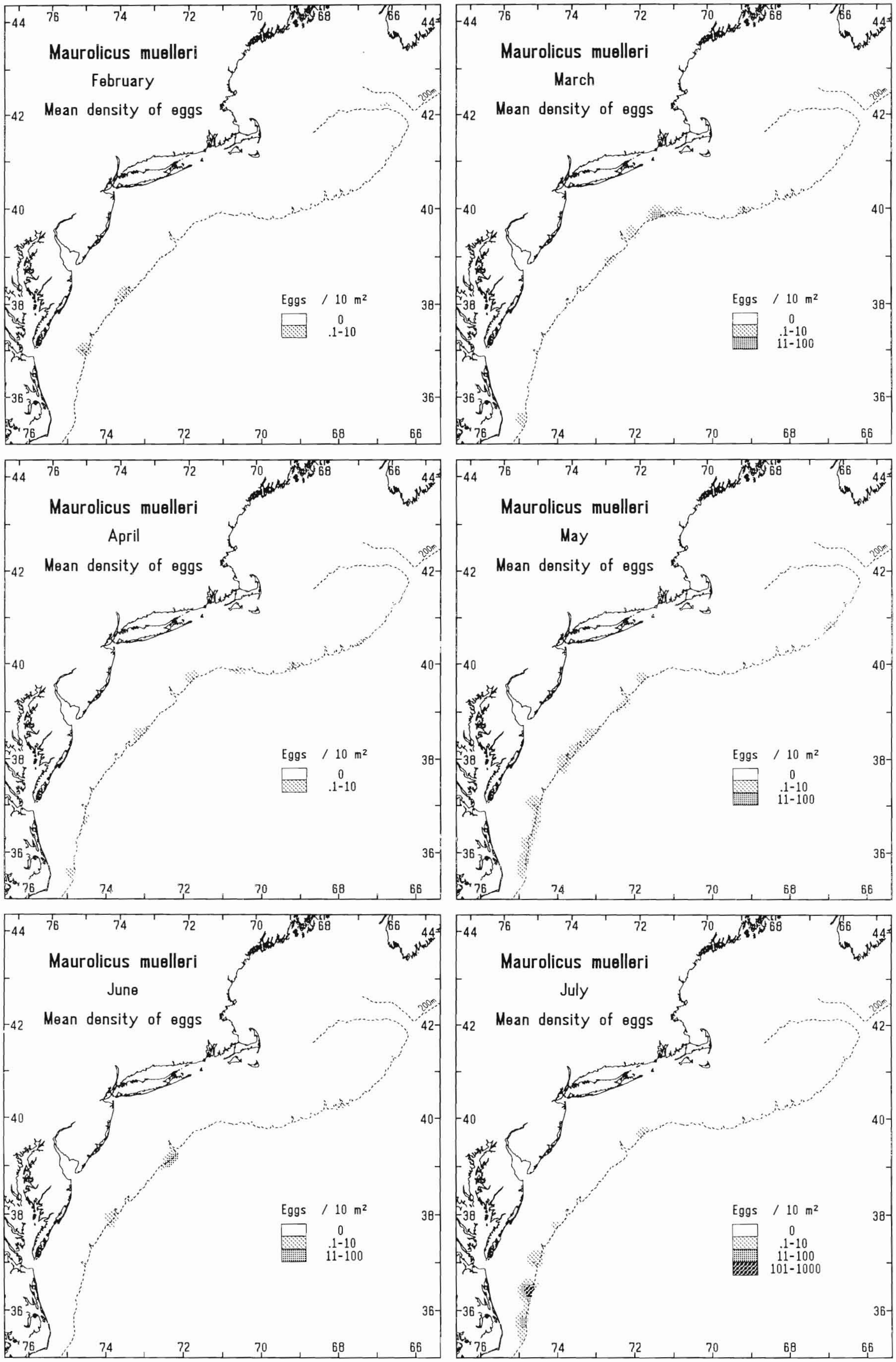
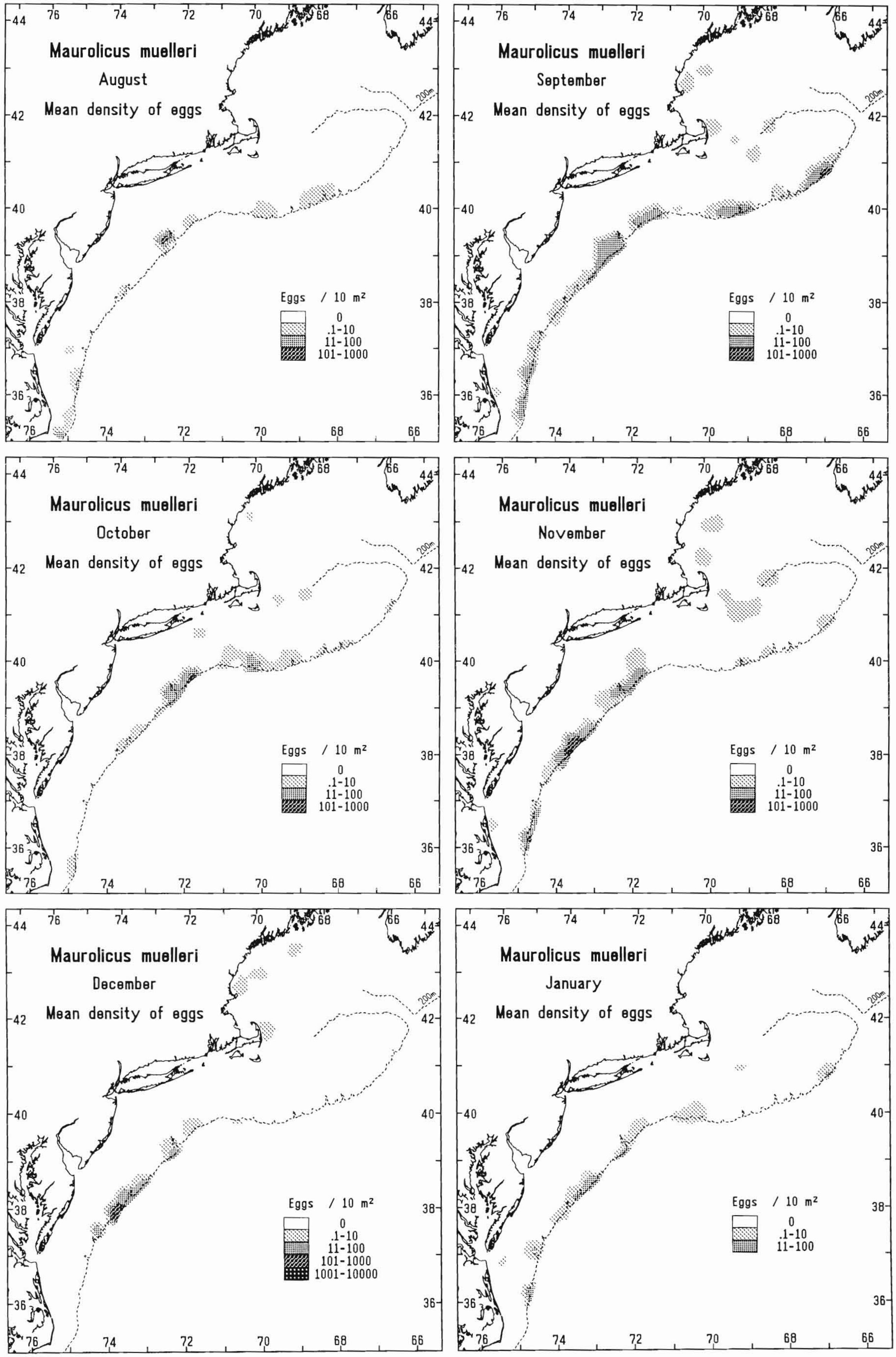


Figure 19

Maurolicus muelleri; composite monthly areal plots of mean egg densities (no./10 m^2).



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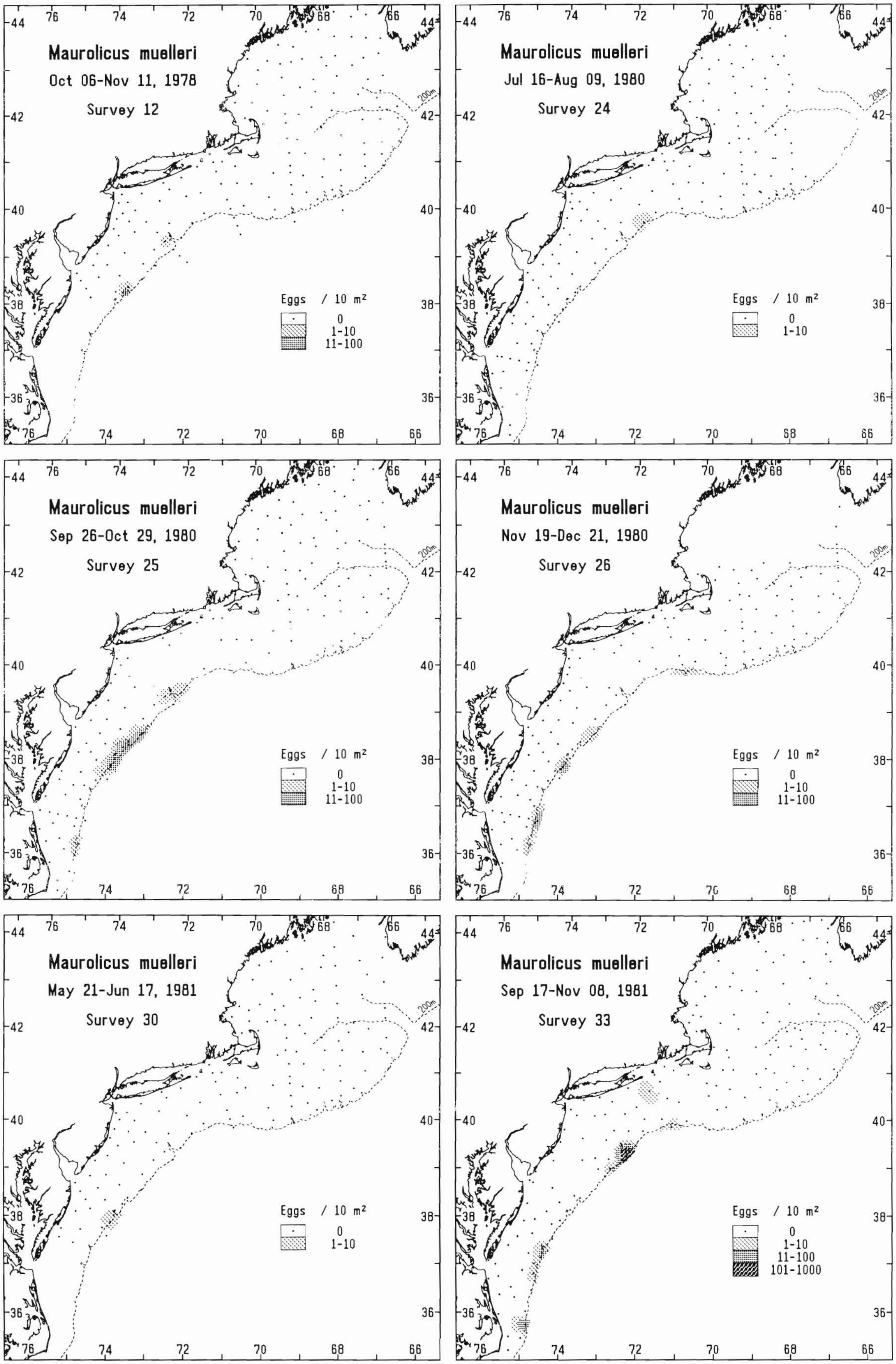
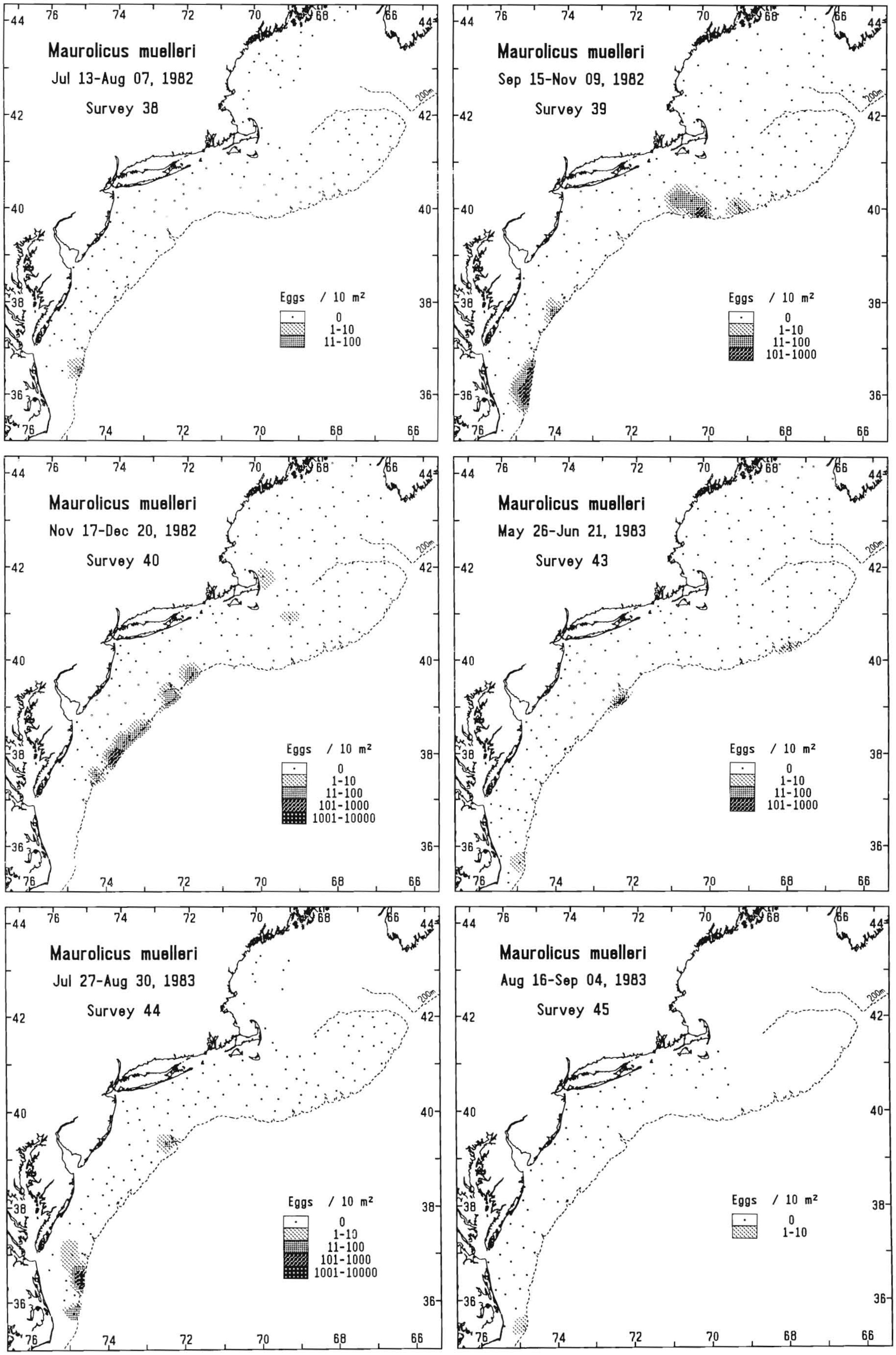


Figure 20

Maurolicus muelleri; survey areal plots of egg densities (no./10 m²).



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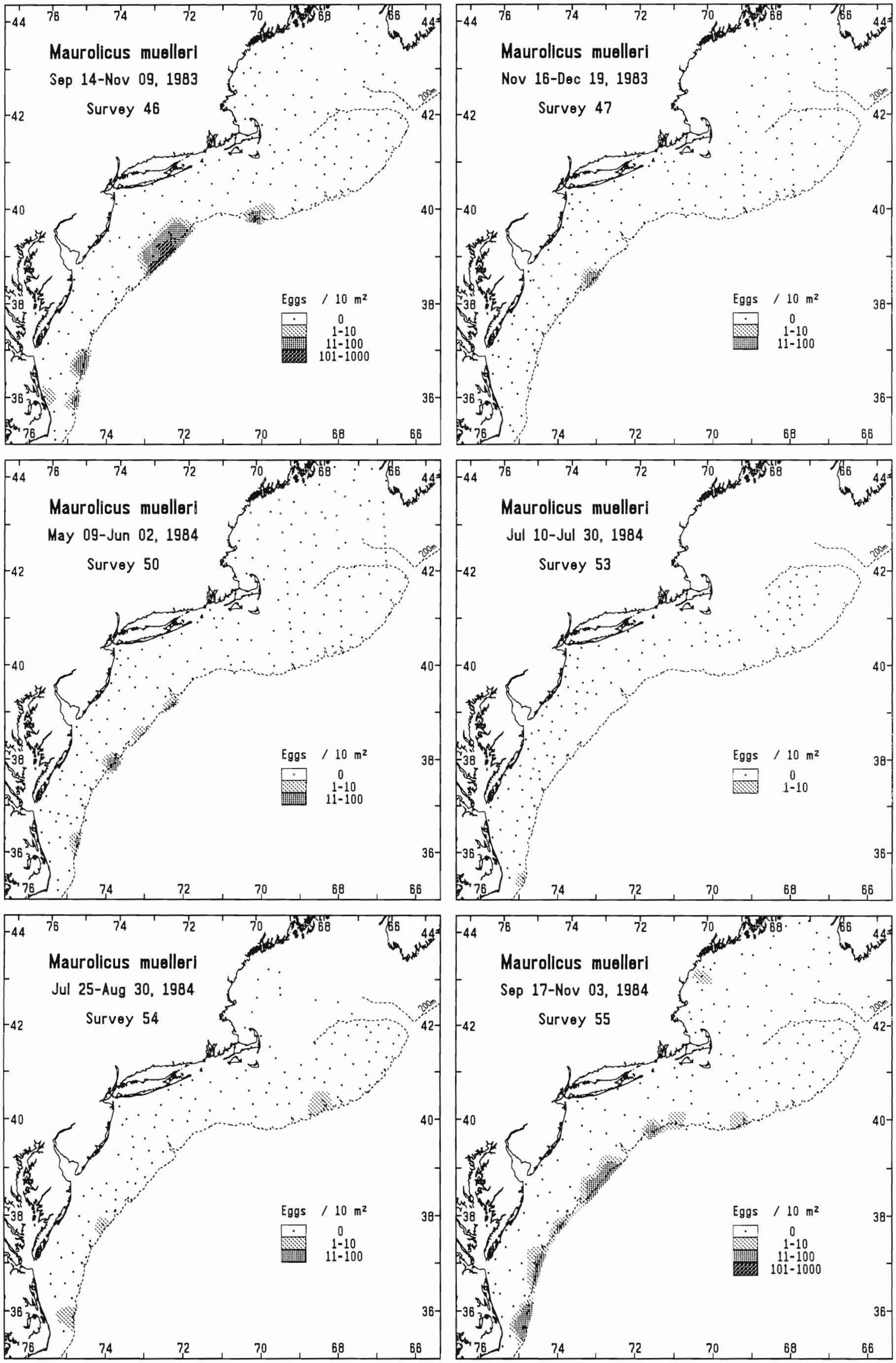

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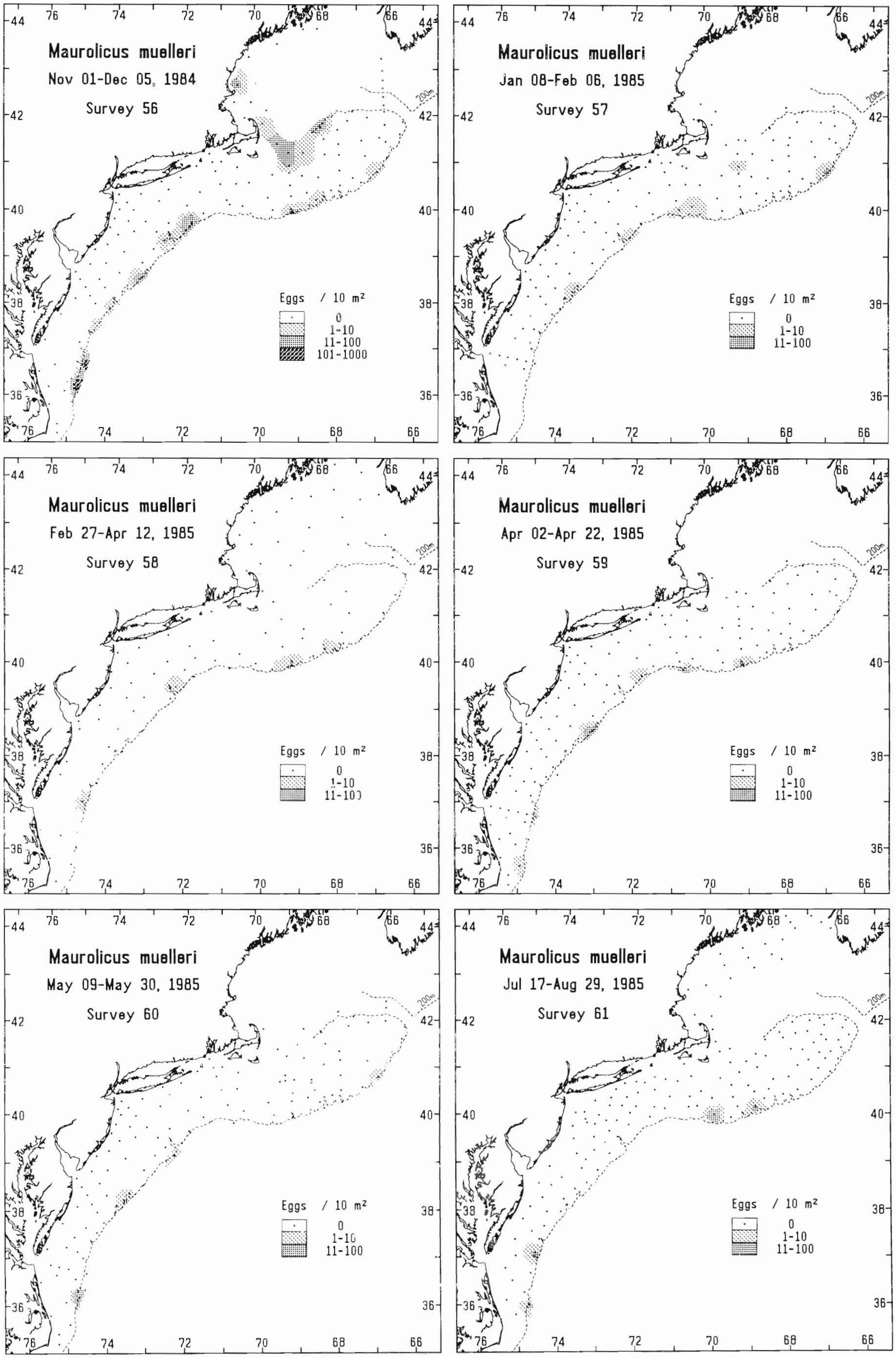

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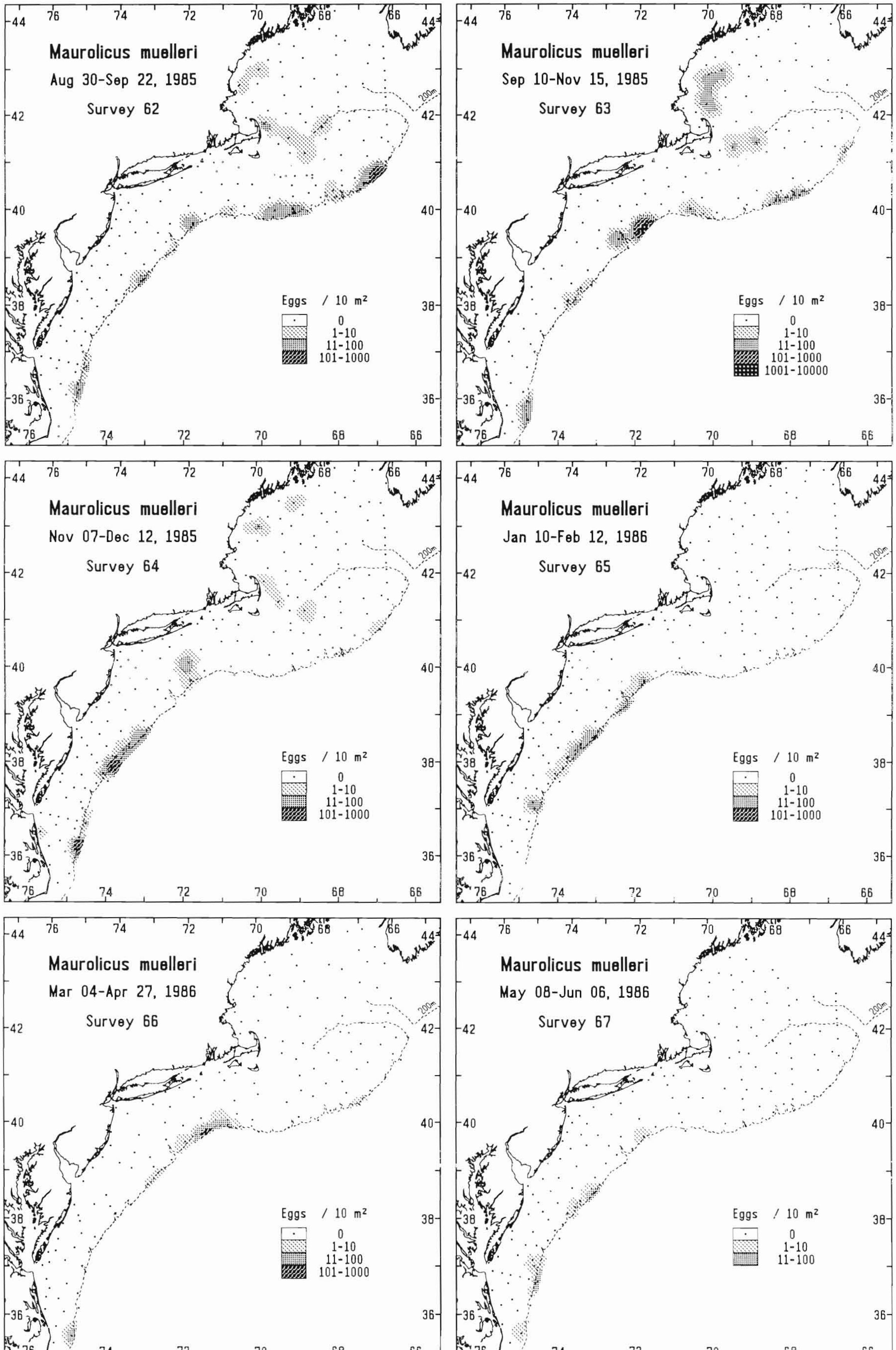

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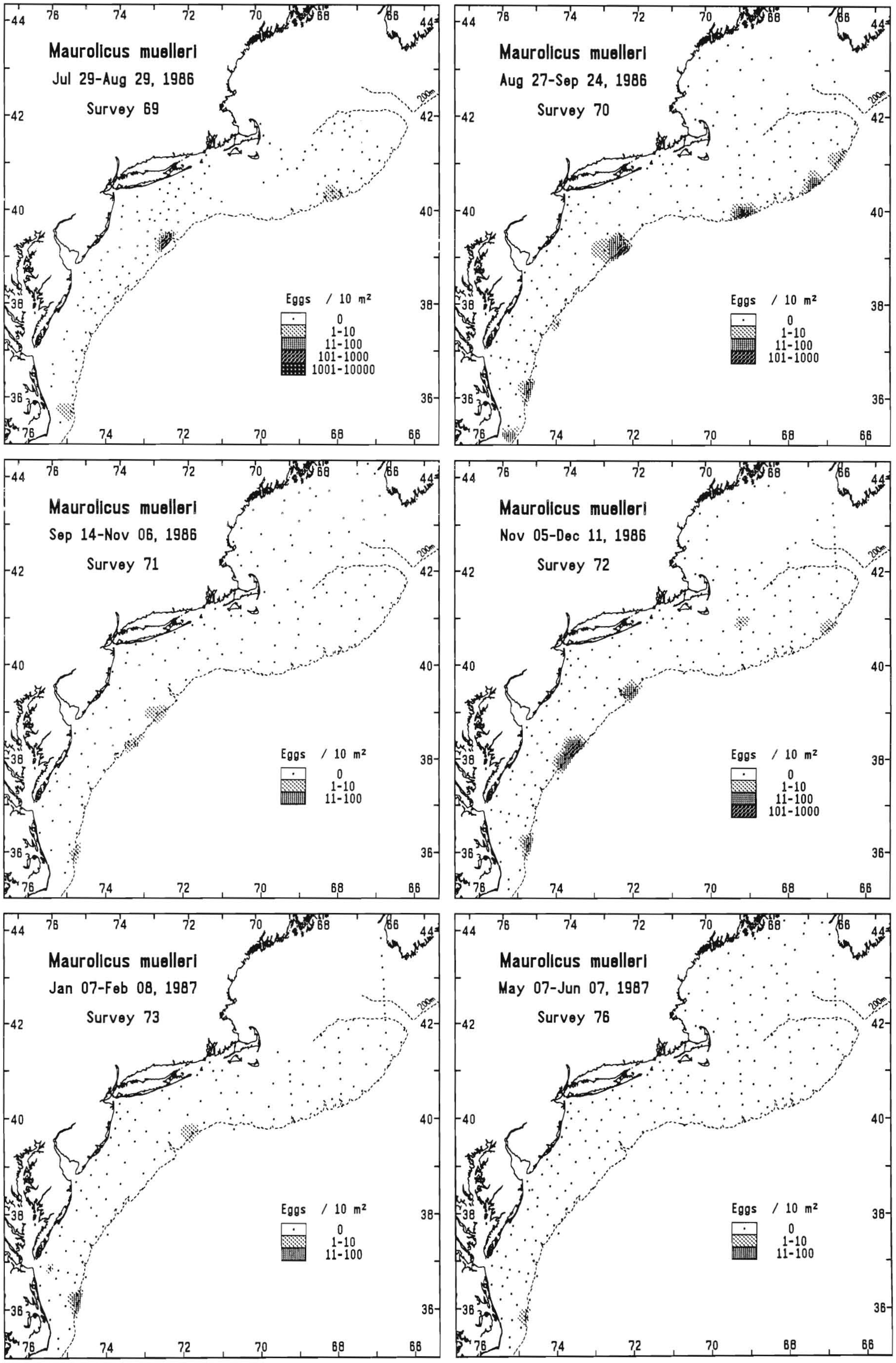

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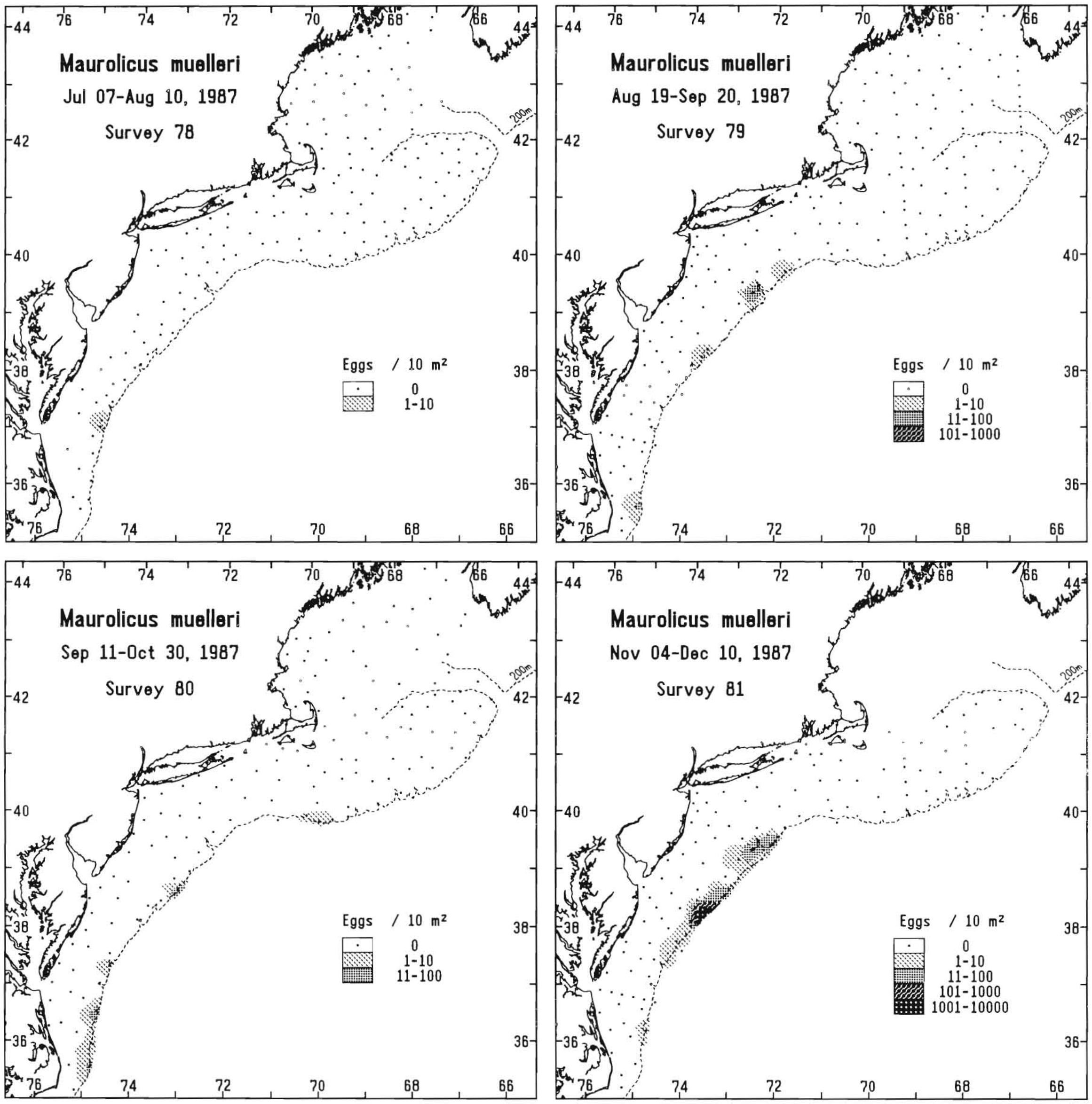


Figure 20 (continued)

Brosme brosme, cusk (Figs. 21–23)

Brosme brosme eggs occurred primarily in the Gulf of Maine and Georges Bank subareas and occasionally in southern New England and Middle Atlantic waters (Fig. 22). They were collected from March to November and were most abundant in late spring and summer (Fig. 21).

Spawning began in some years as early as March, but more often in April. Eggs occasionally occurred along the shelf edge as far south as Virginia and Maryland, but more commonly along the southern and eastern portions of Georges Bank, and at scattered locations in the Gulf of Maine. During May and June spawning increased, with eggs occurring extensively throughout the Gulf of Maine subarea and over the southern portion of Georges Bank. Spawning simultaneously declined throughout all areas from July to November.

The high egg densities in 1983 (survey 43) do not appear related to bias in sampling coverage. The entire MARMAP area was sampled during that survey without bias to any particular subarea or location (Fig. 23).

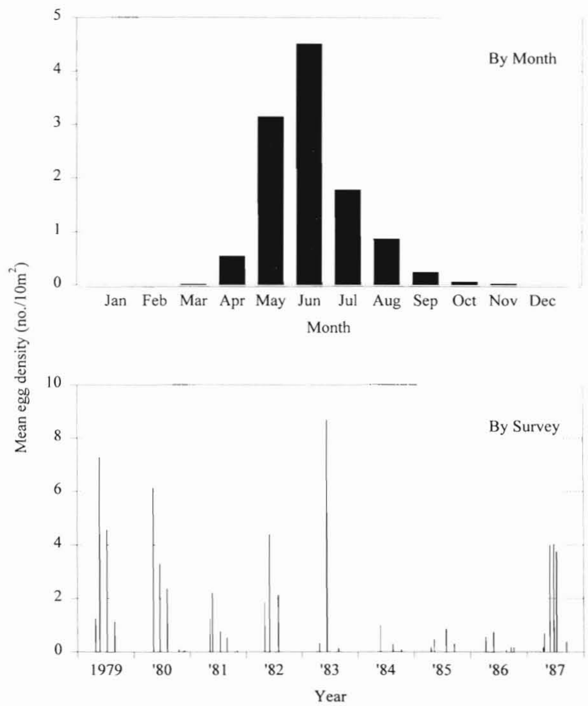


Figure 21
Brosme brosme; mean-egg-density graphs by month (top) and by survey (bottom) for the total MARMAP area.

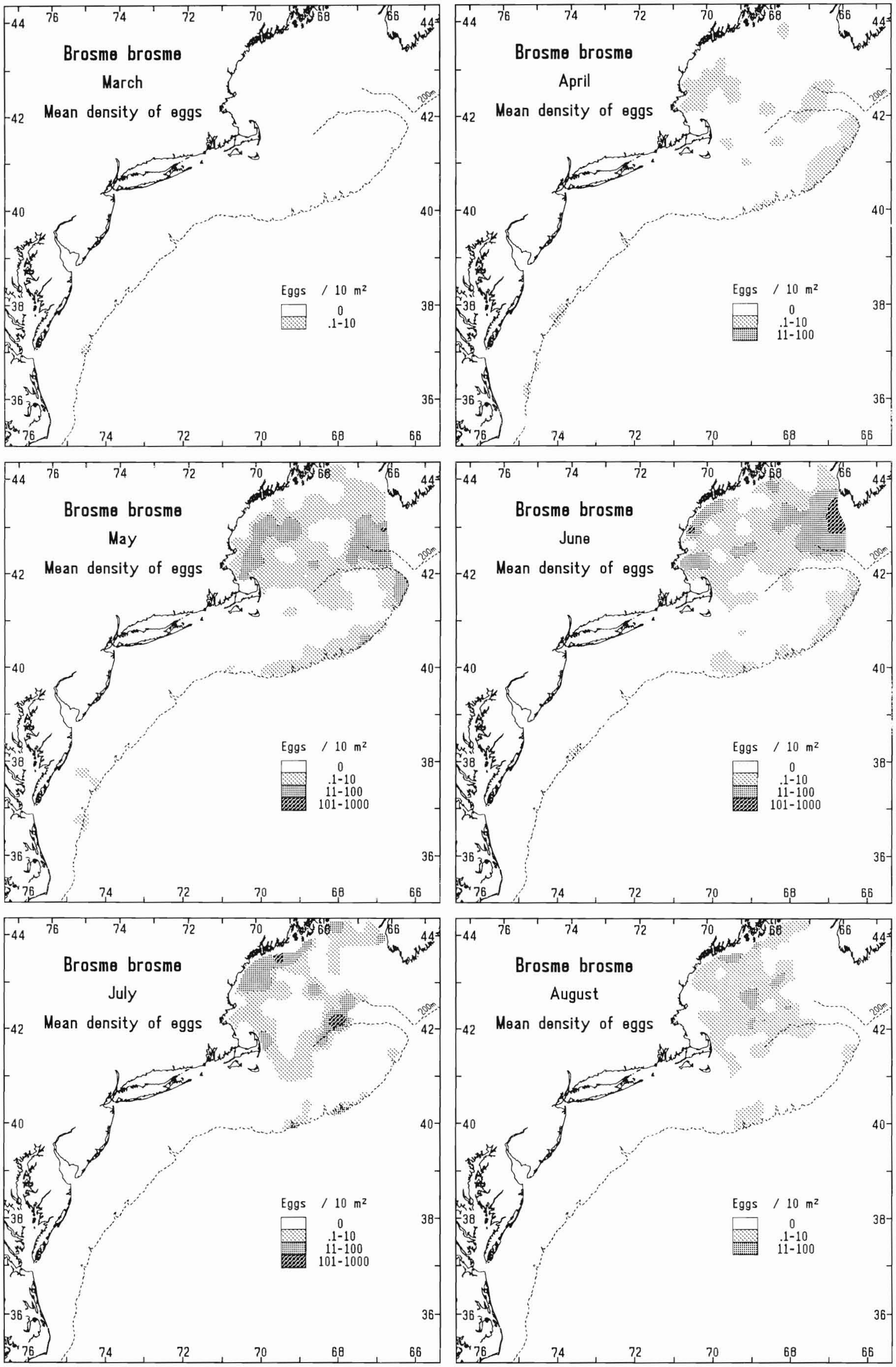
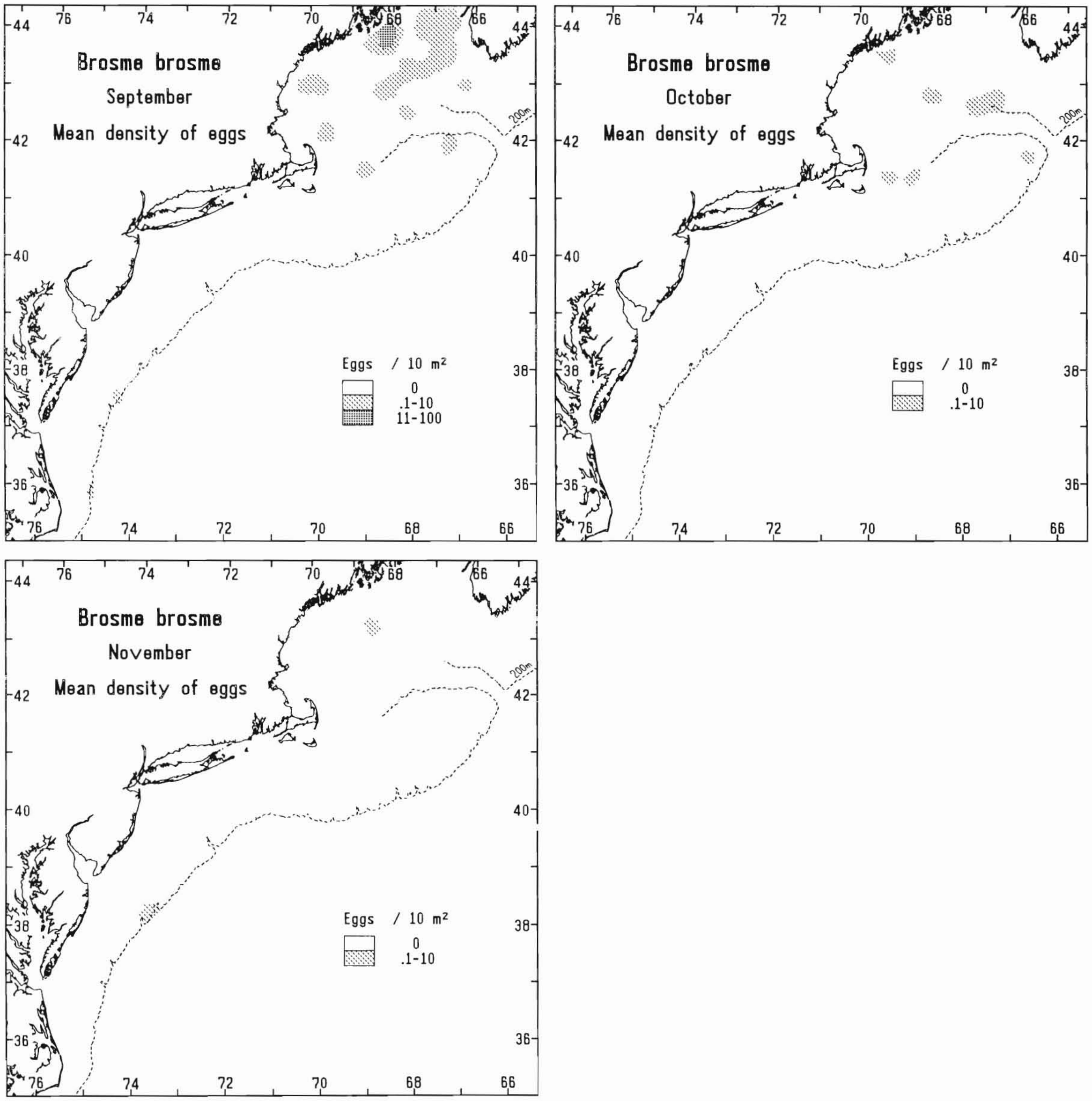


Figure 22
Brosme brosme; composite monthly areal plots of mean egg densities (no./10 m²).



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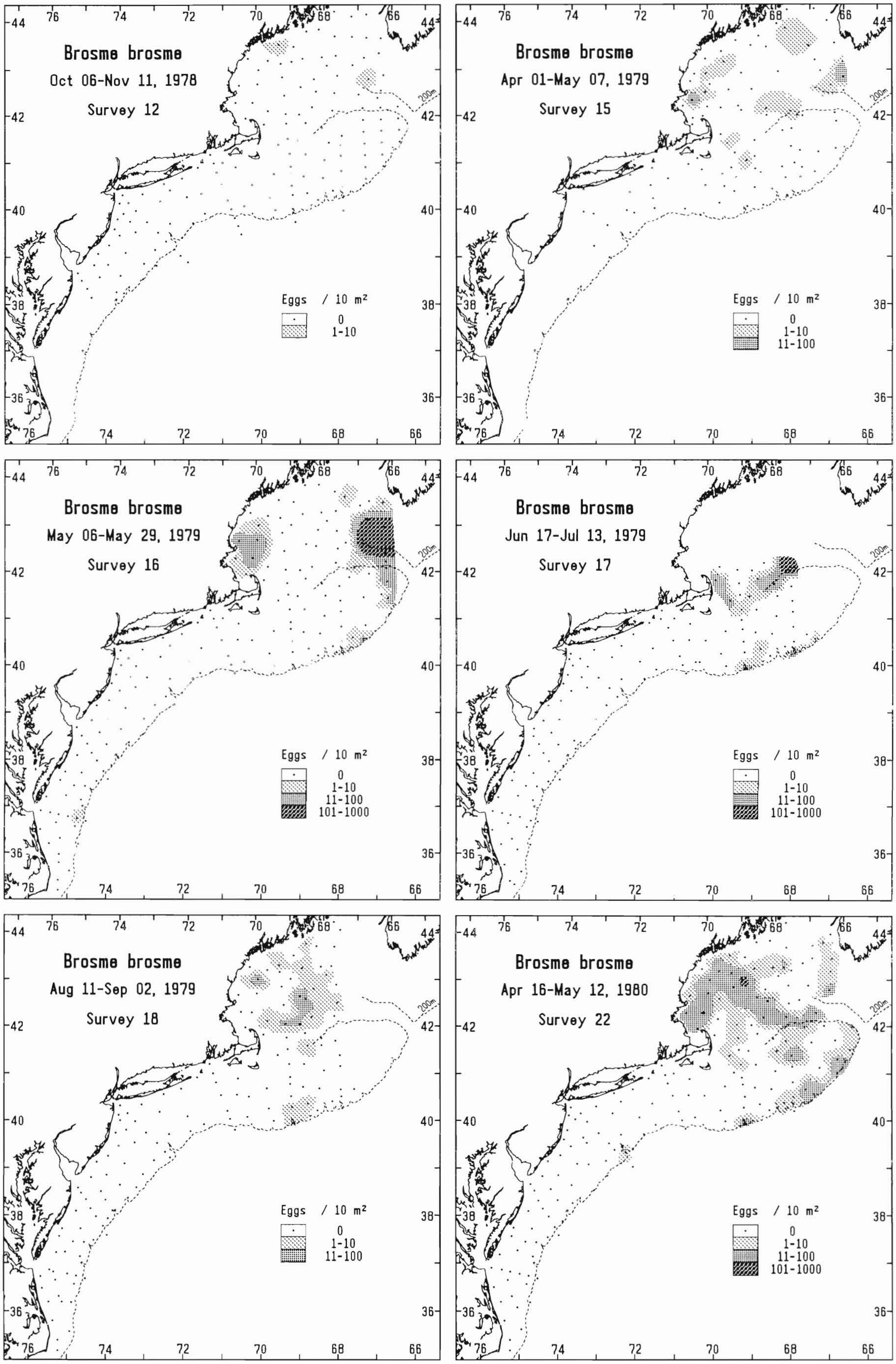
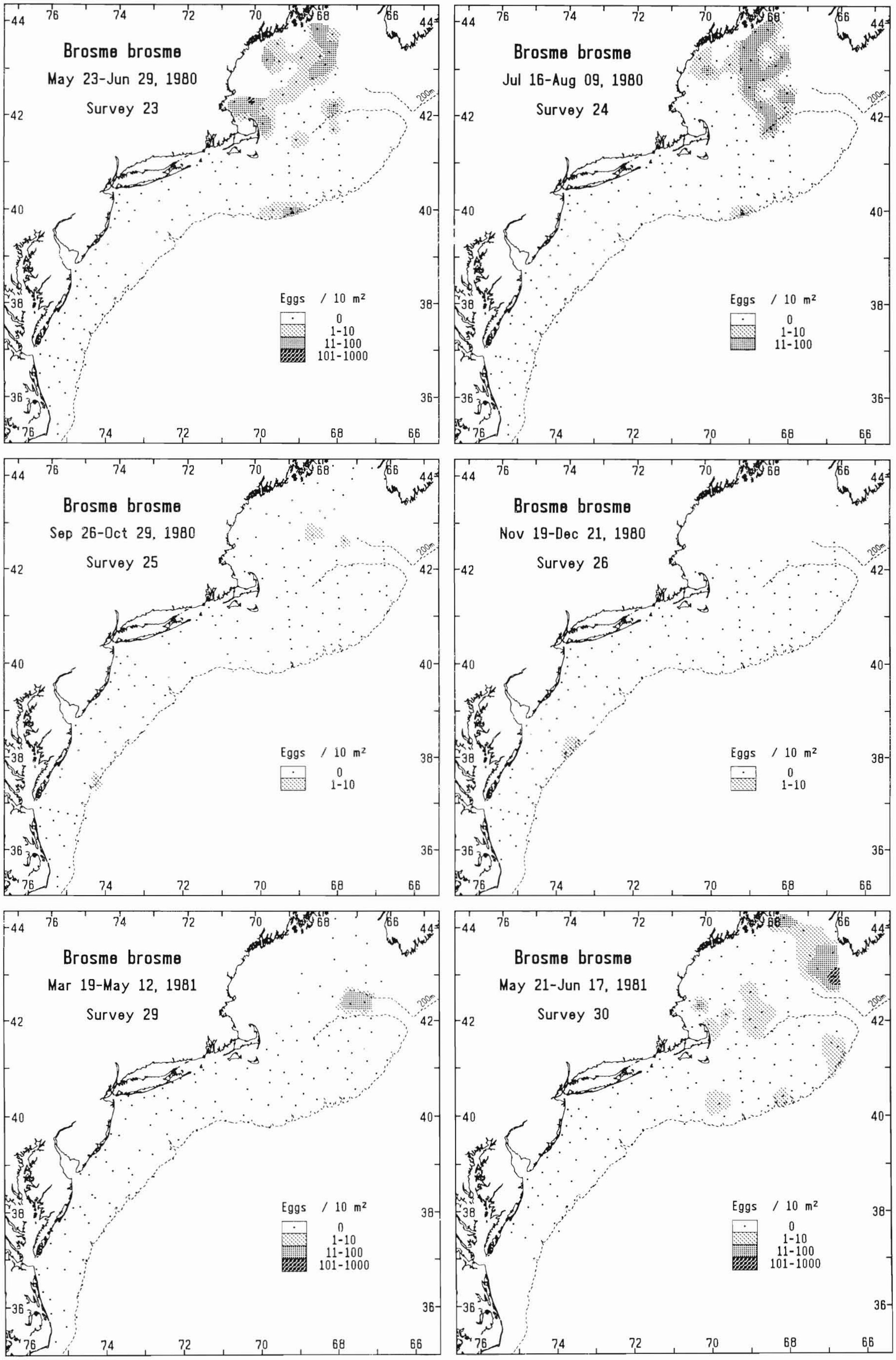


Figure 23

Brosme brosme; survey areal plots of egg densities (no./10 m²).



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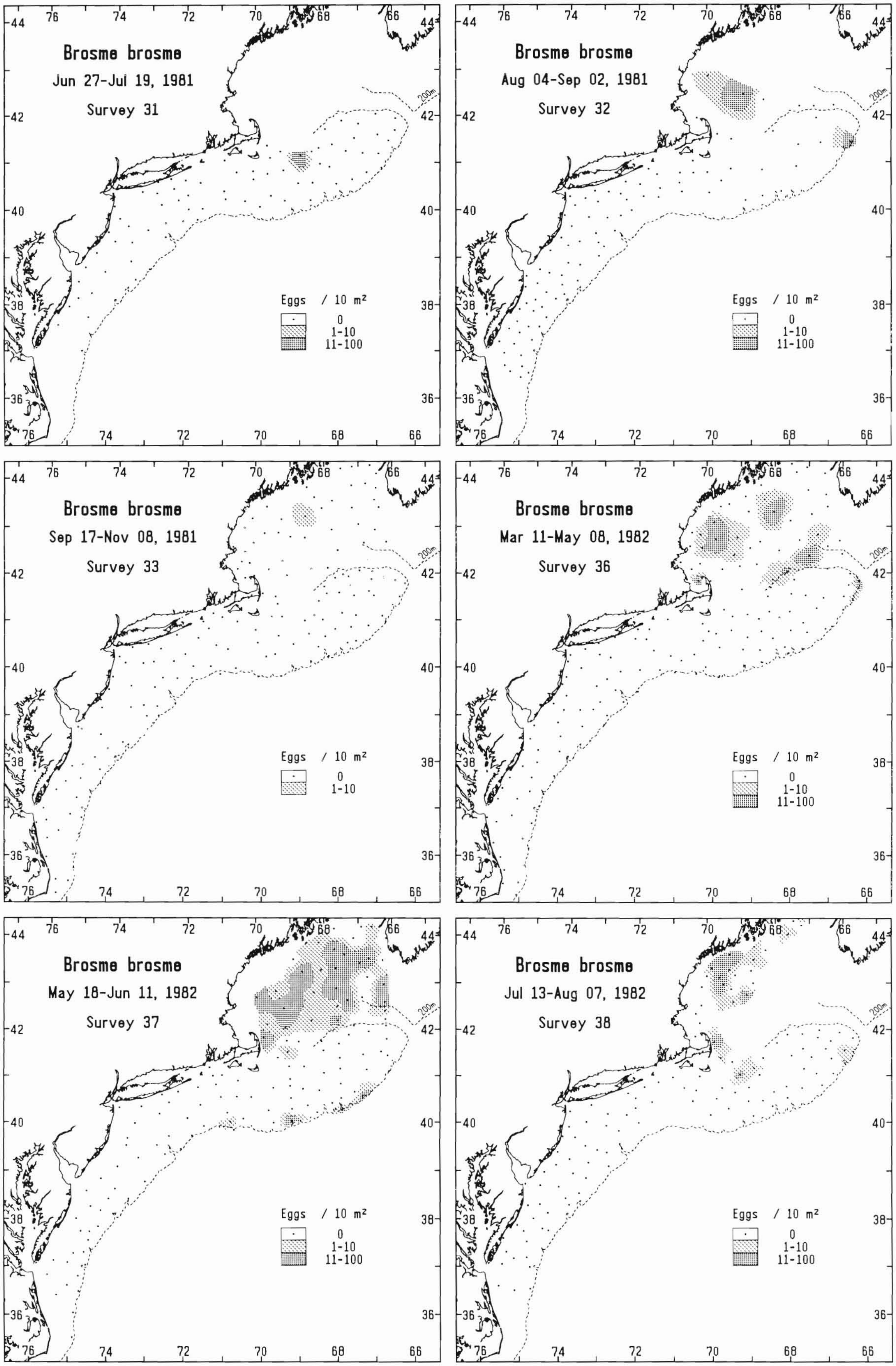

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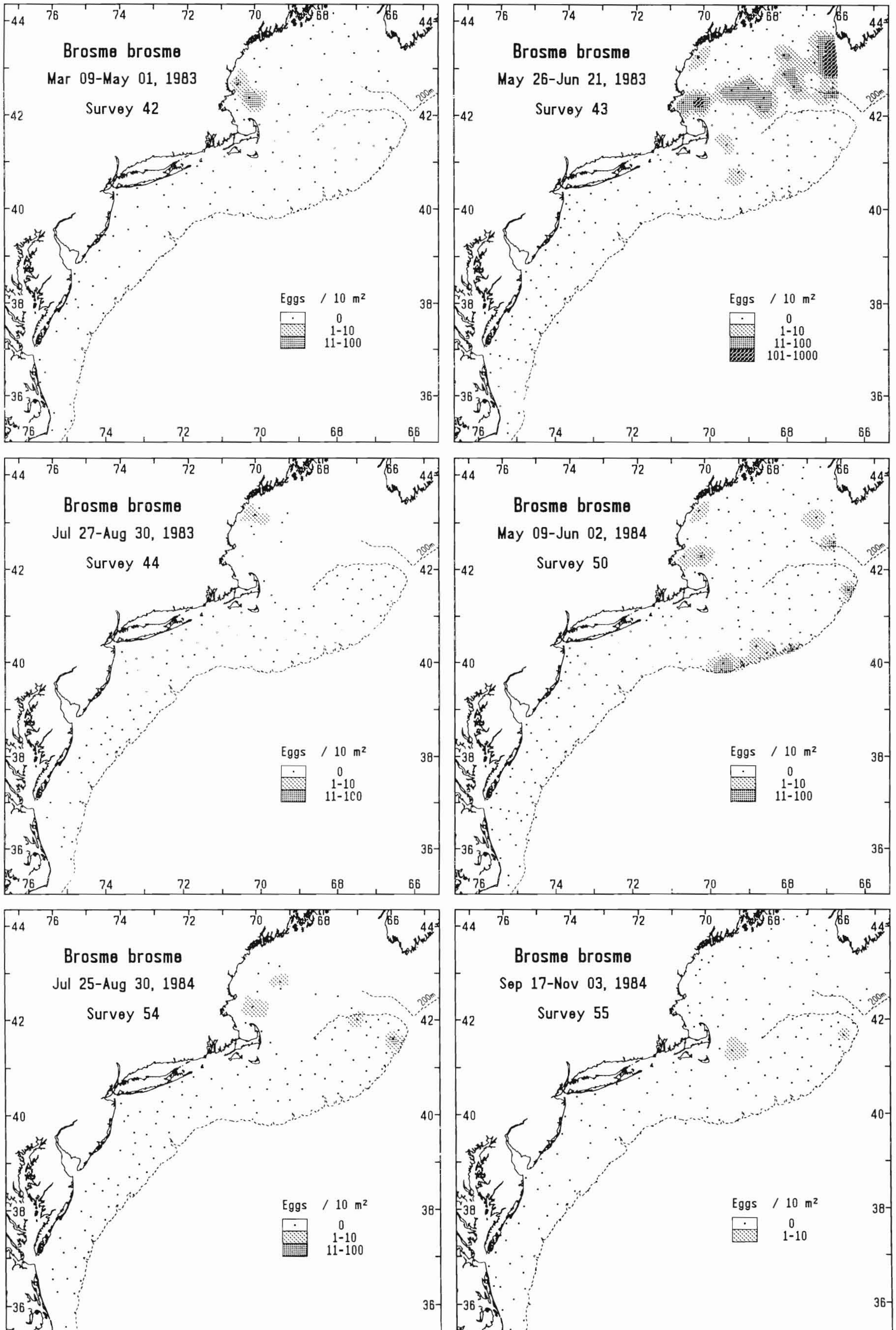

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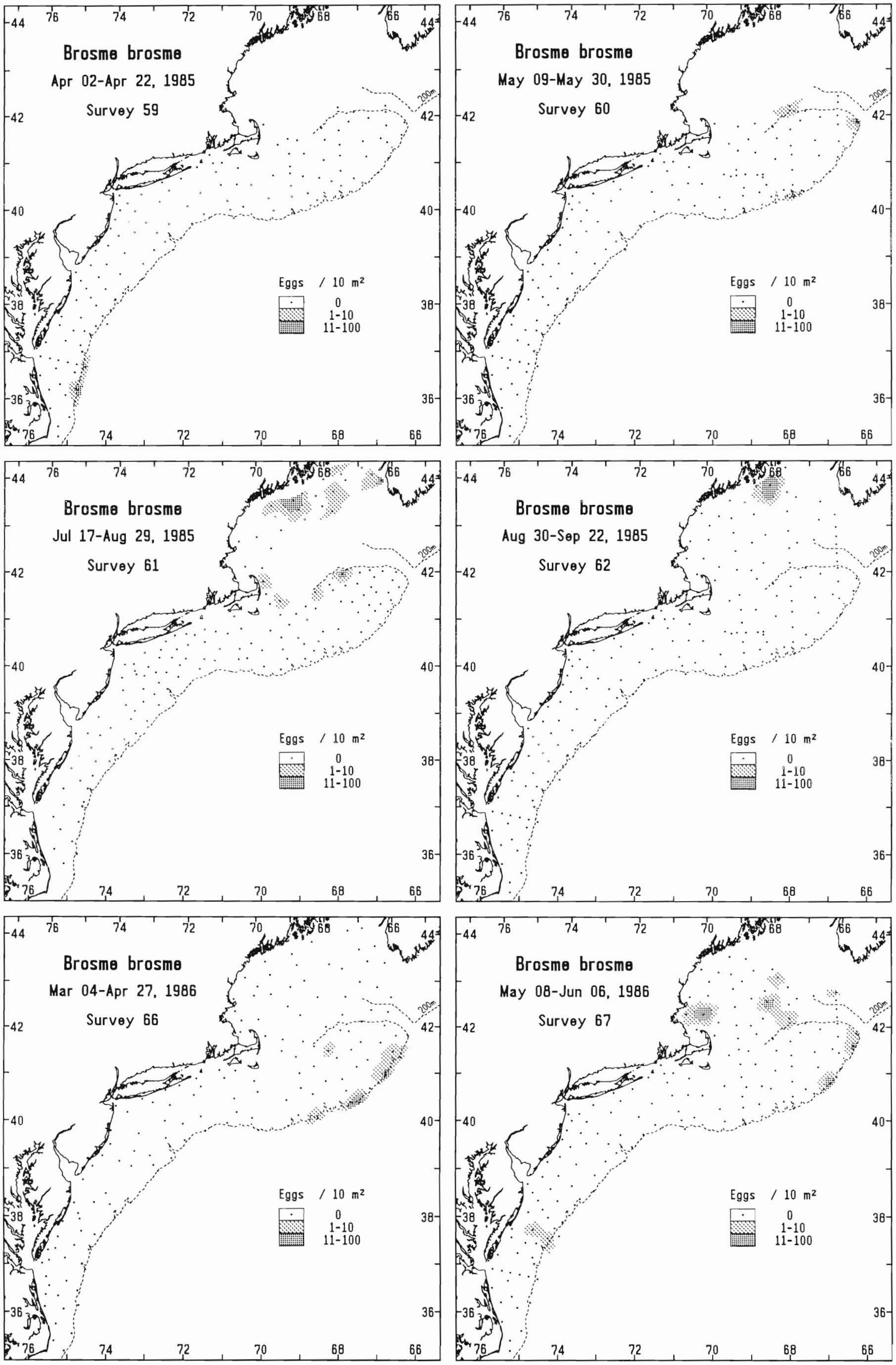

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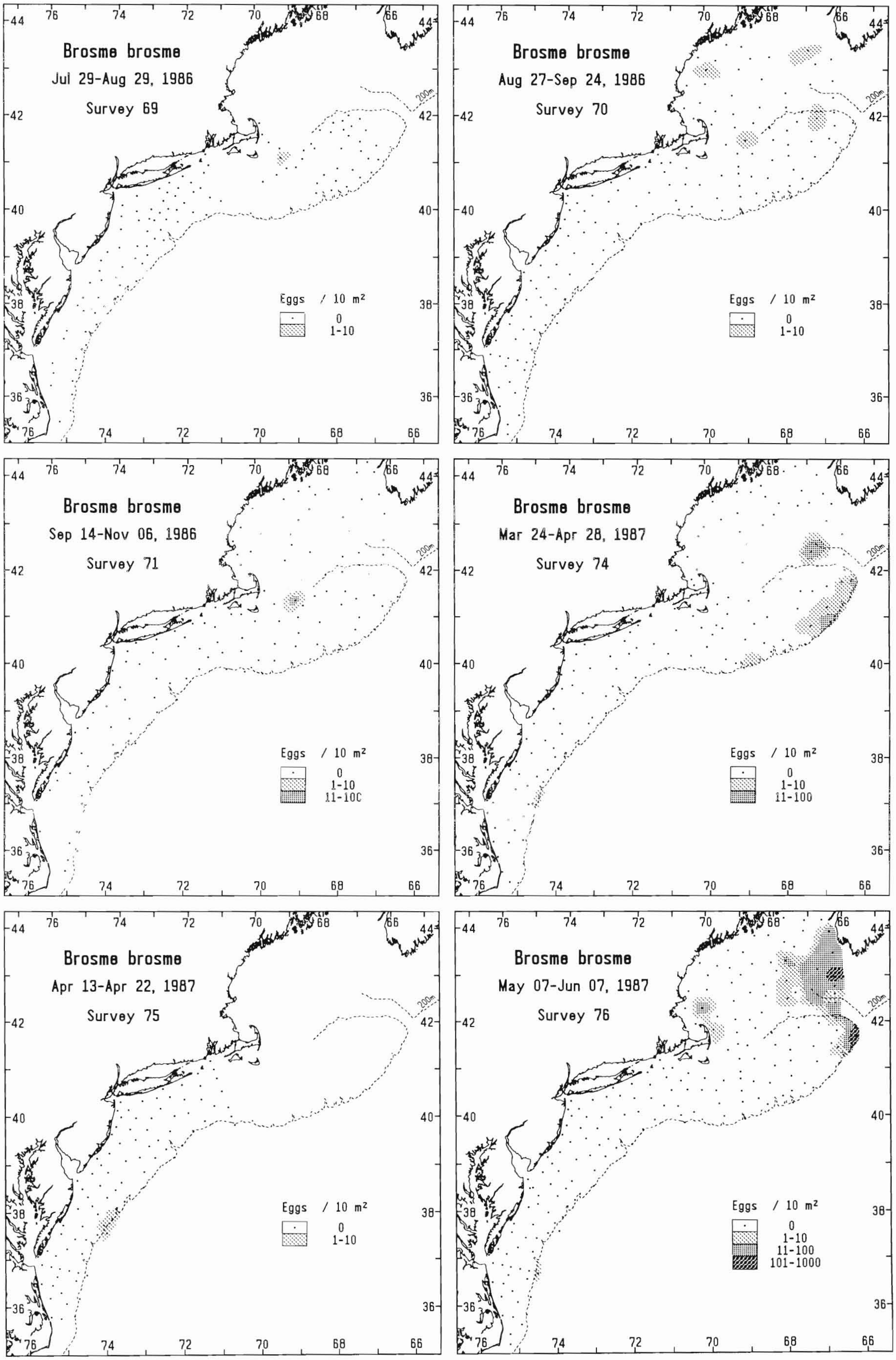

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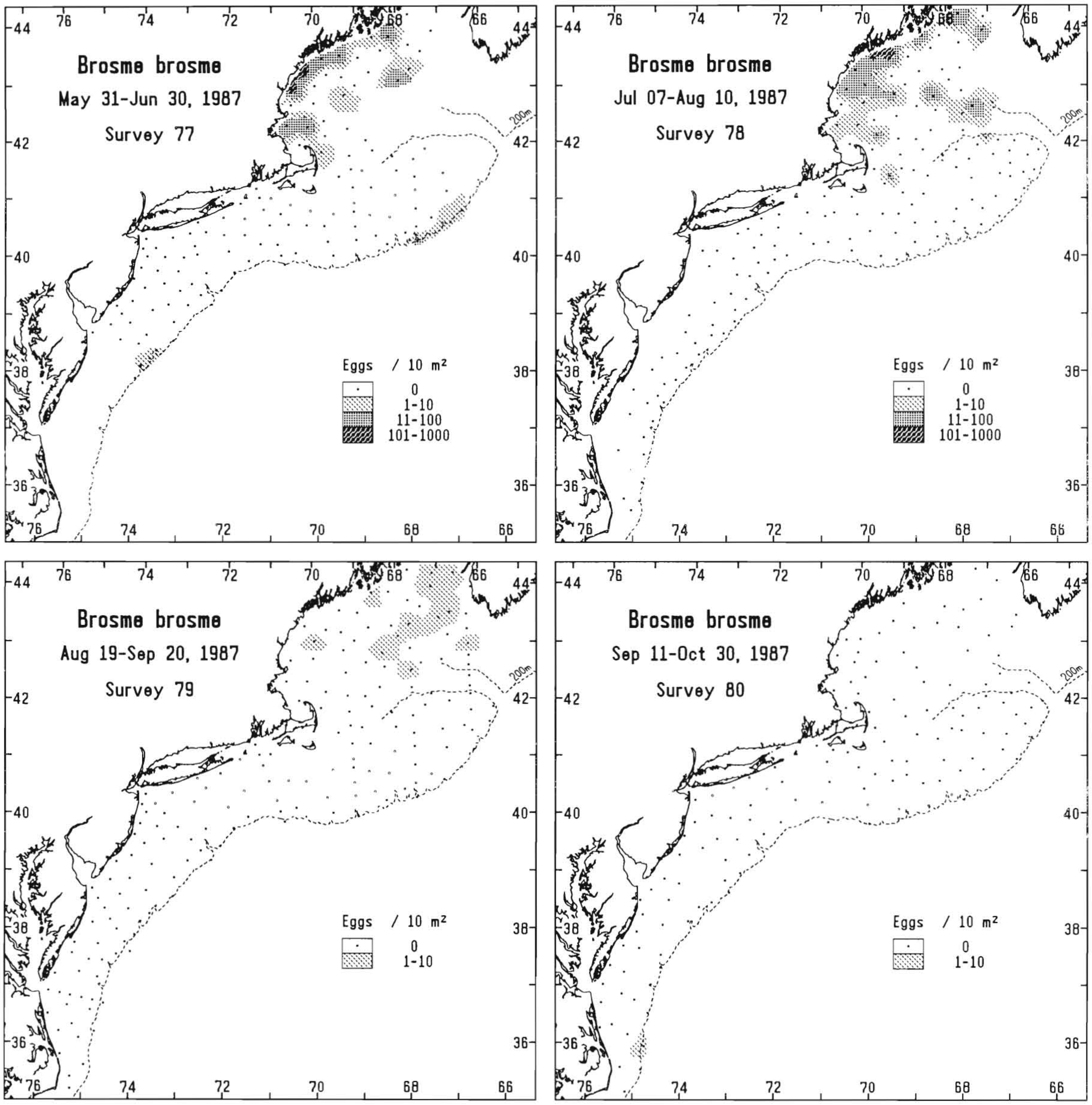


Figure 23 (continued)

Enchelyopus cimbrius, fourbeard rockling (Figs. 24–26)

Enchelyopus cimbrius eggs were collected throughout the year. From May to September they were commonly collected north and east of New Jersey, and were particularly abundant in western Gulf of Maine, peripheral Georges Bank, and southern New England waters. Although eggs occurred year round, there was a marked seasonal cycle in abundance with a peak in June and a minimum from October to March (Fig. 24). Eggs mainly were collected in deep water in winter months and in shallower waters during summer (Fig. 25).

Spawning was at a minimum in February, and eggs were restricted to isolated locations near the shelf edge of southern New England and Middle Atlantic waters (Fig. 25). The spawning area expanded from March to May, particularly in southern New England and Gulf of Maine waters, and in deeper portions of Georges Bank. Peak spawning occurred in June with the majority of eggs occurring in western Gulf of Maine. Spawning declined throughout the area from midsummer through autumn and egg distribution became increasingly patchy (Figs. 24 and 25).

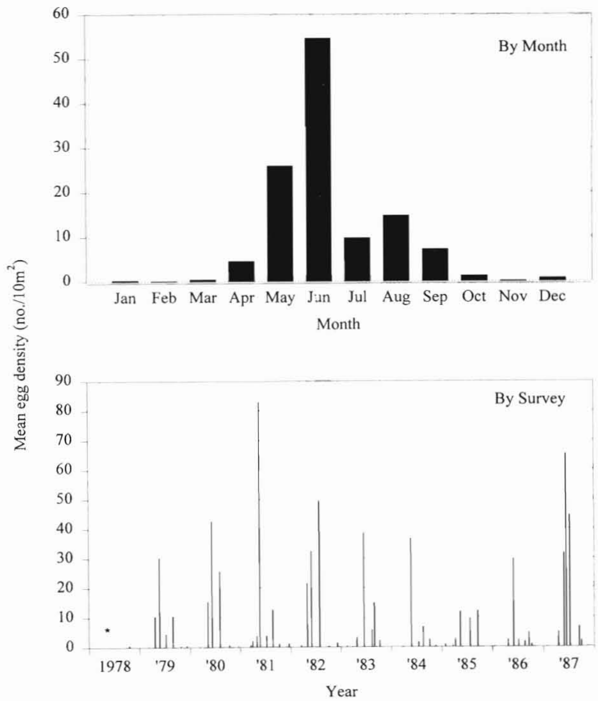


Figure 24
Enchelyopus cimbrius; mean-egg-density graphs by month (top) and by survey (bottom) for the total MARMAP area. (*Samples from the first four surveys in 1978 were not analyzed for *E. cimbrius* eggs.)

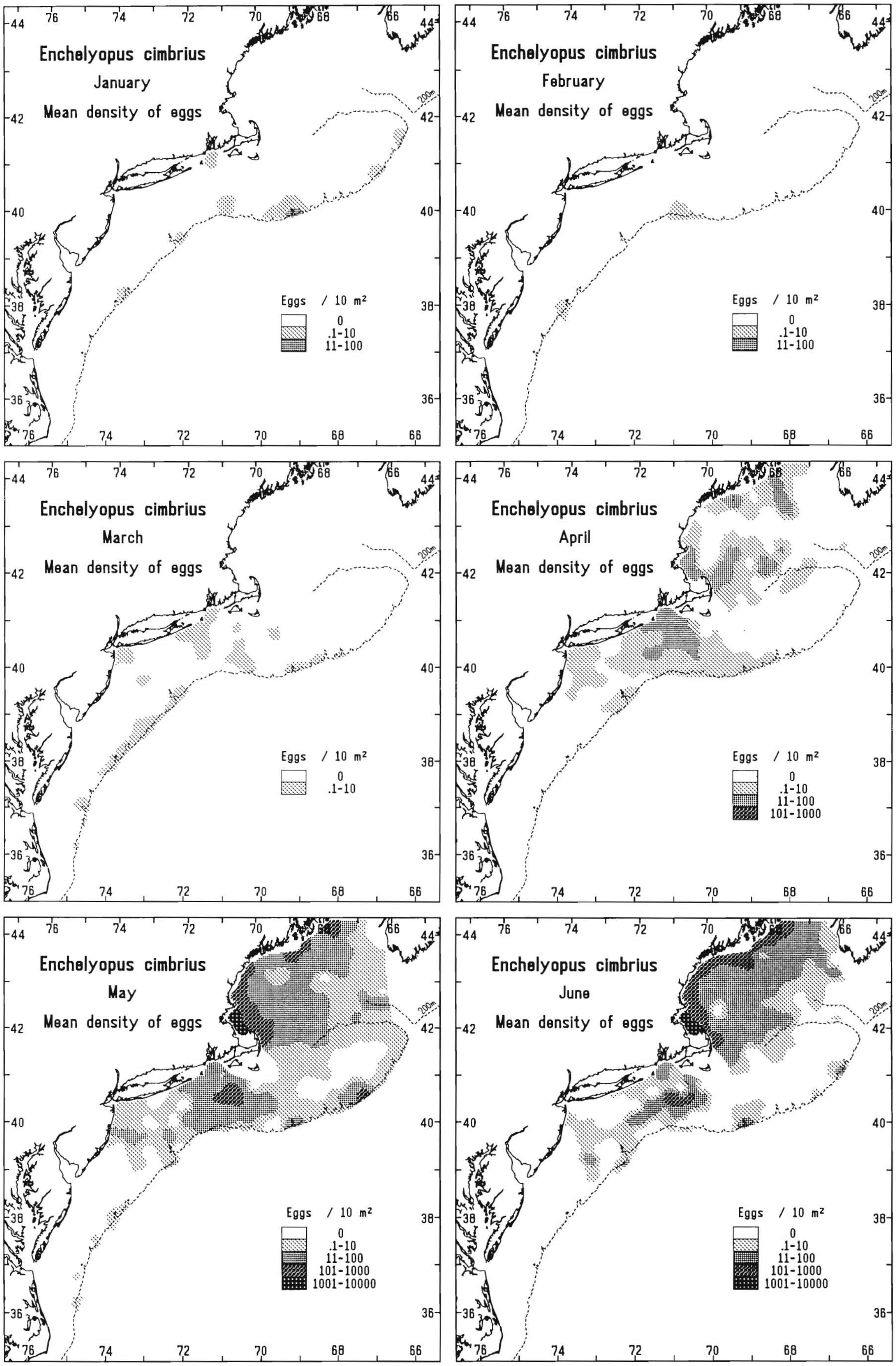


Figure 25
Enchelyopus cimbrius; composite monthly areal plots of mean egg densities (no./10 m²).

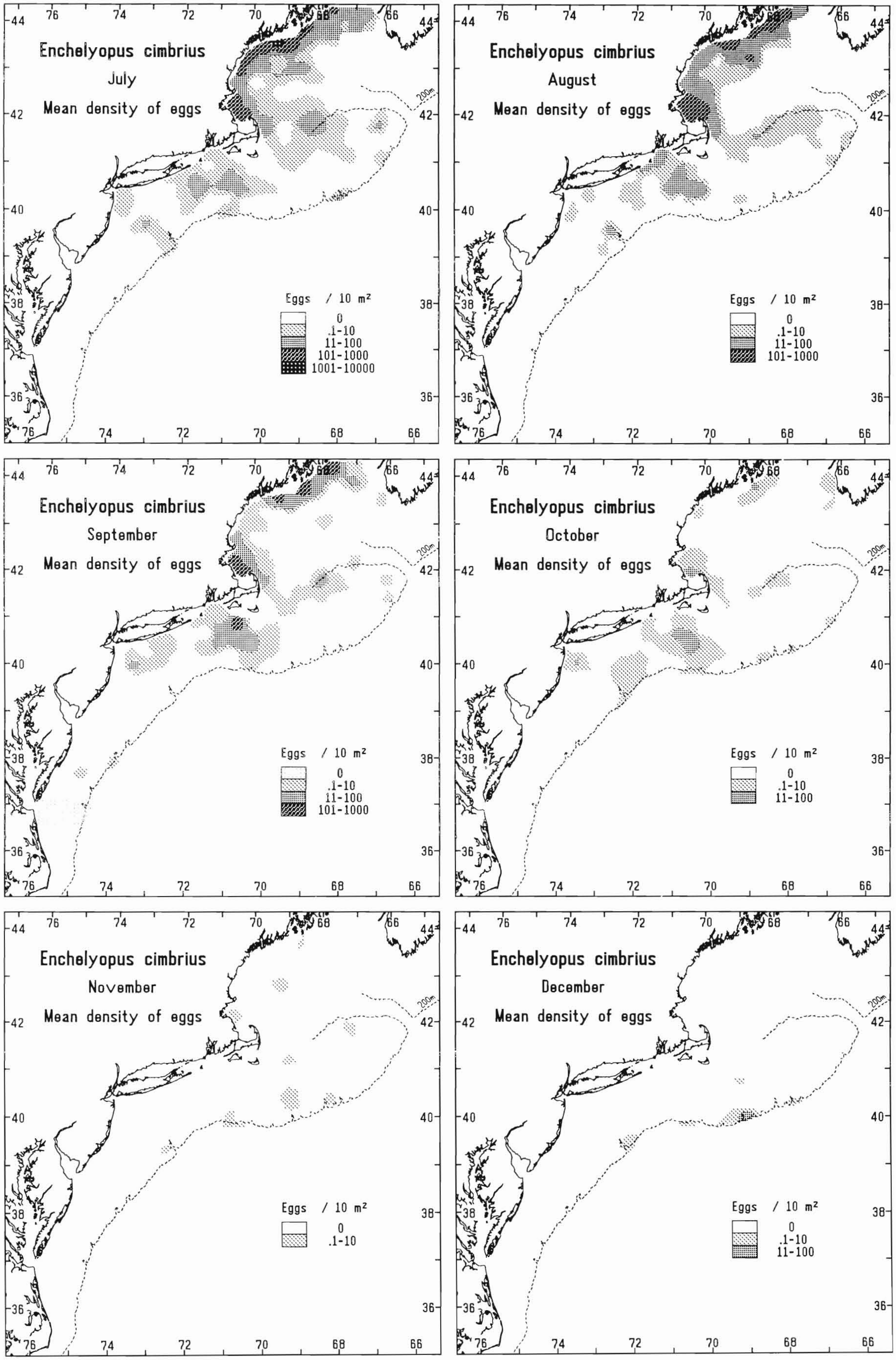


Figure 25 (continued)

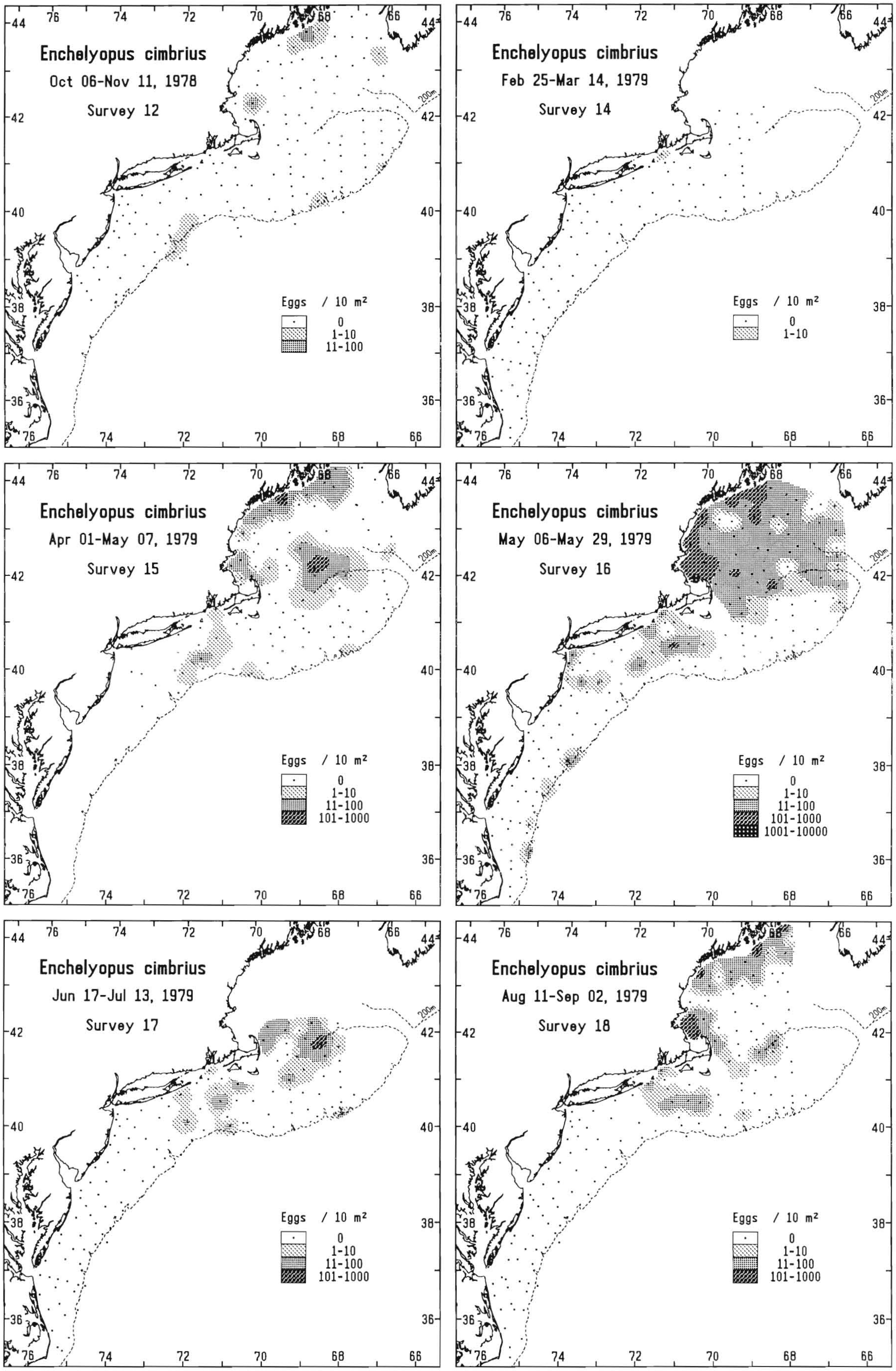
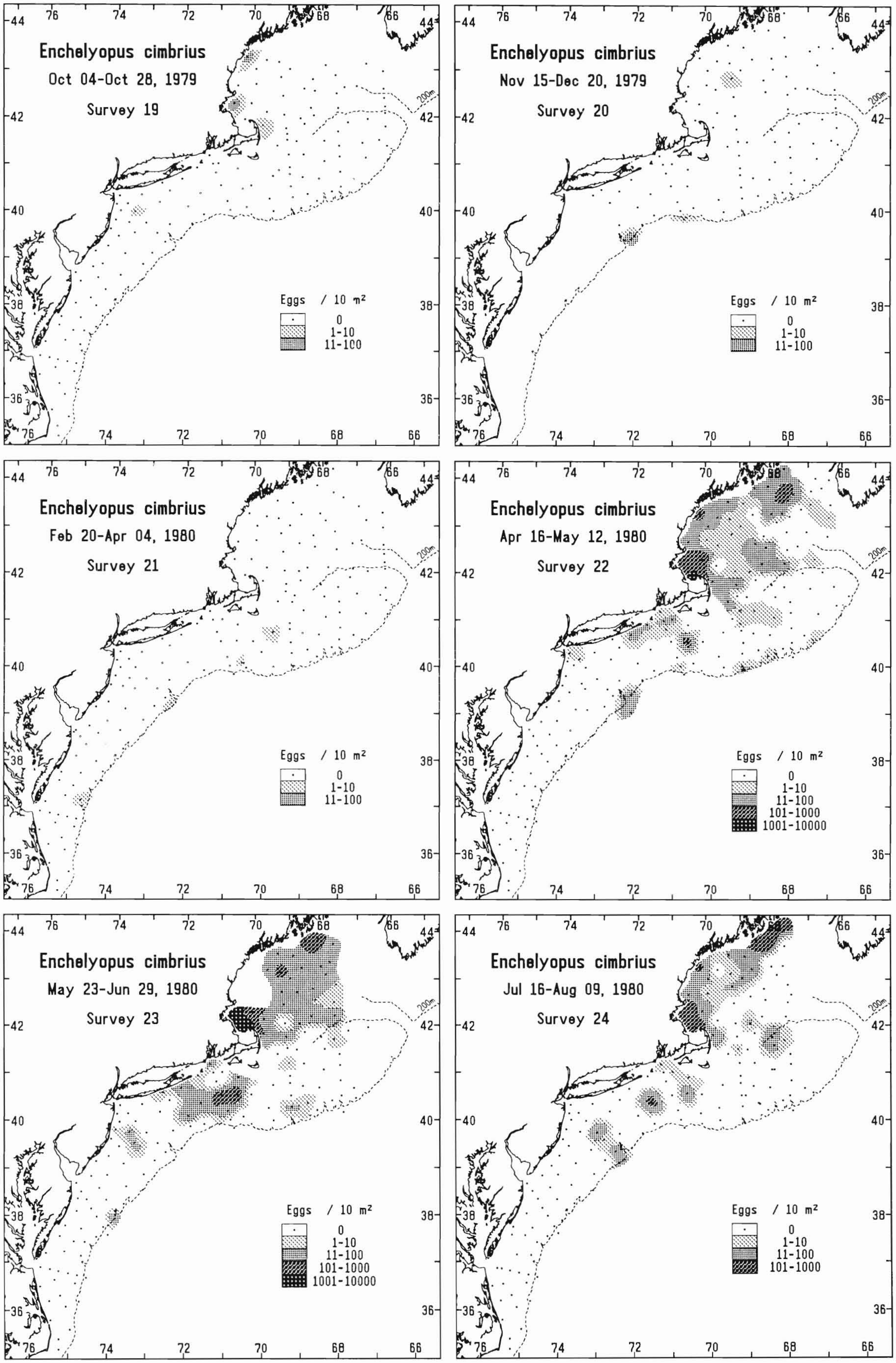


Figure 26

Enchelyopus cimbrius; survey areal plots of egg densities (no./10 m²).



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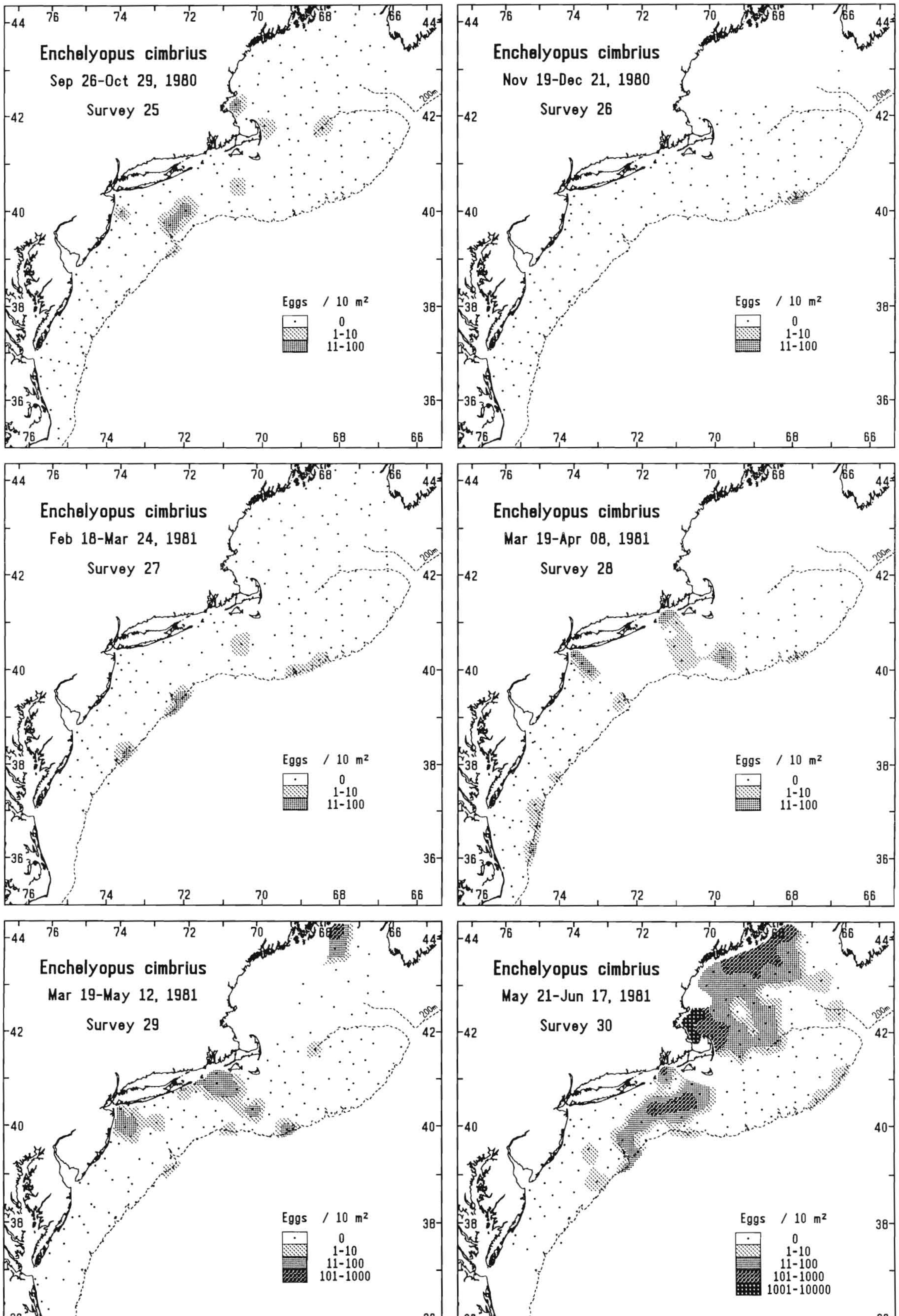

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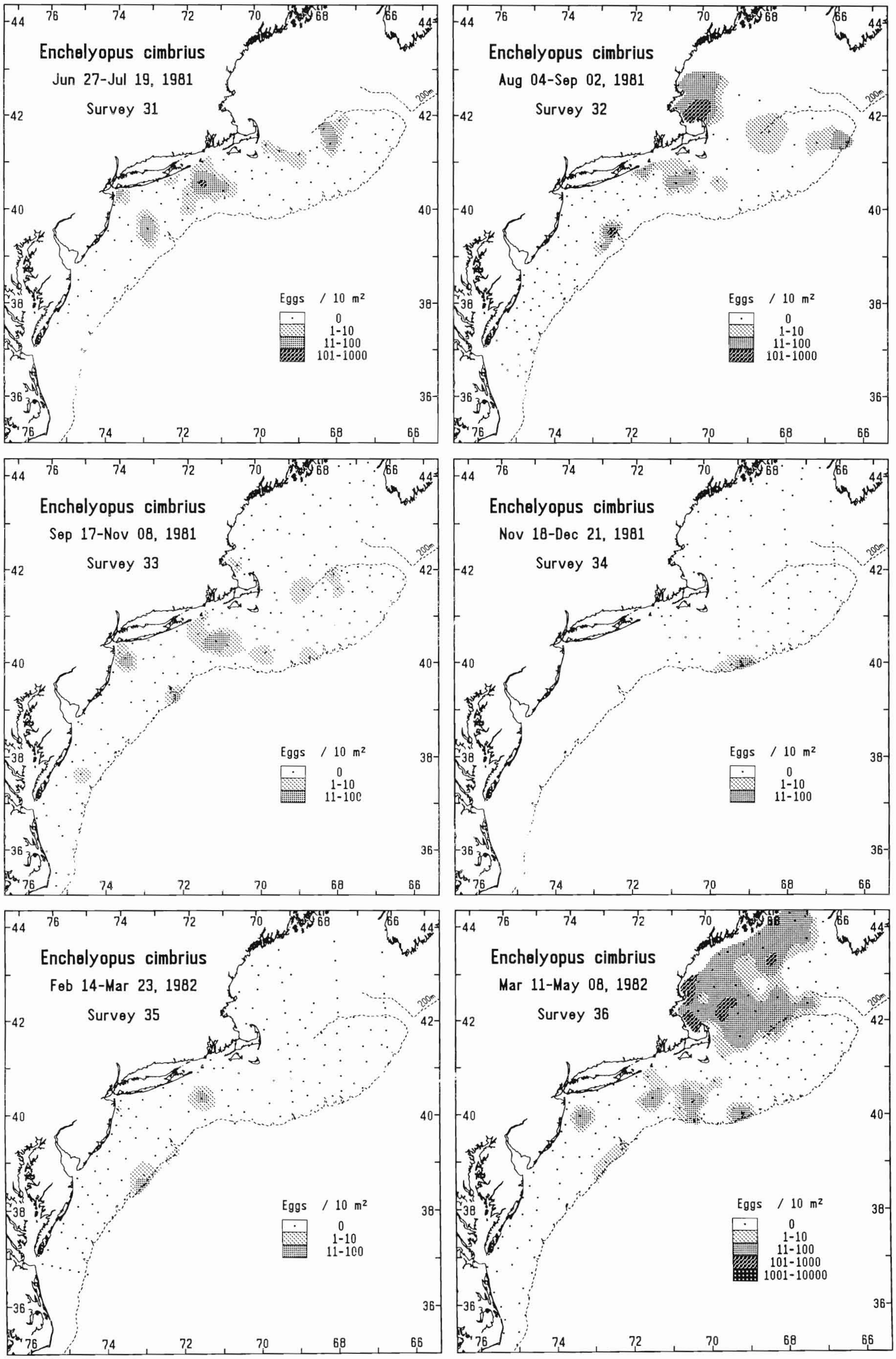

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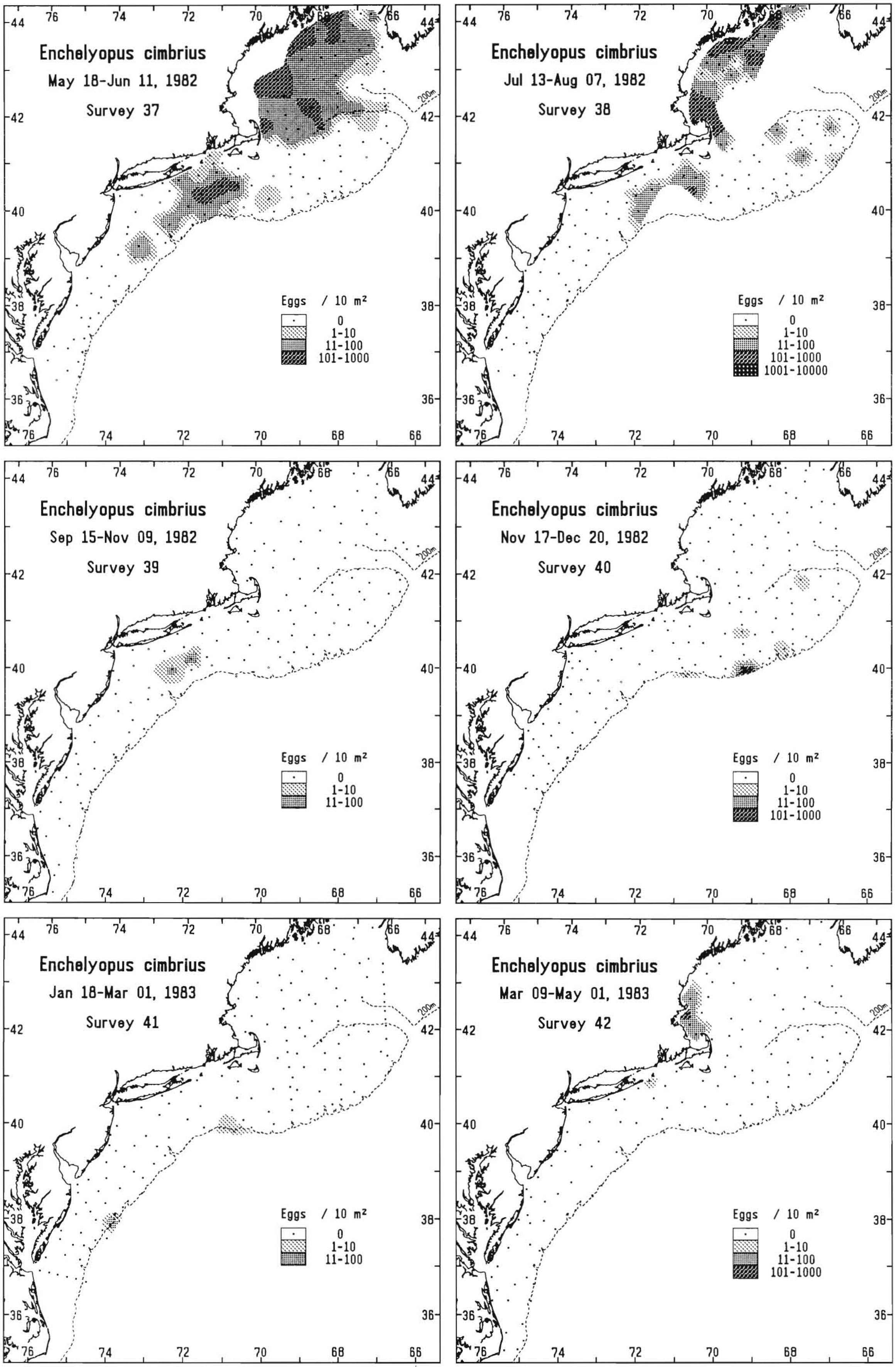

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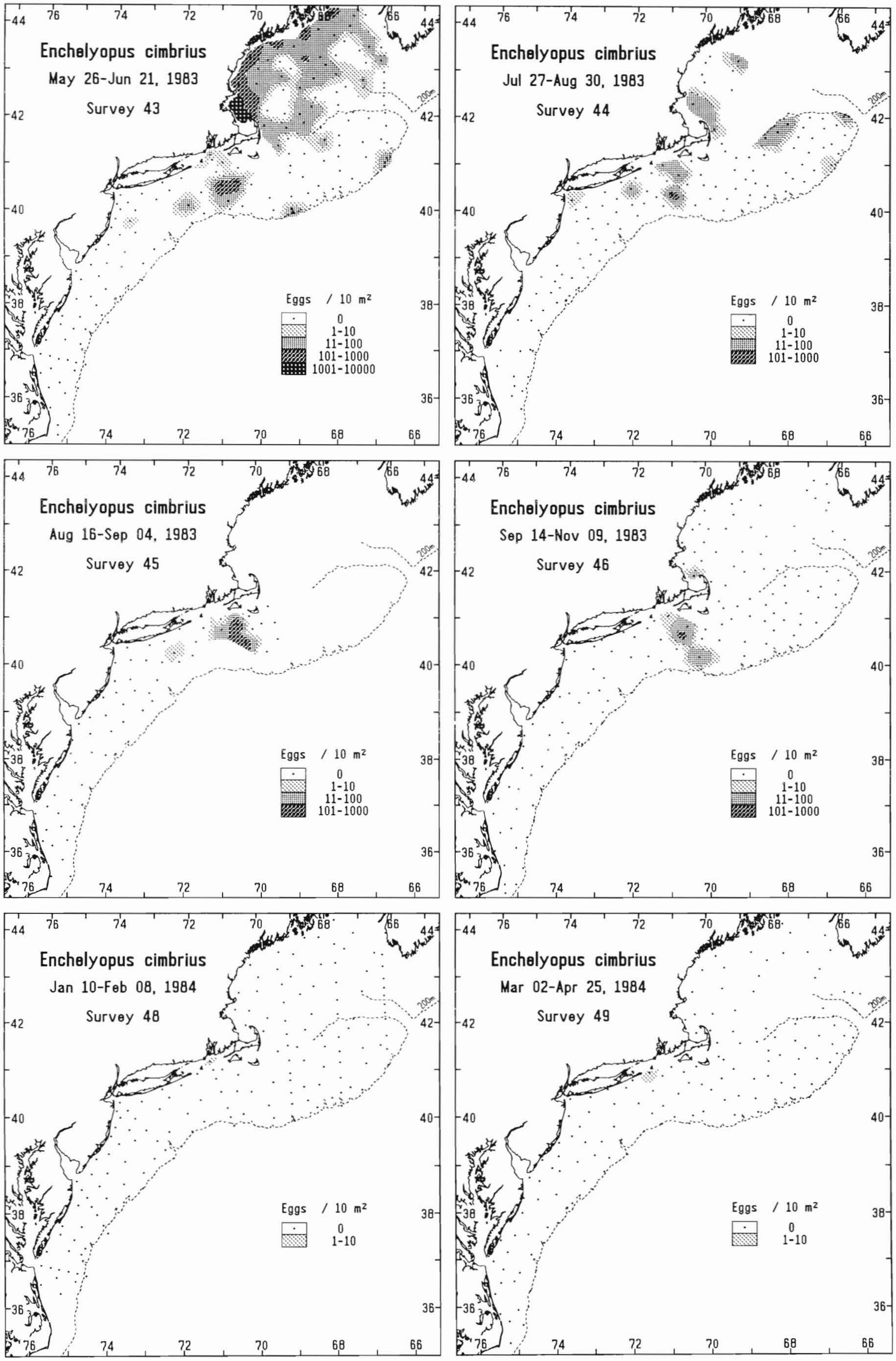

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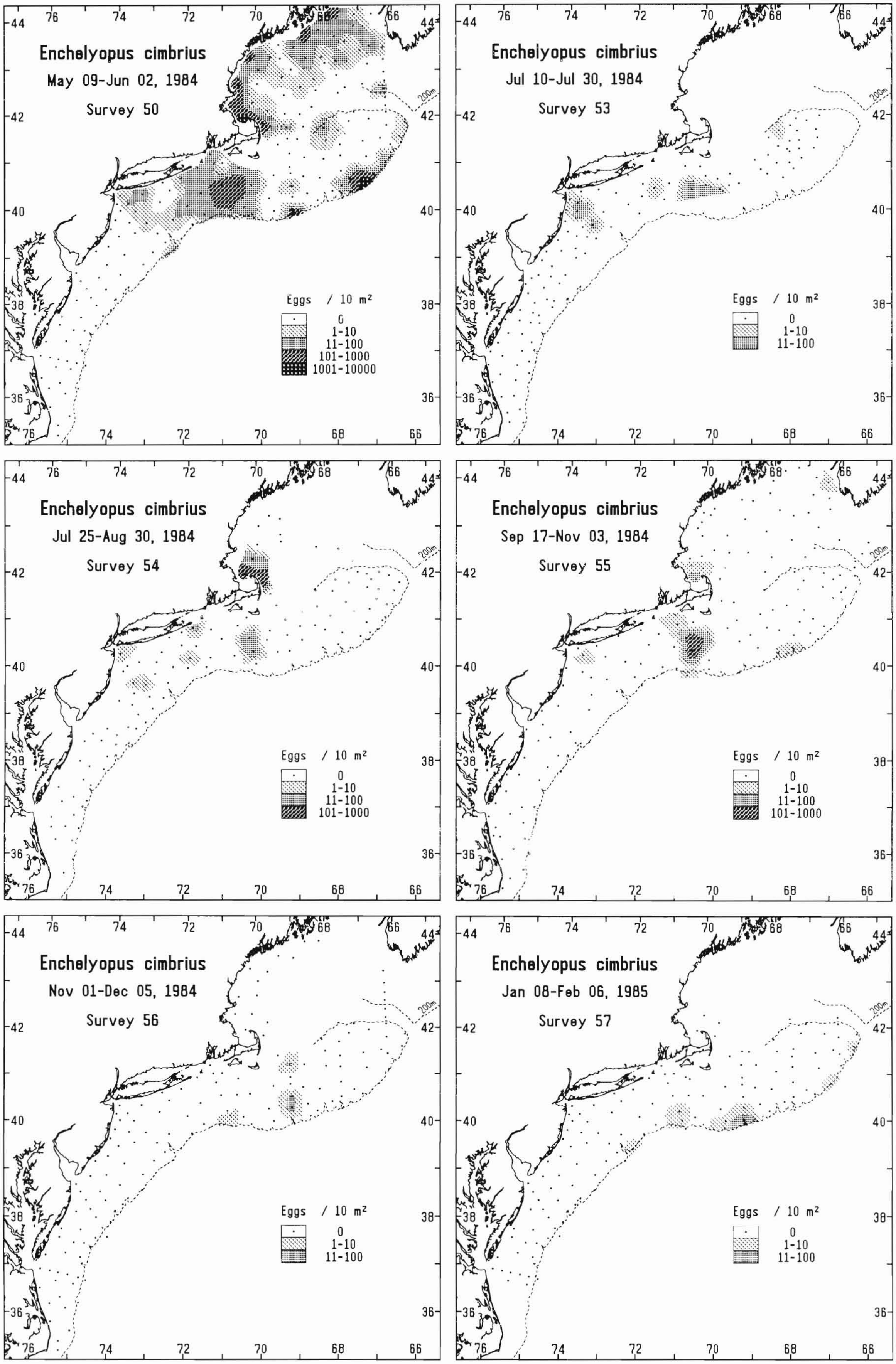

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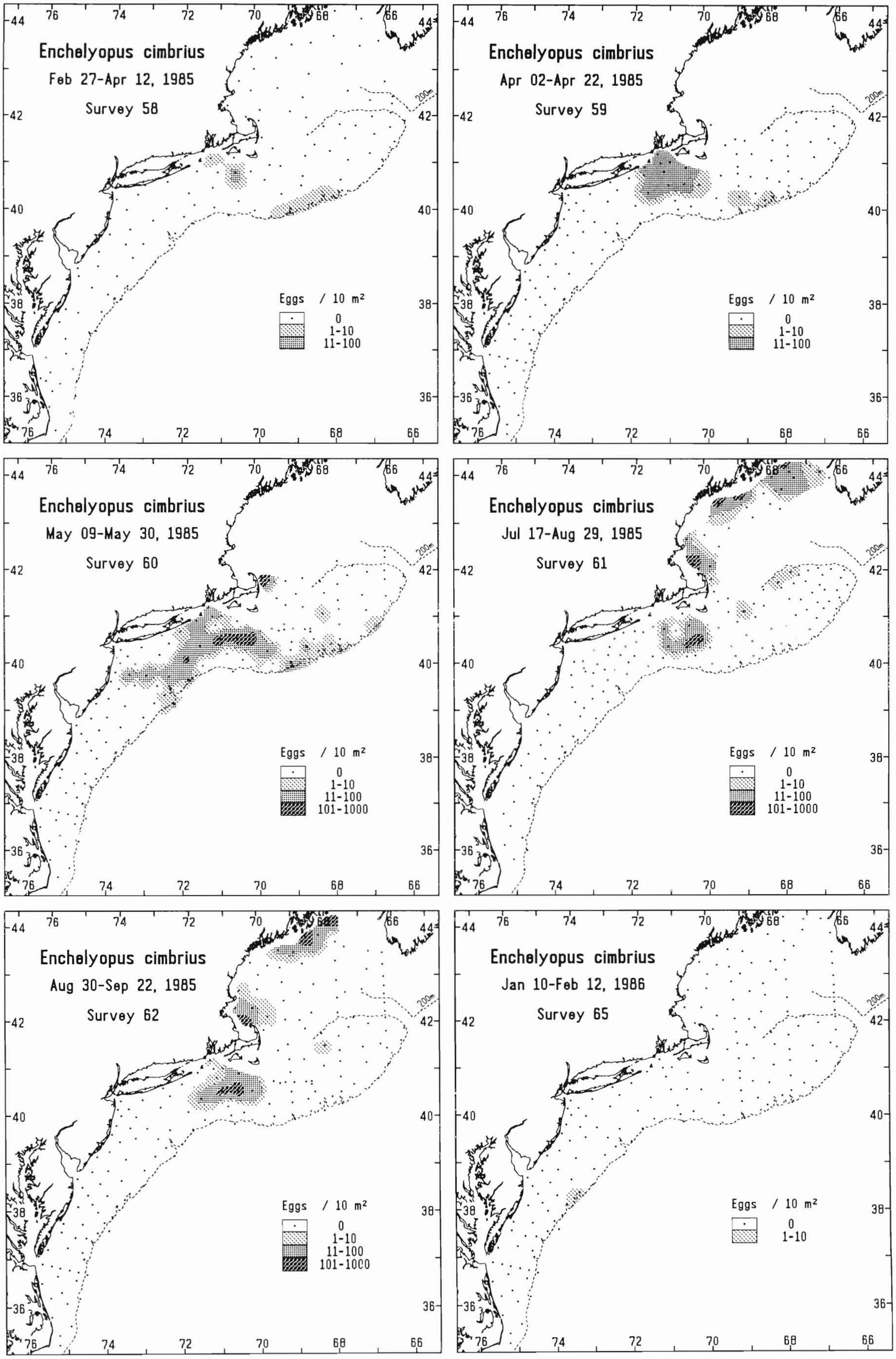

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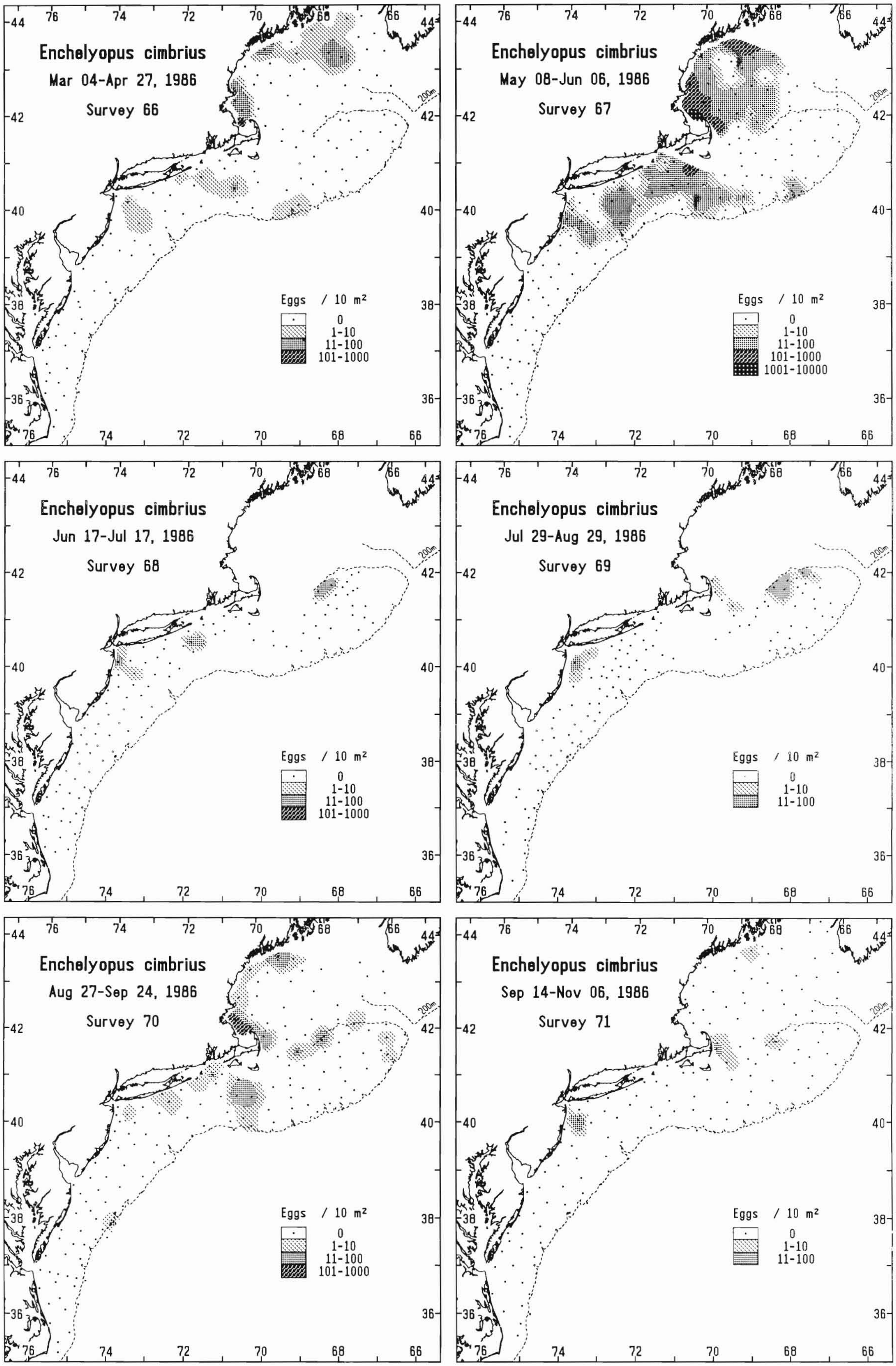

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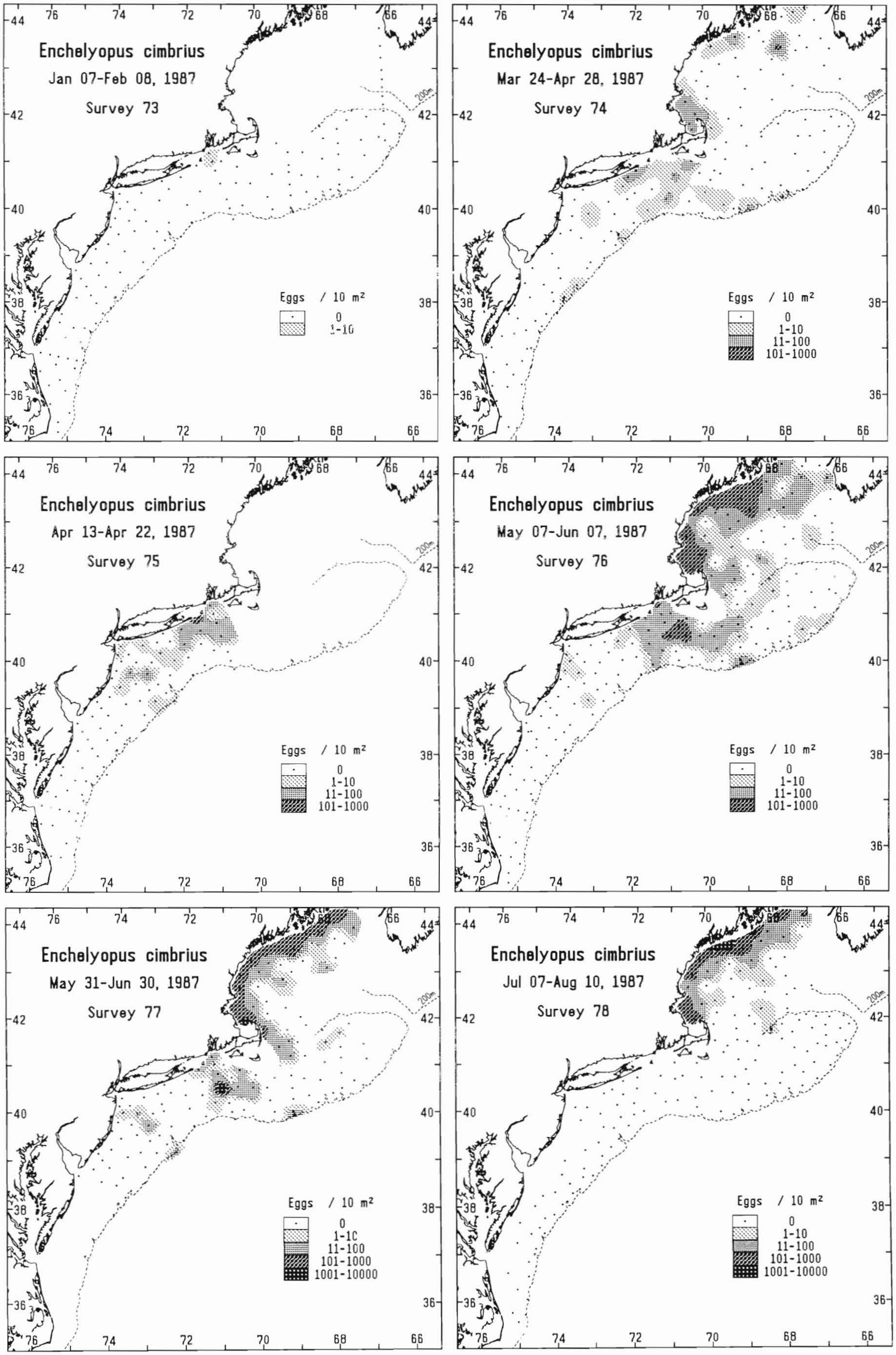

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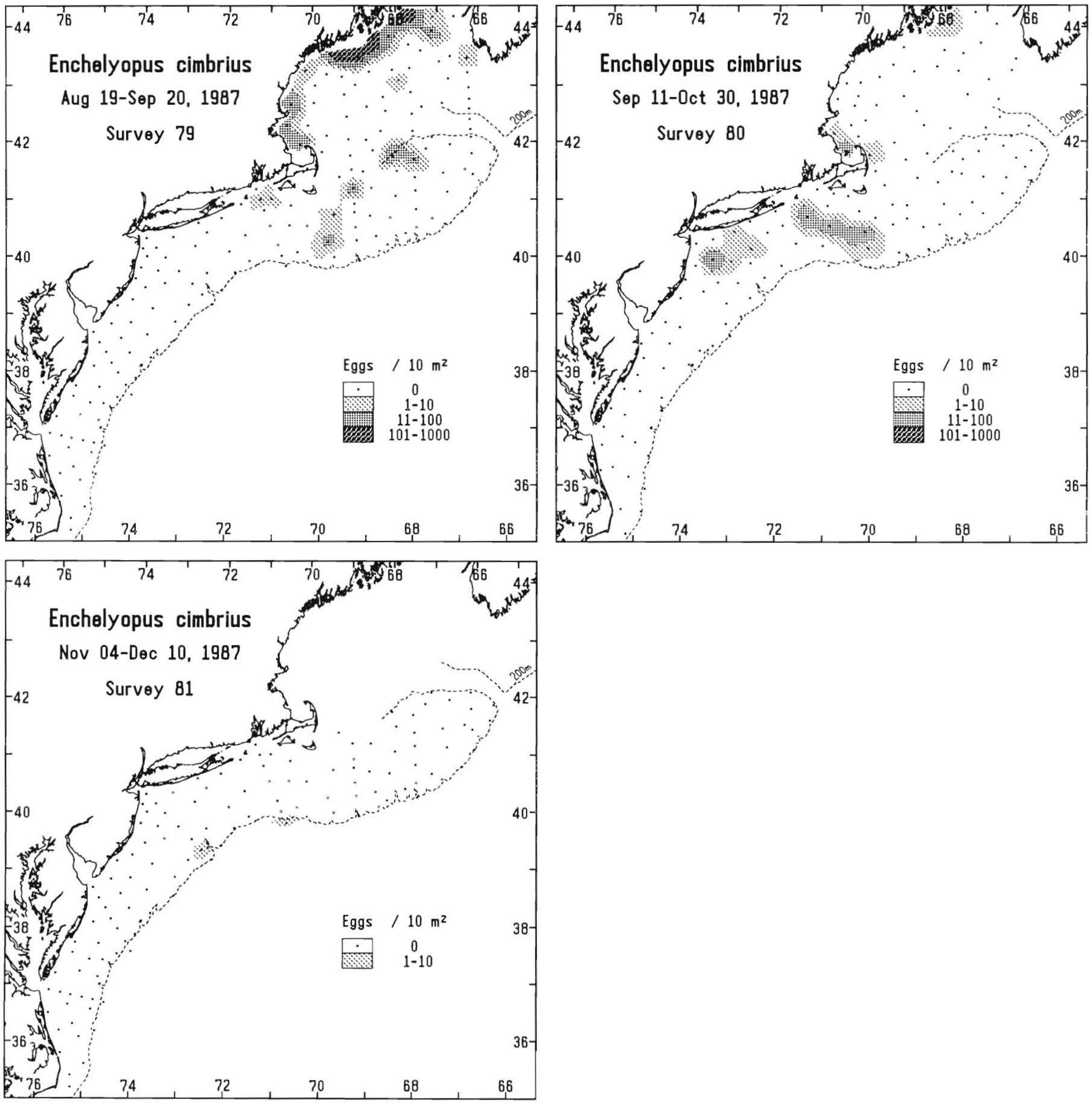


Figure 26 (continued)

Gadus morhua, Atlantic cod (Figs. 27–29)

Gadus morhua eggs were one of the most common species collected (Table 3). Although occurring year-round, they exhibited a pronounced annual cycle of abundance (Fig. 27). Eggs were found over a wide geographic area from Nova Scotia southward almost to Cape Hatteras. Their center of abundance was in western Gulf of Maine, Georges Bank, and southern New England waters. They were taken primarily at locations where the water depth was <100 m, but occurred at virtually all water-column depths sampled.

Egg densities were minimal during August and September (Figs. 27 and 28). During autumn and winter, spawning increased and expanded in areal distribution throughout the Gulf of Maine, Georges Bank, and southern New England subareas. Maximum average abundance occurred in March with highest densities occurring on Georges Bank (Figs. 27 and 28). A large part of the Gulf of Maine was not sampled in March, when geographic distribution and egg densities were probably at peak levels in that subarea. Throughout spring and early summer, spawning decreased and by late summer was reduced to isolated areas in Gulf of Maine and Georges Bank waters (Fig. 28).

A downward trend in egg abundance was observed over the nine-year sampling period (Fig. 27). The very high abundance for Survey 21 in 1980 (mean density = $294/10\ m^2$) resulted largely from a single catch of eggs which comprised 46% of all Atlantic cod eggs taken over the entire sampling period.

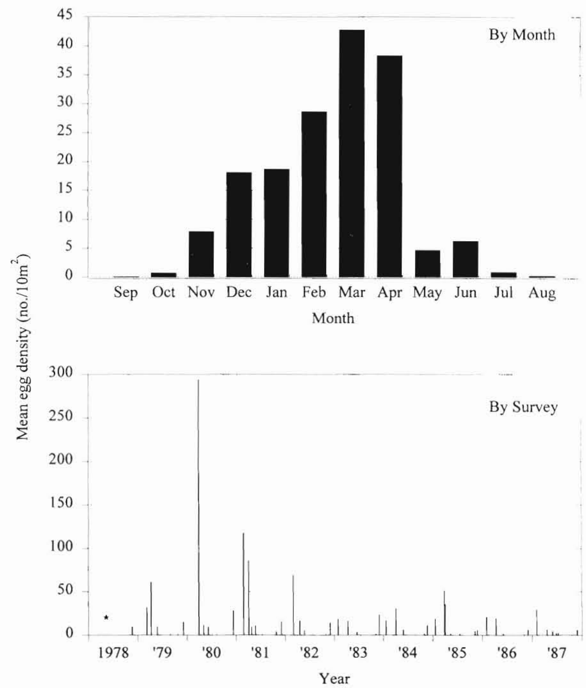


Figure 27
Gadus morhua; mean-egg-density graphs by month (top) and by survey (bottom) for the total MARMAP area. (*Samples from the first four surveys in 1978 were not analyzed for *G. morhua* eggs.)

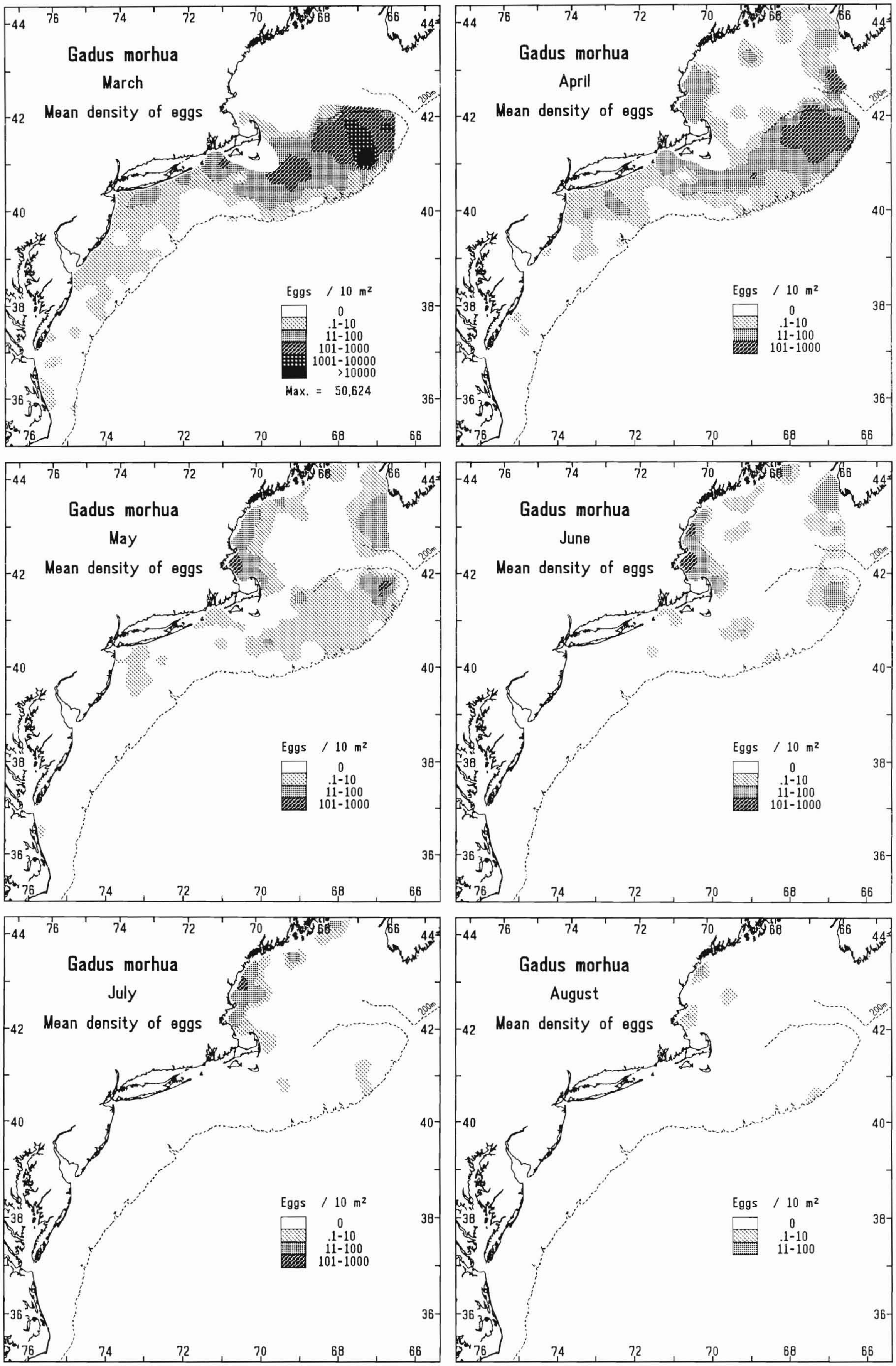


Figure 28
Gadus morhua; composite monthly areal plots of mean egg densities (no./10 m²).

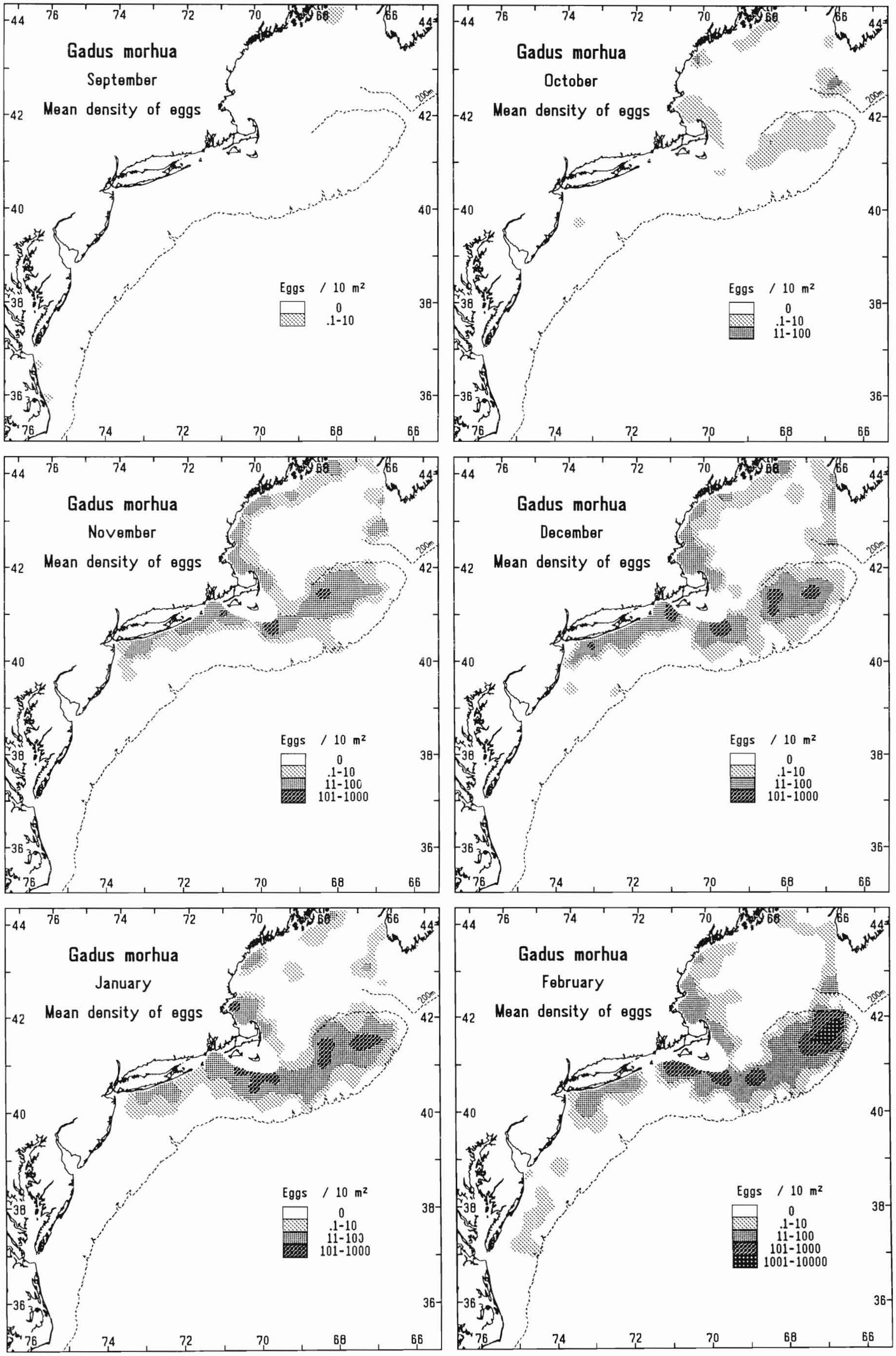


Figure 28 (continued)

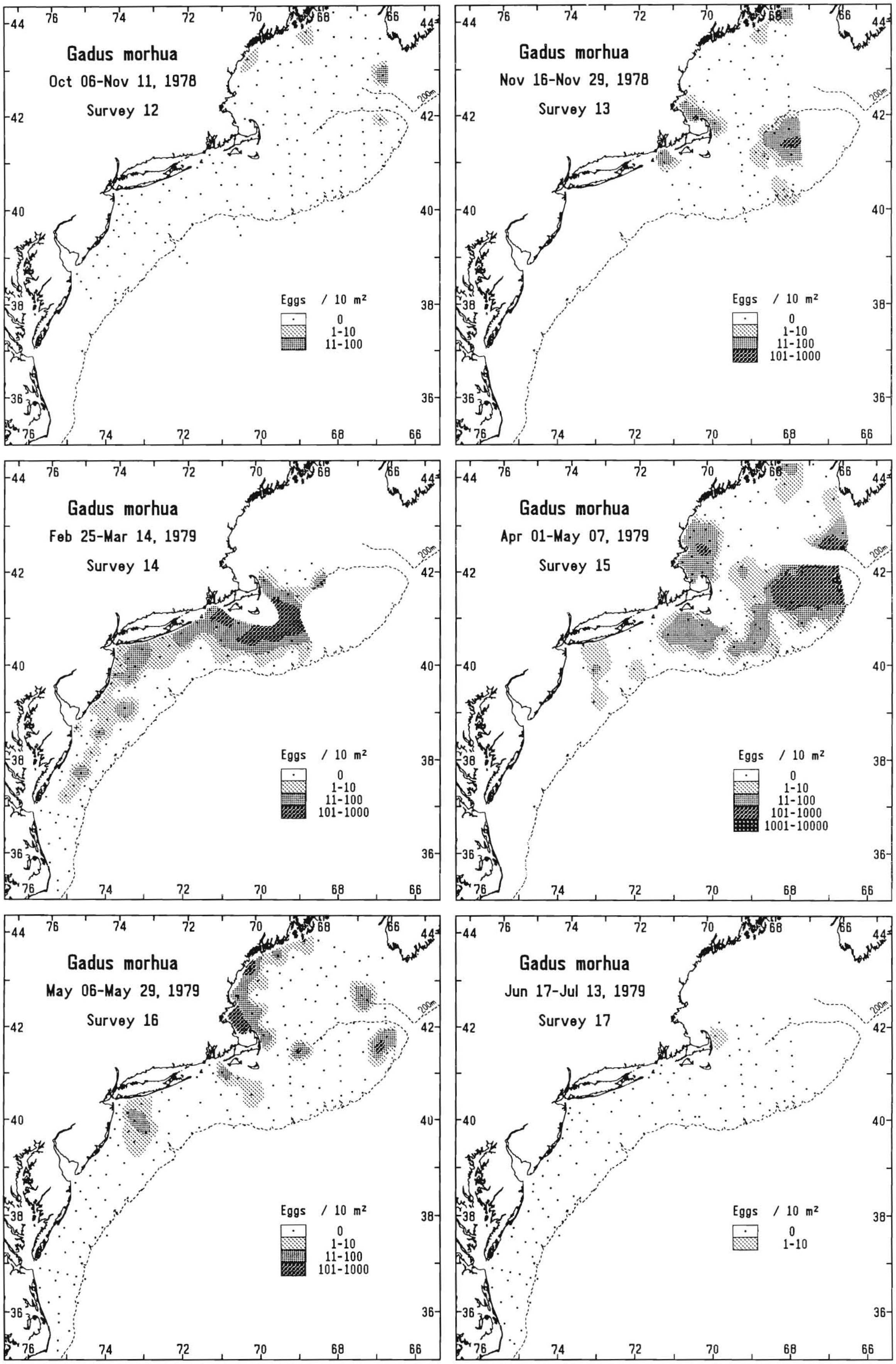


Figure 29

Gadus morhua; survey areal plots of egg densities (no./10 m²).

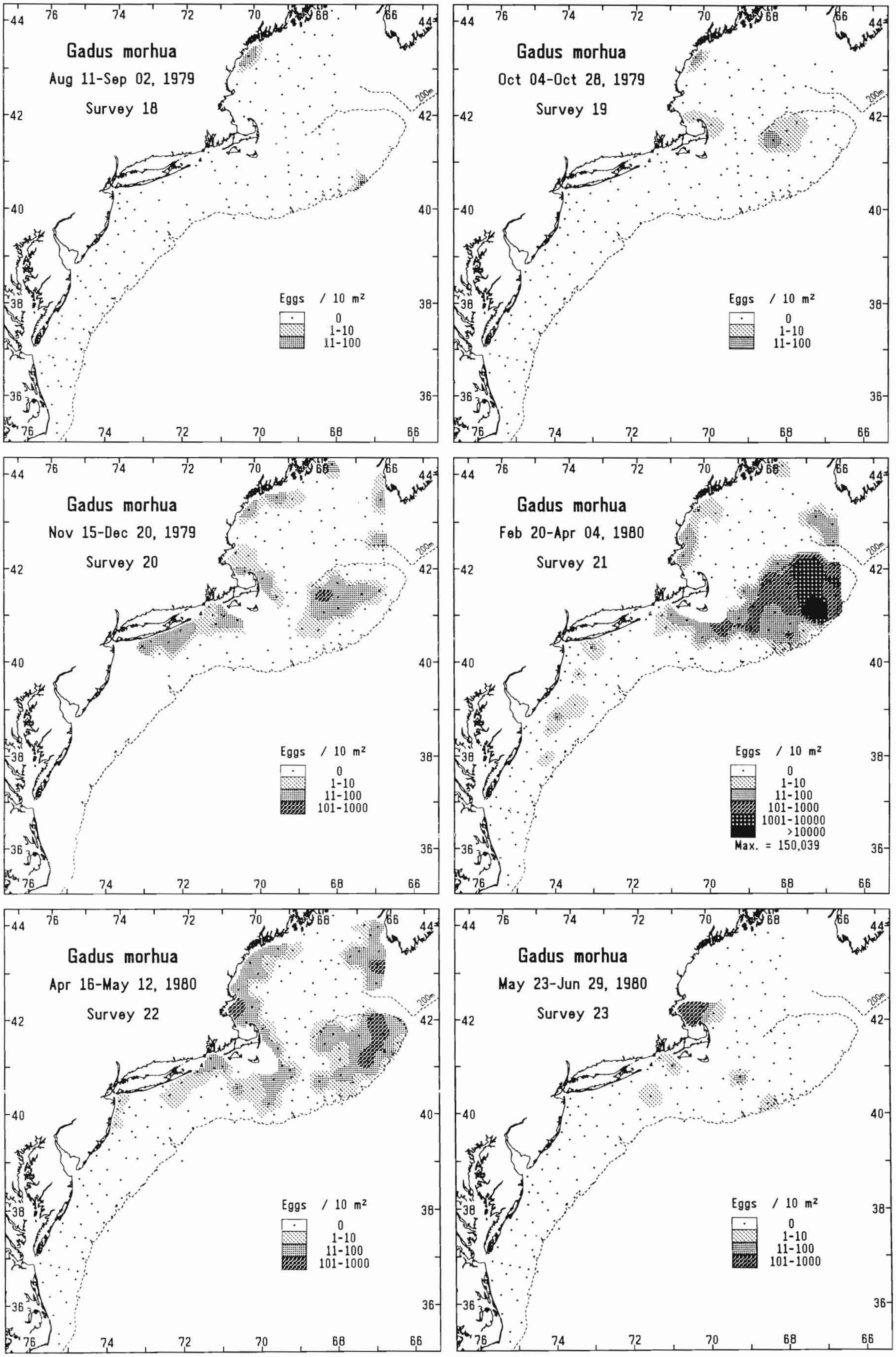
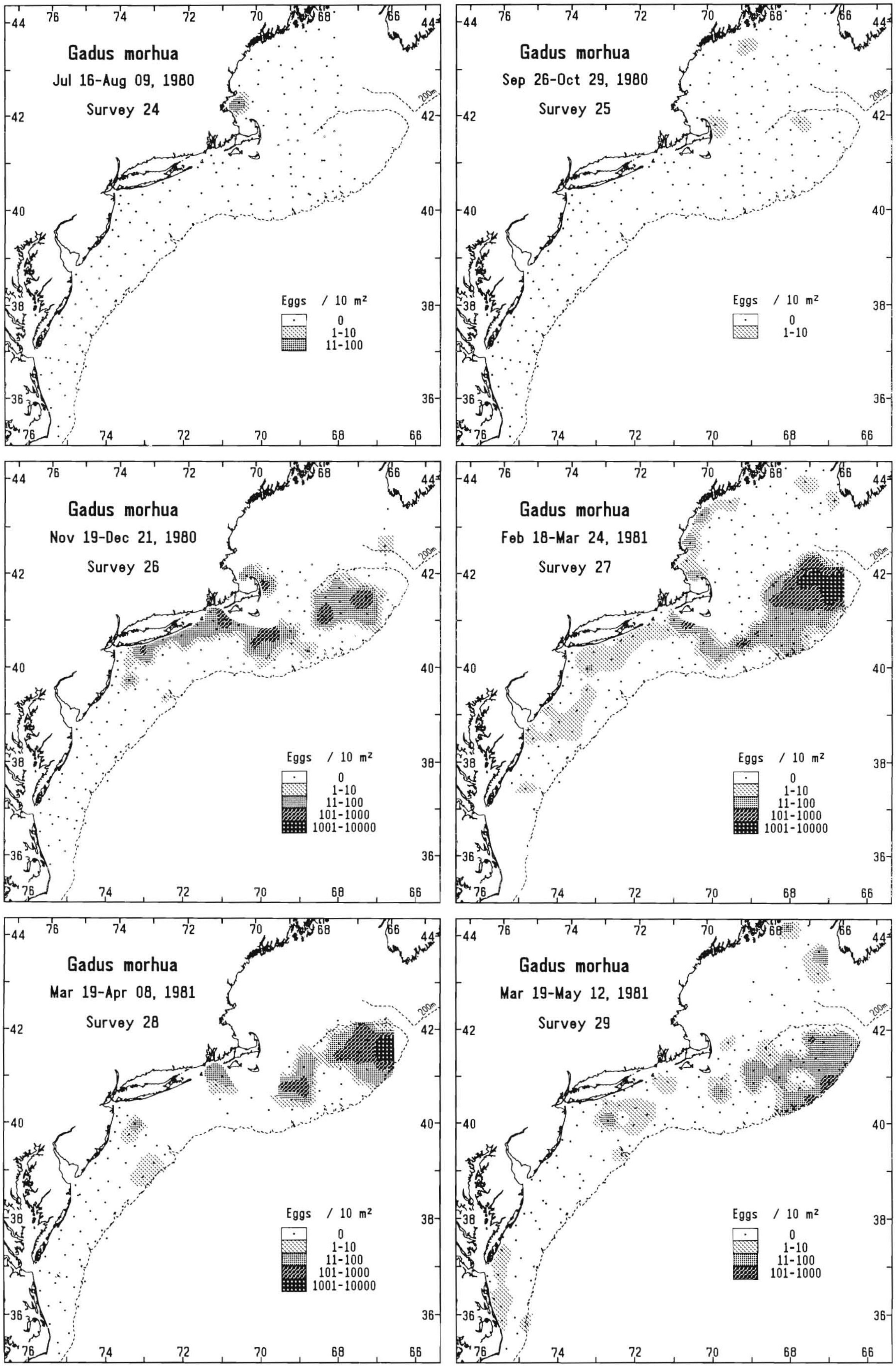


Figure 29 (continued)



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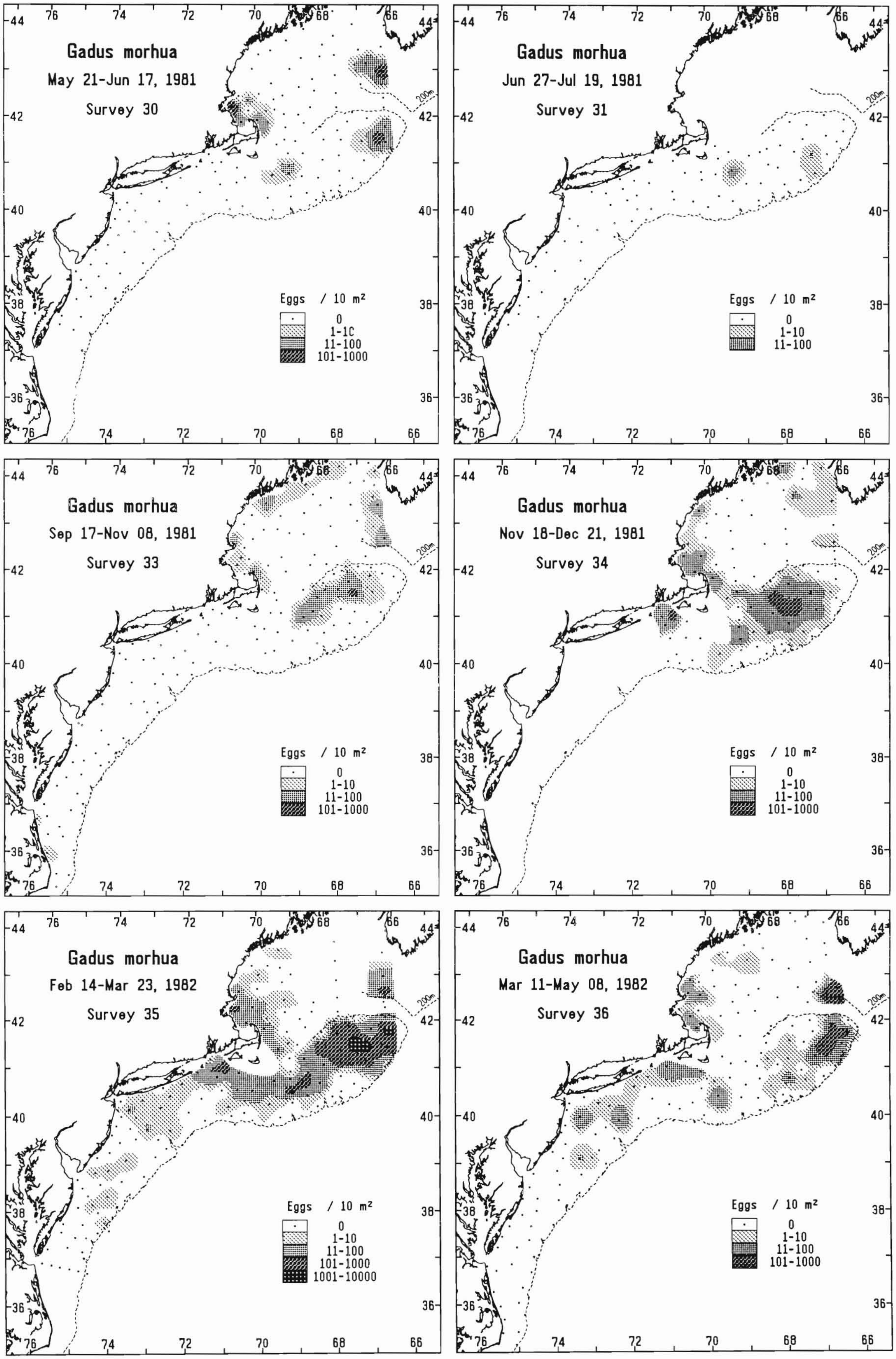

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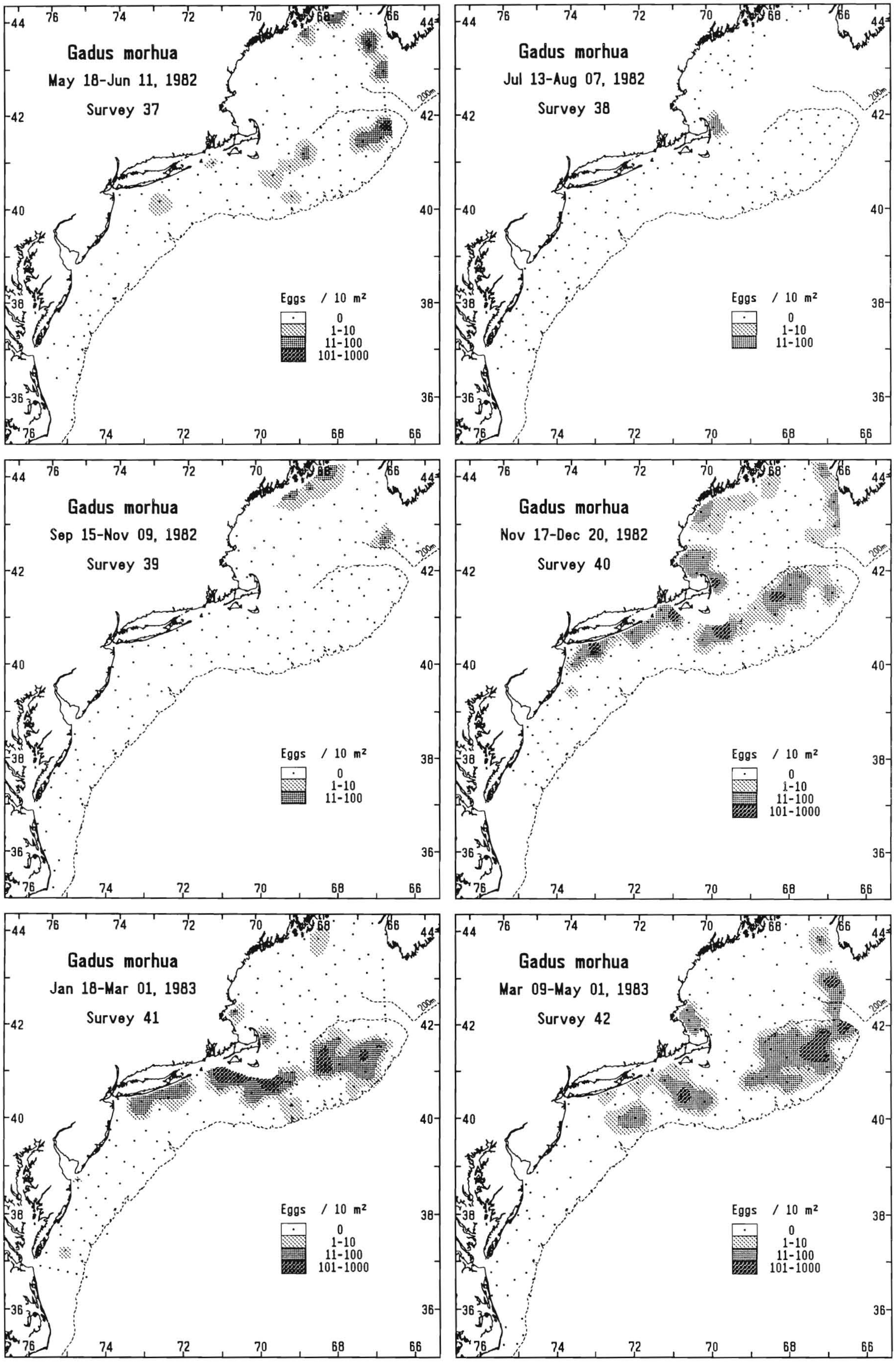

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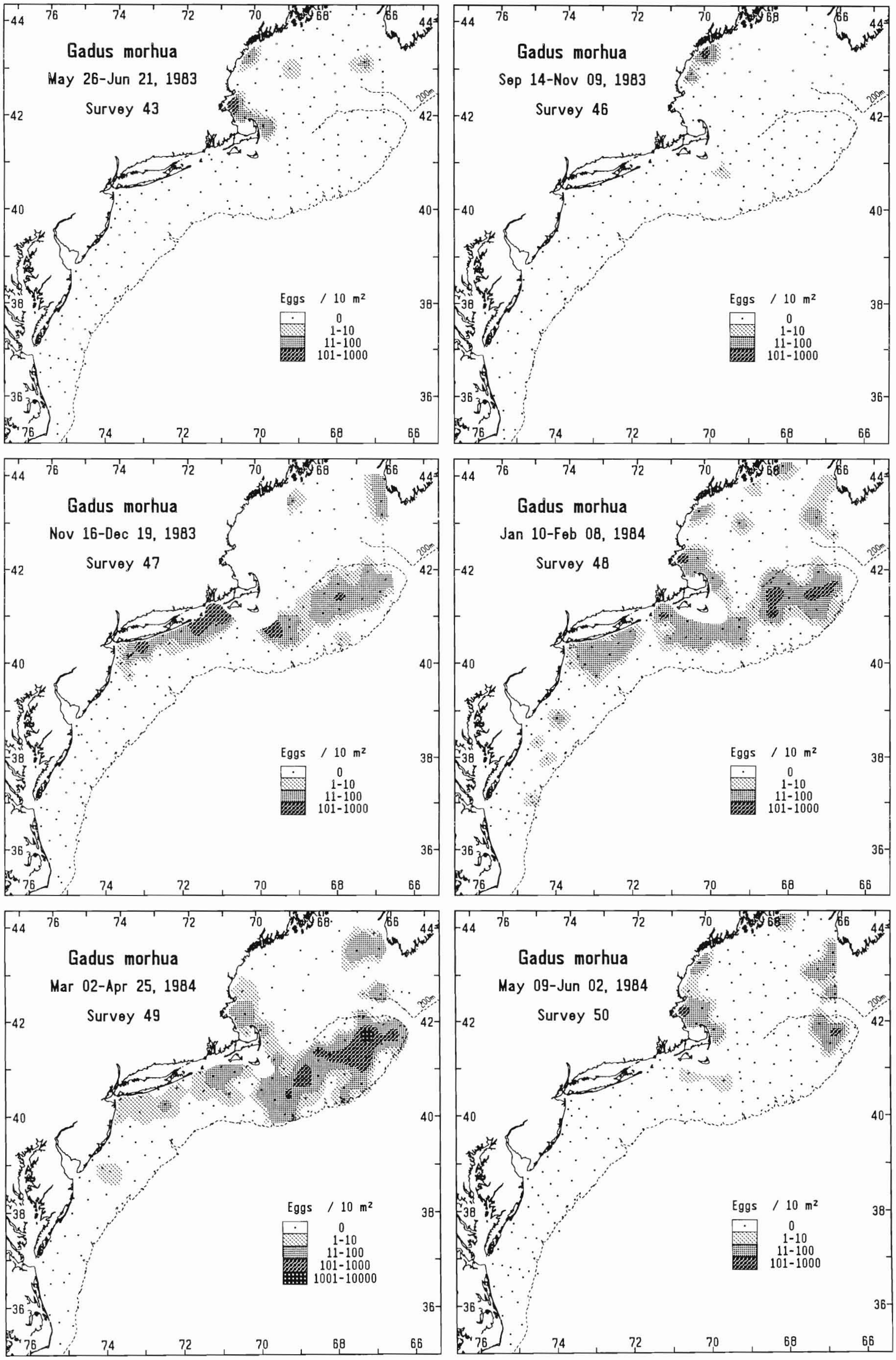

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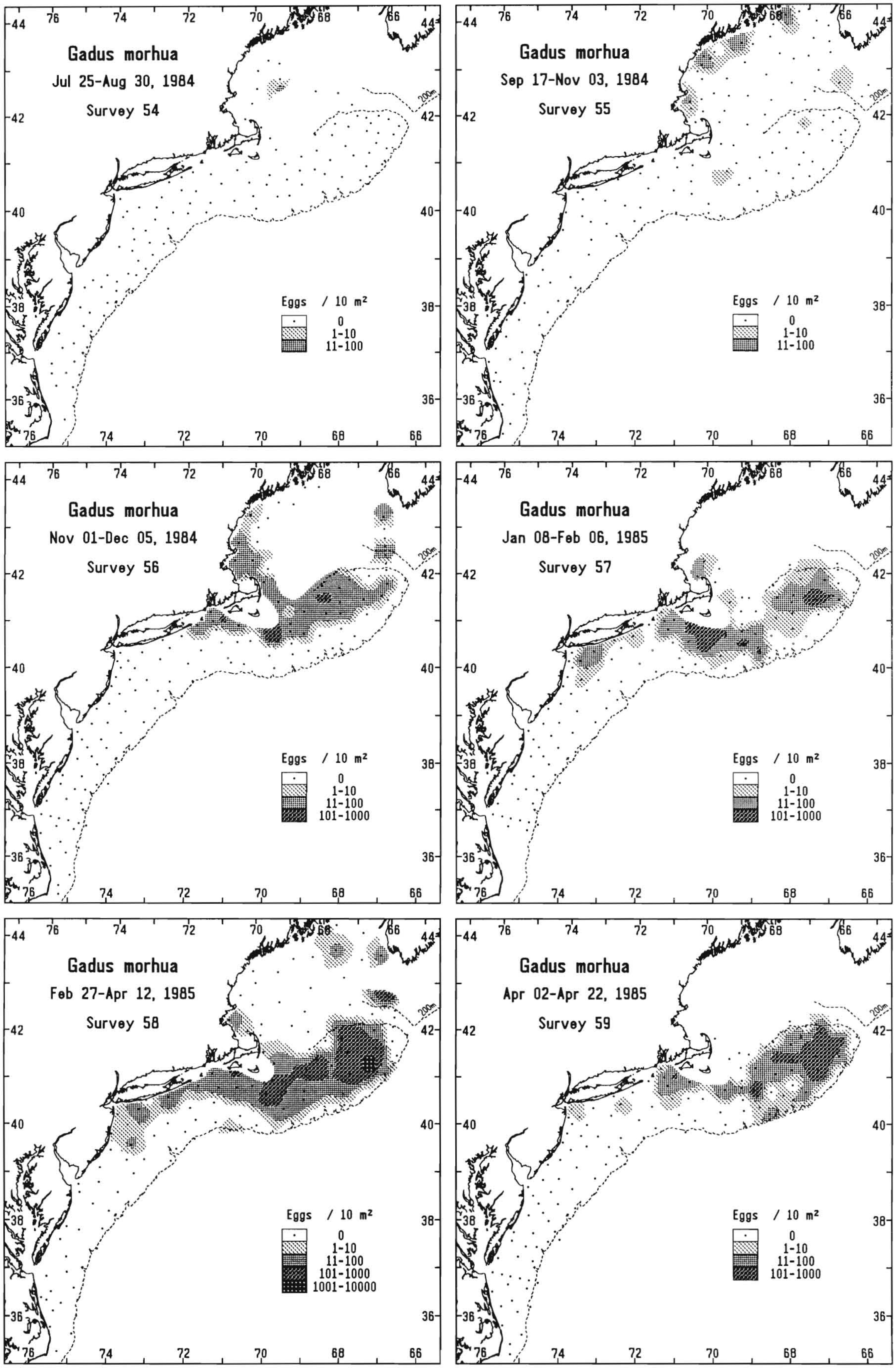

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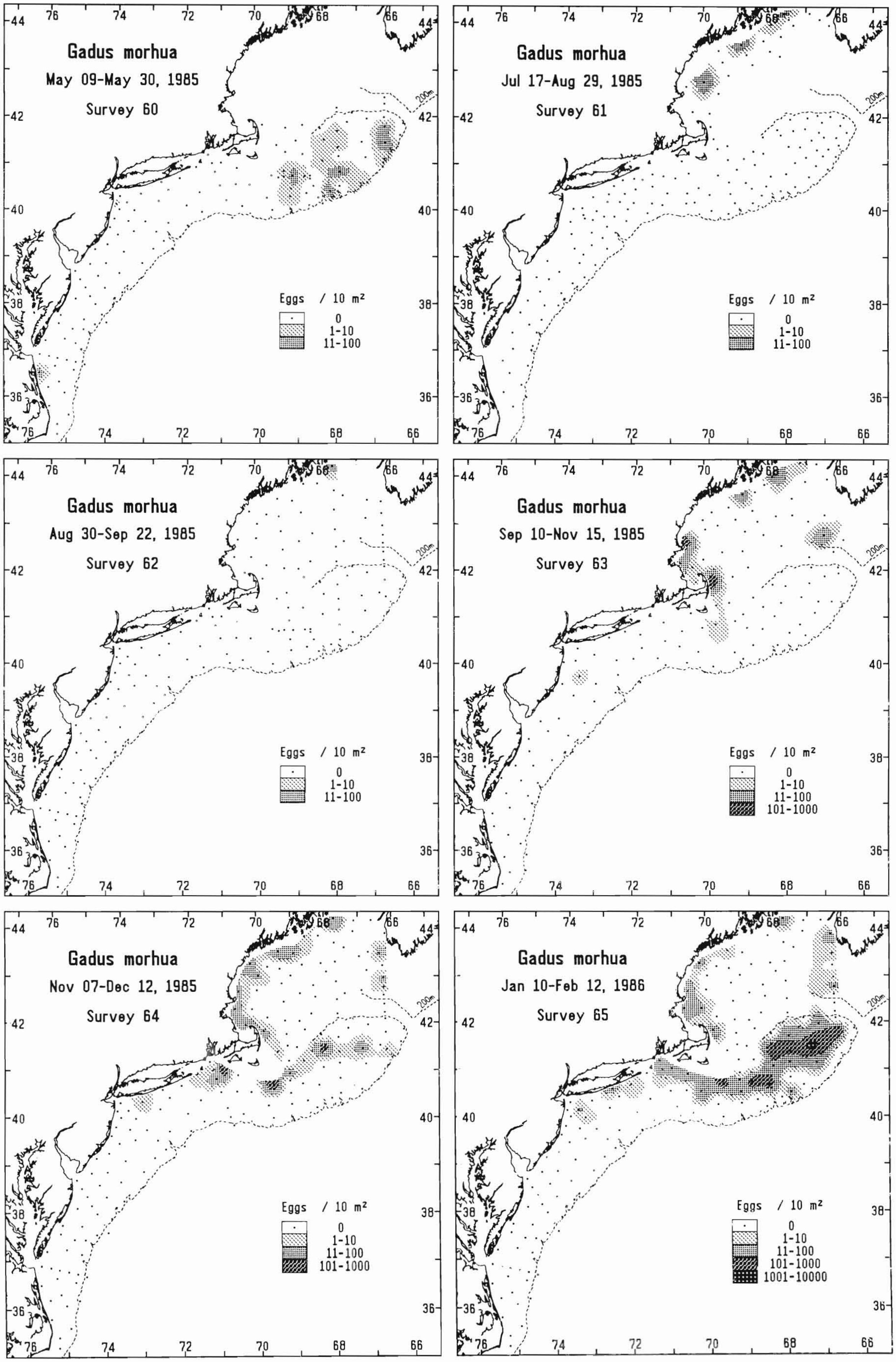

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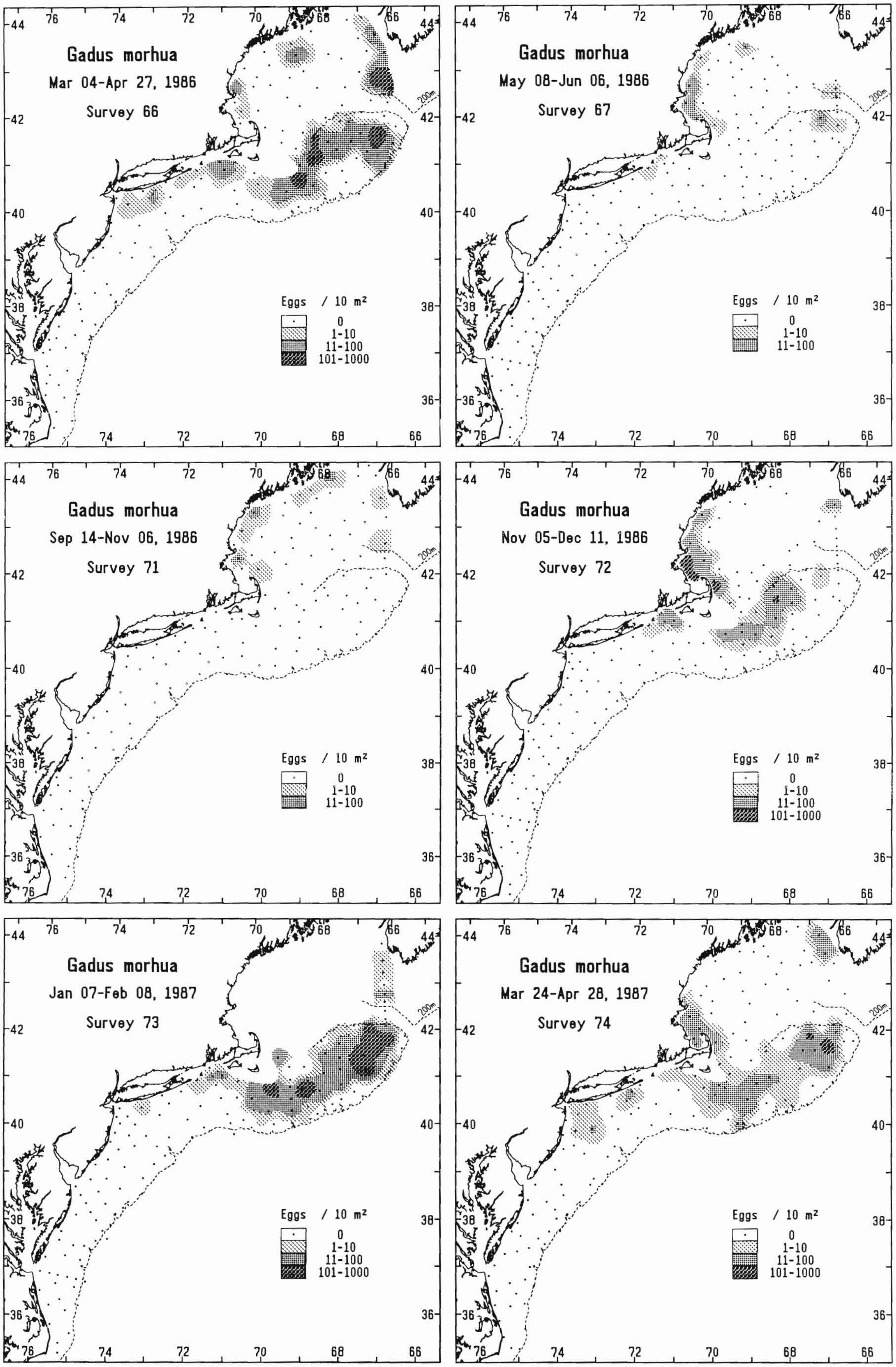

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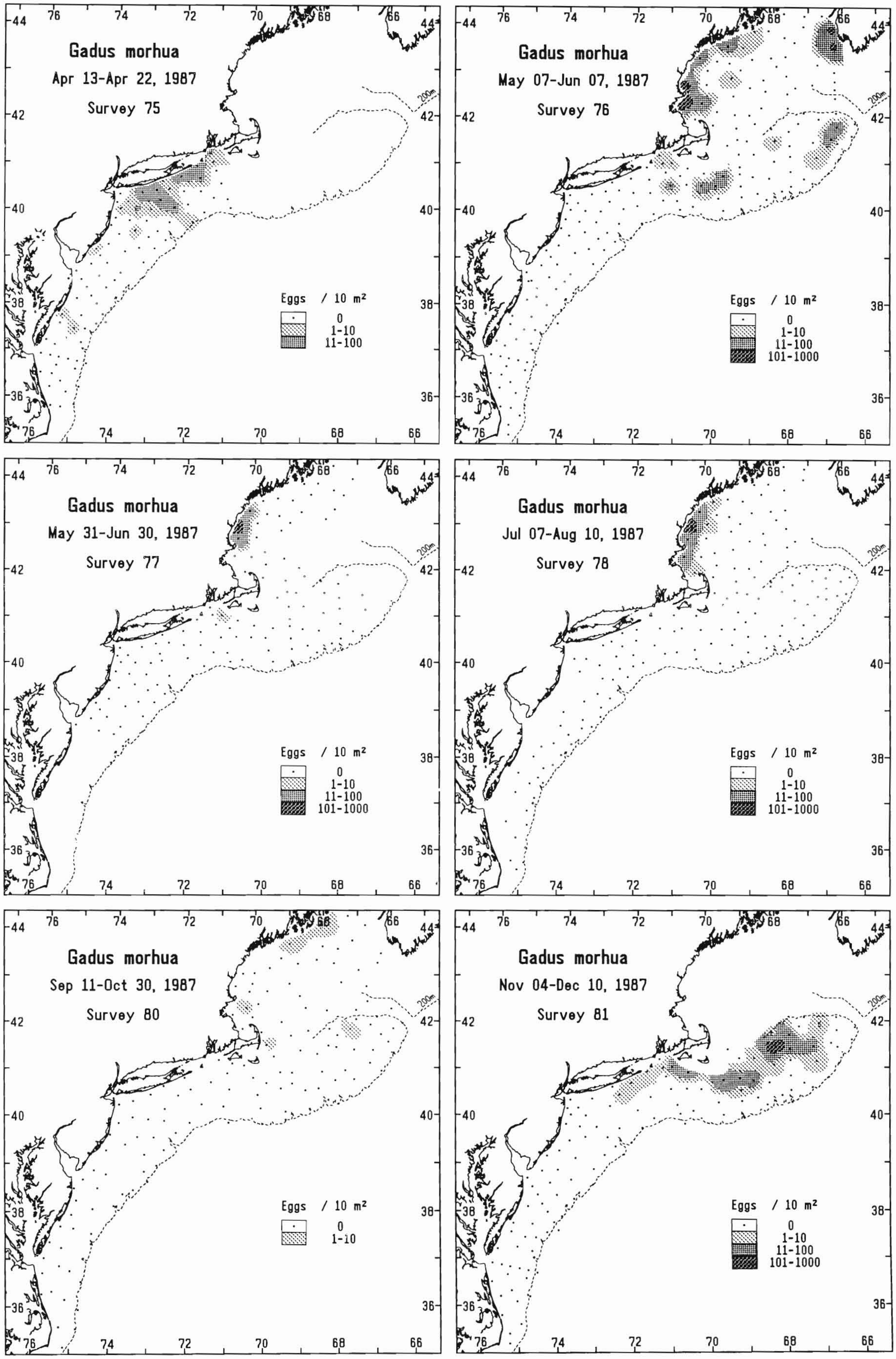


Figure 29 (continued)

Melanogrammus aeglefinus, haddock (Figs. 30–32)

Melanogrammus aeglefinus eggs were collected from January to August, and were most abundant in April (Fig. 30). They occurred on Nantucket Shoals and adjacent waters, Georges Bank, the Scotian Shelf, and in the Gulf of Maine. Eggs collected during March 1984 indicated that in some years spawning occurred as far south as southern New Jersey (Fig. 32). Abundance and distribution of eggs in the Gulf of Maine and Scotian Shelf during March is unknown as we did not sample much of those areas that month (Figs. 2 and 31).

Spawning began in January on the Scotian Shelf and Georges Bank and was concentrated on the eastern portion of the Bank. As the season advanced, spawning increased in intensity and areal extent, occurring south to Nantucket Shoals and north into the Gulf of Maine. However, the major spawning area remained on eastern Georges Bank and Scotian Shelf. During June and July spawning decreased dramatically and by August eggs occurred only in isolated patches in coastal waters of western Gulf of Maine (Fig. 31).

A downward trend in spawning intensity was observed over the nine-year sampling period (Fig. 30). For the first two years (1979 and 1980), mean egg densities exceeded 130/10 m^2; during the remaining seven years (1981–87) mean egg densities ranged from 19 to 60/10 m^2. This decline in spawning was similar to that found for Atlantic cod over the same time period (Fig. 27). While both gadid species co-occur in the Gulf of Maine and on Georges Bank, their spawning seasons differ; Atlantic cod spawn over a greater area and a longer season, and reach a peak in spawning about one month earlier than haddock.

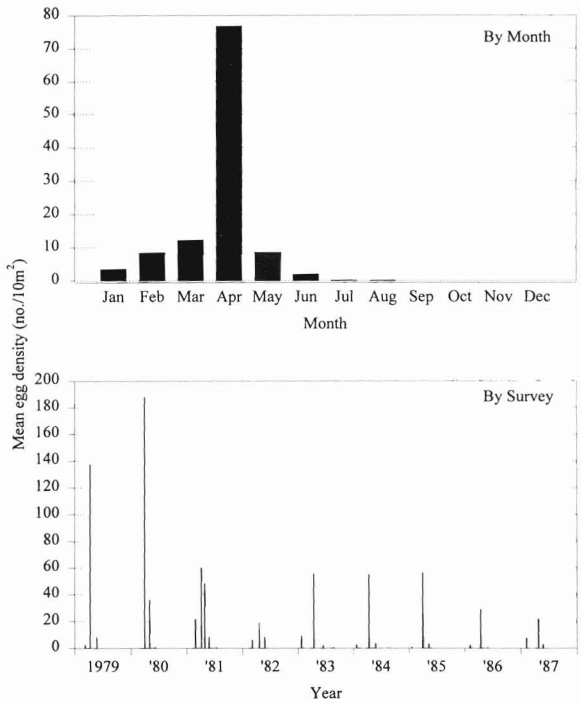


Figure 30
Melanogrammus aeglefinus; mean-egg-density graphs by month (top) and by survey (bottom) for the total MARMAP area.

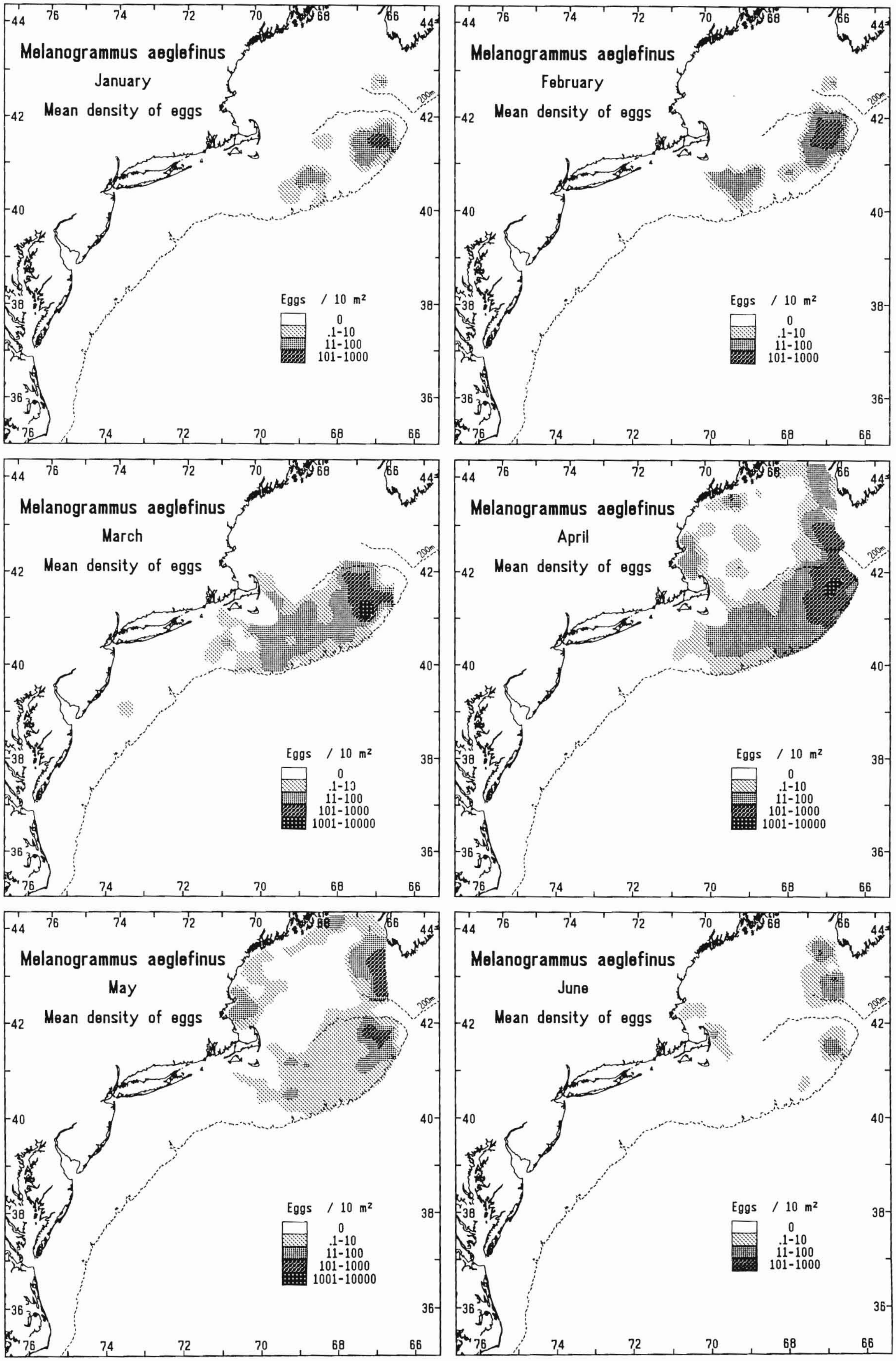


Figure 31

Melanogrammus aeglefinus; composite monthly areal plots of mean egg densities (no./10 m²).

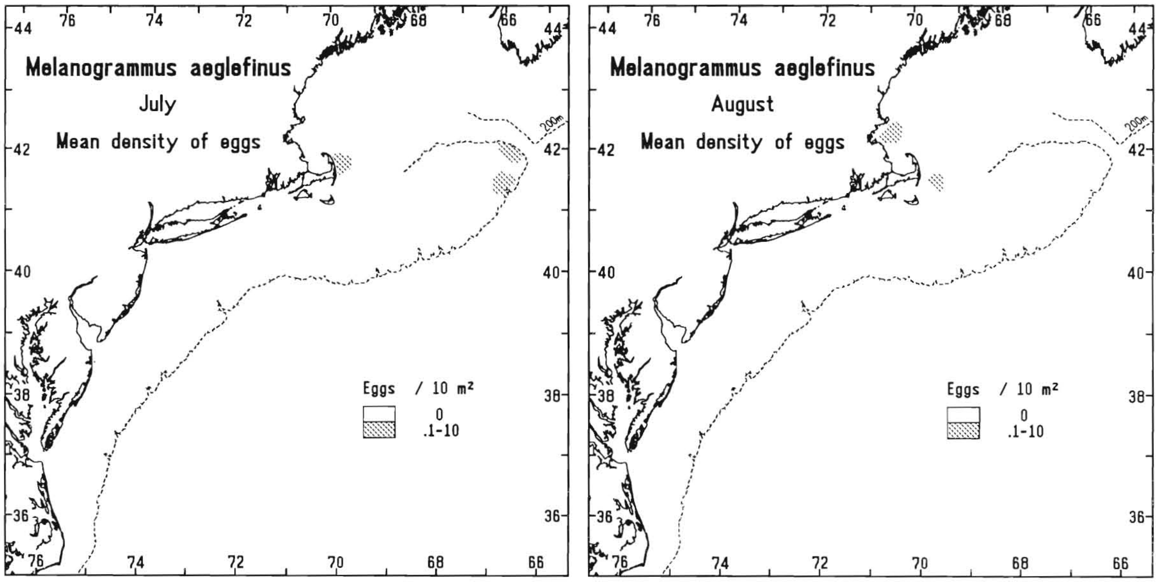


Figure 31 (continued)

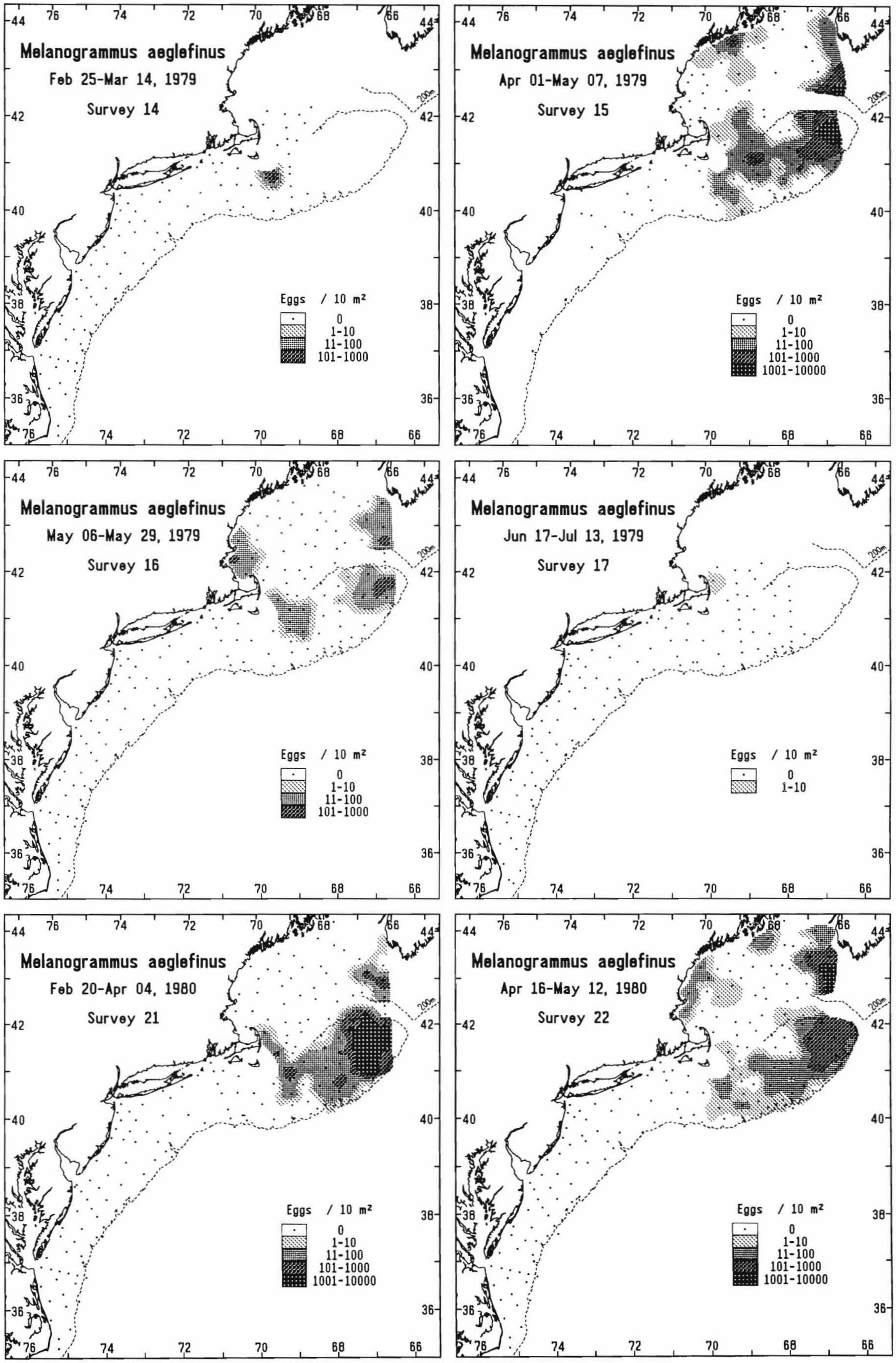


Figure 32
Melanogrammus aeglefinus; survey areal plots of egg densities (no./10 m²).

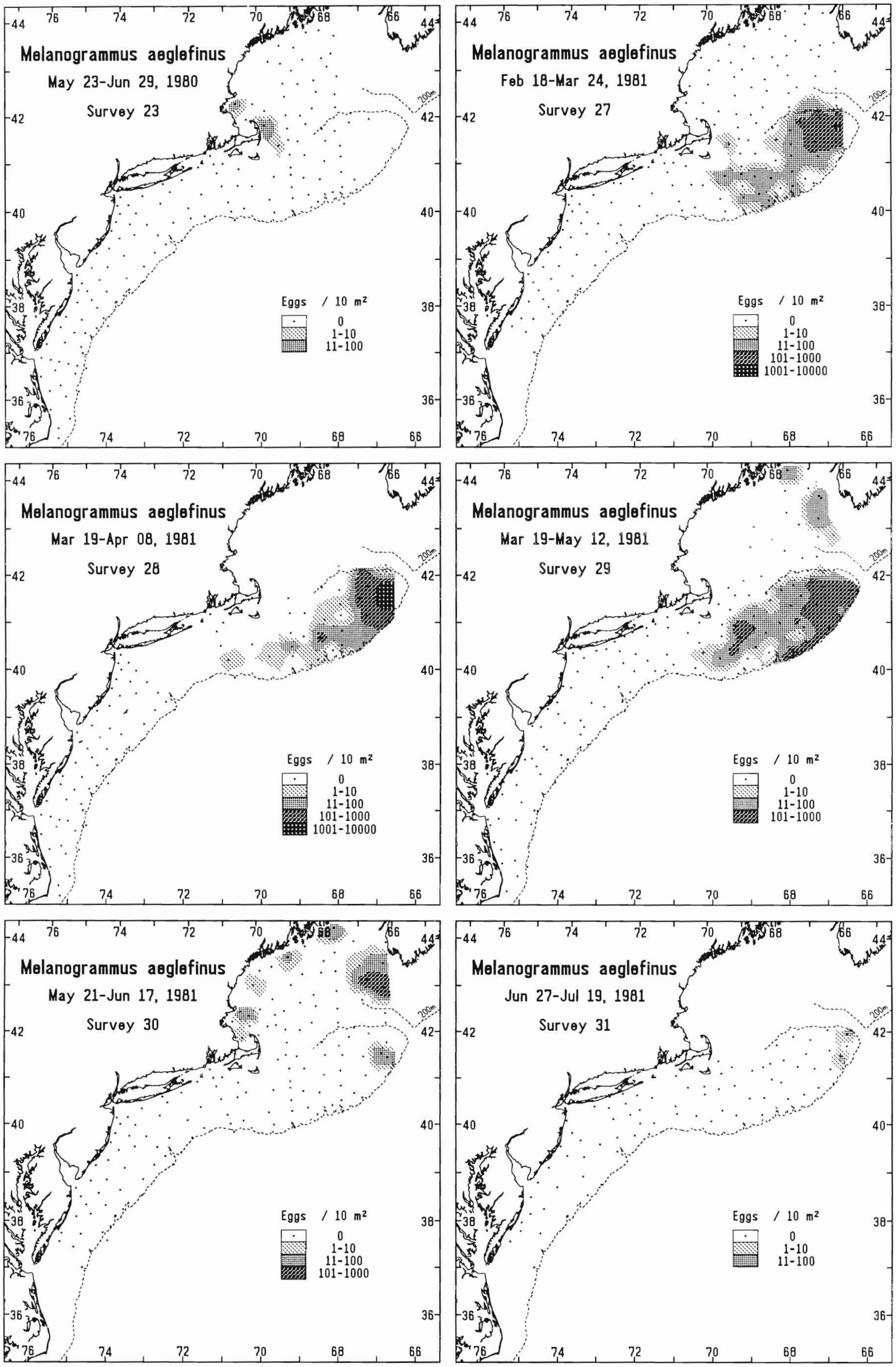
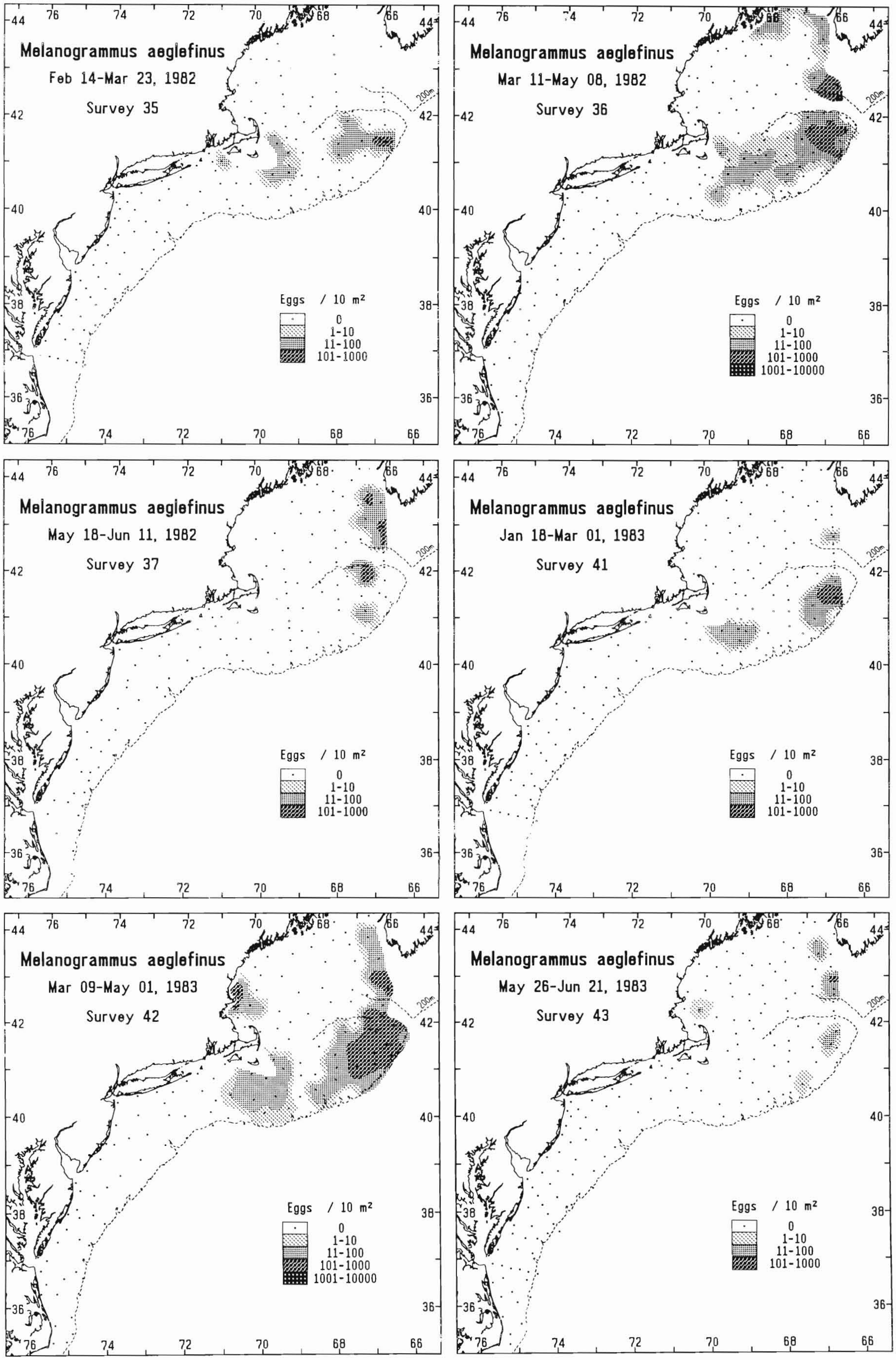


Figure 32 (continued)



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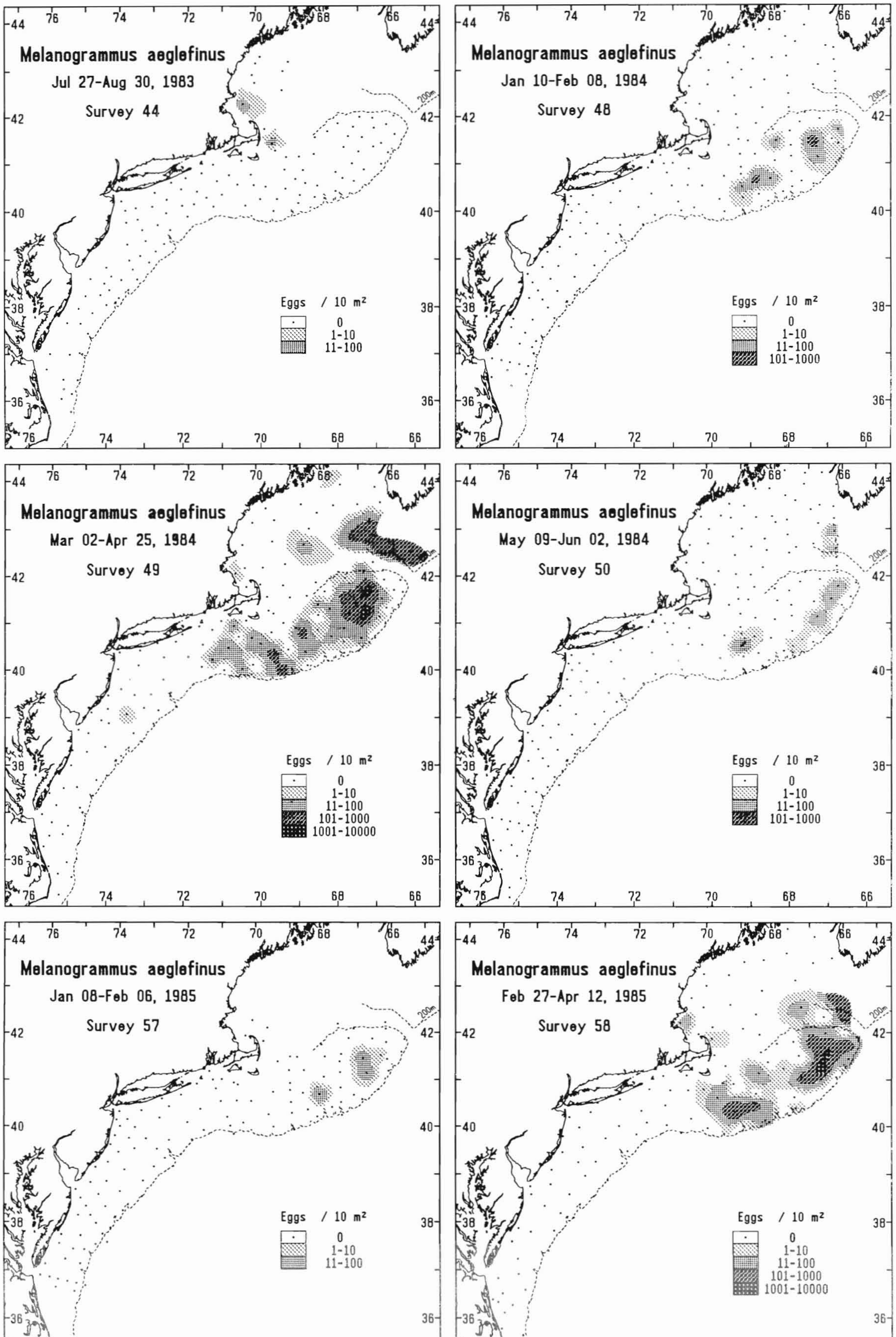

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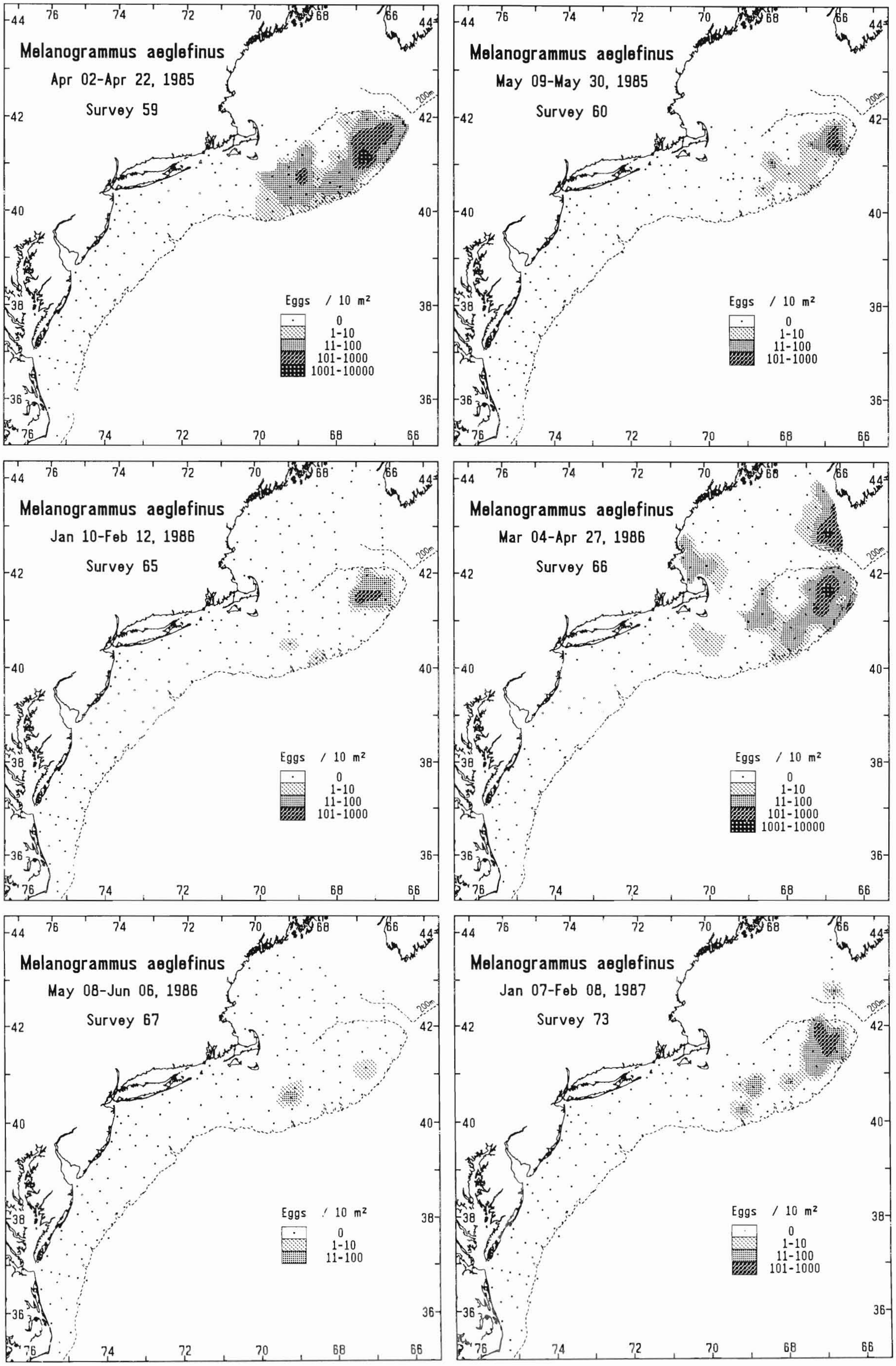

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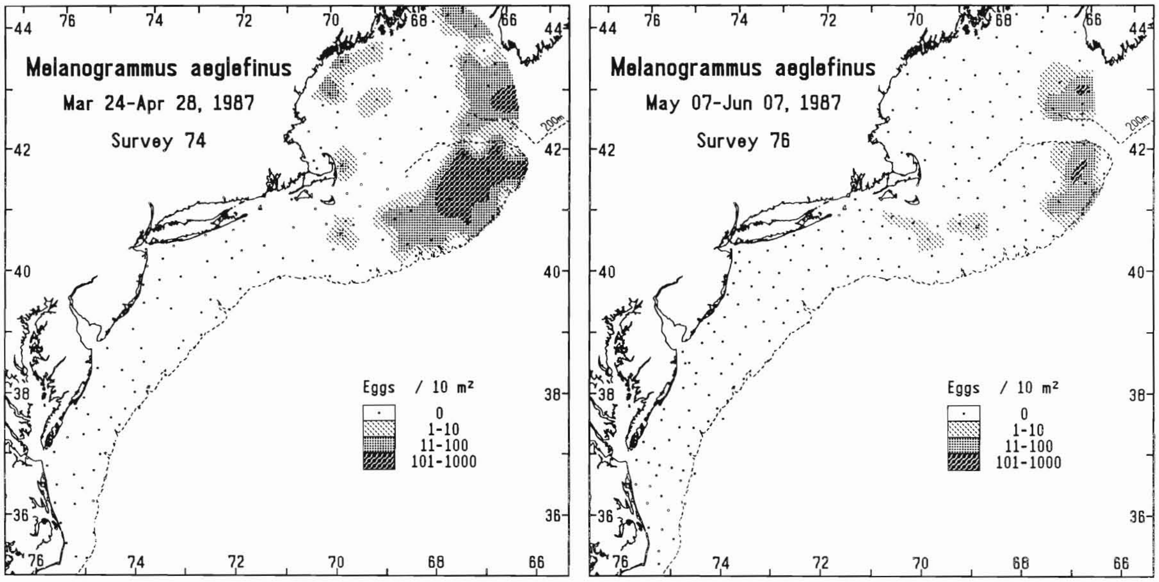


Figure 32 (continued)

Merluccius albidus, offshore hake (Figs. 33–35)

Merluccius albidus eggs were collected during all months of the year, indicating year-round spawning, and were most abundant from April to June (Fig. 33). They generally occurred along the outer, deeper portions of the continental shelf from eastern and southeastern Georges Bank to off Chesapeake Bay.

While spawning intensity is cyclic, with a marked peak from April to June (Fig. 33), there did not appear to be a corresponding shift in areas of egg occurrence, either on or off the shelf, or north or south along the shelf (Fig. 34). The apparent secondary peak in egg abundance during October was most likely a sampling artifact. Many ichthyoplankton samples taken during July and August were collected on shellfish assessment surveys that seldom sampled out to the shelf edge. Thus, bi-modality in monthly egg densities reflected undersampling during July–September in areas where *Merluccius albidus* eggs would most likely occur.

Spawning intensity declined during the nine years surveyed. Mean egg densities exceeded 10/10 m² during three of the first four full years surveyed (1979–82), but remained below 5/10 m², with one exception (in 1984) during the last five years. The relatively high mean egg density observed in 1984 was influenced by collections taken during survey 50 where densities were high. There was no apparent bias in sampling coverage during that survey to explain these high densities (Fig. 35).

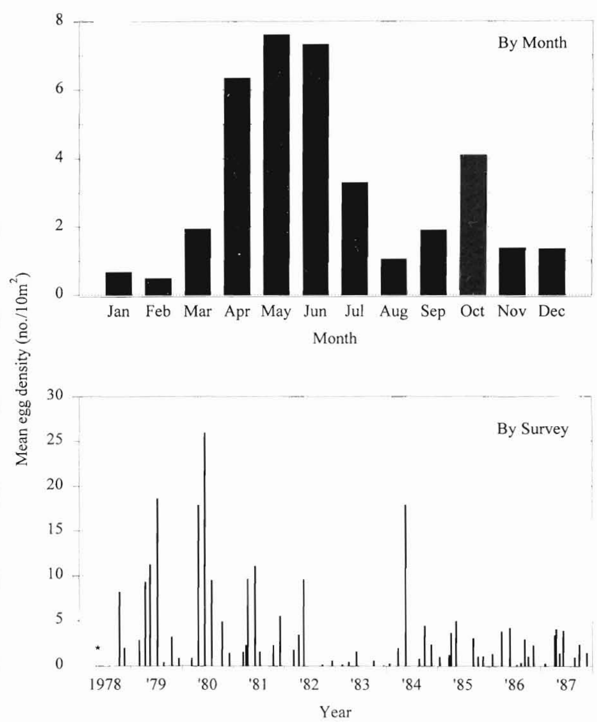


Figure 33

Merluccius albidus; mean-egg-density graphs by month (top) and by survey (bottom) for the total MARMAP area. (*Samples from the first four surveys in 1978 were not analyzed for *M. albidus* eggs.)

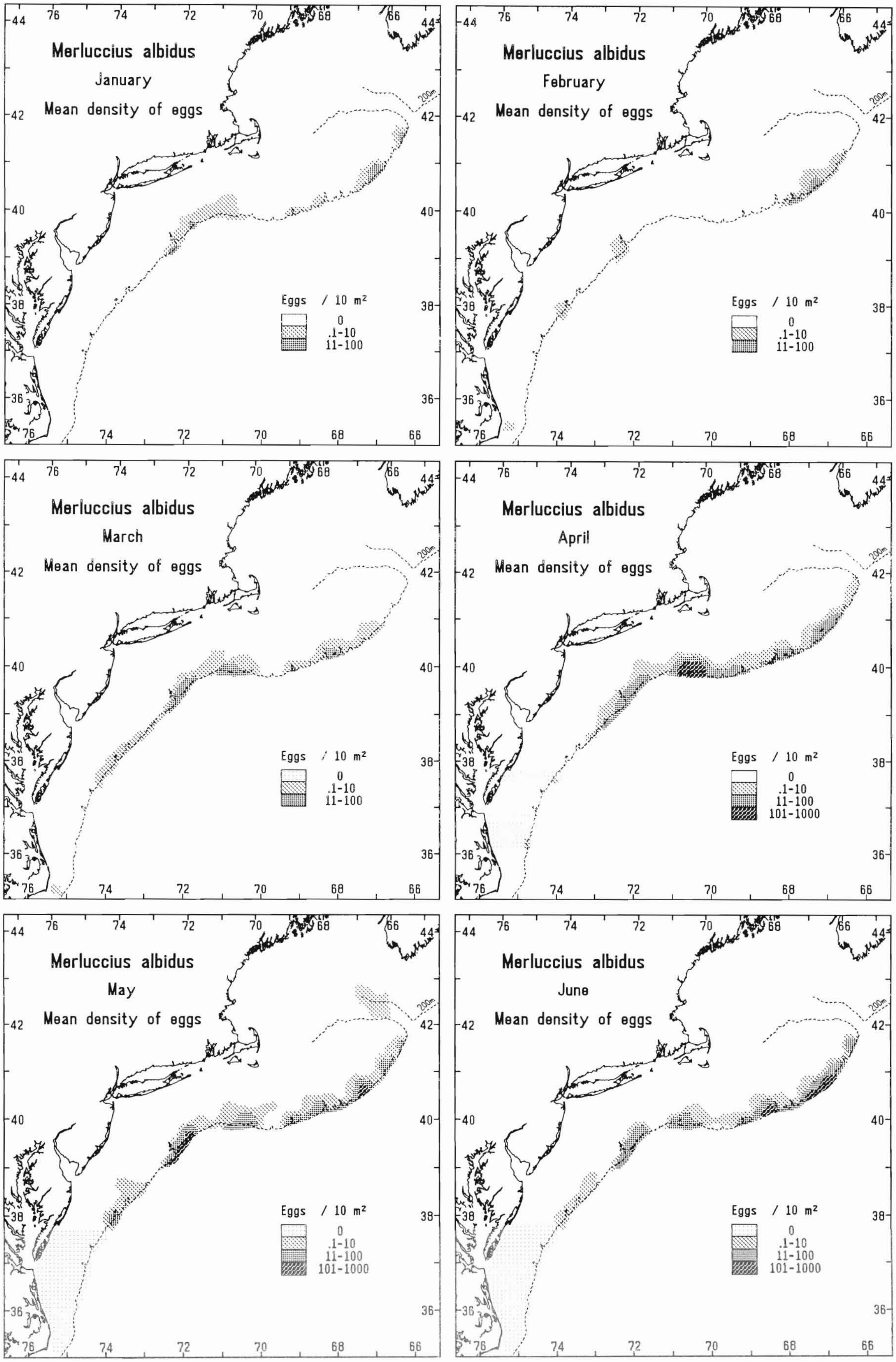
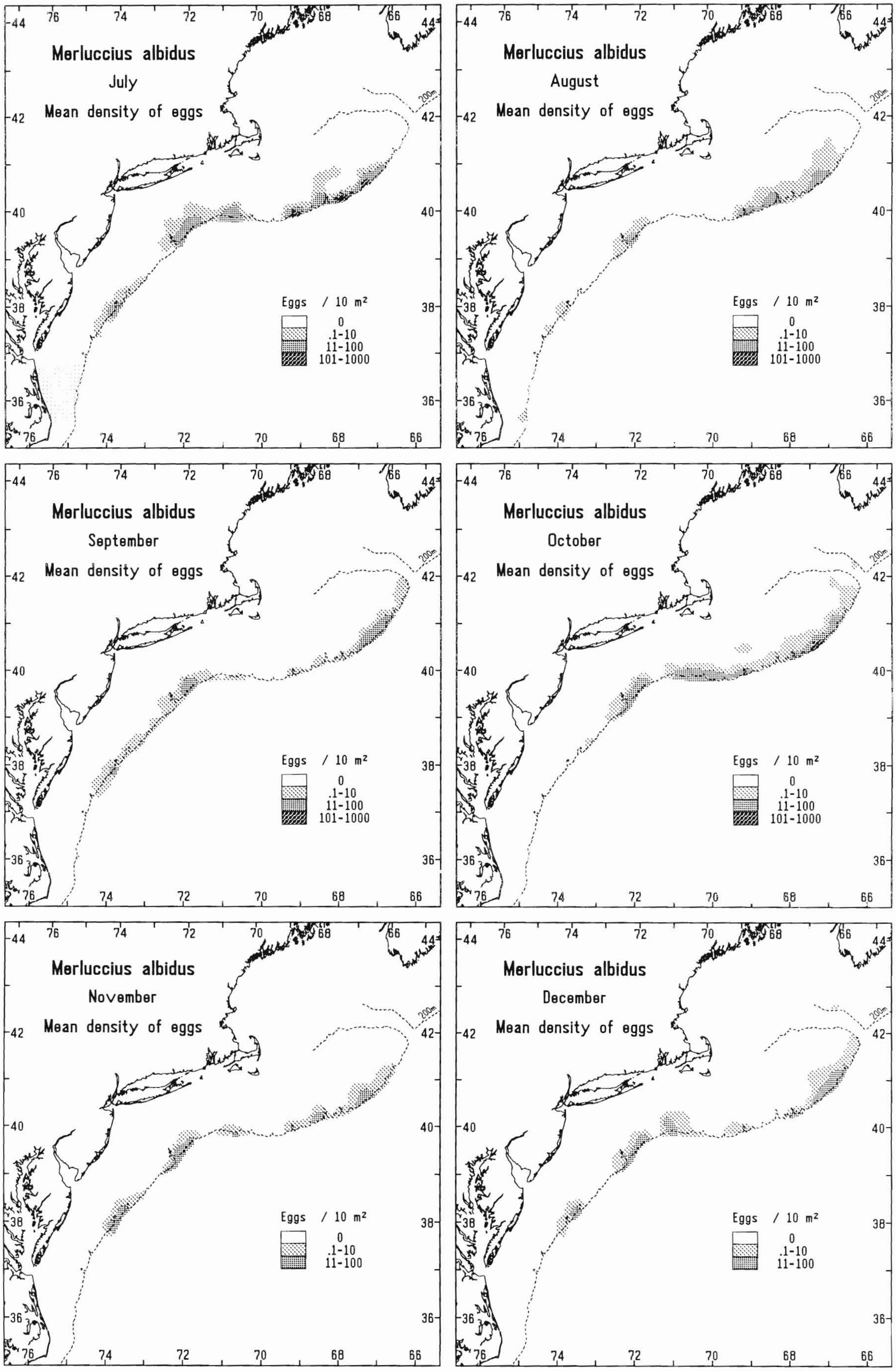


Figure 34
Merluccius albidus; composite monthly areal plots of mean egg densities (no./10 m²).



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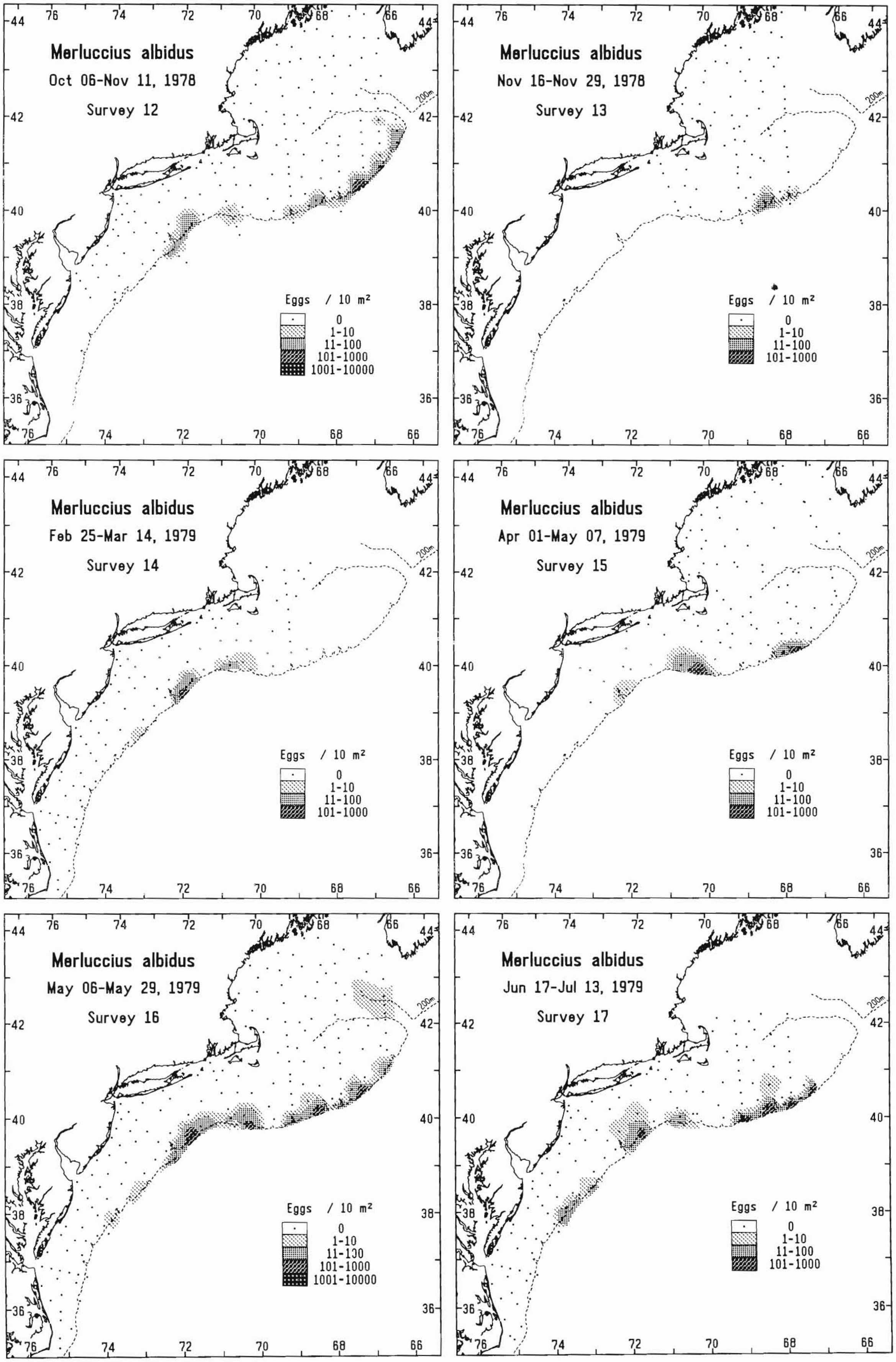
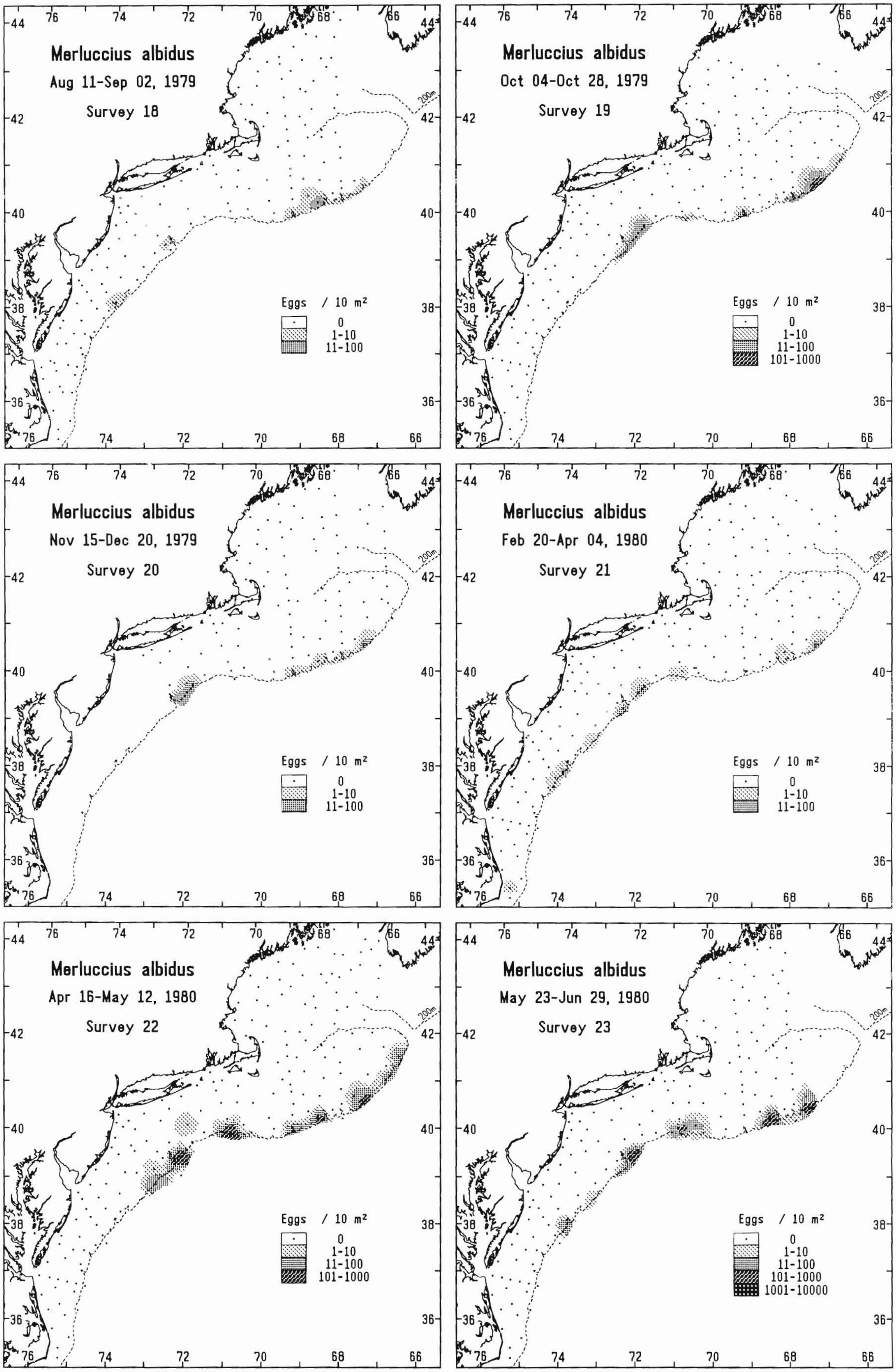


Figure 35
Merluccius albidus; survey areal plots of egg densities (no./10 m²).



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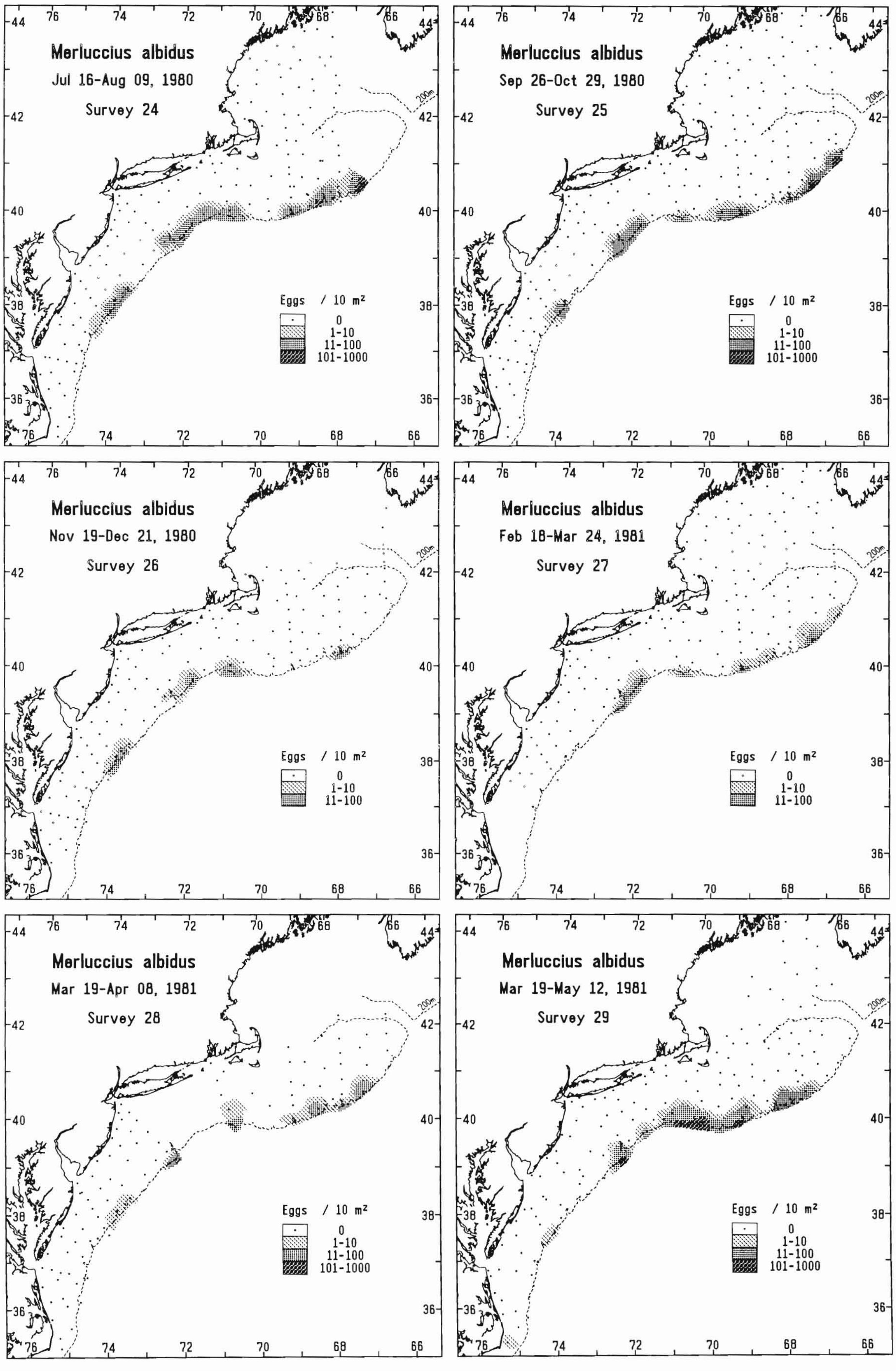

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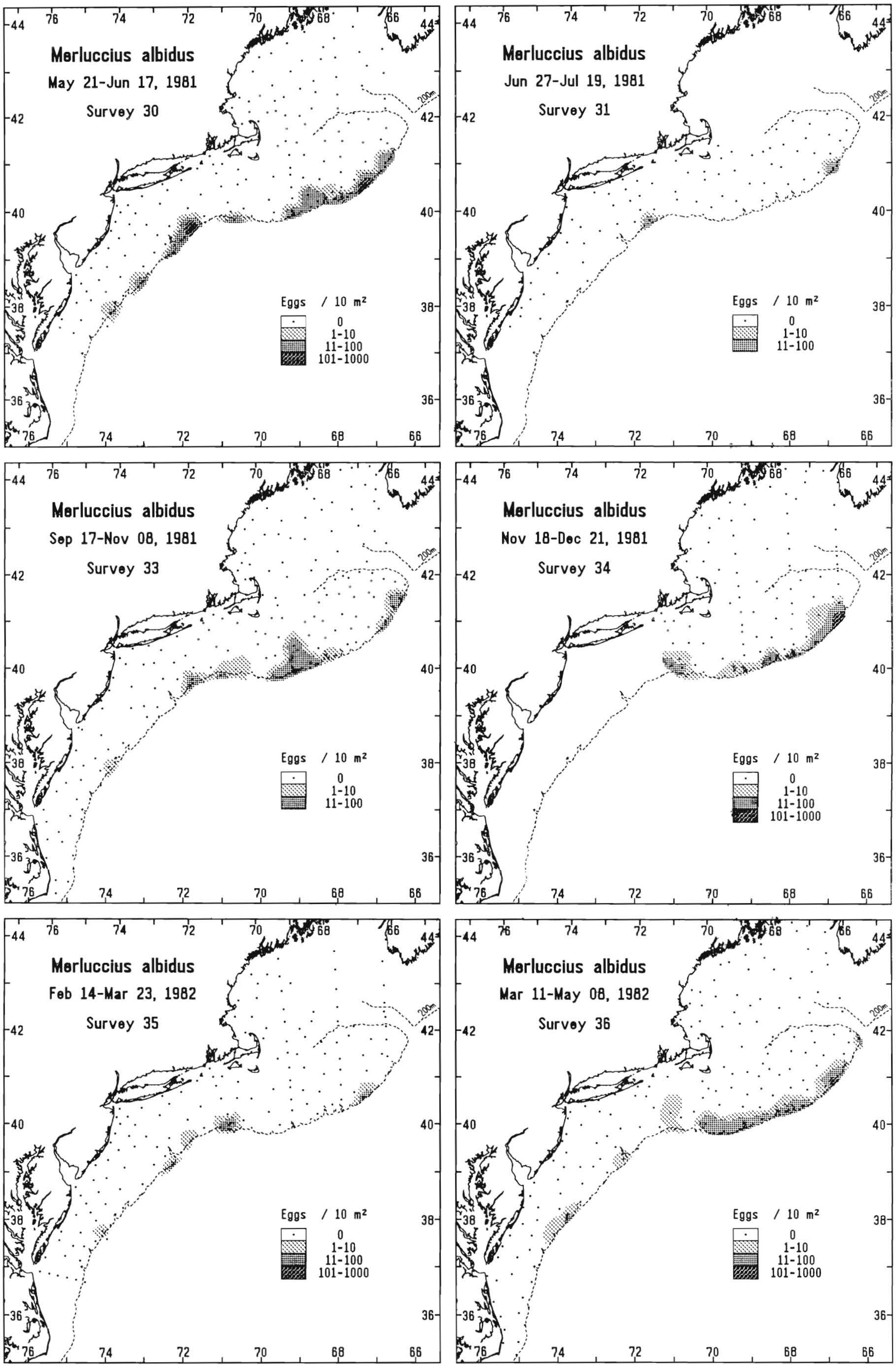

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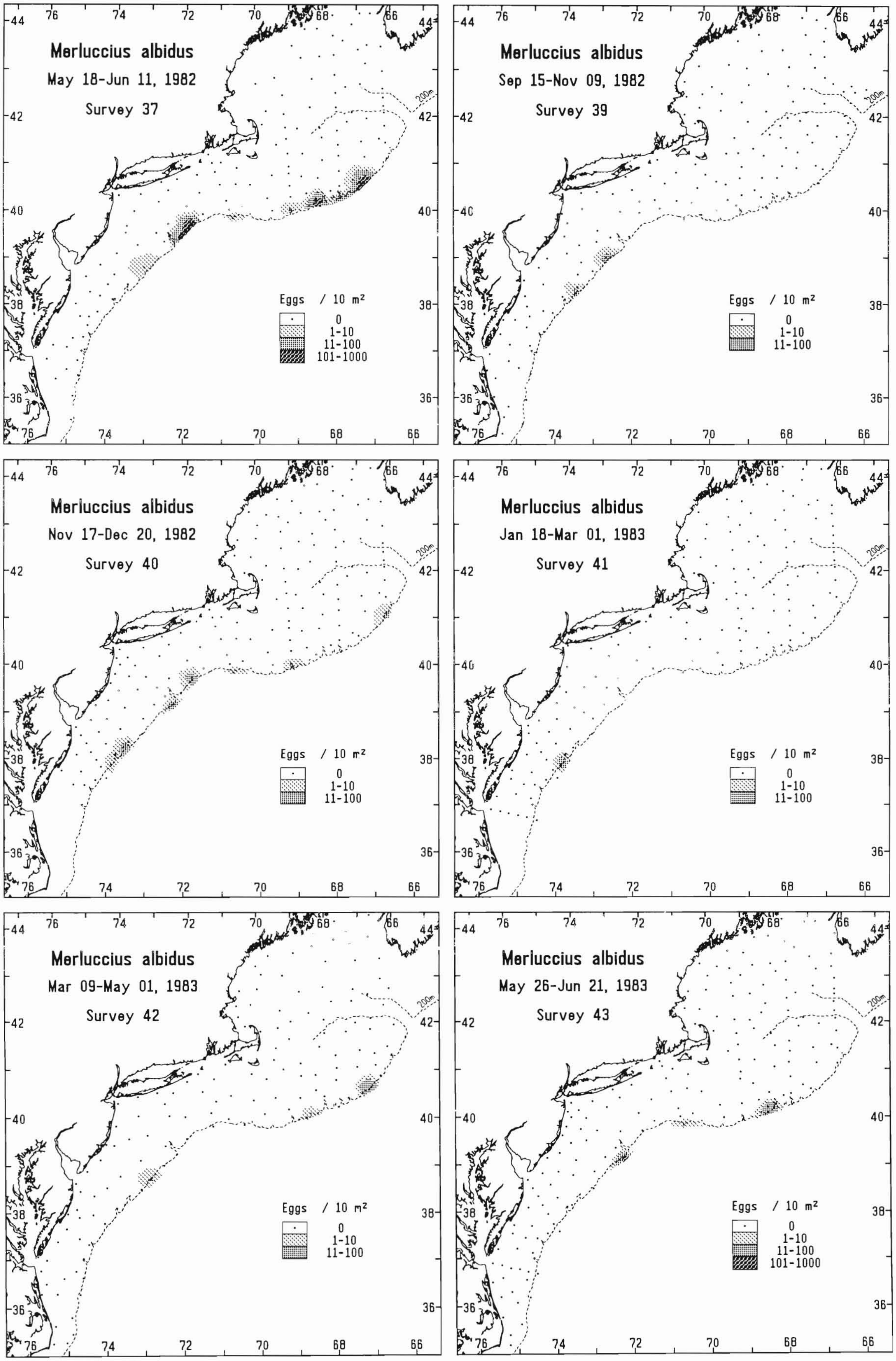

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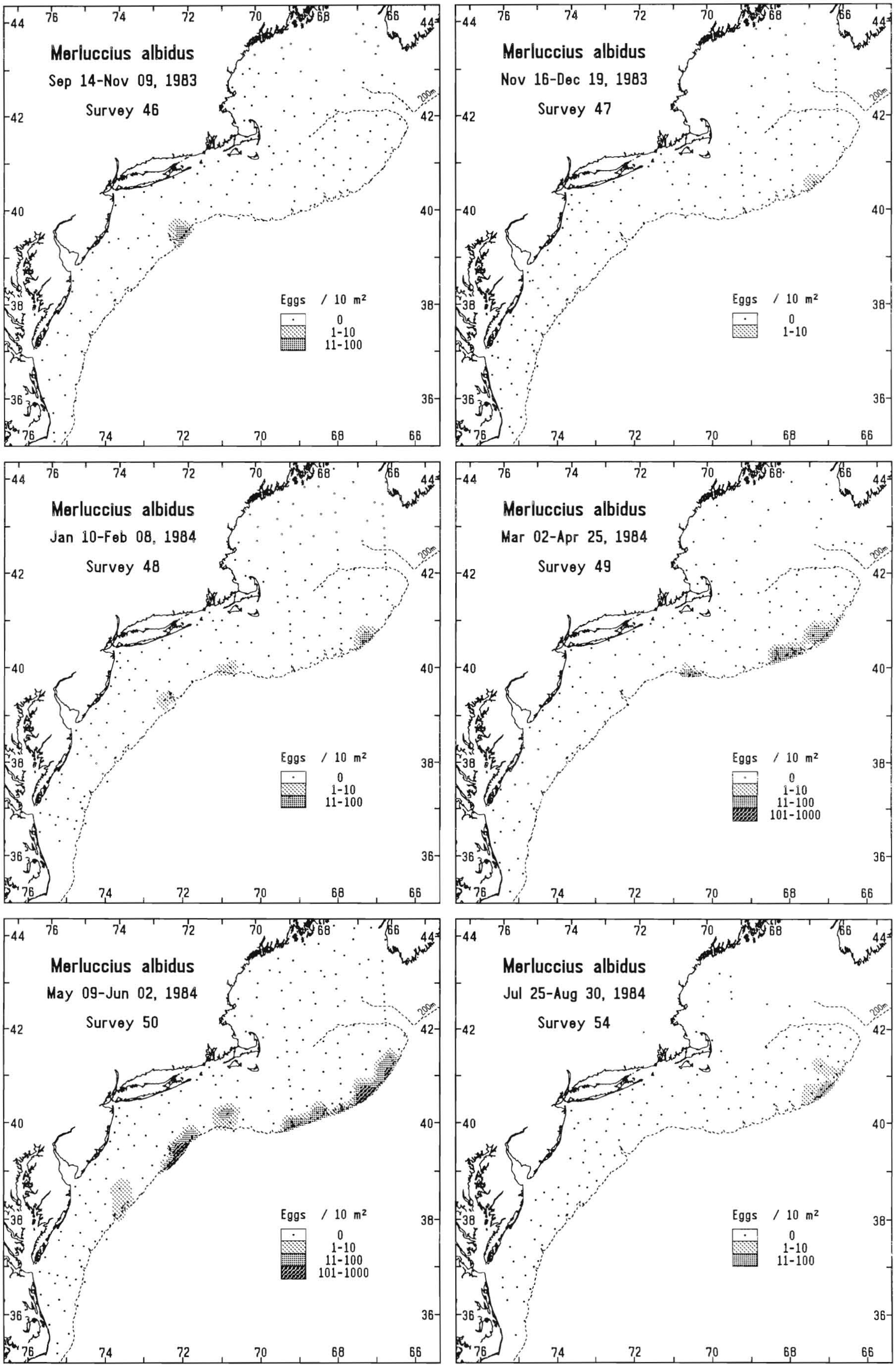

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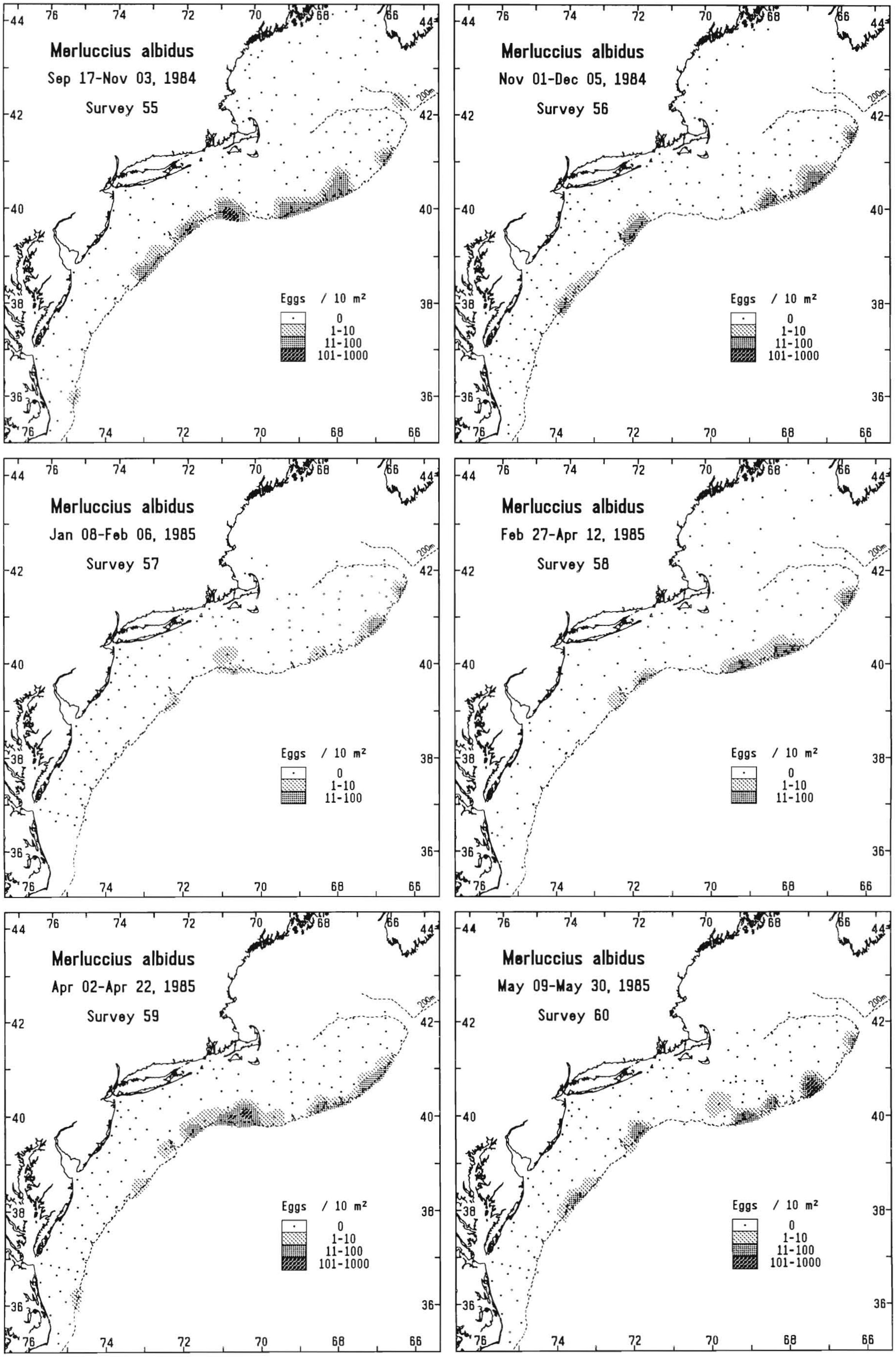

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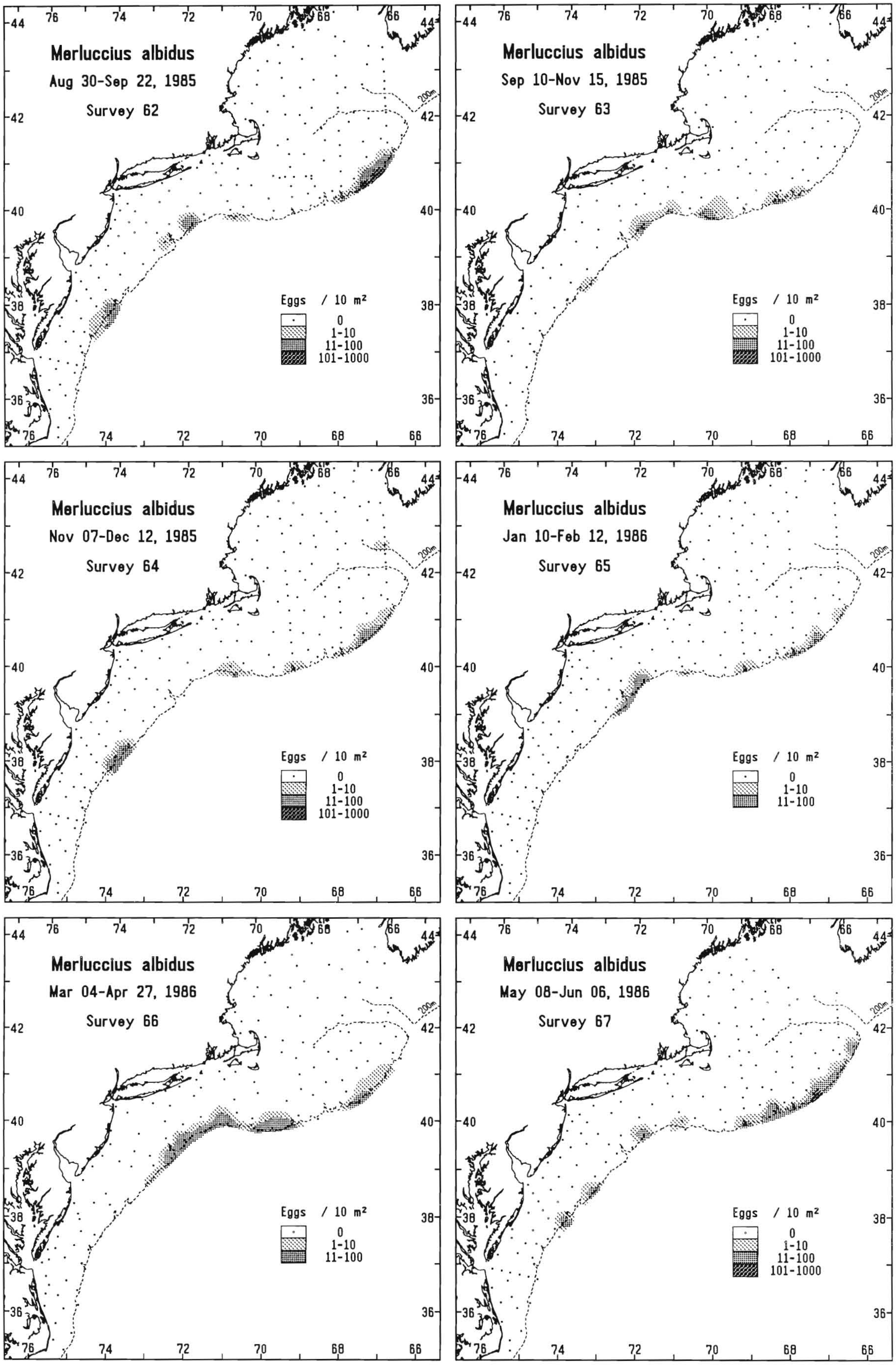

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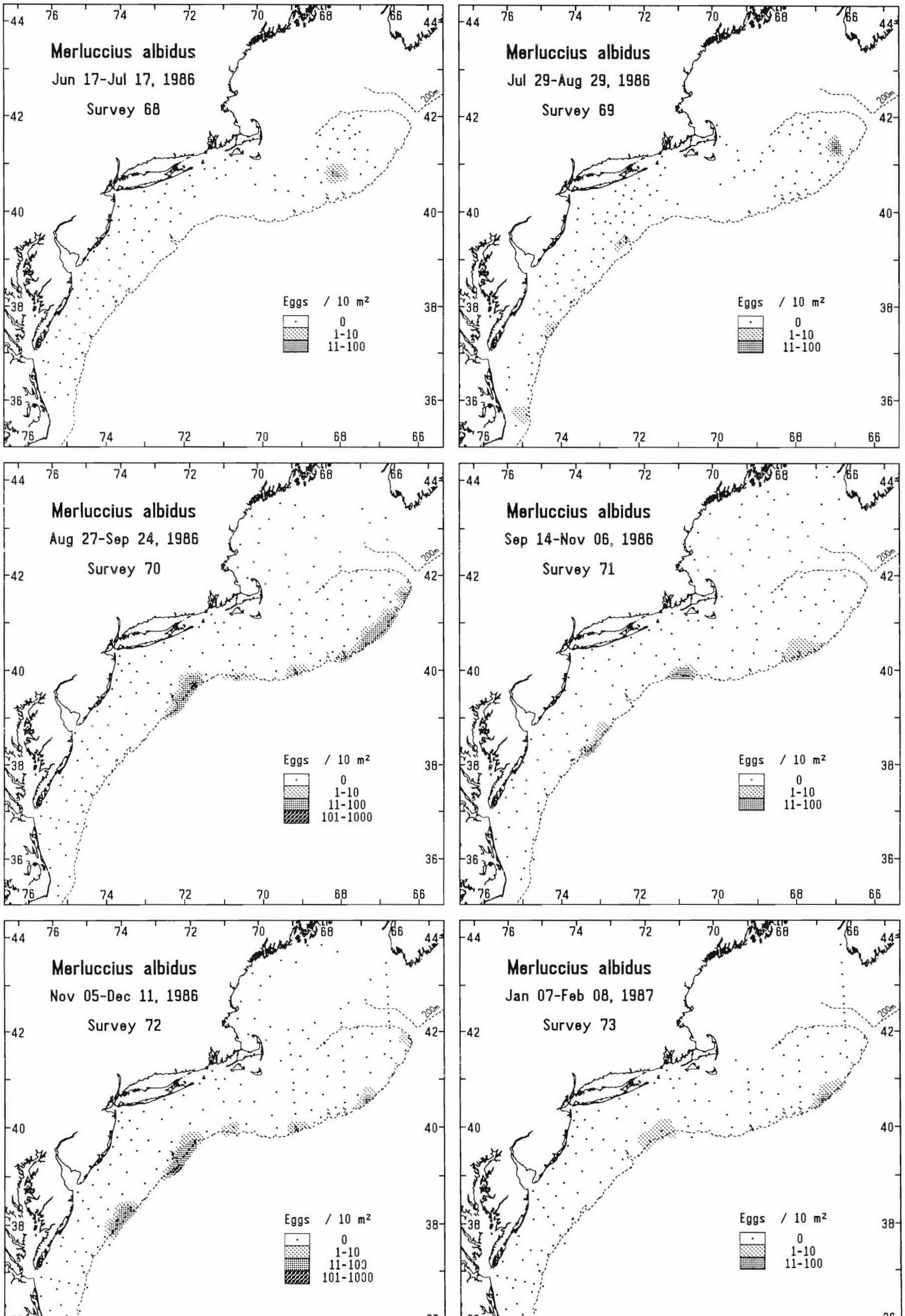

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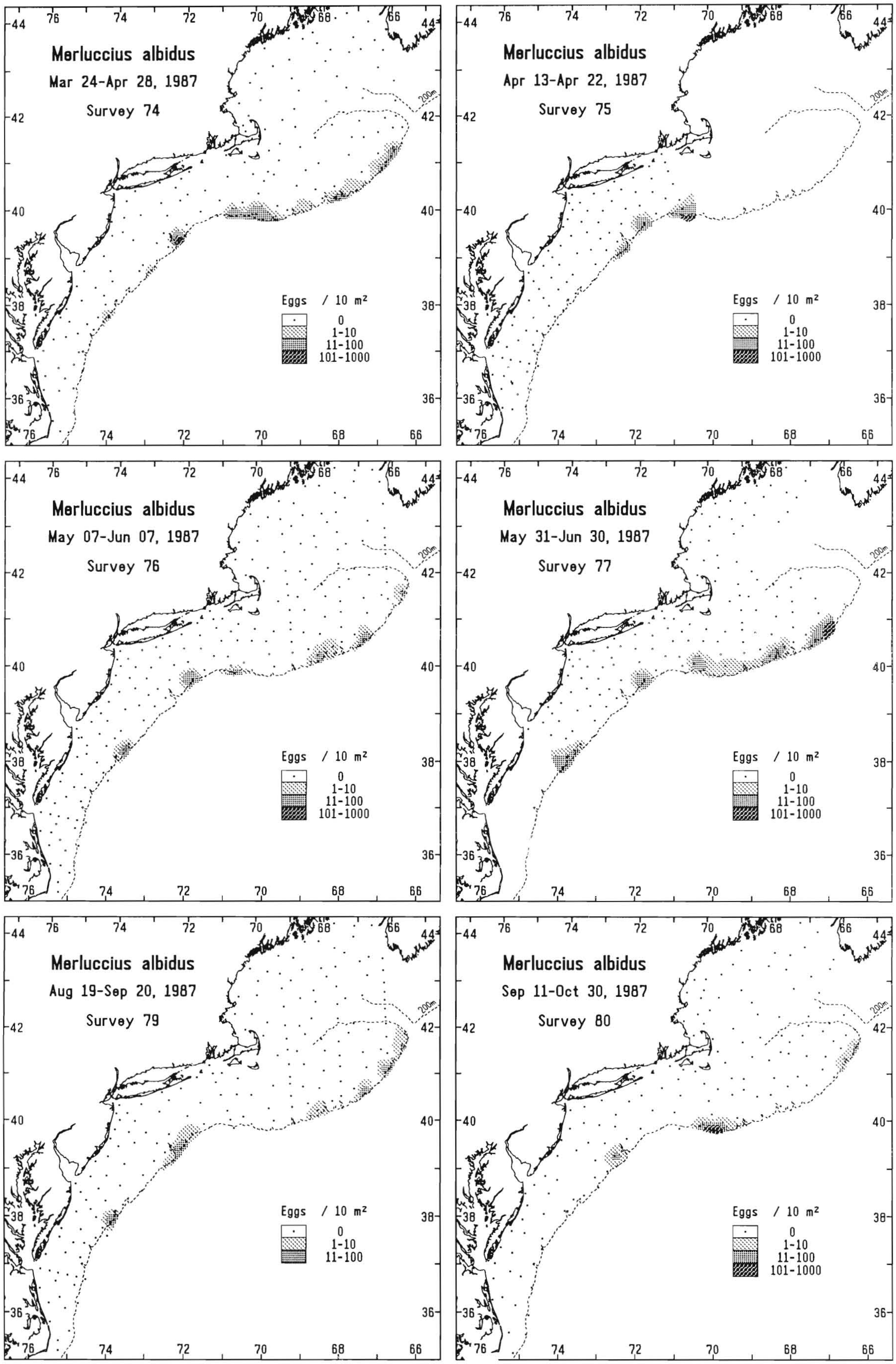

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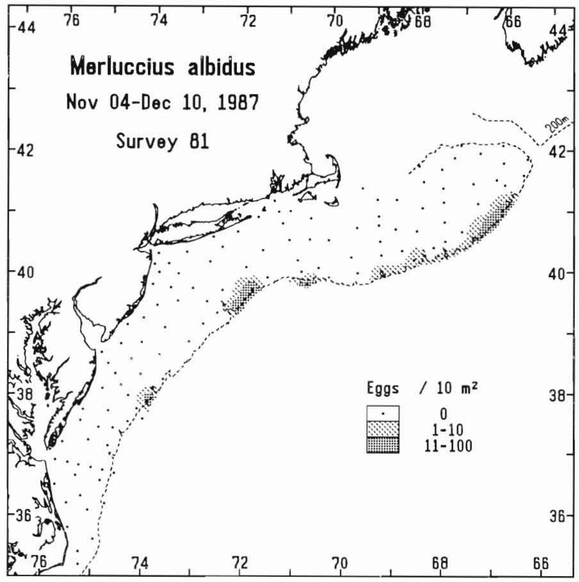


Figure 35 (continued)

Merluccius bilinearis, silver hake (Figs. 36–38)

Merluccius bilinearis eggs were very abundant and one of the most commonly occurring taxa (Table 3). They were collected throughout the year, but were most abundant from May to September, when mean densities over the nine years exceeded 1,000/10 m^2 at individual locations (Figs. 36 and 37).

During winter months (January to March) spawning was restricted to deeper waters from southern Georges Bank to off Chesapeake Bay. Spring warming during April and June was accompanied by a dramatic increase in spawning and a shift to mid-shelf and inner-shelf spawning grounds from approximately Delaware Bay and northward. South of Delaware Bay spawning was concentrated in outer shelf waters year-round. Peak spawning occurred during July and August on Georges Bank and southern New England waters; significant spawning also occurred in Middle Atlantic and inshore Gulf of Maine waters during summer. Following the July/August peak in egg abundance, spawning declined during autumn, and by December eggs were found in isolated locations along the shelf edge (Fig. 37).

An upward trend in spawning intensity was indicated during the nine-year survey period (Fig. 36). This trend was evident despite a probable upward bias for the two highest mean egg densities observed (1984 and 1986), caused by under-sampling in the Gulf of Maine.

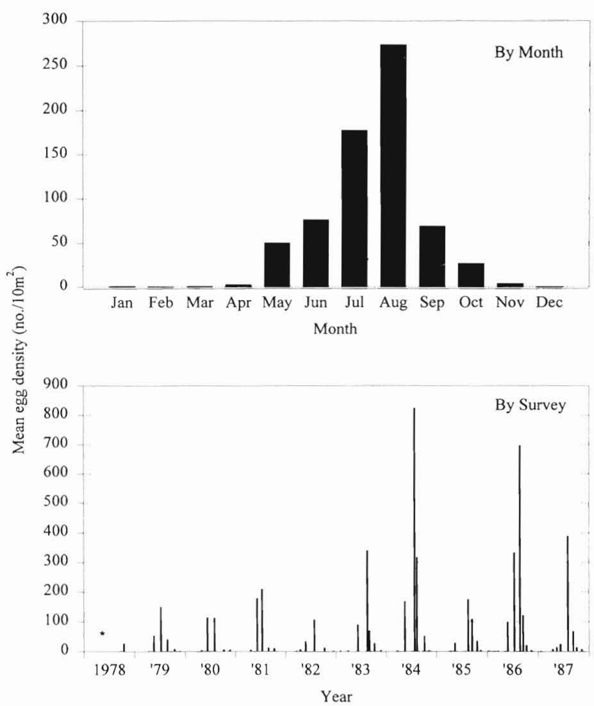


Figure 36
Merluccius bilinearis; mean-egg-density graphs by month (top) and by survey (bottom) for the total MARMAP area. (*Samples from the first four surveys in 1978 were not analyzed for *M. bilinearis* eggs.)

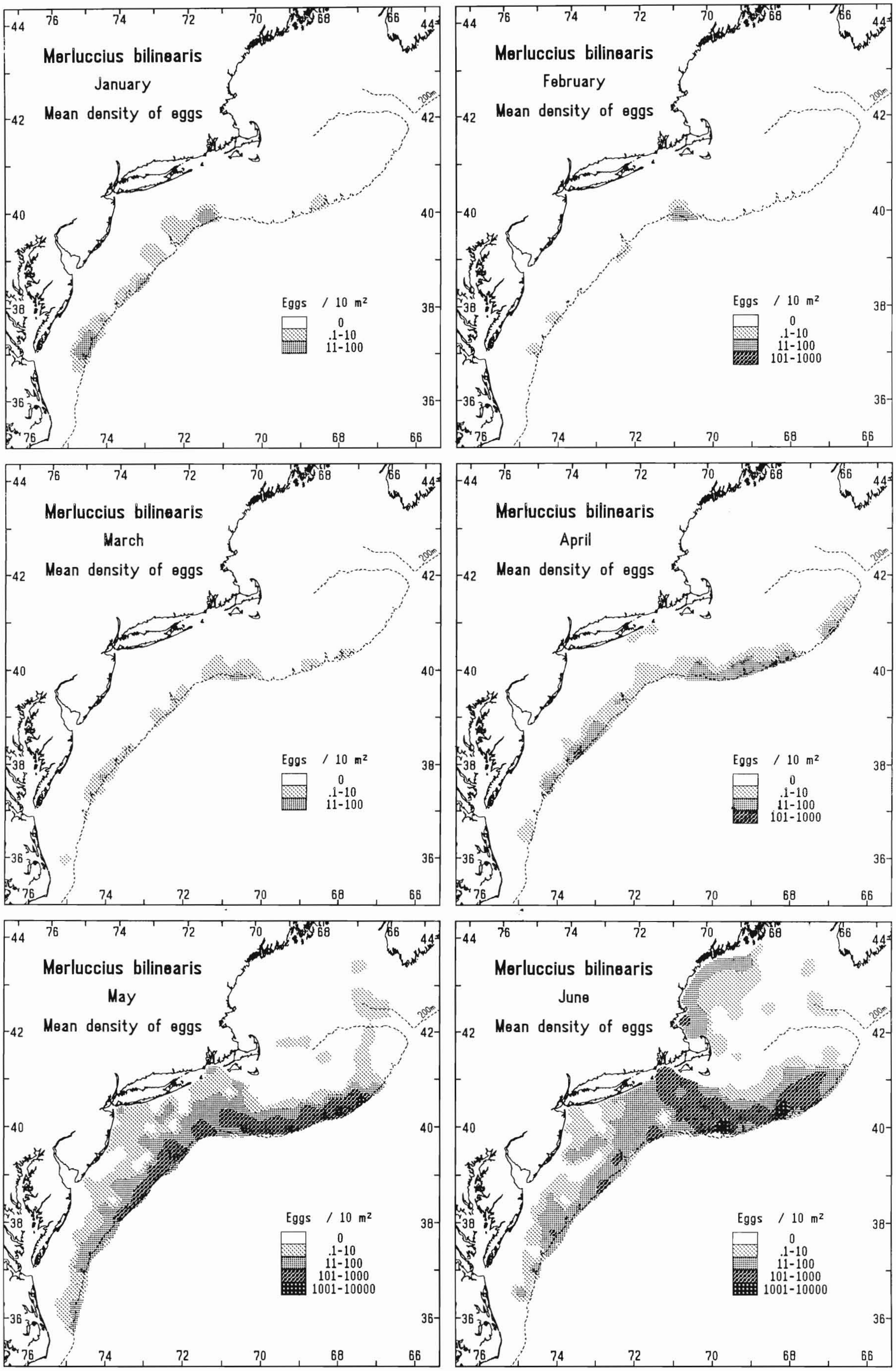


Figure 37
Merluccius bilinearis; composite monthly areal plots of mean egg densities (no./10 m²).

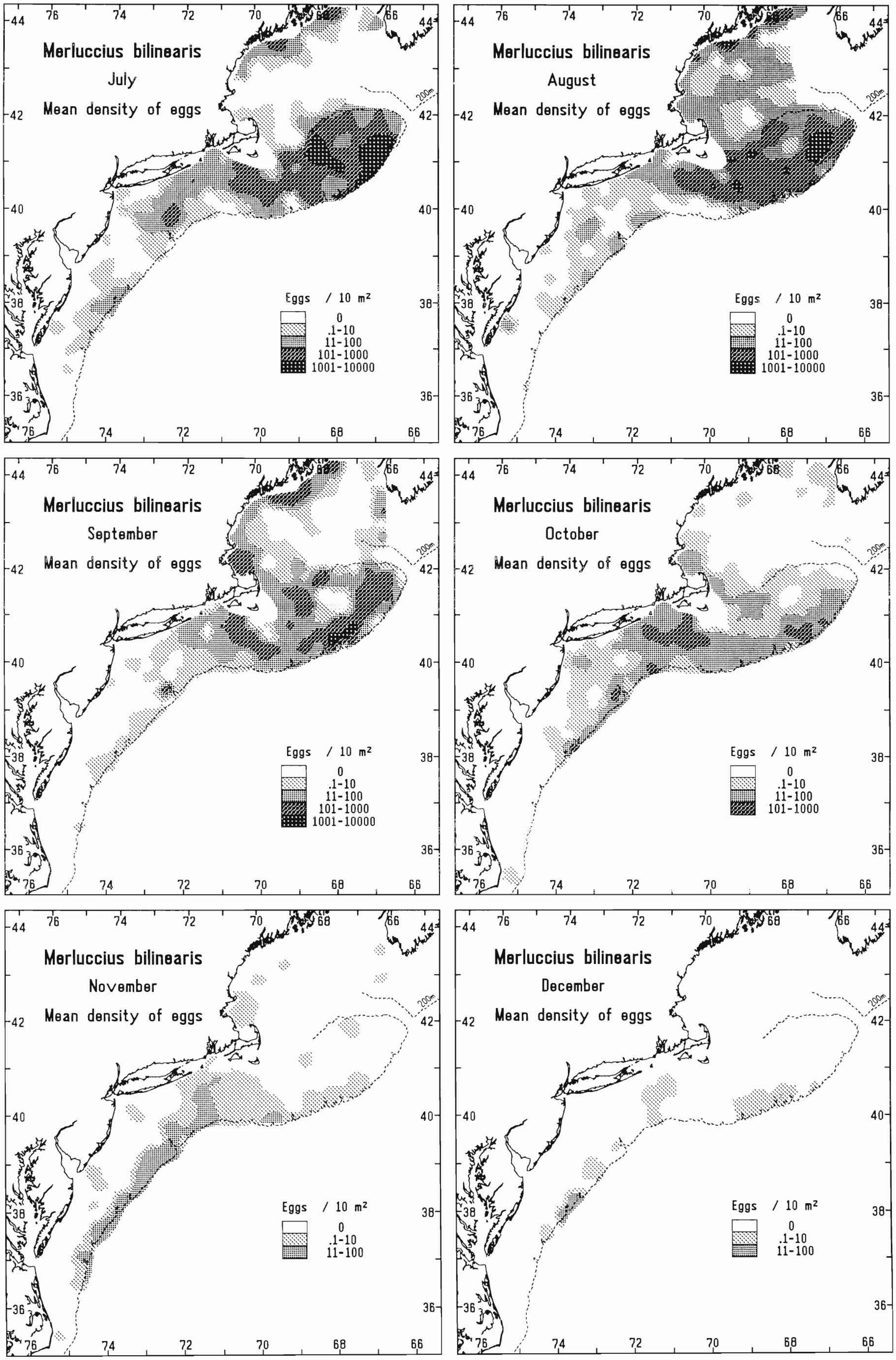


Figure 37 (continued)

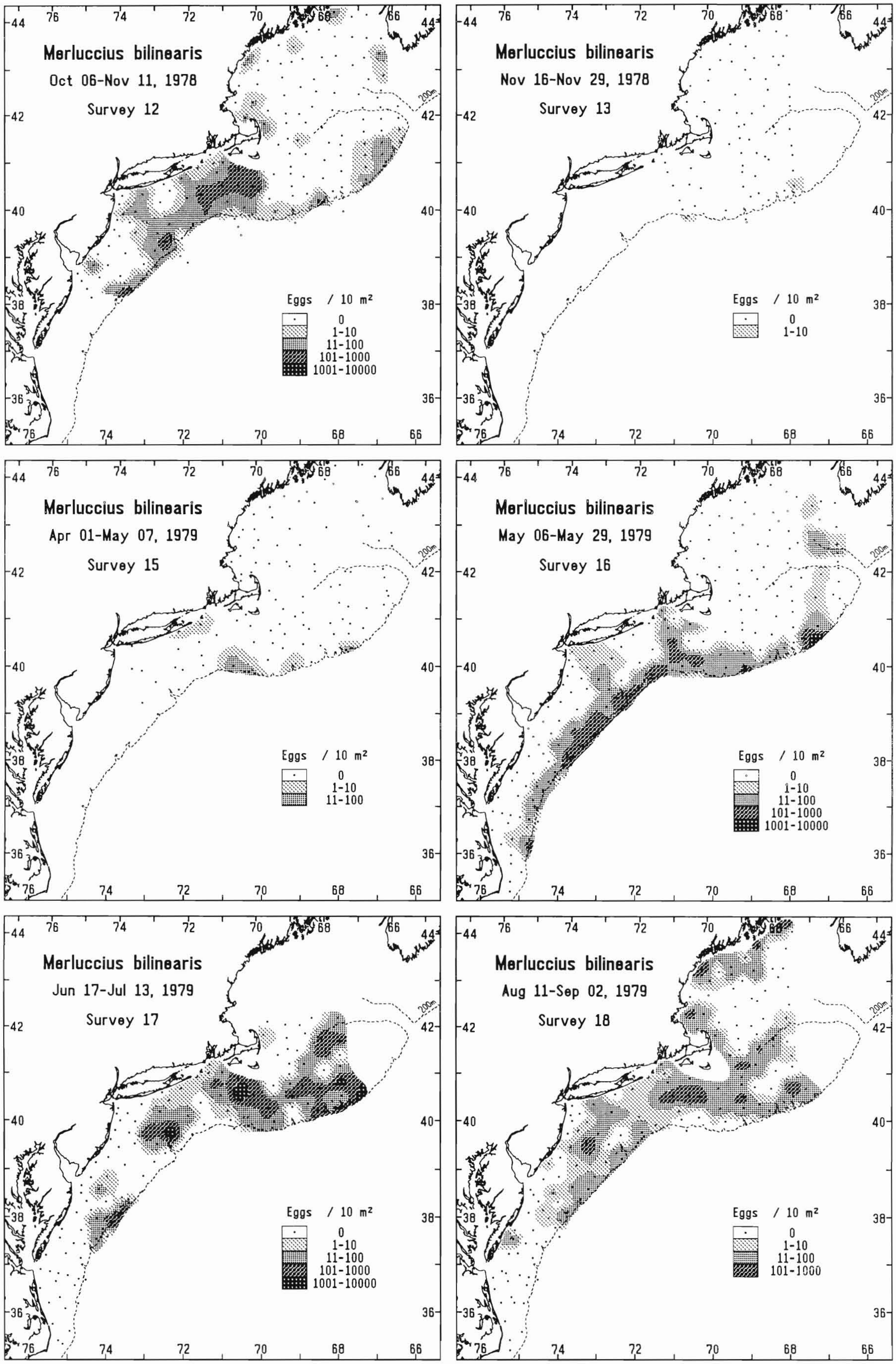


Figure 38
Merluccius bilinearis; survey areal plots of egg densities (no./10 m^2).

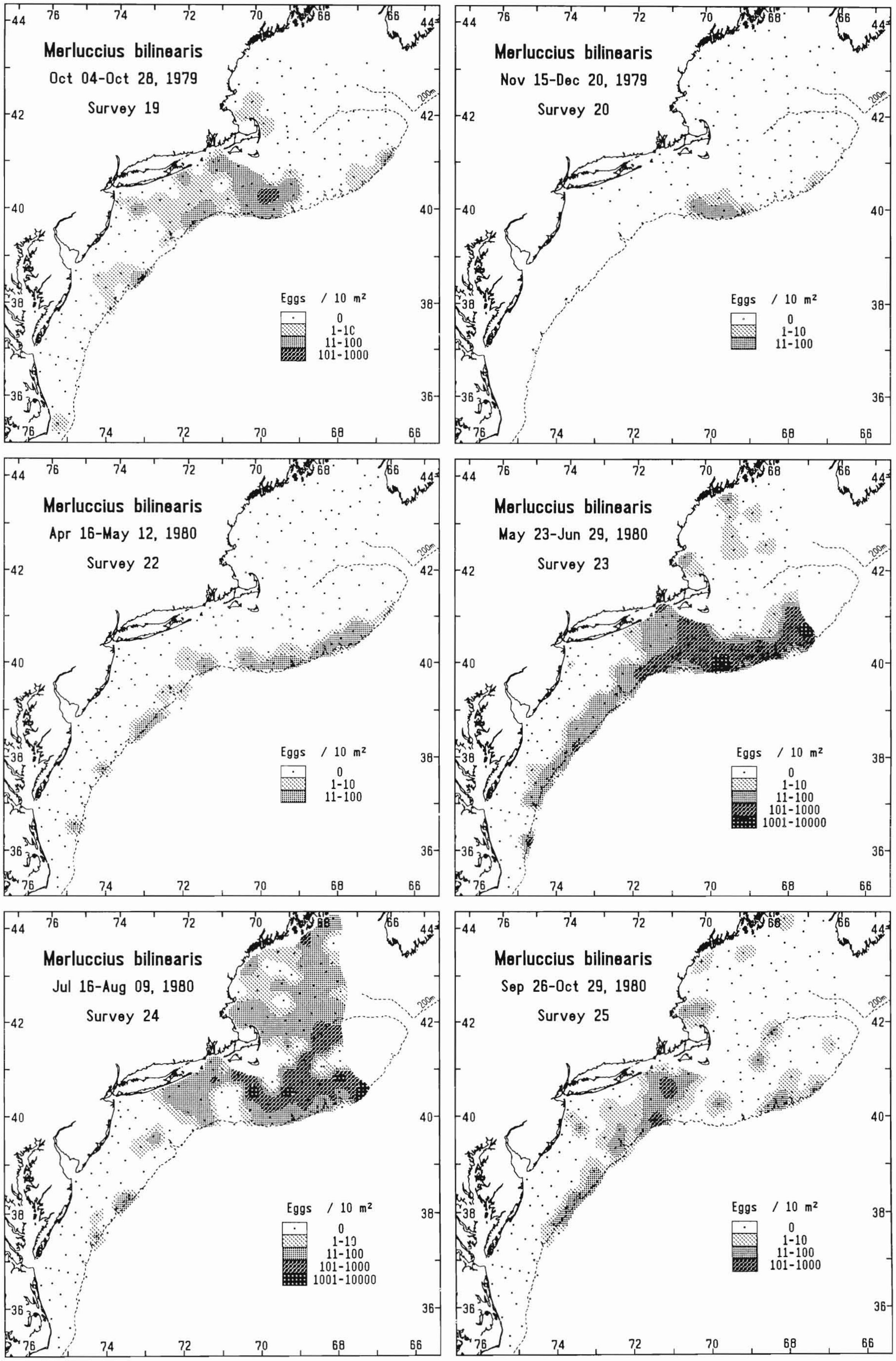
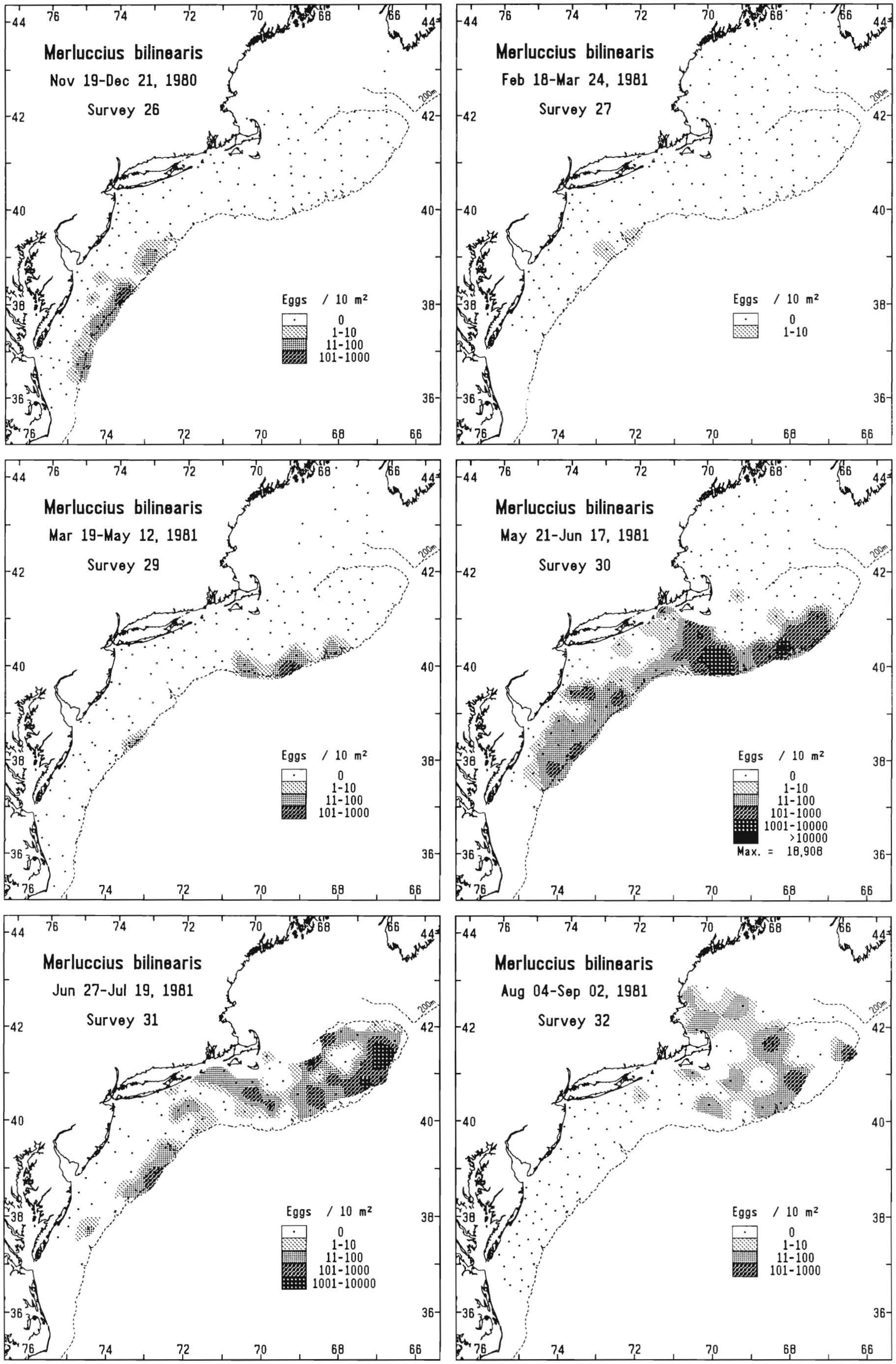


Figure 38 (continued)



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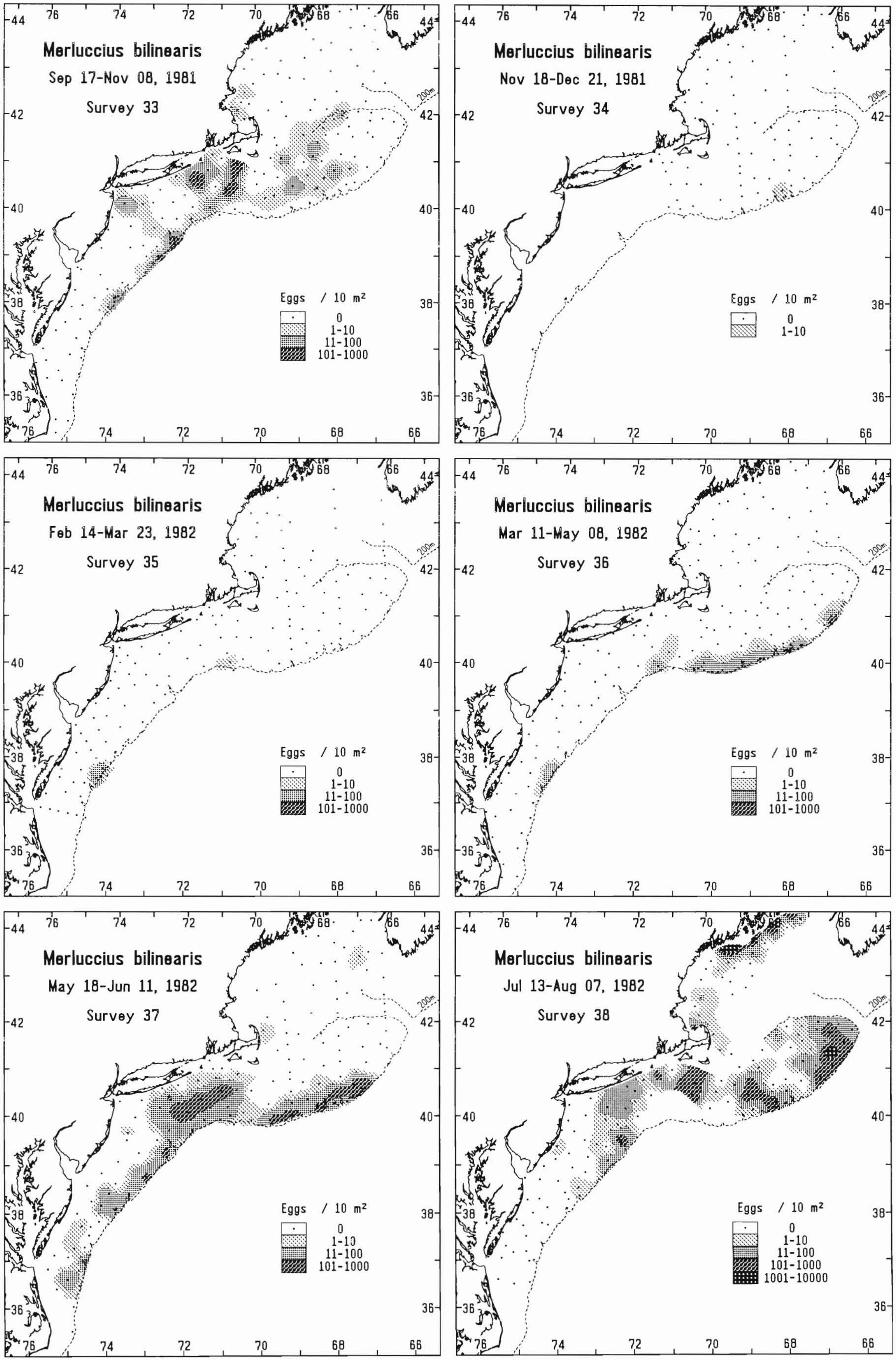

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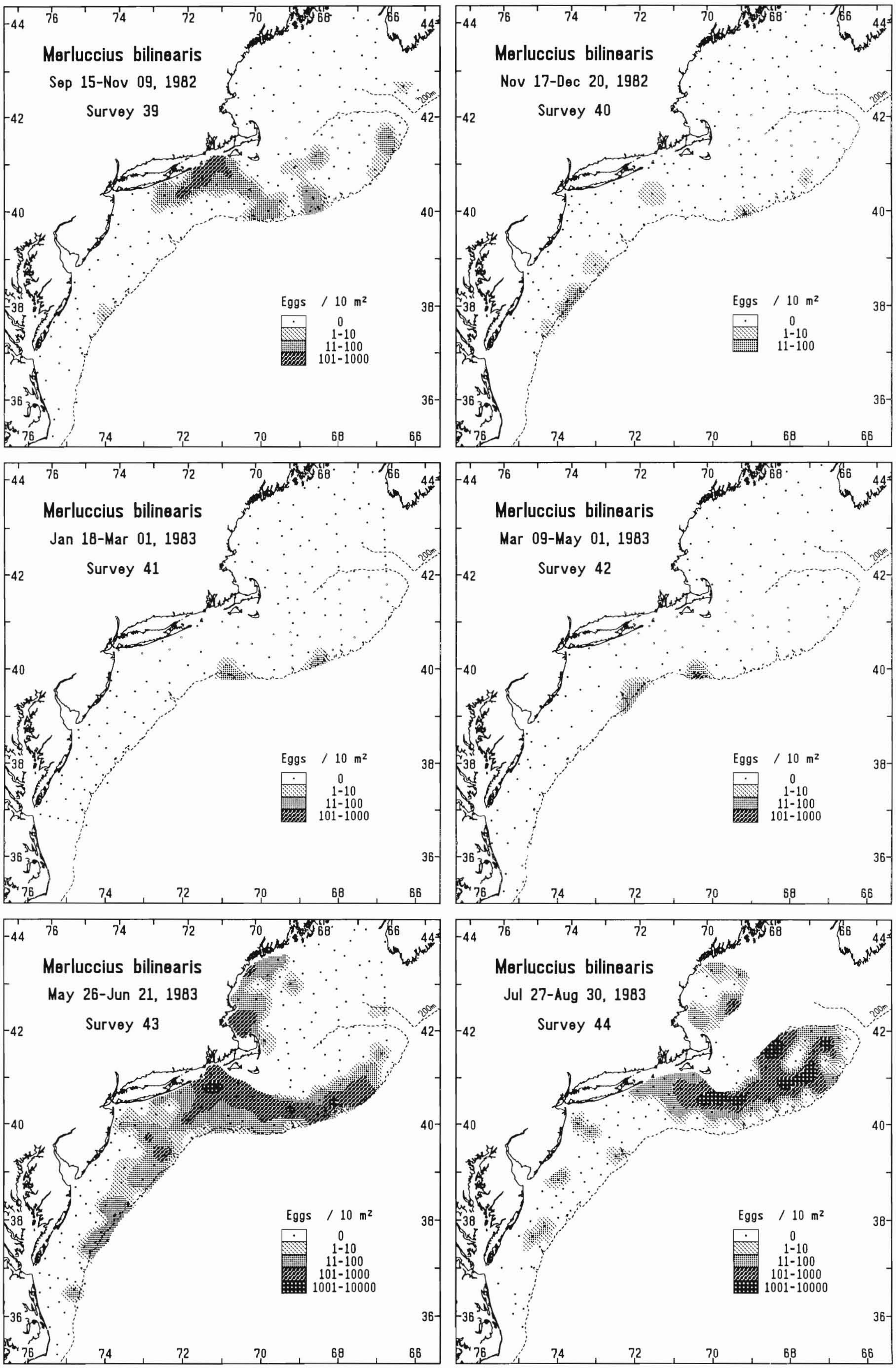

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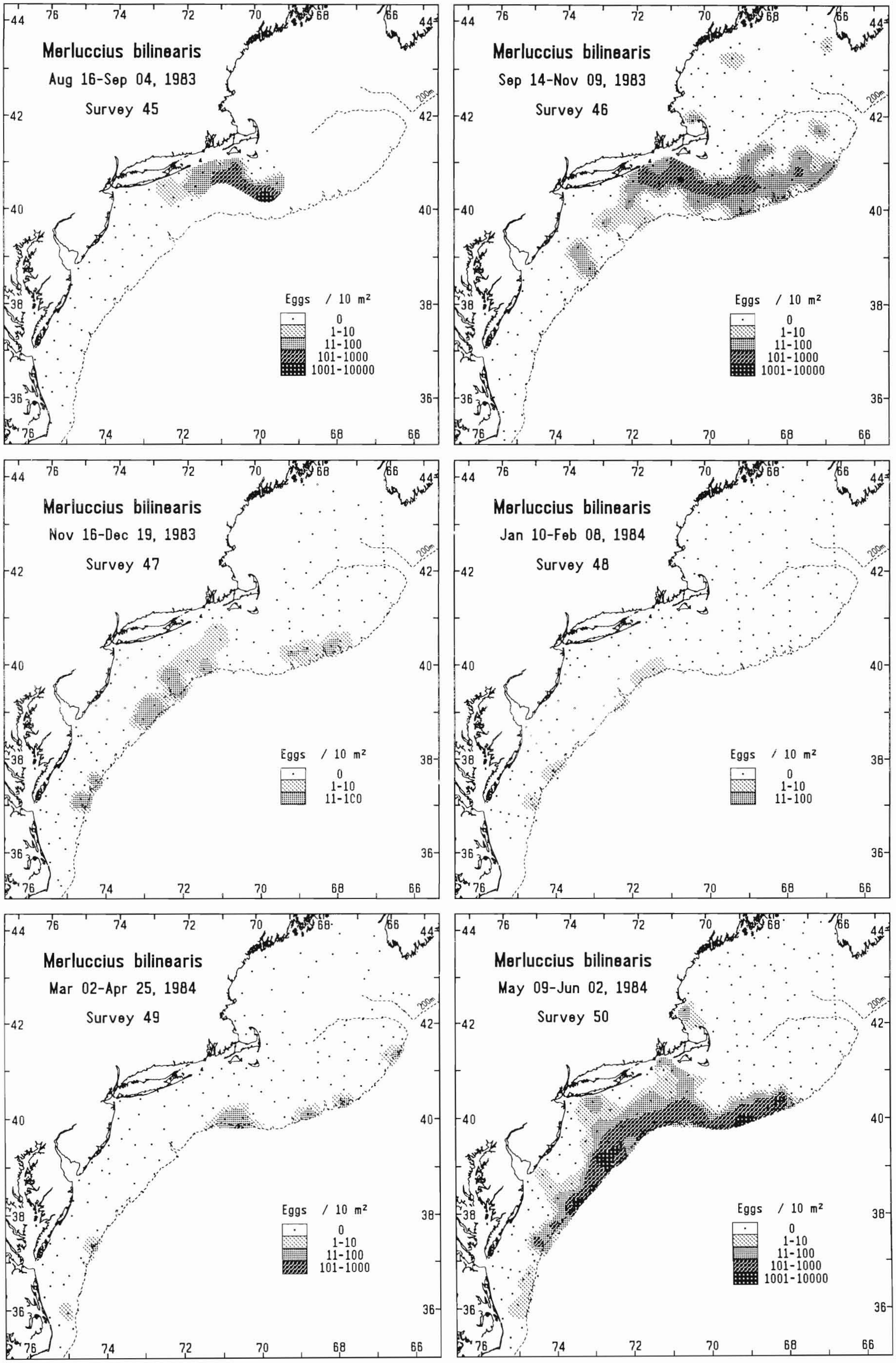

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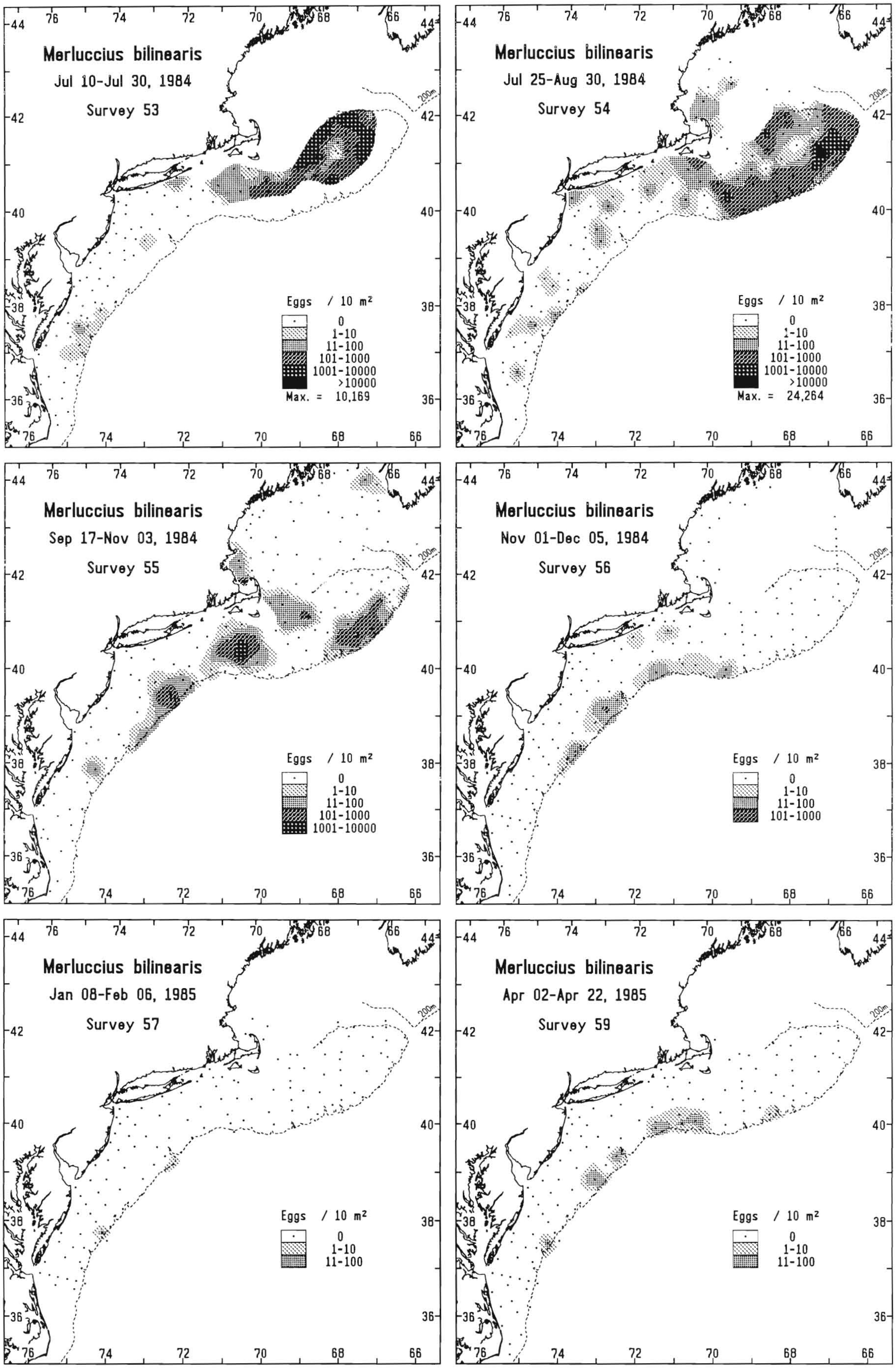

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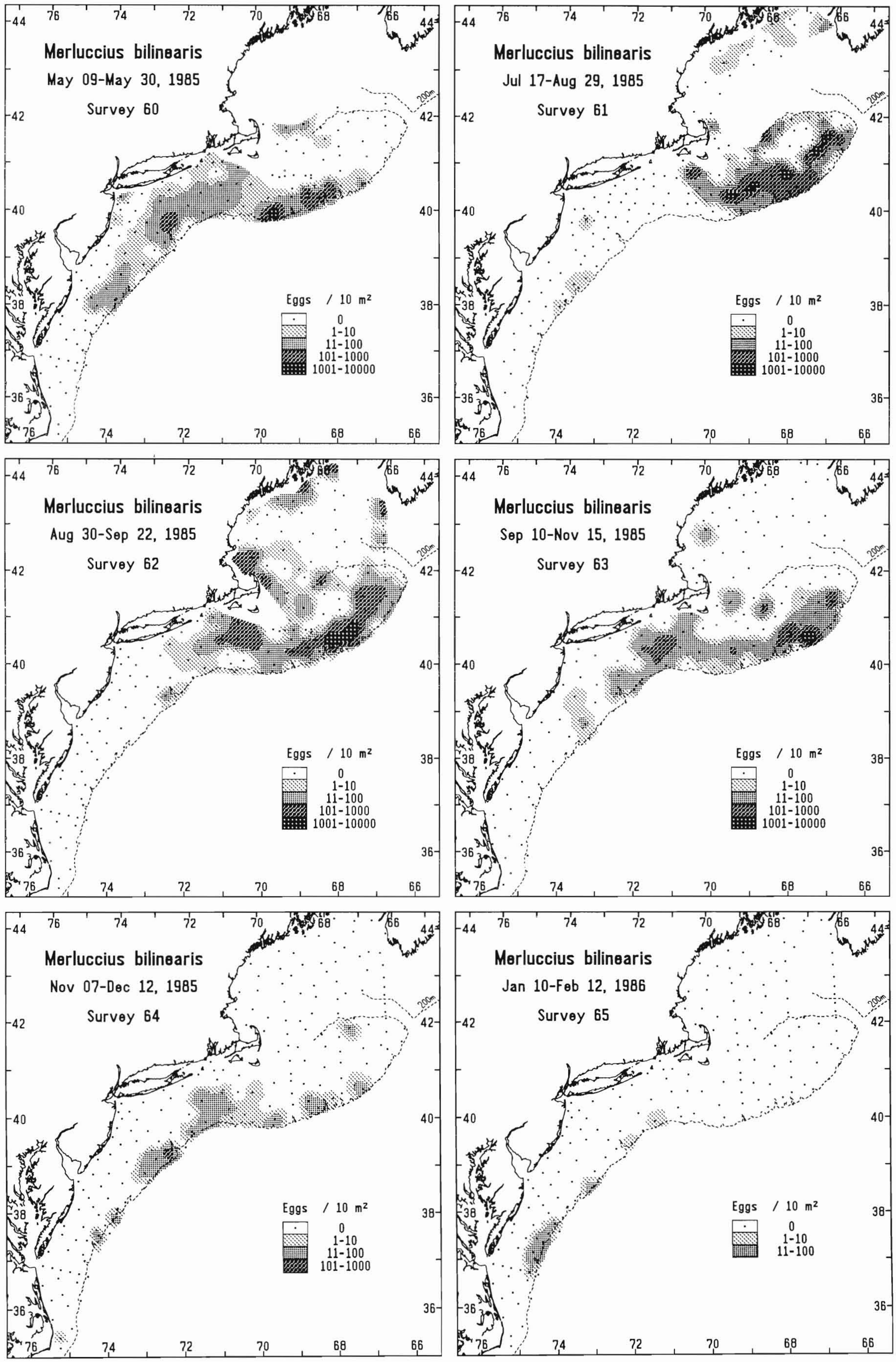
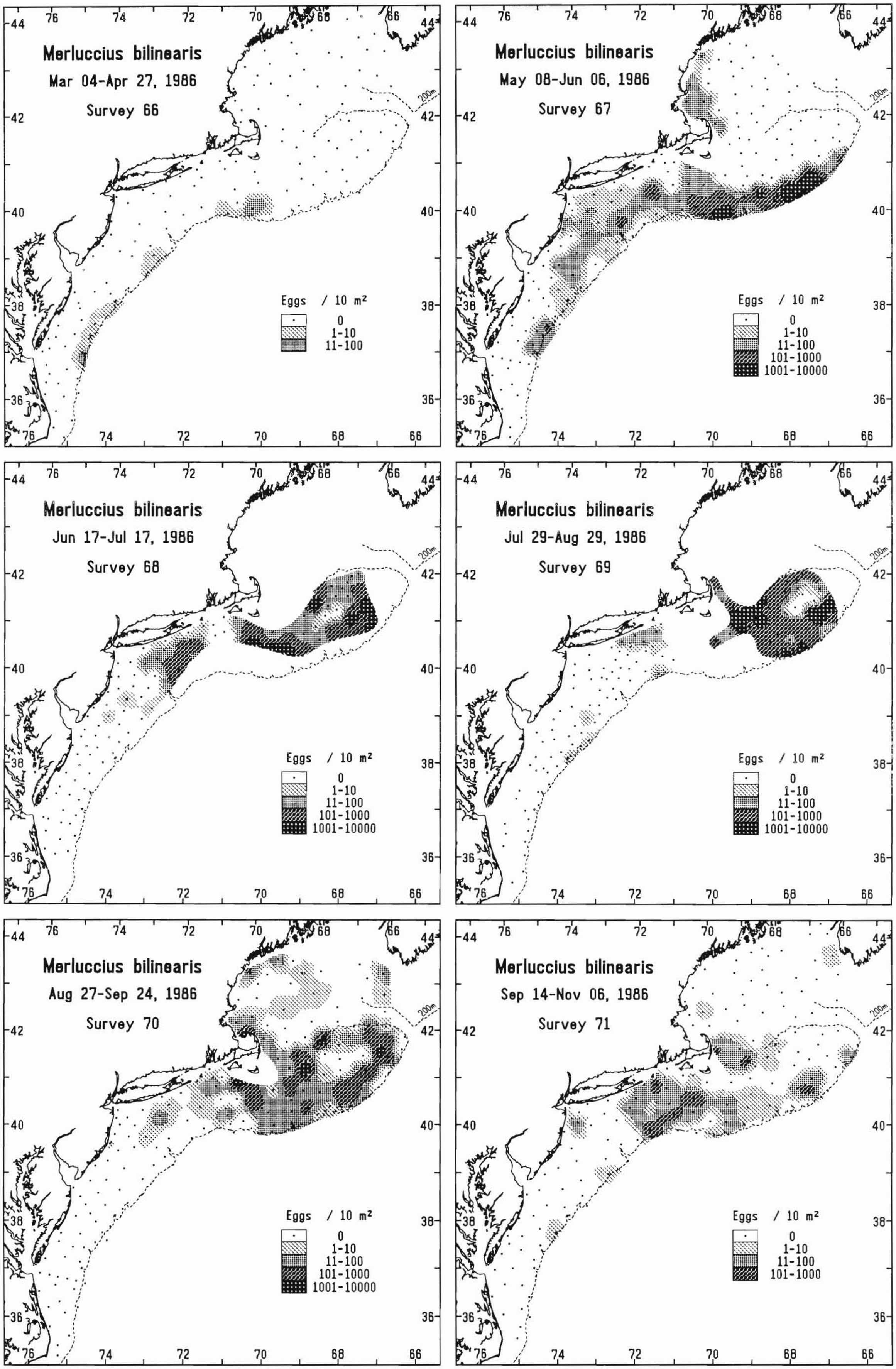


Figure 38 (continued)



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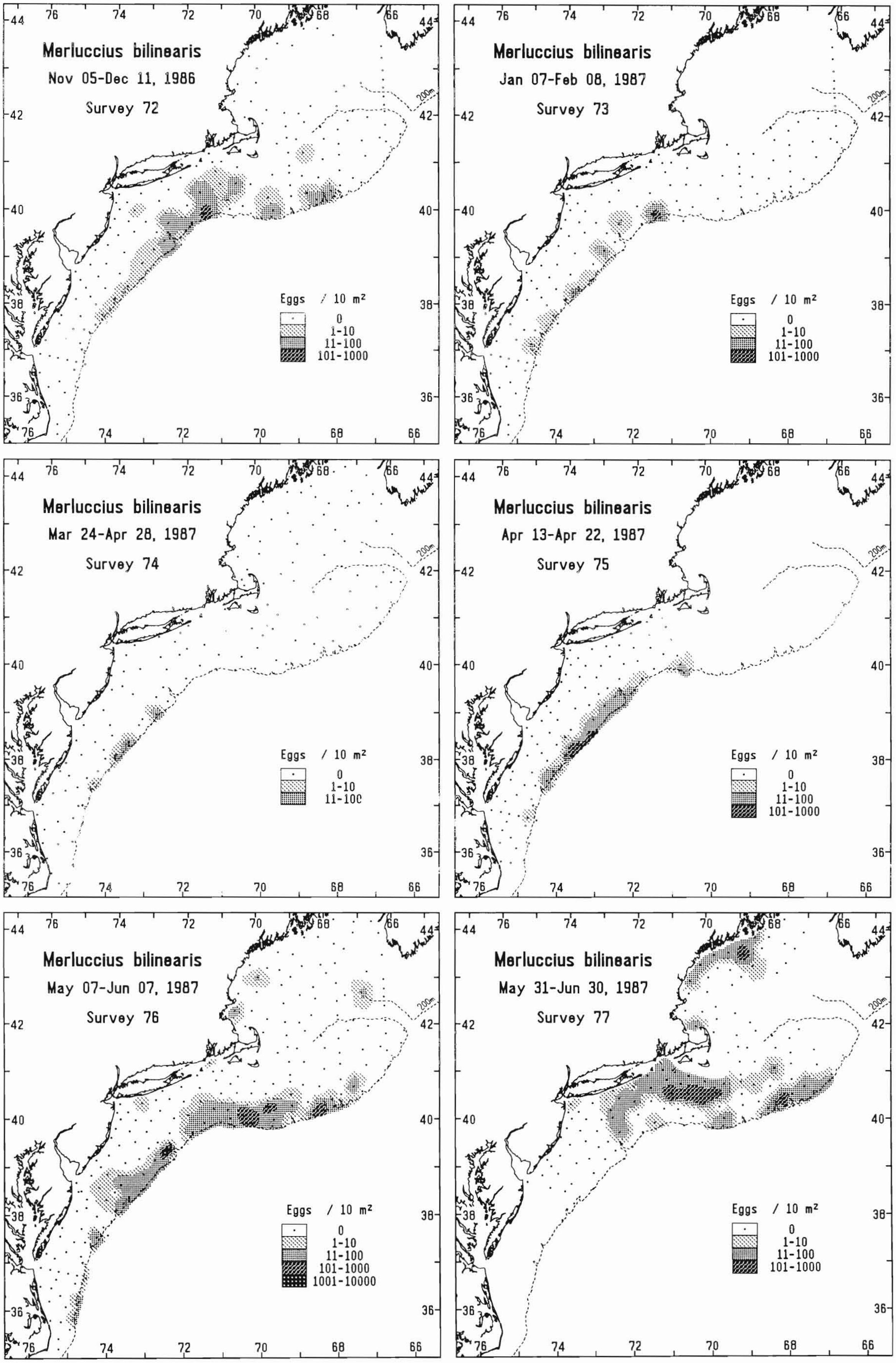

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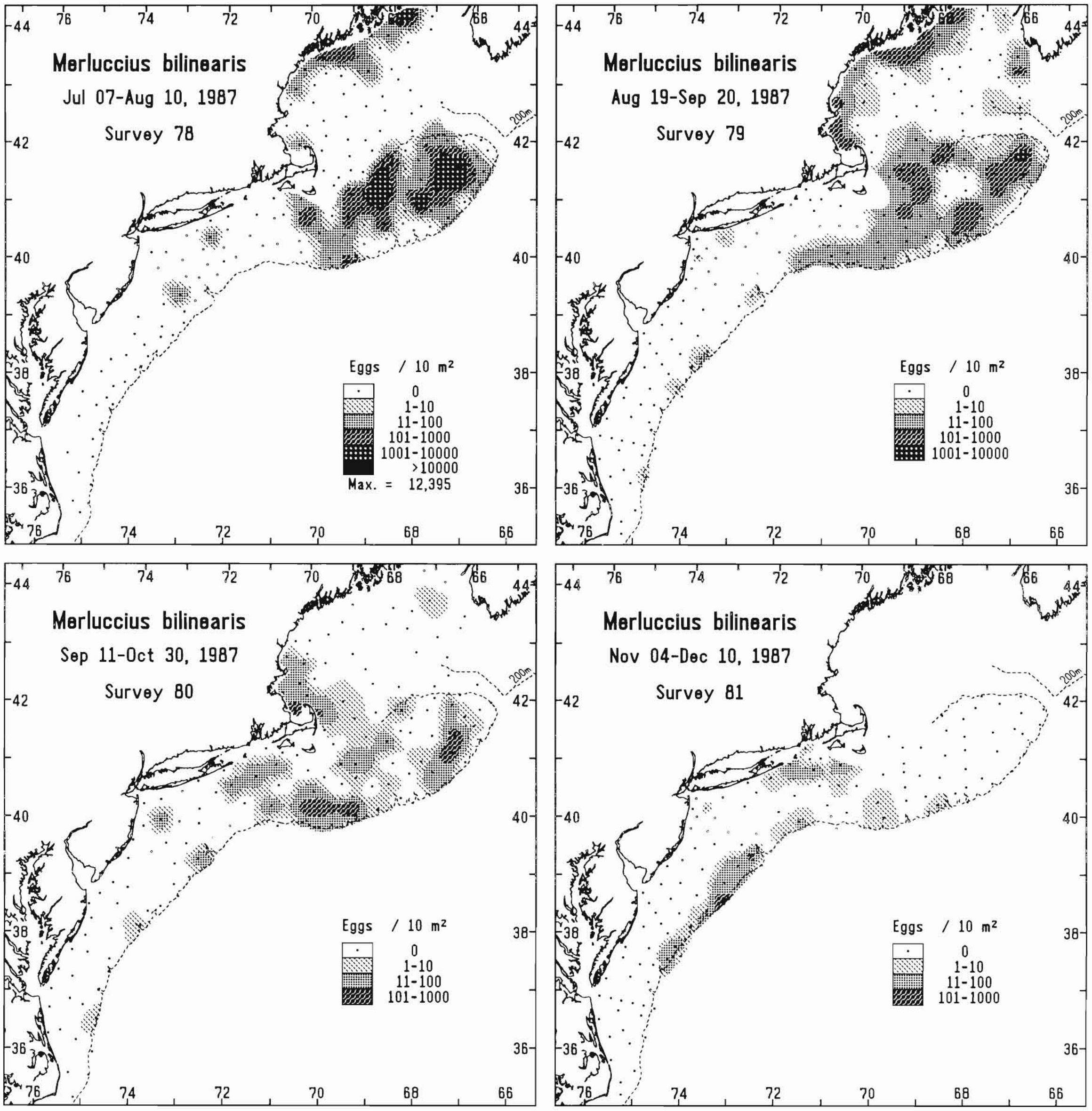


Figure 38 (continued)

Pollachius virens, pollock (Figs. 39–41)

Pollachius virens eggs were collected from October to June (Fig. 39) and were most abundant during winter, with the highest mean egg densities occurring in December and January (Fig. 39). Greatest numbers of eggs were found on Georges Bank and in shallower waters of western and eastern Gulf of Maine. Lesser numbers occurred throughout the Southern New England subarea and only infrequently in the Middle Atlantic subarea (Figs. 40 and 41).

Spawning began in October at scattered locations on Georges Bank and in the western and eastern portions of the Gulf of Maine. During November spawning increased and became more widespread in those subareas. At peak spawning during December and January, egg densities were concentrated in western Gulf of Maine and Georges Bank waters. Eggs occasionally occurred in the southern New England subarea as far west and south as Hudson Canyon. The distribution of eggs continued to expand towards the southwest into February and occasionally reached Delaware Bay. From March through June spawning persisted, but at a diminishing rate, with eggs occurring at increasingly isolated locations in the Gulf of Maine and on Georges Bank. Due to a lack of sampling in most of the Gulf of Maine during March, both the mean egg density and the egg distribution for that month are probably low and incomplete, respectively.

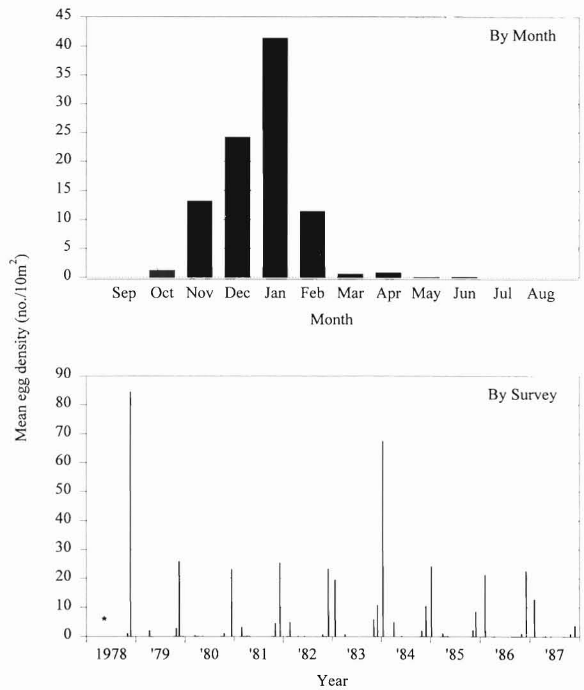


Figure 39
Pollachius virens; mean-egg-density graphs by month (top) and by survey (bottom) for the total MARMAP area. (*Samples from the first four surveys in 1978 were not analyzed for *P. virens* eggs.)

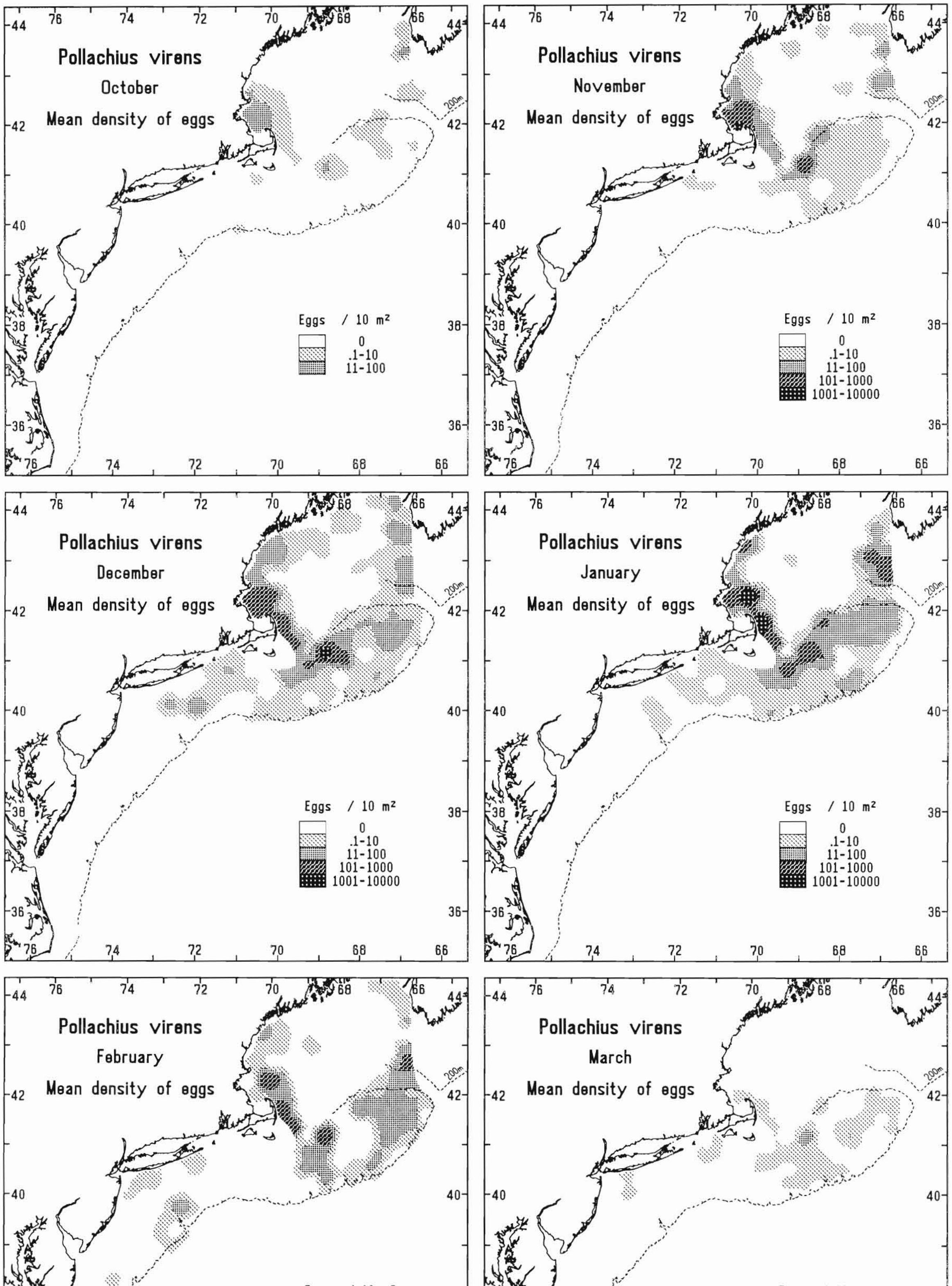
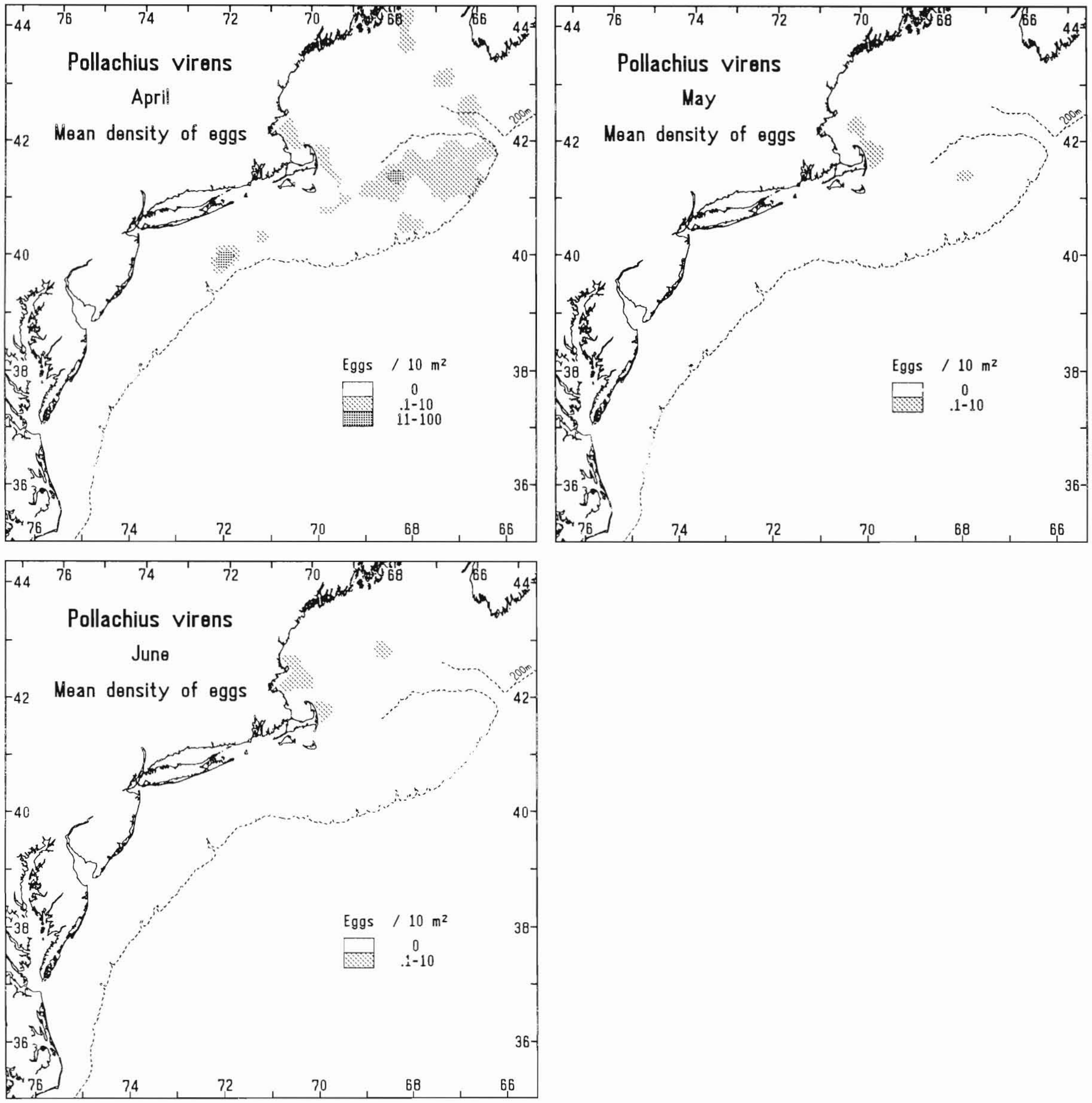


Figure 40

Pollachius virens; composite monthly areal plots of mean egg densities (no./10 m^2).



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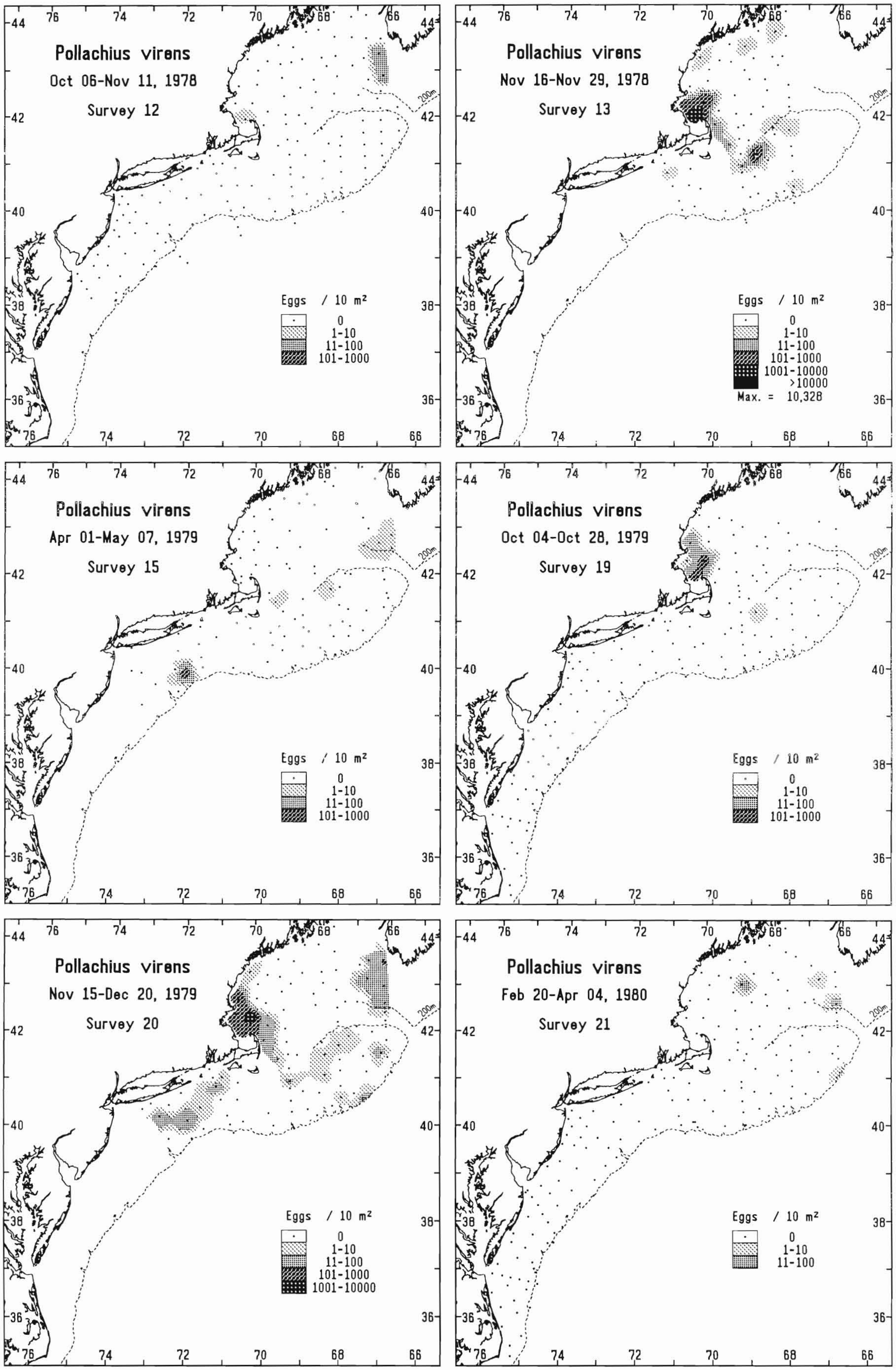
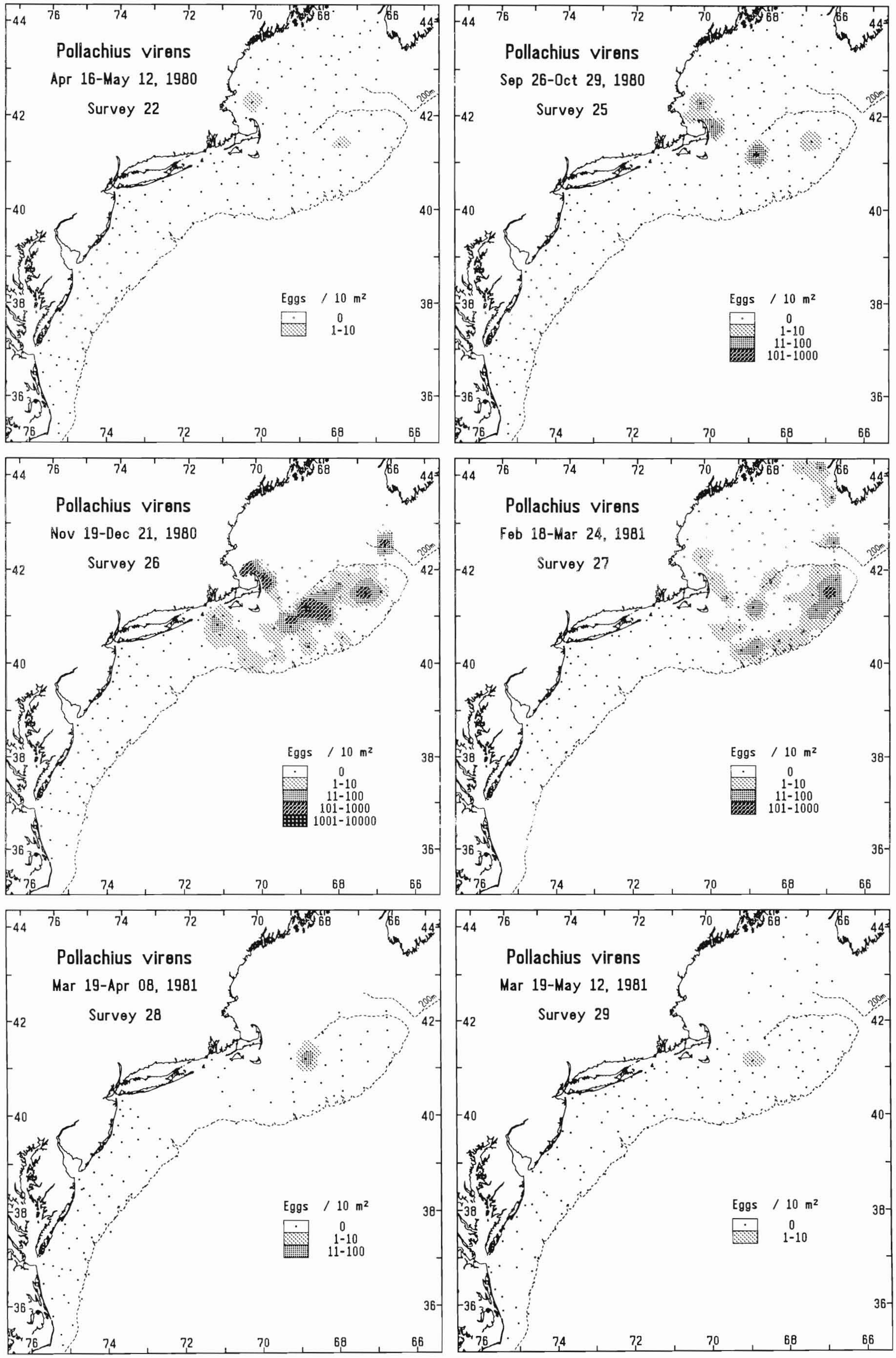


Figure 41
Pollachius virens; survey areal plots of egg densities (no./10 m²).



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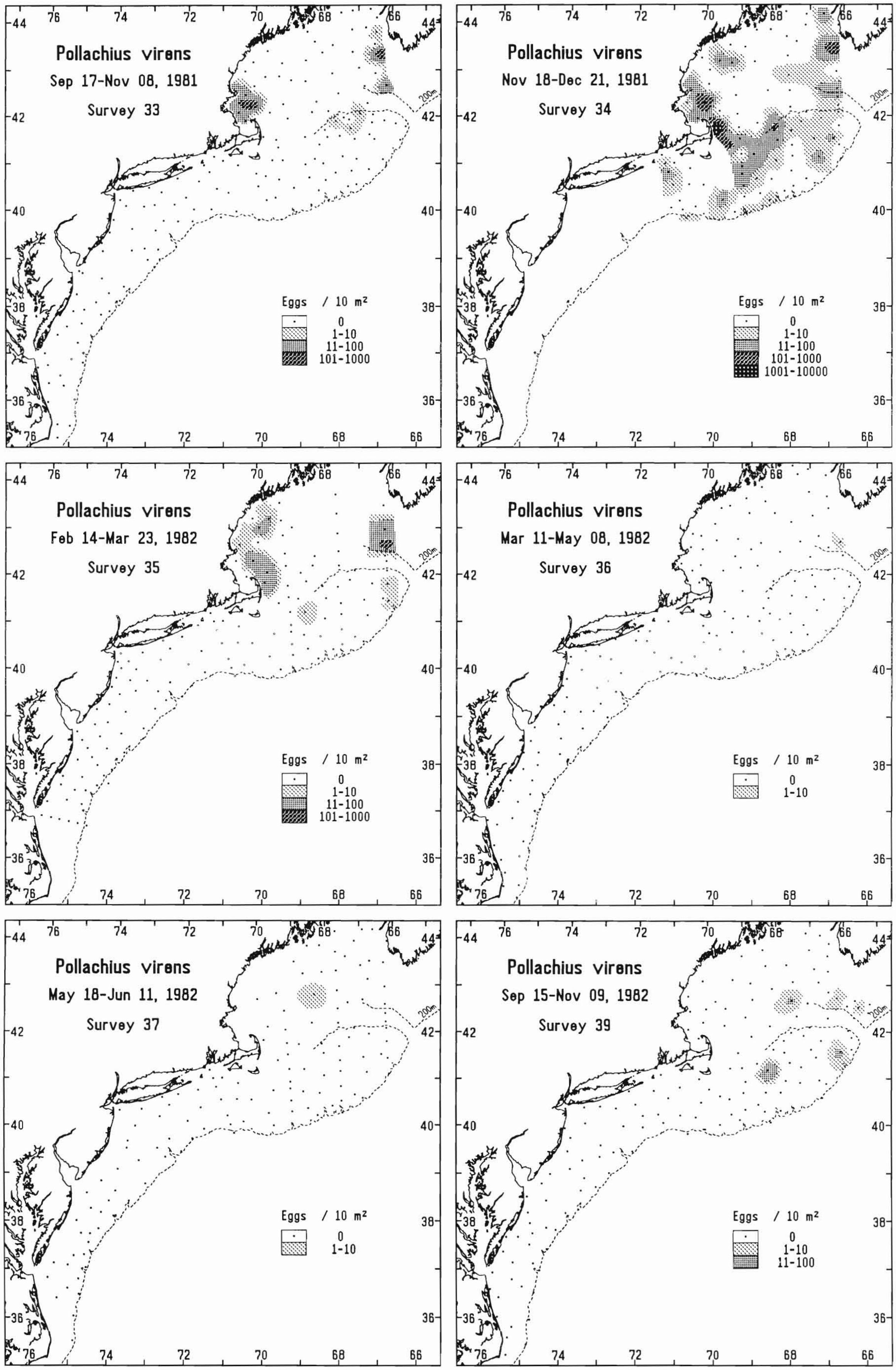

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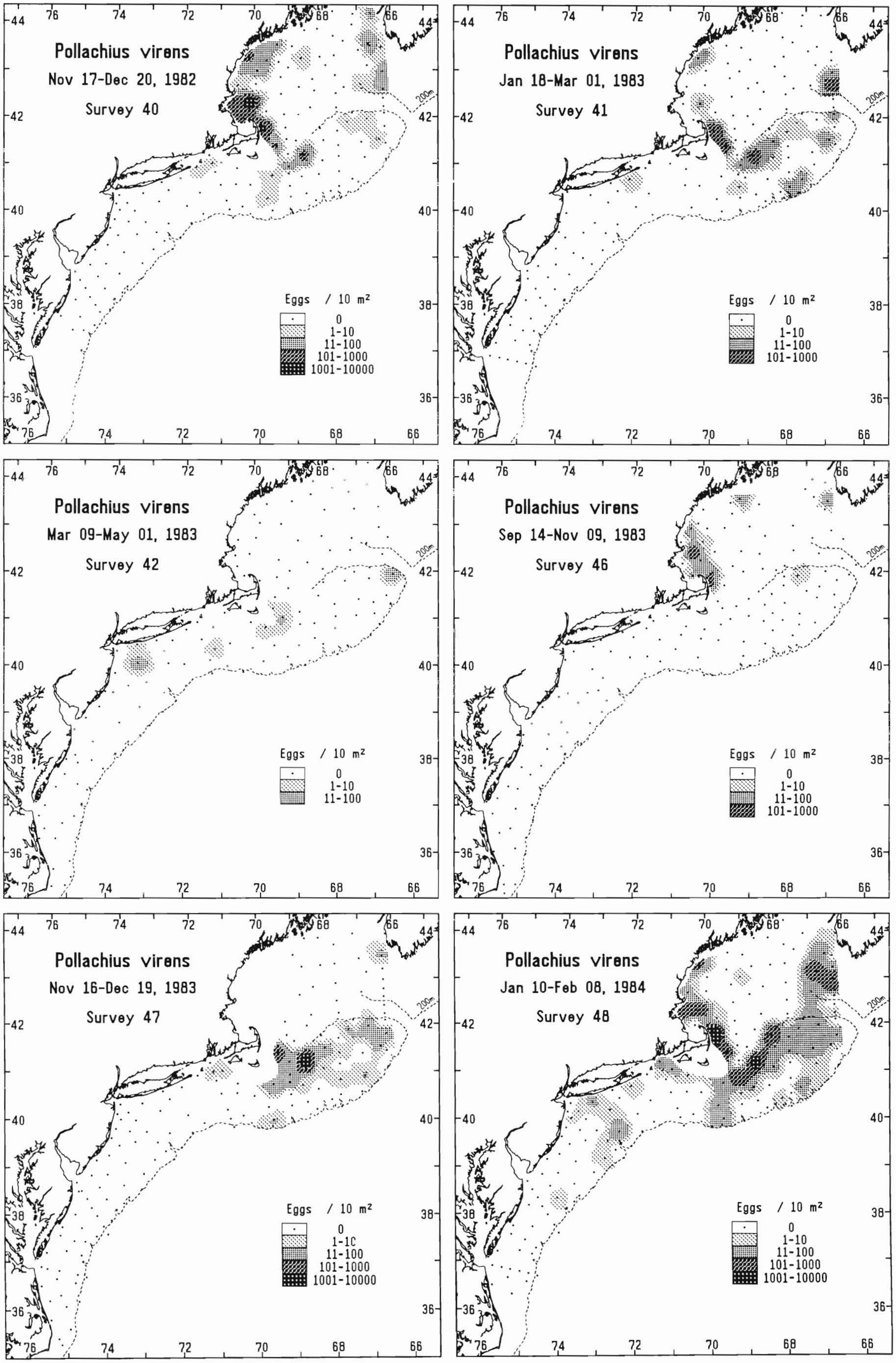

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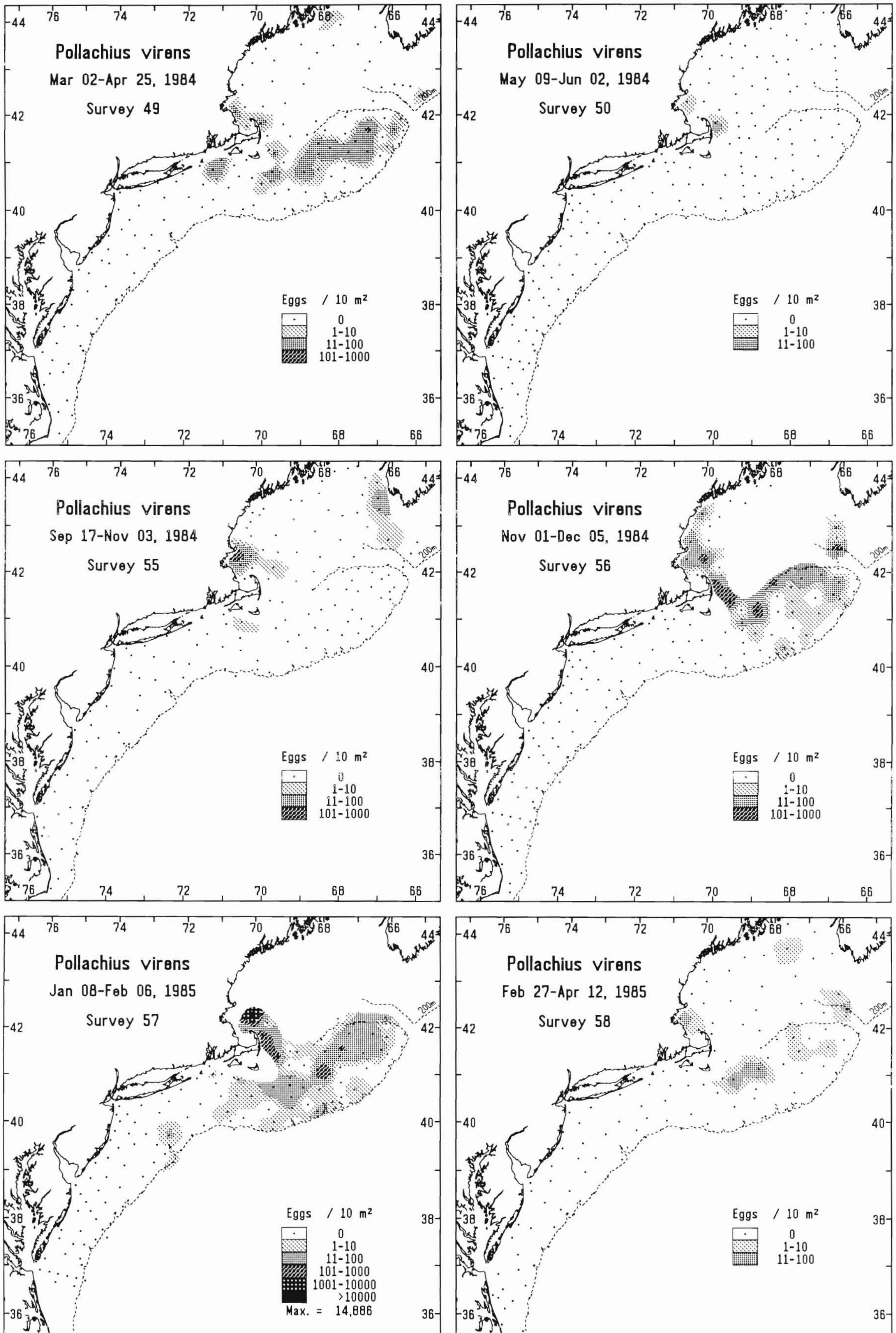

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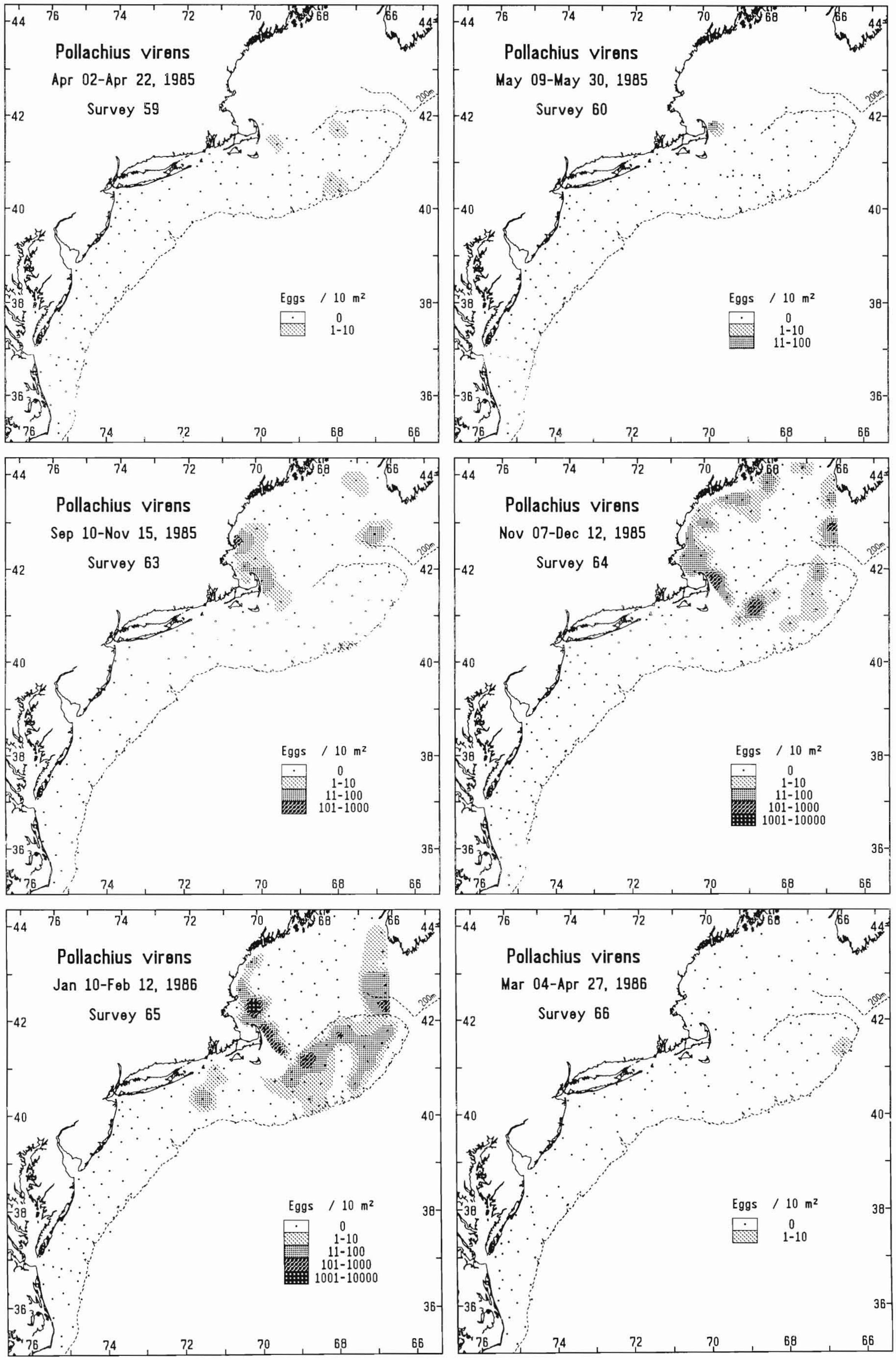


Figure 41 (continued)

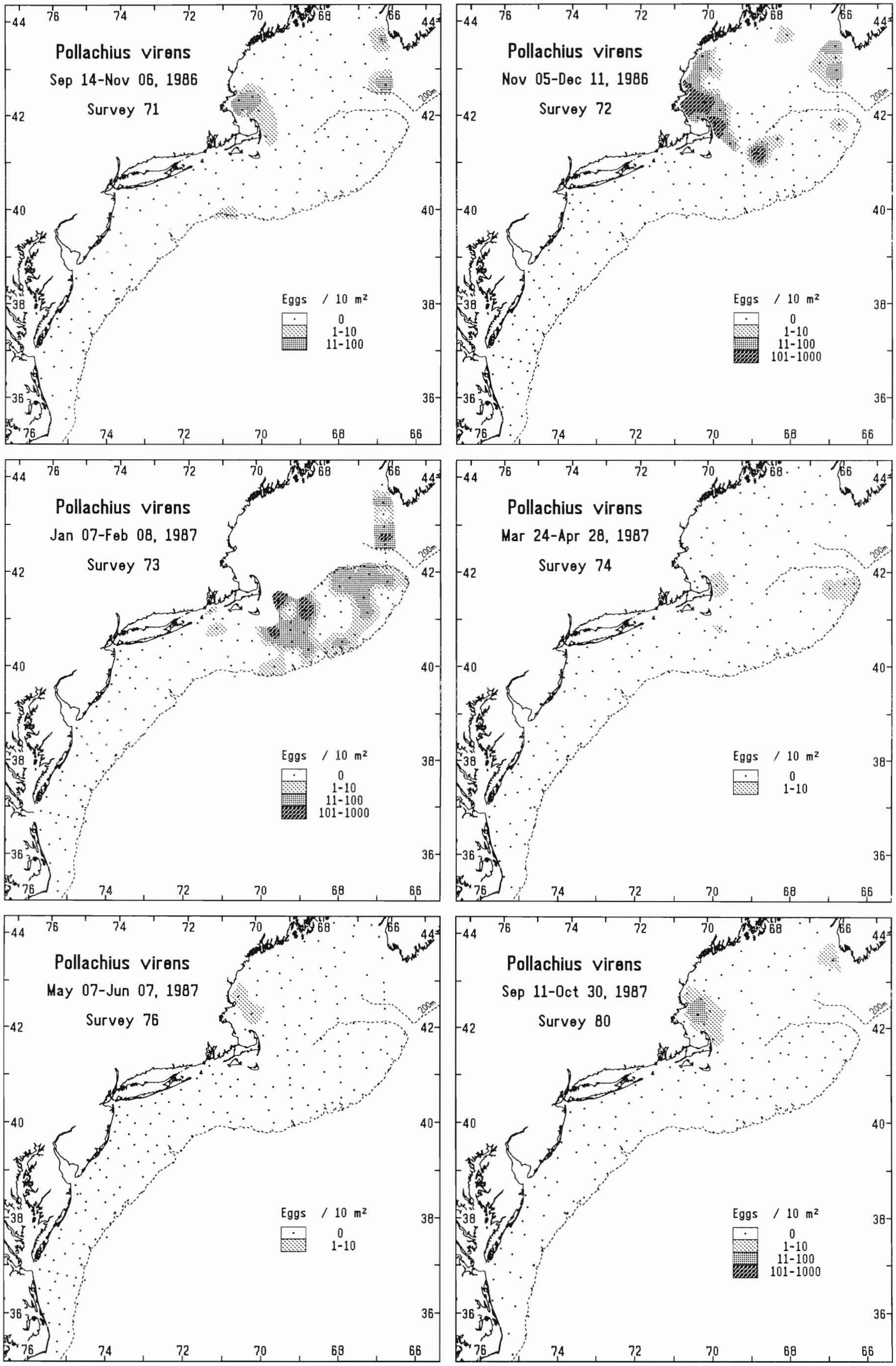


Figure 41 (continued)

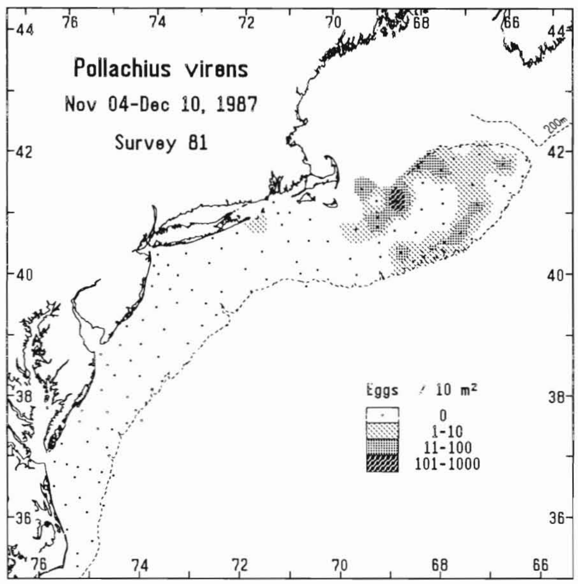


Figure 41 (continued)

Urophycis spp., hakes (Figs. 42–44)

Urophycis spp. eggs were the most frequently occurring and the third most abundant egg identified (Table 3). They were collected during all months of the year, in all subareas, and occurred from shallow coastal waters to out beyond the shelf (Fig. 43). A seasonal cycle of abundance was observed, with minimal numbers and the most restricted geographic distribution observed in winter and early spring, and the greatest abundance and widest distribution during summer (Figs. 42 and 43).

Urophycis spp. eggs in winter and early spring (December to April) occurred mainly in outer shelf waters of the Middle Atlantic and Southern New England subareas (Fig. 43). During spring and summer when shelf waters were warming, egg concentrations shifted onto the shelf throughout these two subareas, as well as onto Georges Bank and into the Gulf of Maine, particularly the western portion. The process was reversed with late summer and autumn cooling. From September to December egg abundances decreased and major concentrations of eggs shifted towards the outer shelf of the Middle Atlantic and southern New England subareas.

With the exception of 1983, a decrease in *Urophycis* spp. egg abundance was observed over the nine-year sampling period (Fig. 42). Survey 44 in 1983, which produced the highest mean egg density, lacked coverage in inshore Middle Atlantic waters and in eastern and central Gulf of Maine (Fig. 44); both areas of expected low egg density. This would tend to bias the sampled mean egg density.

Because these eggs were not identified to species, and there are probably four species included in our "*Urophycis* spp." (*U. chesteri, U. chuss, U. regia,* and *U. tenuis*), the egg data can only serve as supporting evidence of spawning times and areas.

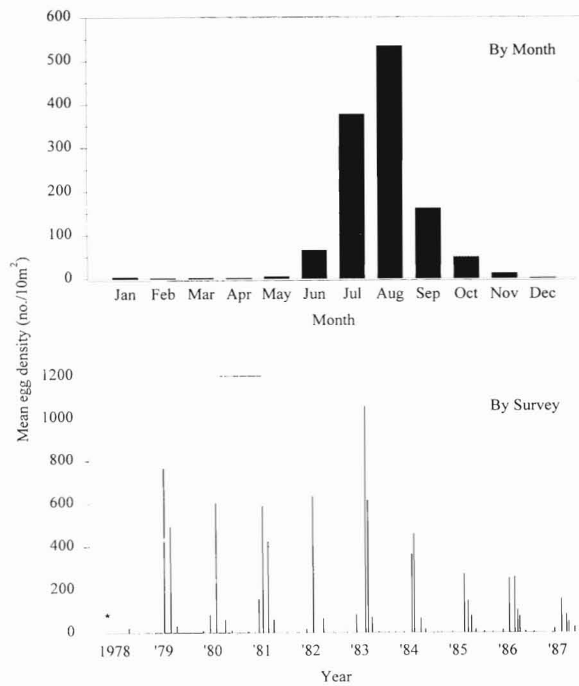


Figure 42

Urophycis spp.; mean-egg-density graphs by month (top) and by survey (bottom) for the total MARMAP area. (*Samples from the first four surveys in 1978 were not analyzed for *Urophycis* spp. eggs.)

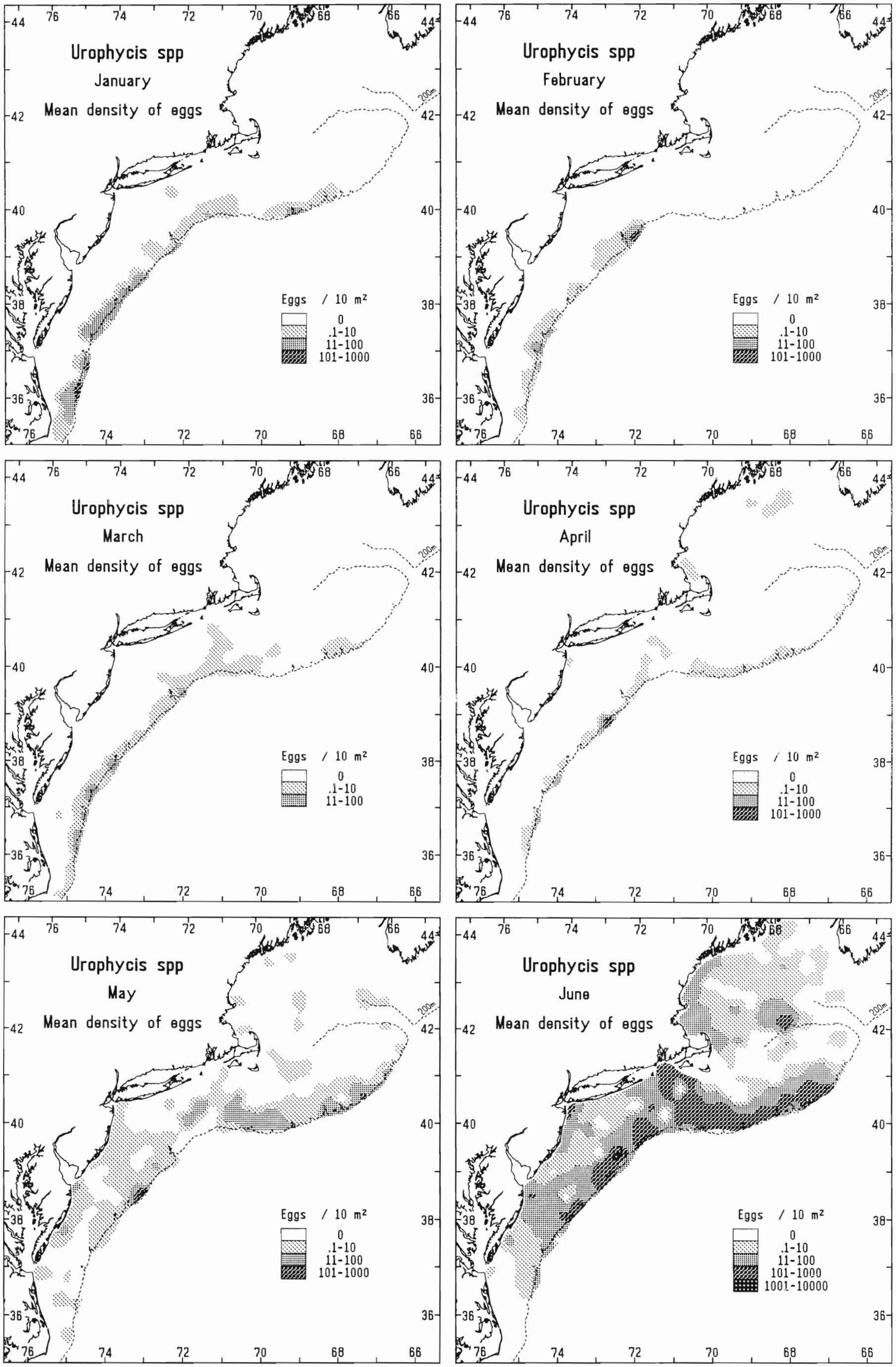


Figure 43

Urophycis spp.; composite monthly areal plots of mean egg densities (no./10 m²).

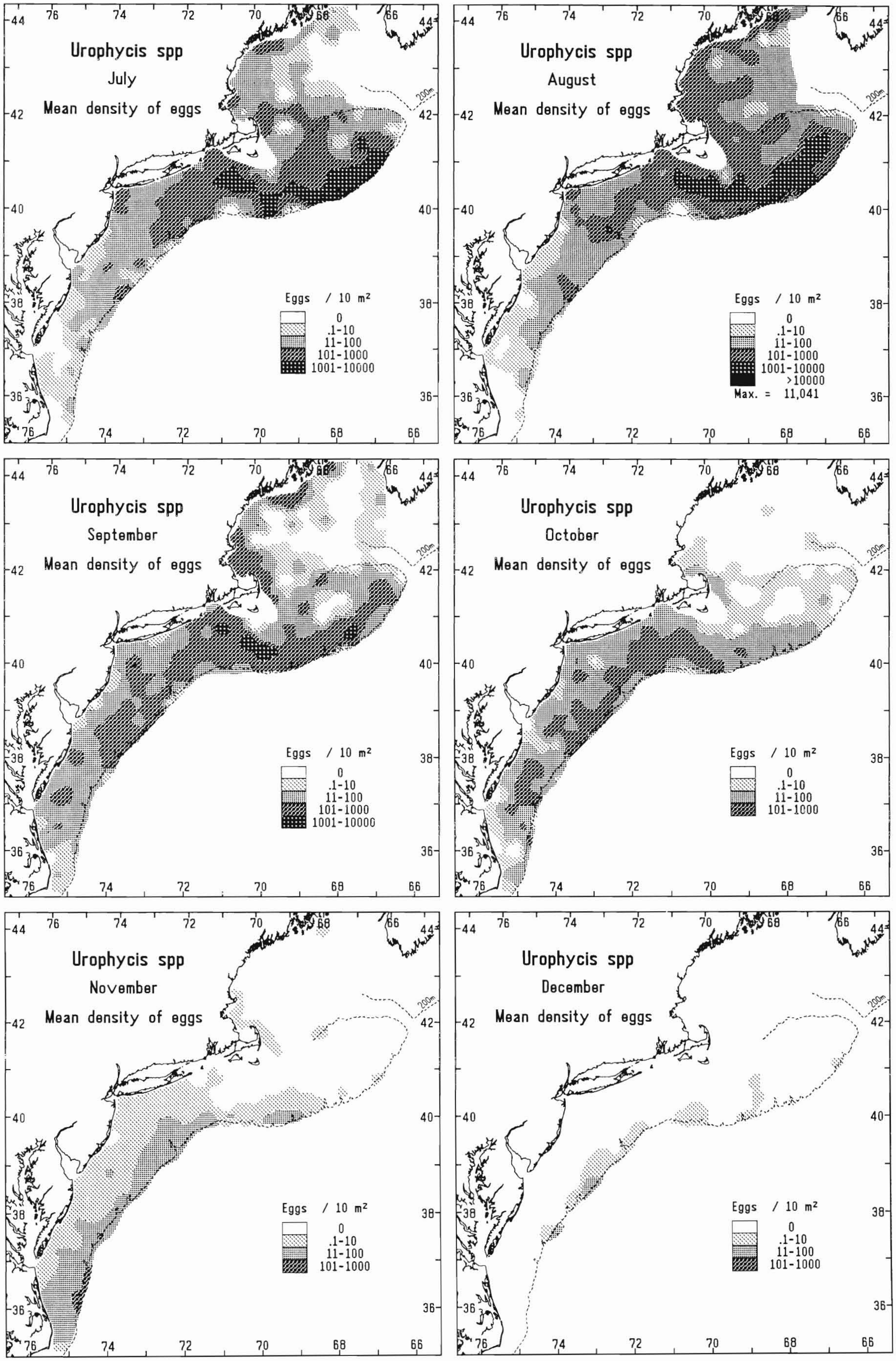


Figure 43 (continued)

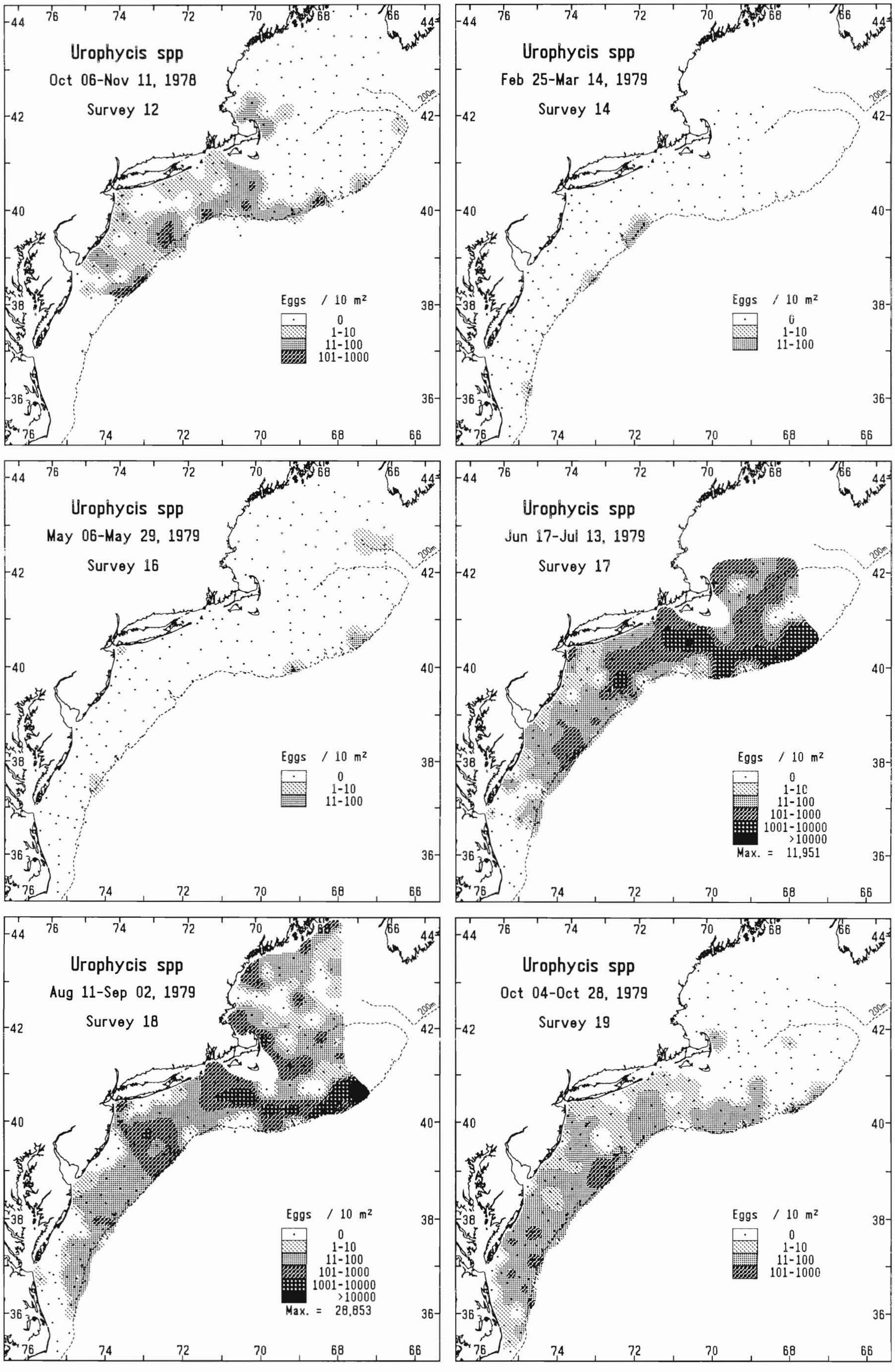


Figure 44

Urophycis spp.; survey areal plots of egg densities (no./10 m²).

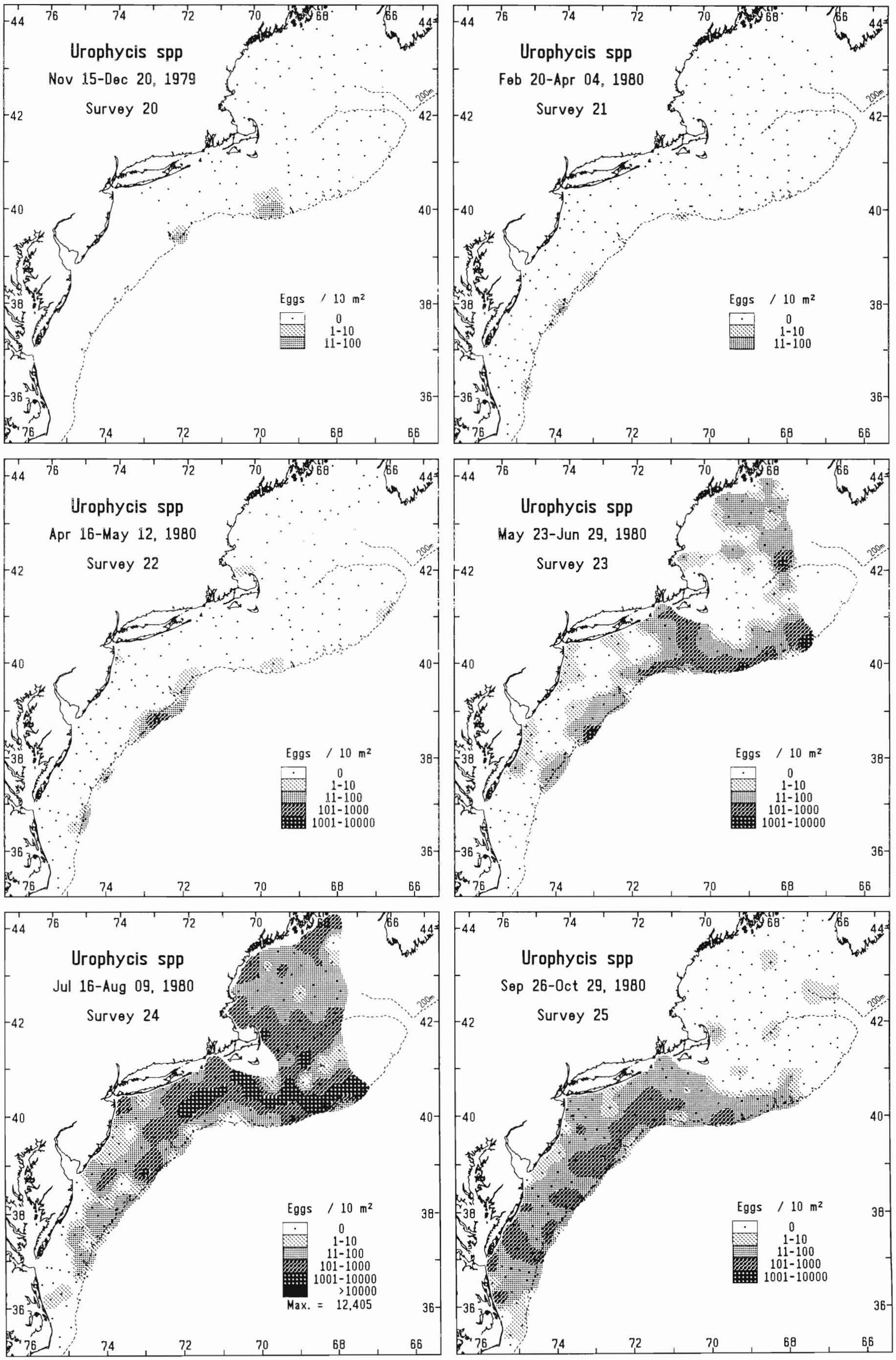


Figure 44 (continued)

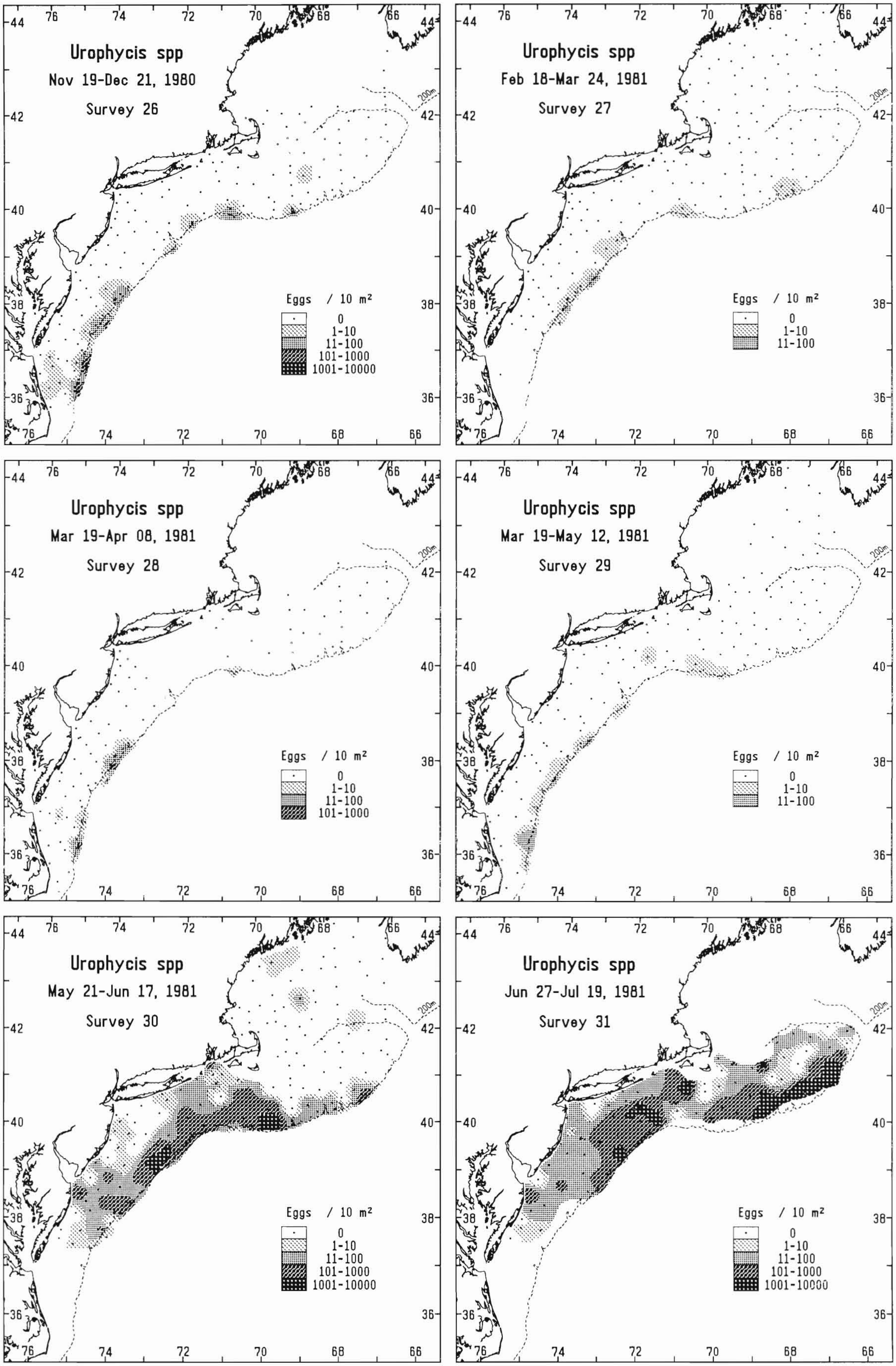


Figure 44 (continued)

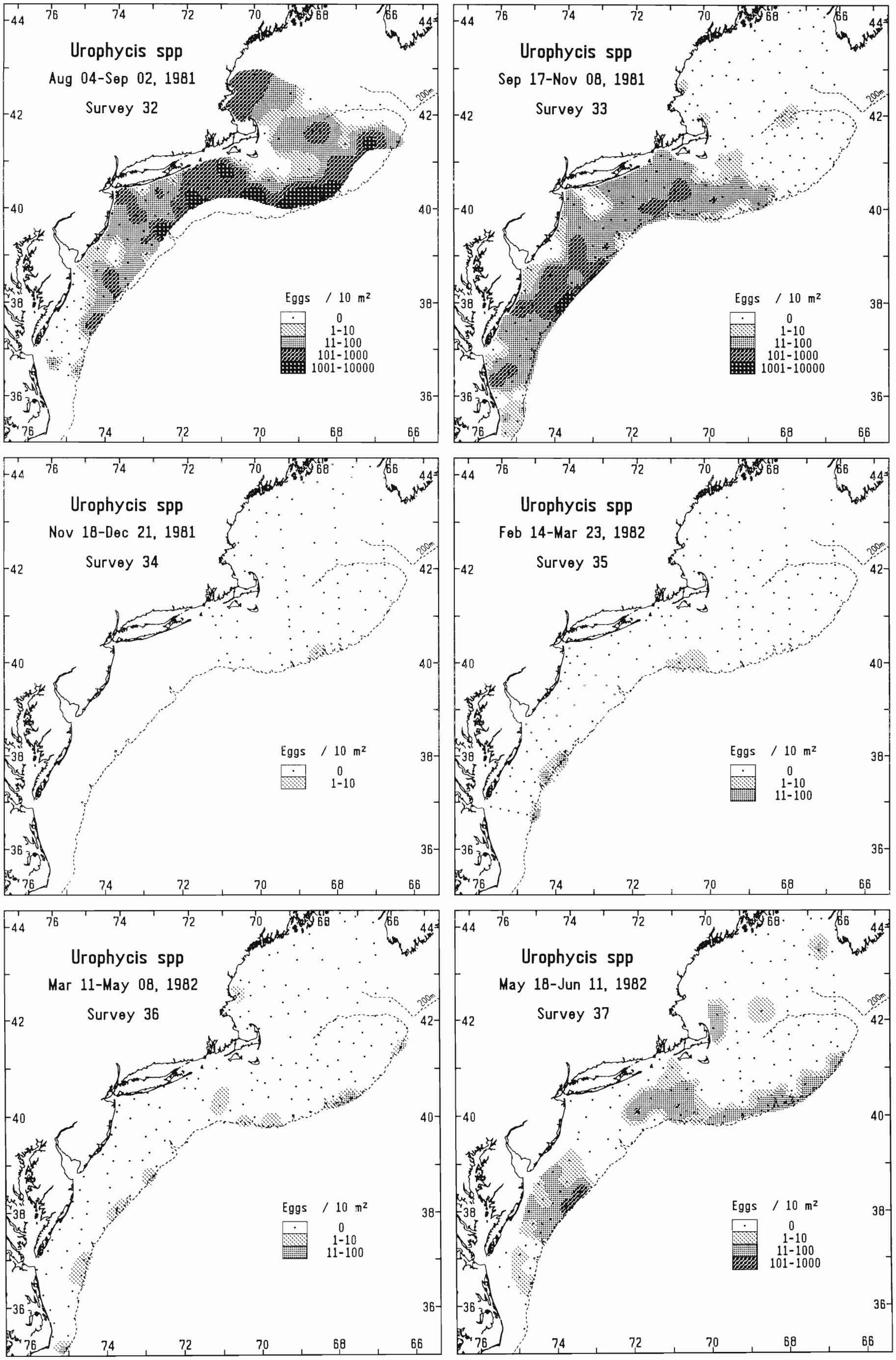
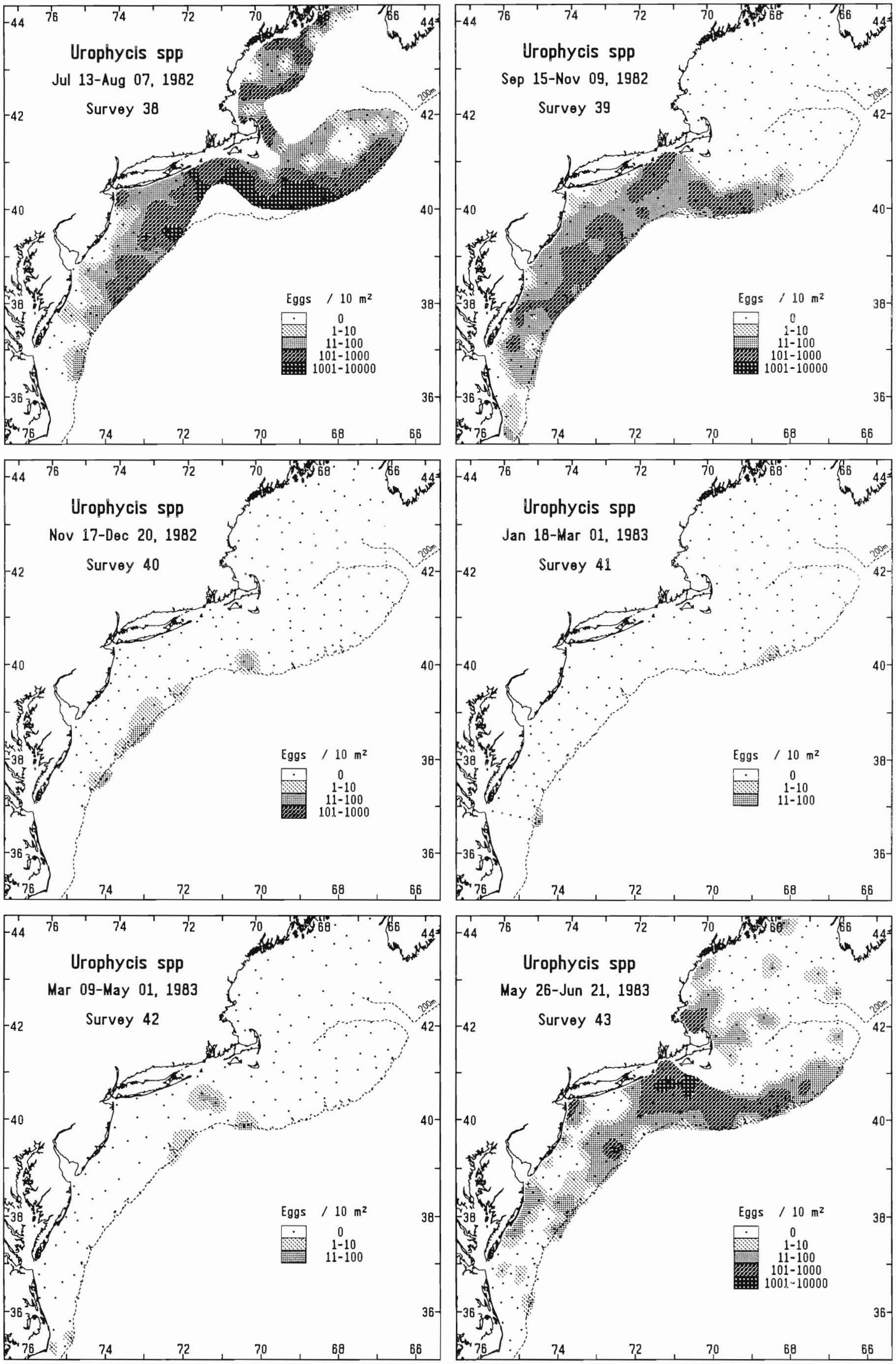


Figure 44 (continued)



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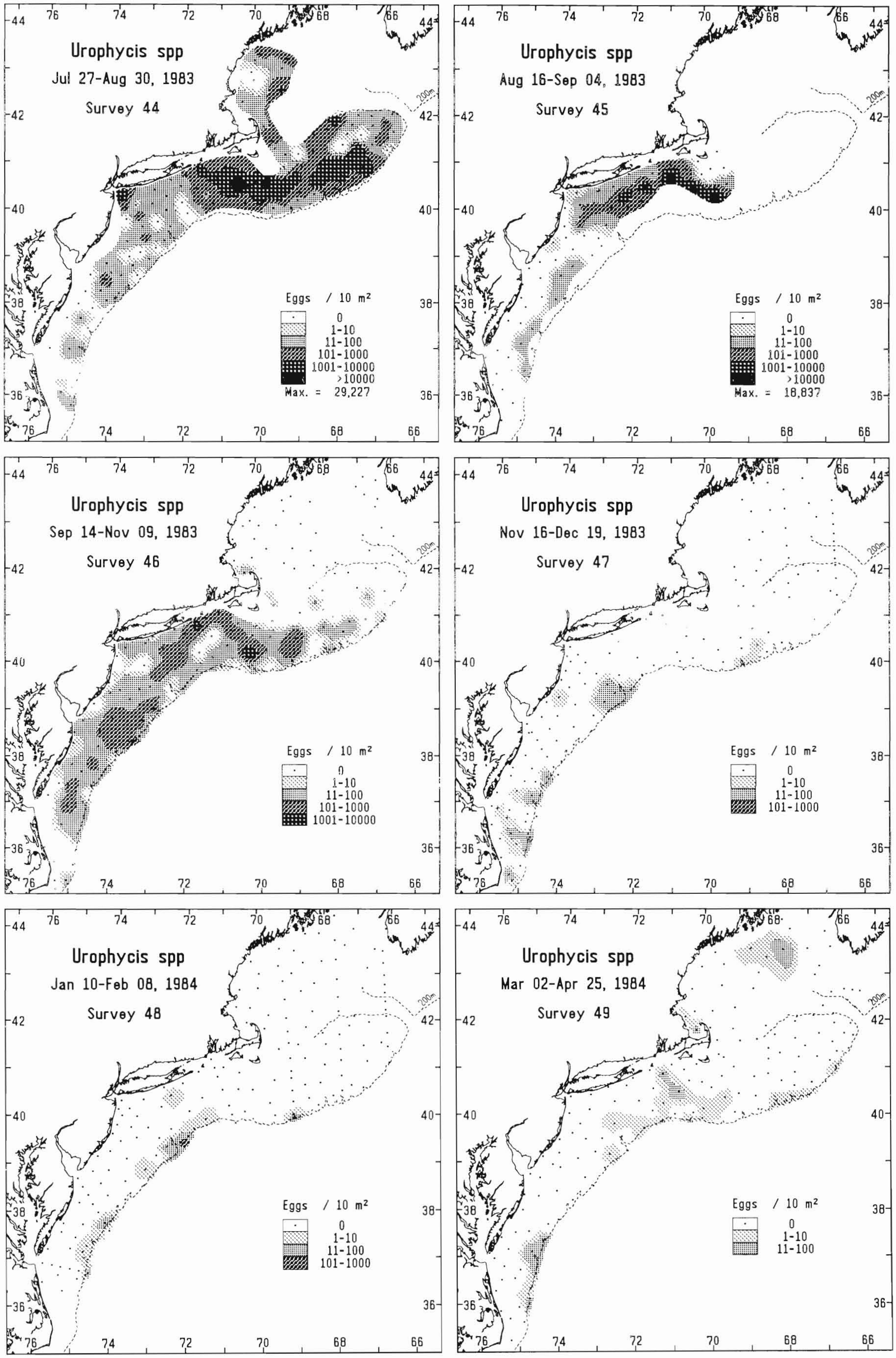

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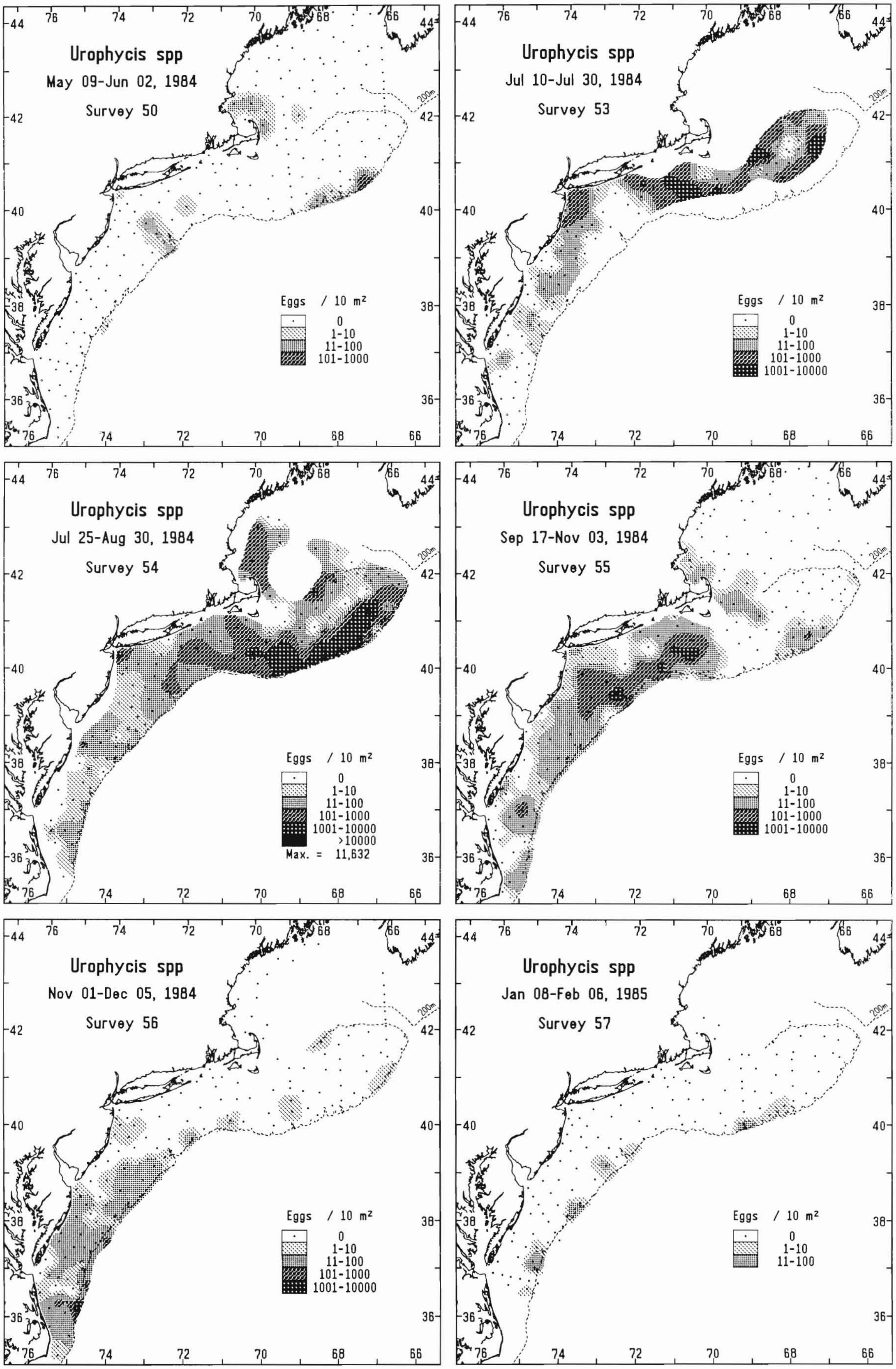

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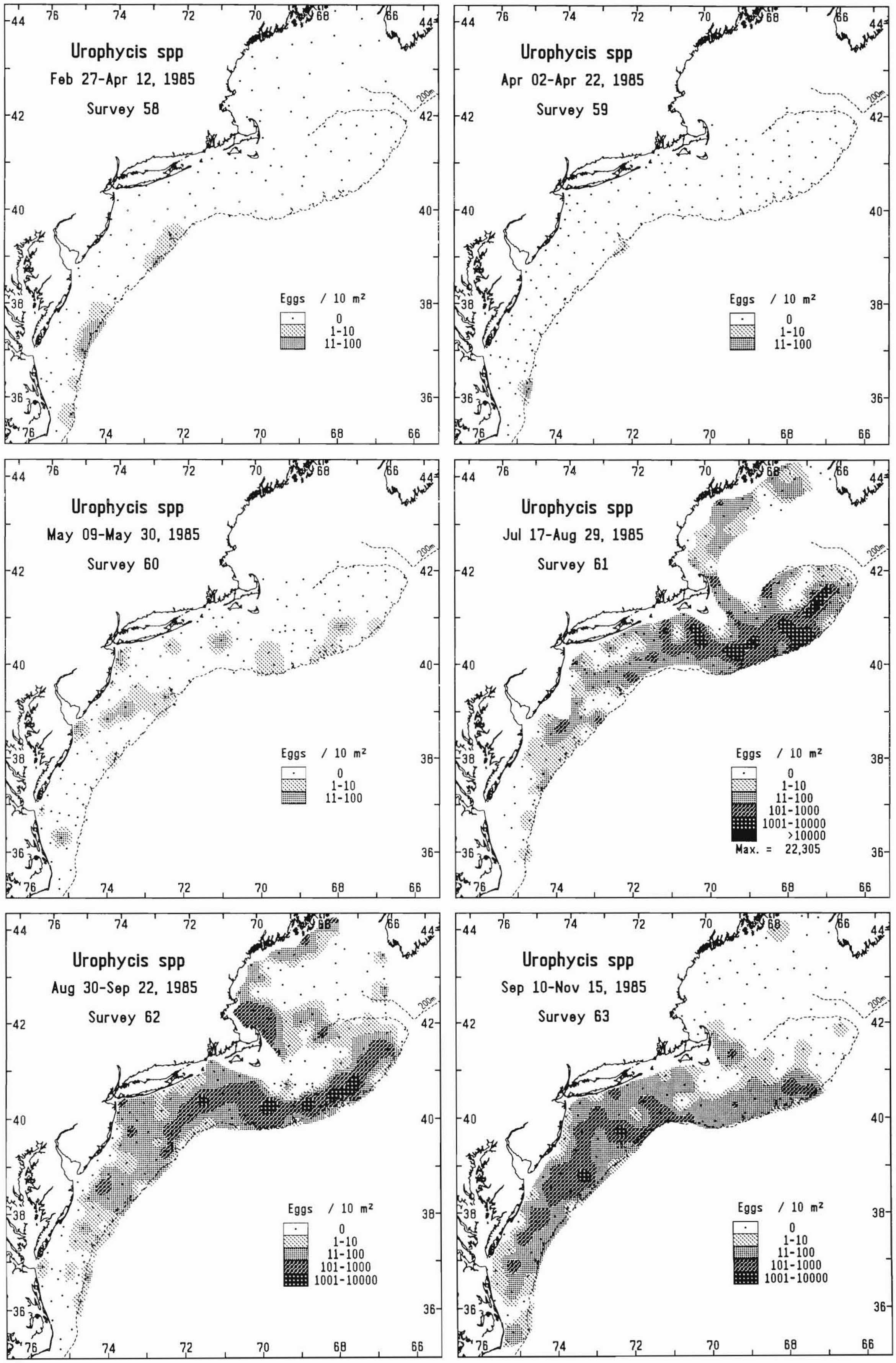

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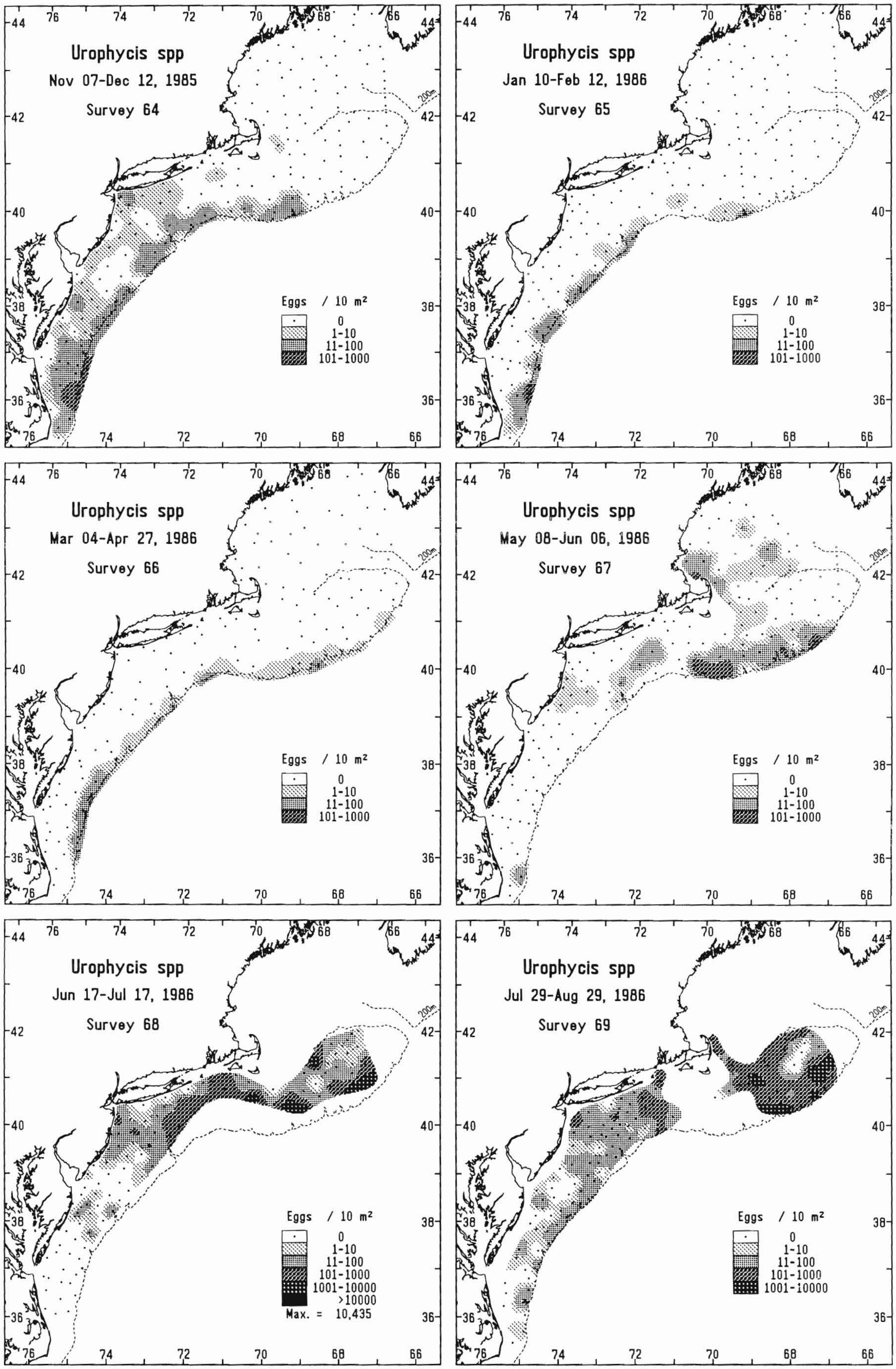

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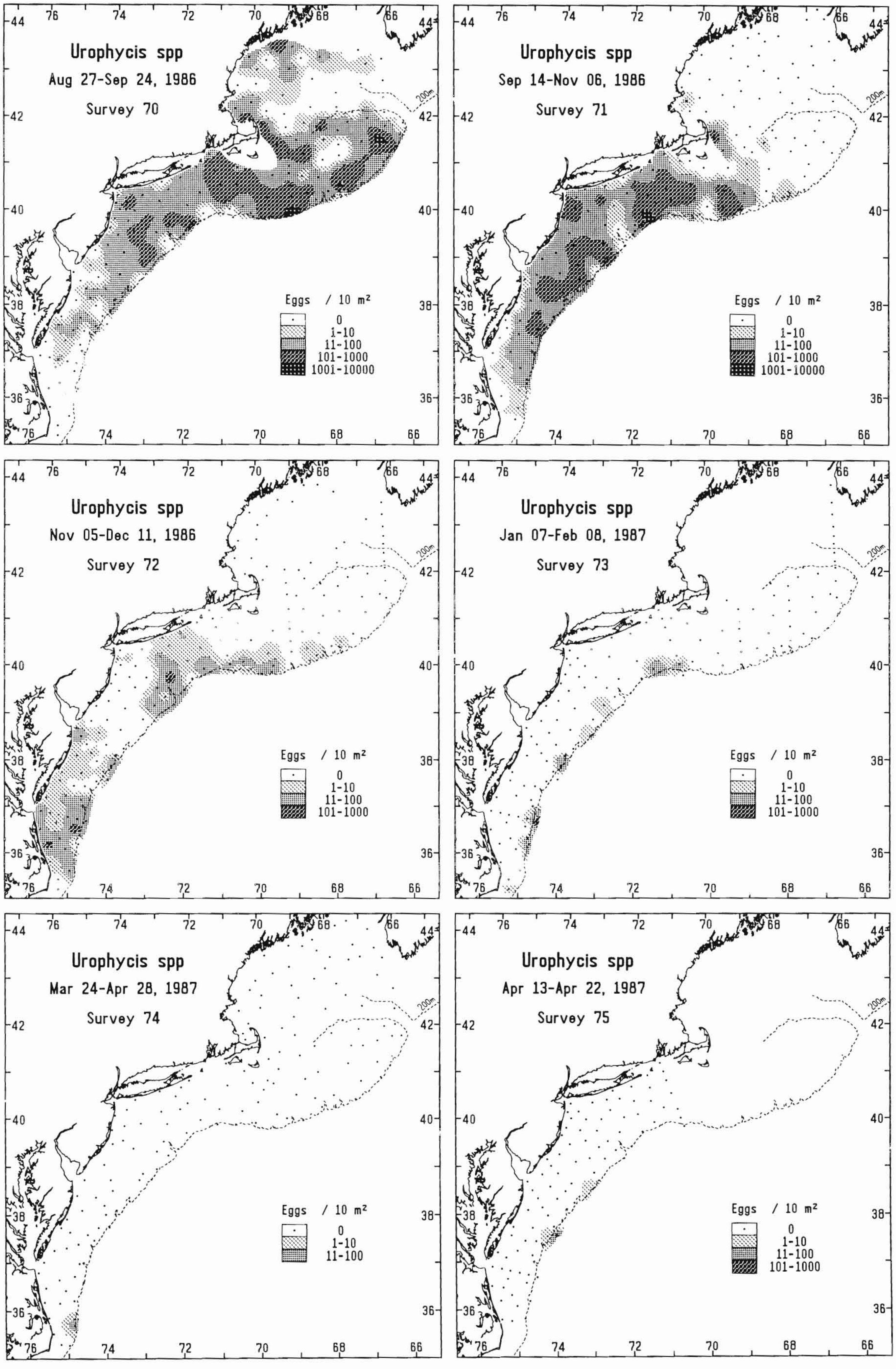

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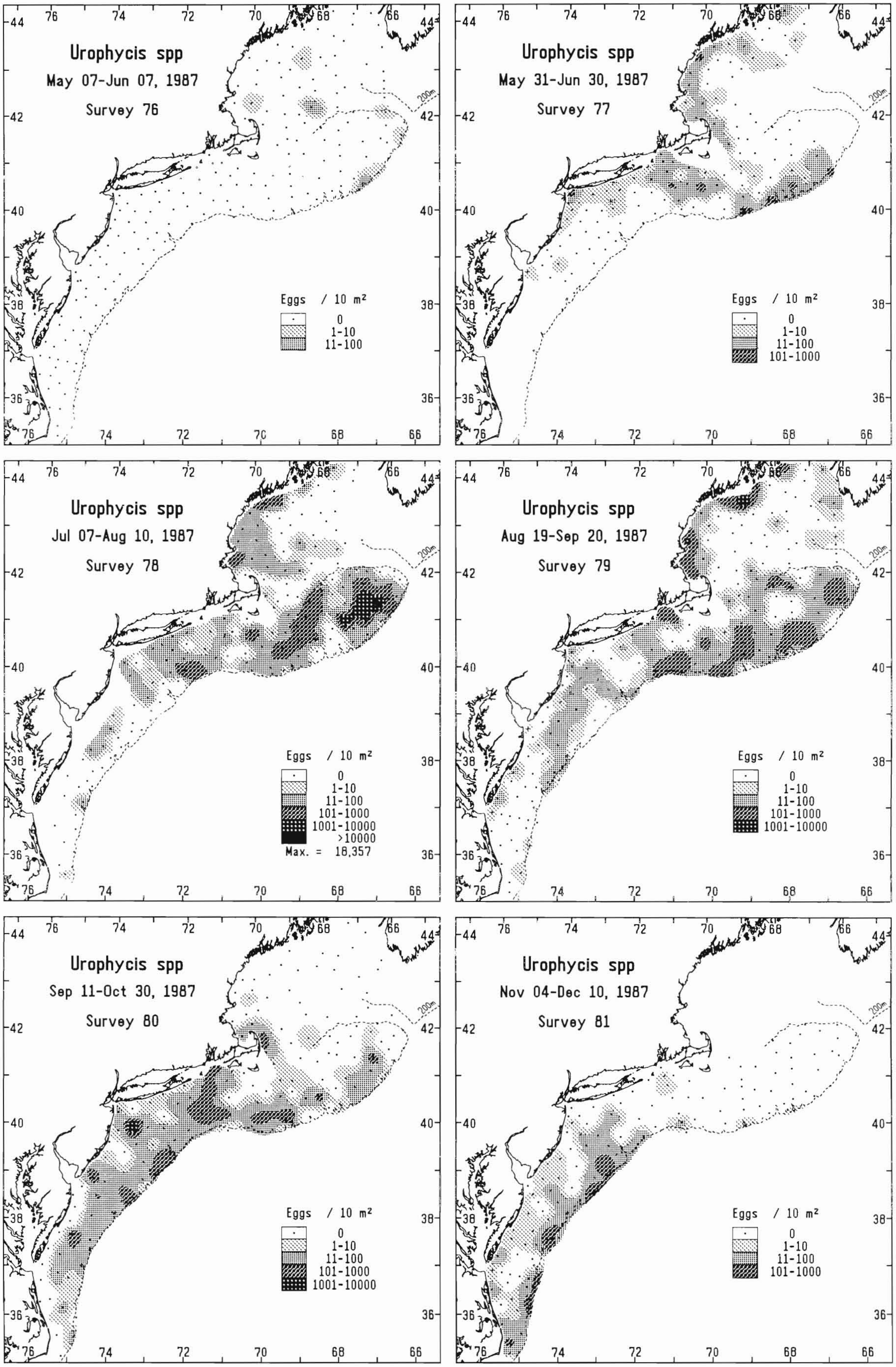


Figure 44 (continued)

Prionotus spp., searobins (Figs. 45–47)

Prionotus spp. eggs were collected throughout most of the year and were most abundant during late summer and absent only during February and December. The two species considered are *P. carolinus* and *P. evolans*, and given that their spawning habits may differ, the two-species nature of the data may contribute to a dichotomy in spawning area.

Spawning began in some years as early as March or April in southern areas, but typically increased significantly in May. North of Chesapeake Bay in May, eggs occurred both inshore and offshore (Fig. 46). During any given May survey they tended to occur in one or the other of these locations. However, in May 1985 they were caught in both areas (Survey 60, Fig. 47). During June and July, spawning increased in both area and intensity, especially in the Middle Atlantic and inshore southern New England subareas. Spawning extended onto Georges Bank in at least three of the nine years surveyed (Fig. 47). At the peak of spawning in August and September (Fig. 45), eggs were most concentrated in the Middle Atlantic and southern New England subareas. North of Chesapeake Bay they were mainly collected in inner shelf waters. South of the Bay they were spread across the entire shelf. As spawning declined in October and November, the areal distribution of searobin eggs decreased, receded southward, and shifted offshore (Fig. 46).

The unusually high mean egg abundance observed during survey 45 in 1983 (Fig. 45) was influenced by our sampling coverage and was probably biased upward. Otherwise, there was no apparent change in mean egg density over the sampling period.

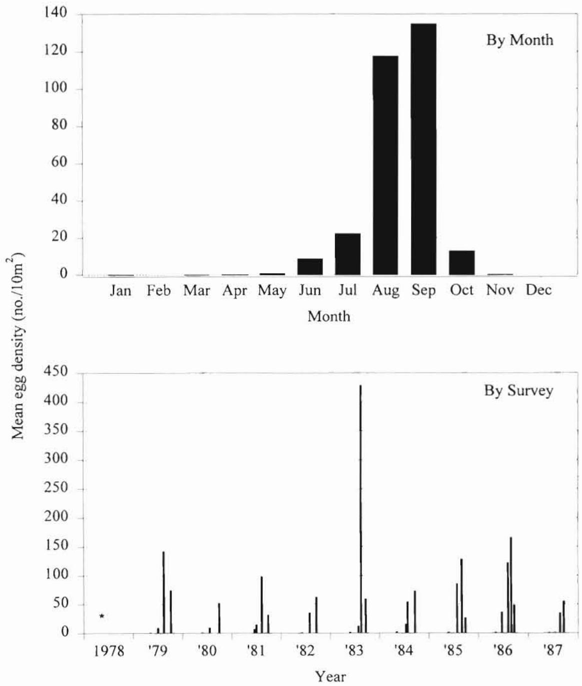


Figure 45

Prionotus spp.; mean-egg-density graphs by month (top) and by survey (bottom) for the total MARMAP area. (*Samples from the first four surveys in 1978 were not analyzed for *Prionotus* spp. eggs.)

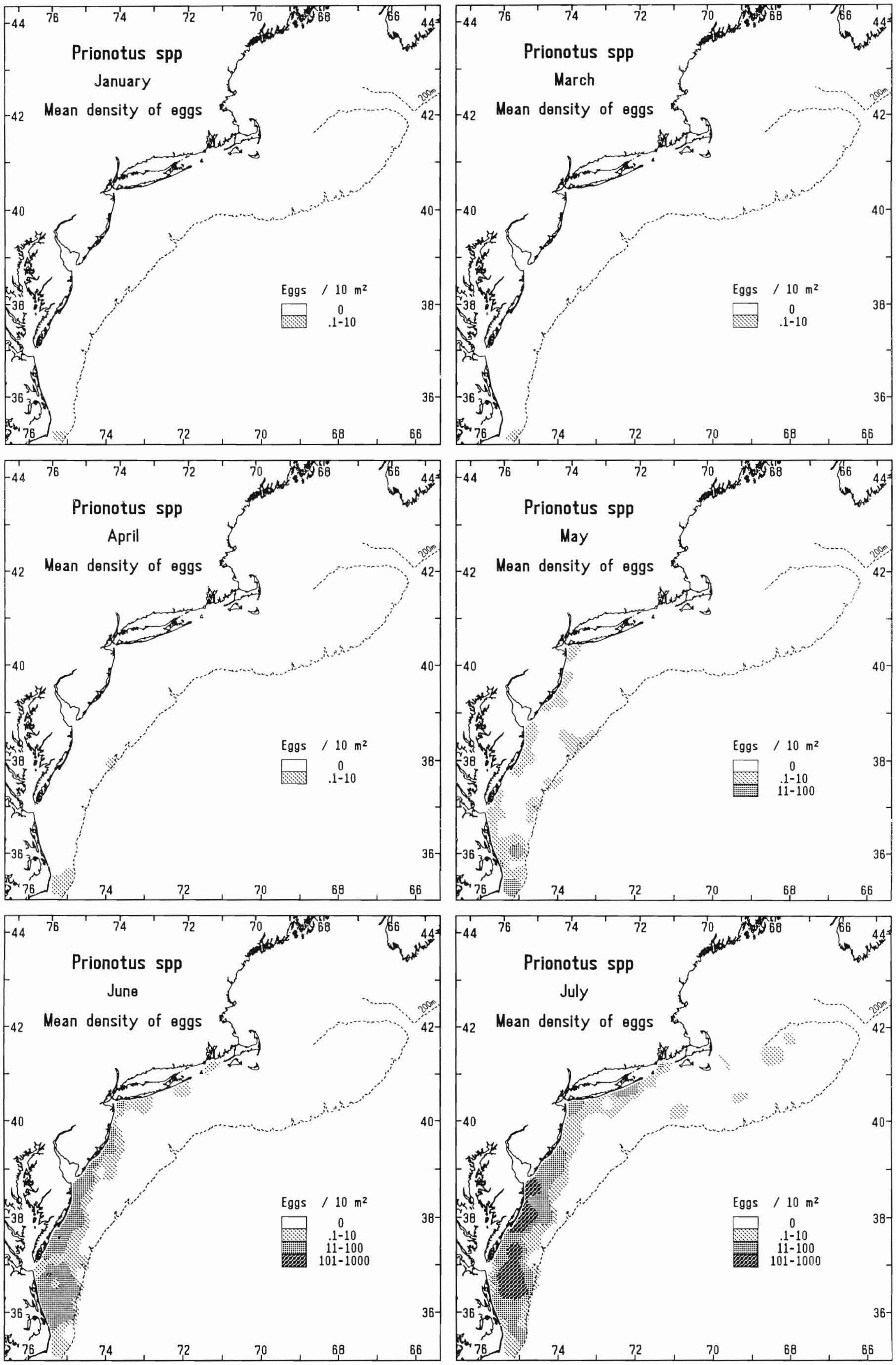


Figure 46

Prionotus spp.; composite monthly areal plots of mean egg densities (no./10 m²).

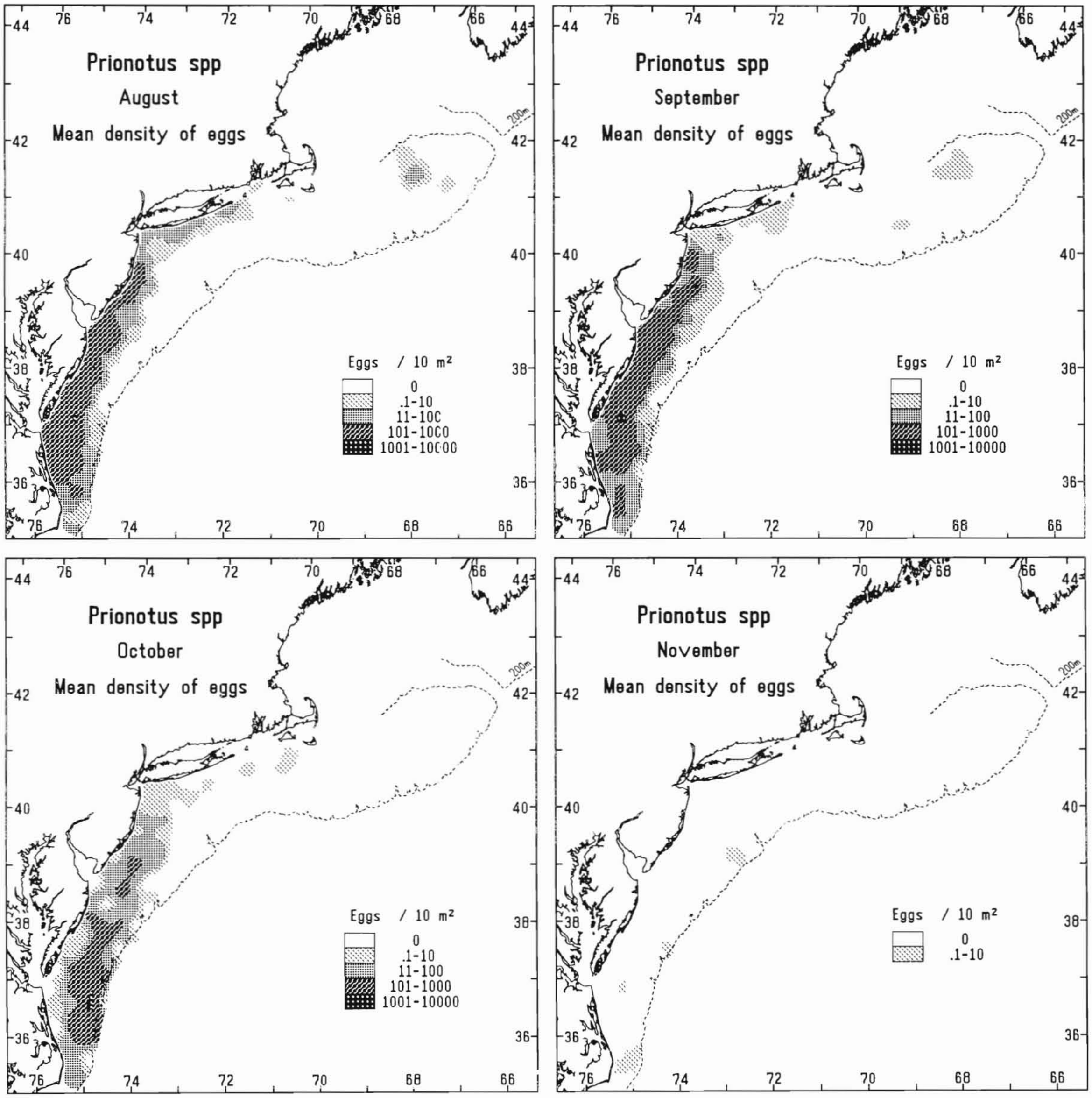


Figure 46 (continued)

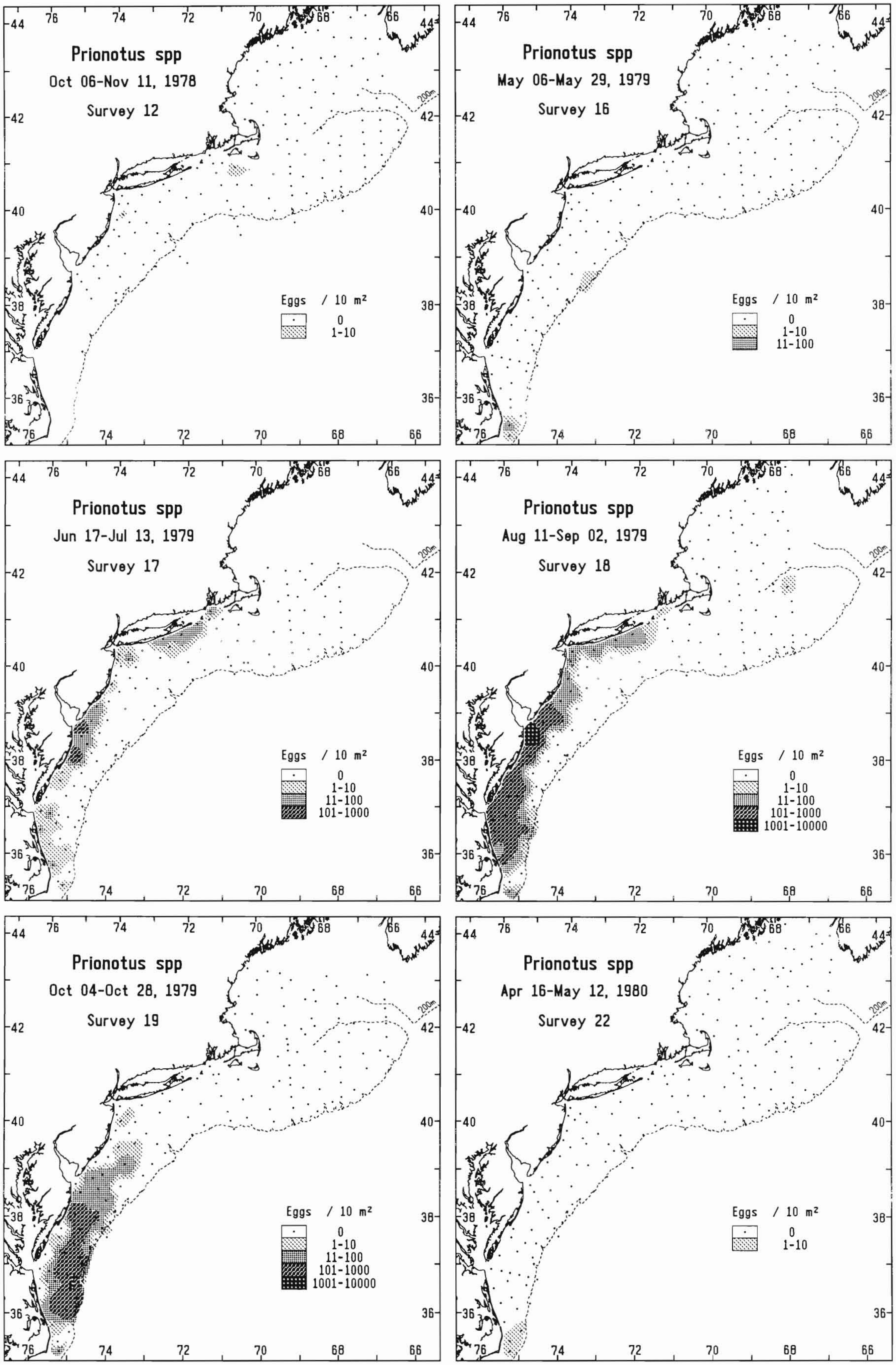
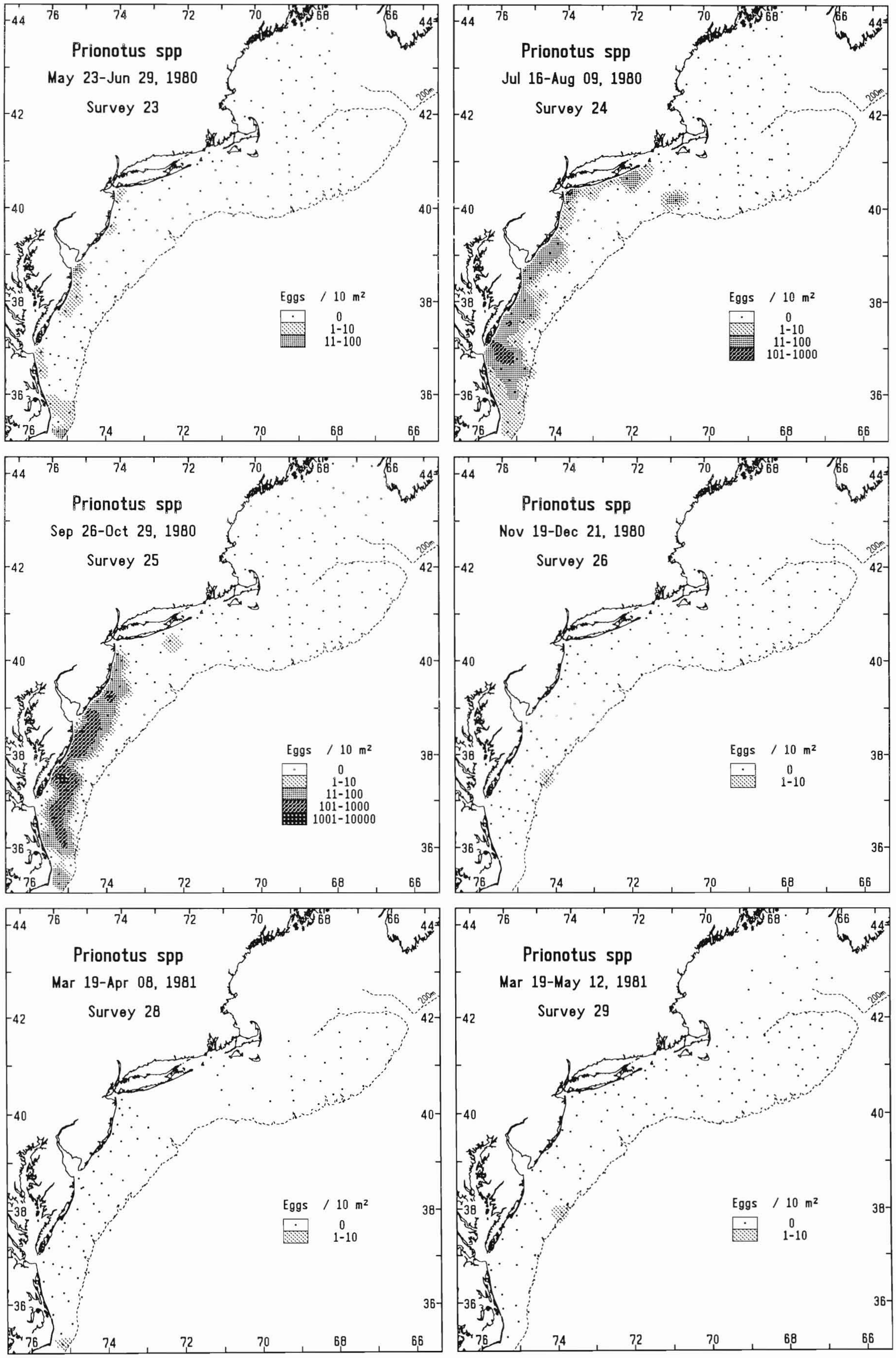


Figure 47
Prionotus spp.; survey areal plots of egg densities (no./10 m²).



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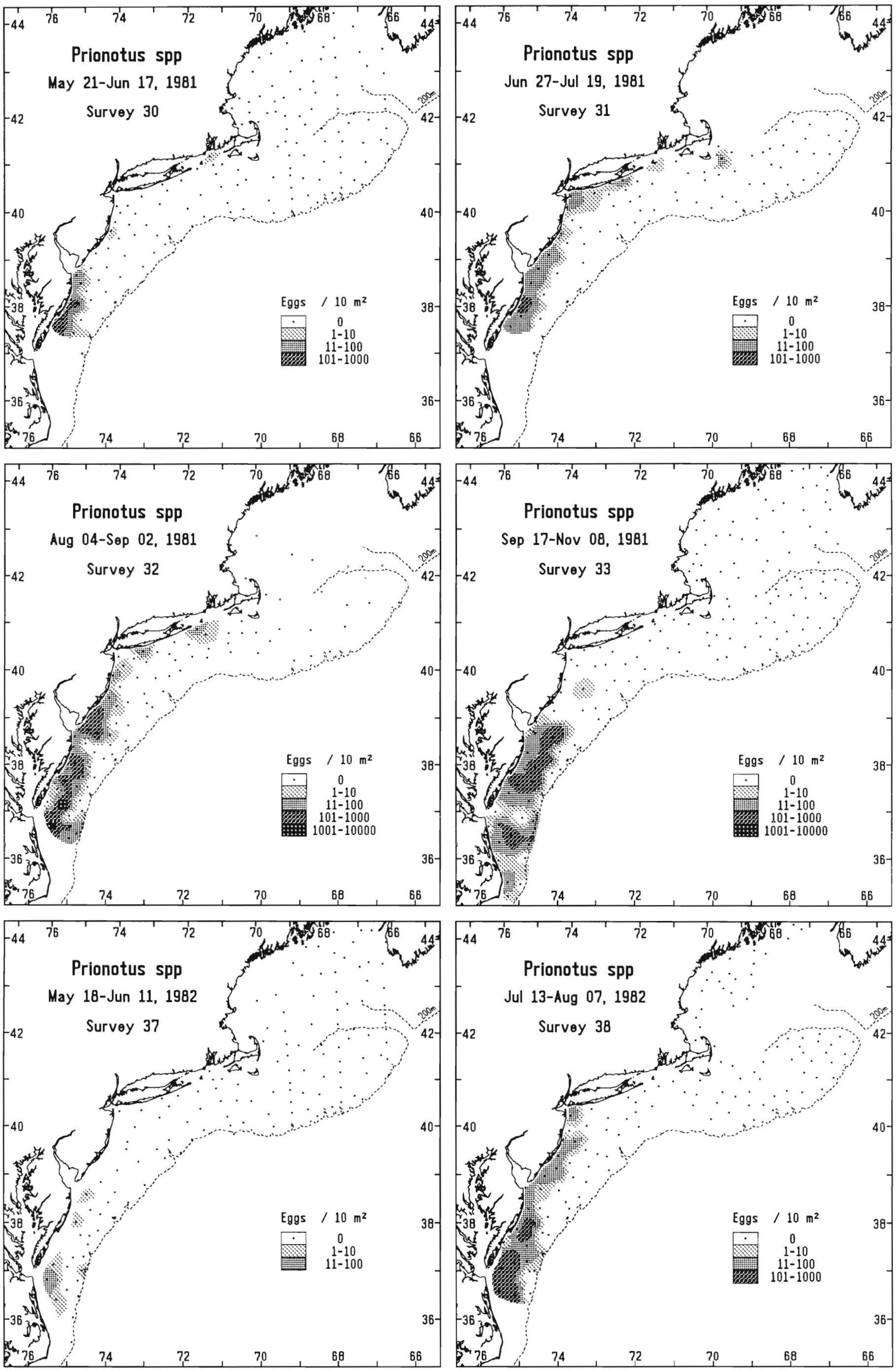

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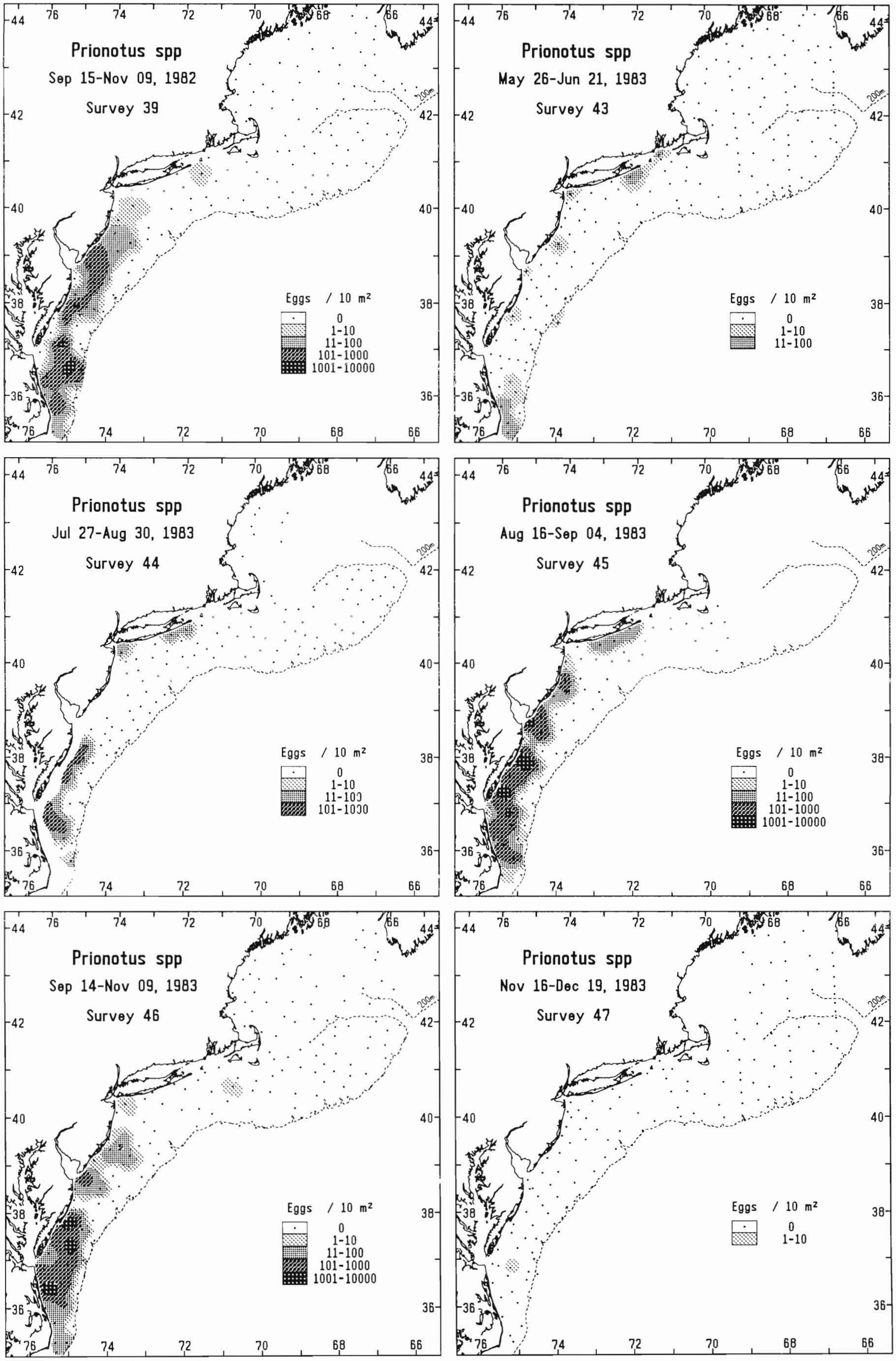

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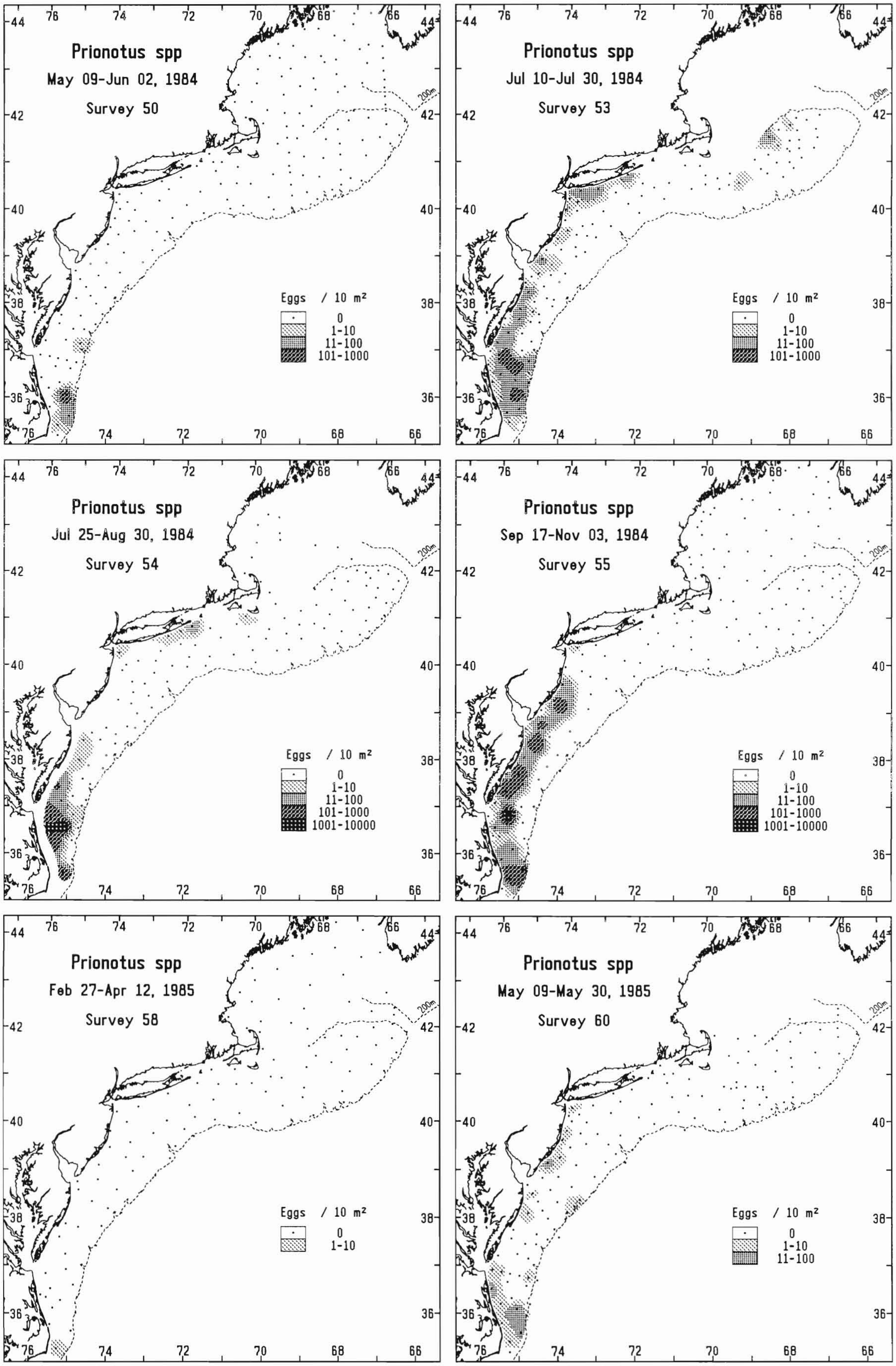

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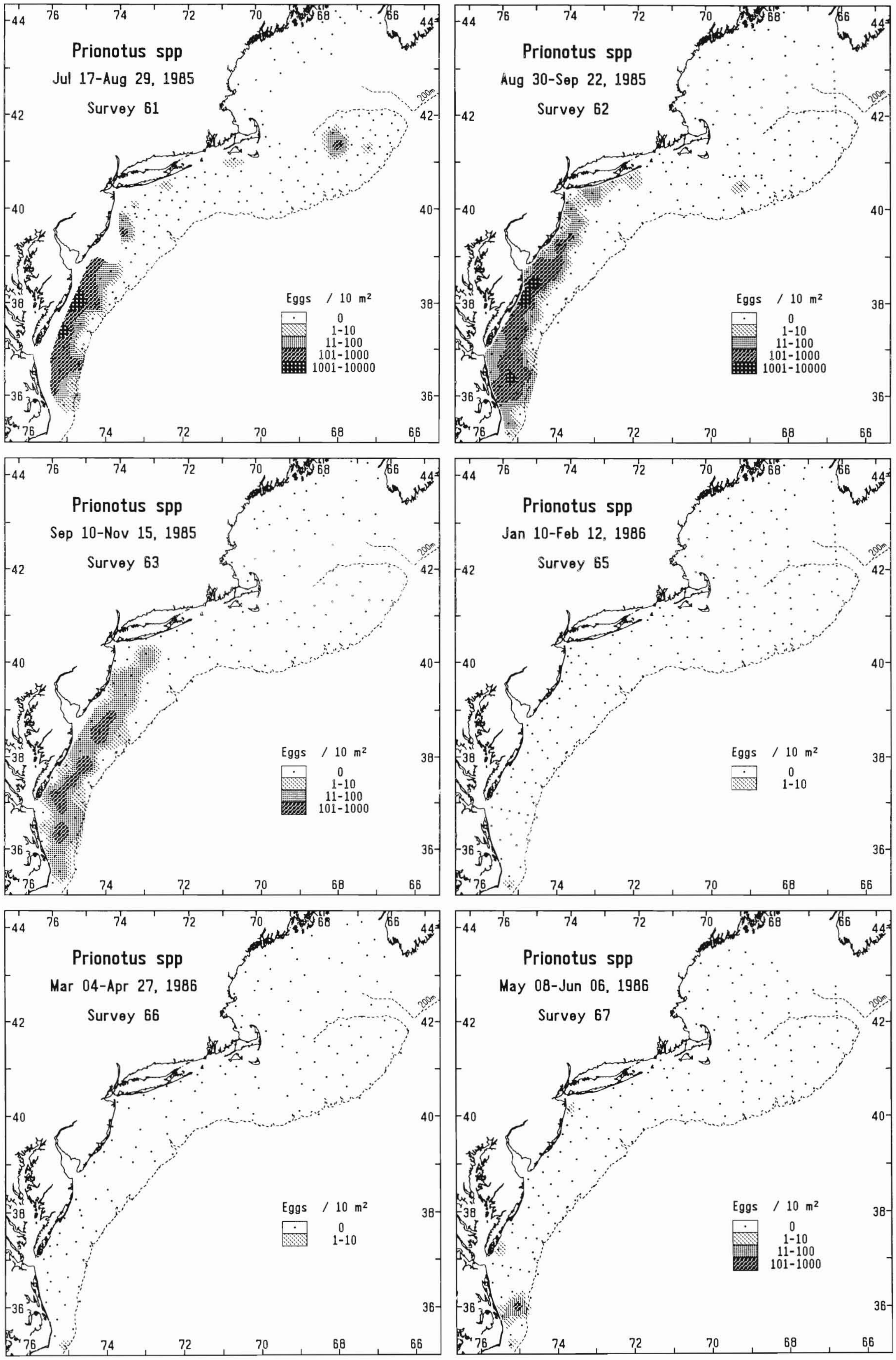

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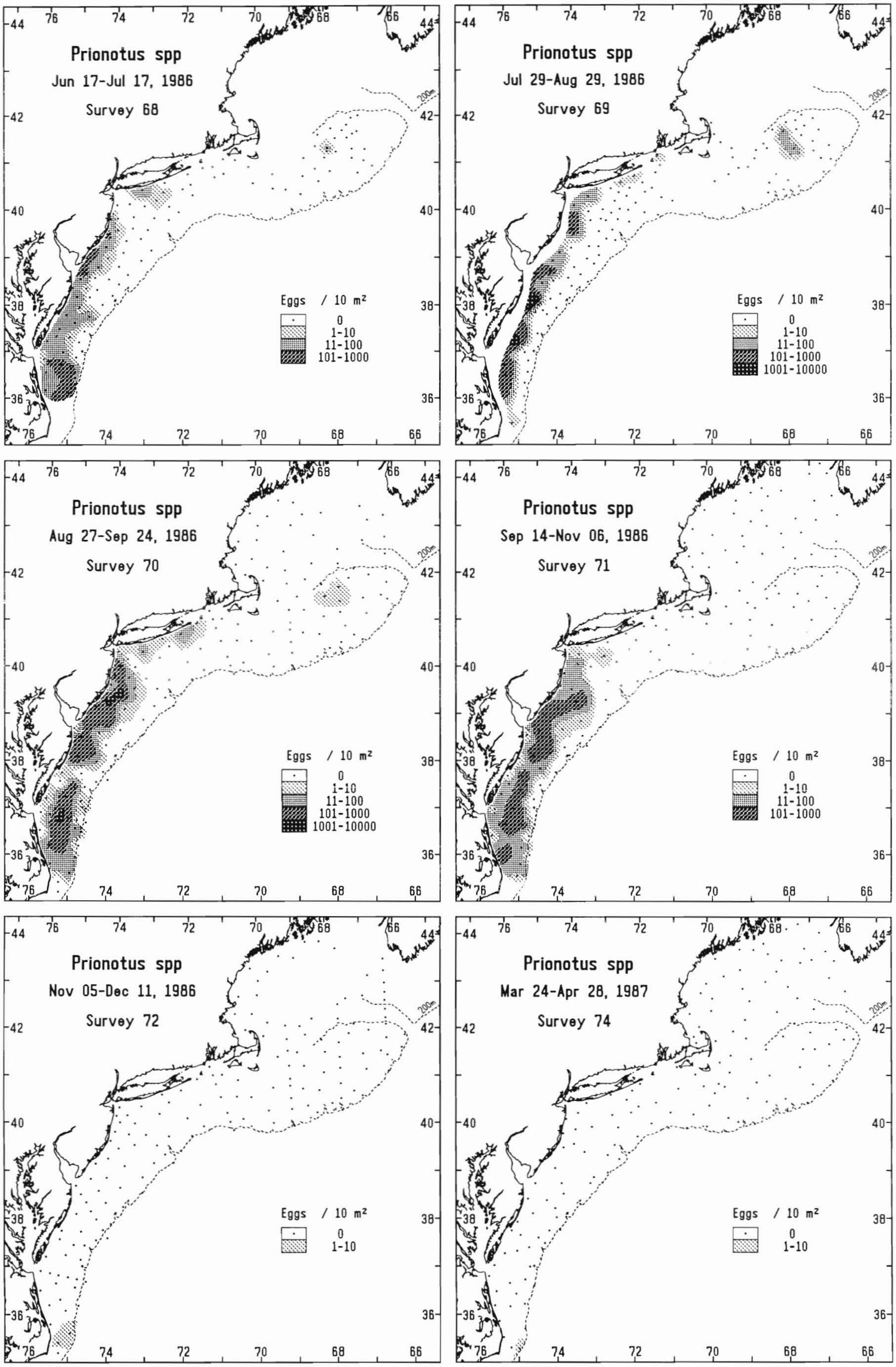

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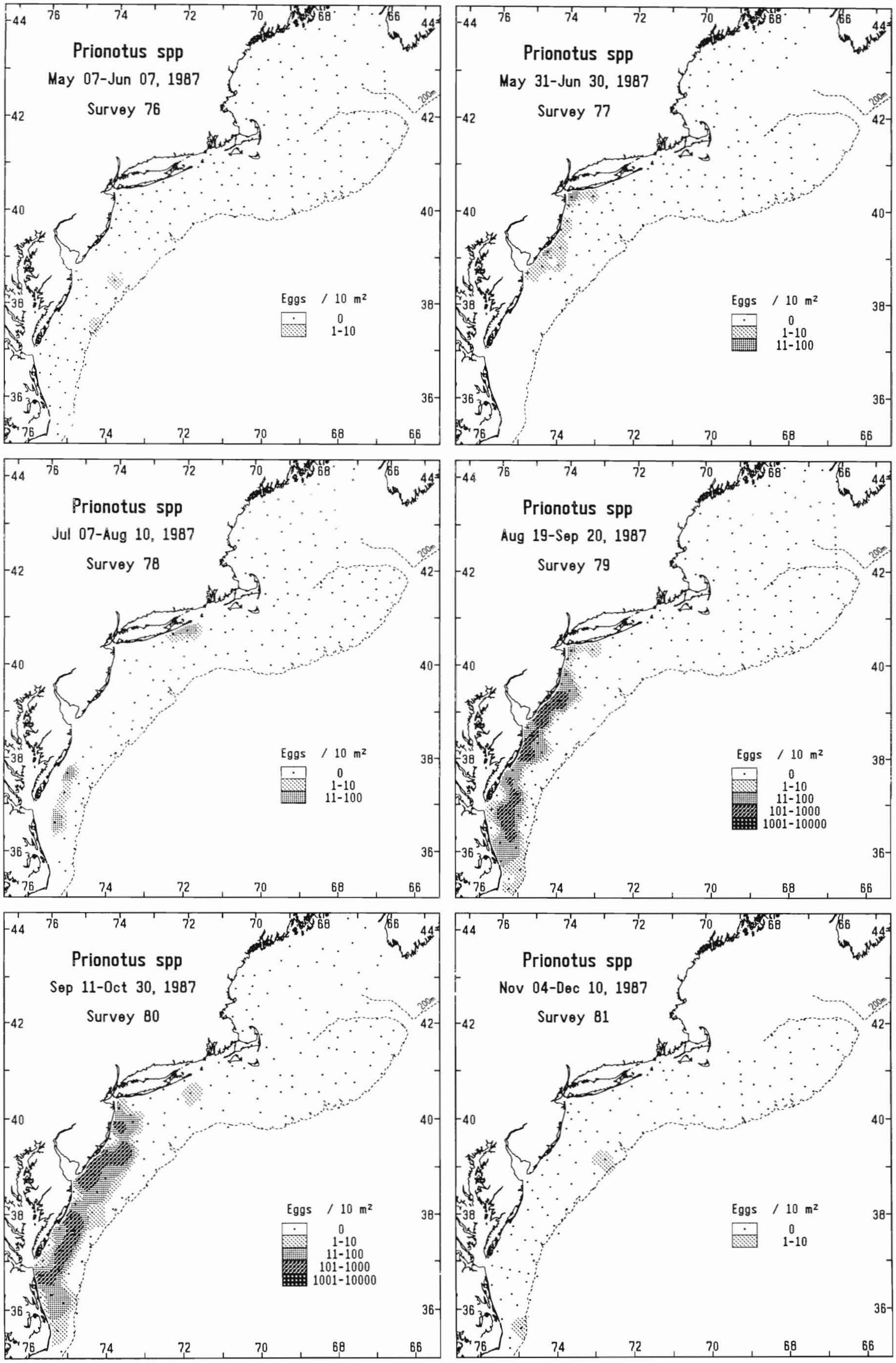


Figure 47 (continued)

Centropristis striata, black sea bass (Figs. 48–50)

Centropristis striata eggs occurred in January and from April to October; they were most abundant from June to September (Fig. 48). These eggs occurred mainly in the Middle Atlantic subarea, but also occurred in southern New England waters to eastern Long Island during peak spawning (Fig. 49). They extended across the shelf in southern areas, but tended to be restricted to mid-shelf and the inner half of shelf waters in the northern portion of their range.

Spawning began between Cape Hatteras and Chesapeake Bay as early as April but more commonly did not begin until May (Fig. 50). Spawning expanded northward during June to August, occurring predominantly in the inner half of shelf waters. Peak spawning occurred in August (Fig. 48) when eggs occurred from south of Chesapeake Bay to off Long Island and were most concentrated between Cape Hatteras and southern New Jersey. Spawning declined during September and October, resulting in increasingly patchy egg distributions and greatly diminished mean egg densities (Figs. 48 and 49).

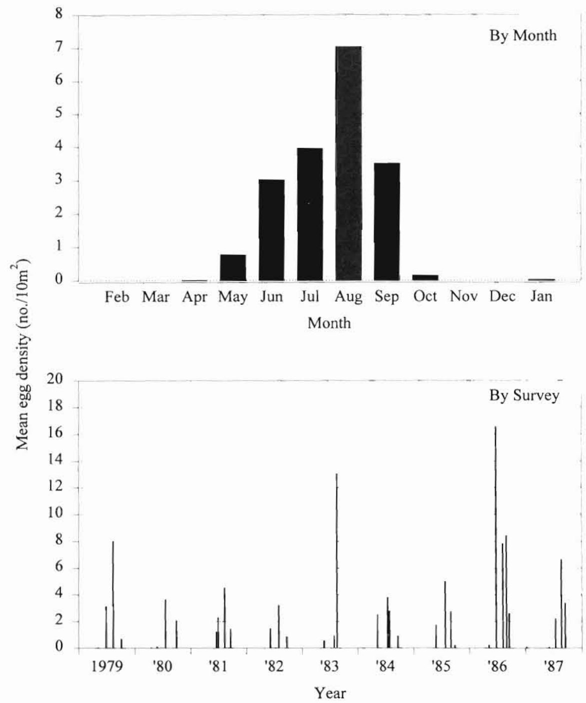


Figure 48
Centropristis striata; mean-egg-density graphs by month (top) and by survey (bottom) for the total MARMAP area.

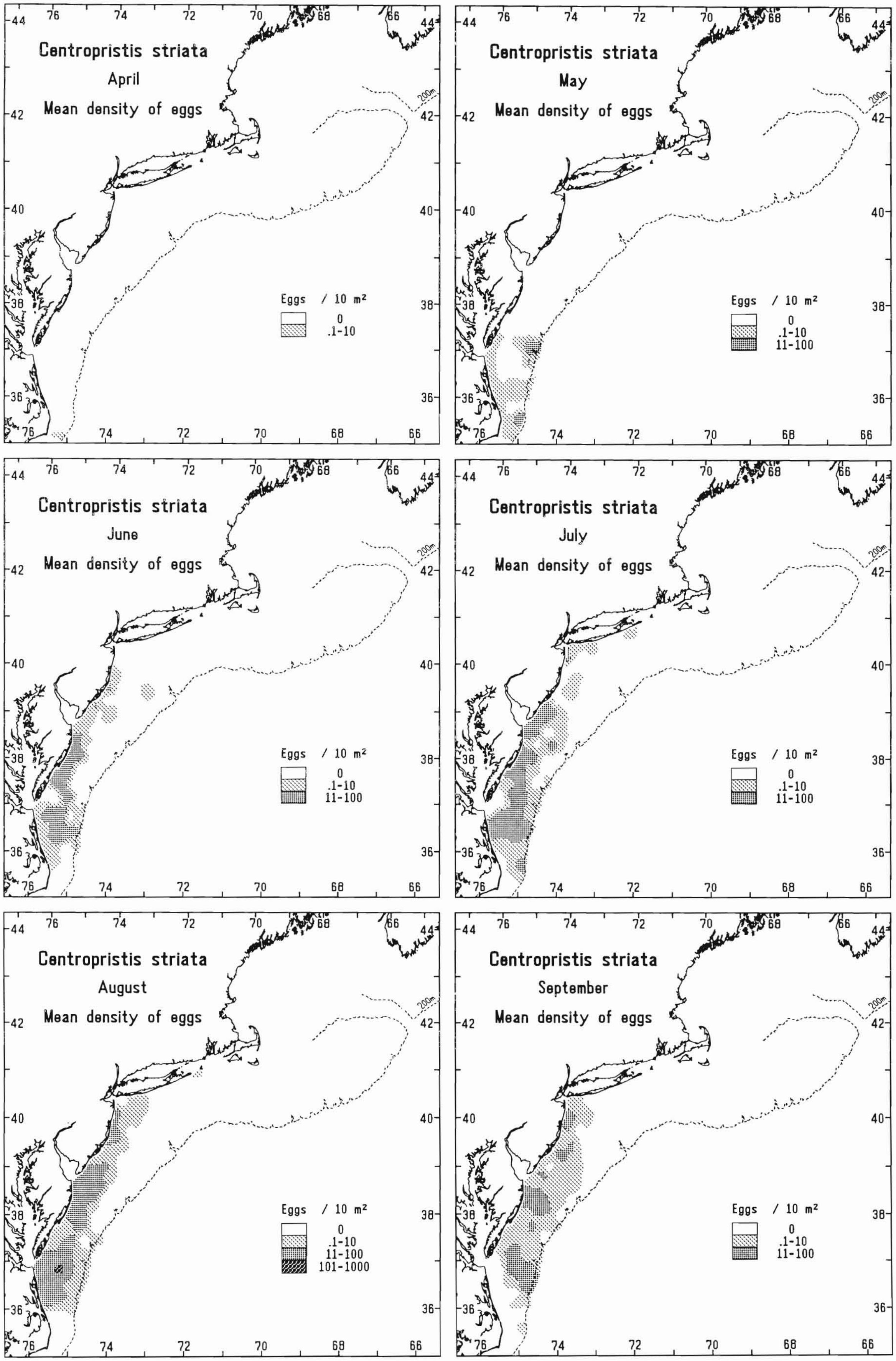


Figure 49

Centropristis striata; composite monthly areal plots of mean egg densities (no./10 m²).

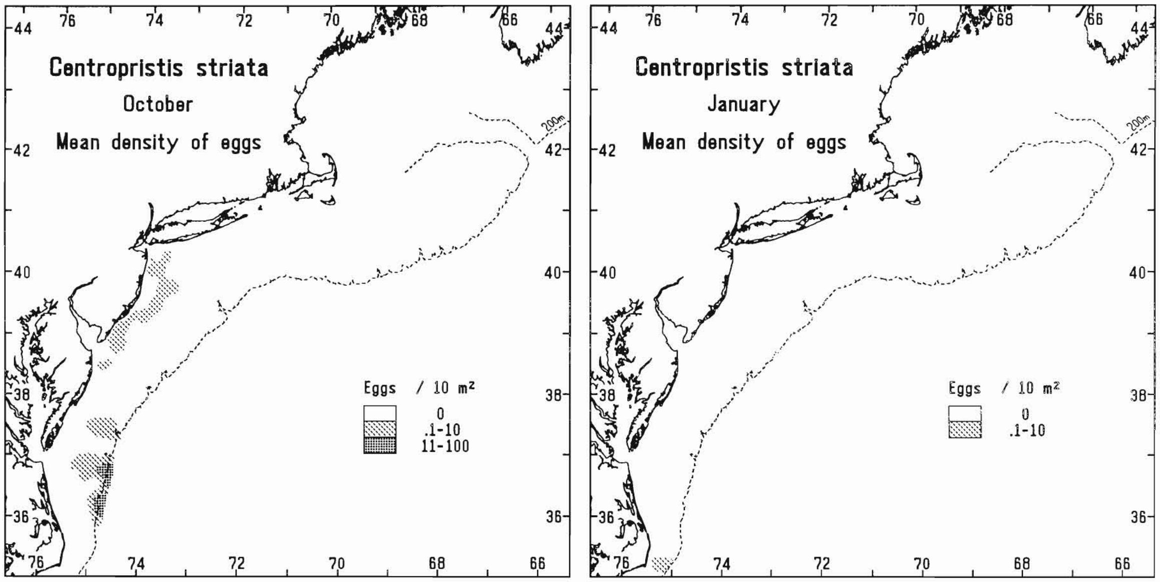


Figure 49 (continued)

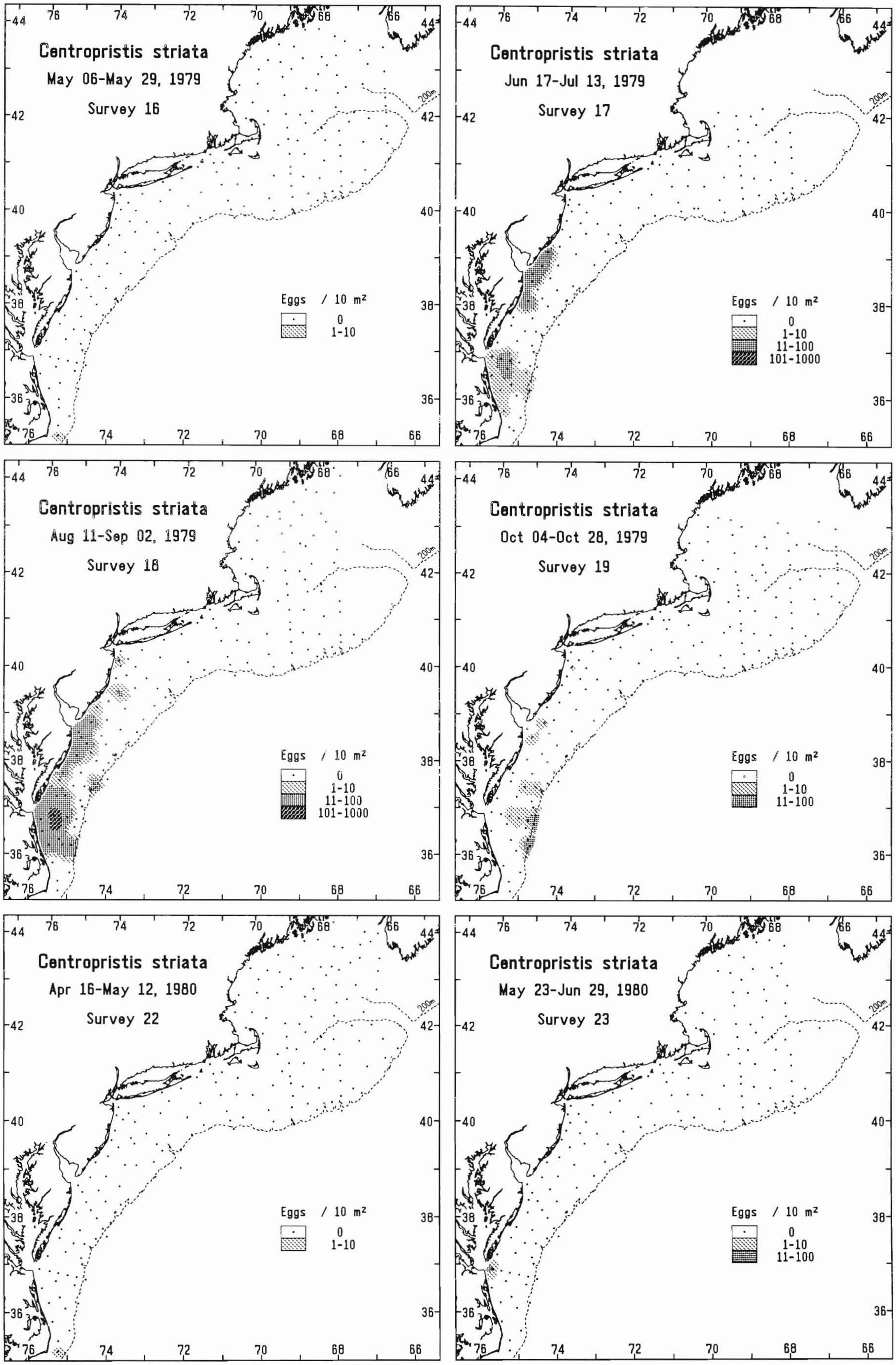


Figure 50
Centropristis striata; survey areal plots of egg densities (no./10 m²).

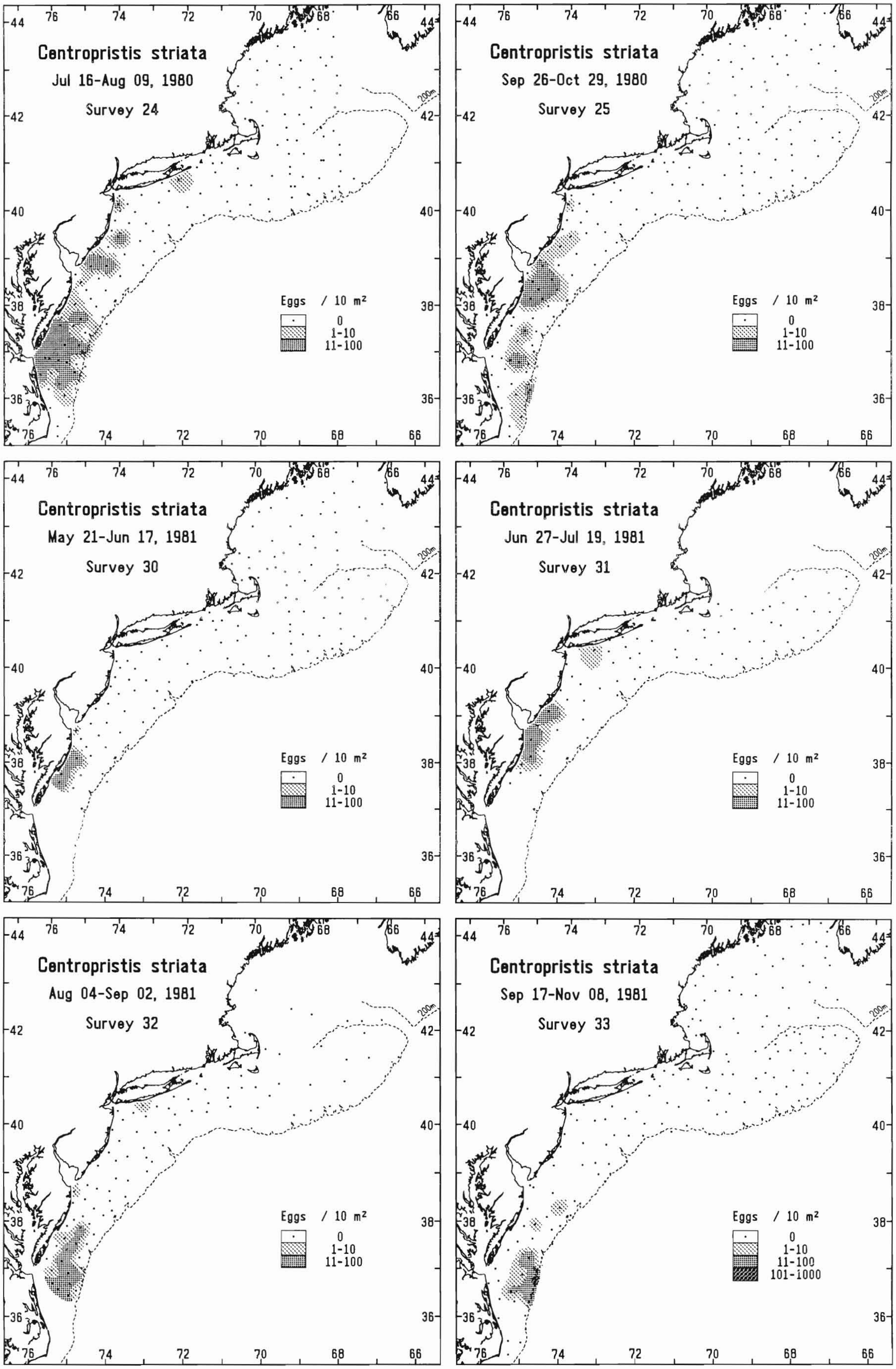


Figure 50 (continued)

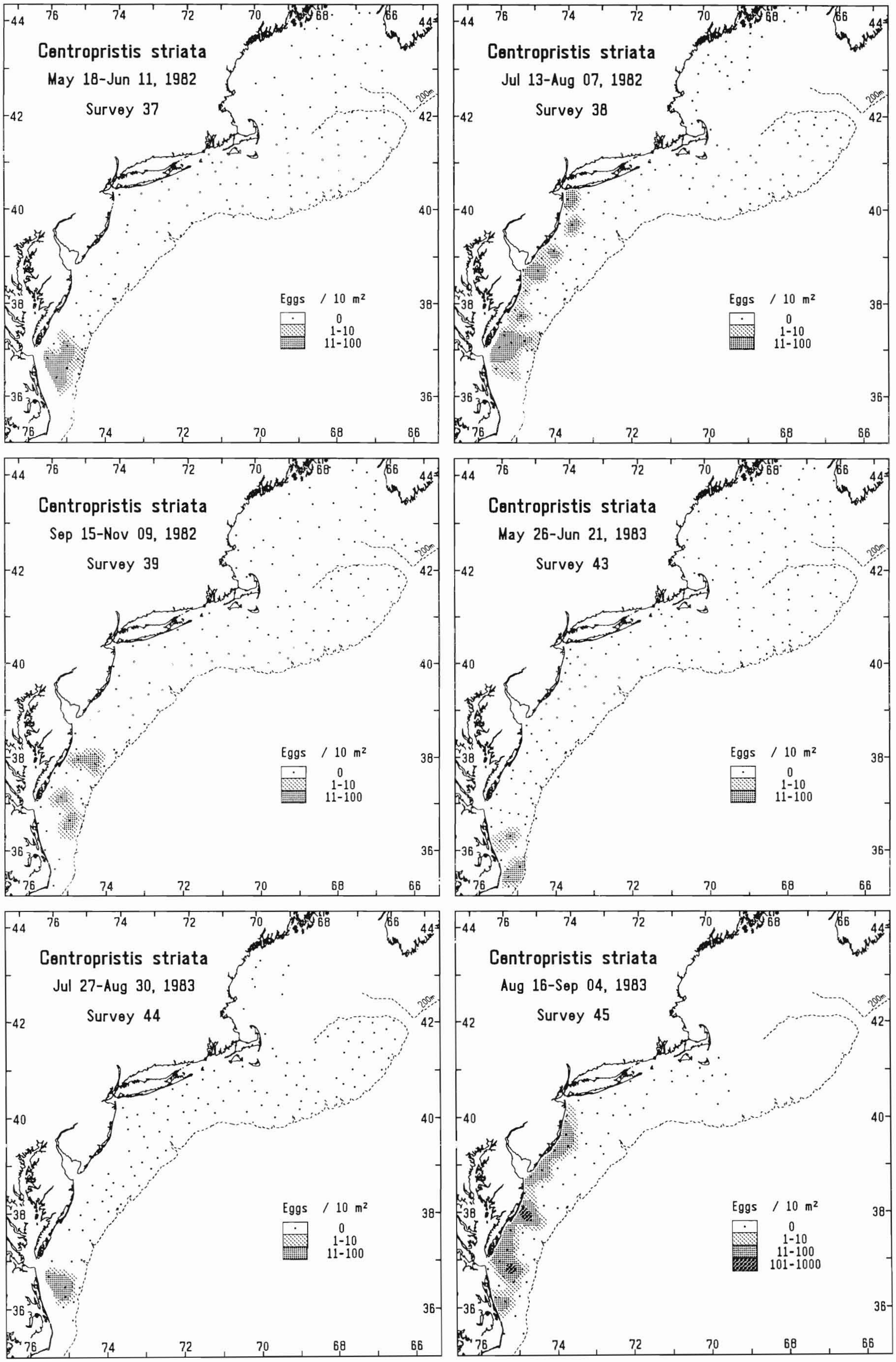


Figure 50 (continued)

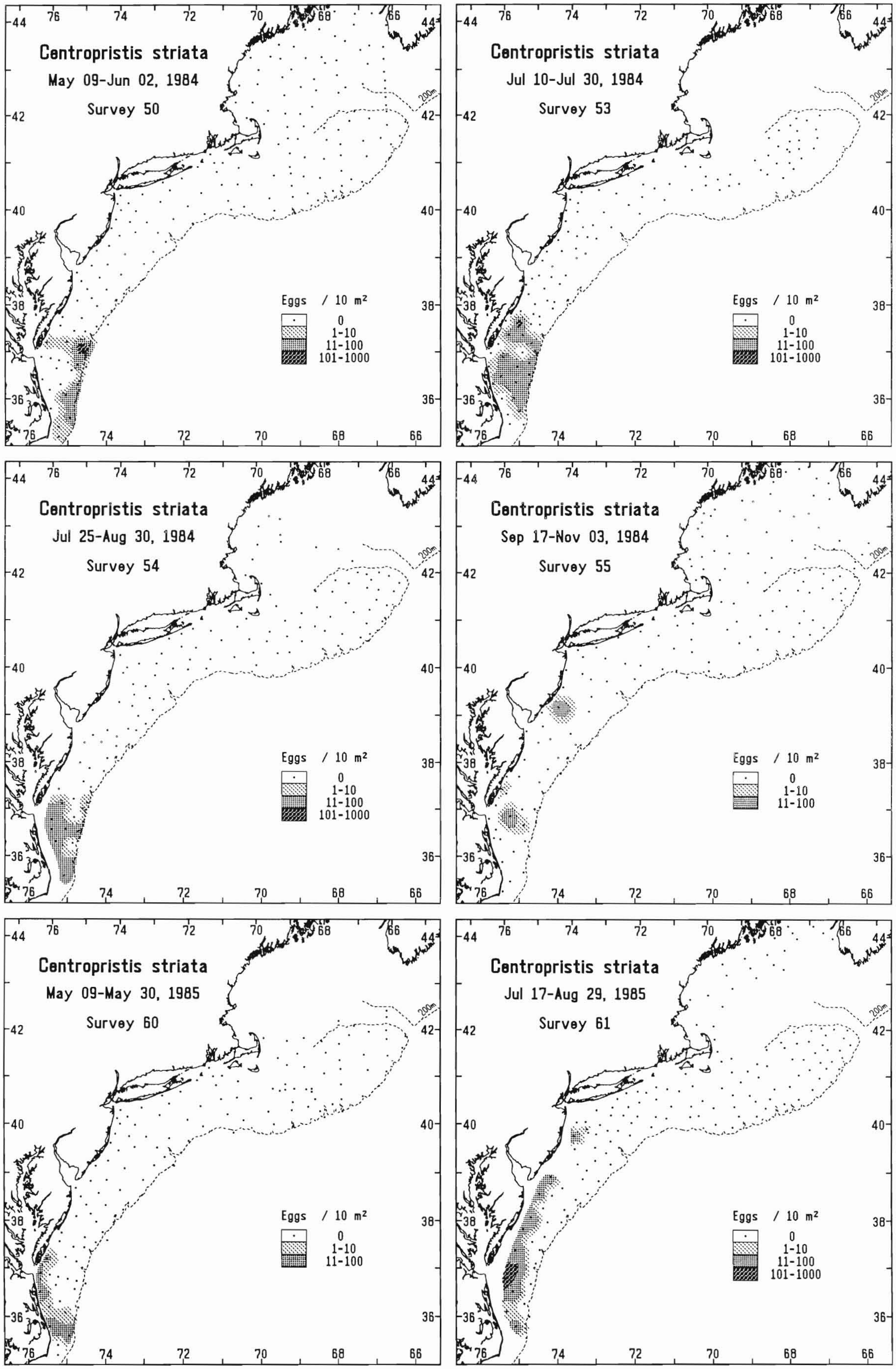


Figure 50 (continued)

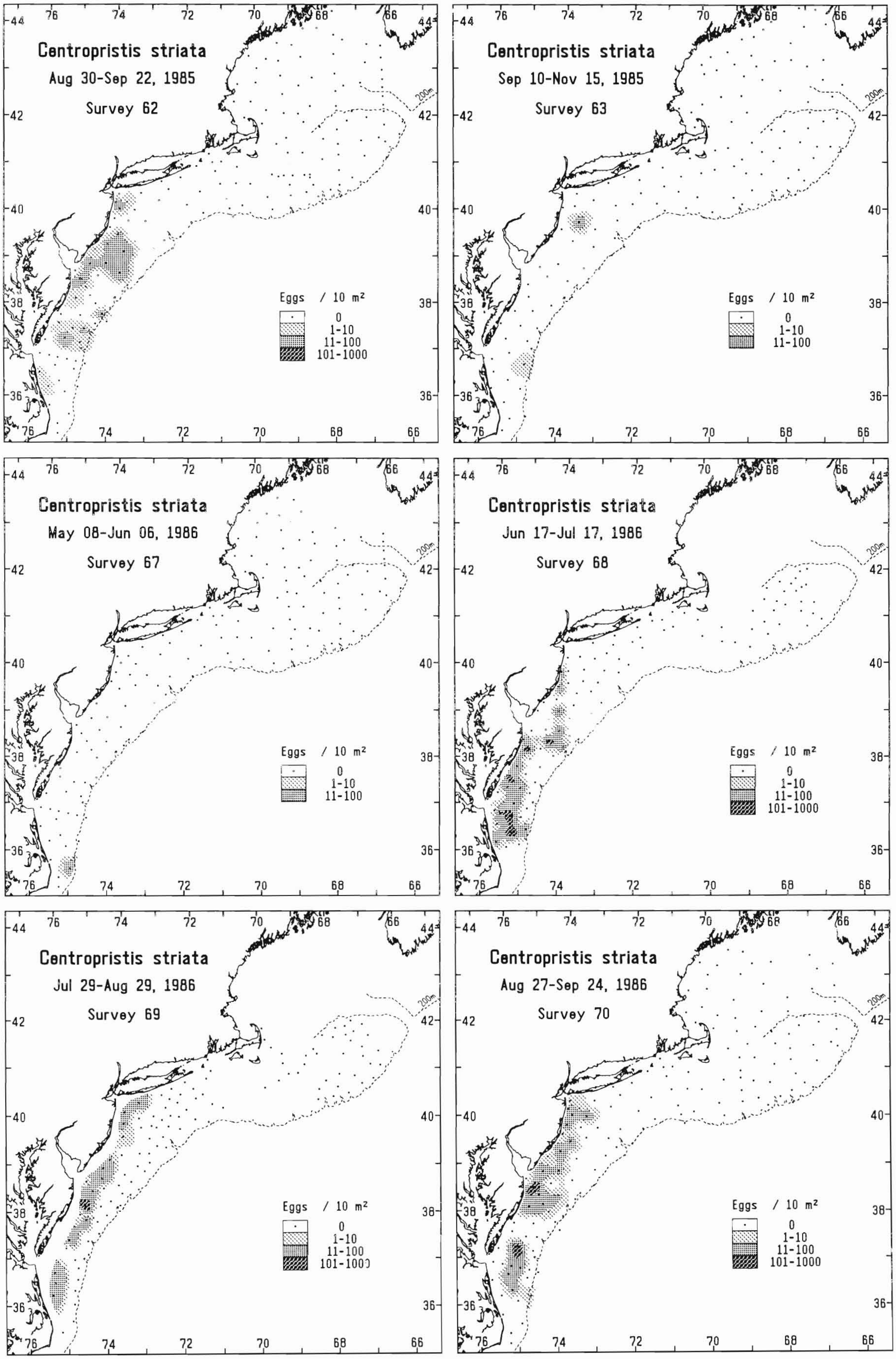


Figure 50 (continued)

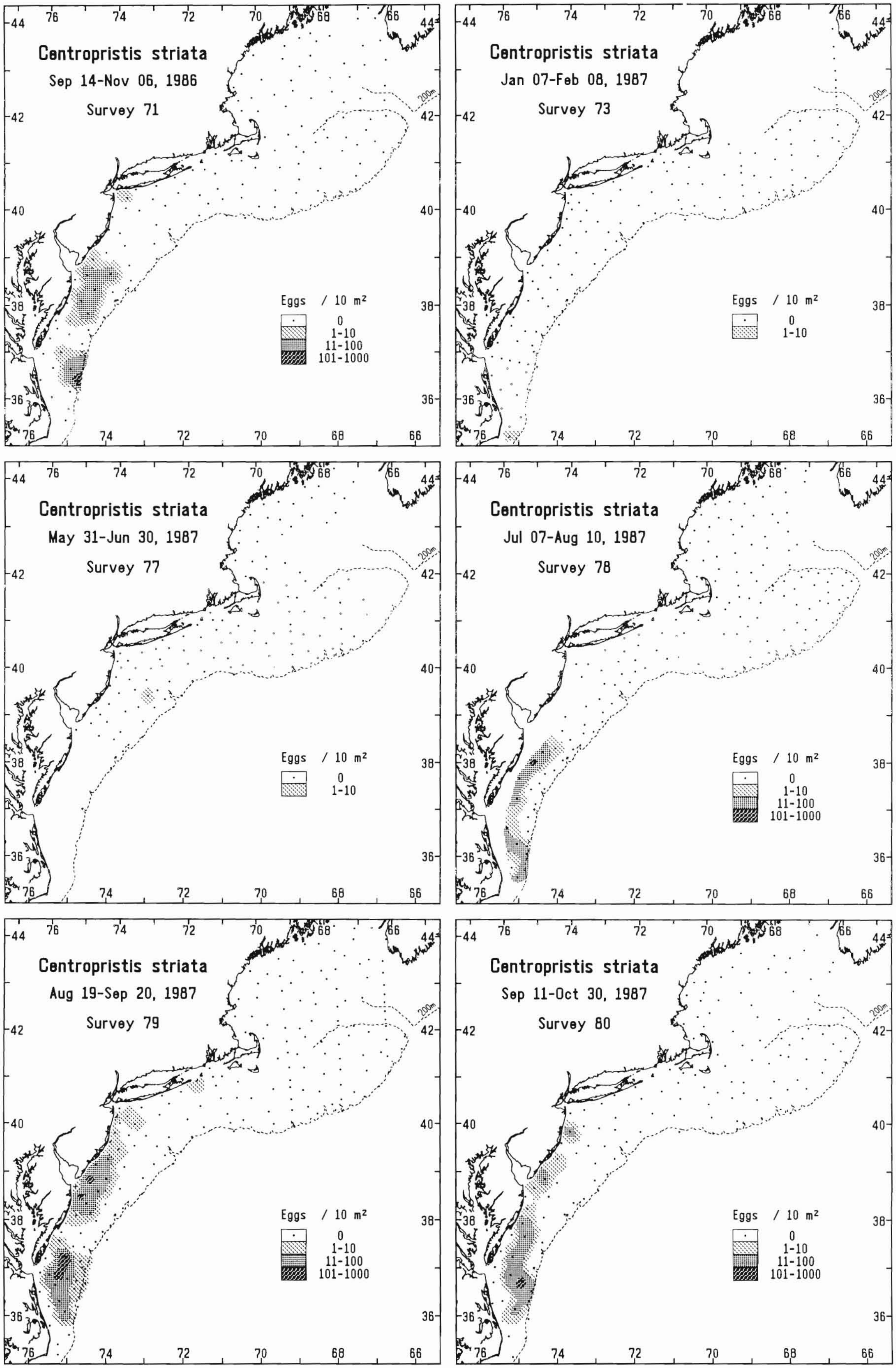


Figure 50 (continued)

Lopholatilus chamaeleonticeps, tilefish (Figs. 51–53)

Lopholatilus chamaeleonticeps eggs were collected from March to November and were restricted to the outer edge of the continental shelf. The highest mean egg densities occurred in May and June (Fig. 51).

Spawning began in March or April along the shelf edge from east of Delaware Bay and New Jersey to south of Nantucket Shoals. At the peak of spawning in May and June, eggs occurred from south of Chesapeake Bay to southeastern Georges Bank. Spawning diminished in the following months and ended by November (Fig. 52).

A downward trend in mean-egg-densities was apparent over the nine-year survey period. The four highest values occurred from 1979 to 1983, and the lowest annual values during the last five years (Fig. 51).

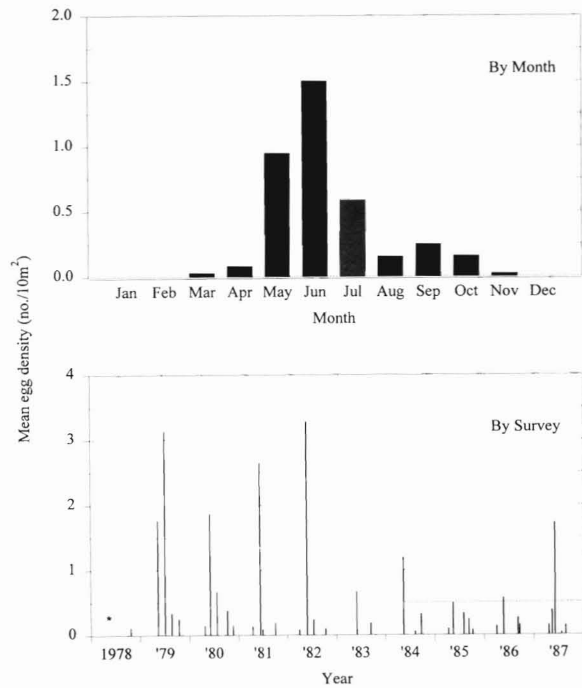


Figure 51
Lopholatilus chamaeleonticeps; mean-egg-density graphs by month (top) and by survey (bottom) for the total MARMAP area. (*Samples from the first four surveys in 1978 were not analyzed for *L. chamaeleonticeps* eggs.)

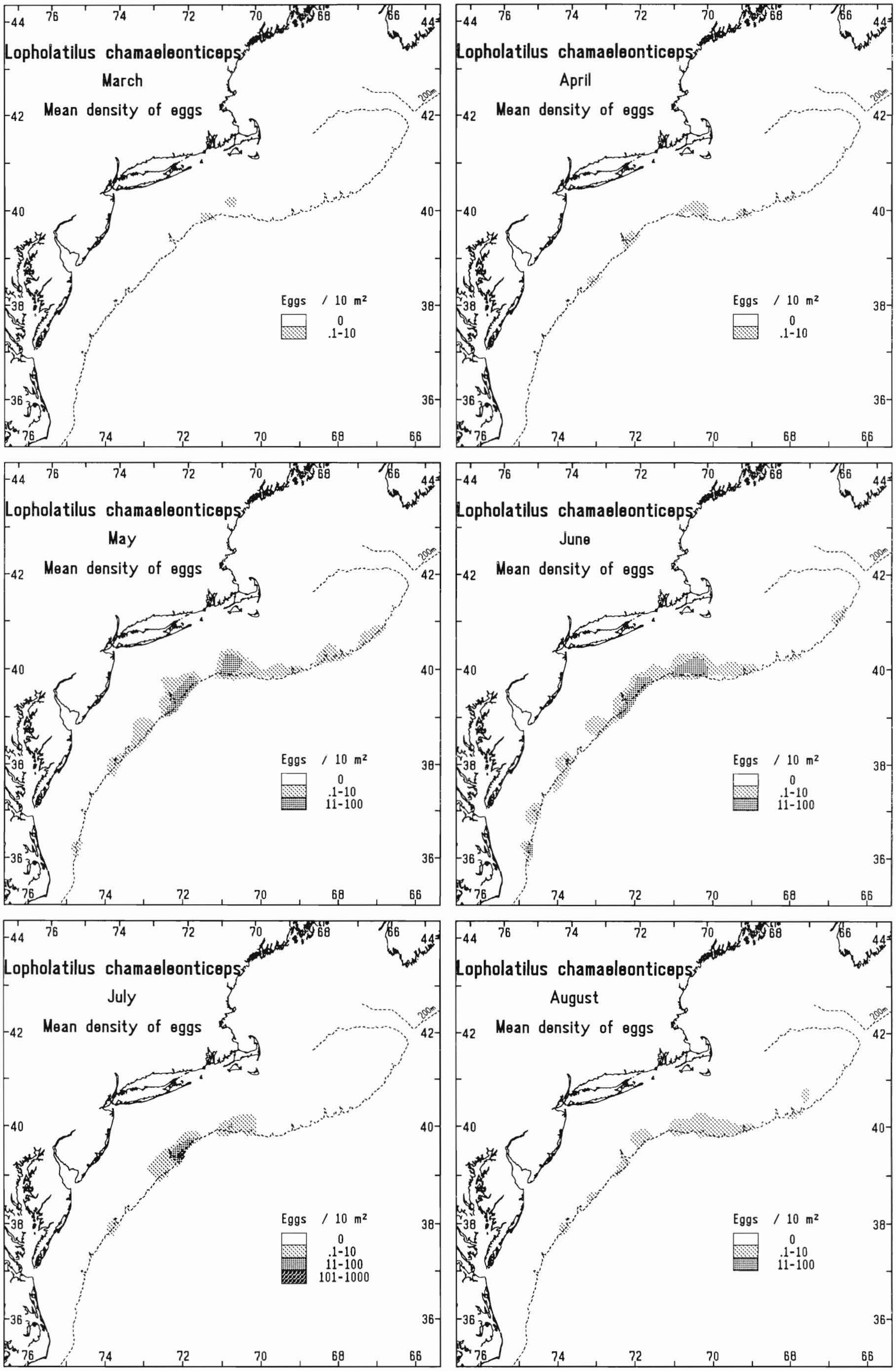


Figure 52

Lopholatilus chamaeleonticeps; composite monthly areal plots of mean egg densities (no./10 m²).

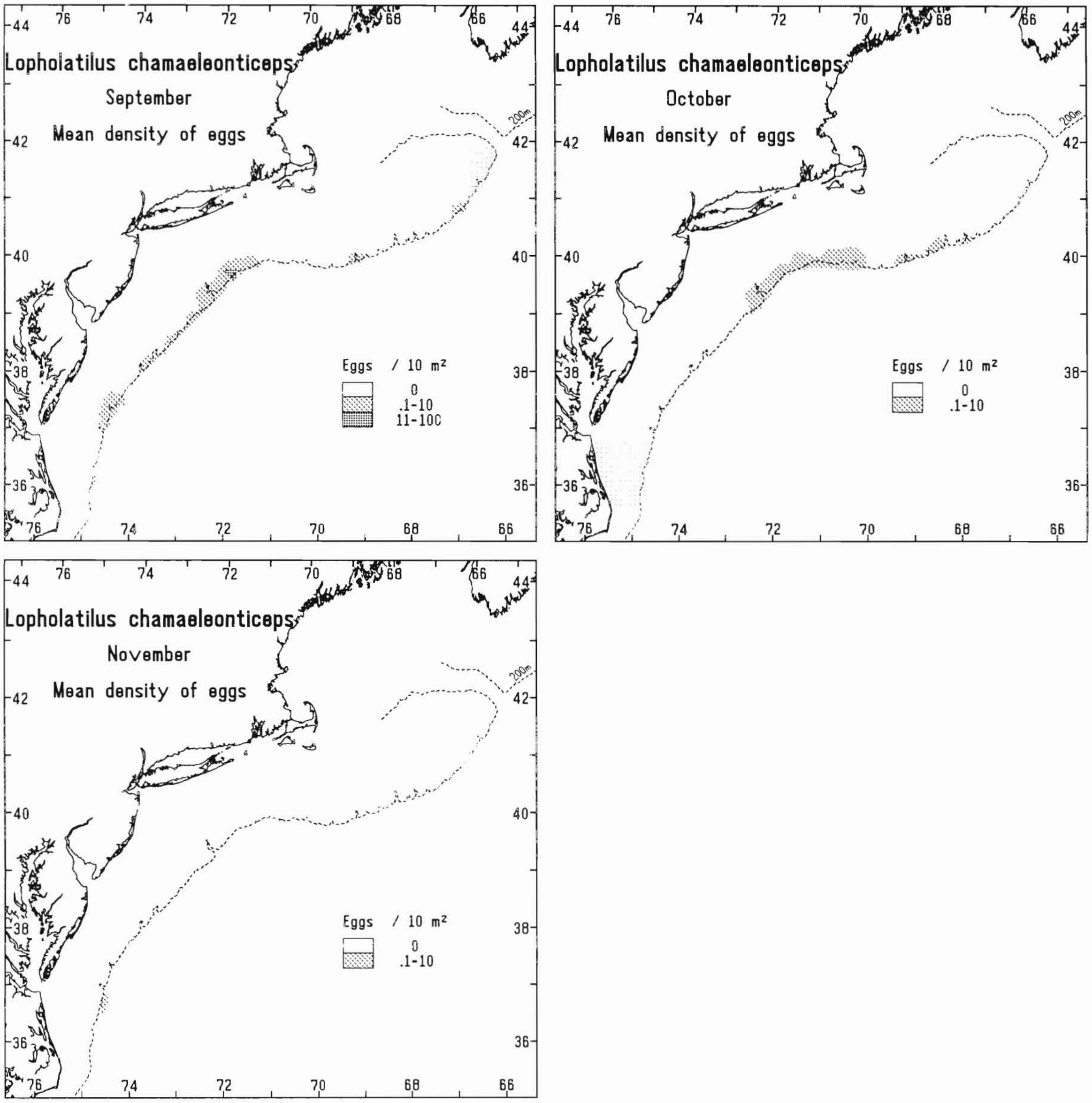


Figure 52 (continued)

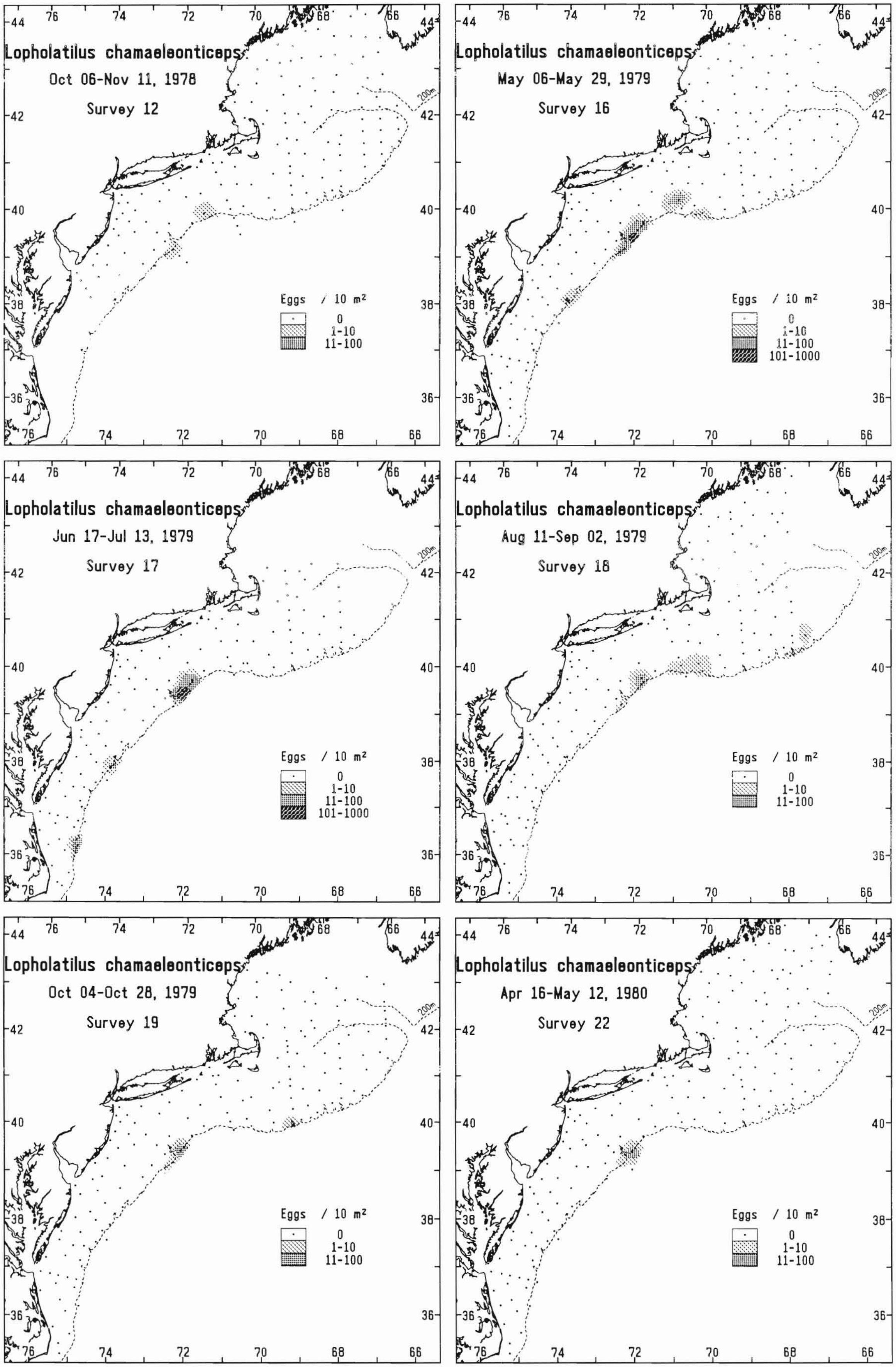
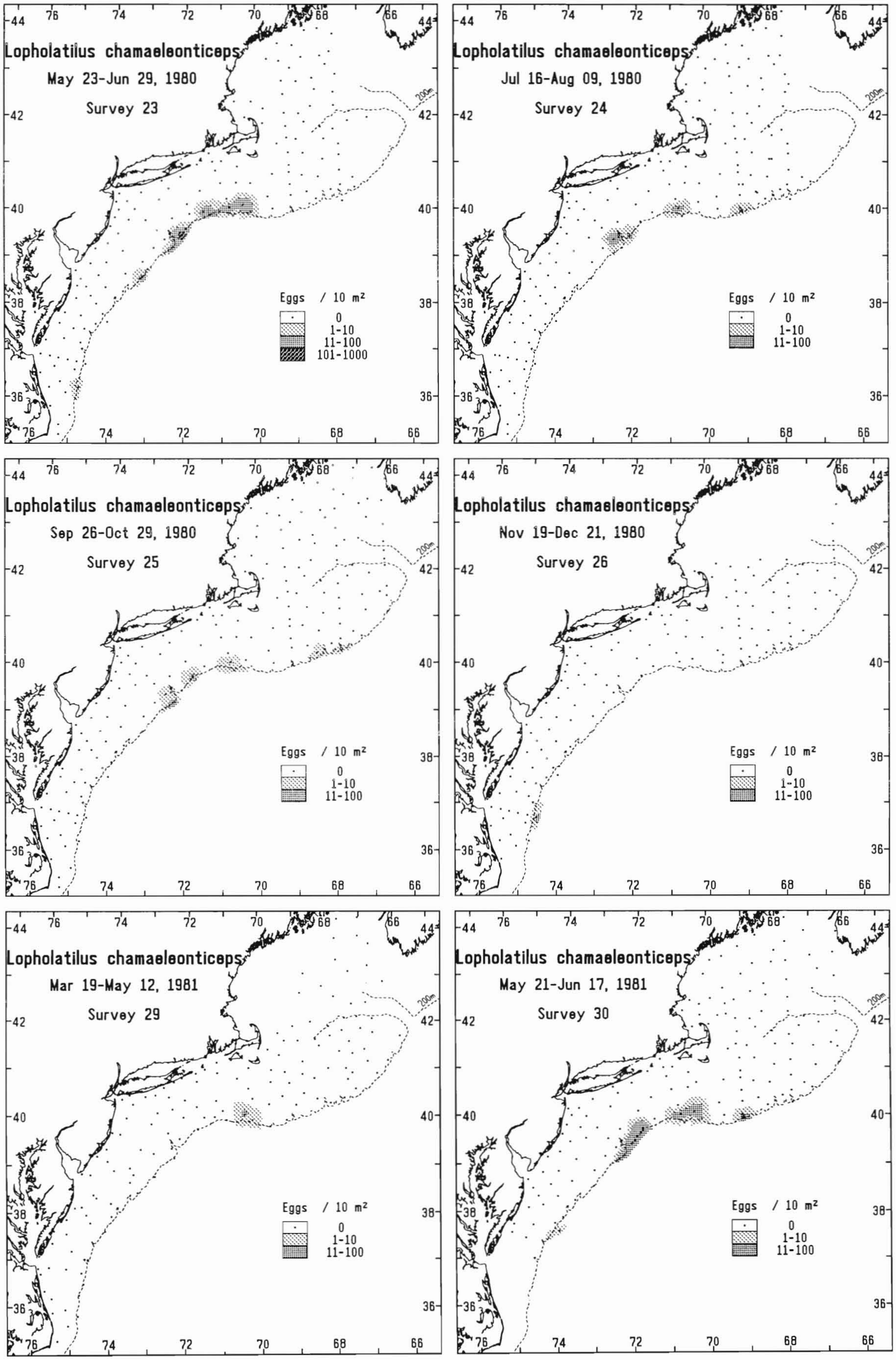


Figure 53

Lopholatilus chamaeleonticeps; survey areal plots of egg densities (no./10 m²).



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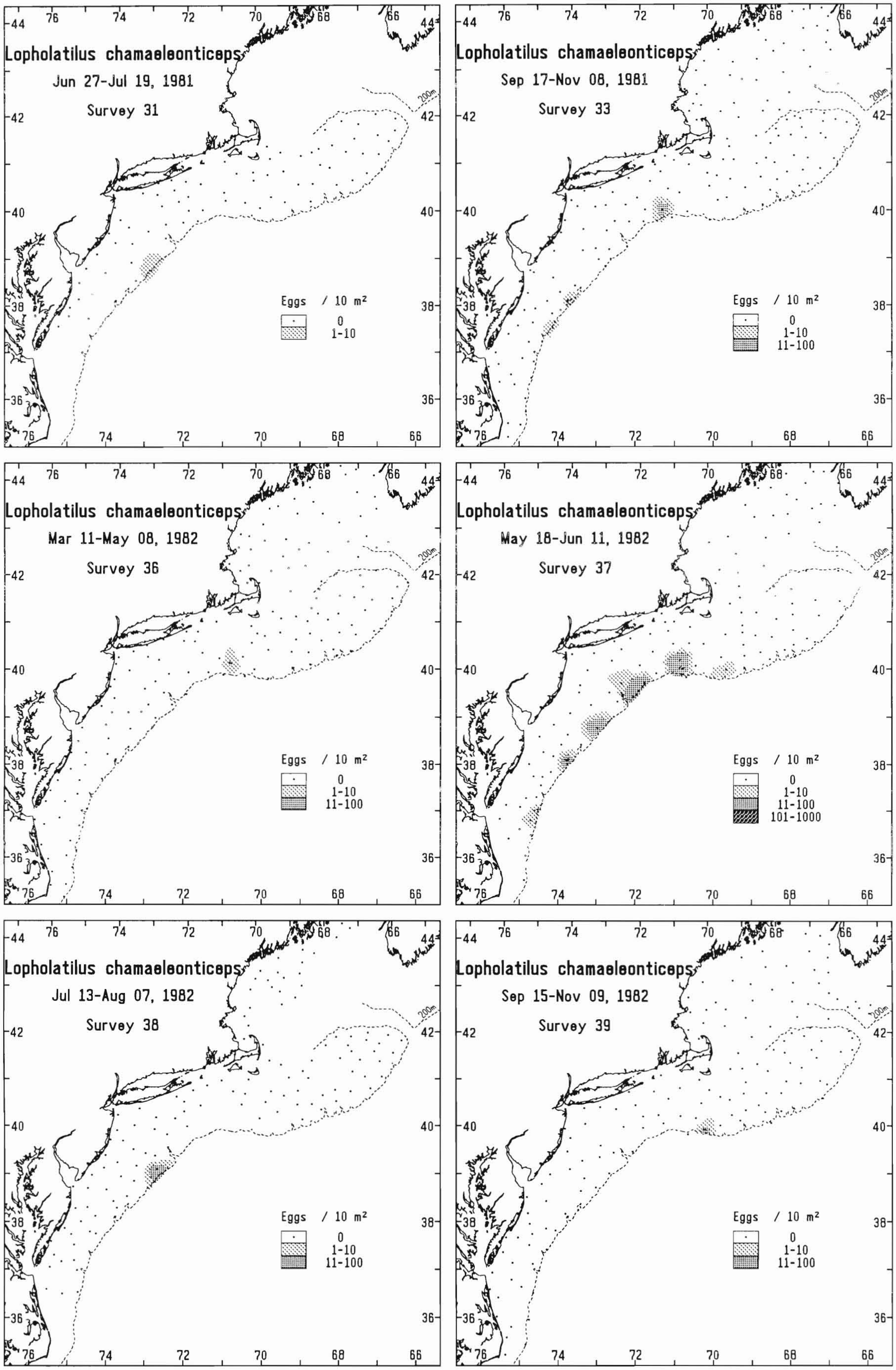

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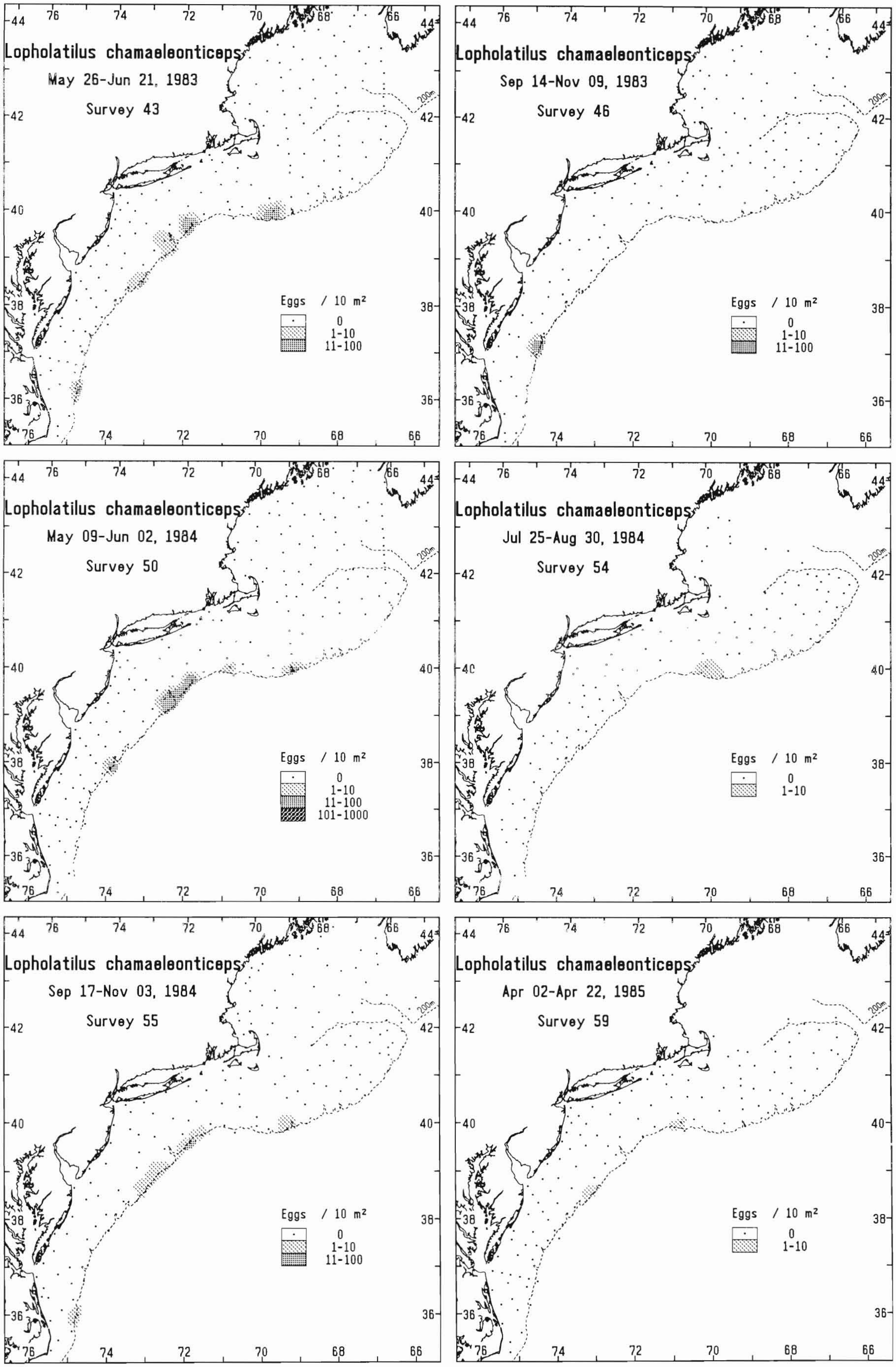


Figure 53 (continued)

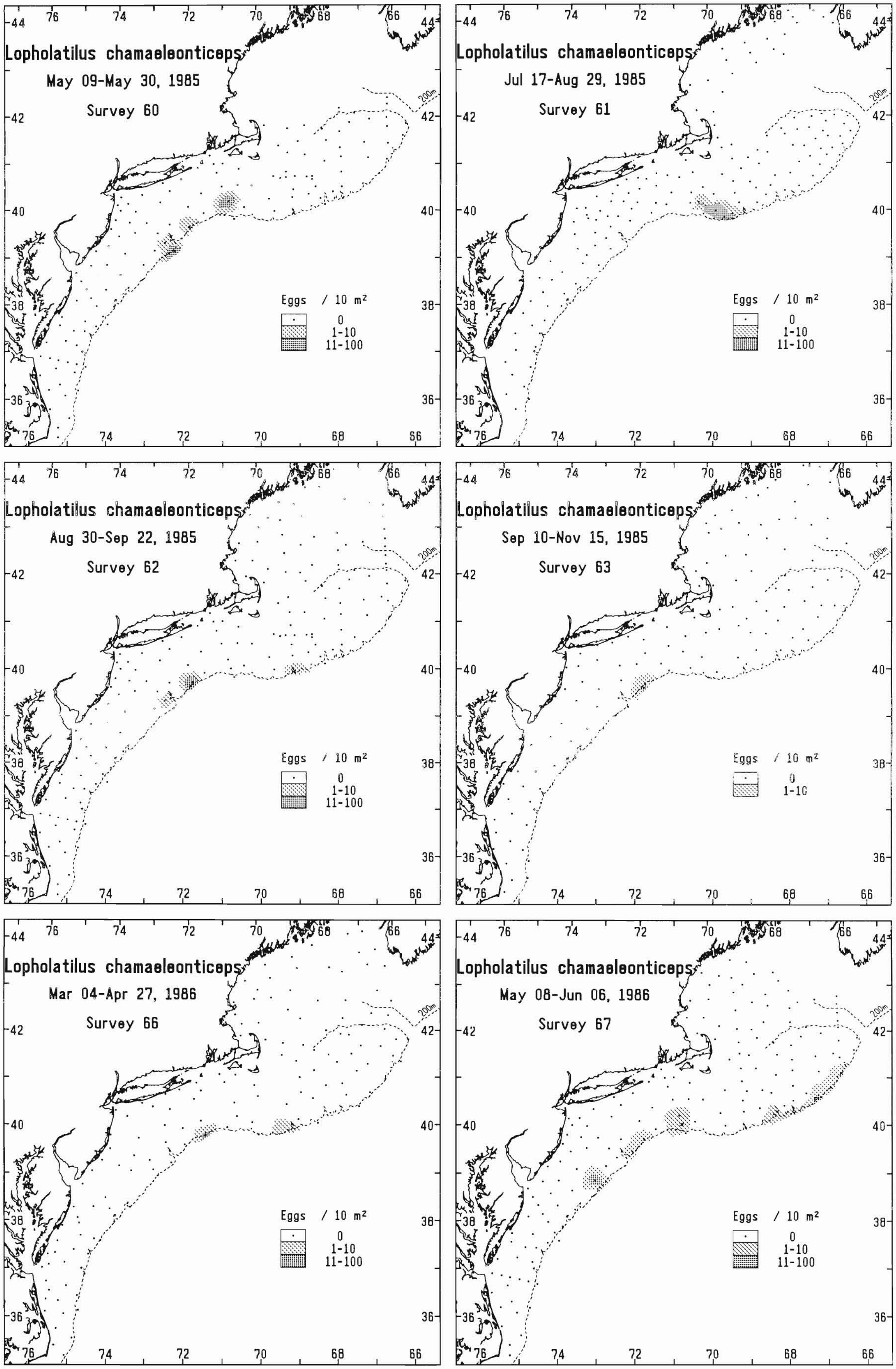


Figure 53 (continued)

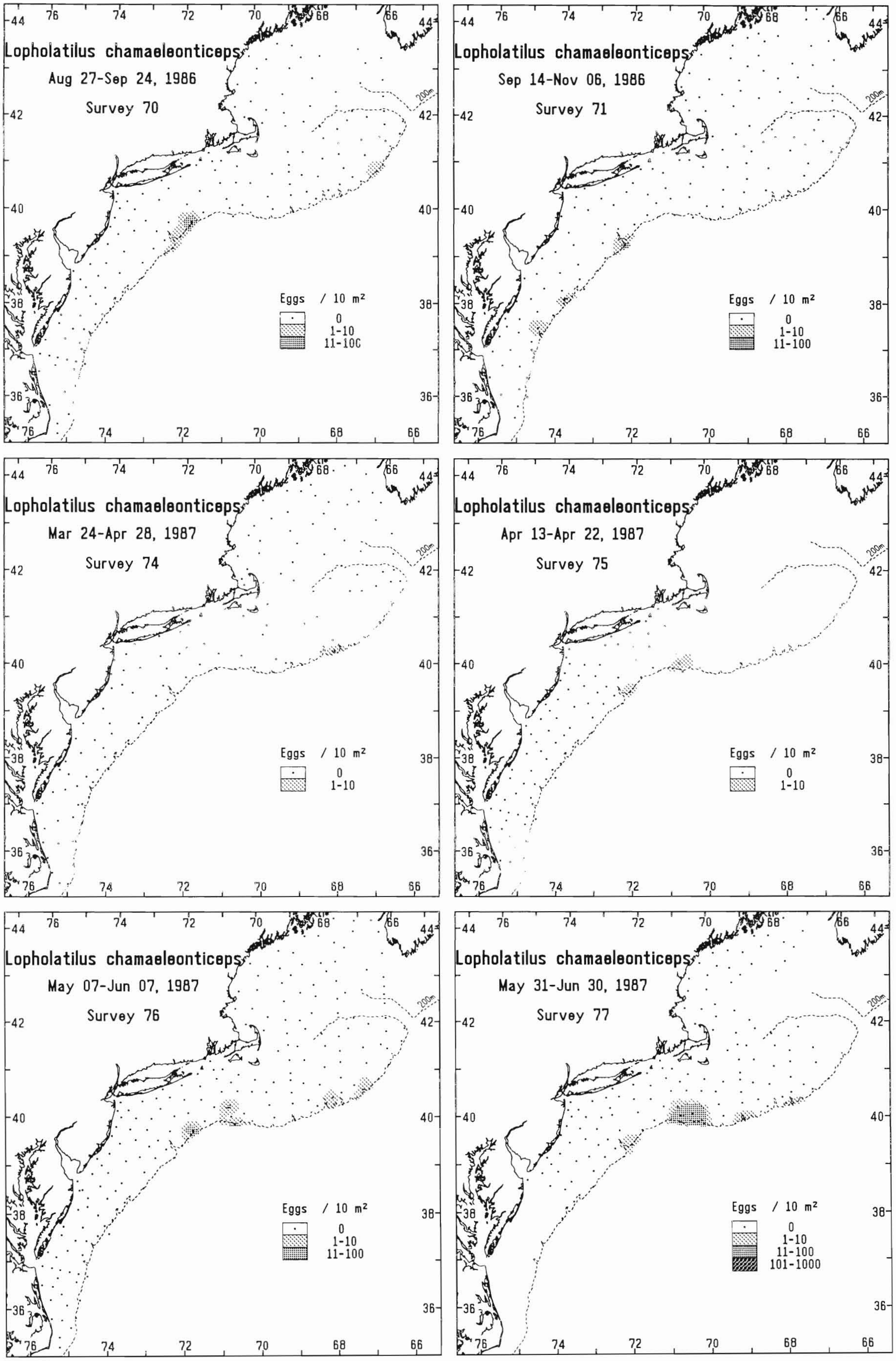


Figure 53 (continued)

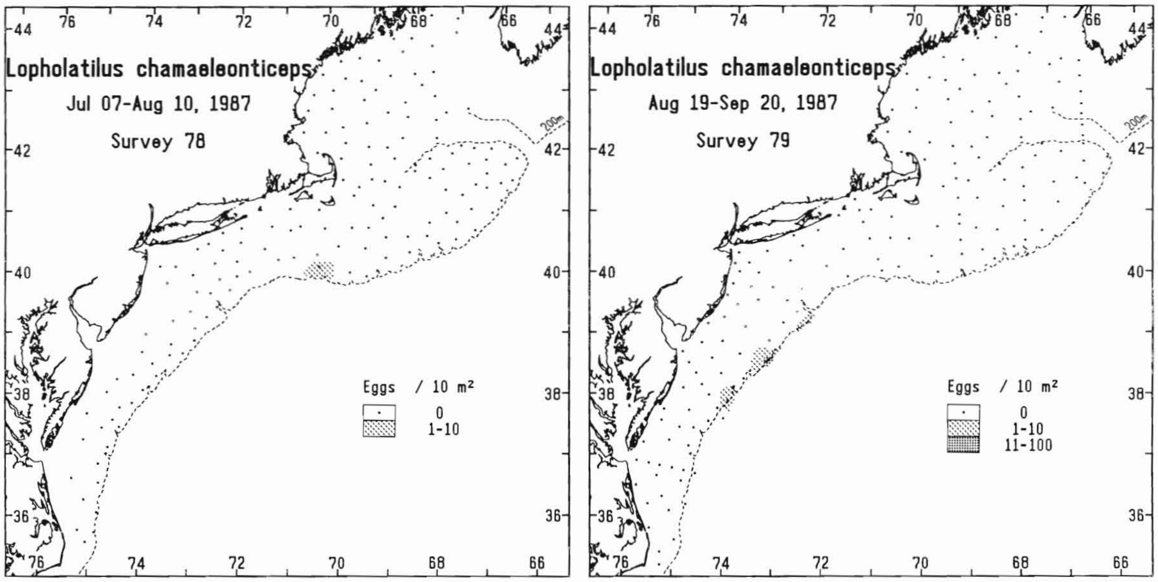


Figure 53 (continued)

Pomatomus saltatrix, bluefish (Figs. 54–56)

Pomatomus saltatrix eggs were collected from May to August, and were most abundant in July (Fig. 54). They were distributed in the Middle Atlantic and southern New England subareas (Fig. 55).

P. saltatrix spawning was highly seasonal. In some years it began as early as May near Cape Hatteras, and was well established by June. During June, spawning expanded rapidly northward throughout the Middle Atlantic subarea with the broadest areas of egg distribution occurring in the southern half of that subarea. Although eggs occurred across the breadth of the shelf, greatest concentrations occurred in mid-shelf waters. Peak spawning occurred in July when the egg distribution extended into southern New England waters, with the center of abundance off Delaware Bay and New Jersey. Spawning continued into August but at a diminished rate (Fig. 55). Spawning ceased by the end of August.

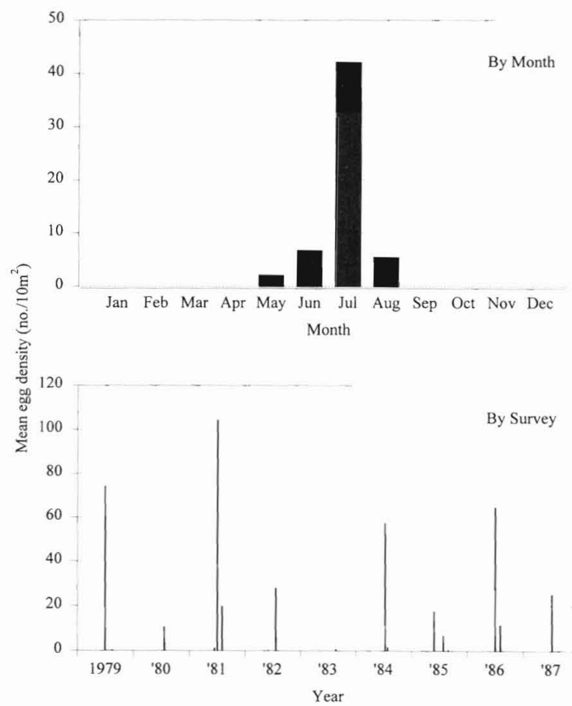


Figure 54
Pomatomus saltatrix; mean-egg-density graphs by month (top) and by survey (bottom) for the total MARMAP area.

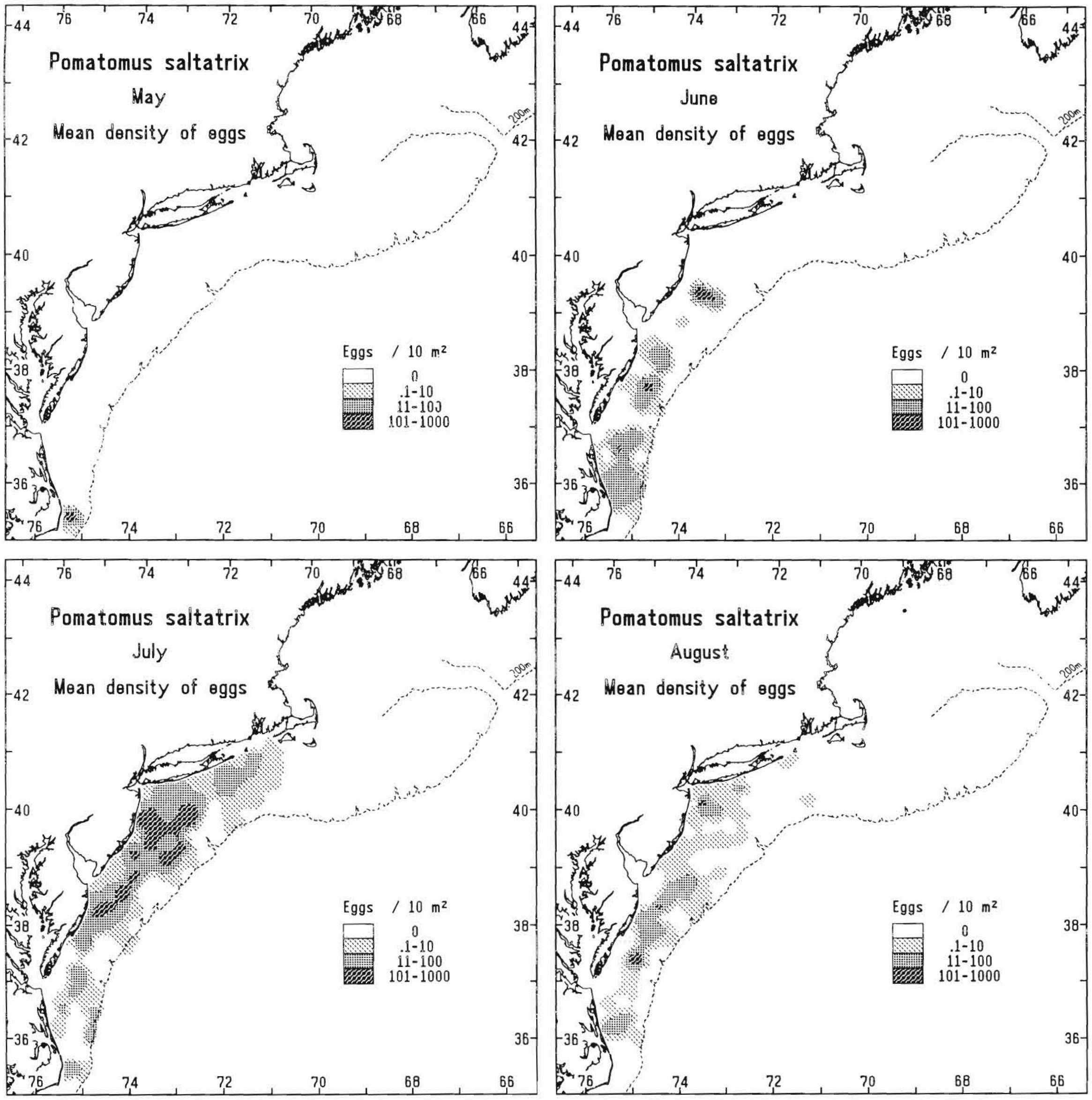


Figure 55

Pomatomus saltatrix; composite monthly areal plots of mean egg densities (no./10 m²).

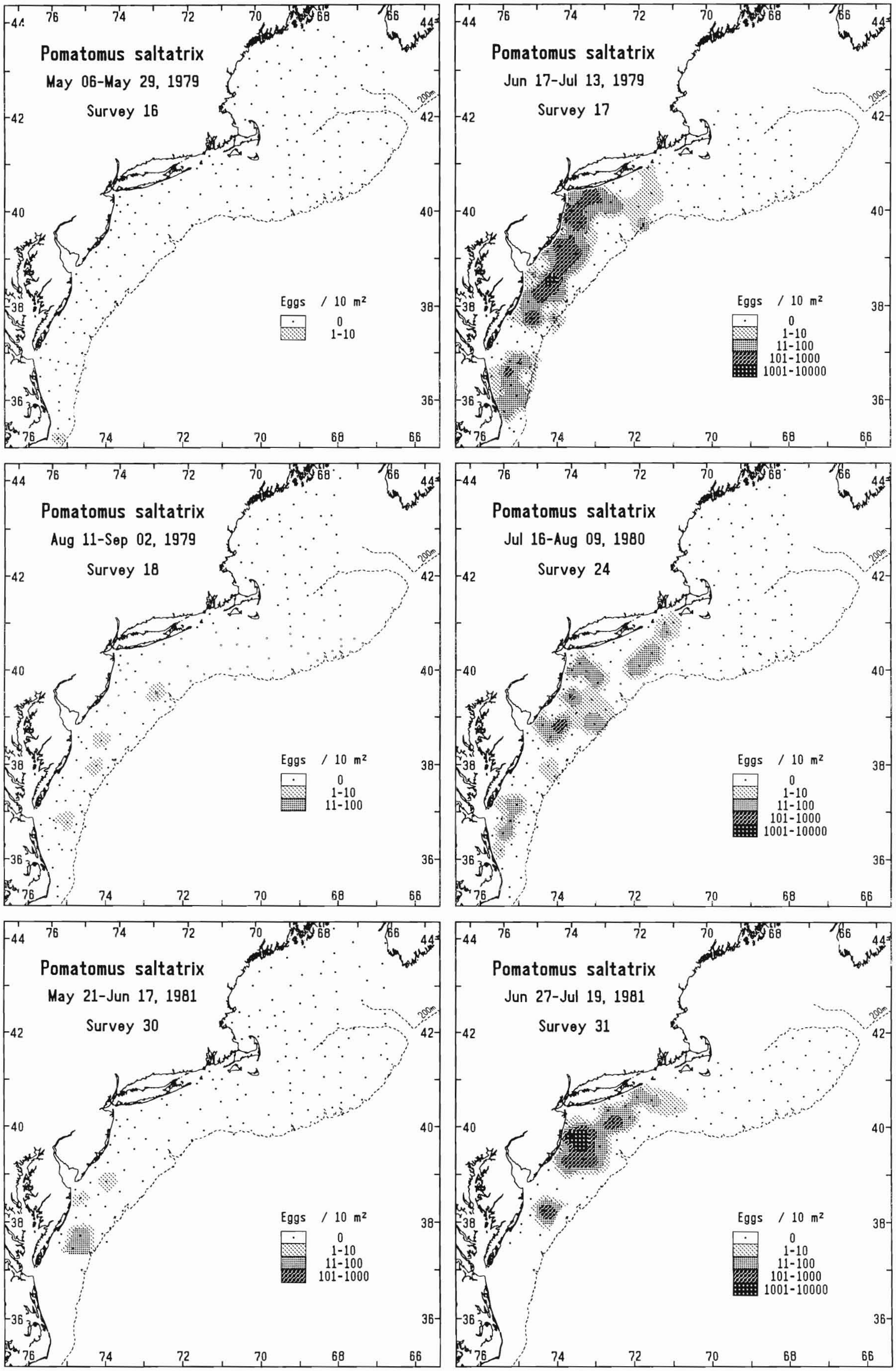

Pomatomus saltatrix
May 06-May 29, 1979
Survey 16
Eggs / 10 m²
0
1-10
Pomatomus saltatrix
Jun 17-Jul 13, 1979
Survey 17
Eggs / 10 m²
0
1-10
11-100
101-1000
1001-10000
Pomatomus saltatrix
Aug 11-Sep 02, 1979
Survey 18
Eggs / 10 m²
0
1-10
11-100
Pomatomus saltatrix
Jul 16-Aug 09, 1980
Survey 24
Eggs / 10 m²
0
1-10
11-100
101-1000
1001-10000
Pomatomus saltatrix
May 21-Jun 17, 1981
Survey 30
Eggs / 10 m²
0
1-10
11-100
101-1000
Pomatomus saltatrix
Jun 27-Jul 19, 1981
Survey 31
Eggs / 10 m²
0
1-10
11-100
101-1000
1001-10000

Figure 56

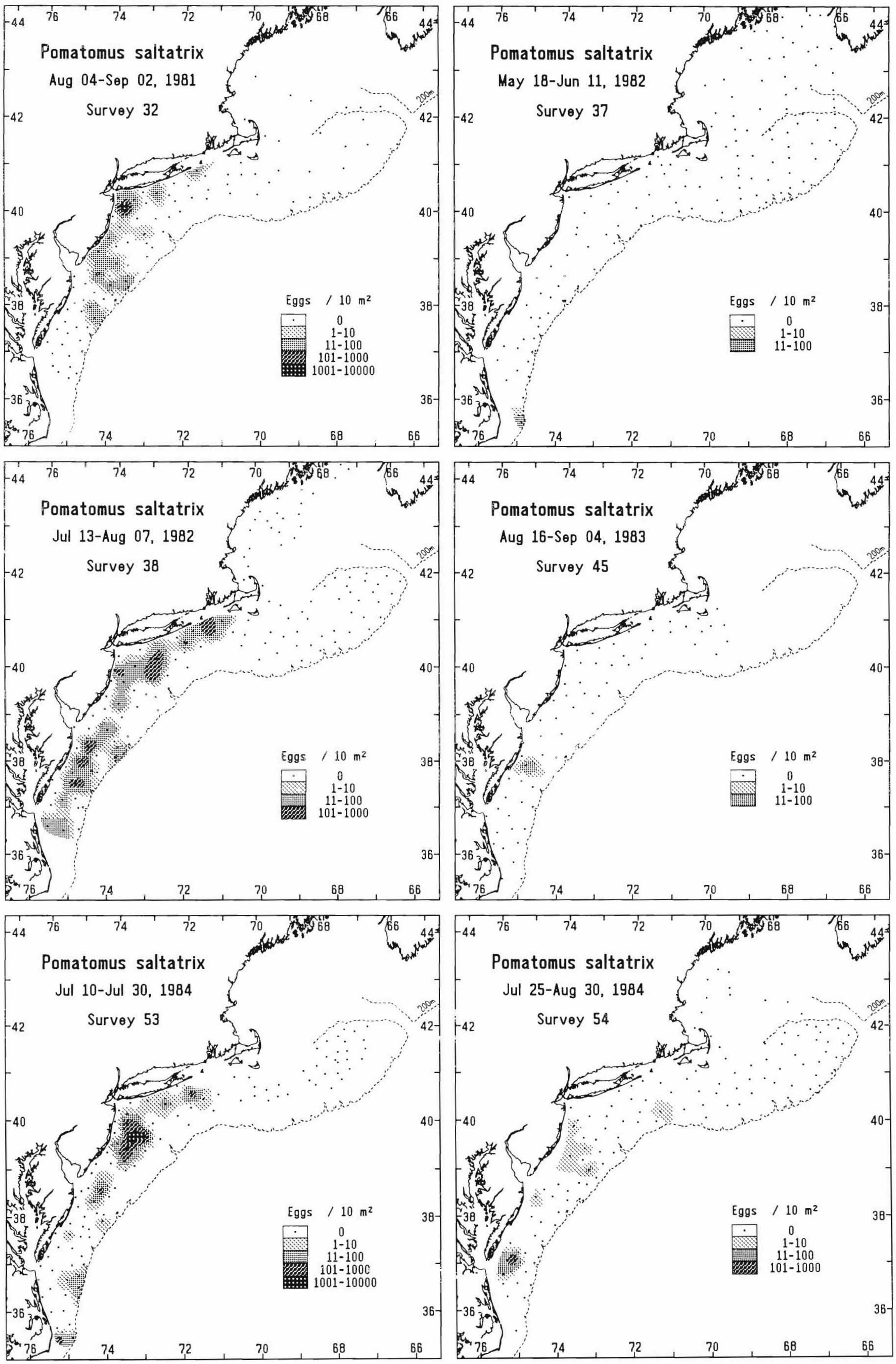


Figure 56 (continued)

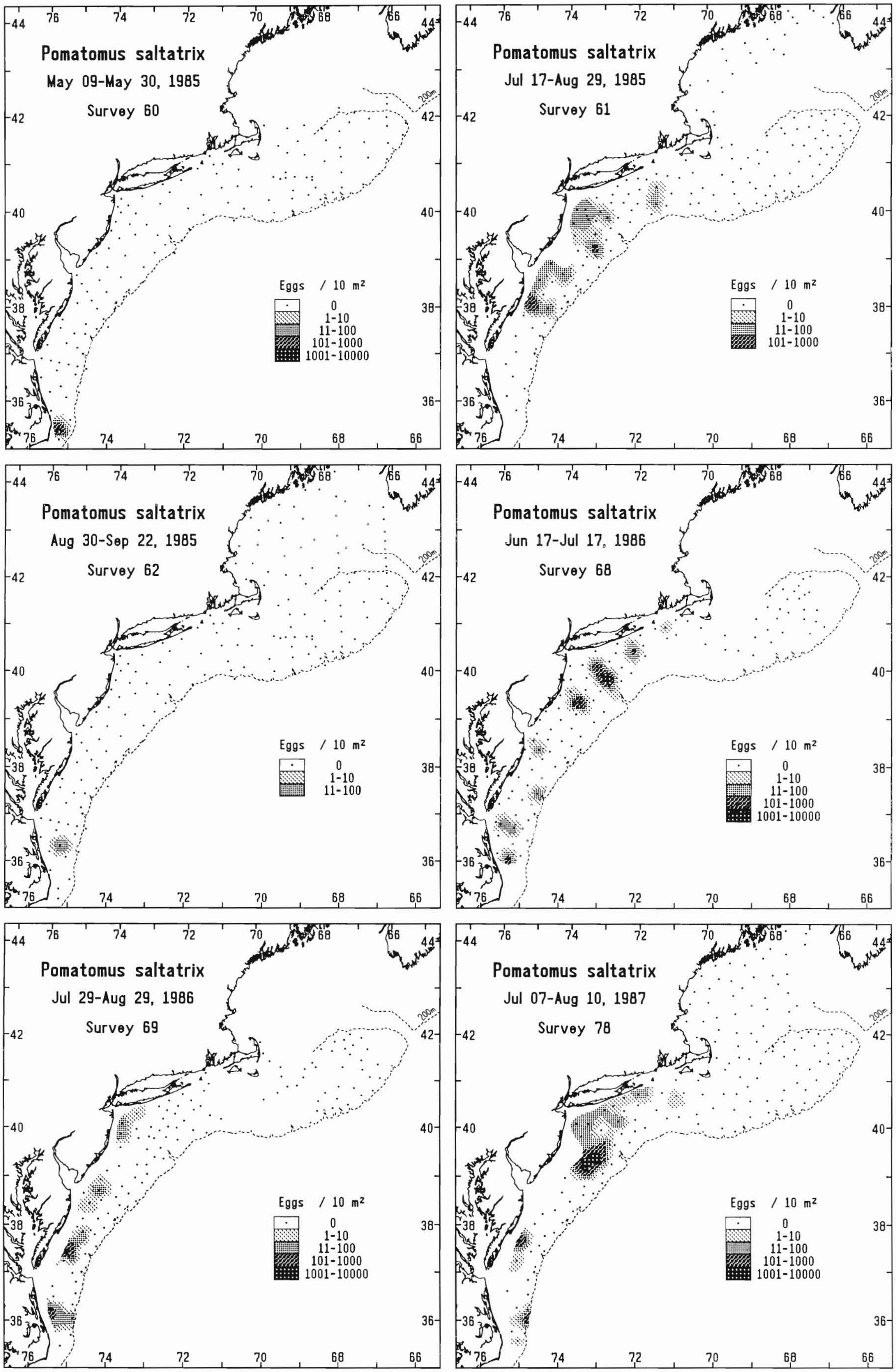


Figure 56 (continued)

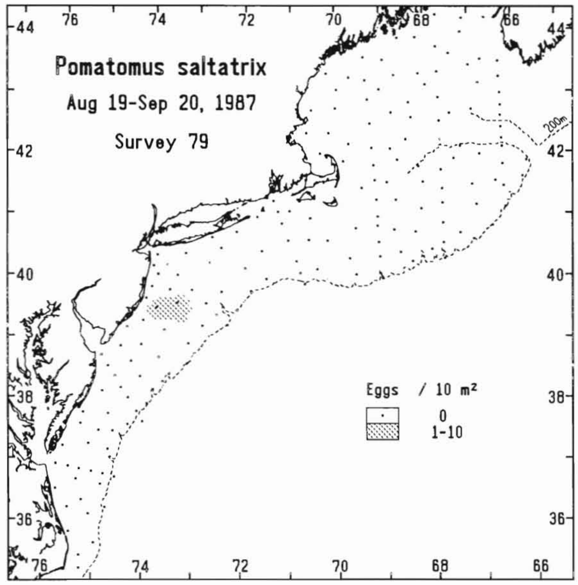


Figure 56 (continued)

Cynoscion regalis, weakfish (Figs. 57–59)

Cynoscion regalis eggs were collected from March to August (Fig. 57) and occurred between Cape Hatteras and Narragansett Bay, predominantly in the inner one-half to one-third of shelf waters.

Spawning began as early as March or April in southern areas. It expanded rapidly northward in nearshore waters, extending to New Jersey in May, to south of Long Island in June, and in some years to Narragansett Bay in July. Thereafter spawning declined; it was reduced to between Cape Hatteras and New Jersey in August and ceased altogether by September (Fig. 58).

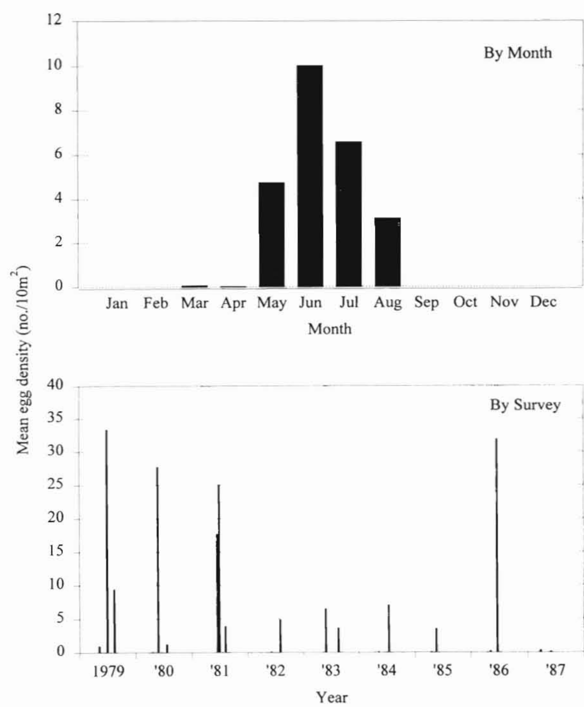


Figure 57
Cynoscion regalis; mean-egg-density graphs by month (top) and by survey (bottom) for the total MARMAP area.

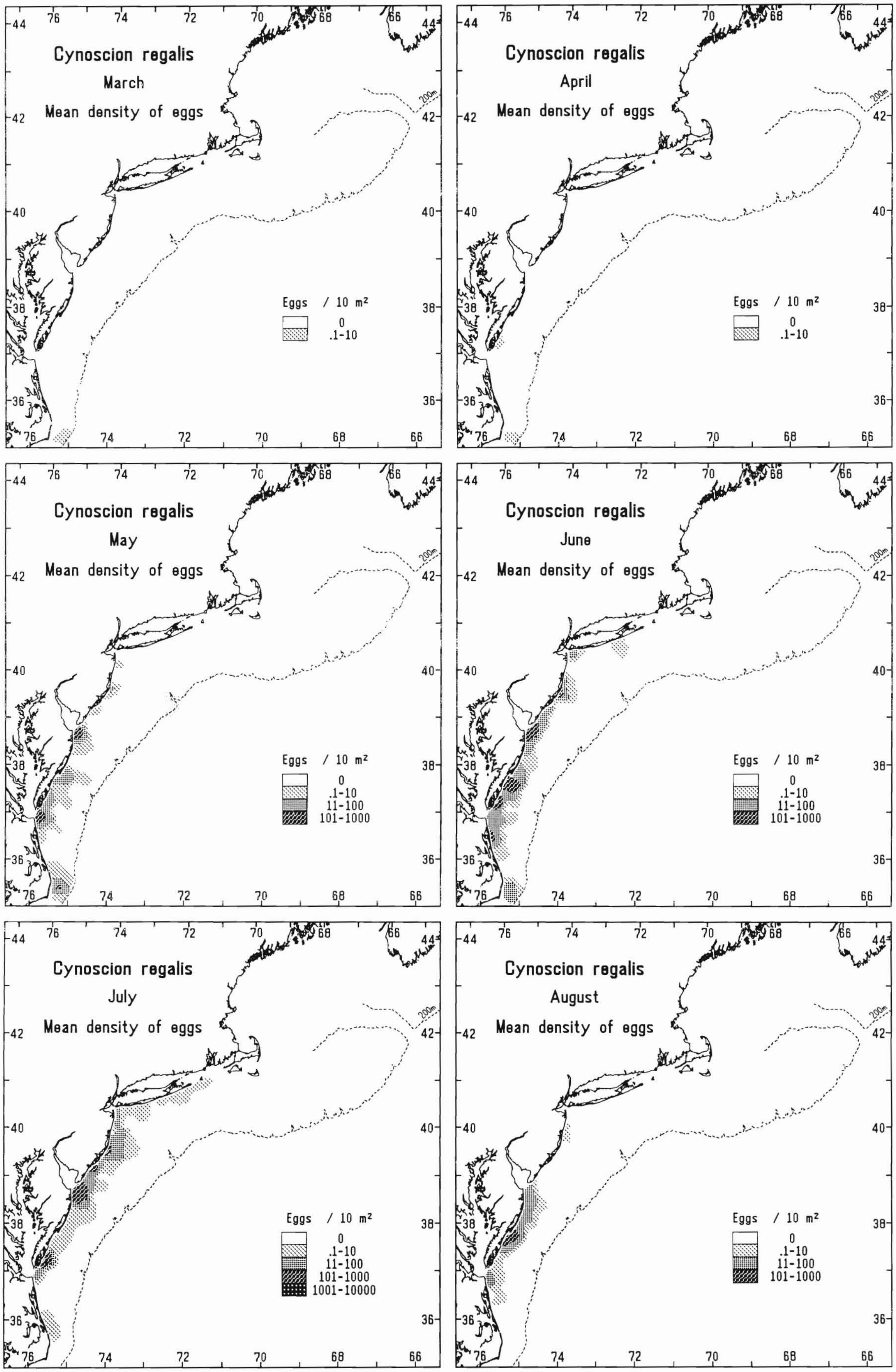


Figure 58

Cynoscion regalis; composite monthly areal plots of mean egg densities (no./10 m²).

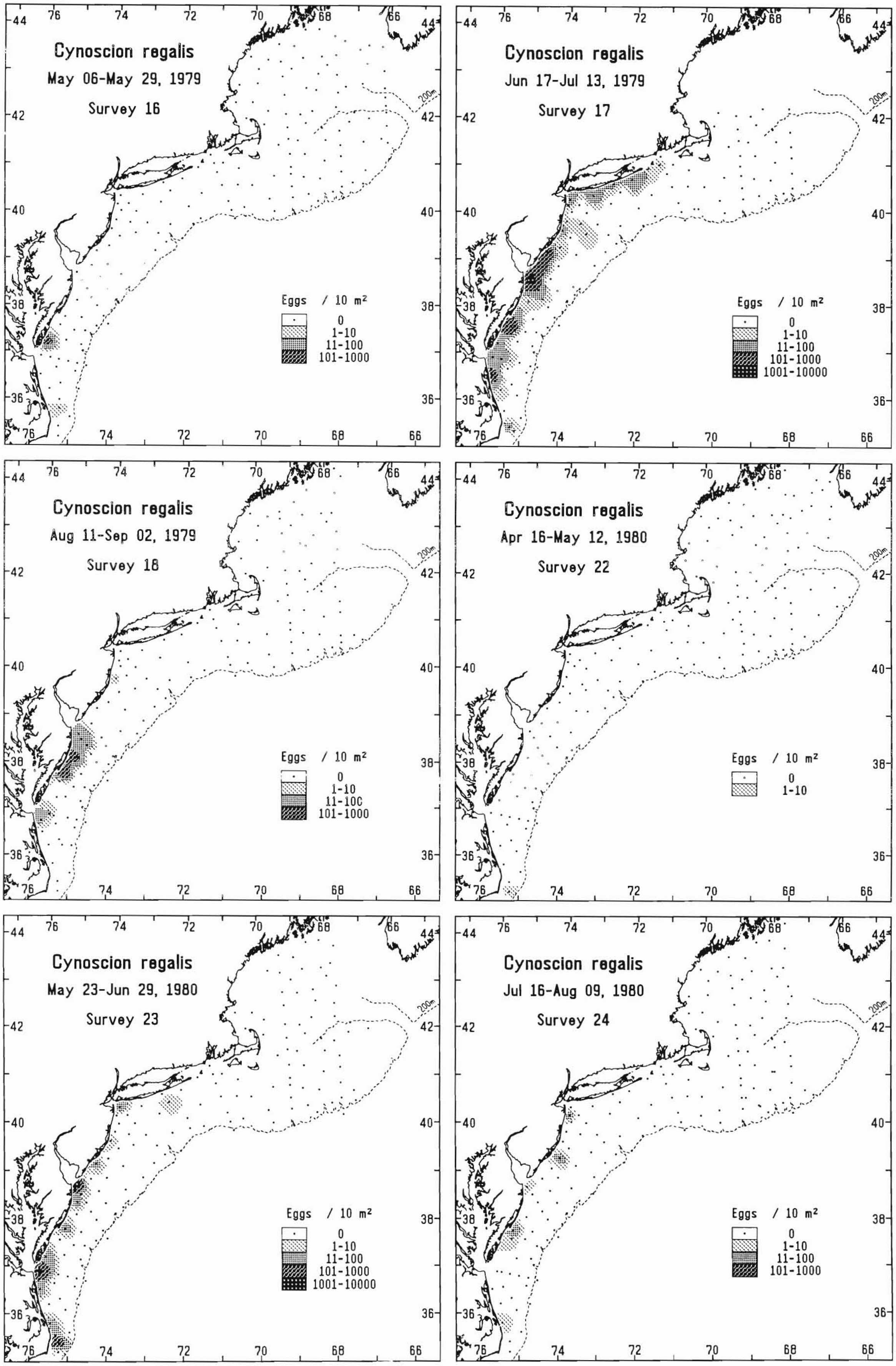


Figure 59

Cynoscion regalis; survey areal plots of egg densities (no./10 m²).

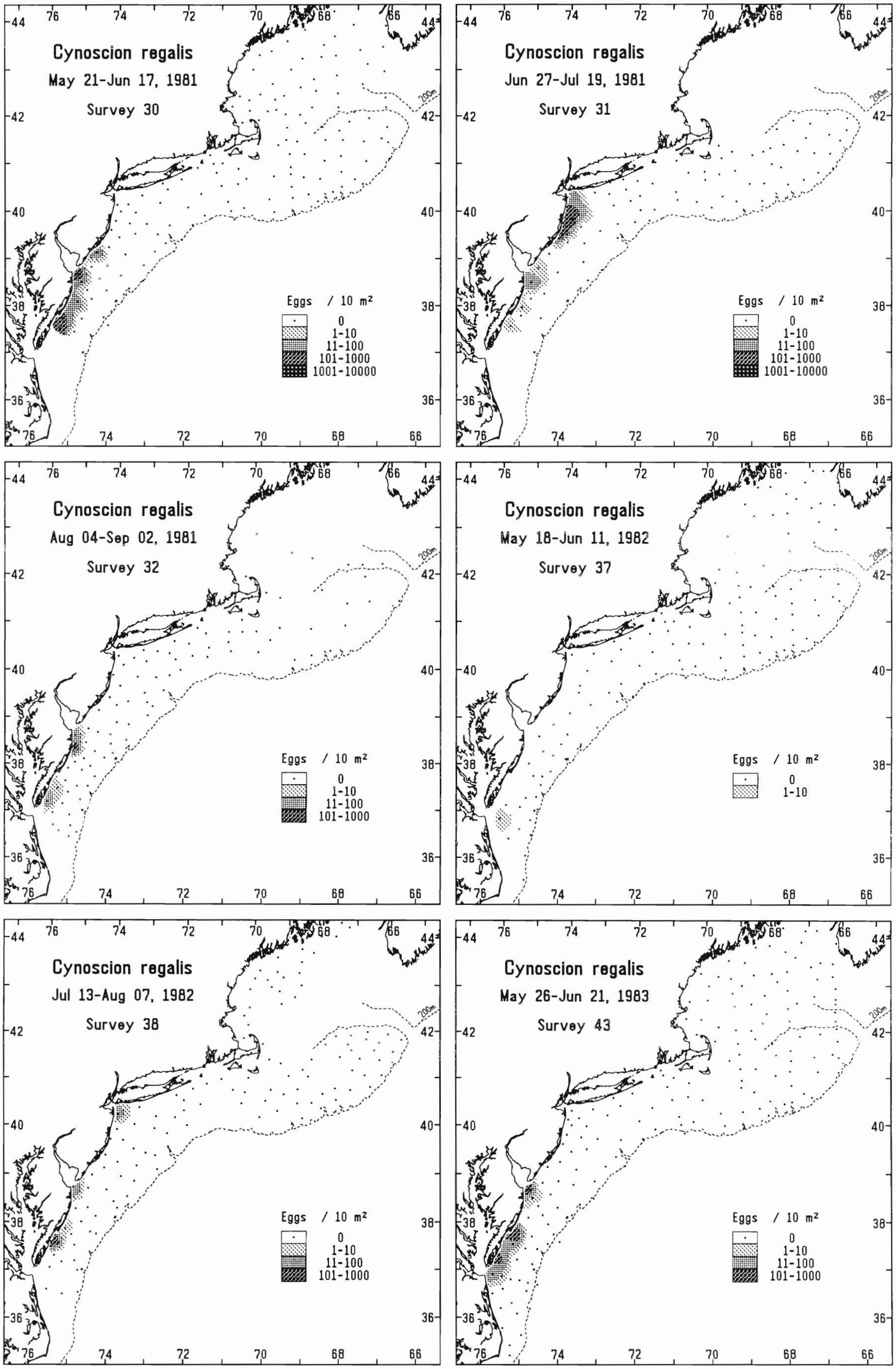


Figure 59 (continued)

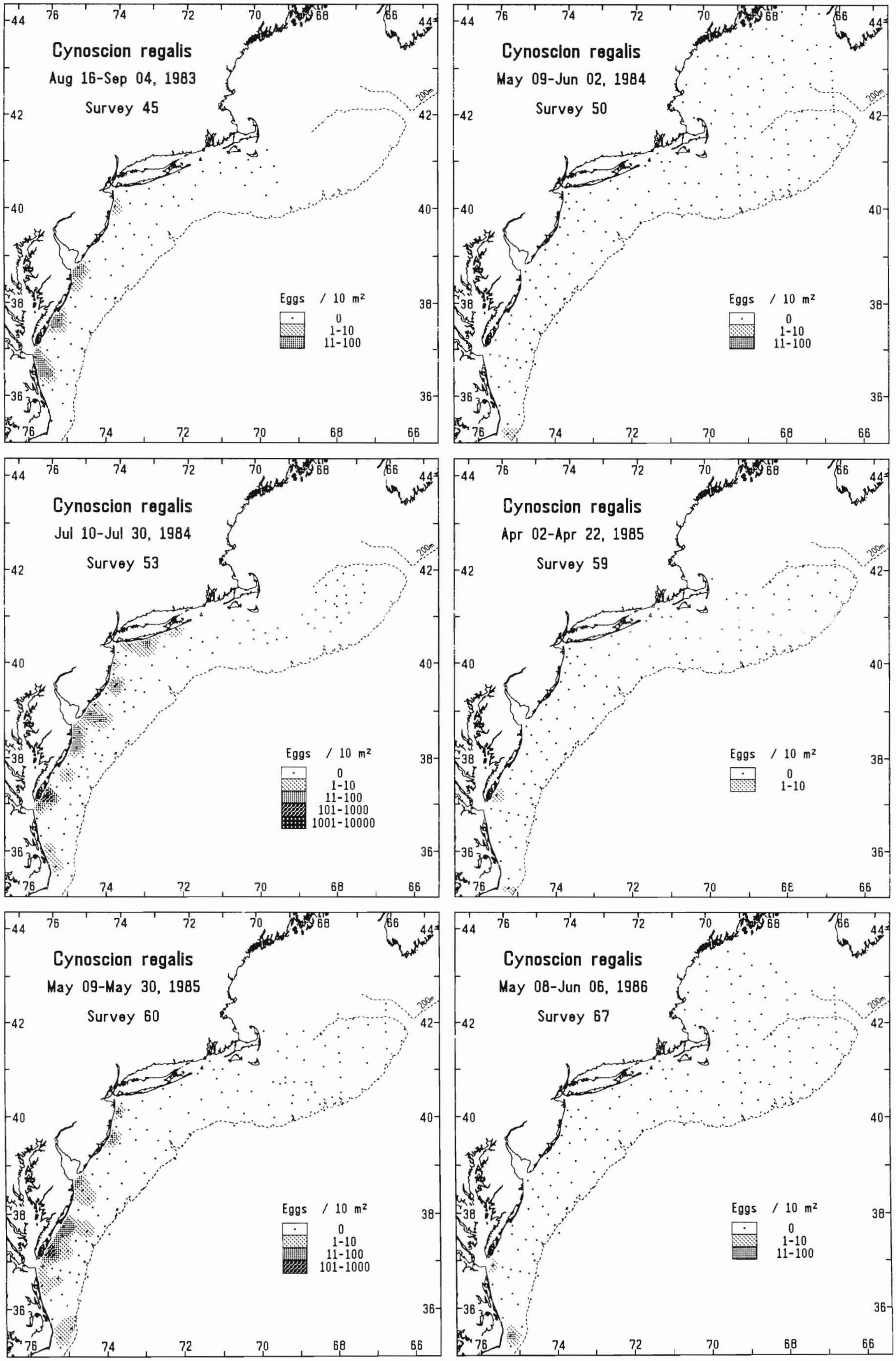


Figure 59 (continued)

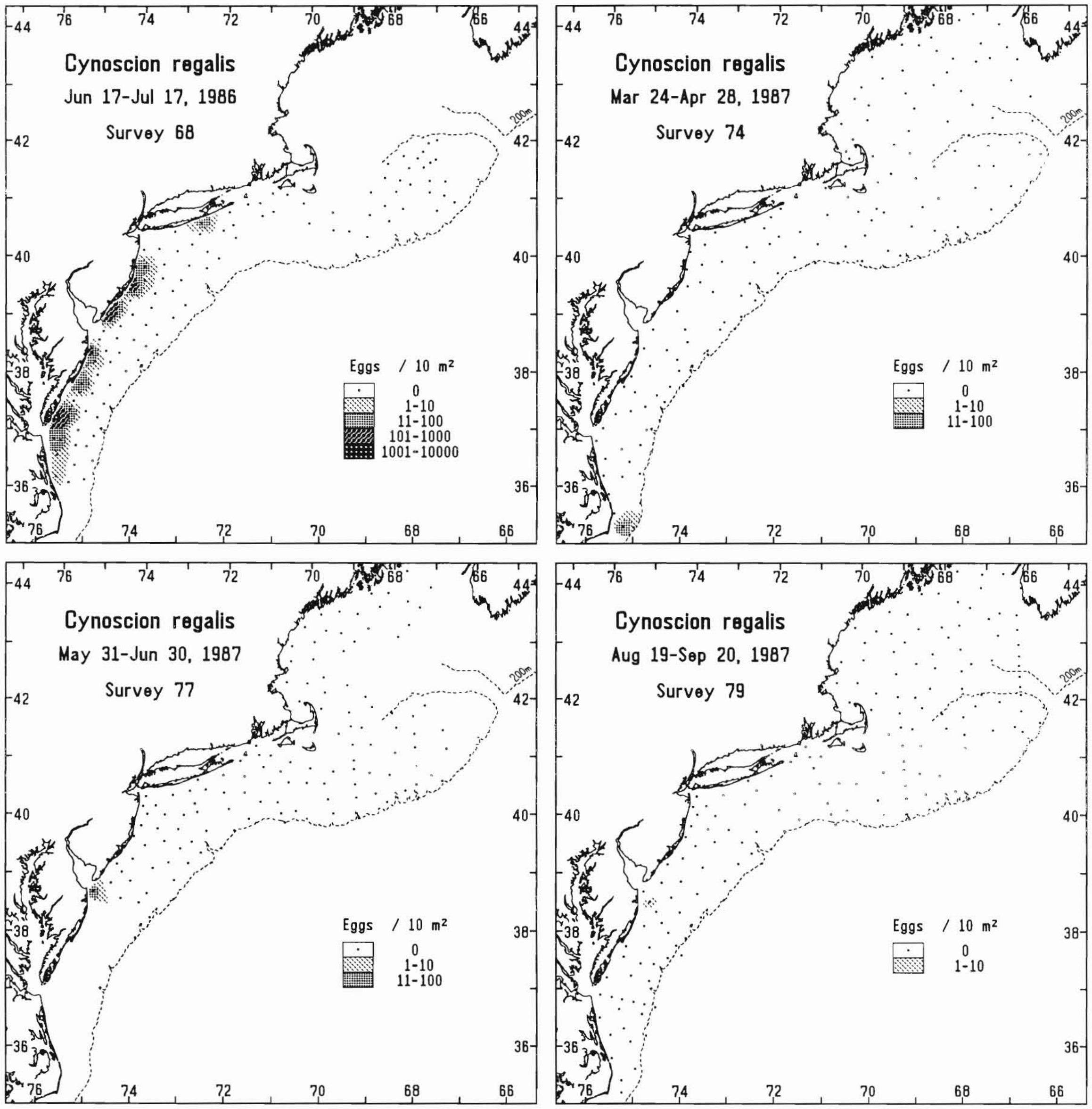


Figure 59 (continued)

Micropogonias undulatus, Atlantic croaker (Figs. 60–62)

Micropogonias undulatus eggs occurred almost exclusively in the Middle Atlantic subarea from July to November (Fig. 60) and they tended to be concentrated in the inner half of the shelf (Fig. 61).

Spawning began in July or August in inshore waters of the Middle Atlantic subarea, initially occurring south of Chesapeake Bay and expanding rapidly northward, as far north as Delaware Bay (Fig. 61) in some years. Peak spawning occurred in September, largely within this same area. Spawning declined during October and November and ceased by December.

The pronounced peak in mean egg density in September and the 10-fold difference between means in September and October could be biased by sampling effort (Fig. 60). The sampling effort in September was biased toward an area where eggs might be expected to occur, while in October toward the area of expected nonoccurrence (Fig. 2).

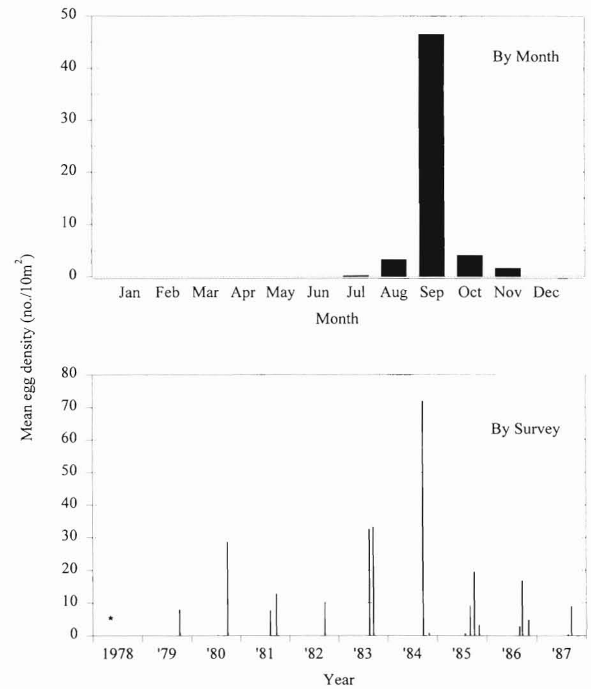


Figure 60
Micropogonias undulatus; mean-egg-density graphs by month (top) and by survey (bottom) for the total MARMAP area. (*Samples from the first four surveys in 1978 were not analyzed for *M. undulatus* eggs.)

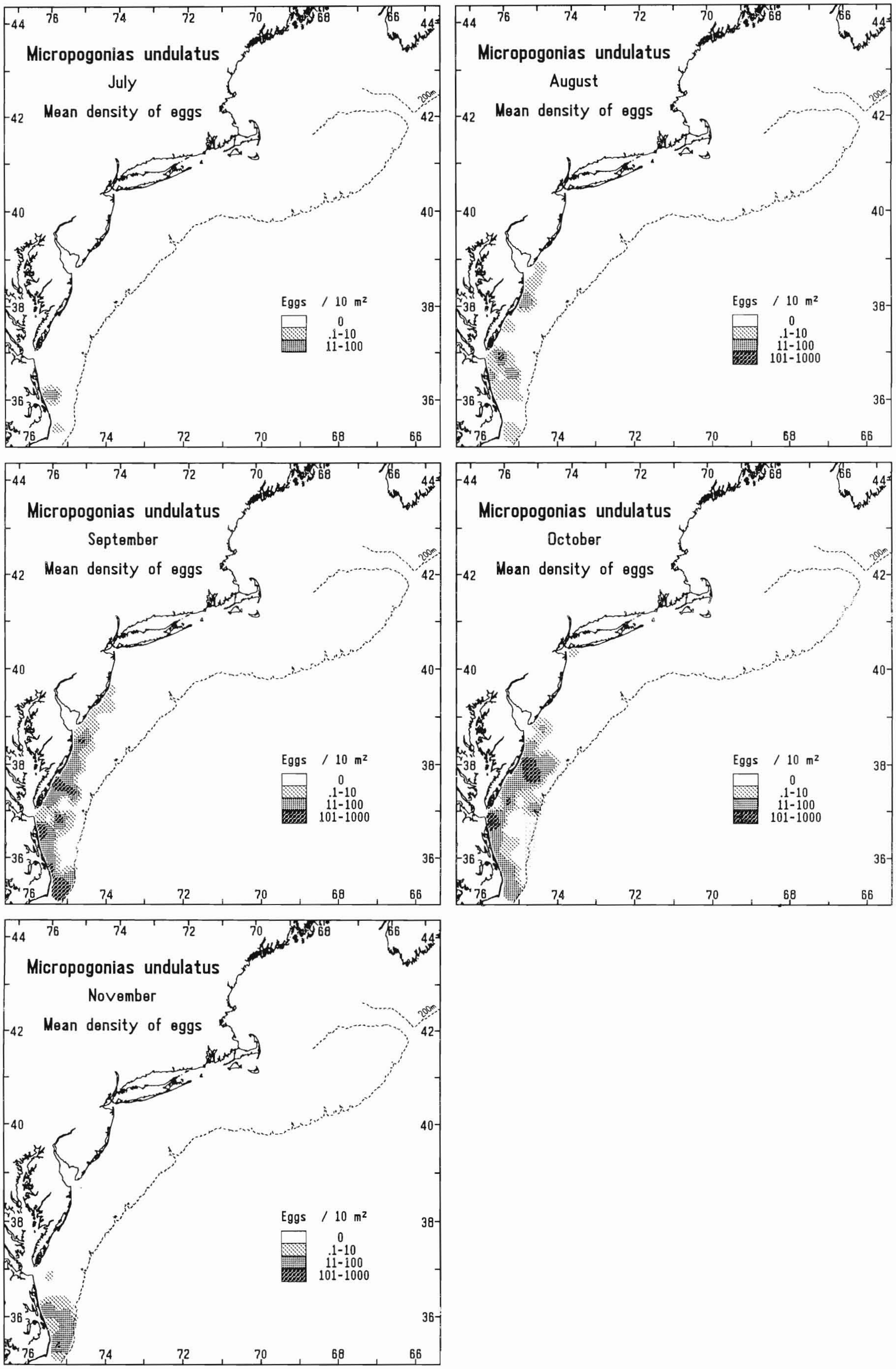


Figure 61

Micropogonias undulatus; composite monthly areal plots of mean egg densities (no./10 m²).

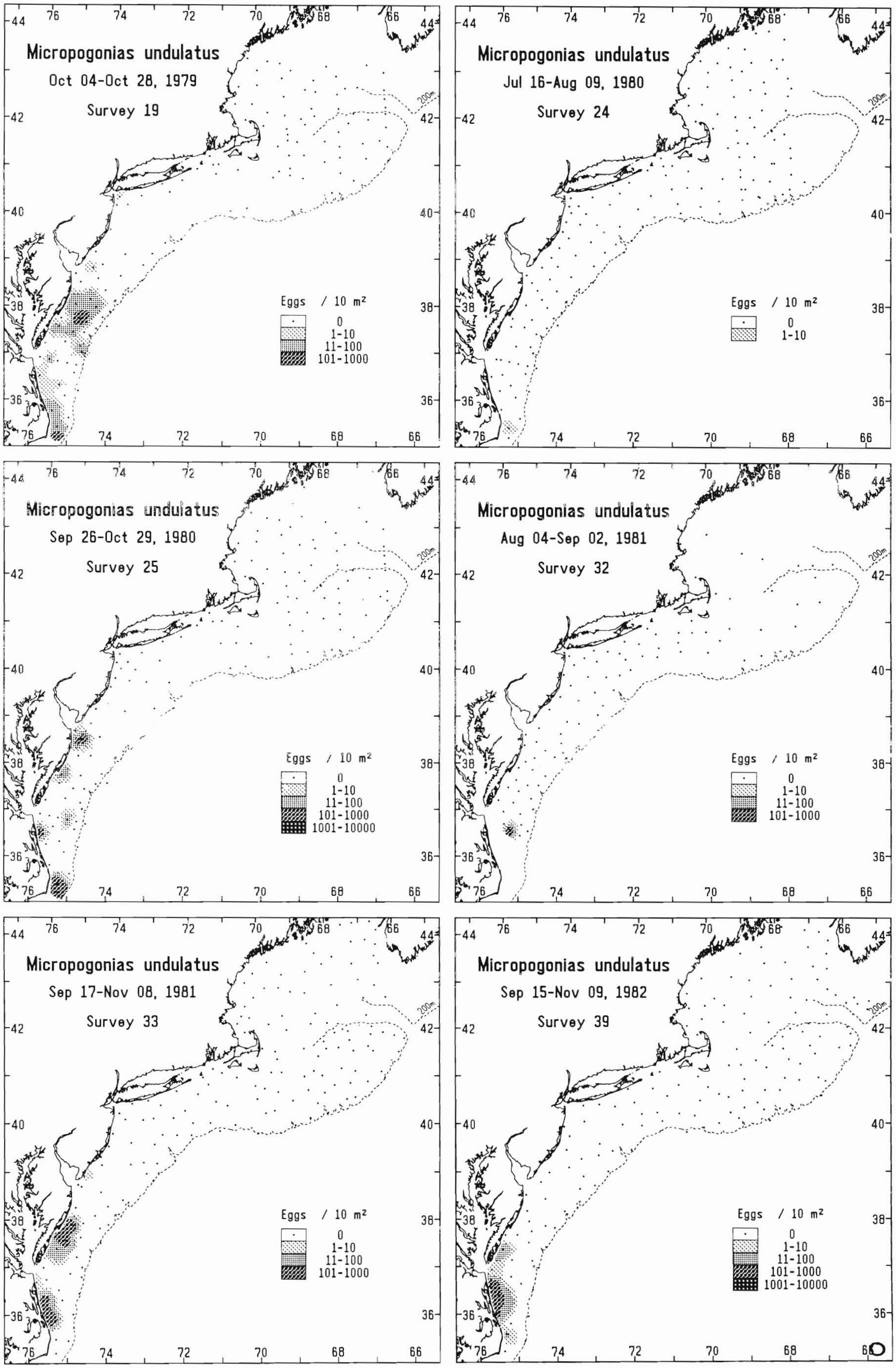


Figure 62
Micropogonias undulatus; survey areal plots of egg densities (no./10 m²).

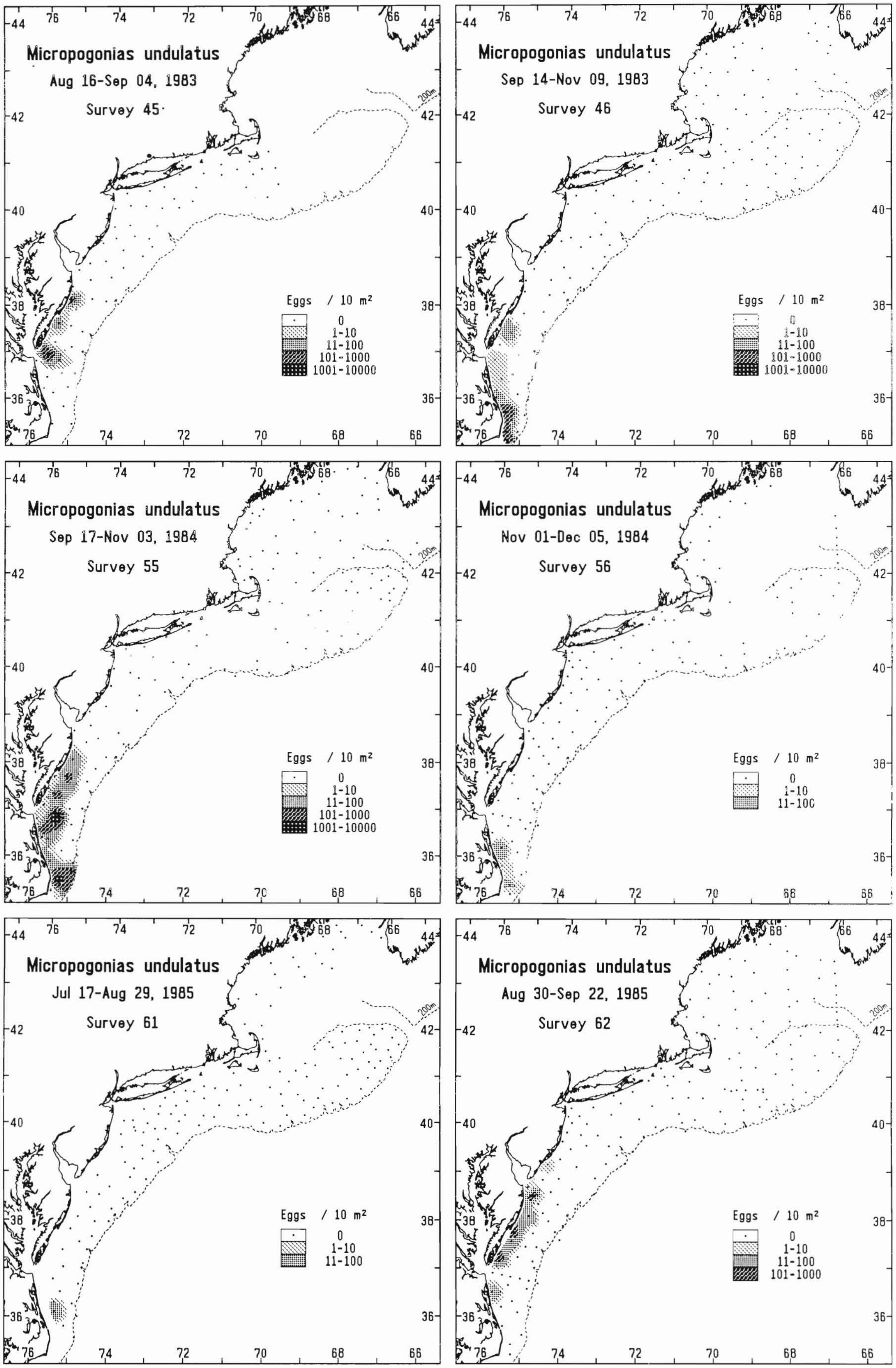


Figure 62 (continued)

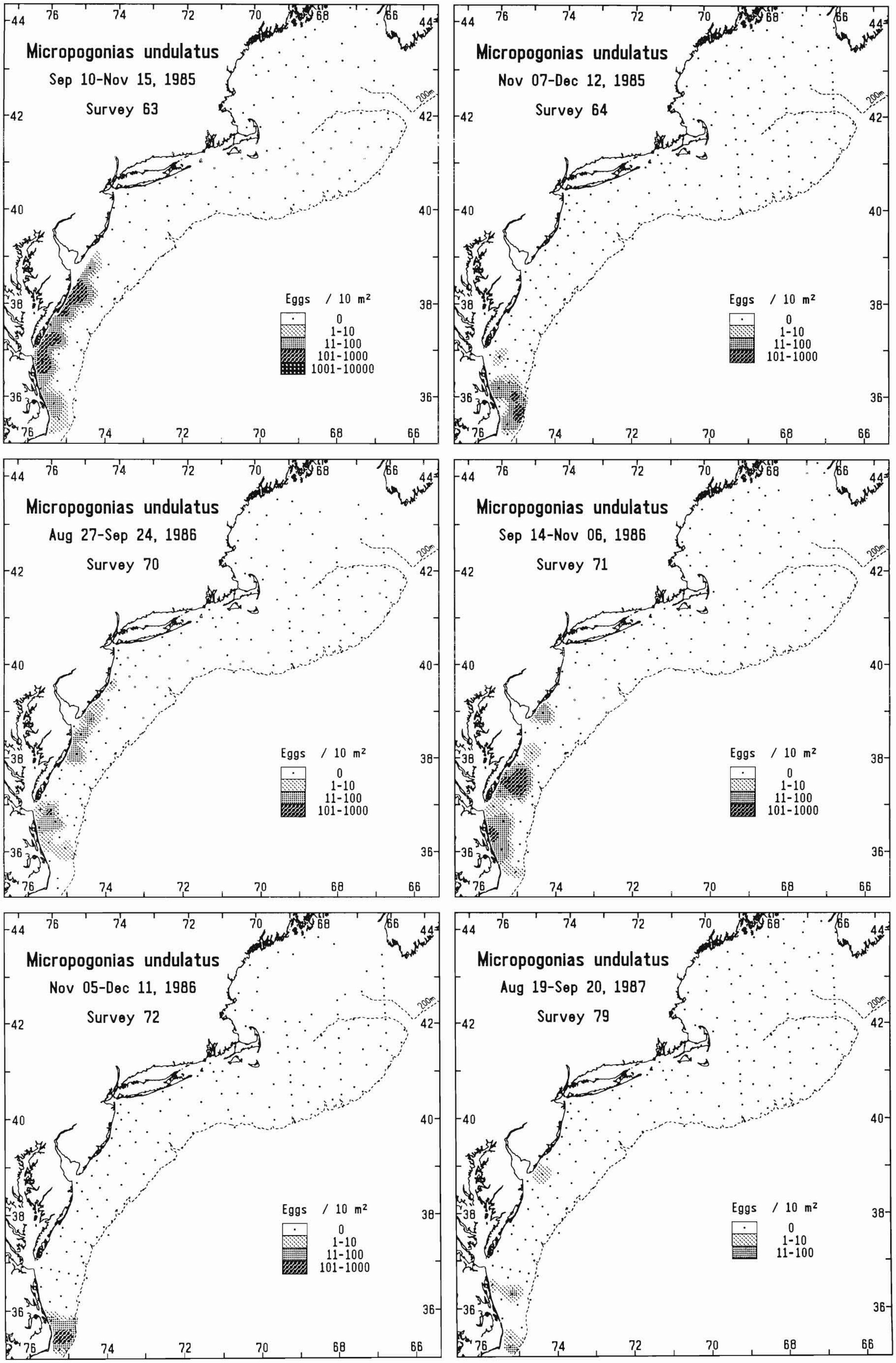


Figure 62 (continued)

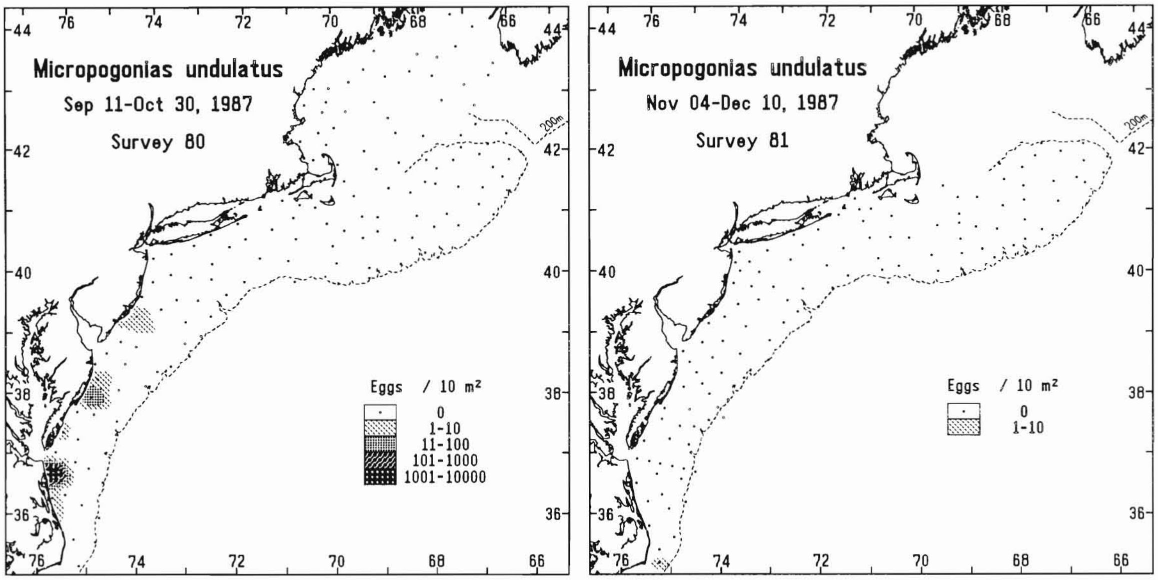


Figure 62 (continued)

Tautoga onitis, tautog (Figs. 63–65)

Tautoga onitis eggs were collected April to September, and were most abundant in early summer (Fig. 63). Eggs occurred in coastal and midshelf waters, reflecting the nearshore distribution of adults (Fig. 64).

Spawning begins as early as April in the southern portion of the Middle Atlantic subarea and by May progresses northward into the southern New England subarea. Peak spawning occurred in inshore waters from south of Chesapeake Bay to Nantucket shoals in June and July, followed by a decline during August. By September, spawning is reduced to isolated locations in southern New England waters and ceased entirely by the end of the month (Fig. 64).

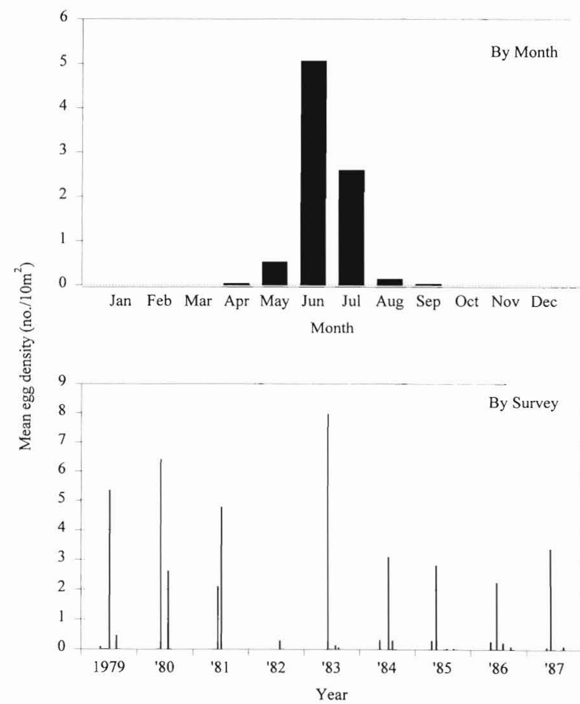


Figure 63

Tautoga onitis; mean-egg-density graphs by month (top) and by survey (bottom) for the total MARMAP area.

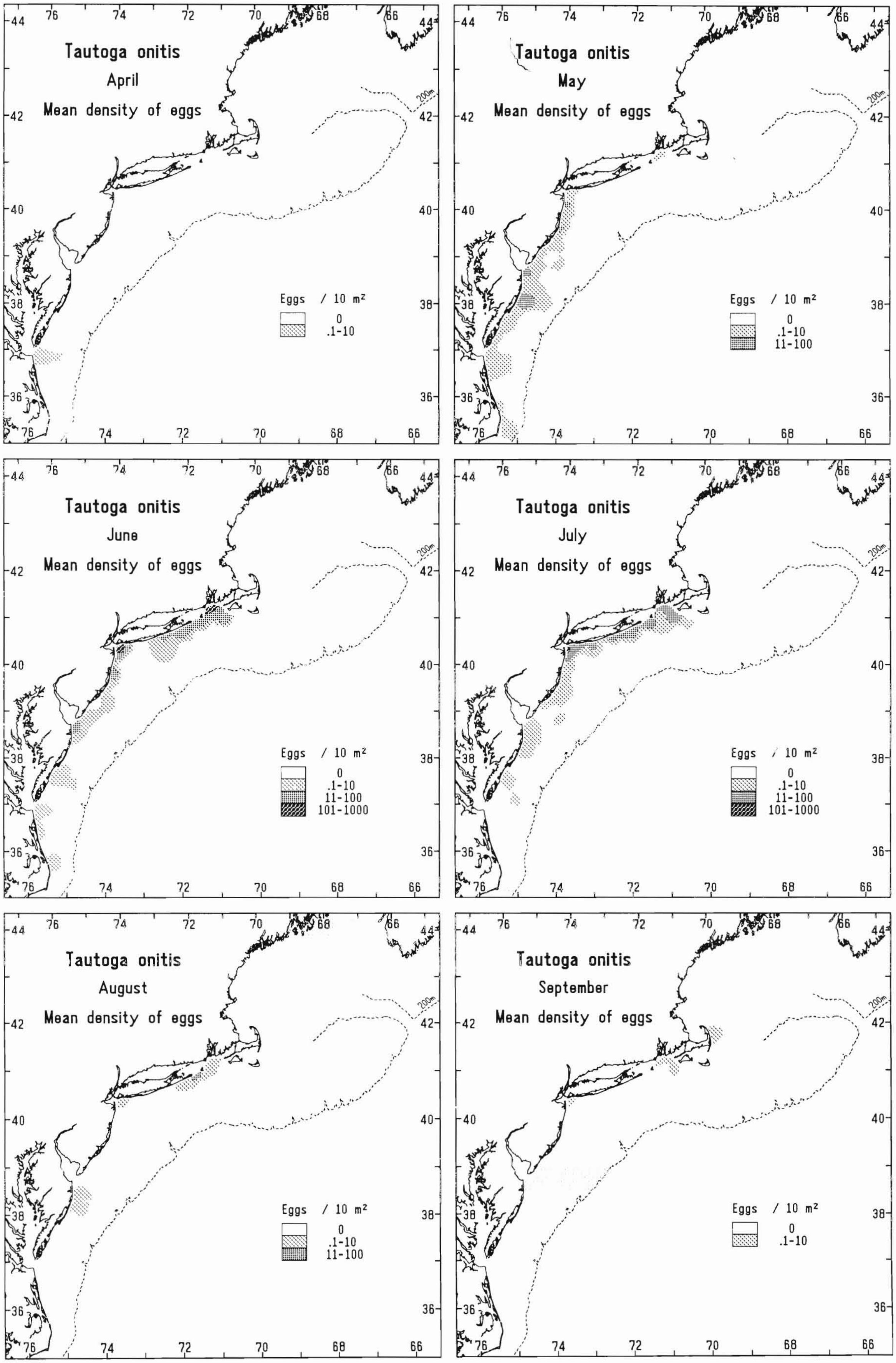


Figure 64

Tautoga onitis; composite monthly areal plots of mean egg densities (no./10 m²).

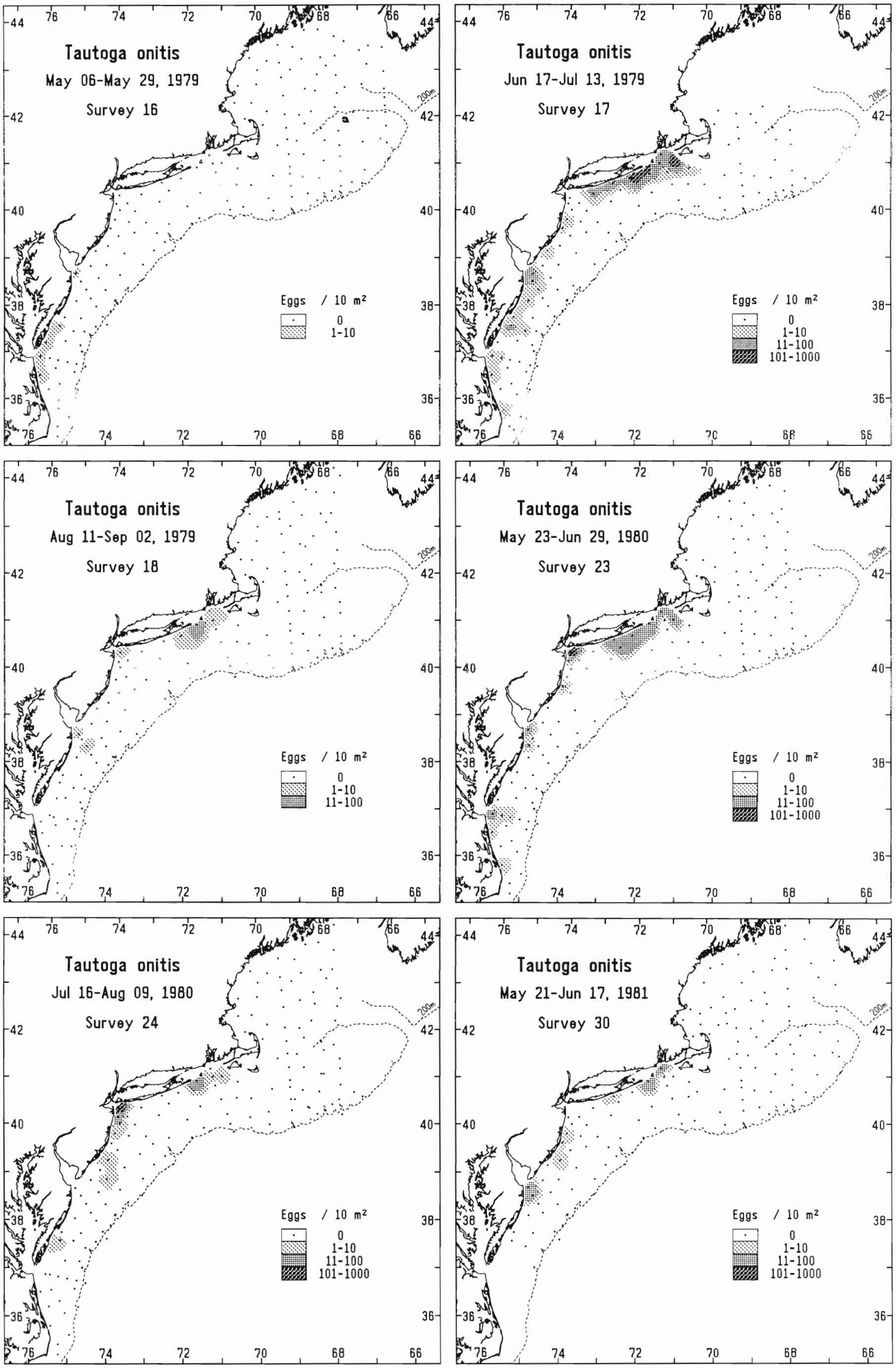


Figure 65

Tautoga onitis; survey areal plots of egg densities (no./10 m²).

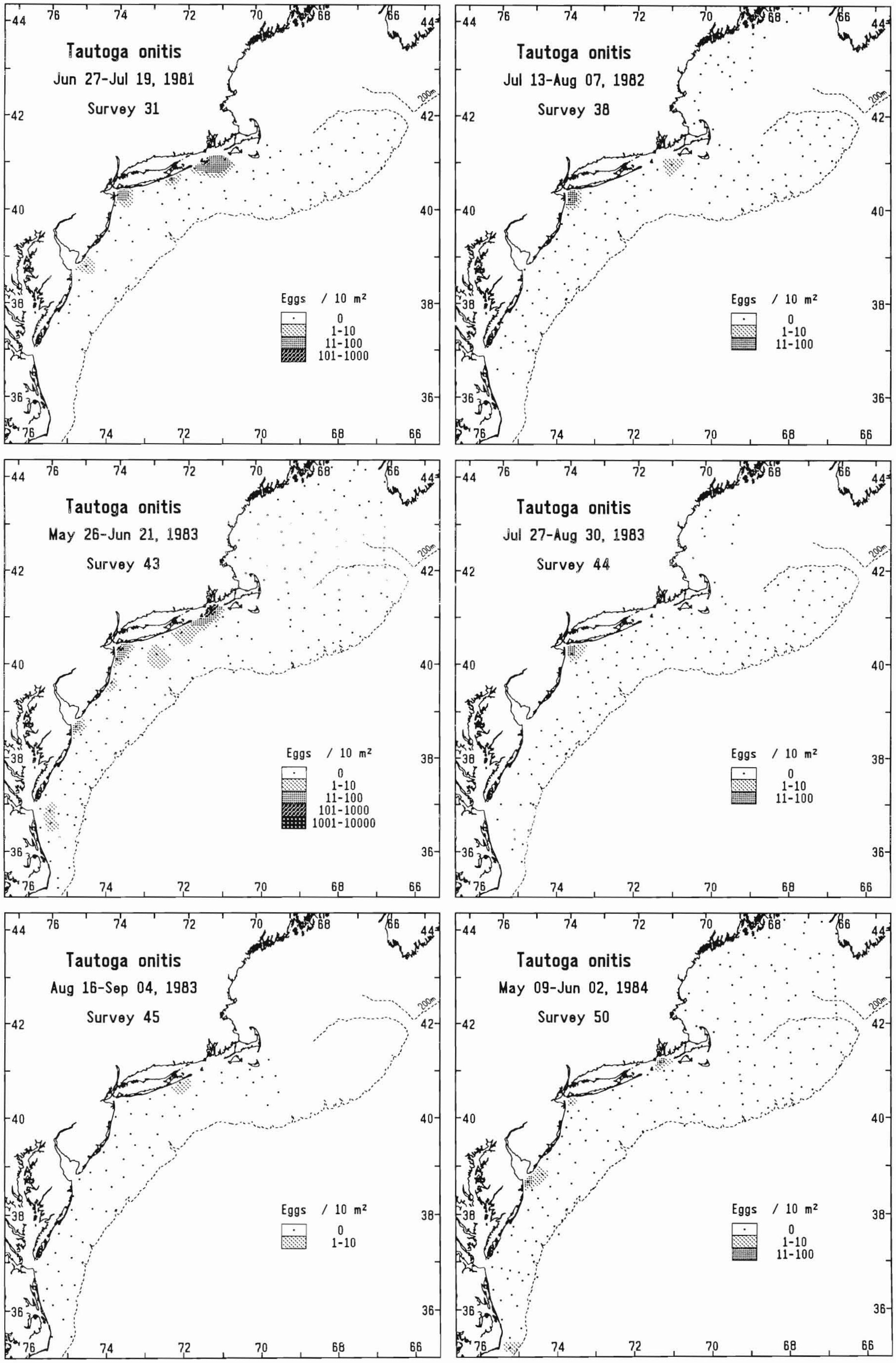


Figure 65 (continued)

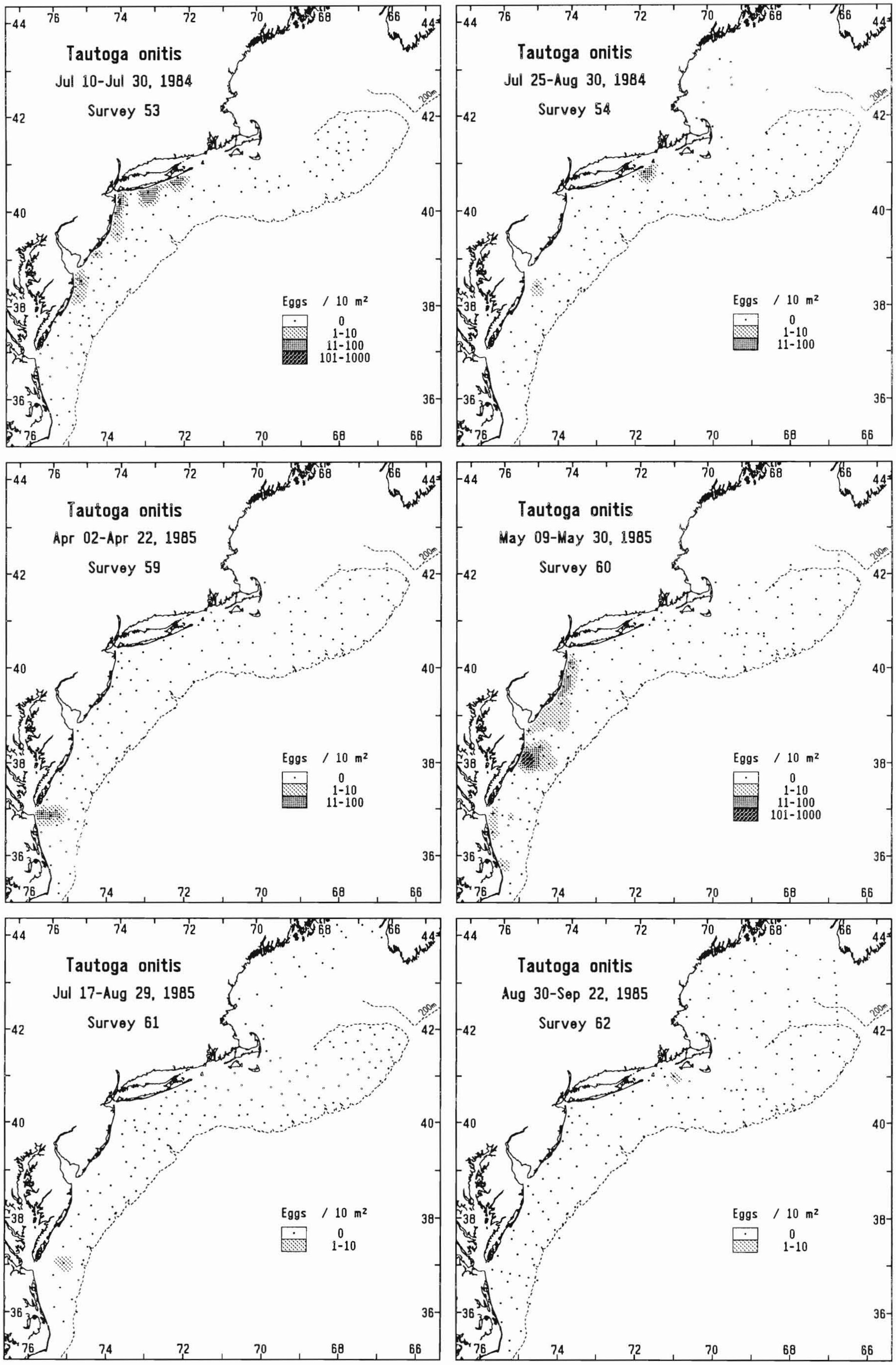


Figure 65 (continued)

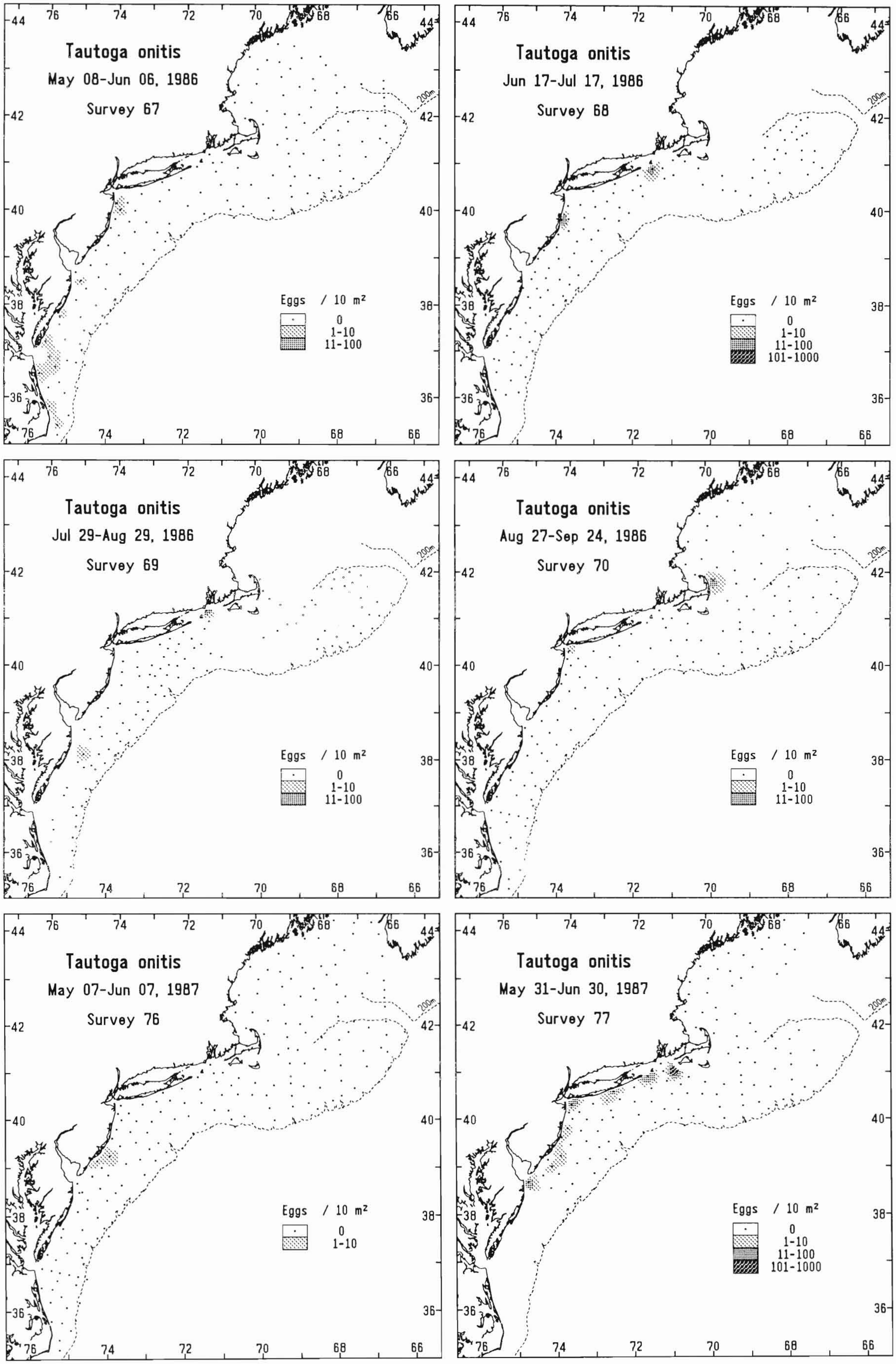


Figure 65 (continued)

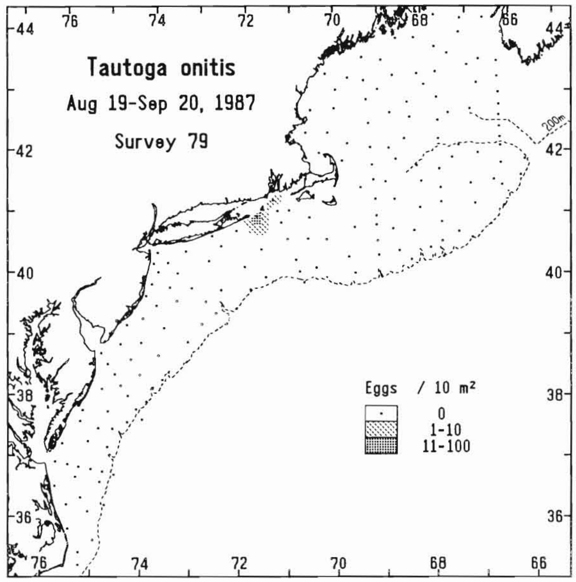


Figure 65 (continued)

Tautogolabrus adspersus, cunner (Figs. 66–68)

Tautogolabrus adspersus eggs were common inshore during spring and summer. They were collected from May to November, and were most abundant in June and July (Fig. 66).

Spawning began in inshore waters during May in the Middle Atlantic and southern New England subareas and in some years in the western Gulf of Maine near Cape Cod, Massachusetts (Fig. 67). Peak intensity occurred during June and July and expanded in area from south of Chesapeake Bay to northern Gulf of Maine and onto Georges Bank. During peak spawning, the greatest numbers of eggs were caught in shallow coastal waters and on central Georges Bank. Spawning declined rapidly during August, particularly in the Middle Atlantic and southern New England subareas, but continued at lower intensities in Georges Bank and peripheral Gulf of Maine waters. From September to November increasingly fewer and more isolated patches of eggs were found, and spawning ceased by the end of November.

There was an apparent decline in egg abundance and spawning level over the nine-year sampling period (Fig. 66). However, at peak spawning periods, particularly for years after 1983, only partial sampling coverage was attained. In addition, the spawning area of *T. adspersus* extends into sounds and embayments that were not sampled in this study.

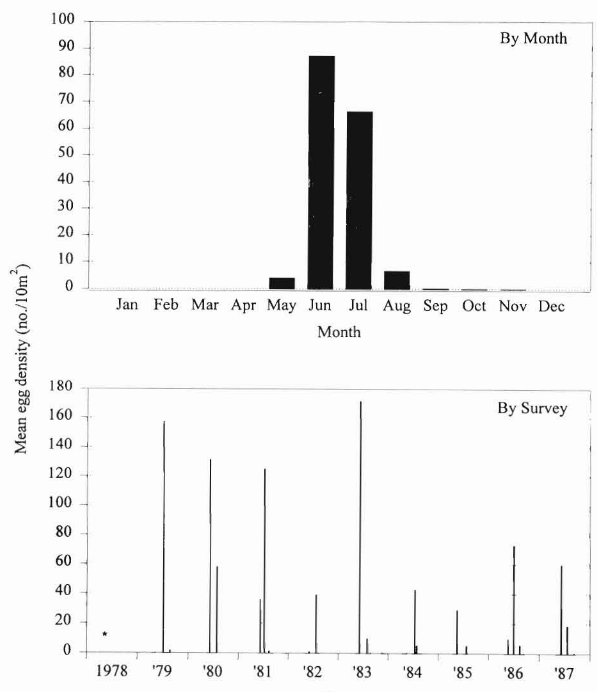


Figure 66
Tautogolabrus adspersus; mean-egg-density graphs by month (top) and by survey (bottom) for the total MARMAP area. (*Samples from the first four surveys in 1978 were not analyzed for *T. adspersus* eggs.)

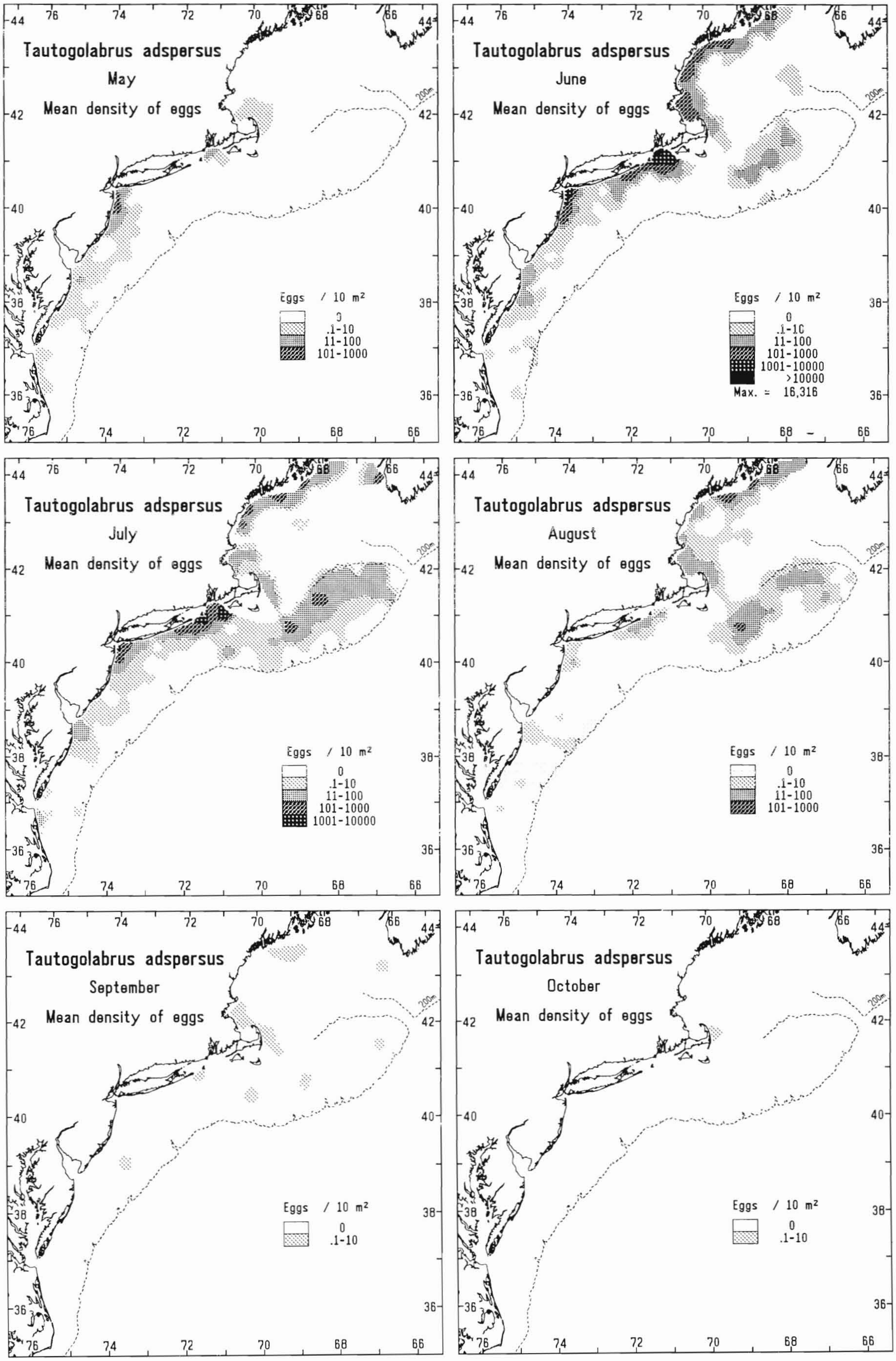

Tautogolabrus adspersus
May
Mean density of eggs
Eggs / 10 m²
0
.1-10
11-100
101-1000
Tautogolabrus adspersus
June
Mean density of eggs
Eggs / 10 m²
0
.1-10
11-100
101-1000
1001-10000
>10000
Max. = 16,316
Tautogolabrus adspersus
July
Mean density of eggs
Eggs / 10 m²
0
.1-10
11-100
101-1000
1001-10000
Tautogolabrus adspersus
August
Mean density of eggs
Eggs / 10 m²
0
.1-10
11-100
101-1000
Tautogolabrus adspersus
September
Mean density of eggs
Eggs / 10 m²
0
.1-10
Tautogolabrus adspersus
October
Mean density of eggs
Eggs / 10 m²
0
.1-10

Figure 67

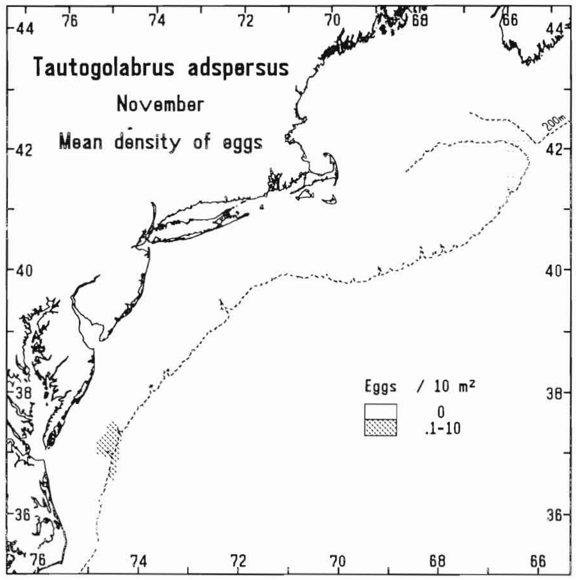


Figure 67 (continued)

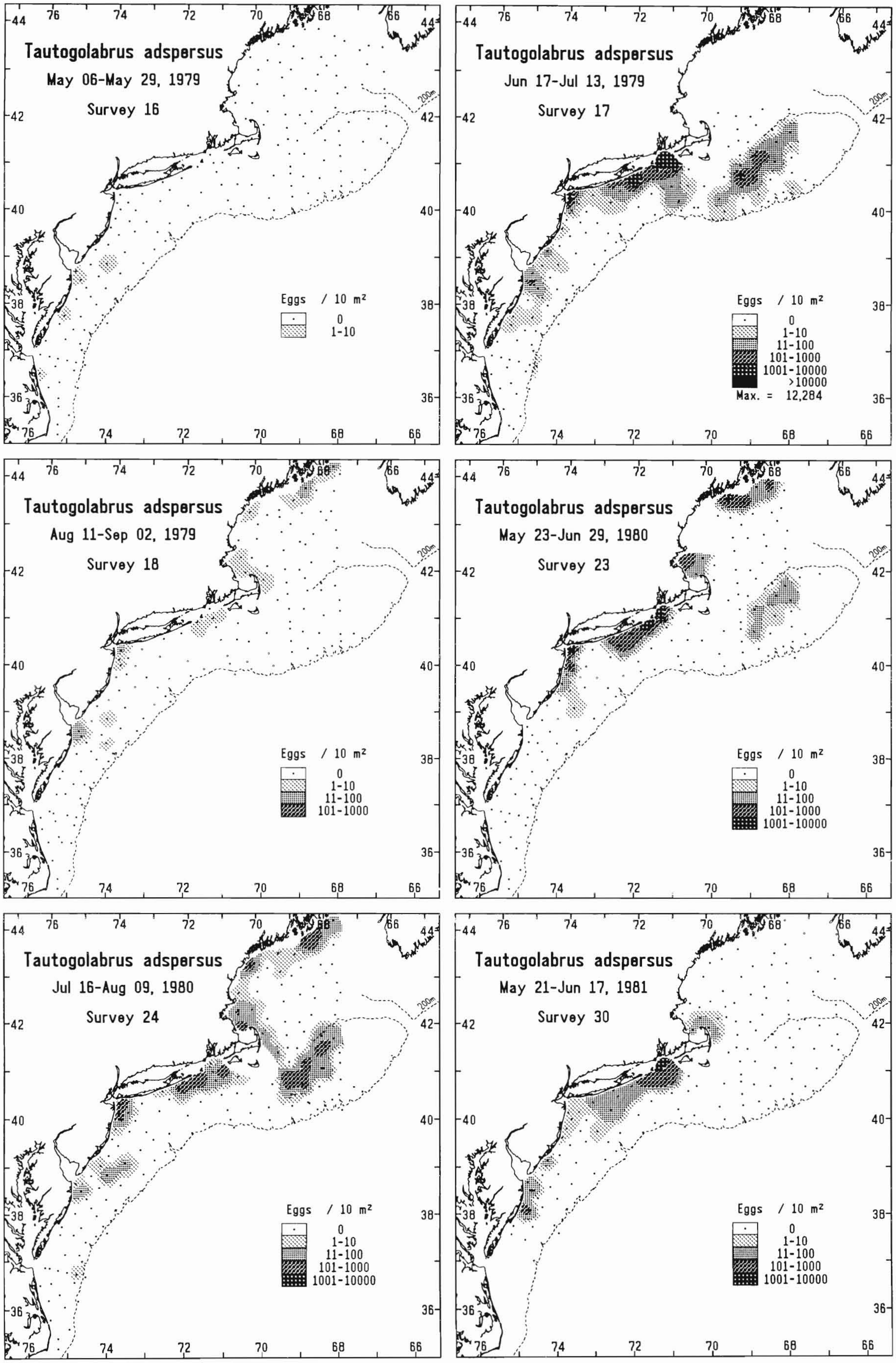


Figure 68

Tautogolabrus adspersus; survey areal plots of egg densities (no./10 m²).

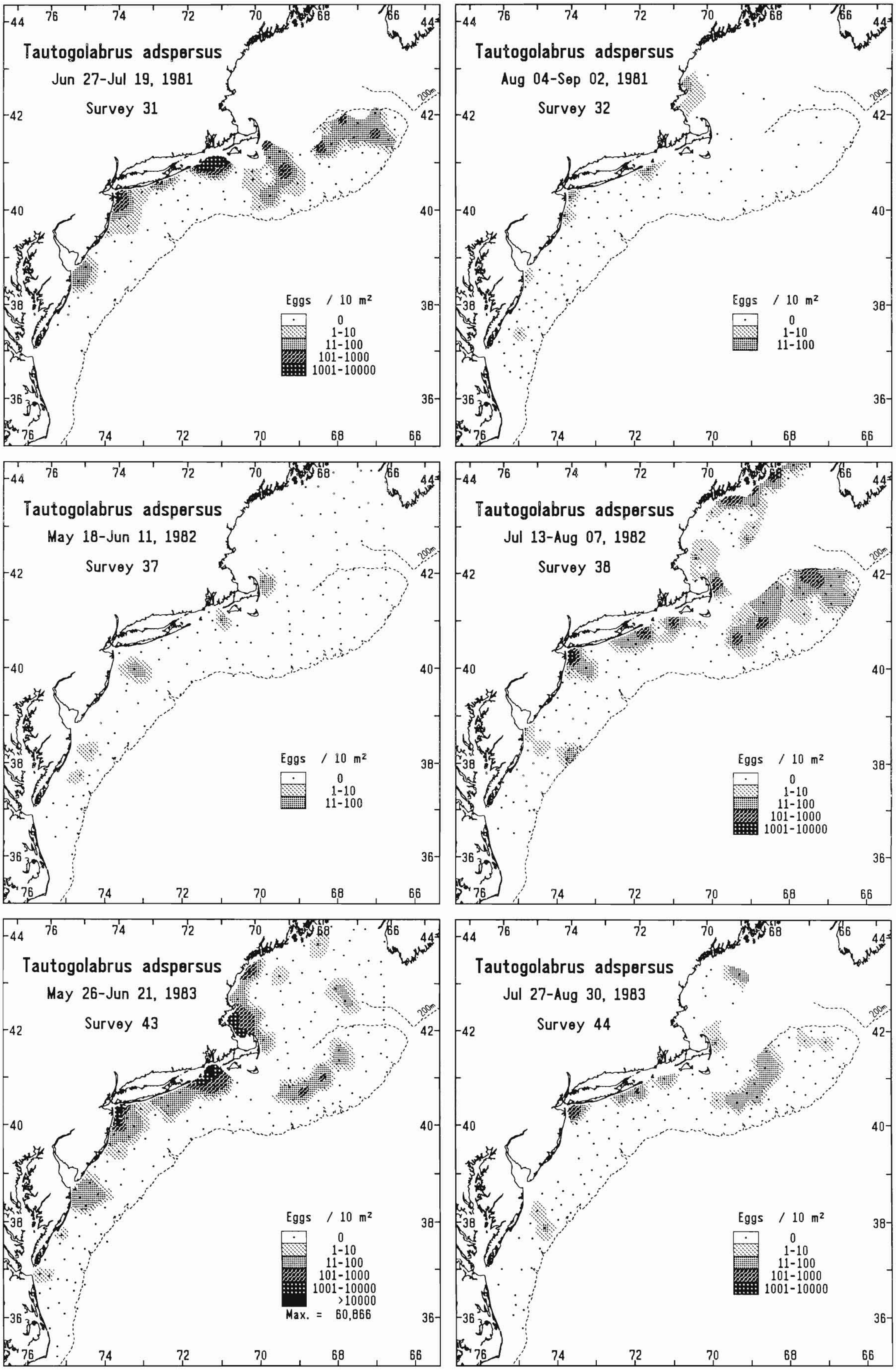


Figure 68 (continued)

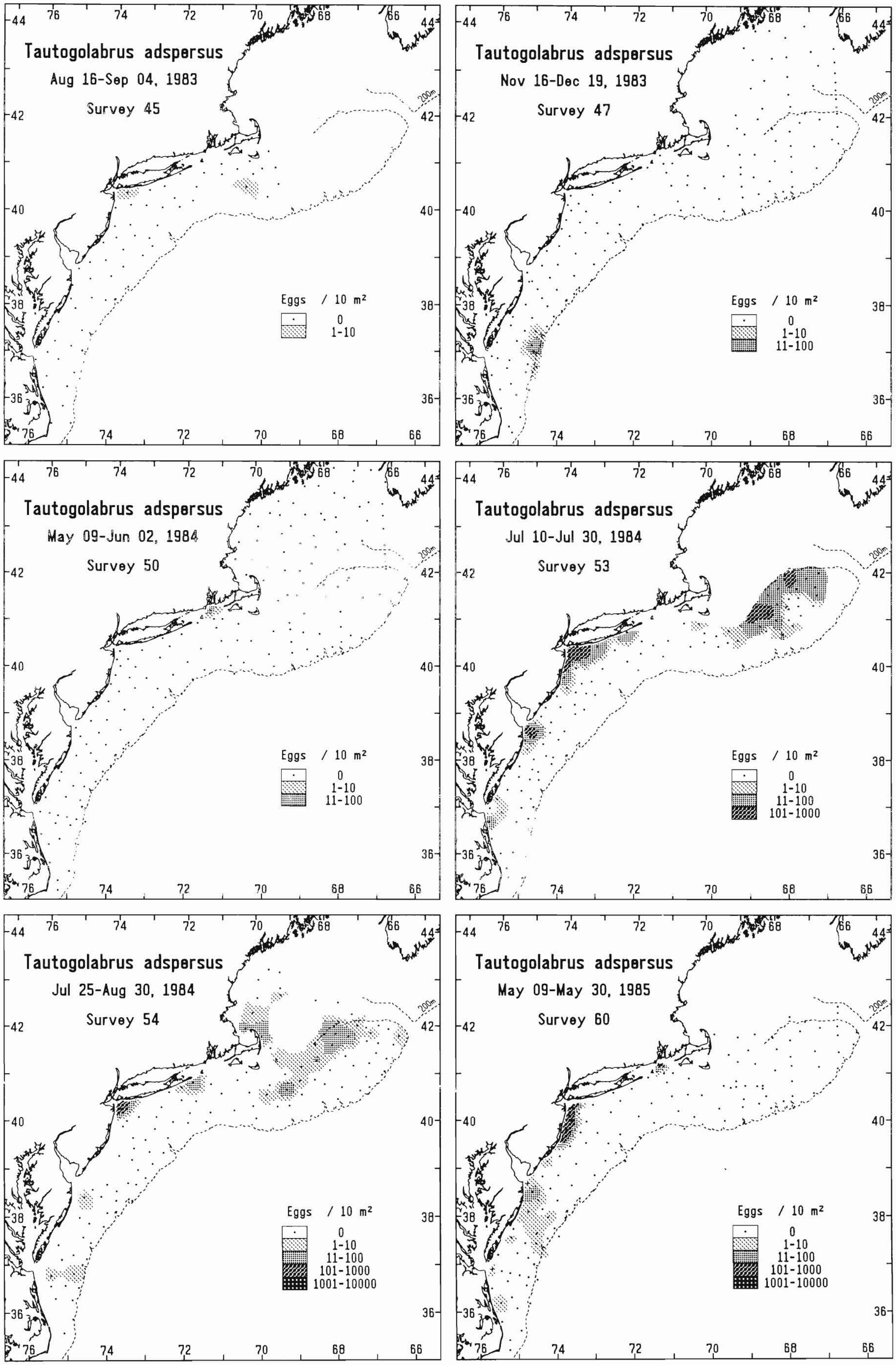


Figure 68 (continued)

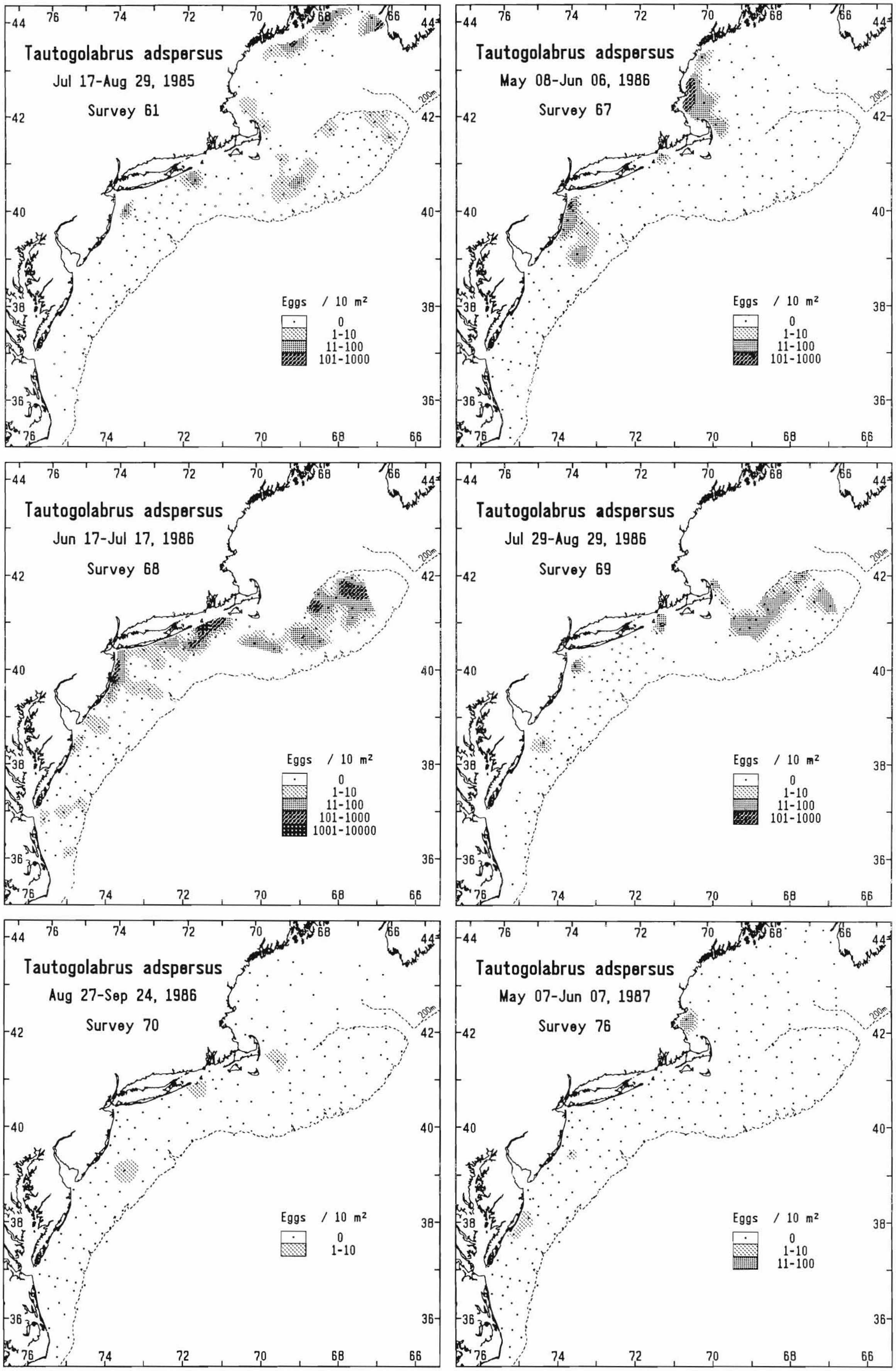


Figure 68 (continued)

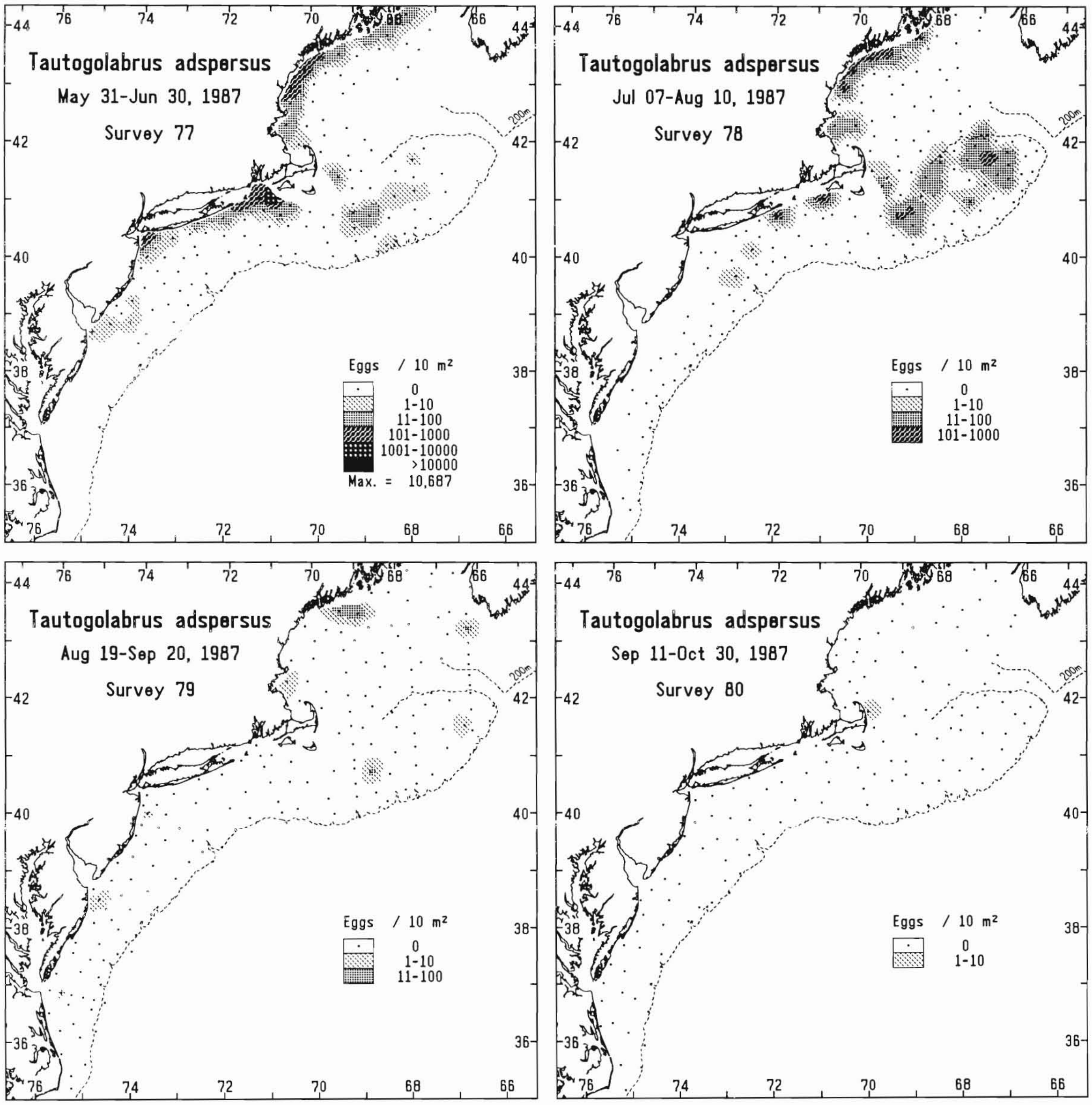


Figure 68 (continued)

Uranoscopidae, stargazers (Figs. 69–71)

Eggs identified as *Uranoscopidae* could include as many as three species (*Astroscopus guttatus, A. y-graecum,* and *Kathetostoma albigutta*). We assumed that most of these eggs were *A. guttatus* whose range is reported as Cape Hatteras, North Carolina, to Long Island, New York; *A. y-graecum* and *Kathetostoma albigutta* reportedly occur at Cape Hatteras and southward (Berry and Anderson, 1961).

Uranoscopidae eggs were collected from April to October. They were found exclusively within the Middle Atlantic subarea and occurred across the entire breadth of the shelf. Mean egg abundance was minimal in April, peaked in July and August, and diminished to almost nothing by the end of October (Fig. 69). Uranoscopid eggs were never very abundant, but remained a consistent component of the ichthyoplankton throughout the study (Fig. 69).

Spawning began as early as April in the southern portion of the Middle Atlantic subarea and spread rapidly northward during May as far as Delaware Bay, occurring mostly in the inner half of shelf waters, particularly in more northern areas. For the remainder of the spawning season (June to October), the total spawning area remained relatively static while major concentrations of eggs tended to shift into slightly deeper mid-shelf waters (Fig. 70).

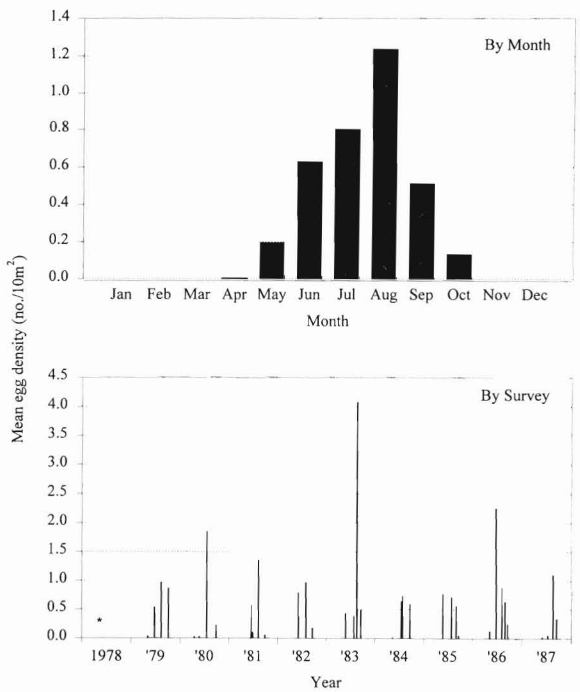


Figure 69
Uranoscopidae; mean-egg-density graphs by month (top) and by survey (bottom) for the total MARMAP area. (*Samples from the first four surveys in 1978 were not analyzed for Uranoscopidae eggs.)

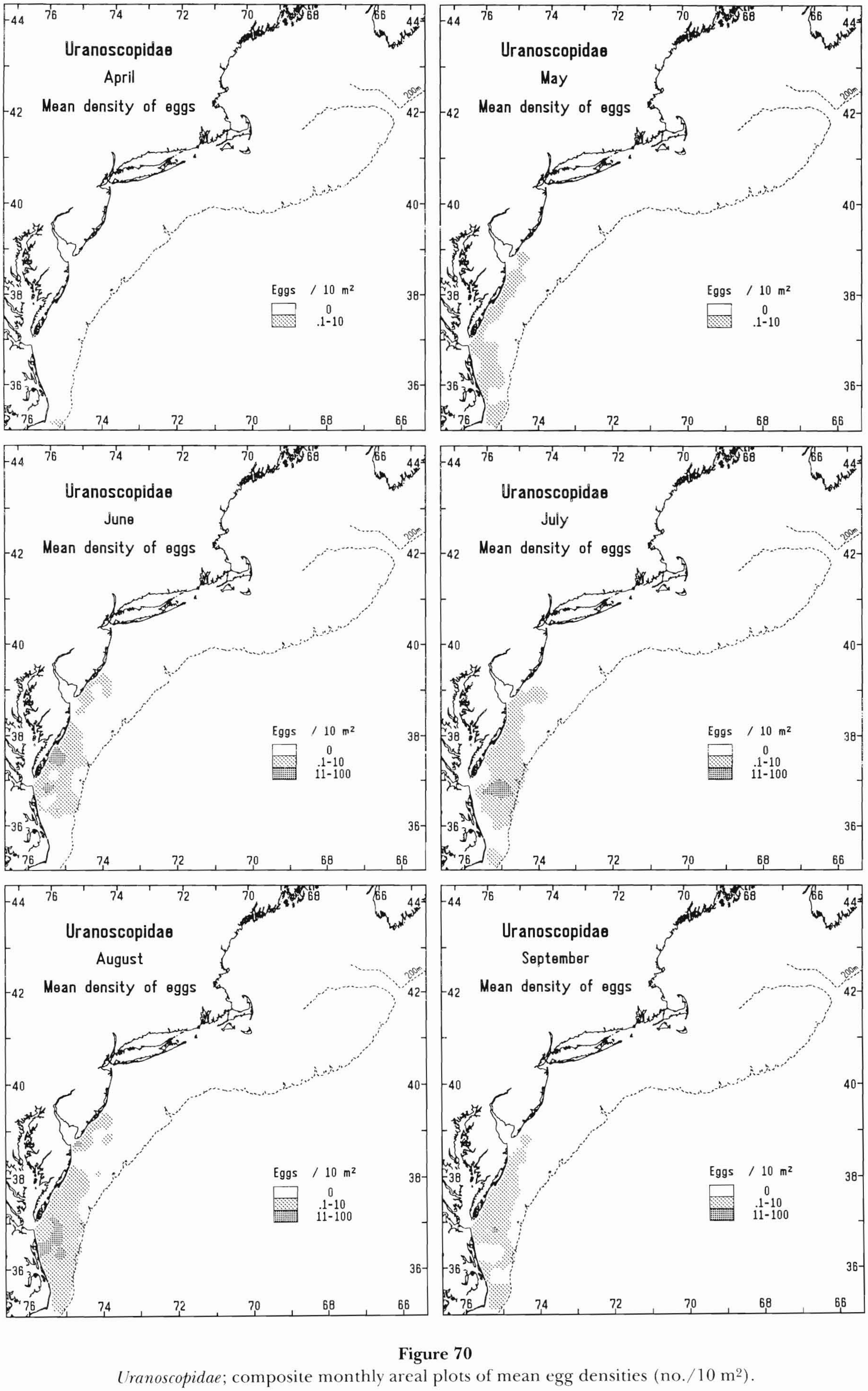


Figure 70

Uranoscopidae; composite monthly areal plots of mean egg densities (no./10 m²).

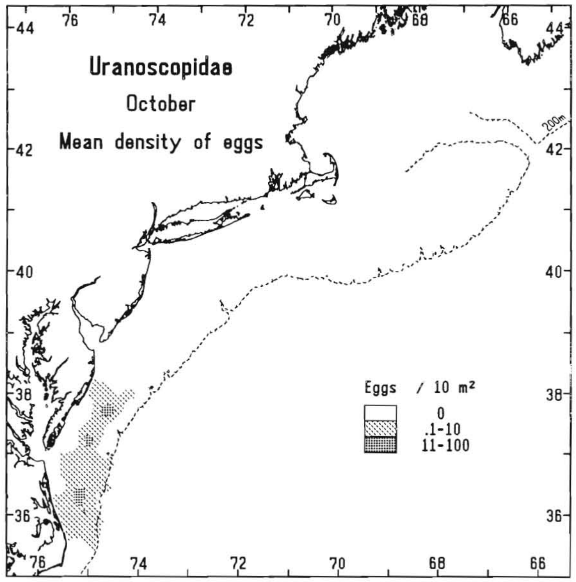


Figure 70 (continued)

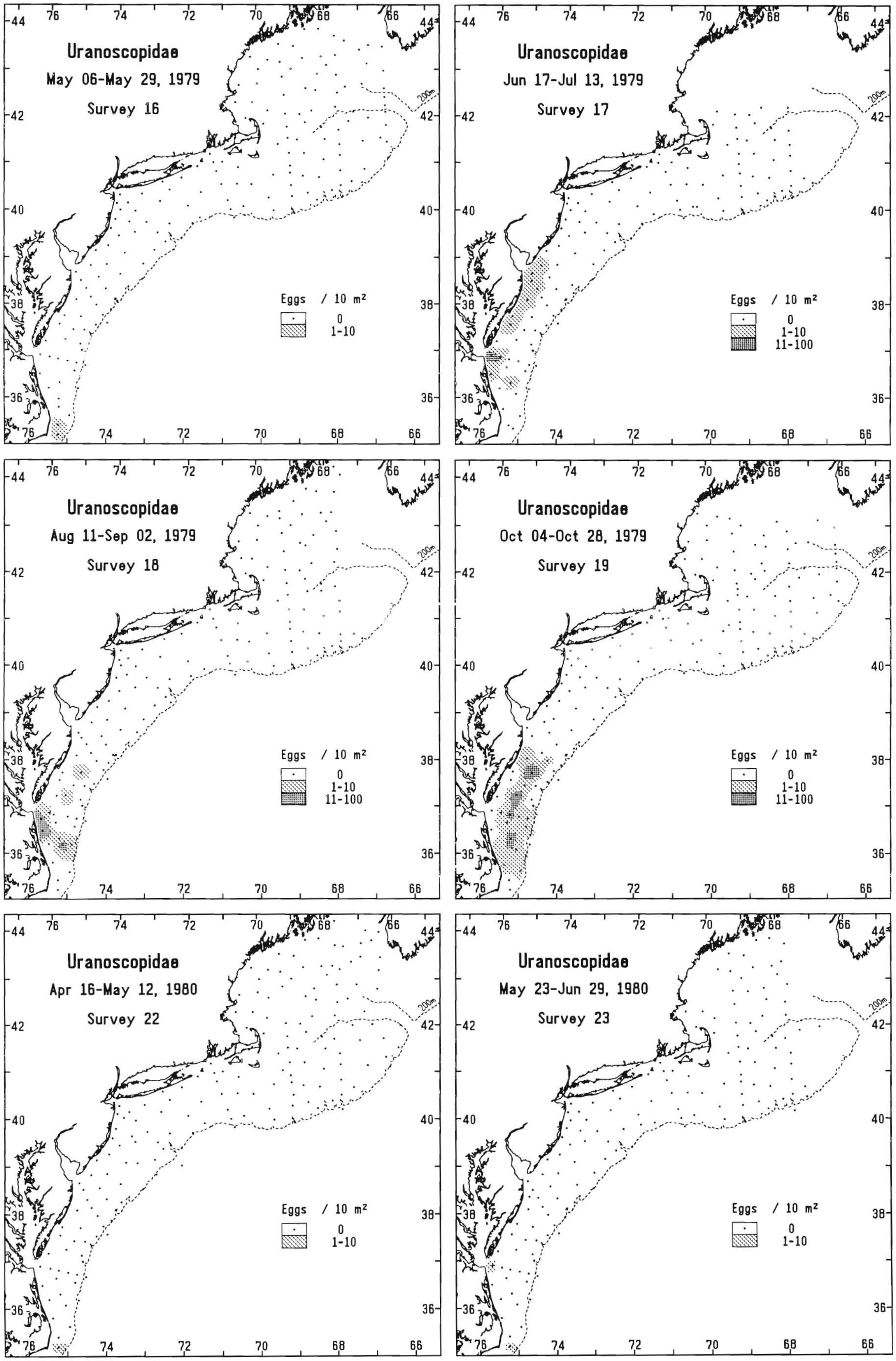


Figure 71
Uranoscopidae; survey areal plots of egg densities (no./10 m²).

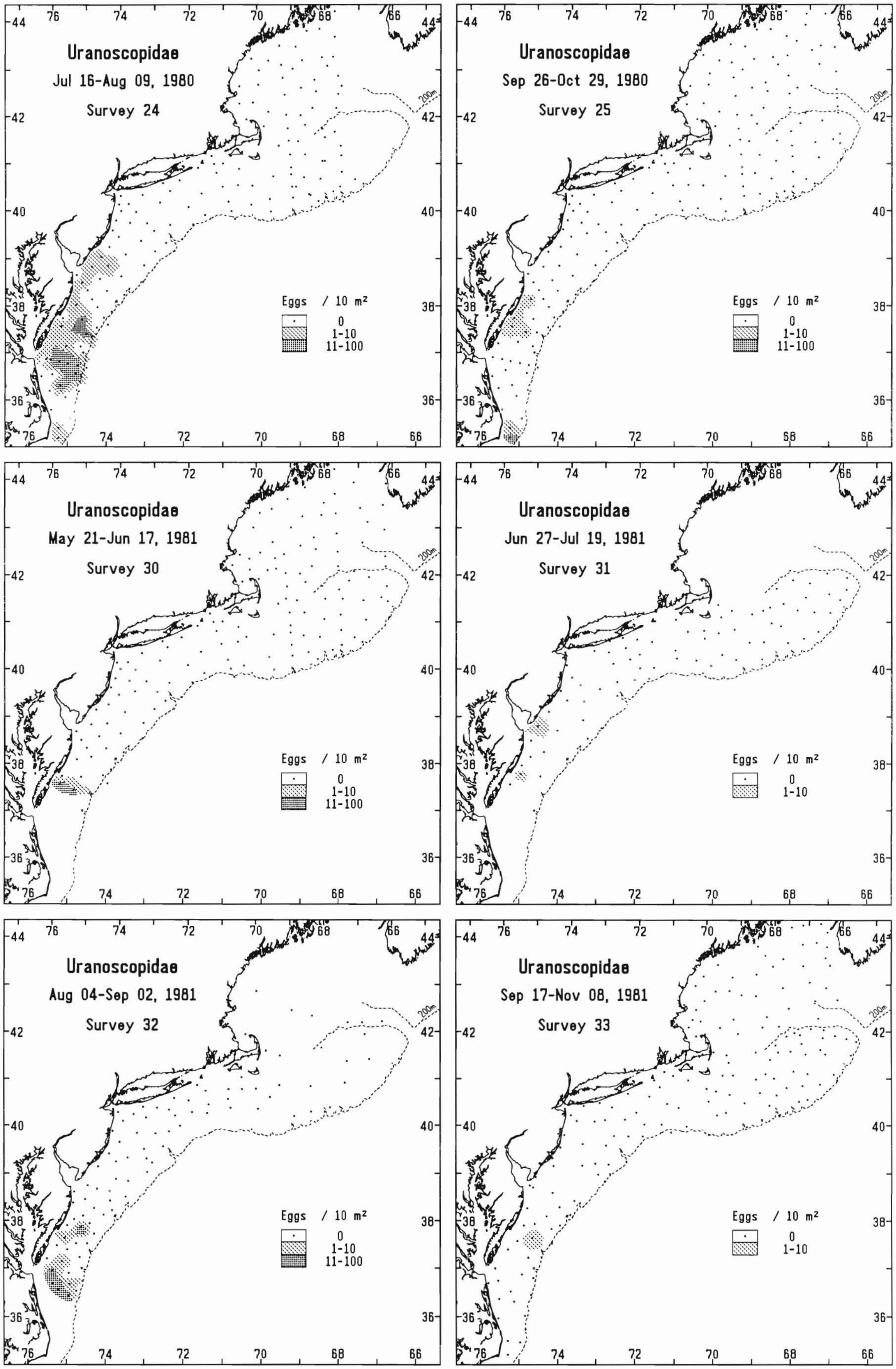


Figure 71 (continued)

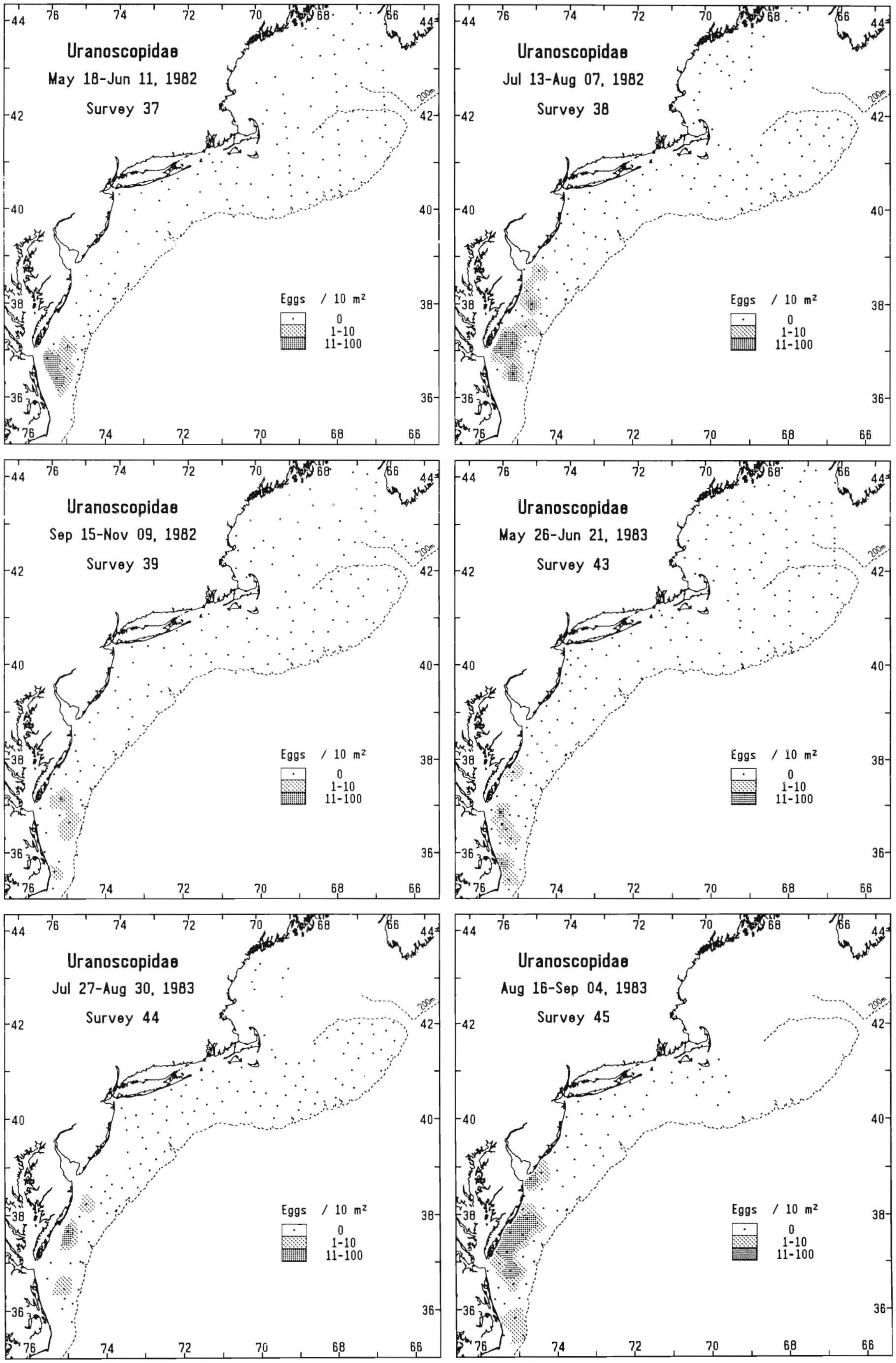


Figure 71 (continued)

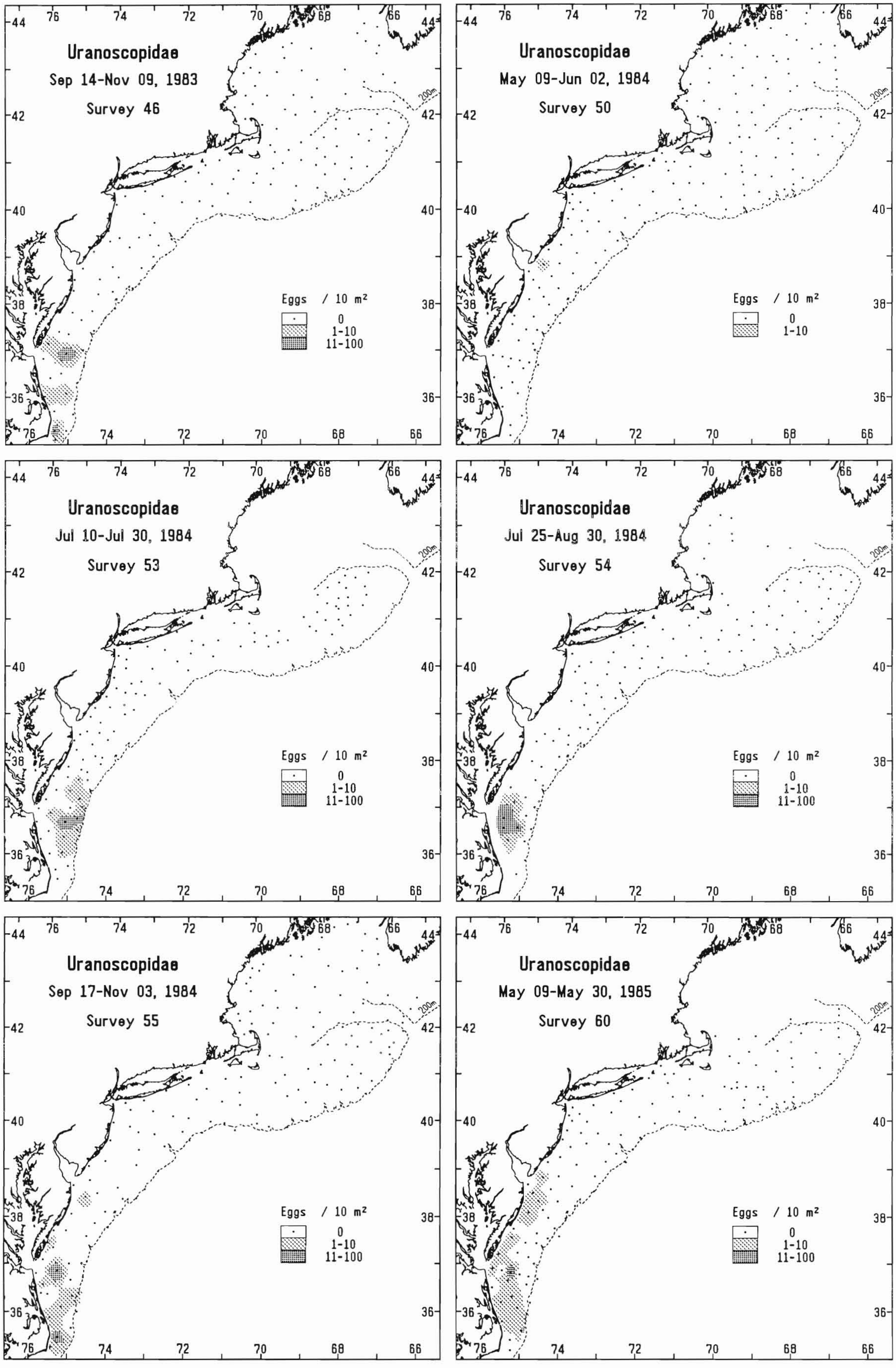


Figure 71 (continued)

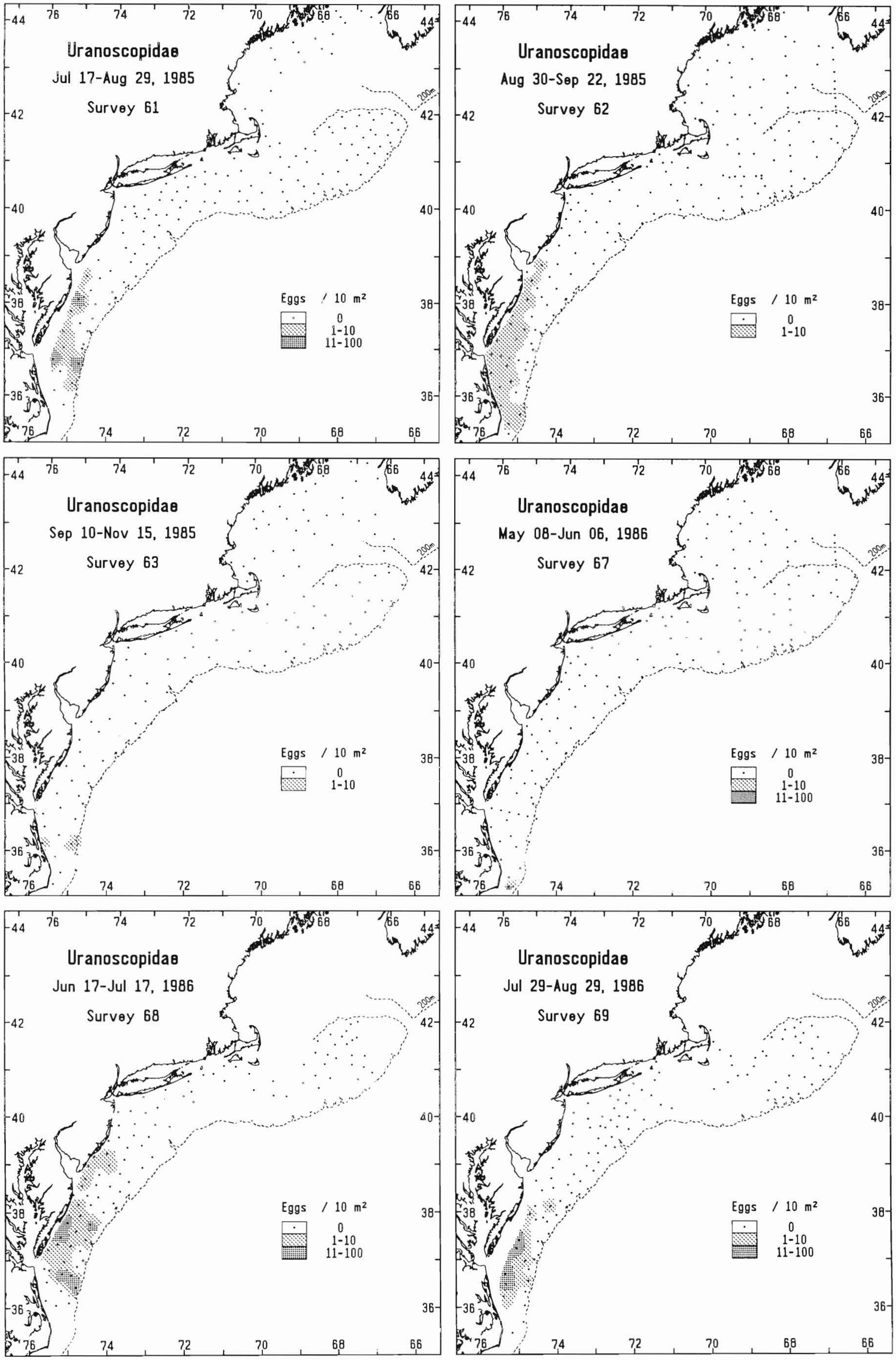


Figure 71 (continued)

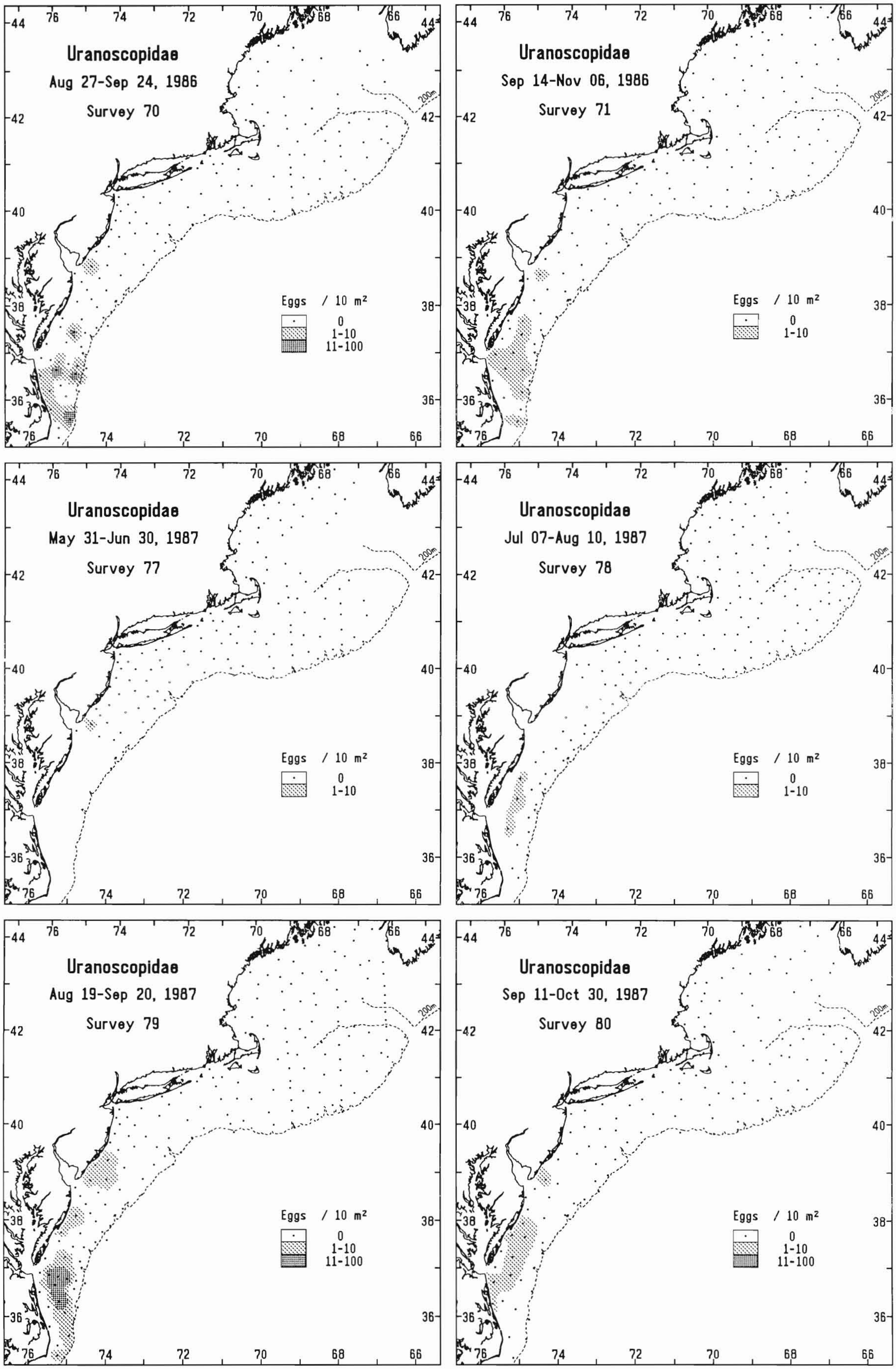


Figure 71 (continued)

Auxis spp., frigate and bullet mackerels (Figs. 72–74)

Auxis spp. eggs were collected from May to September, with highest abundances occurring during summer (Fig. 72). Most were taken south of Delaware Bay in the Middle Atlantic subarea, with isolated occurrences in the outer half of shelf waters in the southern New England subarea (Fig. 73).

Spawning by *Auxis* spp. was highly seasonal. It began and ended abruptly with peaks from June to August (Fig. 72). In some years, eggs first appeared offshore south of Delaware Bay as early as May, but in others, not until June or July. During June, July, and August they generally occurred south of Delaware Bay across the breadth of the shelf. During most years eggs were most abundant near the shelf edge. North and east of Delaware Bay, eggs were found in isolated patches. In September eggs occurred infrequently in isolated patches near the shelf edge. *Auxis* spp. adults occur in neritic and oceanic waters, hence our survey of shelf waters sampled just a portion of their distribution.

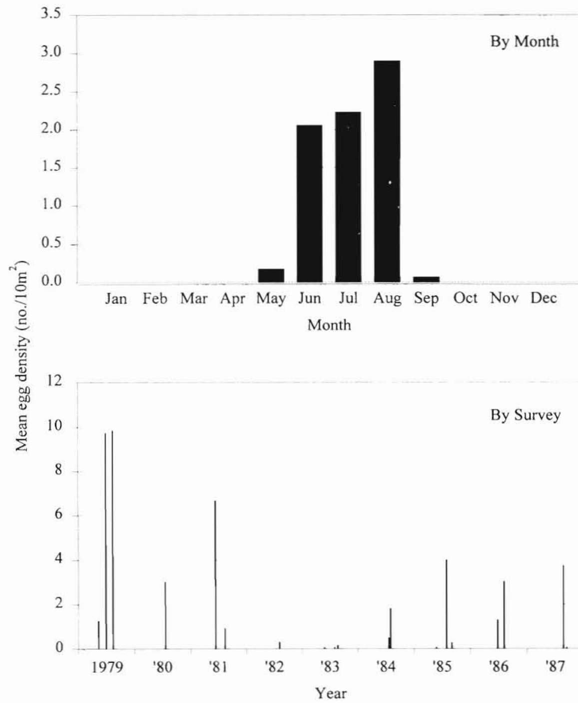


Figure 72
Auxis spp.; mean-egg-density graphs by month (top) and by survey (bottom) for the total MARMAP area.

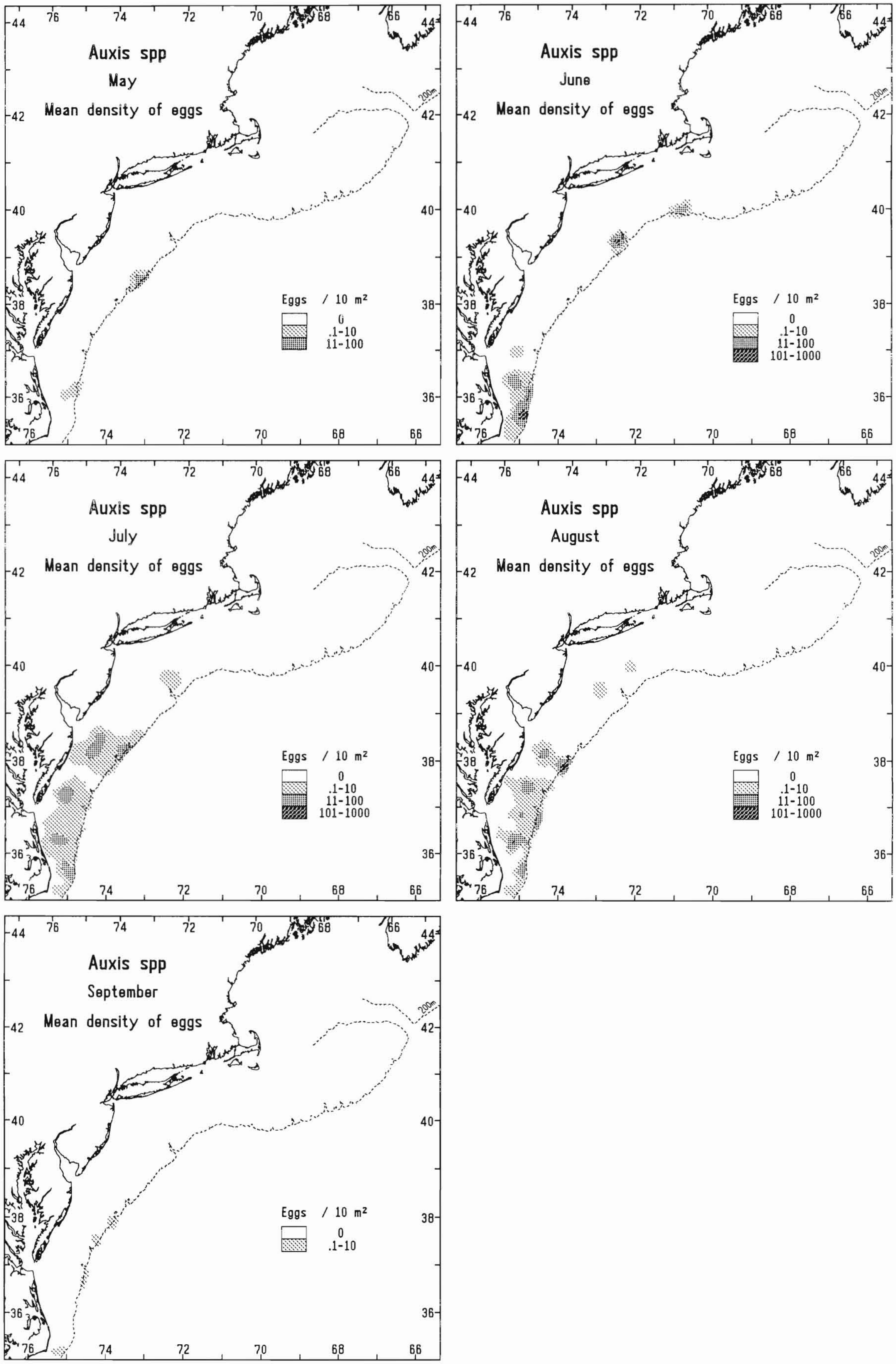


Figure 73

Auxis spp.; composite monthly areal plots of mean egg densities (no./10 m^2).

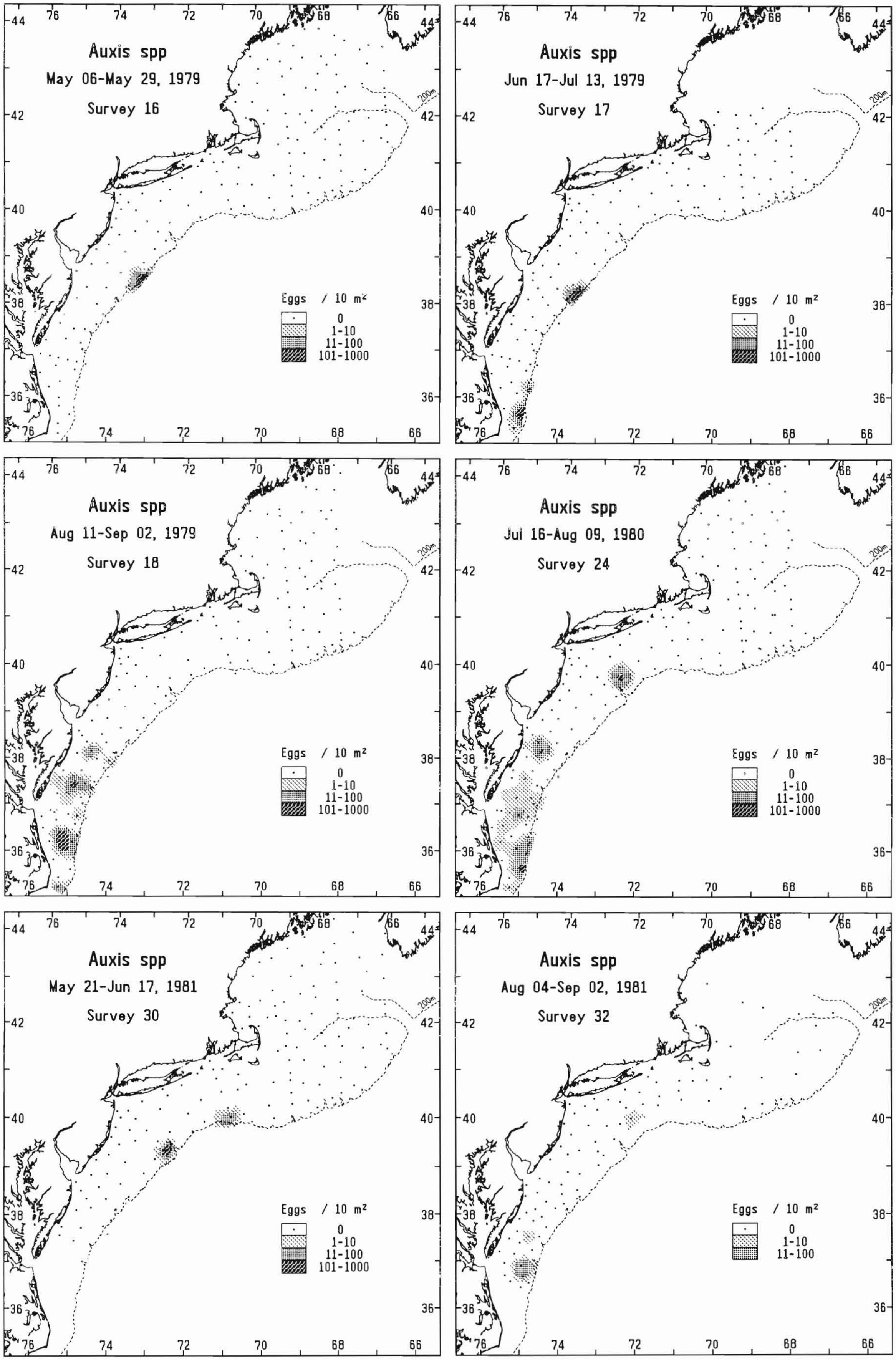


Figure 74
Auxis spp.; survey areal plots of egg densities (no./10 m^2).

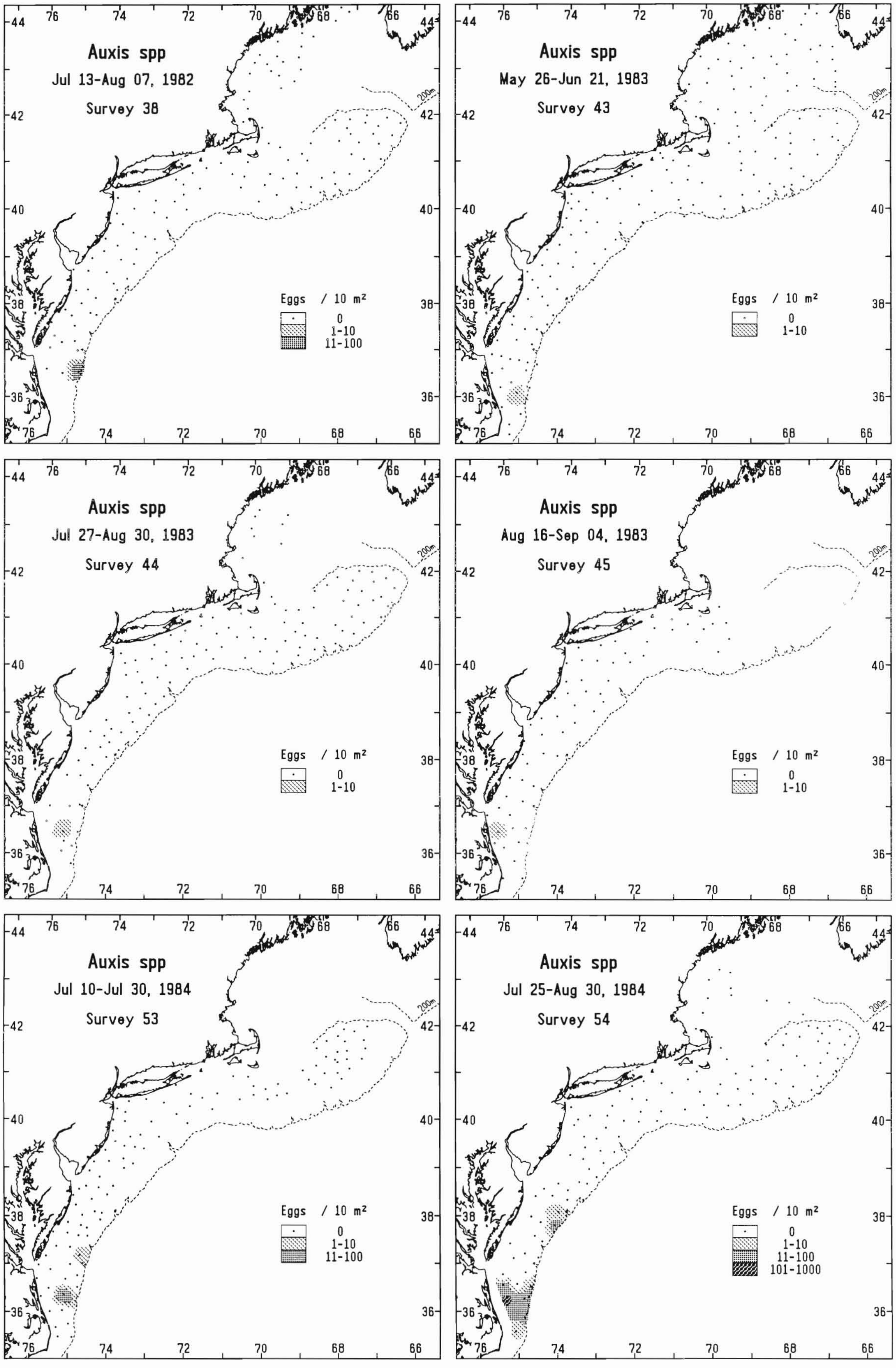


Figure 74 (continued)

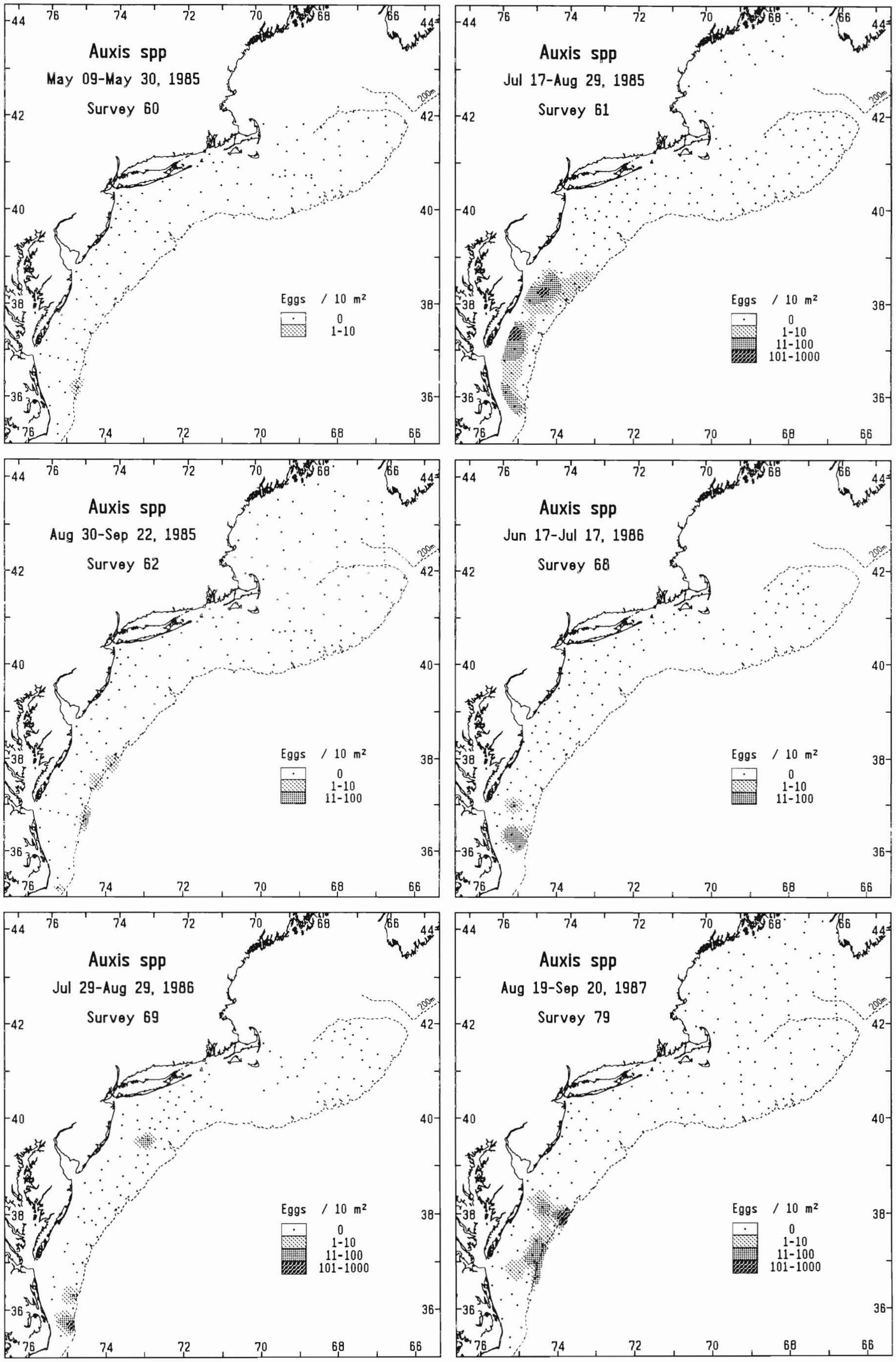


Figure 74 (continued)

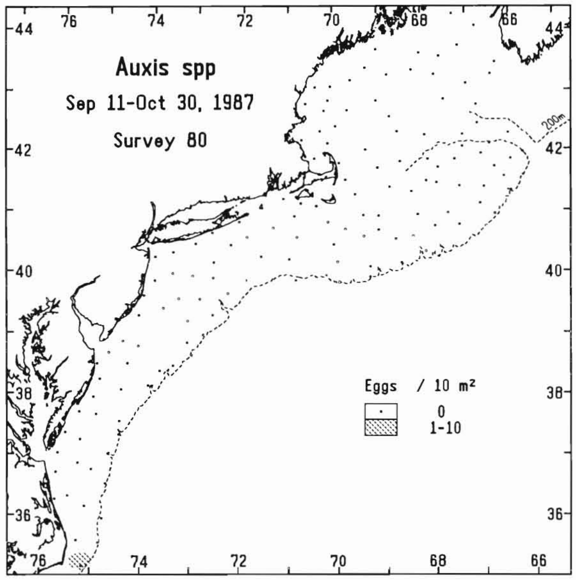


Figure 74 (continued)

Sarda sarda, Atlantic bonito (Figs. 75–77)

Sarda sarda spawned during spring and summer. Eggs were collected from May through August with a peak in abundance during July (Fig. 75) and occurred across the entire breadth of the shelf (Fig. 76).

Spawning began in May in the southern portion of the Middle Atlantic subarea, progressed northward throughout shelf waters to the New York Bight in June, and extended to off Nantucket Shoals by July (Fig. 76). No spawning occurred north and east of Nantucket shoals. The largest concentration of eggs and greatest intensity of spawning occurred during July off New Jersey and Long Island. During August, spawning activity diminished to isolated locations and ceased by the end of the month (Fig. 76).

The mean egg density for survey 17 in 1979 indicated that large numbers of Atlantic bonito spawned. In subsequent years, maximum mean egg densities ranged from 4 to 37% of the 1979 level. The low values for 1985 could indicate a decrease in spawning activity as there was no bias in sampling during 1985 (Figs. 75 and 77).

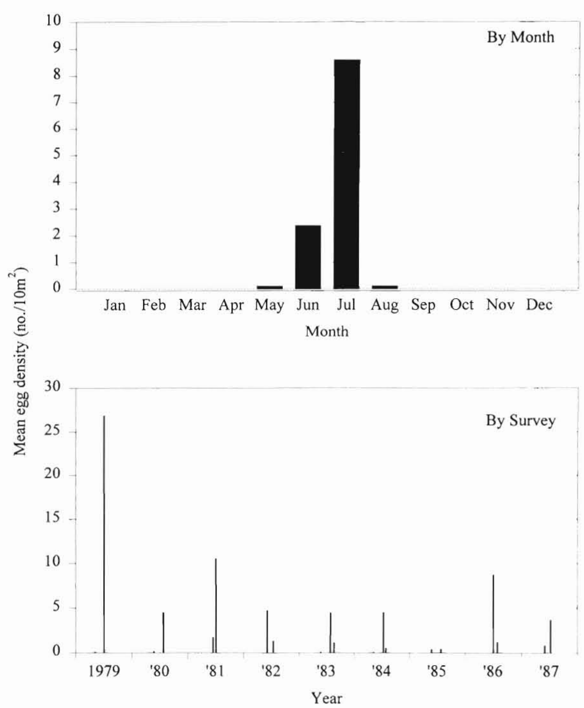


Figure 75
Sarda sarda; mean-egg-density graphs by month (top) and by survey (bottom) for the total MARMAP area.

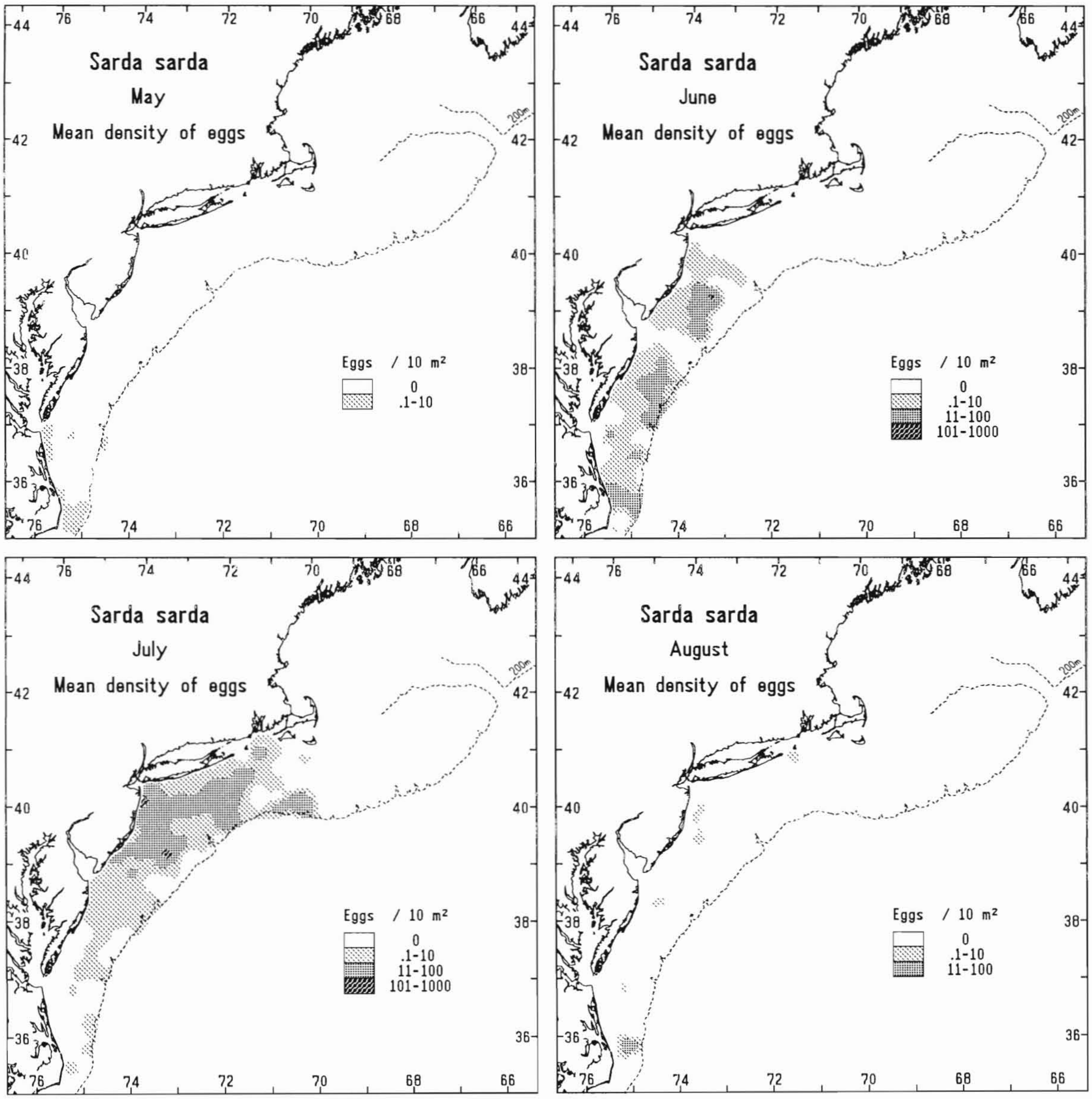


Figure 76
Sarda sarda; composite monthly areal plots of mean egg densities (no./10 m²).

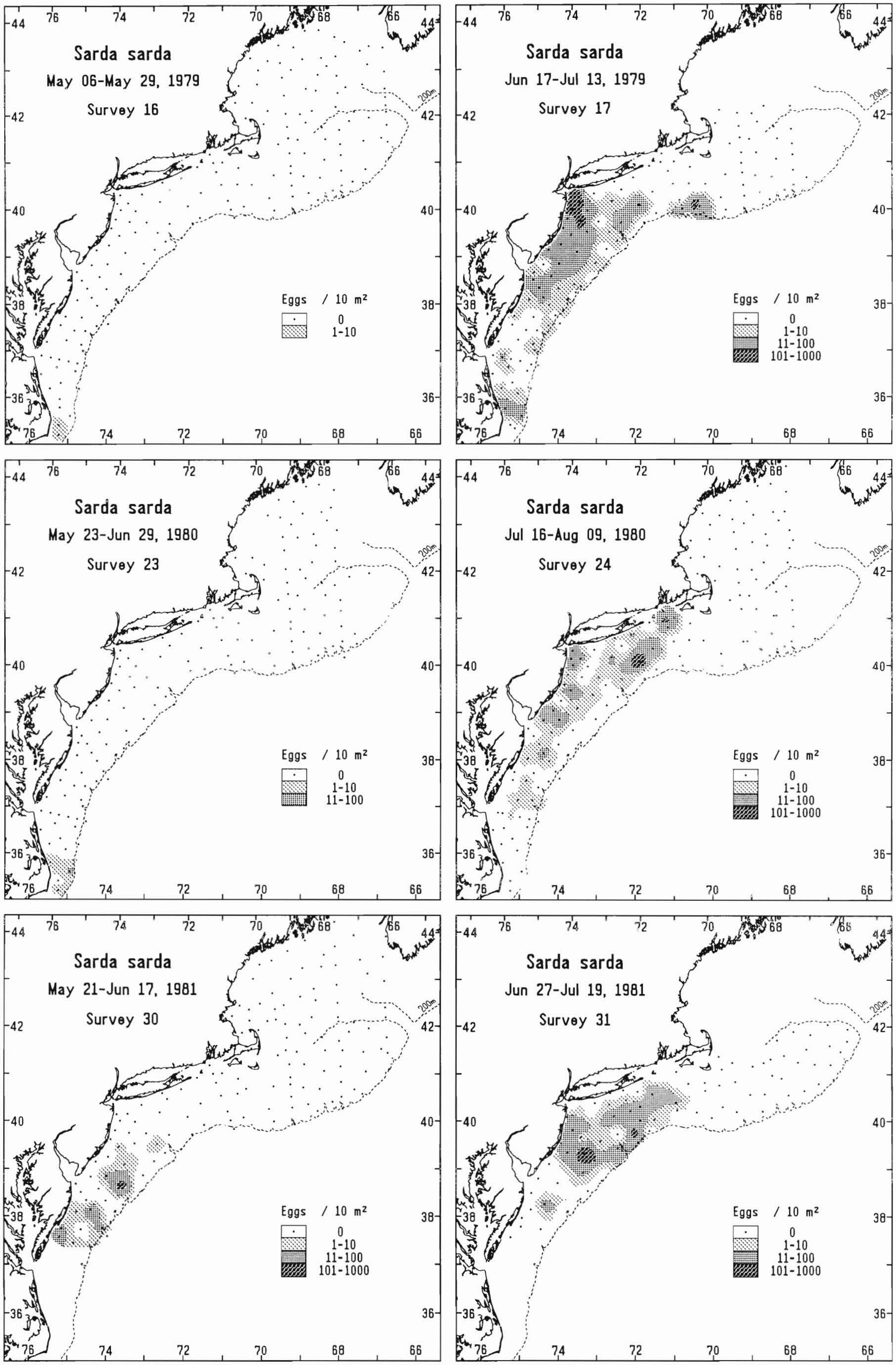


Figure 77

Sarda sarda; survey areal plots of egg densities (no./10 m^2).

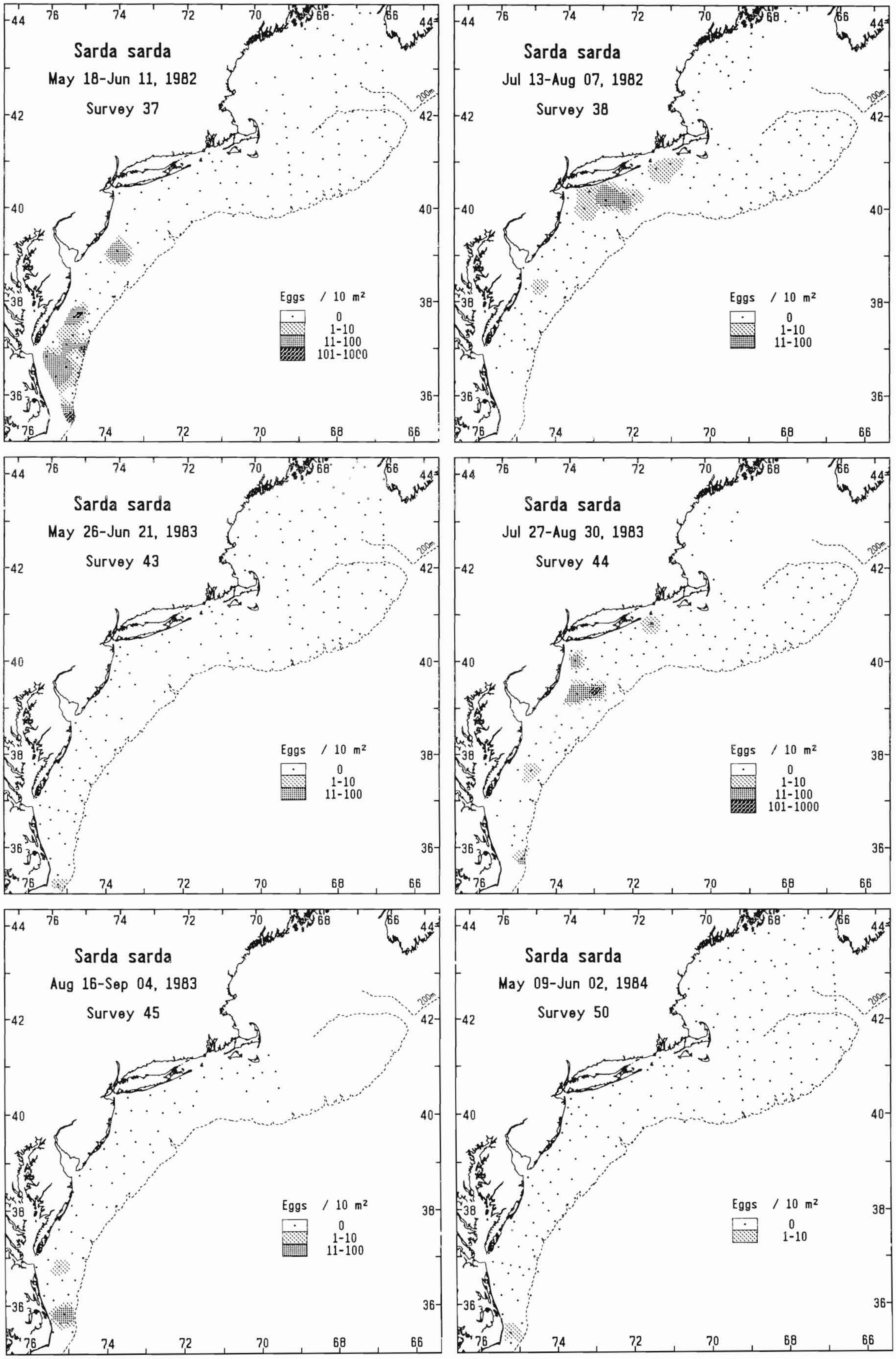


Figure 77 (continued)

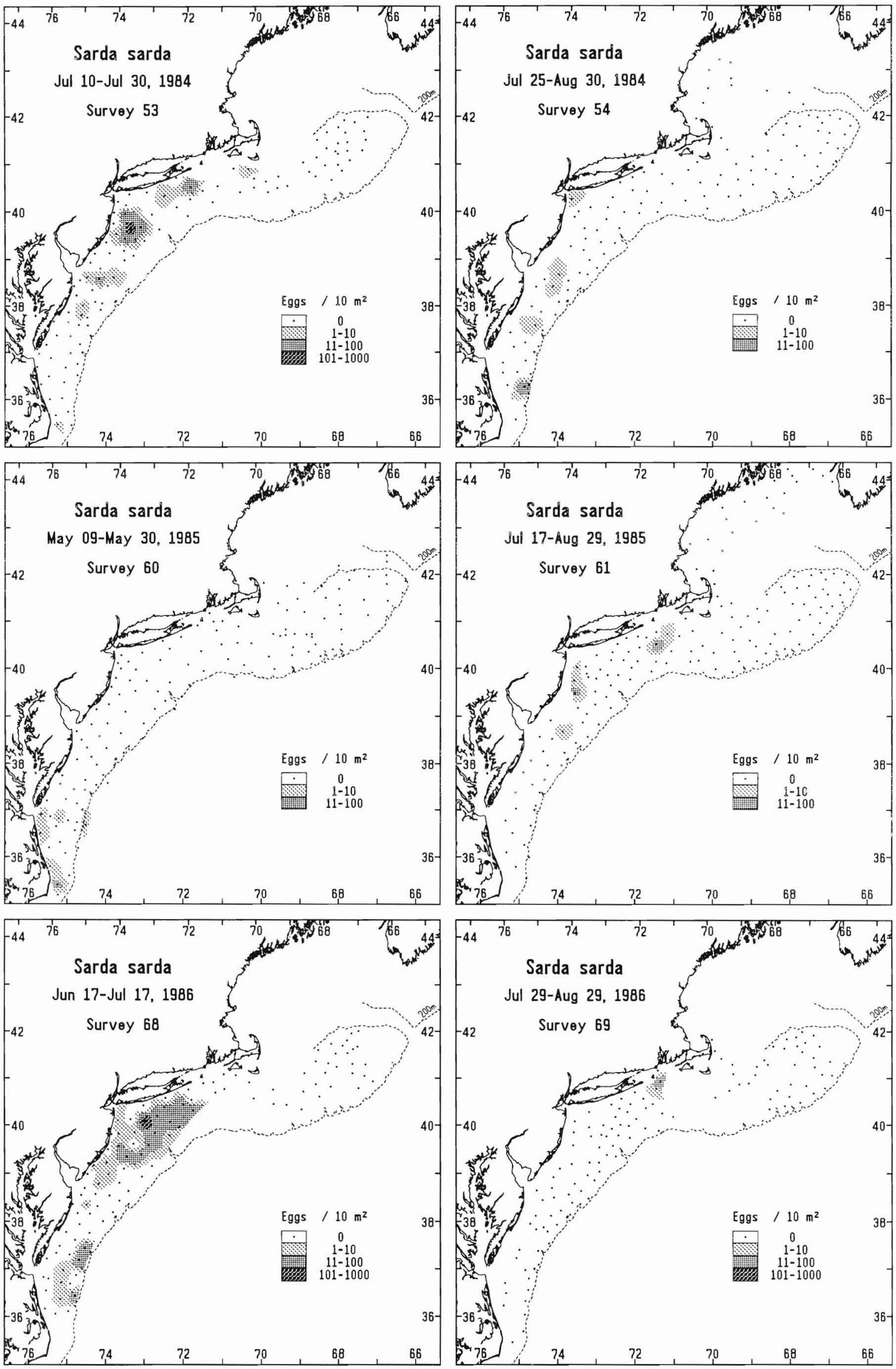


Figure 77 (continued)

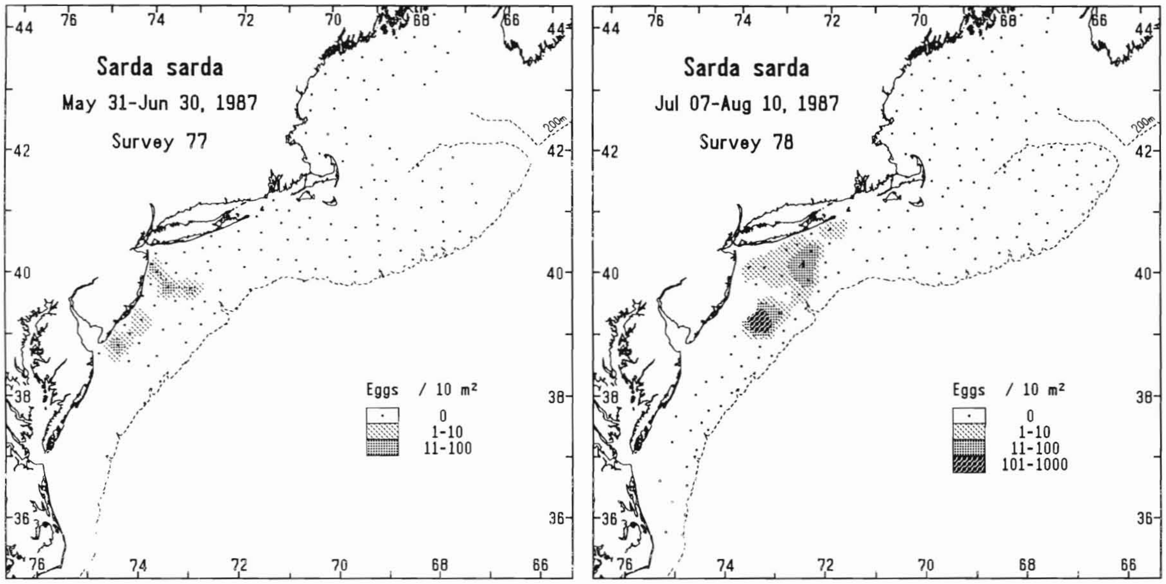


Figure 77 (continued)

Scomber scombrus, Atlantic mackerel (Figs. 78–80)

Scomber scombrus eggs were collected from April to August. They were highly seasonal in occurrence, exhibiting short periods of increasing, peak, and decreasing abundance, and occurred across the entire width of the shelf (Figs. 78 and 79).

S. scombrus eggs were one of the most abundant species taken, second only to *Anchoa mitchilli* in total eggs caught. This is a highly migratory species, and spawns as it moves (Sette, 1943). Areas of high egg abundance, indicating concentrations of spawners, shifted northward and eastward as the season progressed. In April eggs occurred over most of the Middle Atlantic subarea and into southern New England waters. Dramatically higher egg densities in May and June reflected peak spawning that was most intense in southern New England and western Gulf of Maine. Spawning rapidly declined in July, ending in August at isolated locations in southern New England, Georges Bank, and Gulf of Maine.

A decline in egg abundance and spawning levels occurred between 1977 and 1987 (Fig. 78). Neither the two highest survey values shown (1977 and 1979), nor the lower levels in more recent years (except perhaps 1985) could be accounted for by a bias in sampling coverage (Fig. 80).

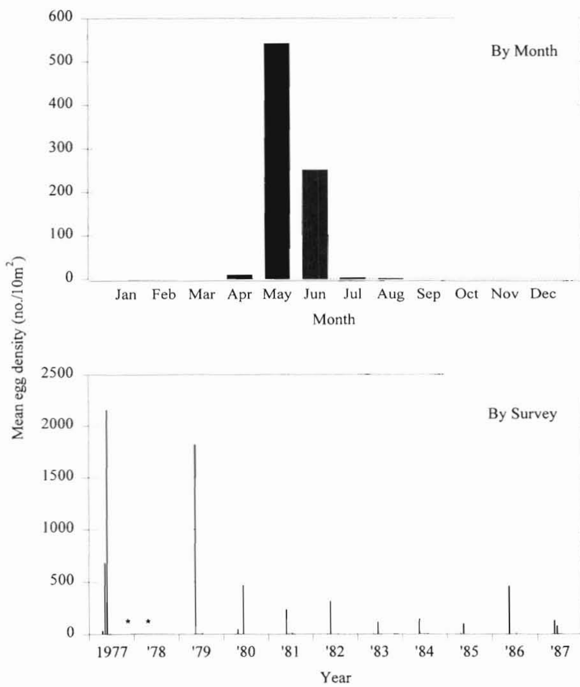


Figure 78
Scomber scombrus; mean-egg-density graphs by month (top) and by survey (bottom) for the total MARMAP area. (*Samples from the last two surveys in 1977 and the first four surveys in 1978 were not analyzed for *S. scombrus* eggs.)

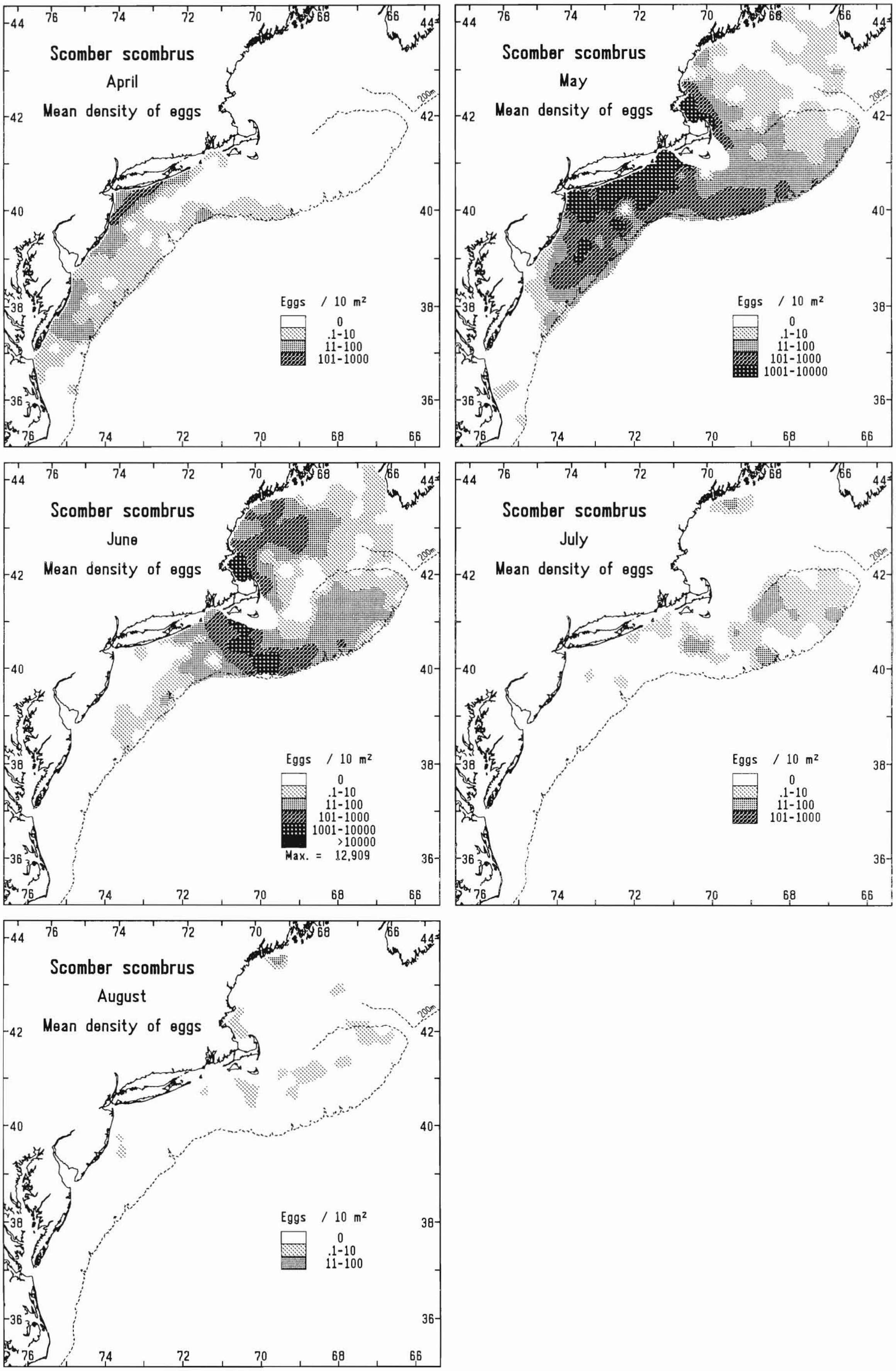


Figure 79

Scomber scombrus; composite monthly areal plots of mean egg densities (no./10 m²).

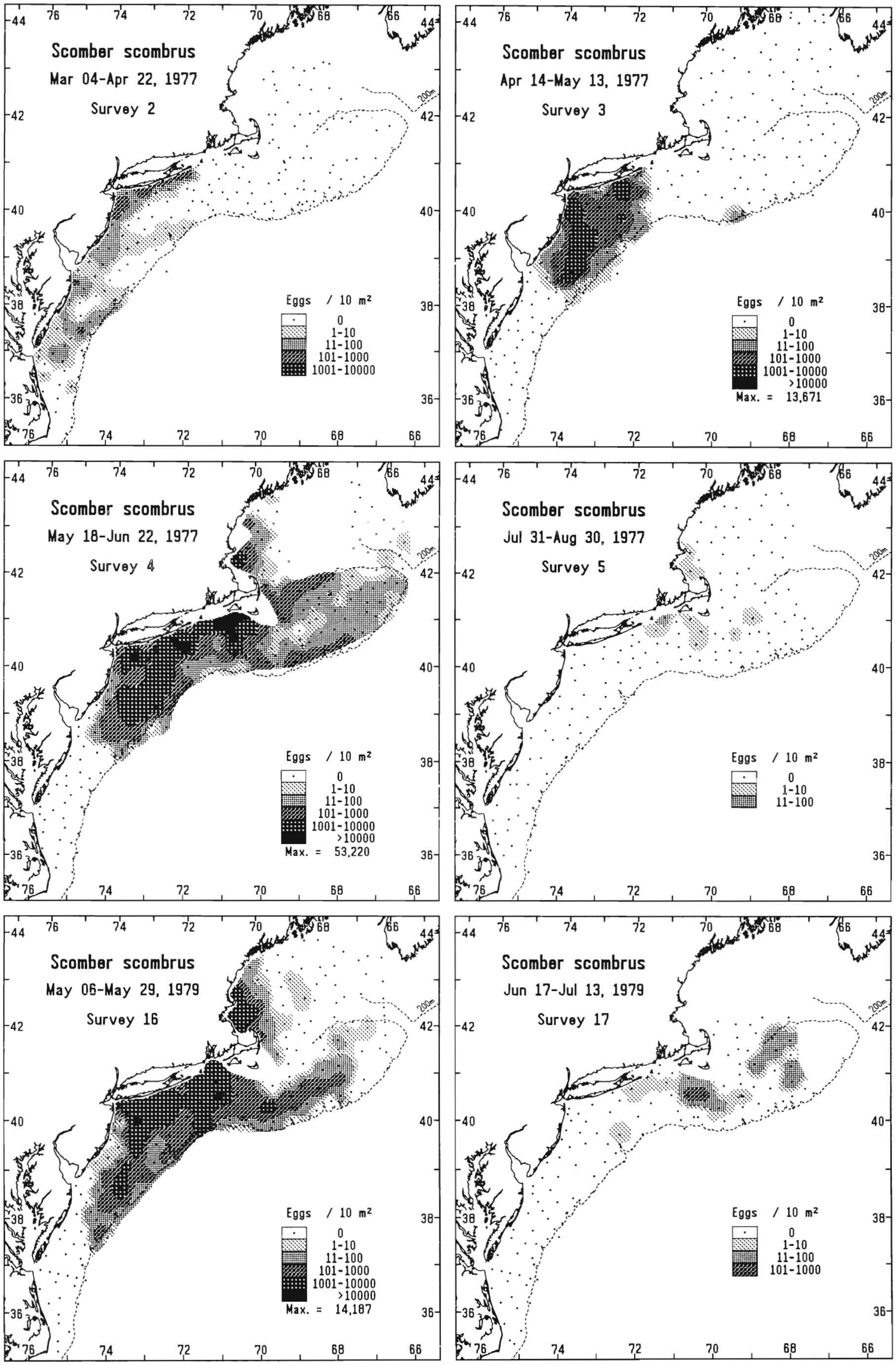


Figure 80
Scomber scombrus; survey areal plots of egg densities (no./10 m²).

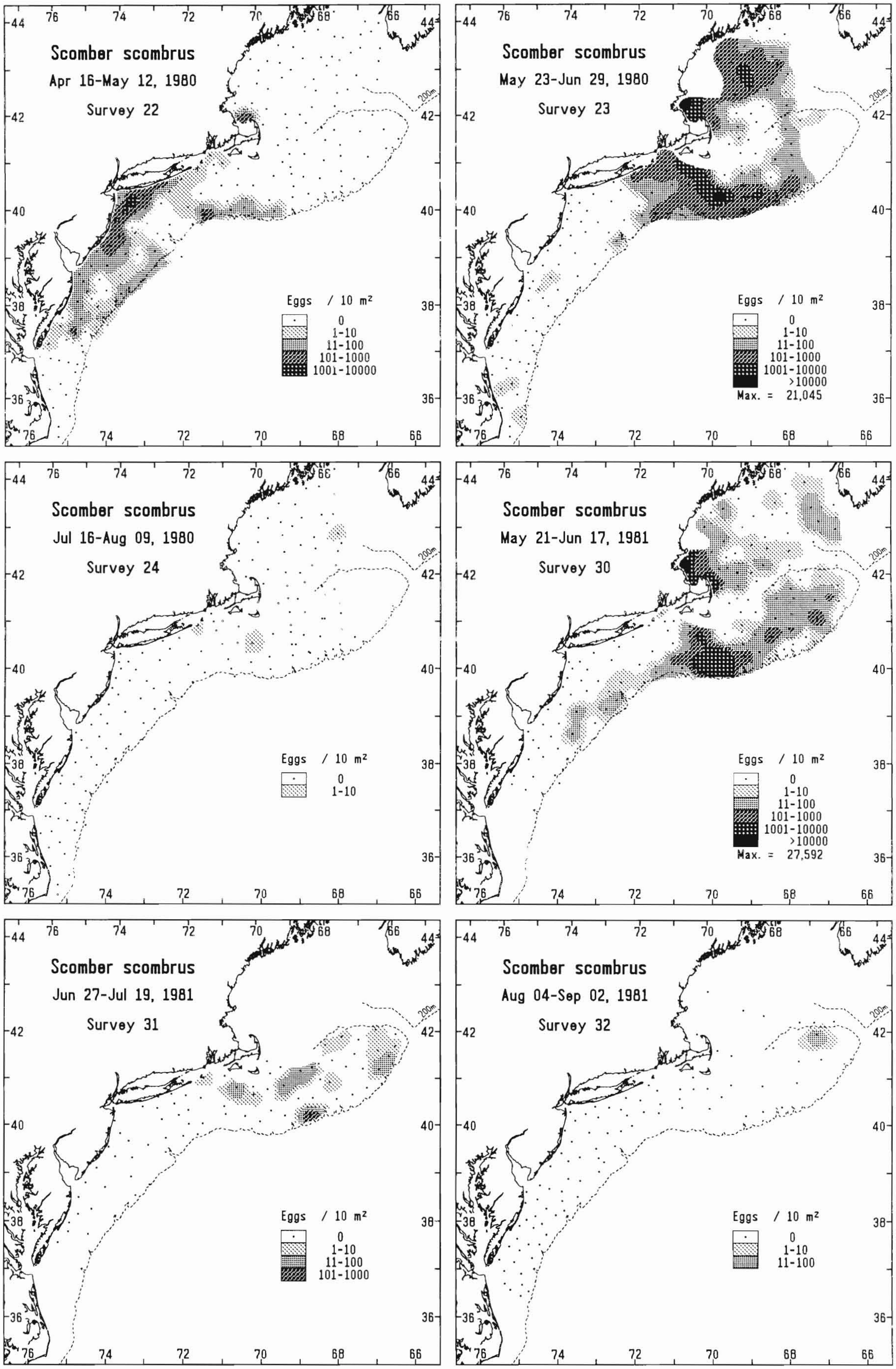


Figure 80 (continued)

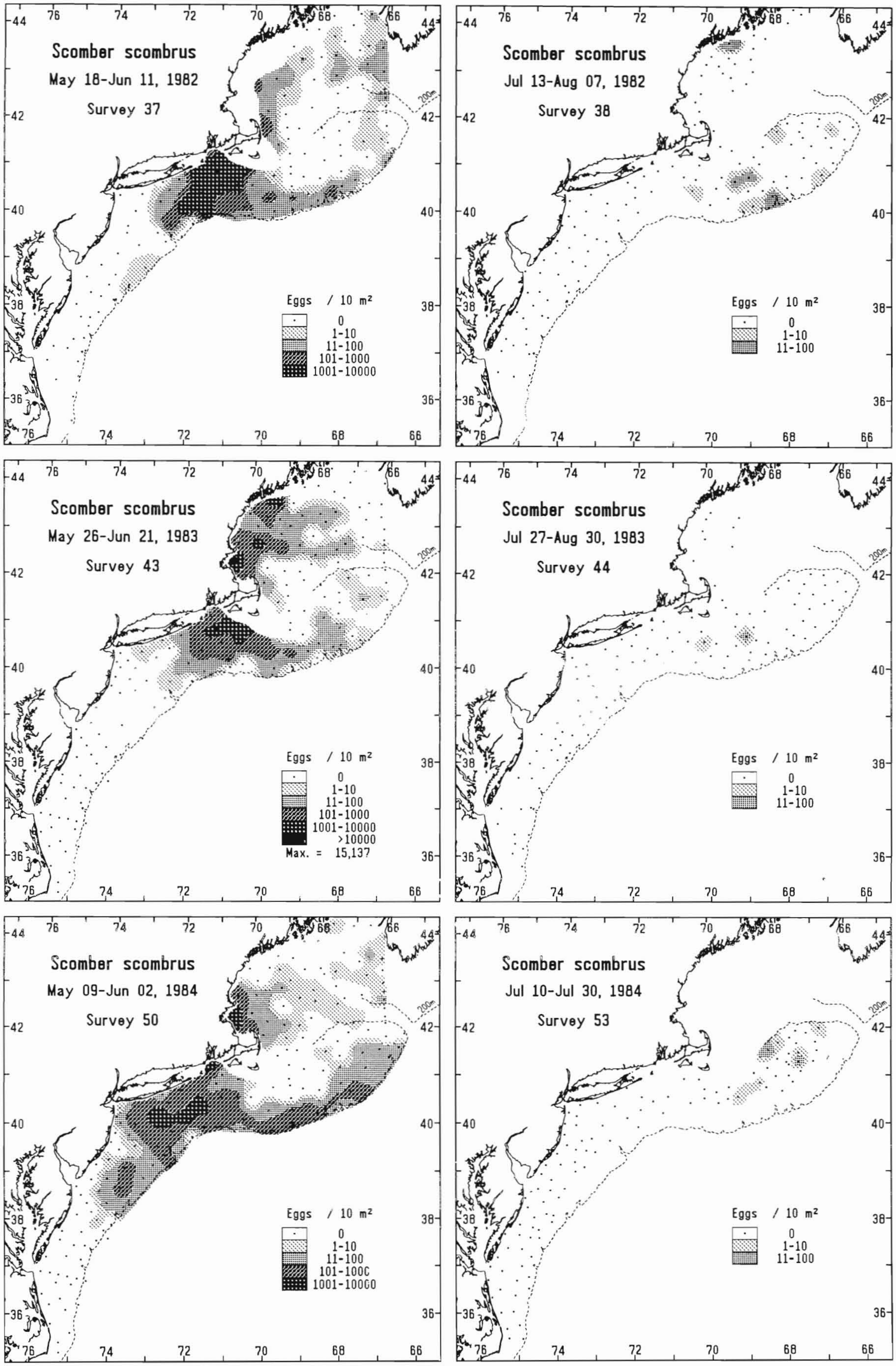


Figure 80 (continued)

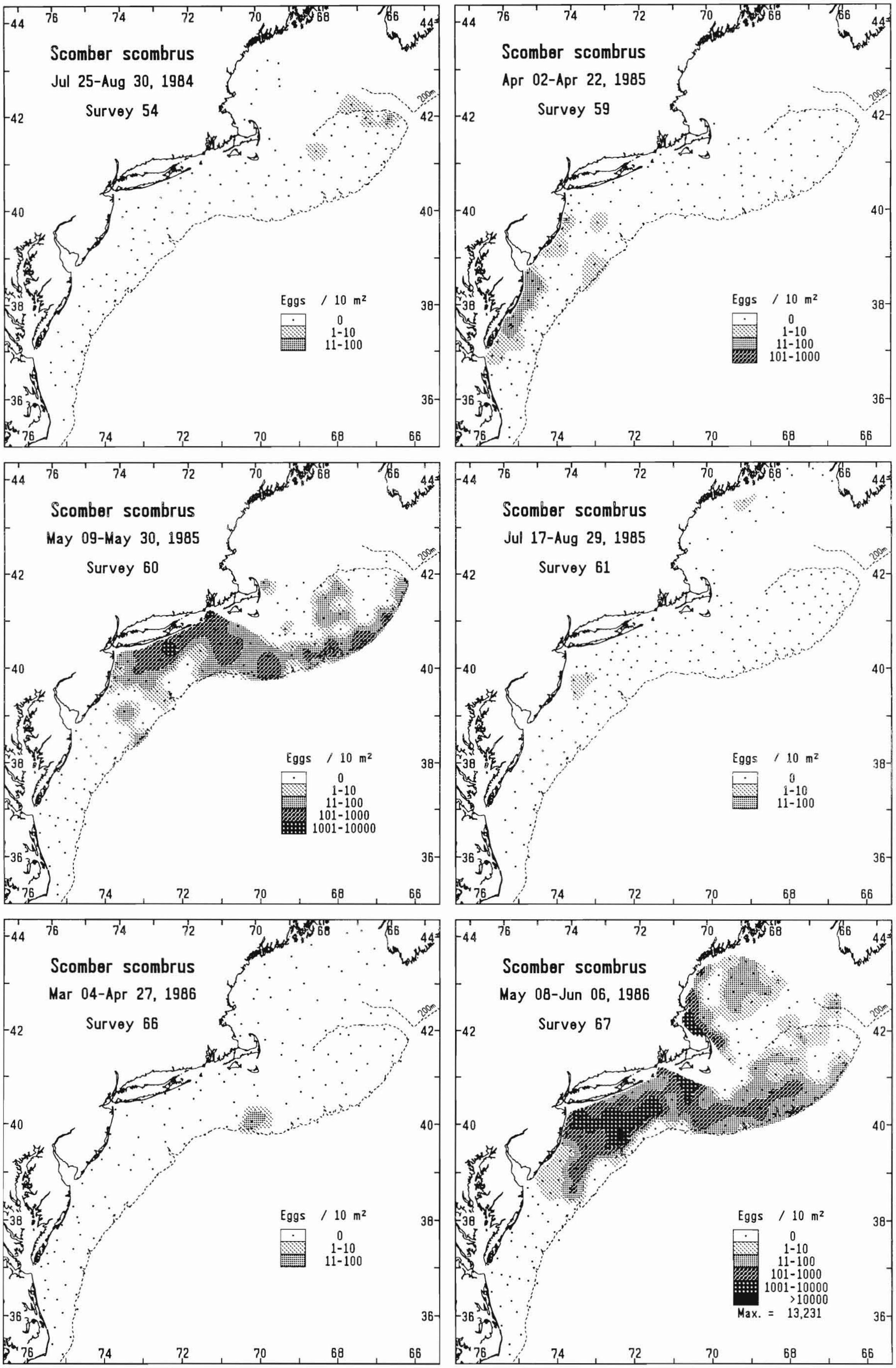


Figure 80 (continued)

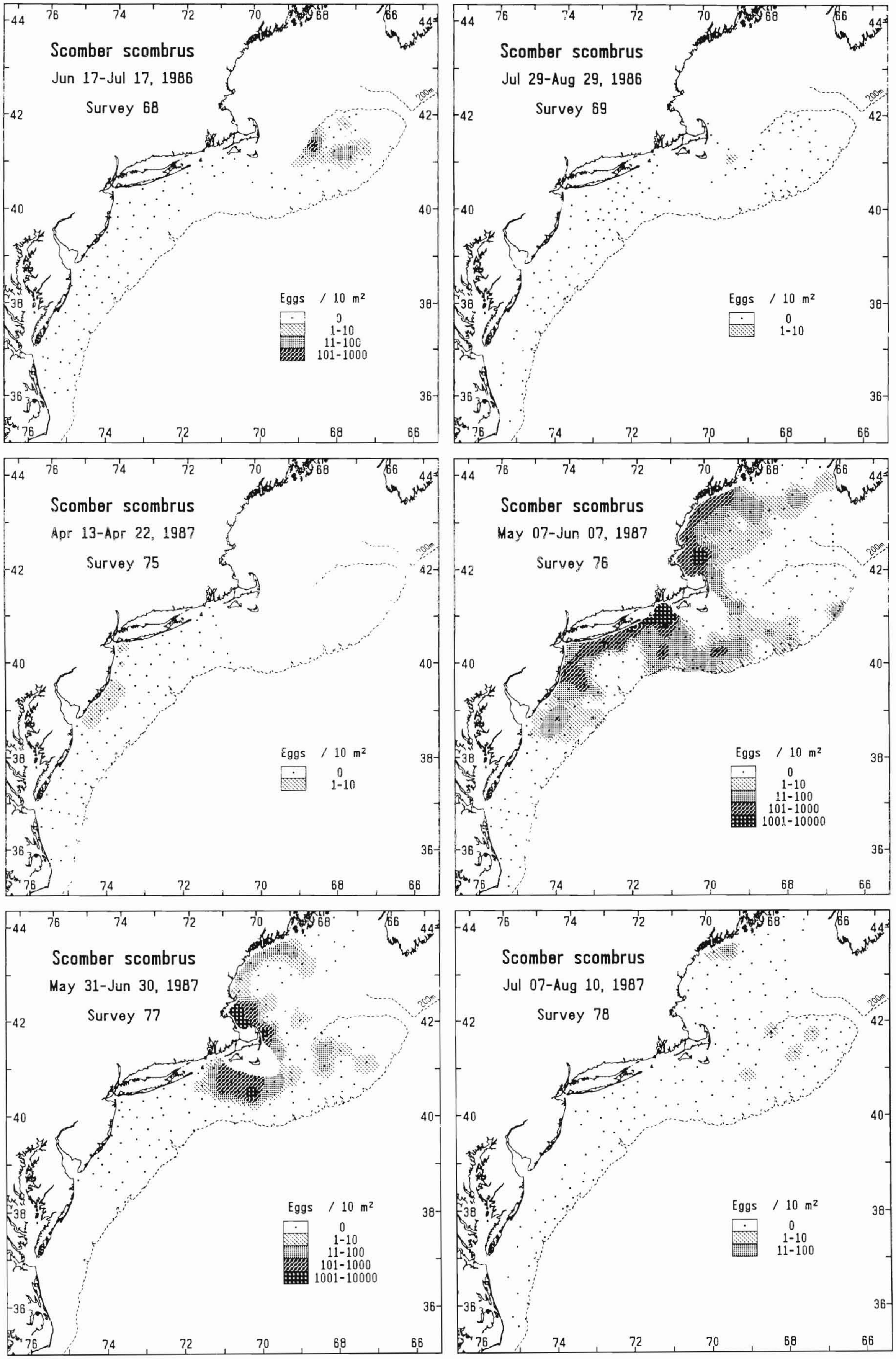


Figure 80 (continued)

Peprilus triacanthus, butterfish (Figs. 81–83)

Peprilus triacanthus eggs were collected from April to September, indicating spring and summer spawning (Fig. 81). They were collected throughout the survey area, with greatest concentrations found in the Middle Atlantic and southern New England subareas.

Spawning began as early as April at isolated locations, primarily along the continental slope where spring water temperatures were higher than those in adjacent shelf waters. As the season advanced and water temperatures rose, spawning advanced shoreward in a south to north progression extending onto Georges Bank and into the Gulf of Maine (Fig. 82). Peak spawning months were June and July, followed by decreased spawning in August and September (Fig. 81).

Spawning intensity decreased over the nine-year study period (Fig. 81). For the first two years (1979 and 1980), high mean egg densities exceeded 80/10 m^2. Peak mean densities for subsequent years were lower (with the exception of 1981 and 1986), ranging from 7/10 m^2 to 41/10 m^2. High densities during 1981 and 1986 (surveys 30, 31, 32, and 68) resulted in part from a lack of adequate sampling effort in areas of expected low abundance, thus biasing results of these surveys upward (Figs. 81 and 83).

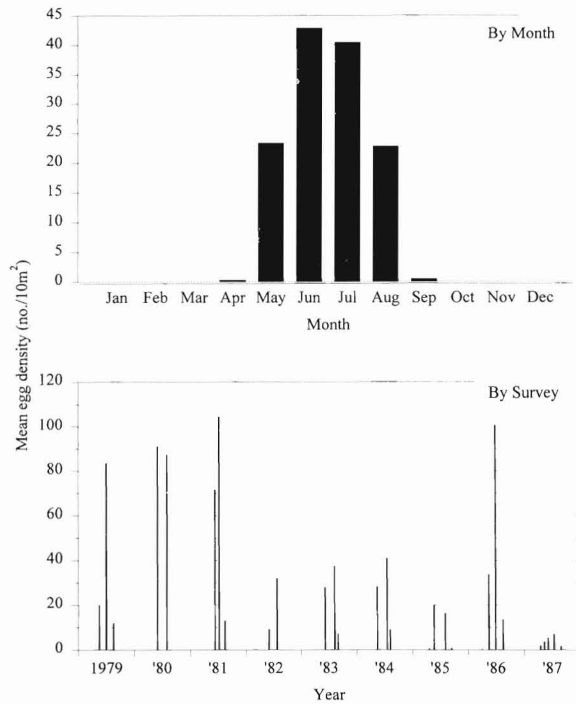


Figure 81
Peprilus triacanthus; mean-egg-density graphs by month (top) and by survey (bottom) for the total MARMAP area.

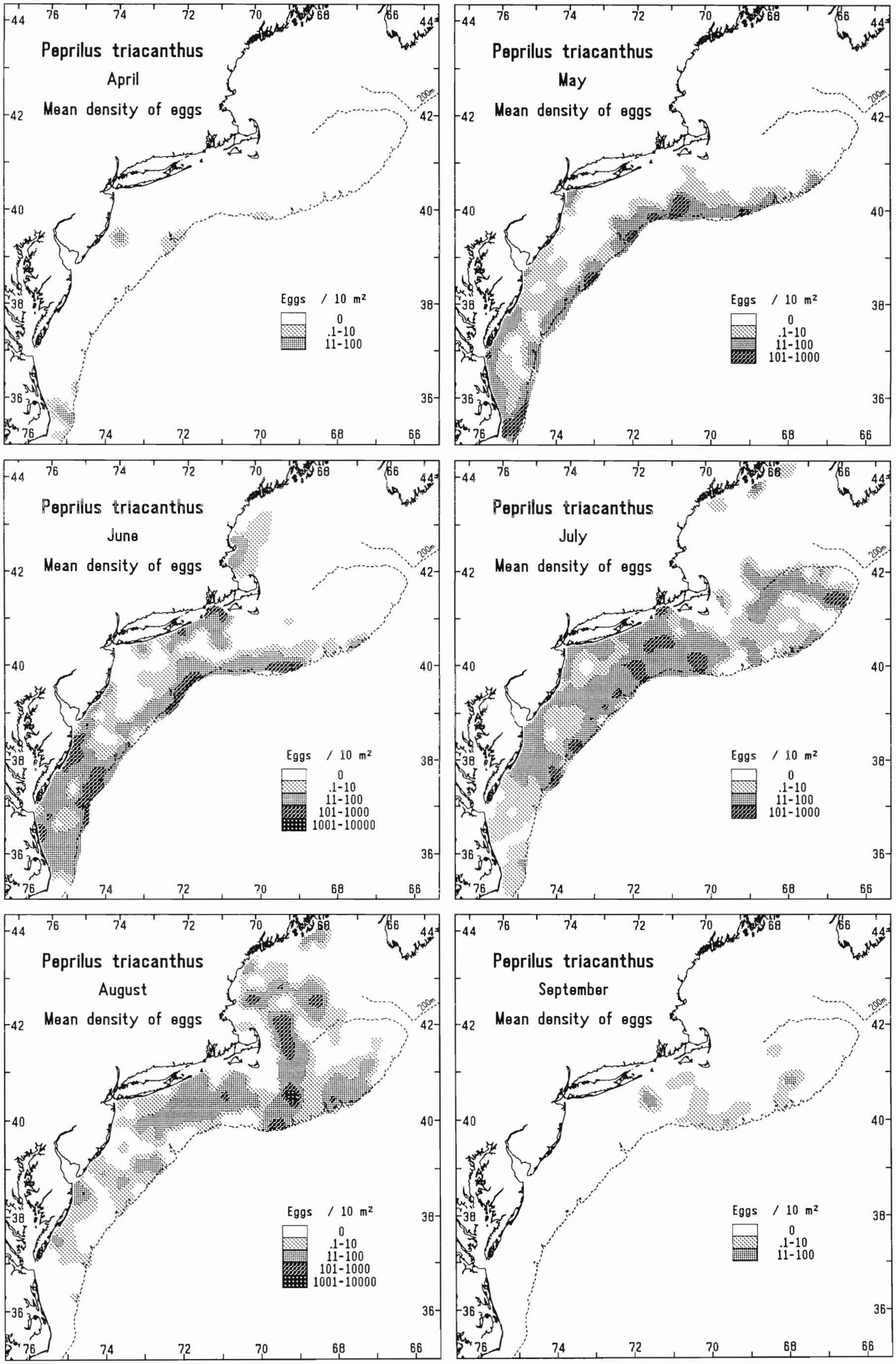


Figure 82
Peprilus triacanthus; composite monthly areal plots of mean egg densities (no./10 m²).

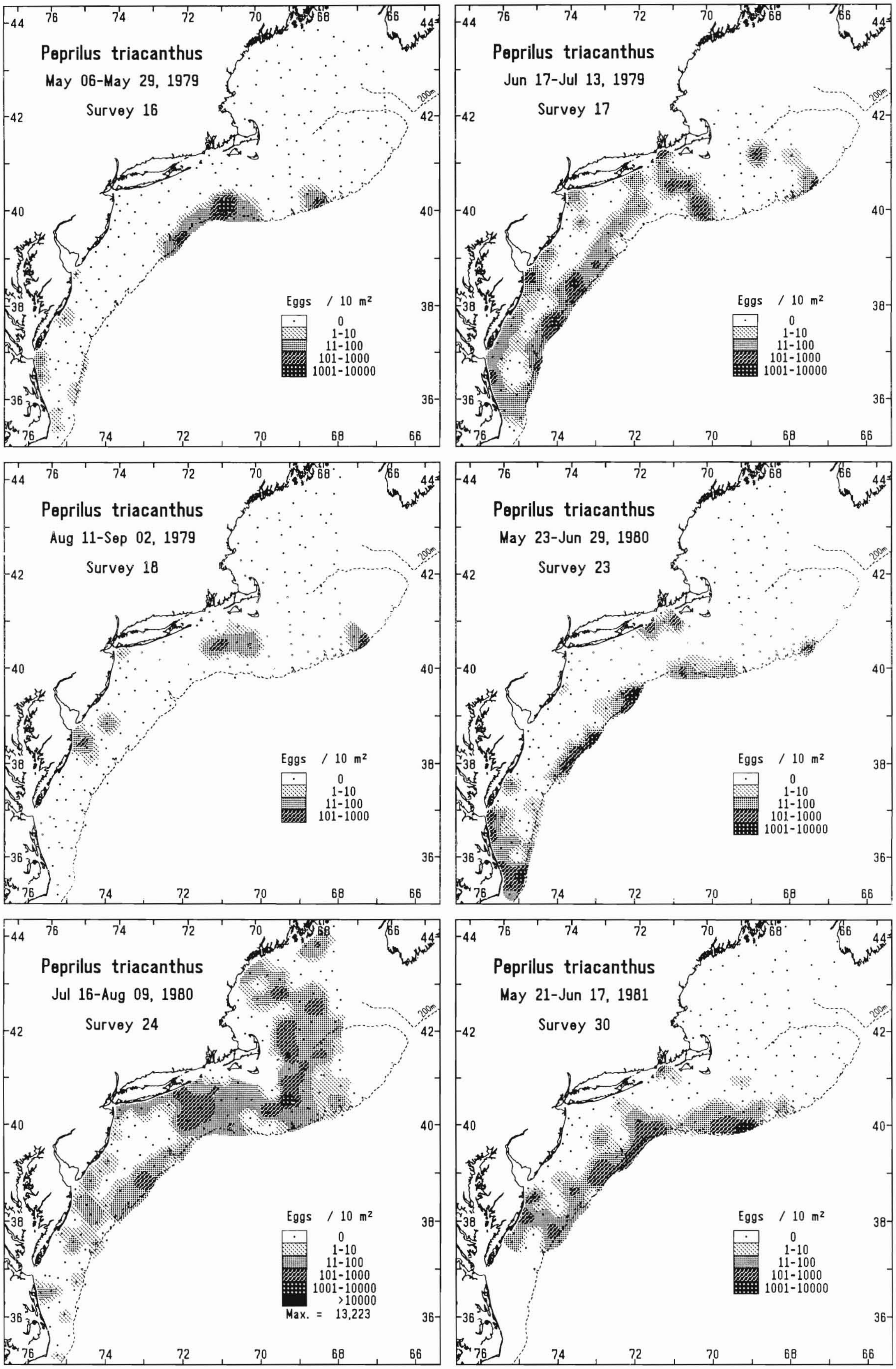


Figure 83

Peprilus triacanthus; survey areal plots of egg densities (no./10 m²).

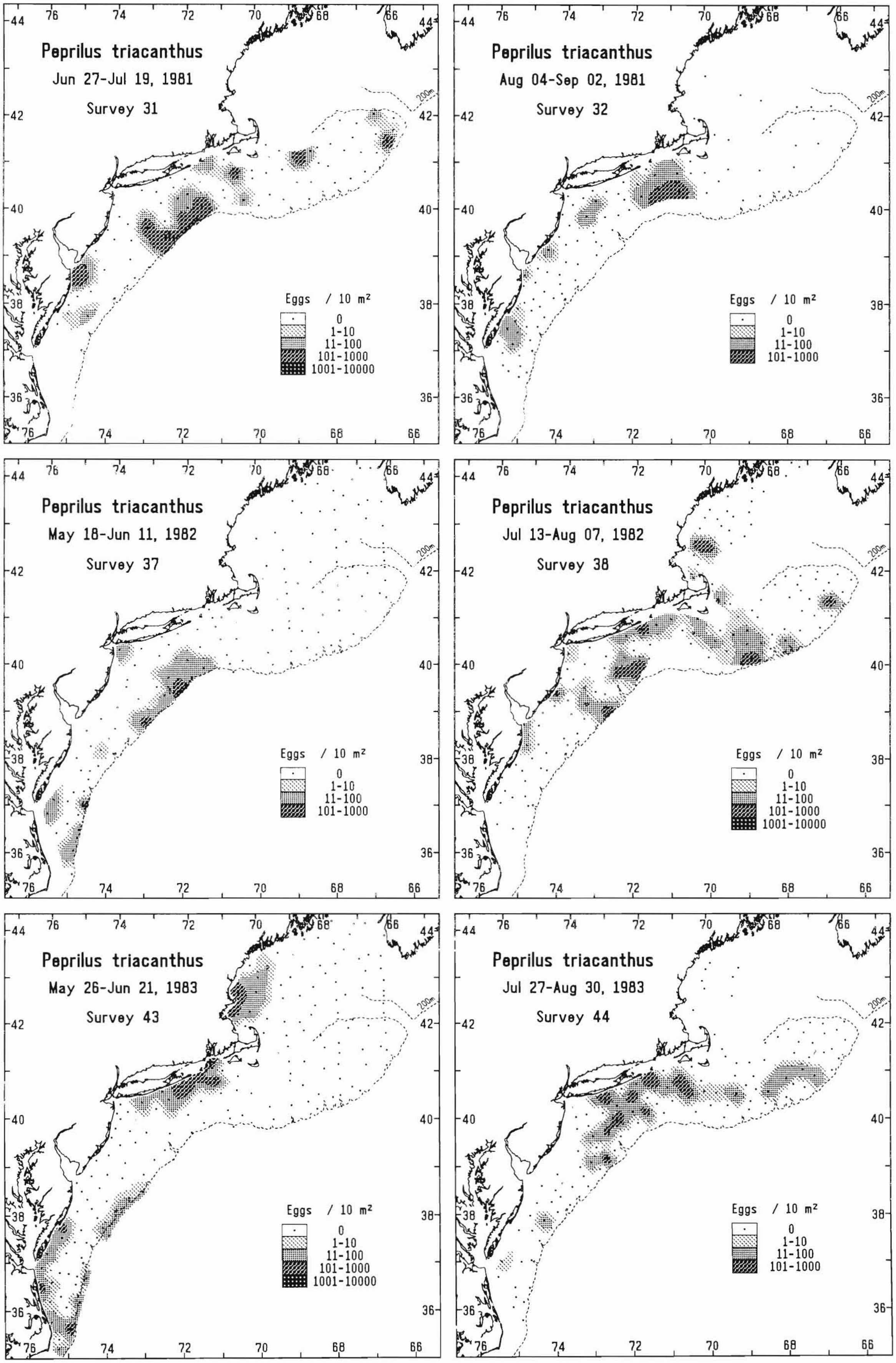


Figure 83 (continued)

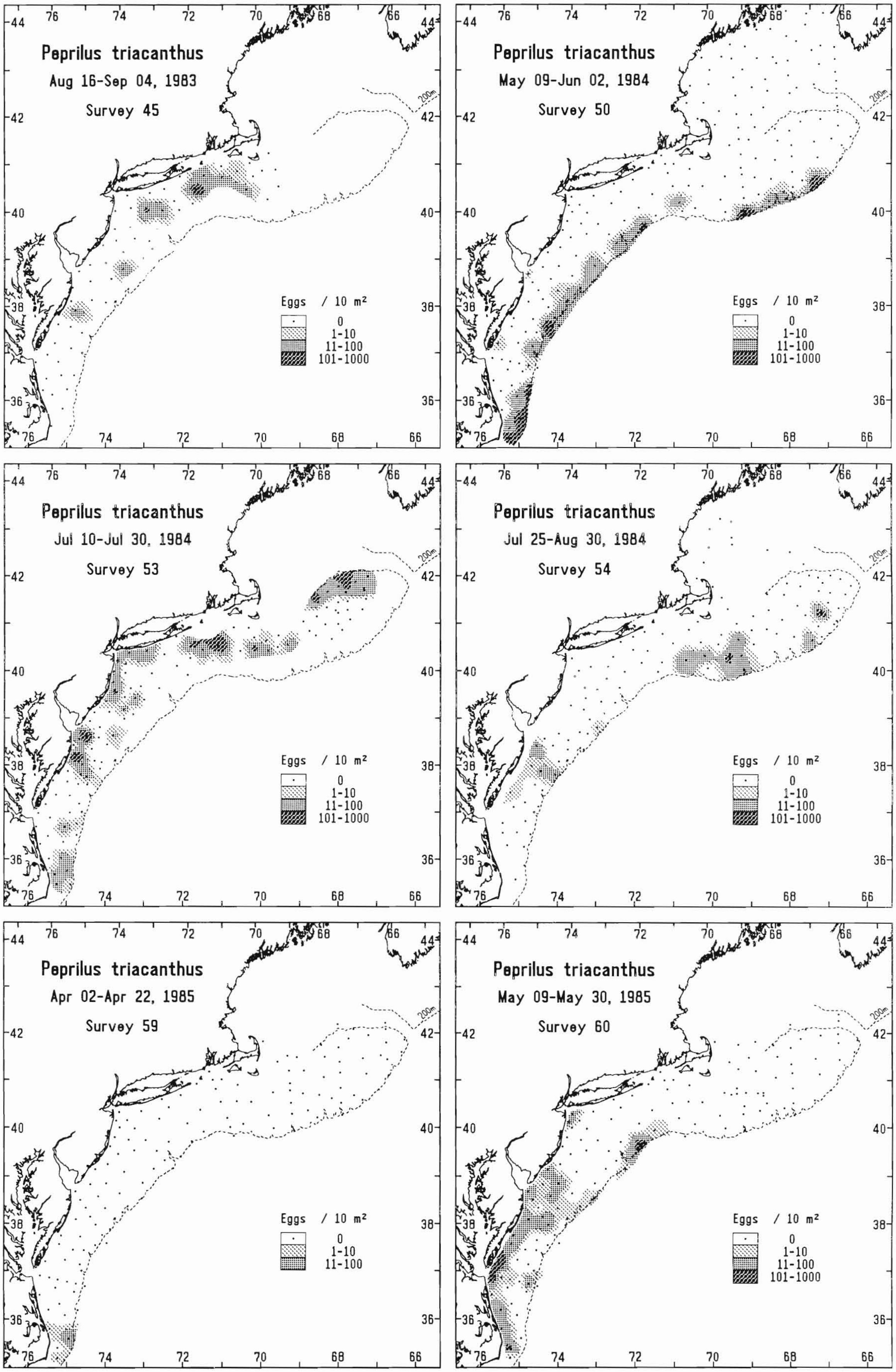


Figure 83 (continued)

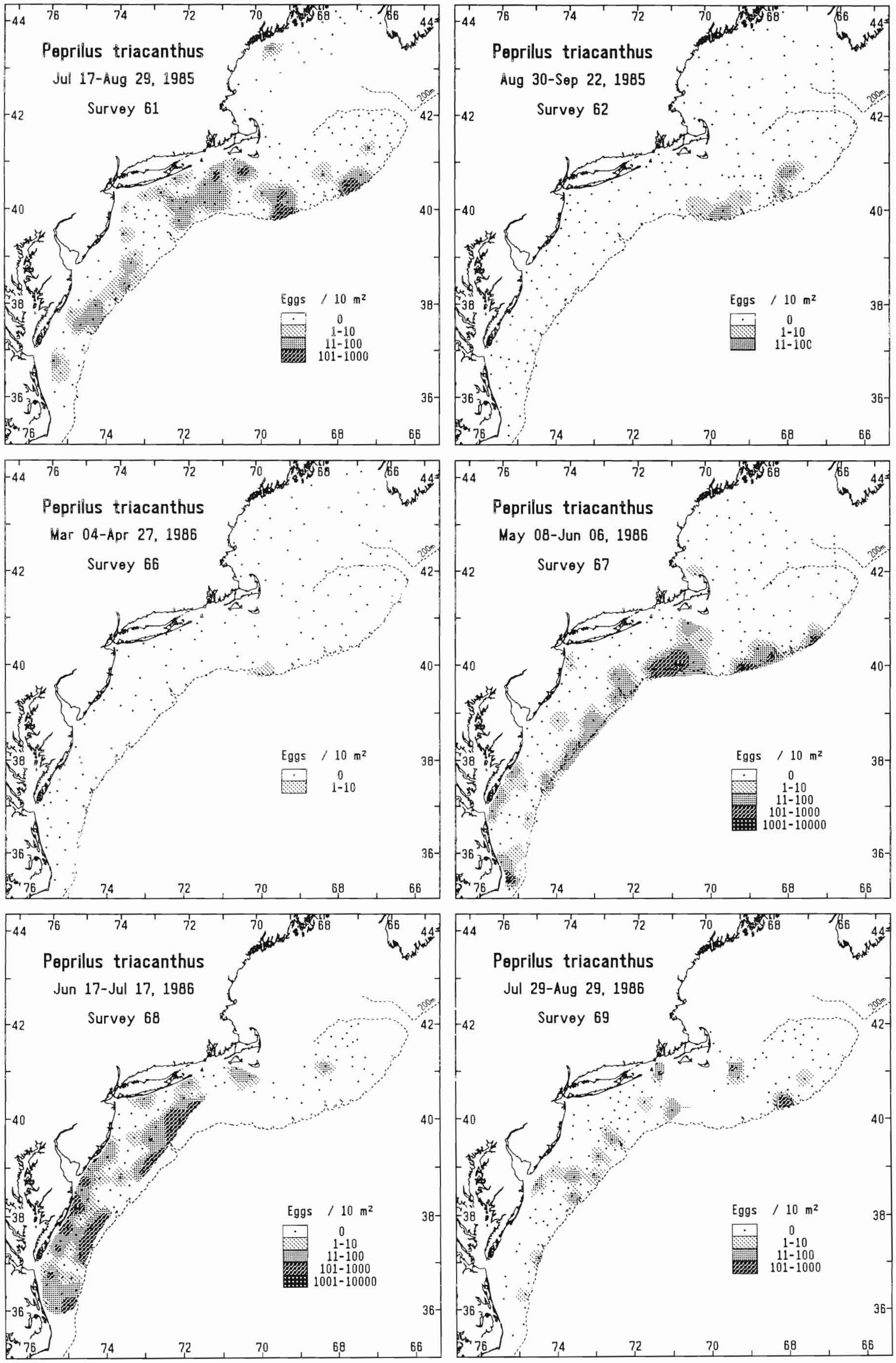


Figure 83 (continued)

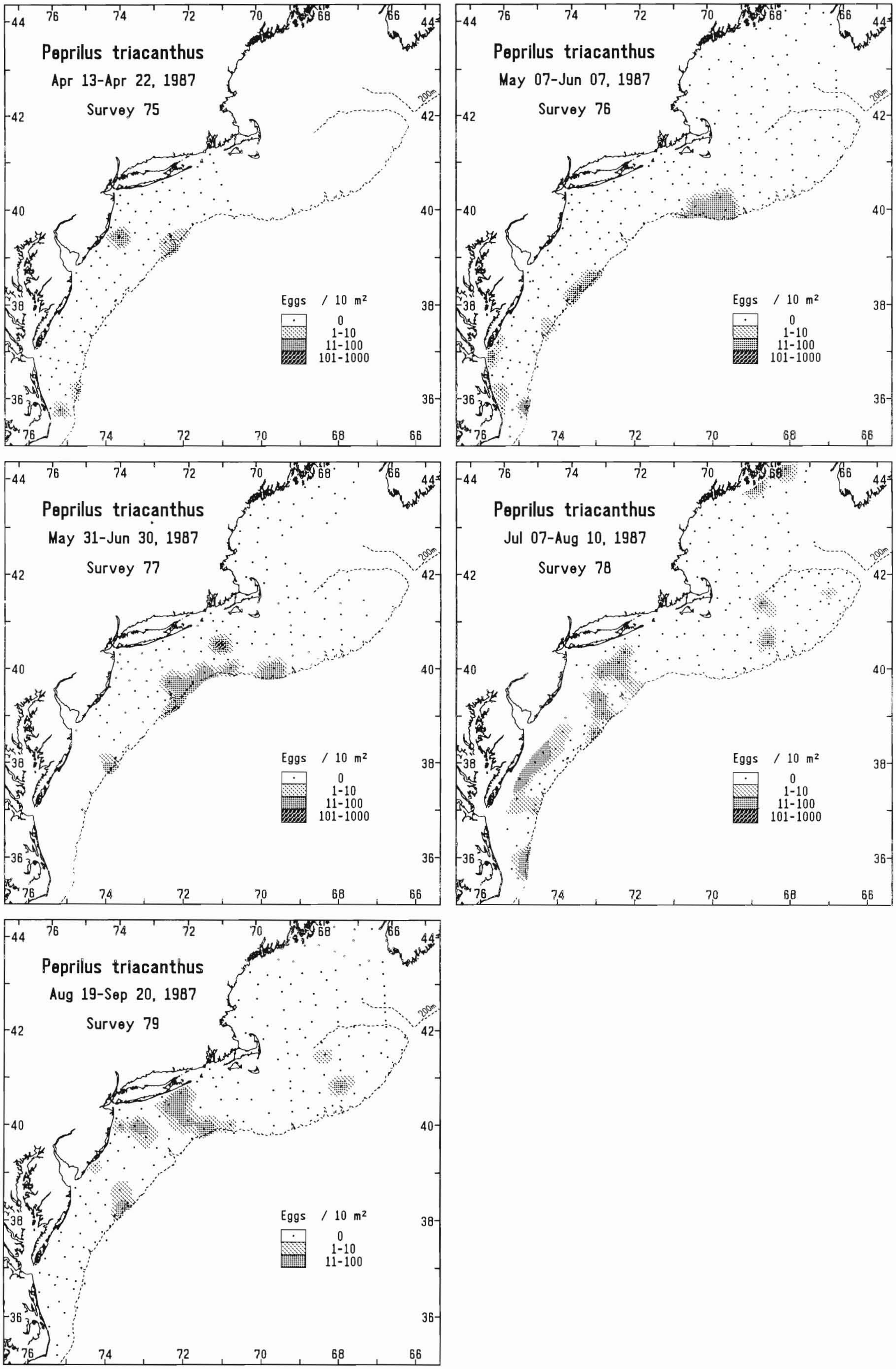


Figure 83 (continued)

Citharichthys/Etropus spp., Gulf Stream and smallmouth flounders (Figs. 84–86)

Eggs assigned to this two-genus category probably consist of two species, the deeper water *Citharichthys arctifrons*, and the relatively shallow water *Etropus microstomus*. The bi-modality in monthly egg distributions from June, July, and August, and to a lesser extent May, is most likely due to the two-species composition of the data.

Eggs of *Citharichthys/Etropus* spp. were collected during 11 months of the year; absent only during December. They were most abundant in summer (Fig. 84).

Spawning began near Cape Hatteras in April and increased rapidly during May. Spawning occurred throughout the Middle Atlantic and southern New England subareas and the southern portion of Georges Bank. Through June, July, and August eggs occurred in the same areas but in greater numbers than in May. Spawning peaked in July and August and, by August, expanded to include most of Georges Bank. Thereafter, spawning decreased in intensity through September and October, and by November decreased dramatically in areal extent (Fig. 85). Spawning was minimal from January to March. The apparent lack of eggs from December samples is most likely due to lack of sampling in all years in the area from Chesapeake Bay southward (Fig. 2). There was no apparent change in the overall abundance of *Citharichthys/Etropus* eggs over the sampling period (Fig. 84).

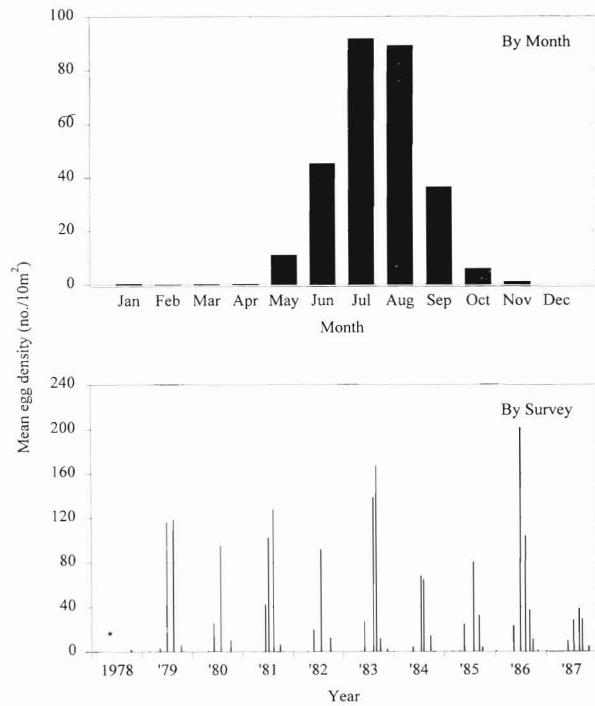


Figure 84

Citharichthys/Etropus; mean-egg-density graphs by month (top) and by survey (bottom) for the total MARMAP area. (*Samples from the first four surveys in 1978 were not analyzed for *Citharichthys/Etropus* eggs.)

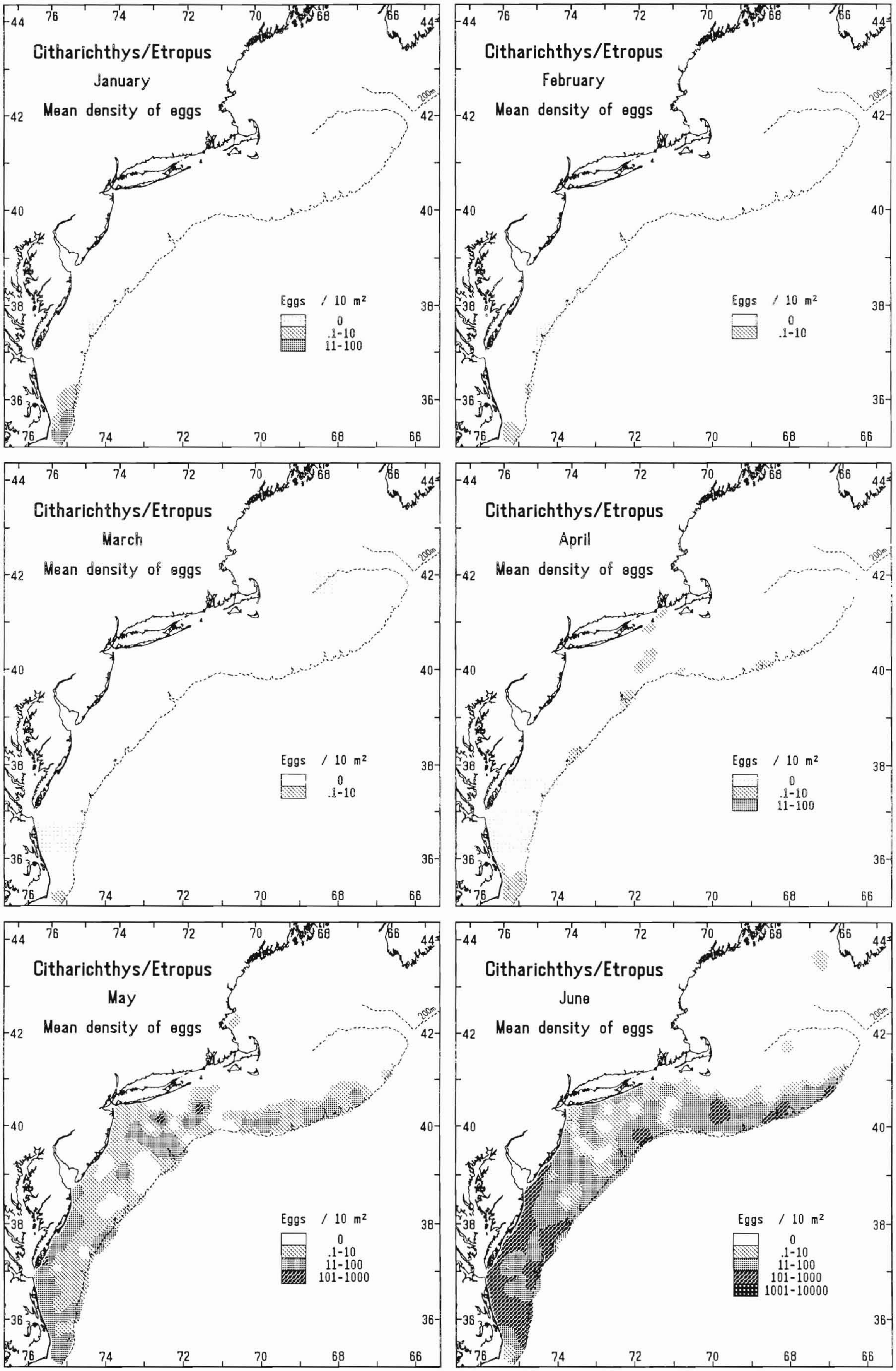


Figure 85

Citharichthys/Etropus; composite monthly areal plots of mean egg densities (no./10 m²).

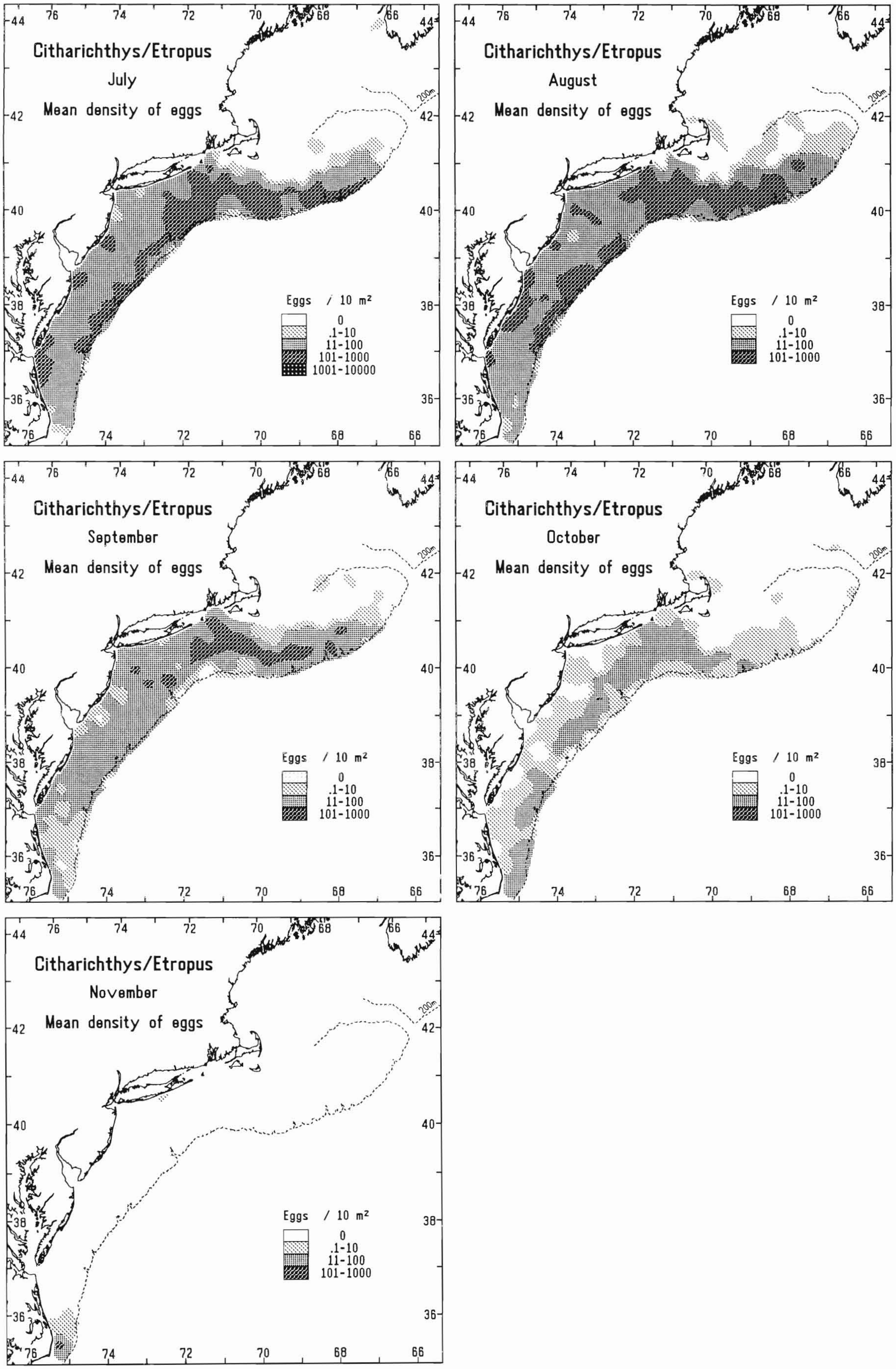


Figure 85 (continued)

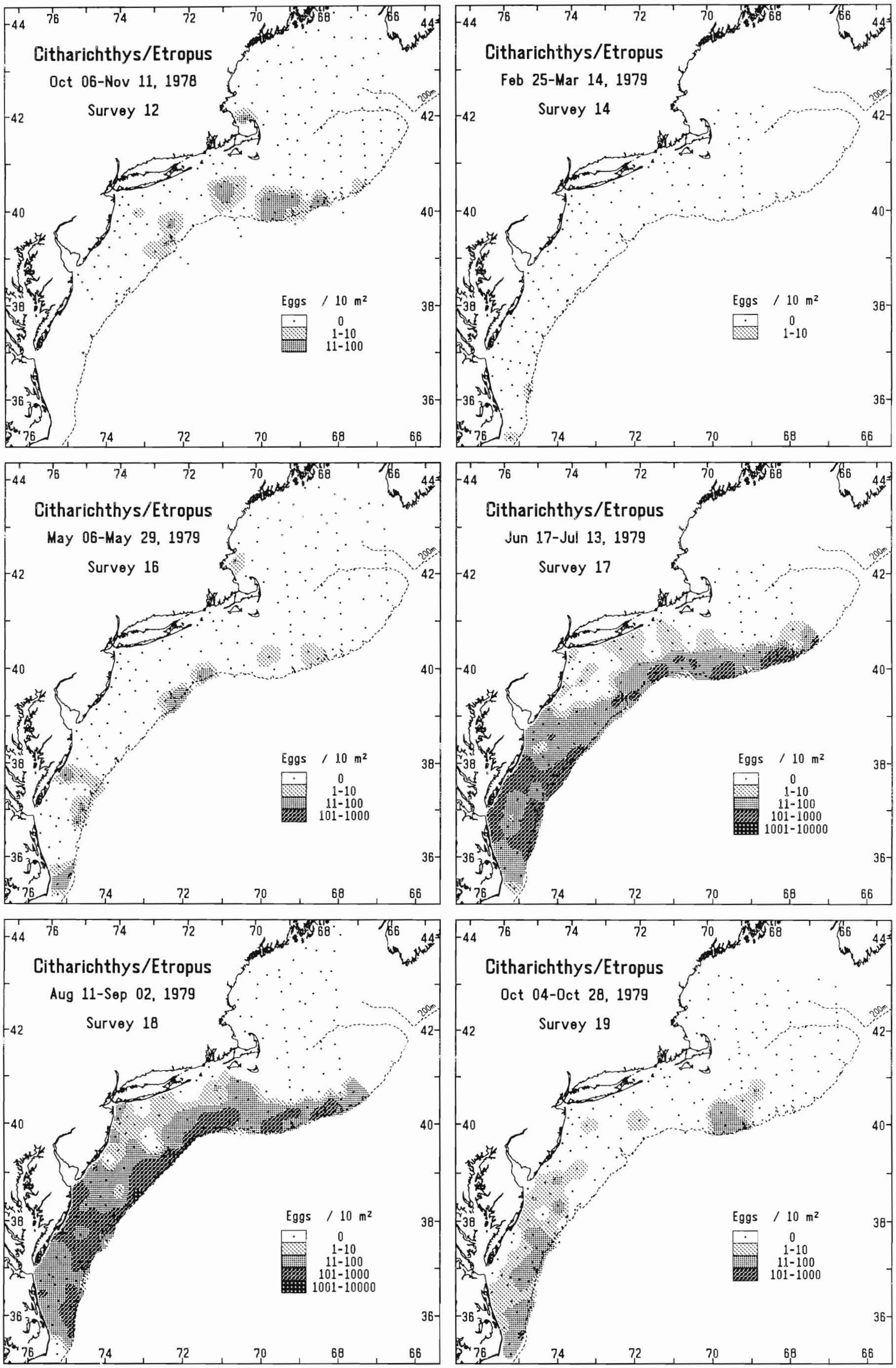


Figure 86
Citharichthys/Etropus; survey areal plots of egg densities (no./10 m²).

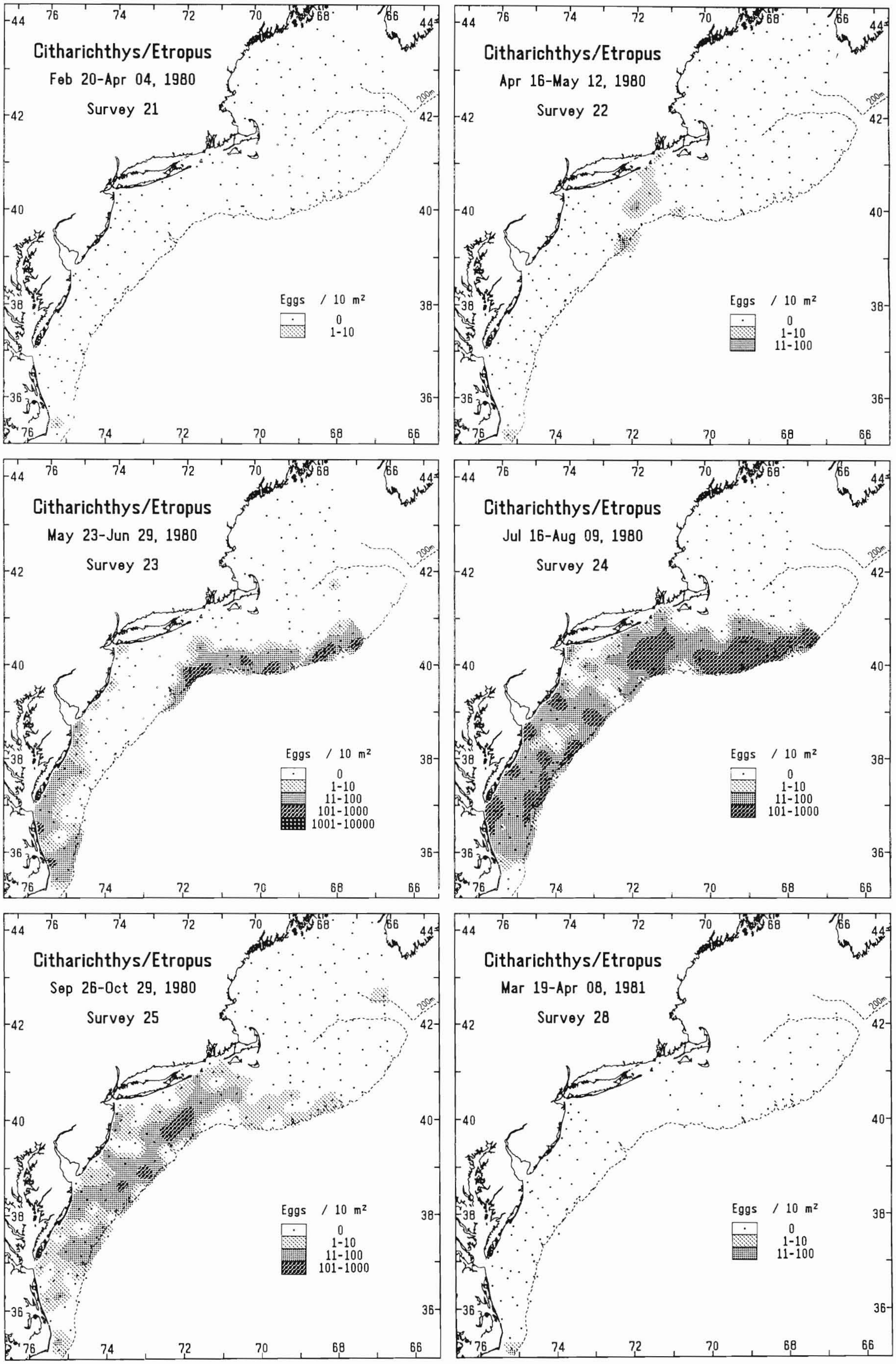
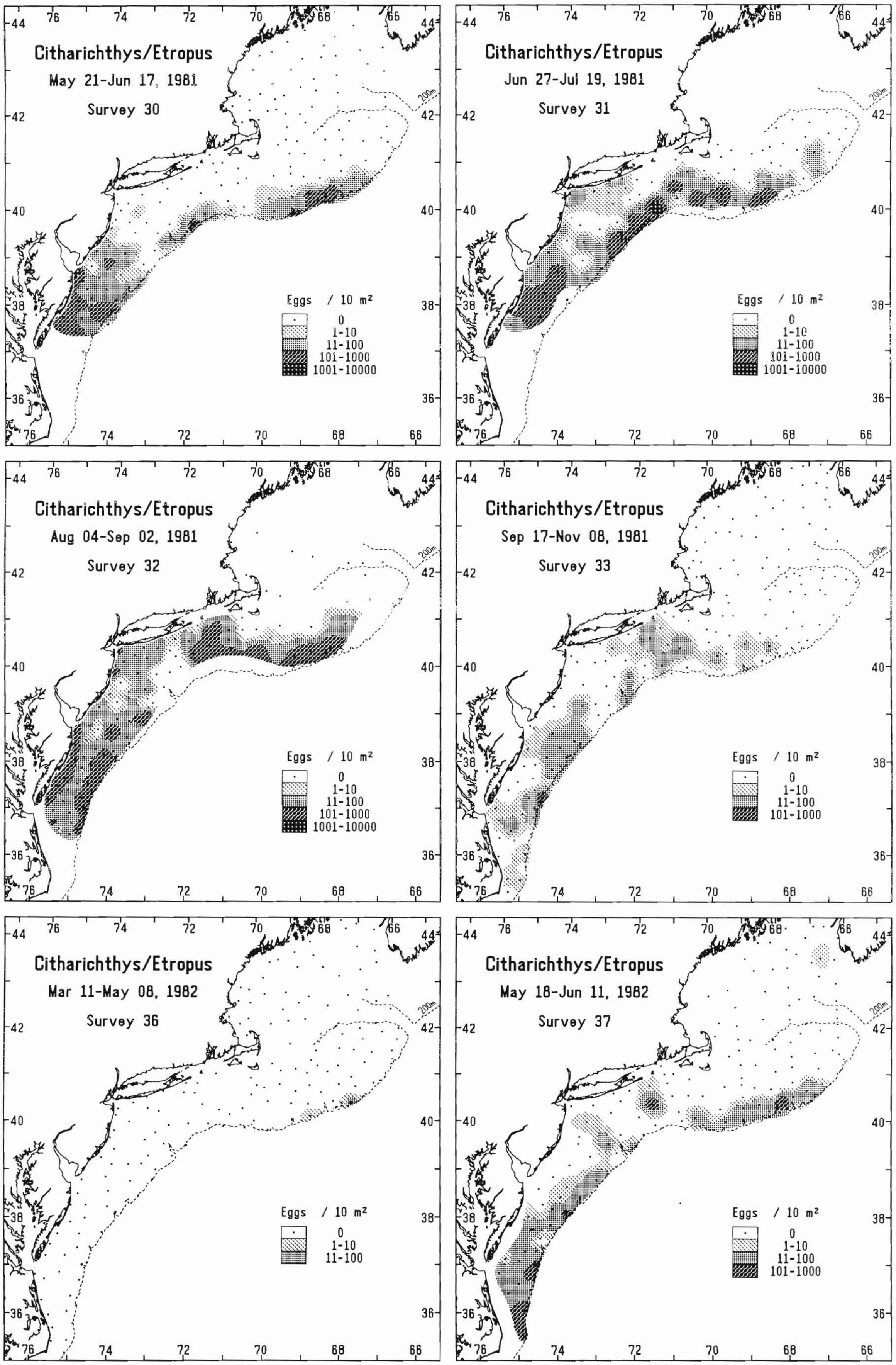


Figure 86 (continued)



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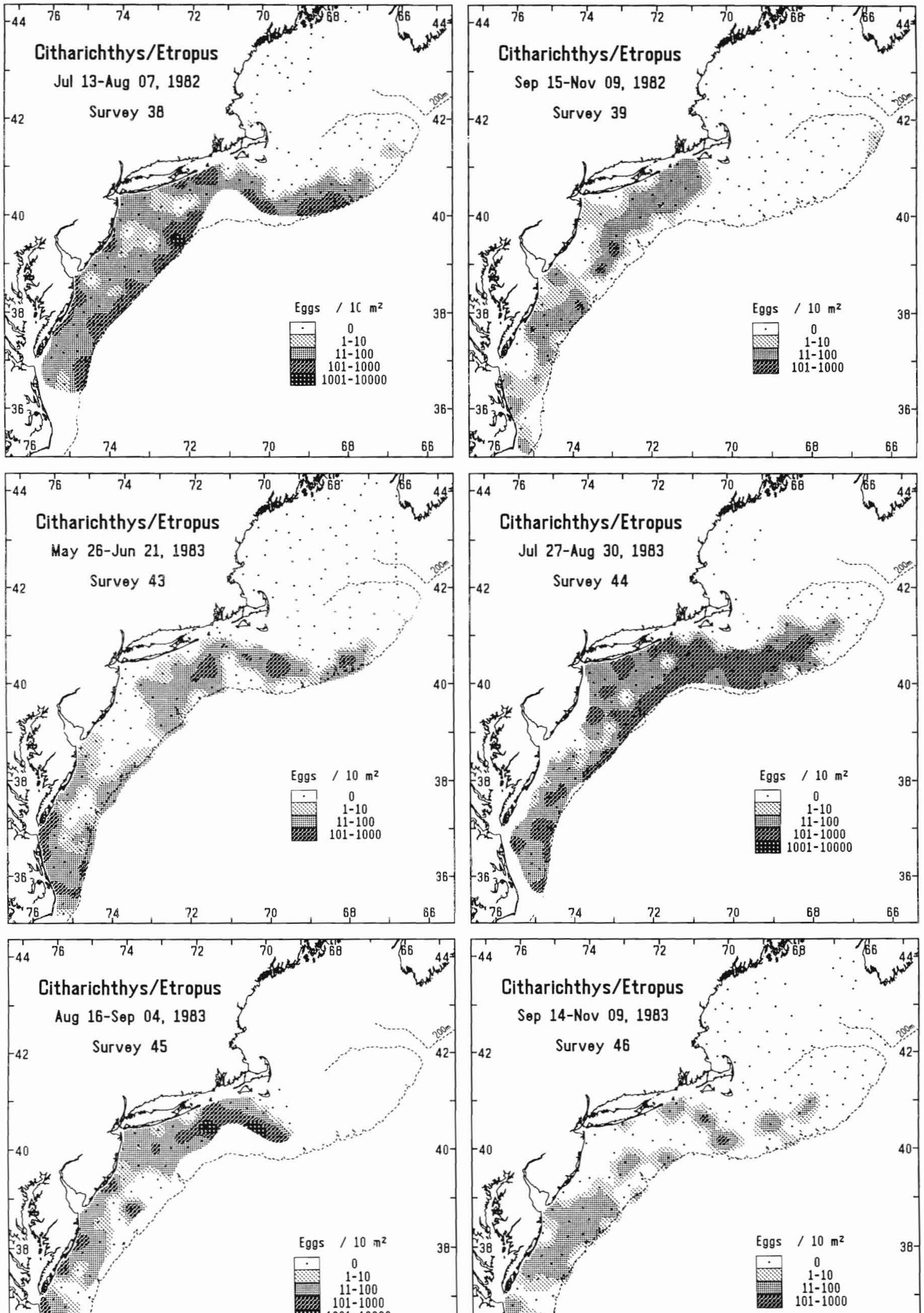

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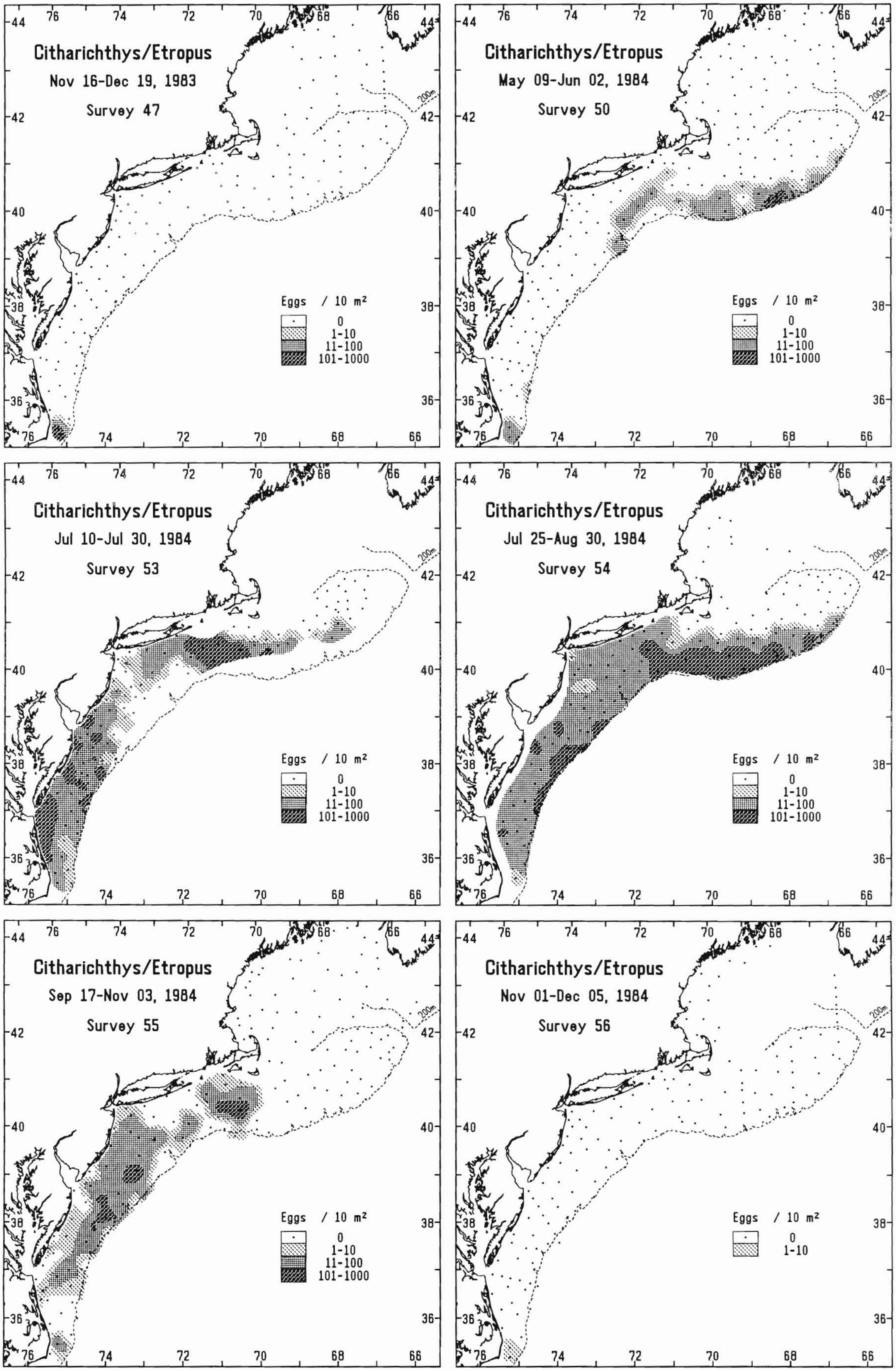

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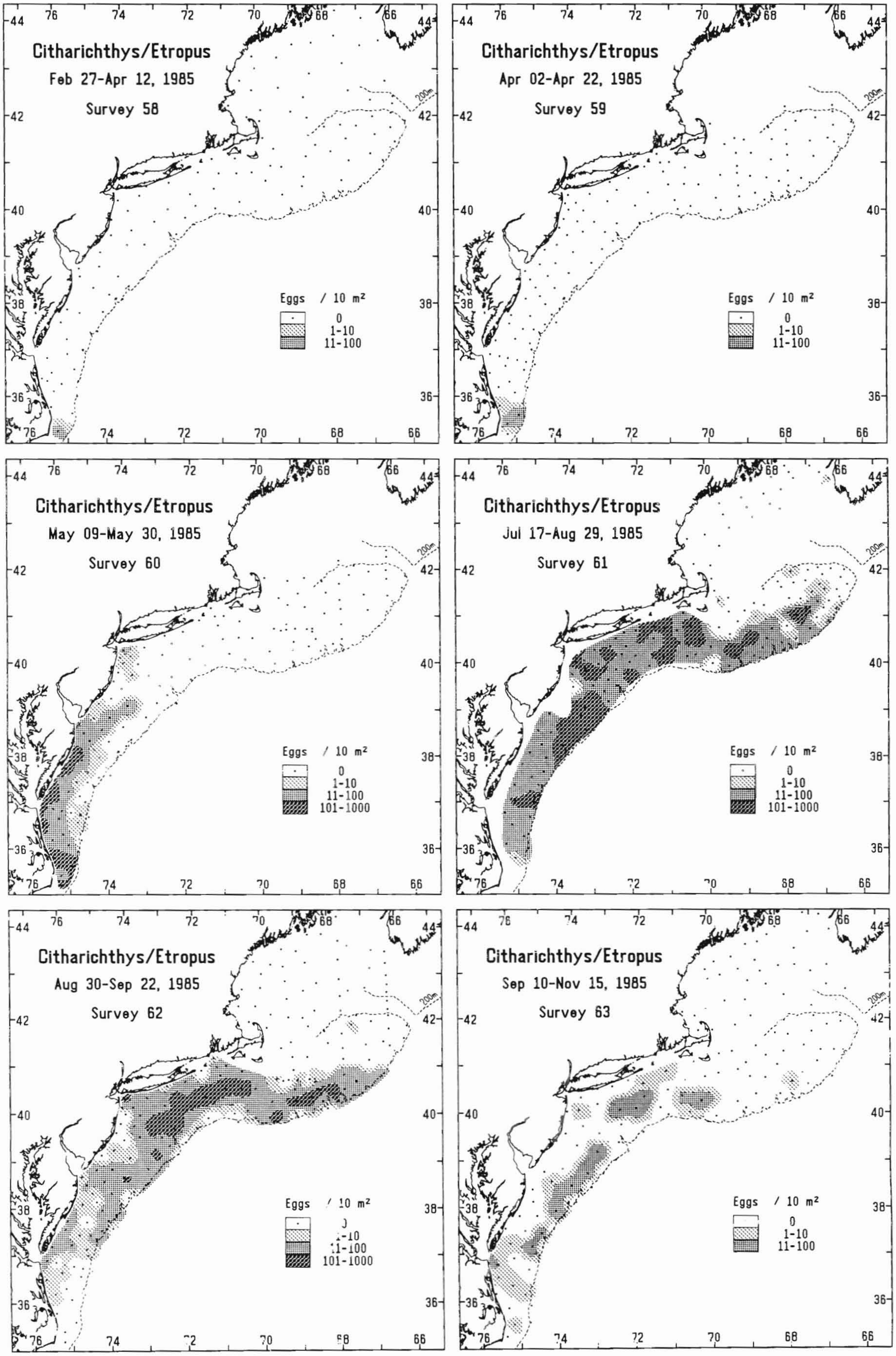
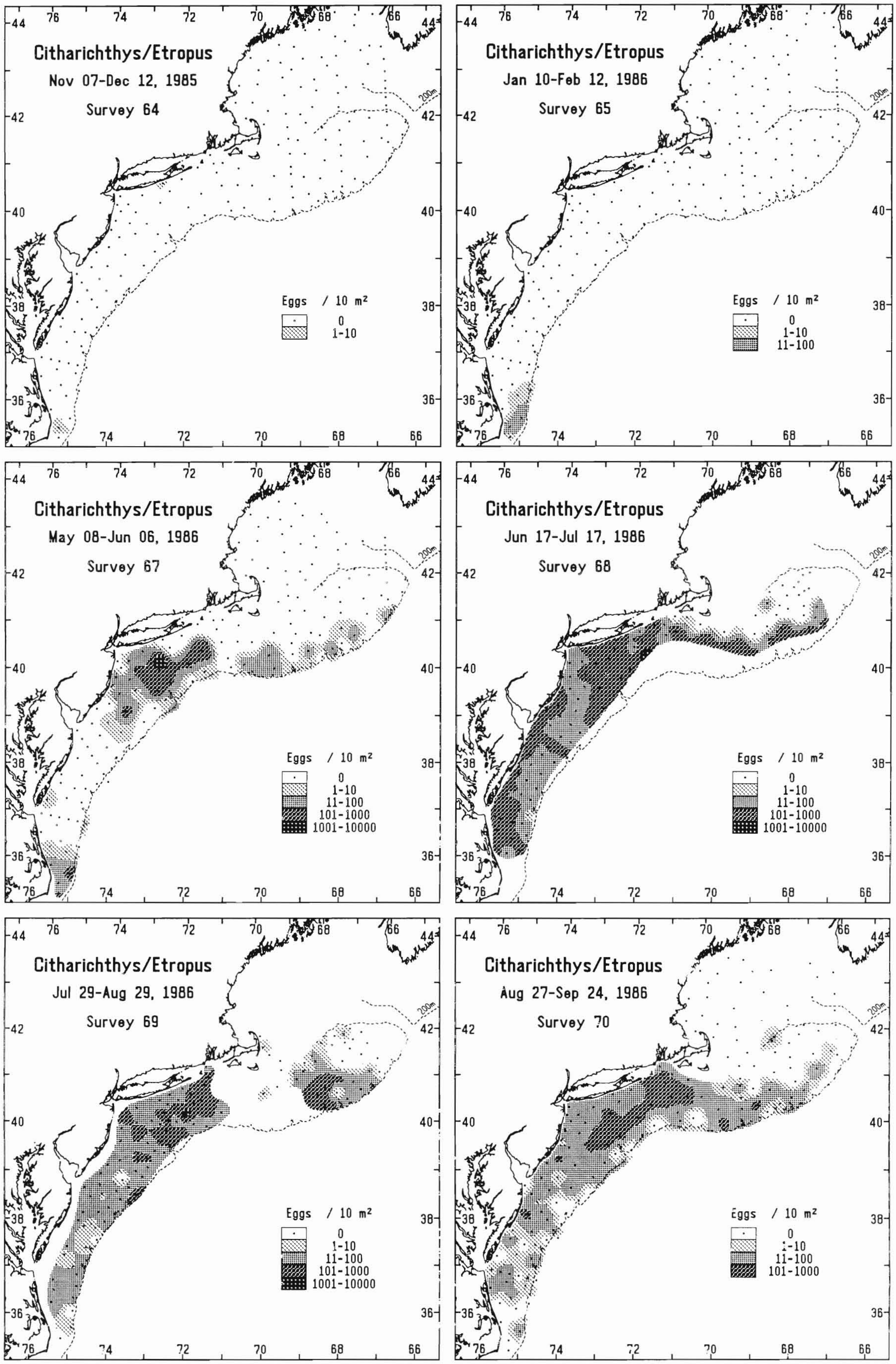


Figure 86 (continued)



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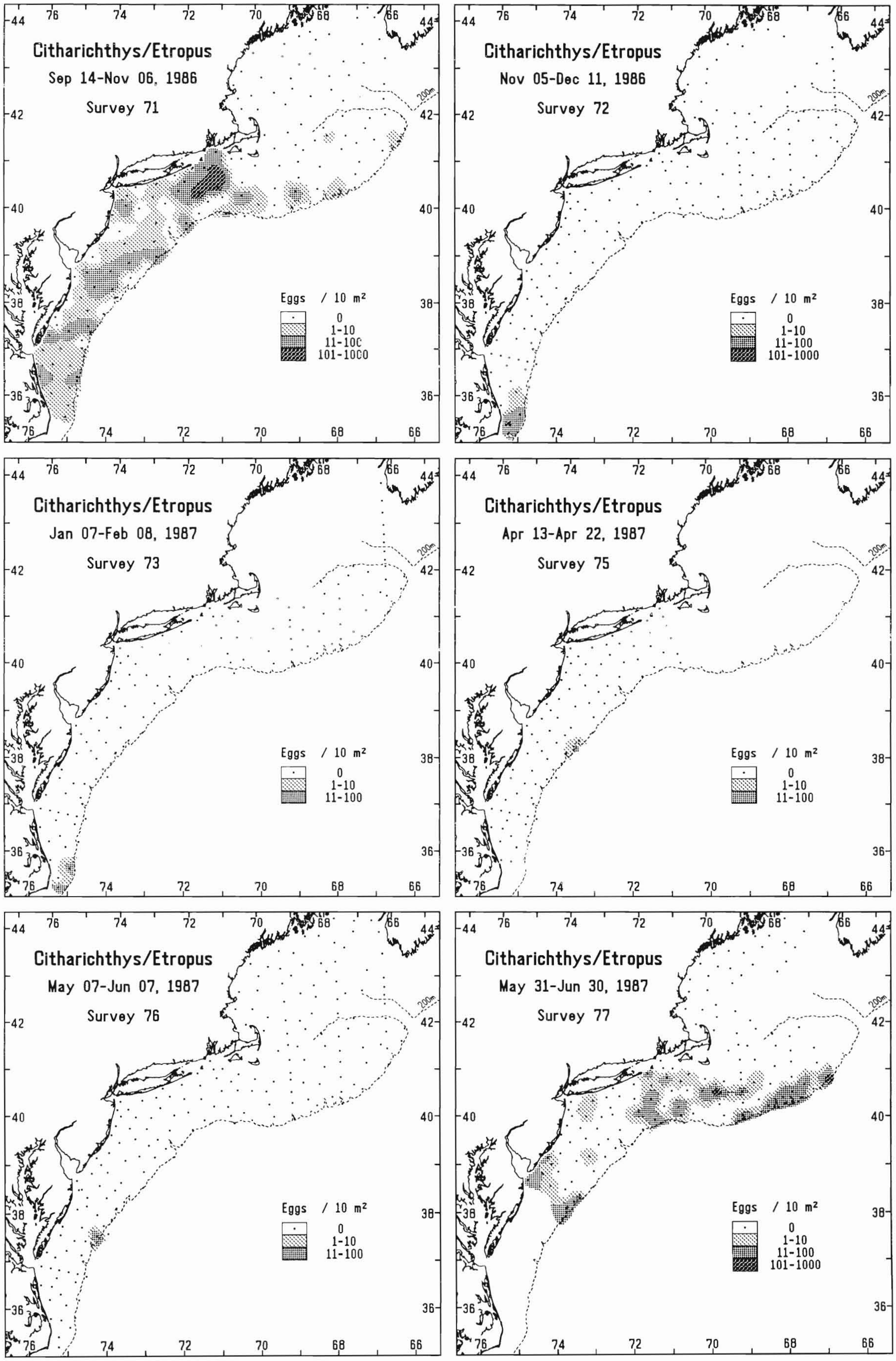

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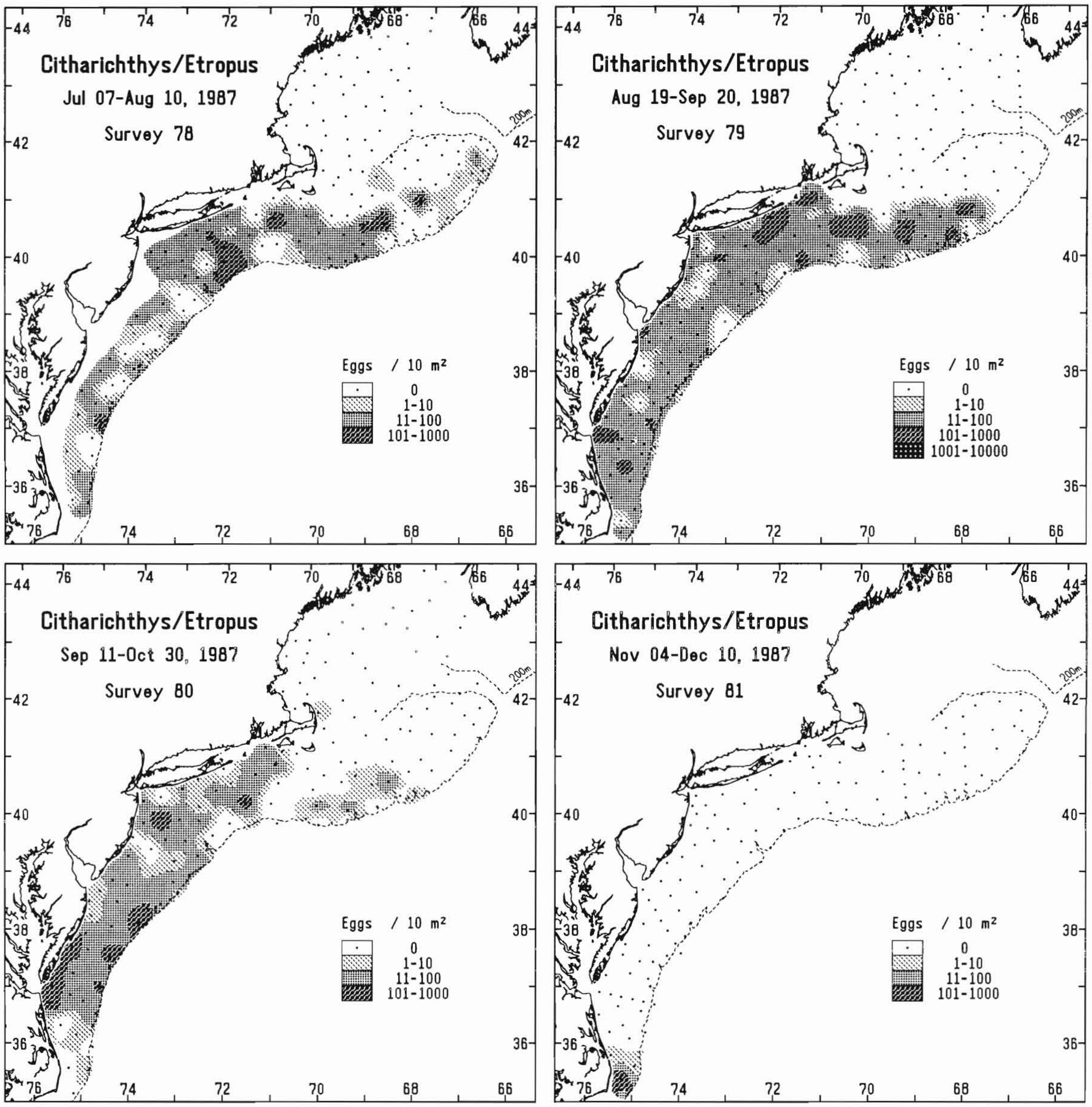


Figure 86 (continued)

Paralichthys dentatus, summer flounder (Figs. 87–89)

Two distinct spawnings of *Paralichthys dentatus* were observed. Intense spawning occurred in autumn and winter of every year over much of the Middle Atlantic and southern New England subareas. A lesser spawning occurred during spring in the southern half of Middle Atlantic waters (Figs. 87 and 88).

The major spawning of *P. dentatus* began in September in inshore waters of the Middle Atlantic and southern New England subareas. Peak spawning occurred in October and egg distribution broadened to include much of Georges Bank. In the Middle Atlantic and southern New England subareas, spawning spread into deeper mid-shelf waters. Spawning in deeper waters continued into November when eggs were found across the entire breadth of the shelf. Major egg concentrations occurred in southern New England and northern Middle Atlantic subareas in mid- and outer-shelf waters. This trend for spawning to occur in increasingly deeper waters during autumn parallels the offshore migration of adults during that season (Smith and Daiber, 1977). In November, spawning on Georges Bank was greatly diminished. Spawning in December and January was reduced to isolated locations in outer shelf waters of the Middle Atlantic and southern New England subareas (Fig. 88). The lesser of the two seasonal spawning events was observed in the southern portion of the Middle Atlantic subarea during April and May (Fig. 89) during 1979, 1986, and 1987.

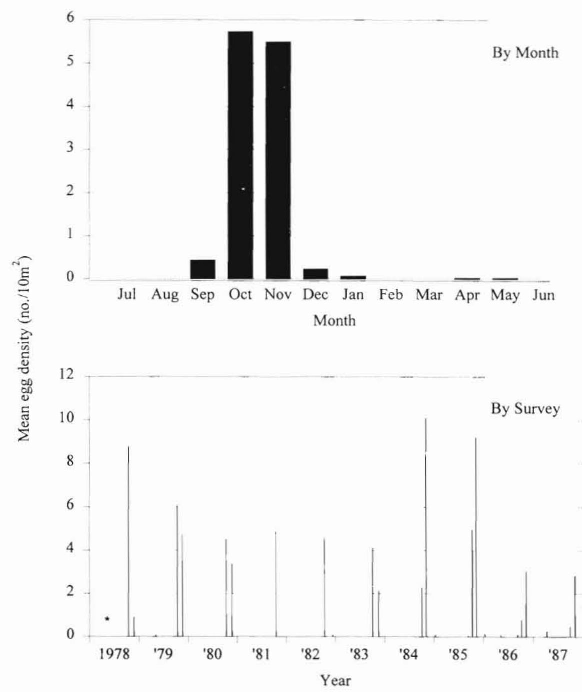


Figure 87

Paralichthys dentatus; mean-egg-density graphs by month (top) and by survey (bottom) for the total MARMAP area. (*Samples from the first four surveys in 1978 were not analyzed for *P. dentatus* eggs.)

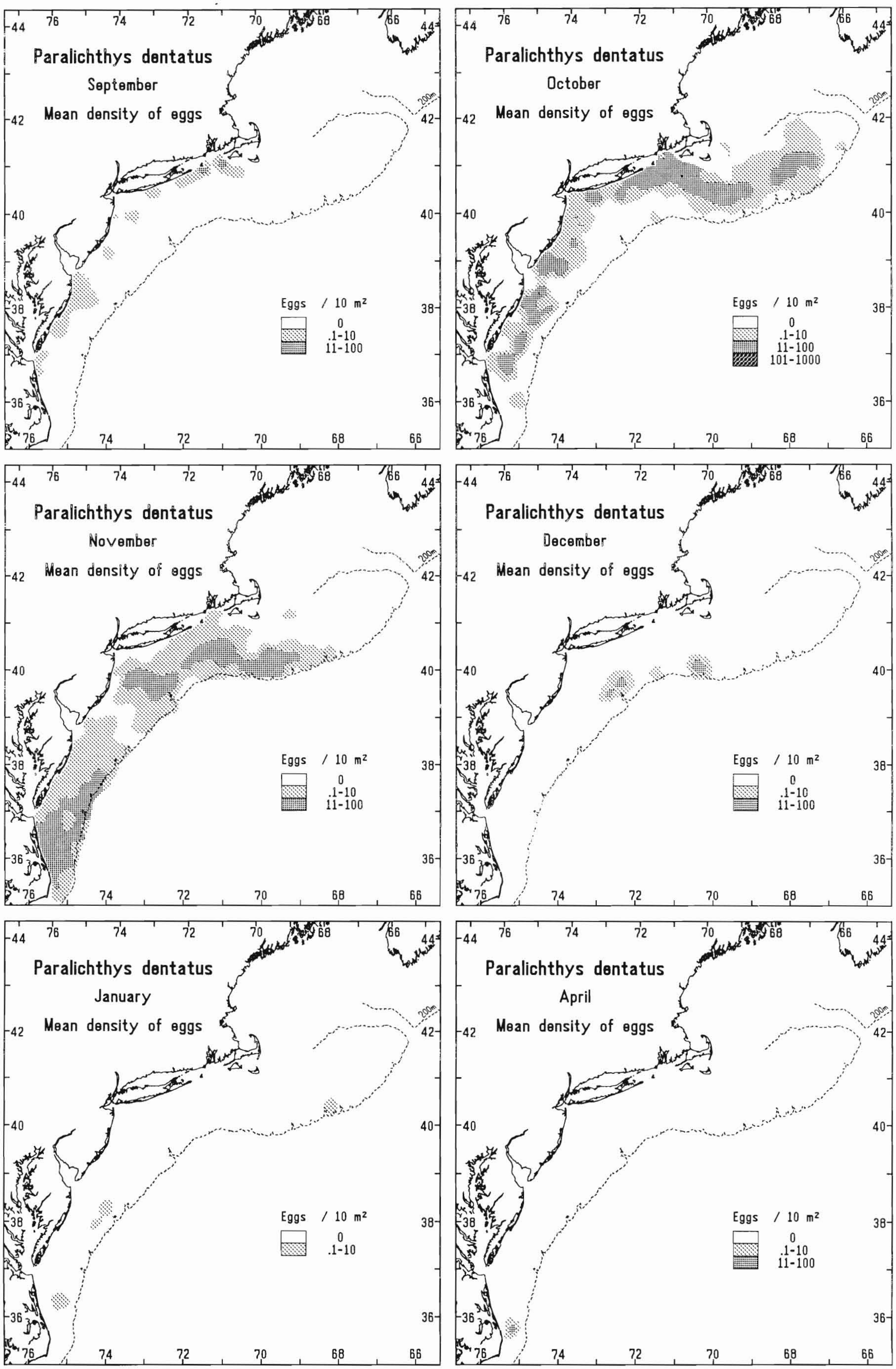


Figure 88

Paralichthys dentatus; composite monthly areal plots of mean egg densities (no./10 m²).

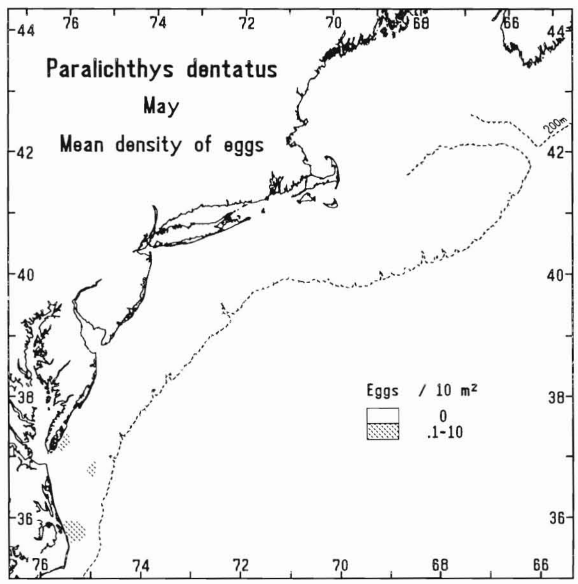


Figure 88 (continued)

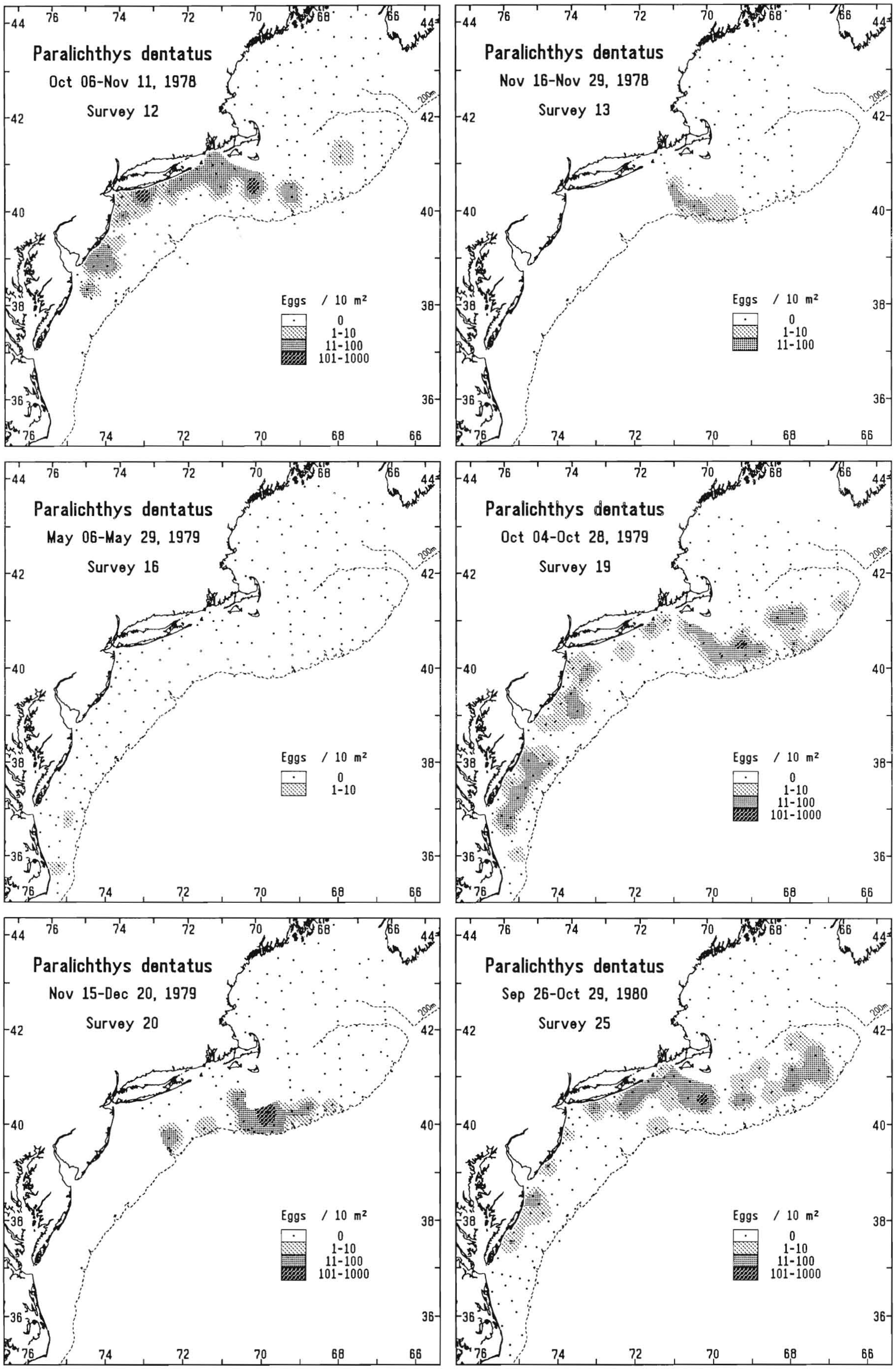


Figure 89

Paralichthys dentatus; survey areal plots of egg densities (no./10 m²).

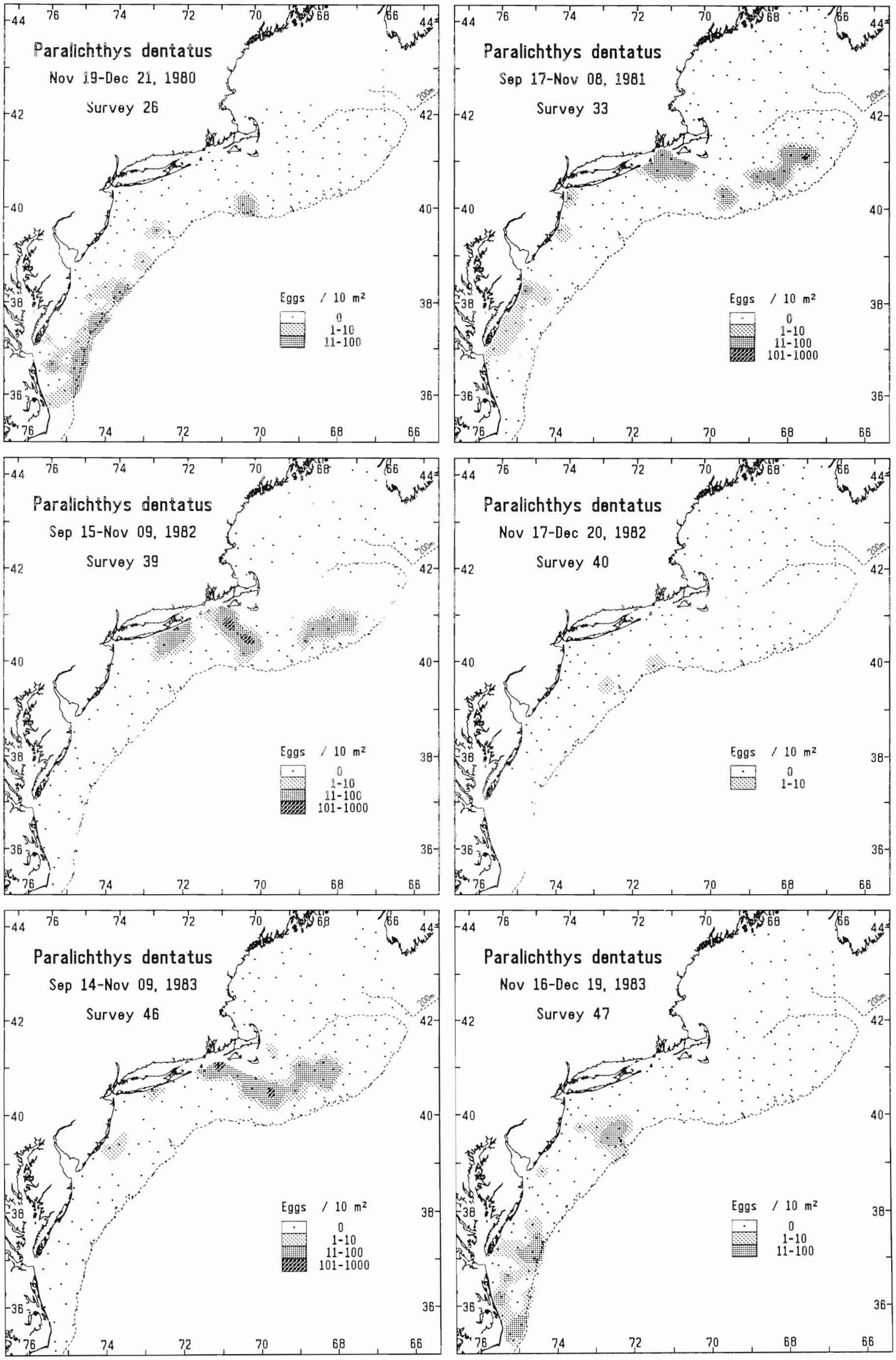


Figure 89 (continued)

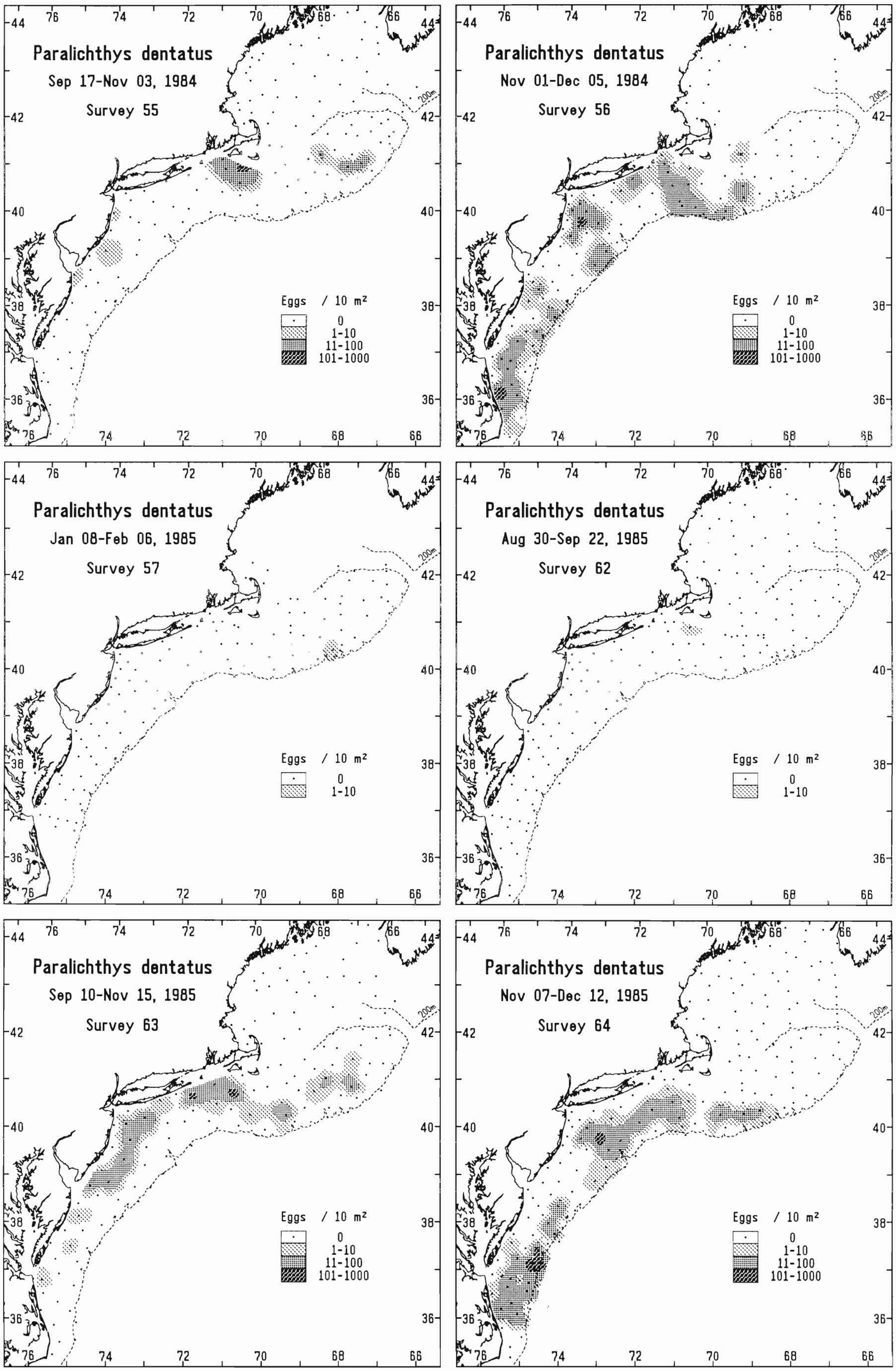
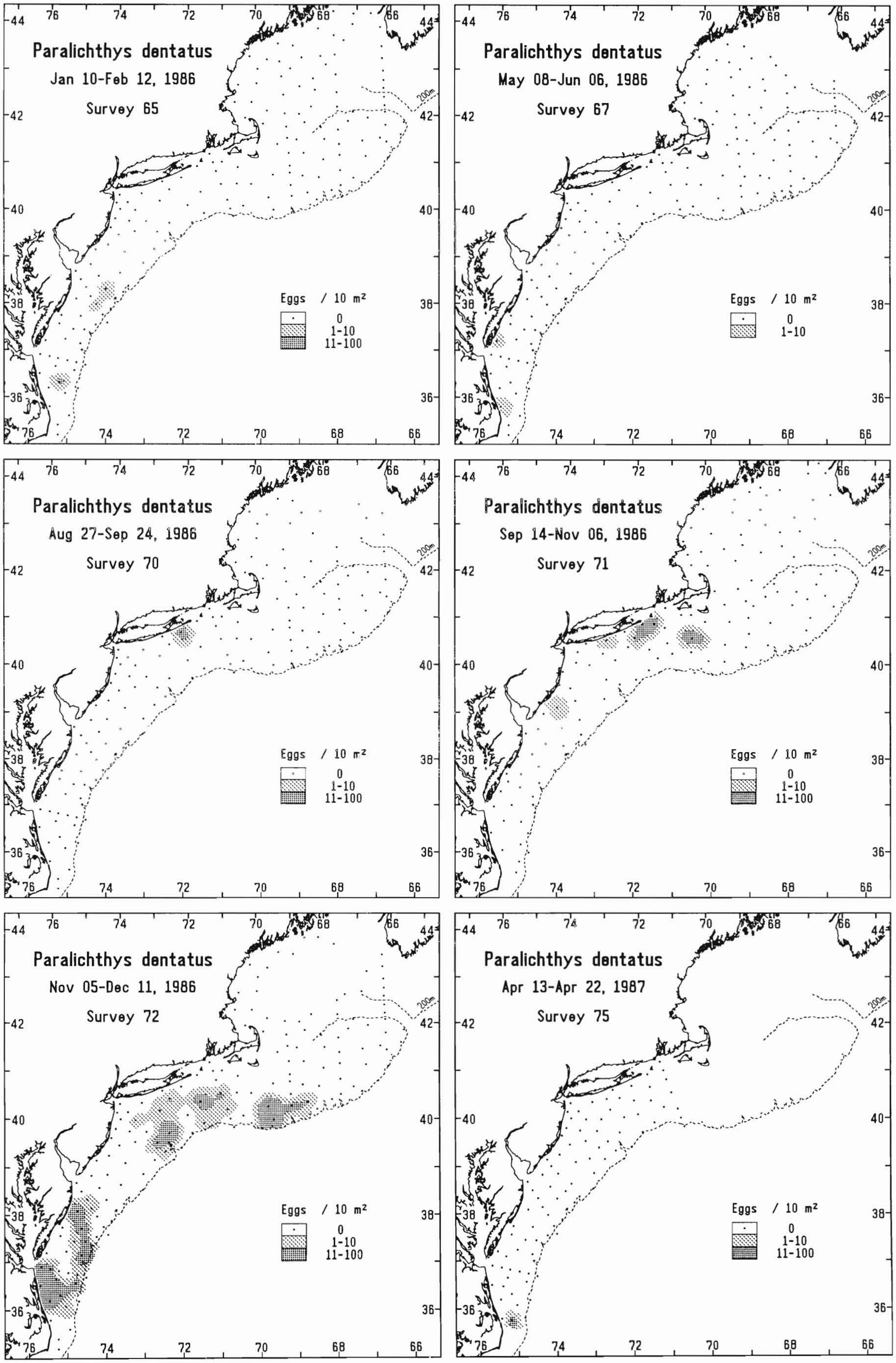


Figure 89 (continued)



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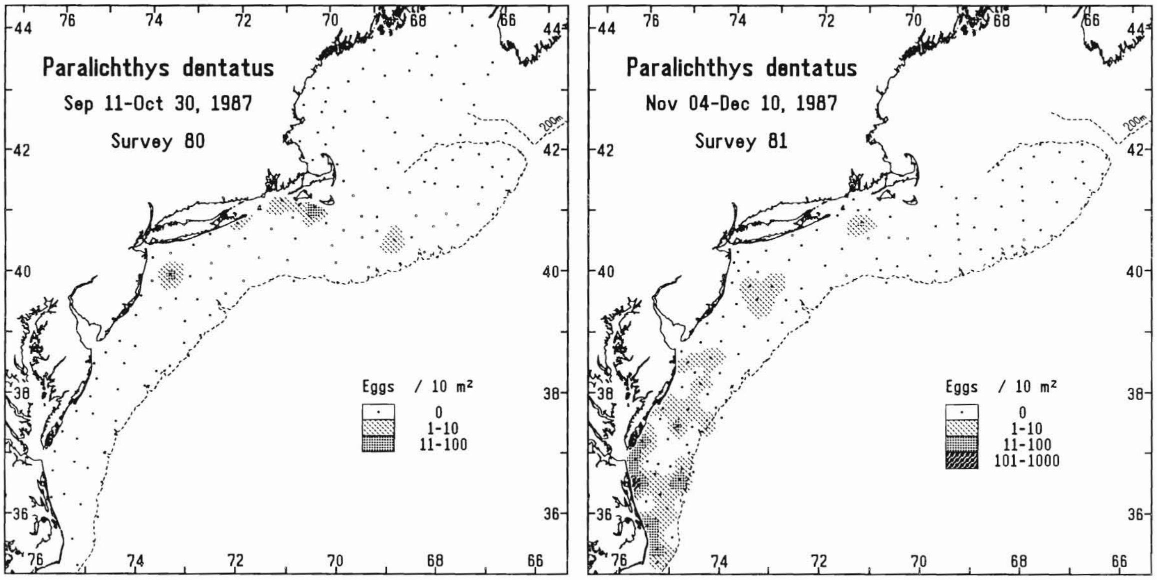


Figure 89 (continued)

Paralichthys oblongus, fourspot flounder (Figs. 90–92)

Paralichthys oblongus eggs were collected from April to November (Fig. 90) and were abundant over most of the eight months, occurring mostly in Middle Atlantic, southern New England, and the southern half of Georges Bank waters and only occasionally in the Gulf of Maine. They occurred over the entire breadth of the shelf (Fig. 91).

Spawning began offshore, usually in May but often as early as April, then spread onto the shelf (see Surveys 16, 50, and 76; Fig. 92). Spawning generally began in the Middle Atlantic subarea and by May was widespread throughout Middle Atlantic, southern New England, and southern Georges Bank subareas. Peak spawning was observed in July when eggs occurred in an almost continuous distribution throughout shelf waters between Cape Hatteras and central or eastern Georges Bank. Spawning remained widespread through August and September, although at decreasing intensity. It greatly diminished in area through October and November, ceasing altogether by December.

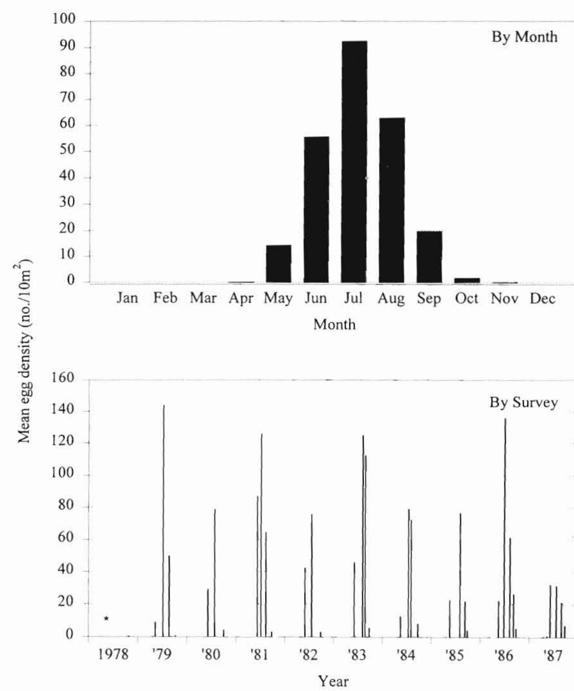


Figure 90

Paralichthys oblongus; mean-egg-density graphs by month (top) and by survey (bottom) for the total MARMAP area. (*Samples from the first four surveys in 1978 were not analyzed for *P. oblongus* eggs.)

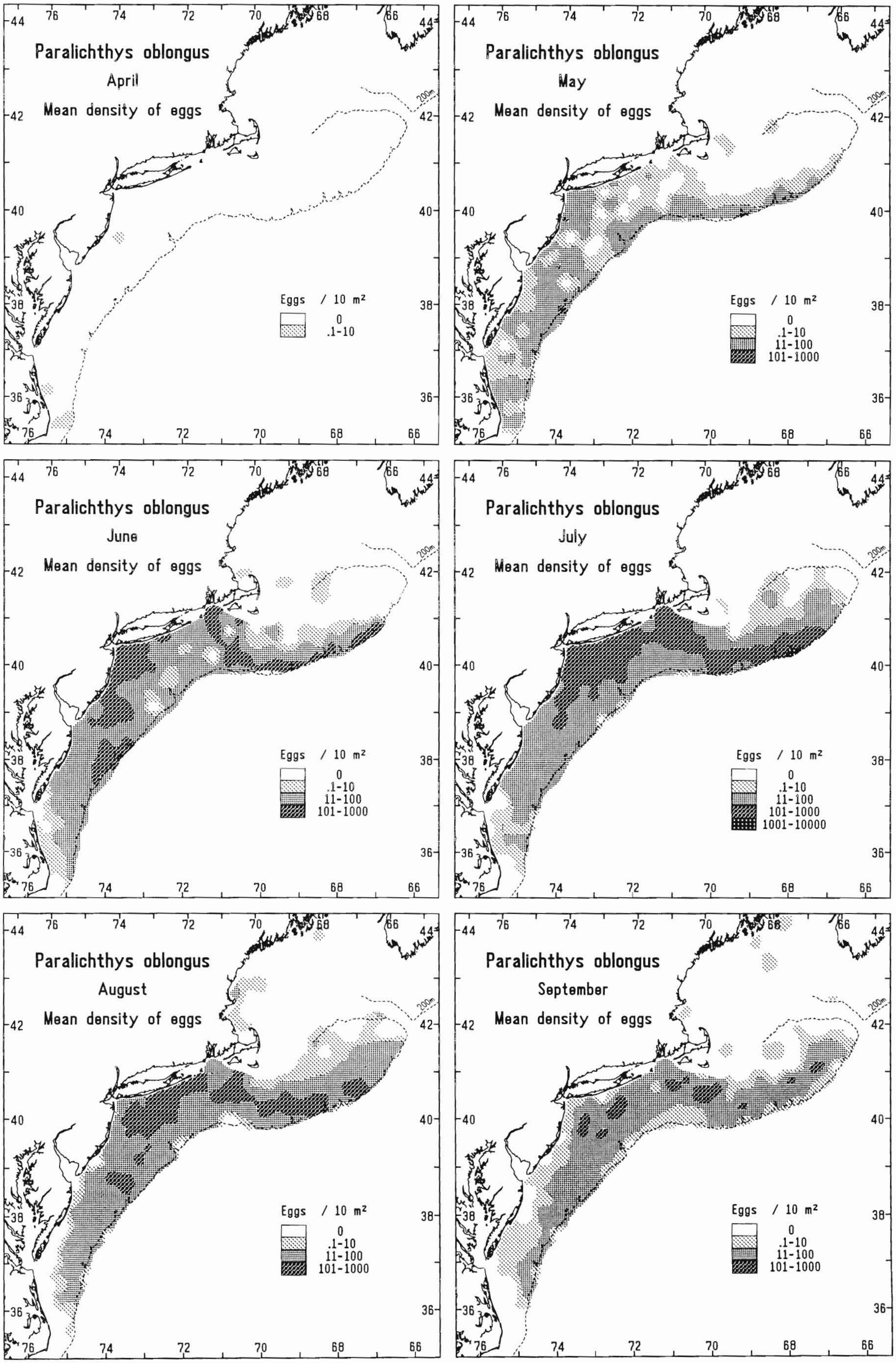


Figure 91

Paralichthys oblongus; composite monthly areal plots of mean egg densities (no./10 m²).

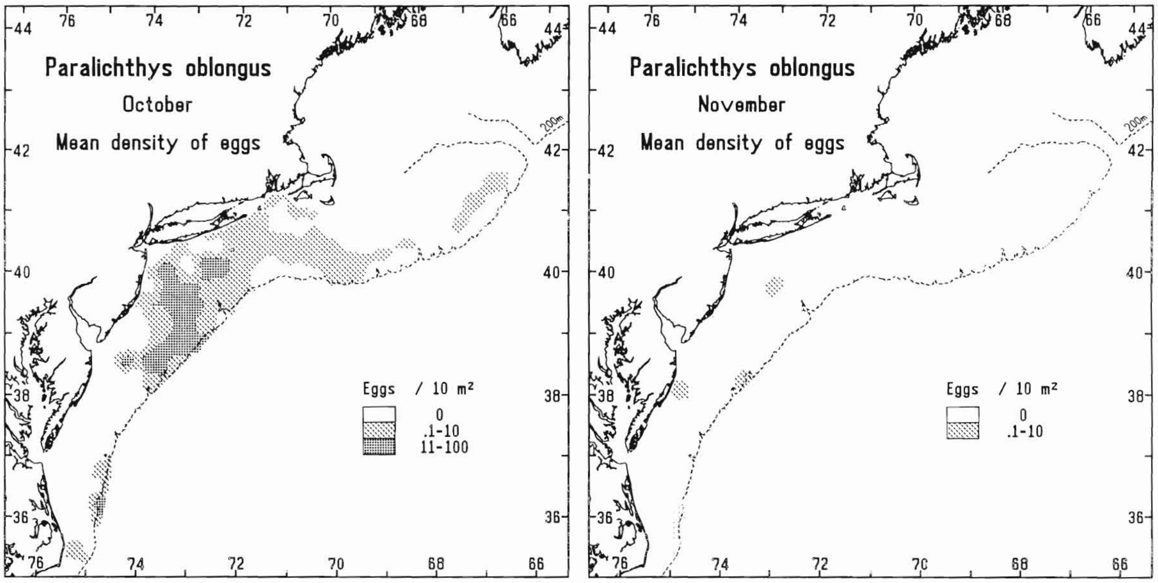


Figure 91 (continued)

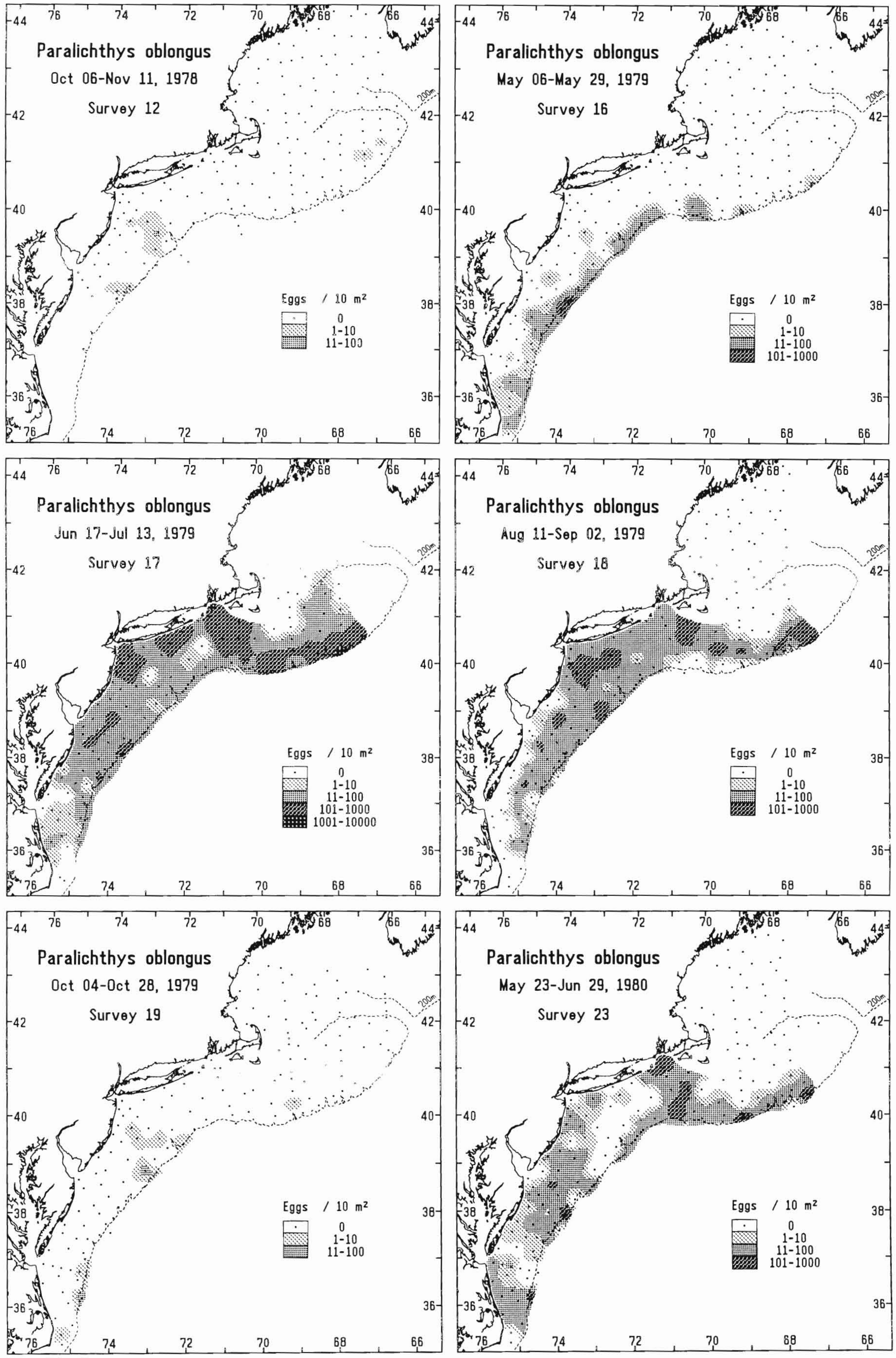


Figure 92

Paralichthys oblongus; survey areal plots of egg densities (no./10 m²).

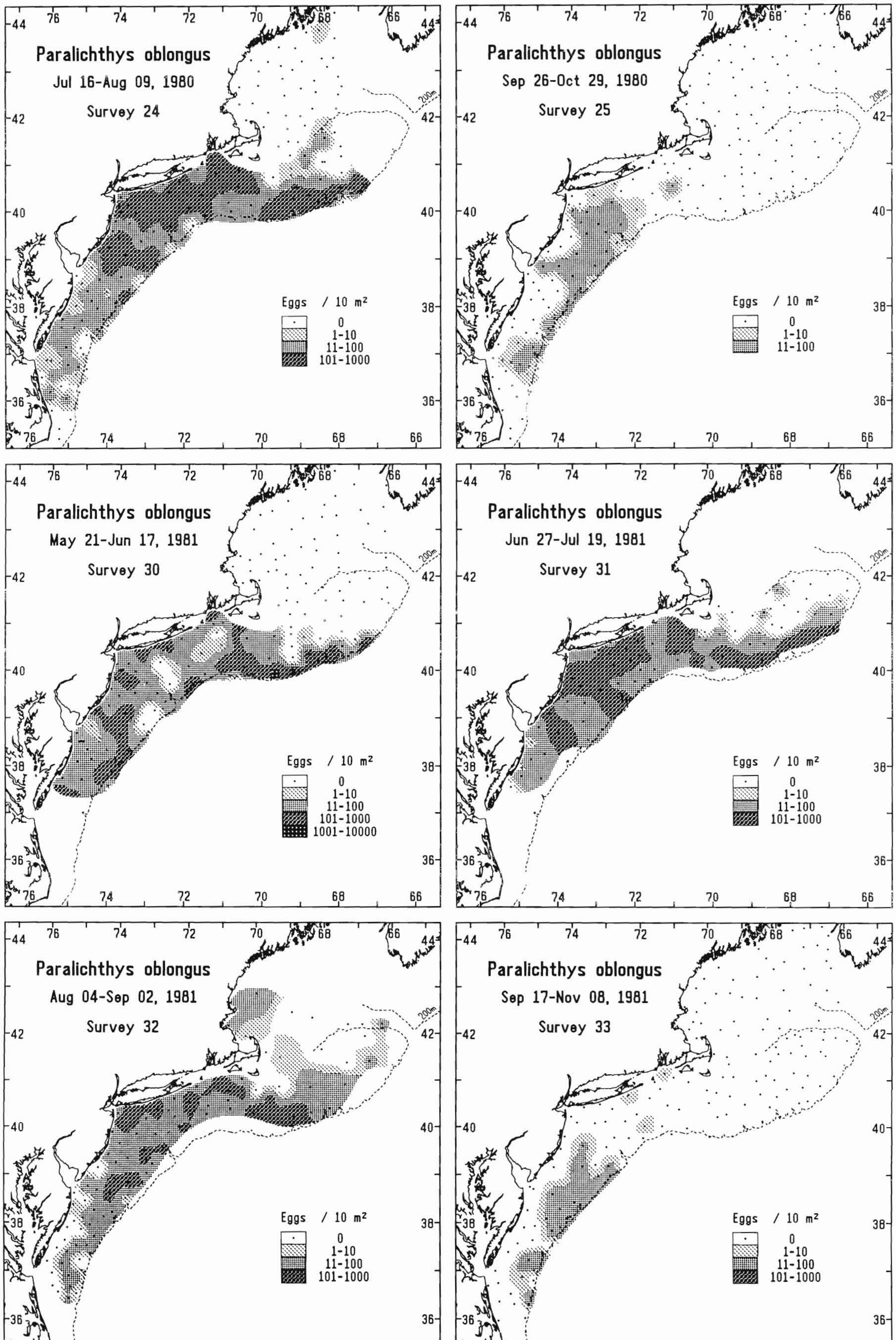


Figure 92 (continued)

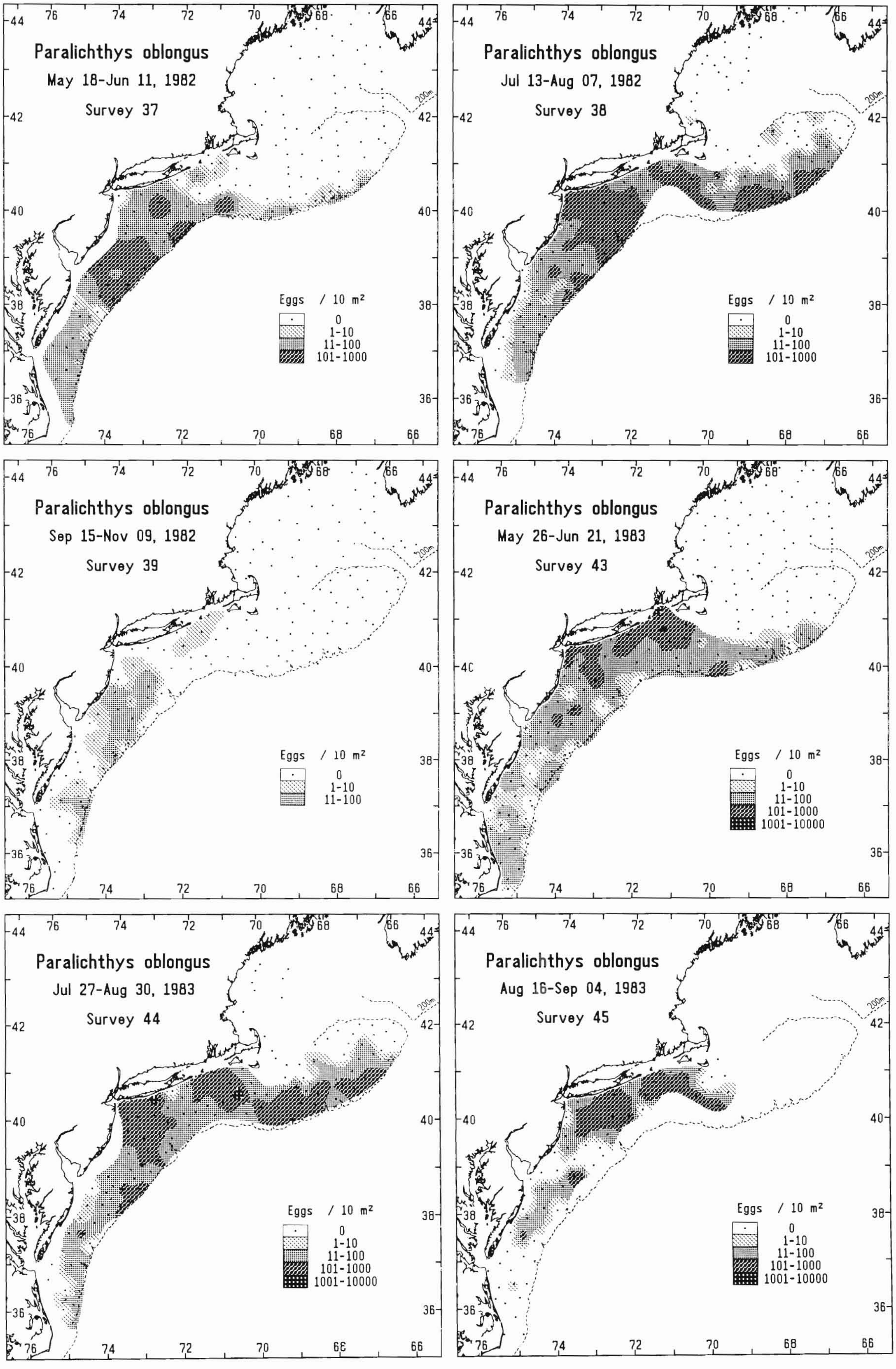
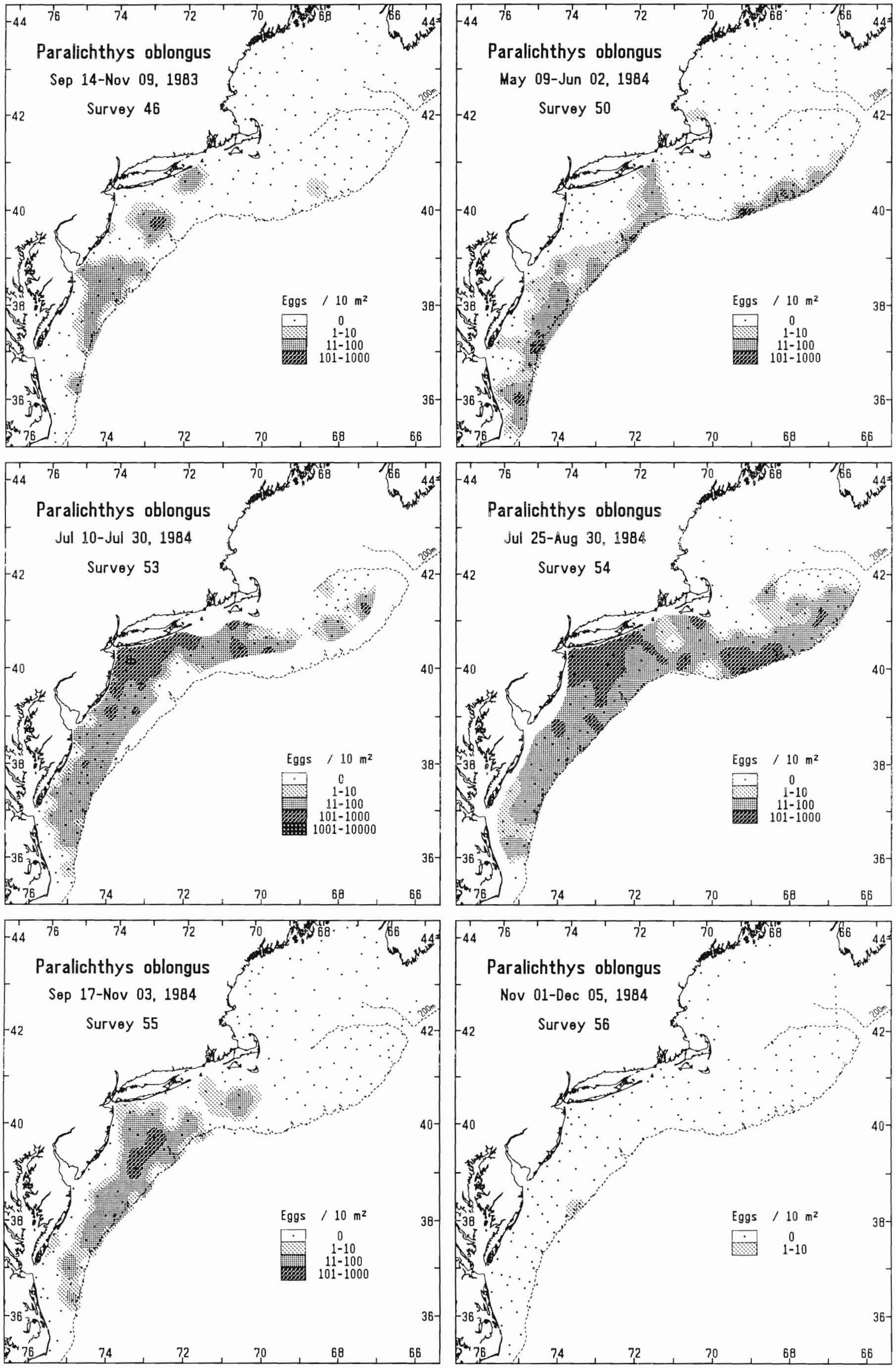


Figure 92 (continued)



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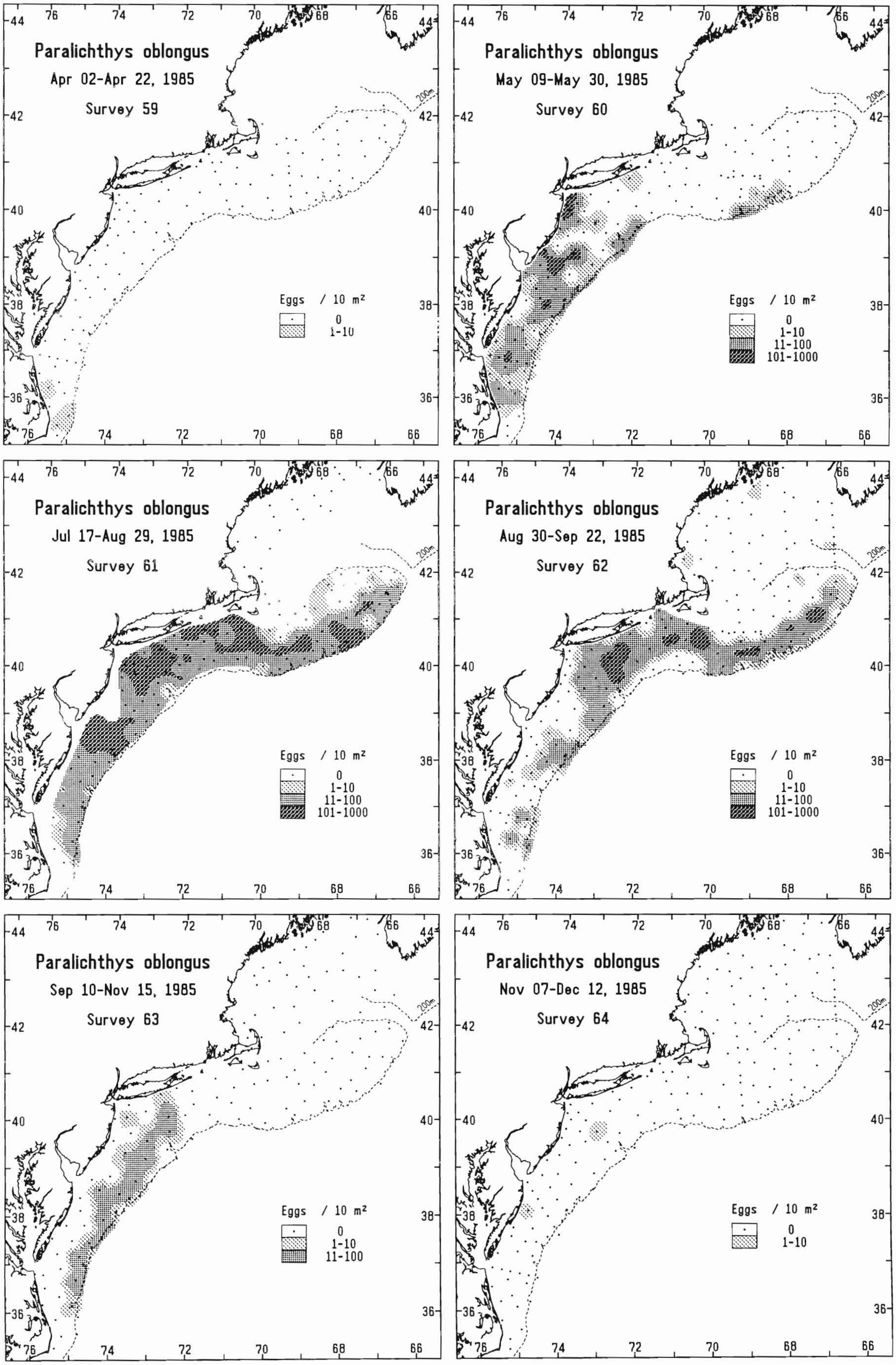


Figure 92 (continued)

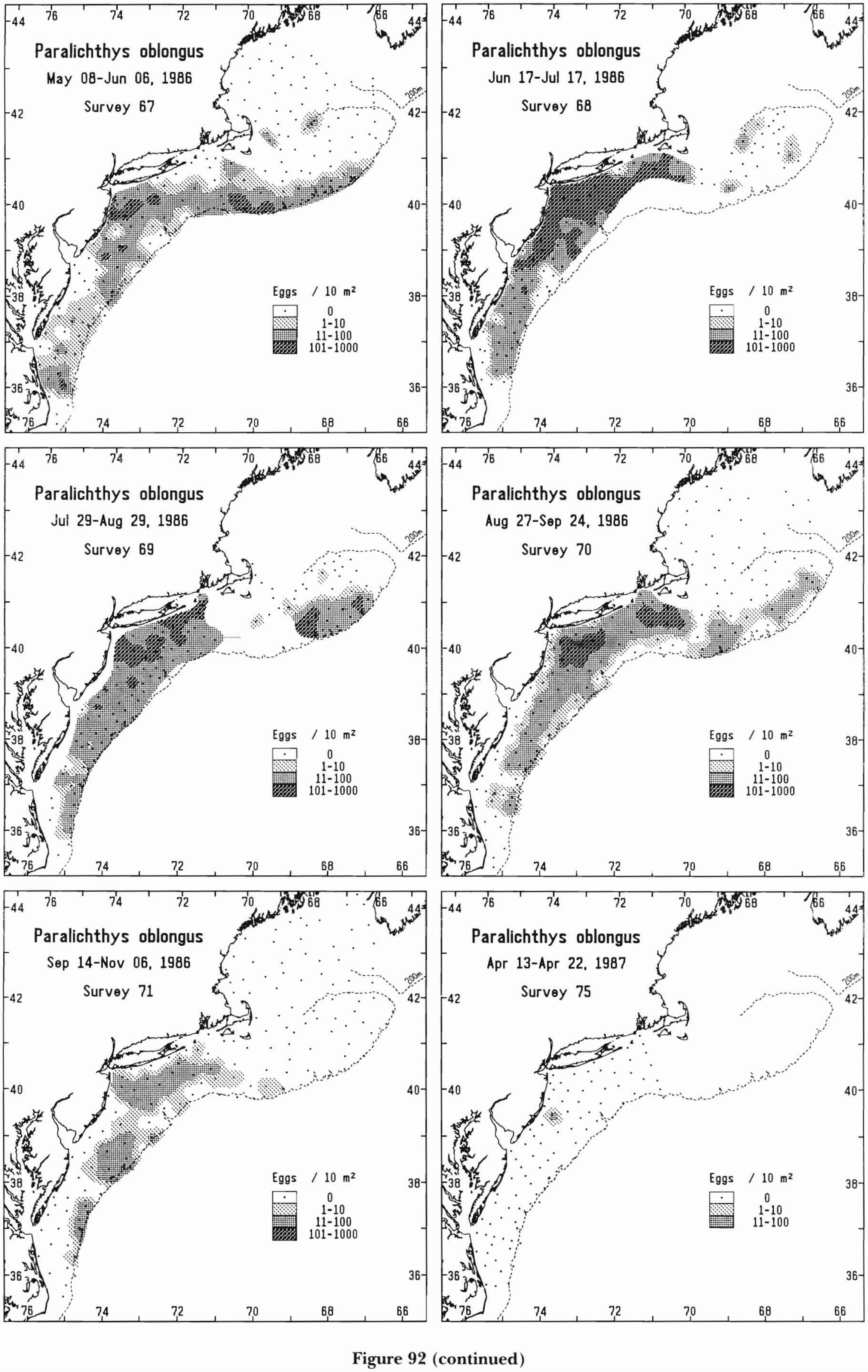


Figure 92 (continued)

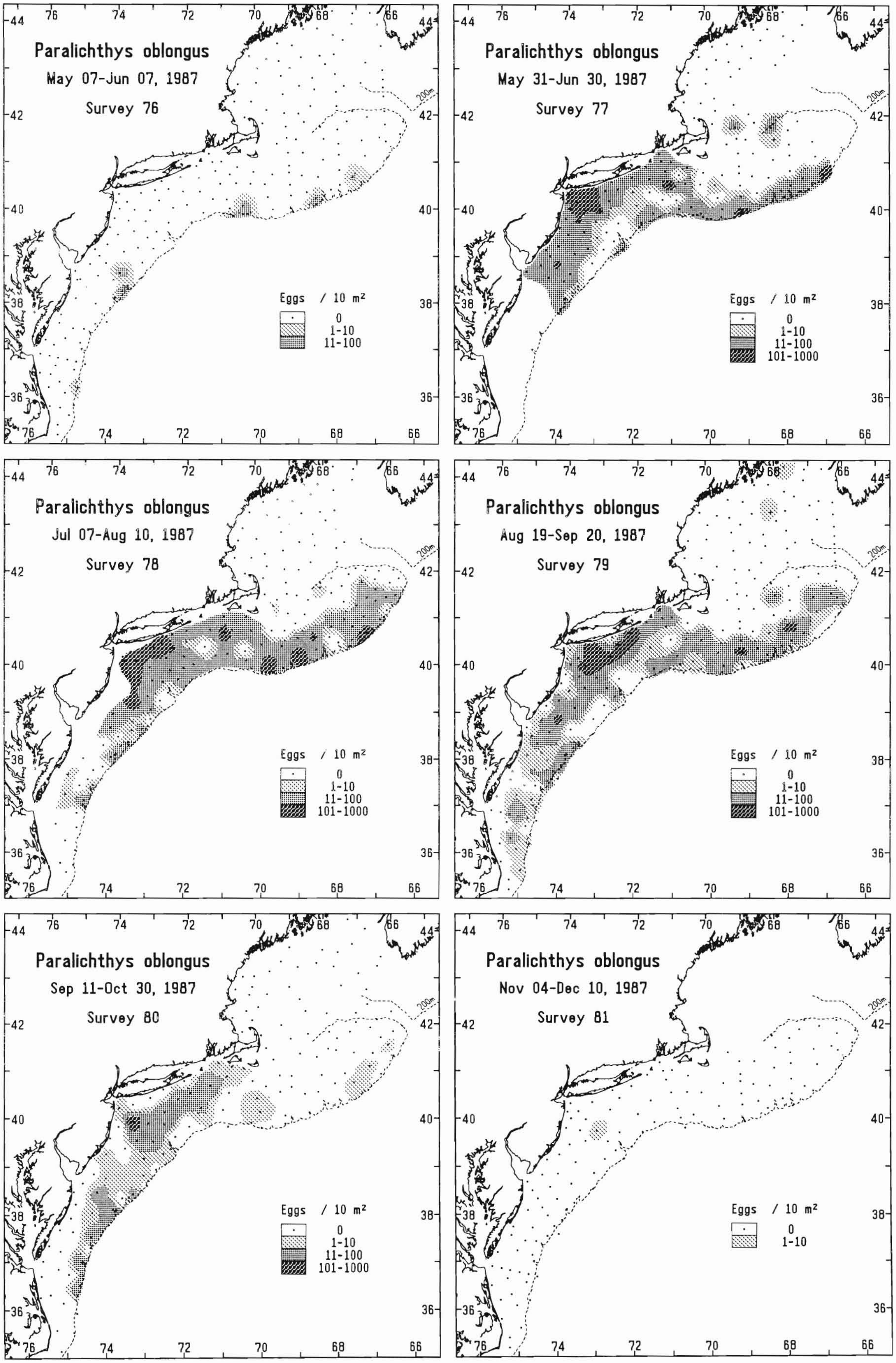


Figure 92 (continued)

Scophthalmus aquosus, windowpane (Figs. 93–95)

Scophthalmus aquosus eggs were collected from February to November and were abundant from May to October (Fig. 93). They were mostly found in nearshore shelf waters and in the central, shallower portion of Georges Bank (Fig. 94).

Spawning began in February or March in inner shelf waters, usually between Cape Hatteras and New Jersey, although in some years as far north as Long Island, New York. The area expanded in April into deeper waters, and onto Georges Bank in some years. Throughout peak spawning months of May through October, eggs were found over broad areas of the Middle Atlantic, southern New England, and Georges Bank subareas, and occasionally into the Gulf of Maine. During this period of sustained high egg abundance the major concentrations of eggs remained in shallower areas. Increased numbers of eggs also occurred offshore, as far as the shelf edge during June to September (Fig. 94). Throughout the spawning season there was a regular progression in the location of areas of high mean egg density (>100/10 m^2), shifting north and east from April to August, then west and south as spawning waned, from August to November (Fig. 94).

The absence of *S. aquosus* eggs in December could be due to the lack of sampling in the southern half of the Middle Atlantic subarea (Fig. 2). With the exception of 1982 and 1987 there appeared to be an upward trend in maximum mean egg density from 1979 to 1987 (Fig. 93).

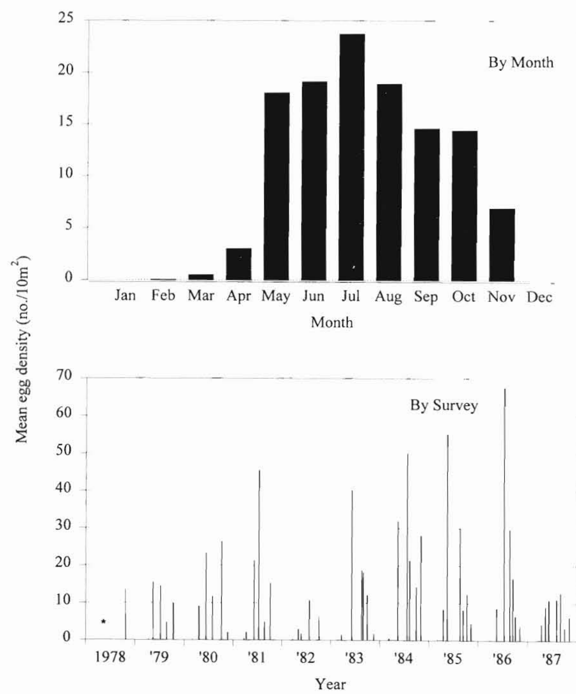


Figure 93
Scophthalmus aquosus; mean-egg-density graphs by month (top) and by survey (bottom) for the total MARMAP area. (*Samples from the first four surveys in 1978 were not analyzed for *S. aquosus* eggs.)

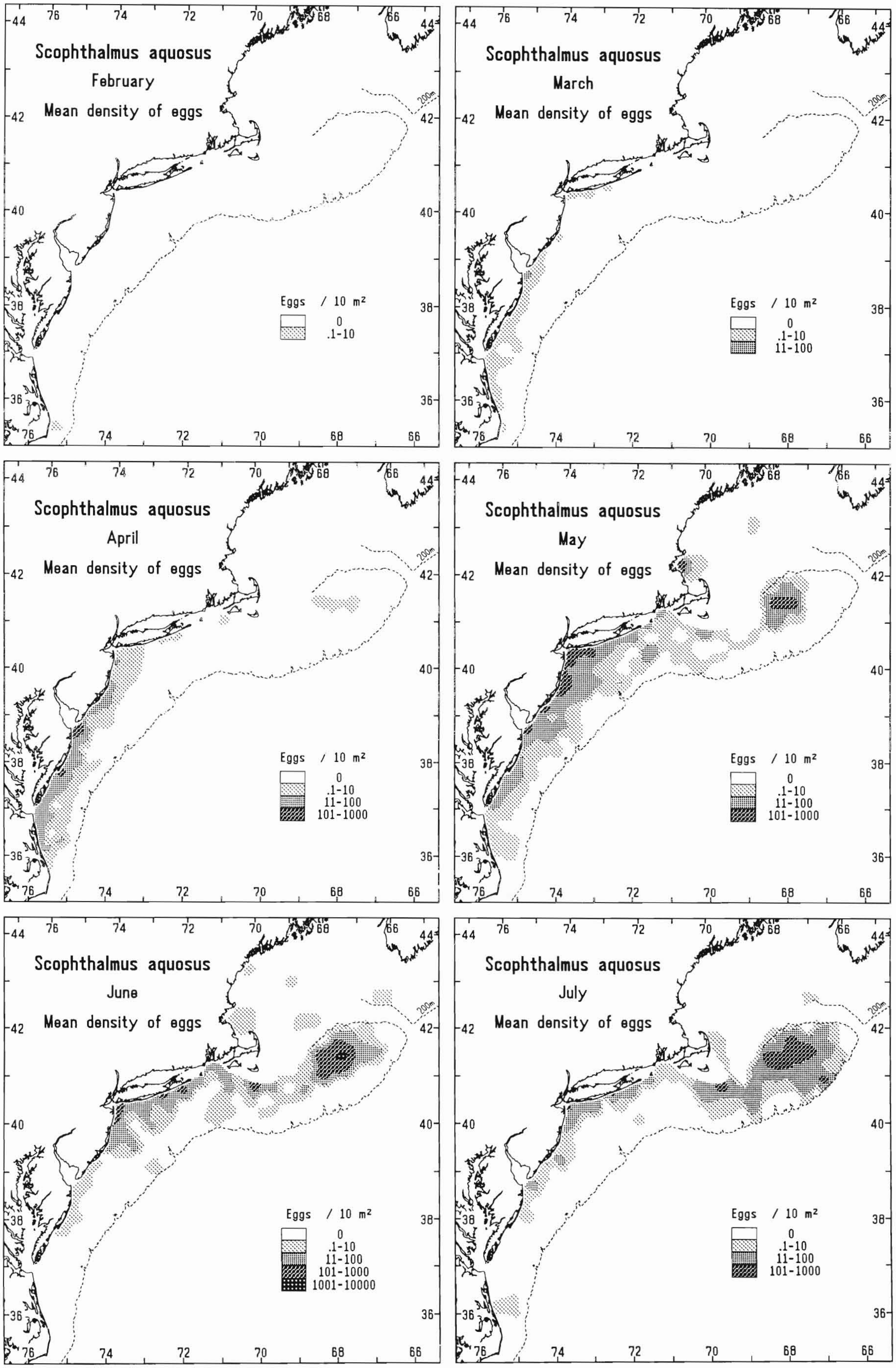


Figure 94

Scophthalmus aquosus; composite monthly areal plots of mean egg densities (no./10 m²).

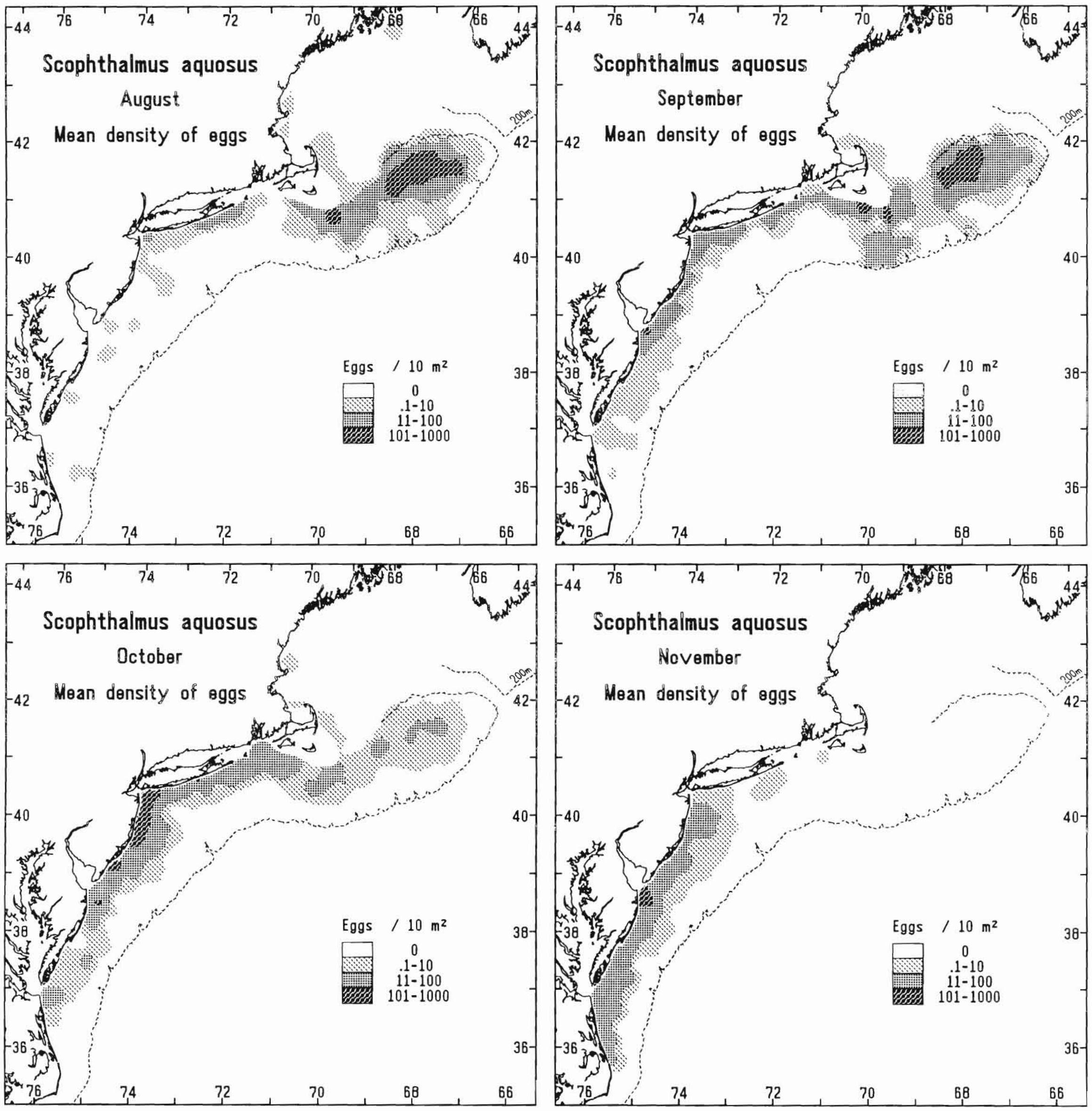


Figure 94 (continued)

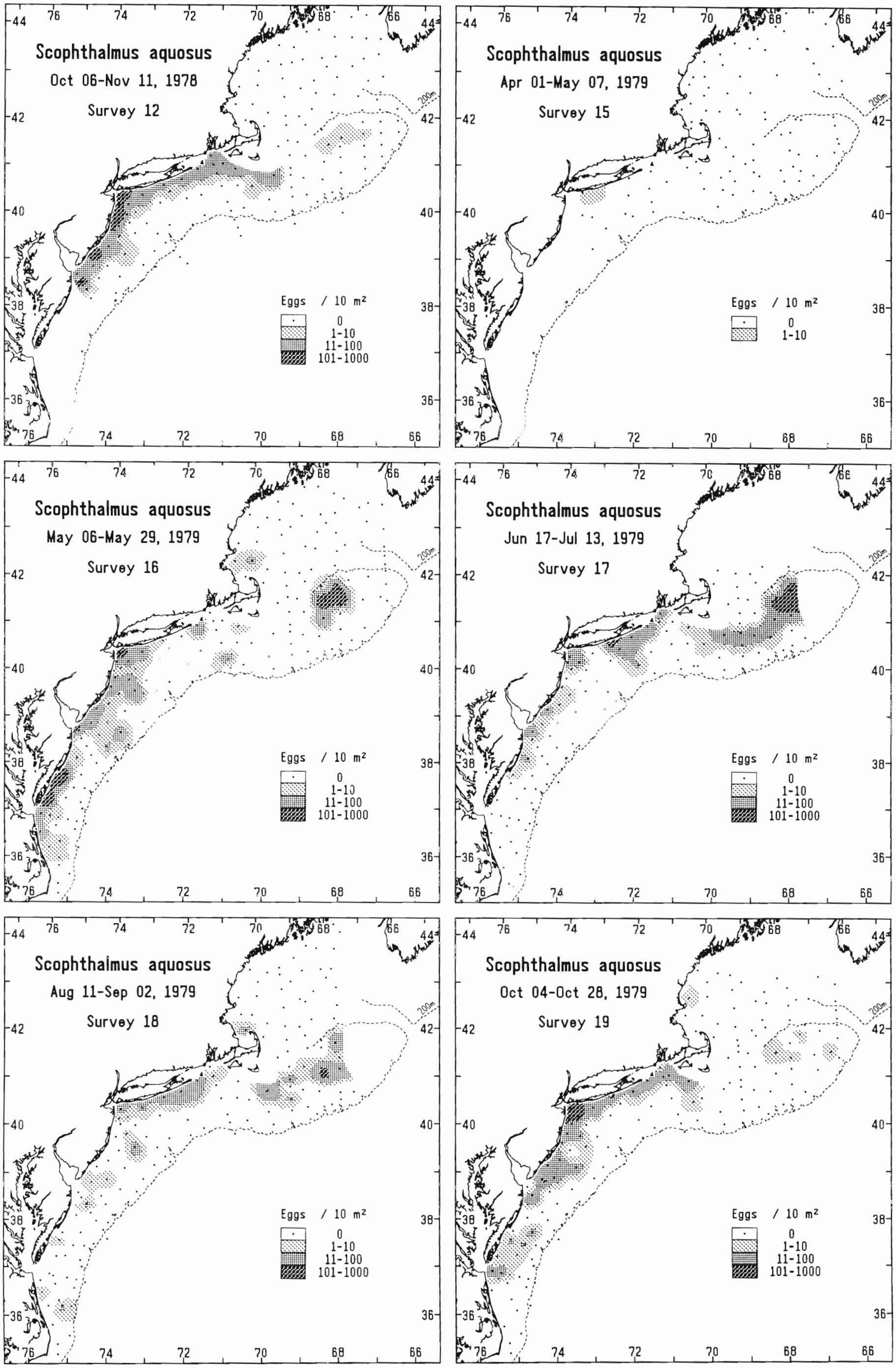


Figure 95
Scophthalmus aquosus; survey areal plots of egg densities (no./10 m^2).

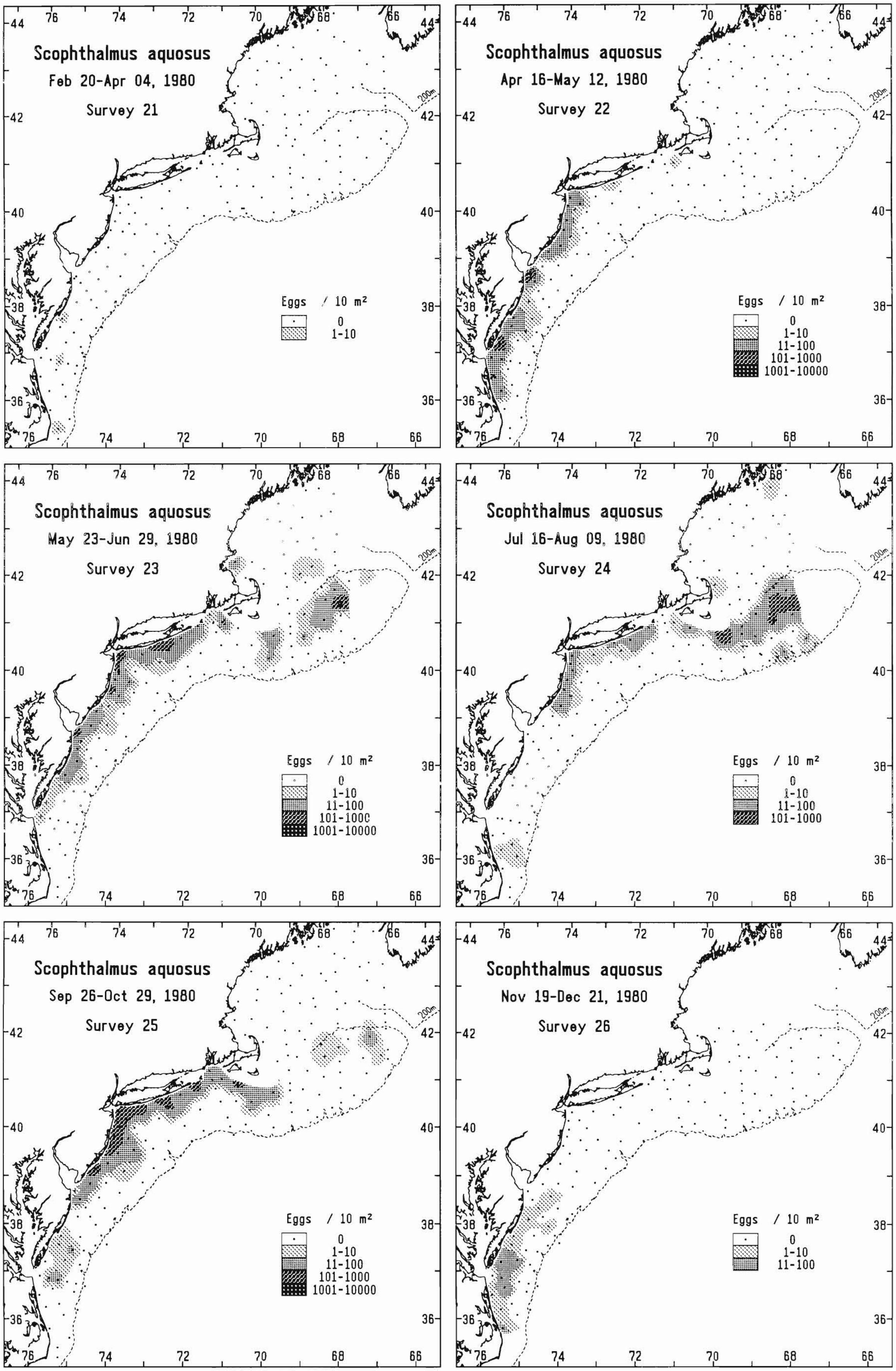
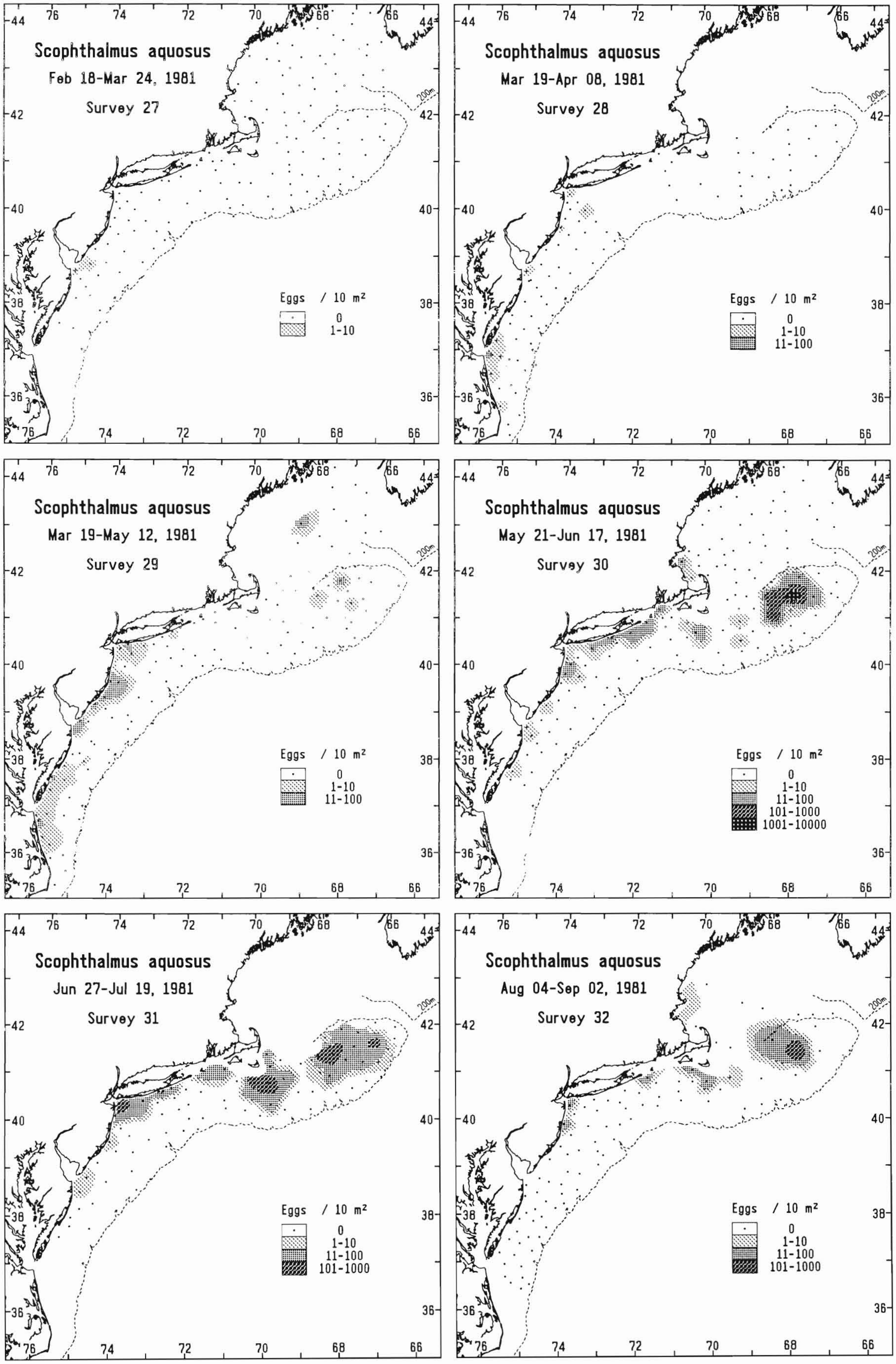


Figure 95 (continued)



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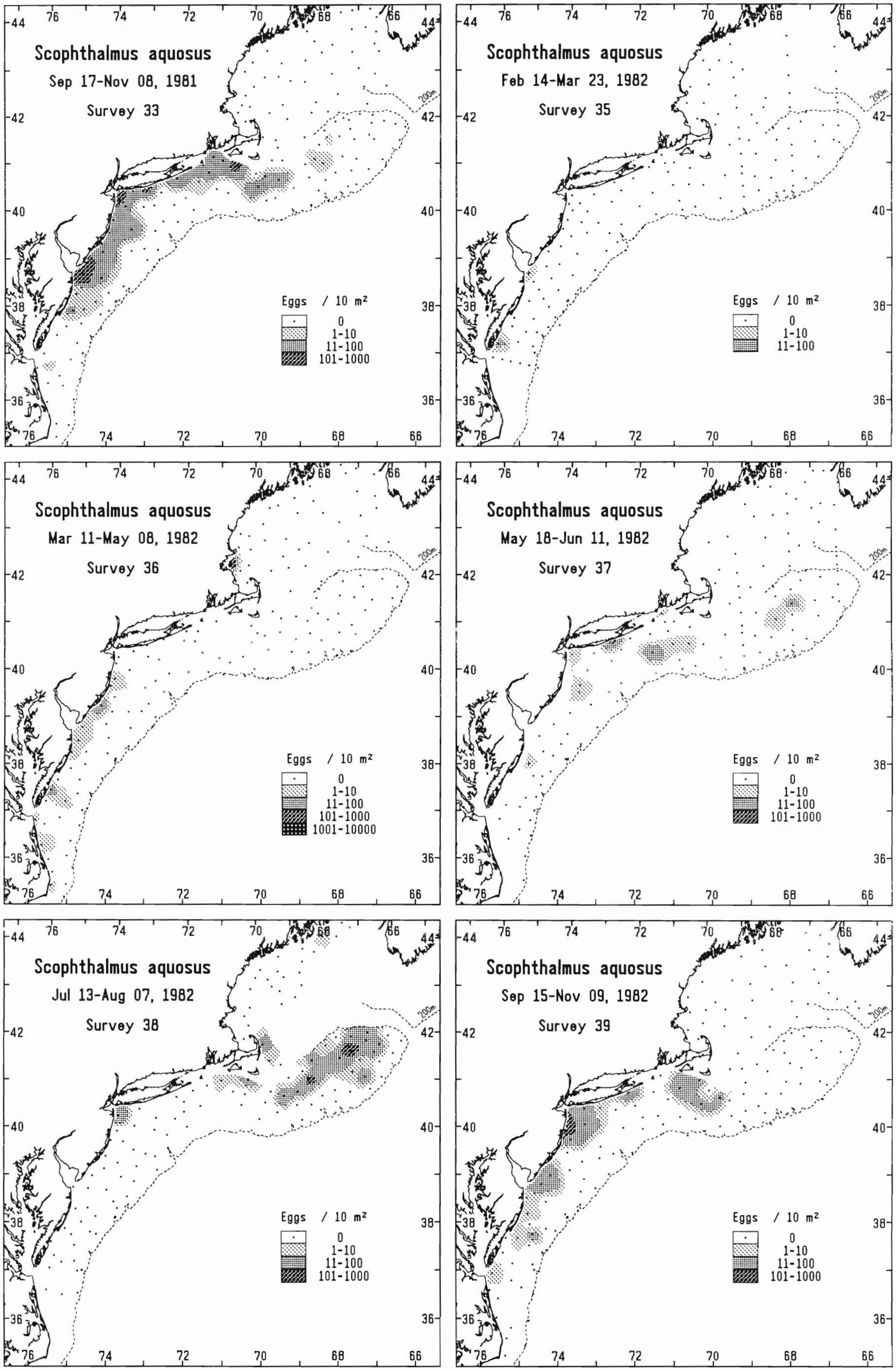
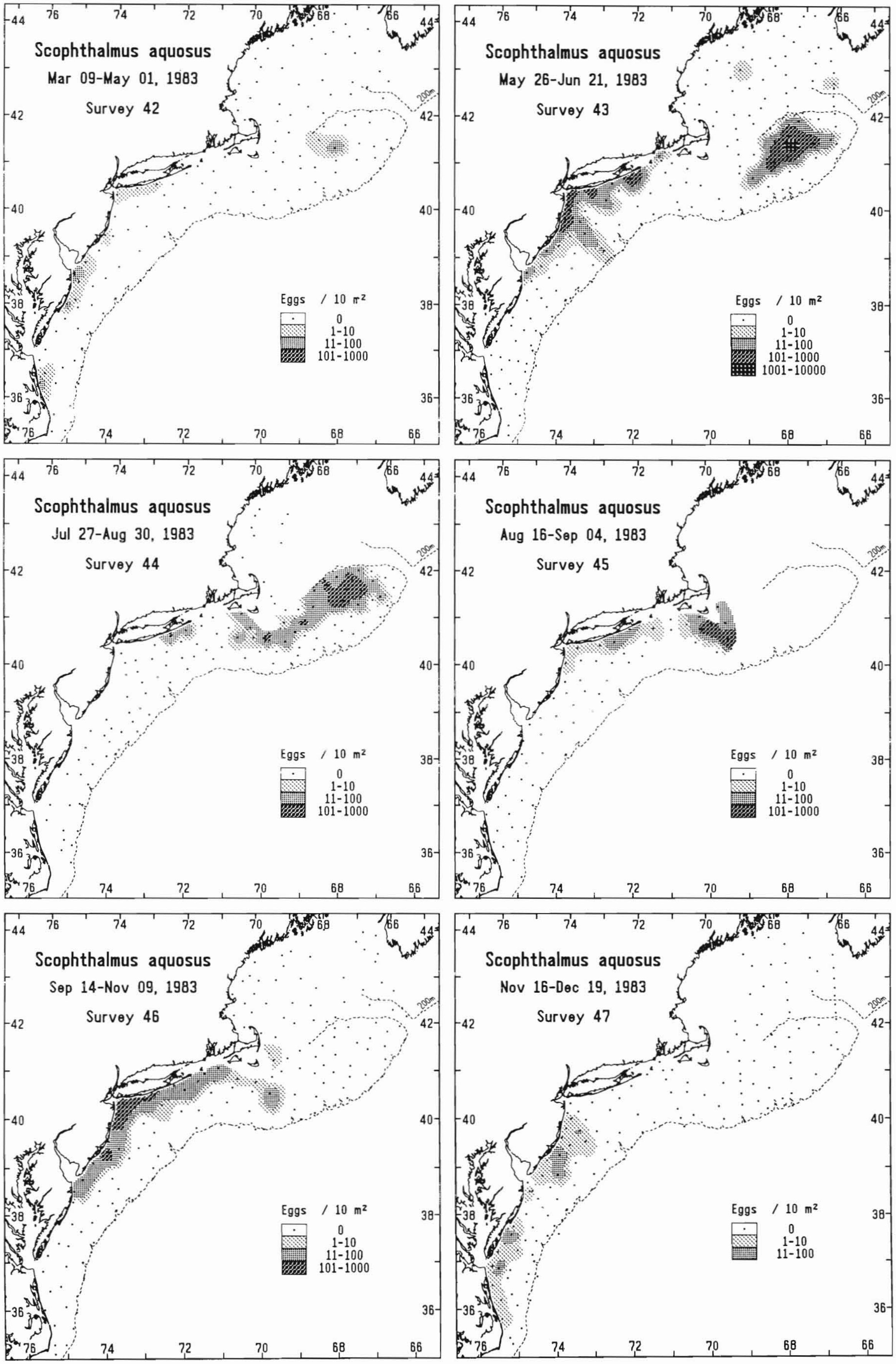


Figure 95 (continued)



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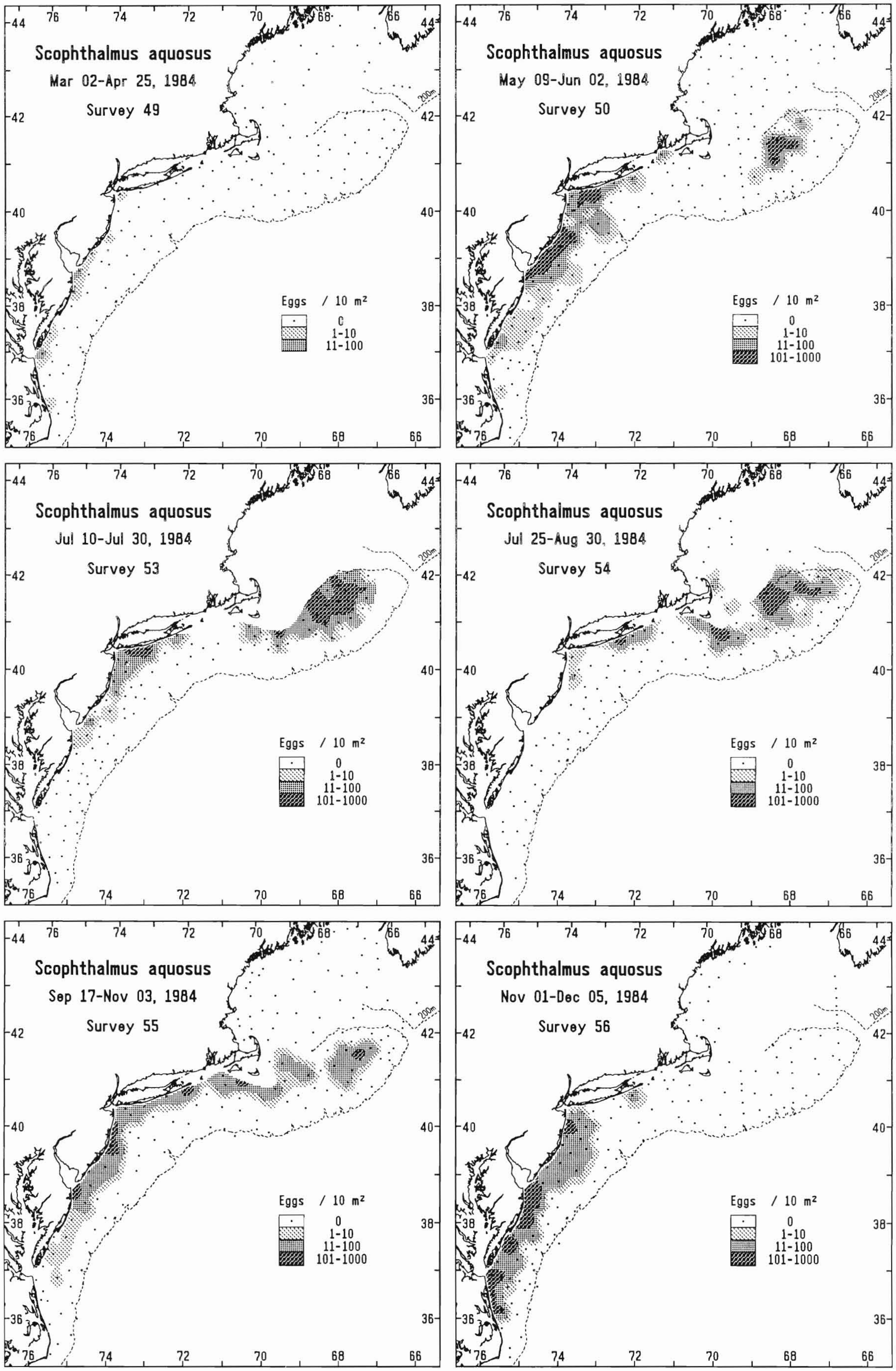

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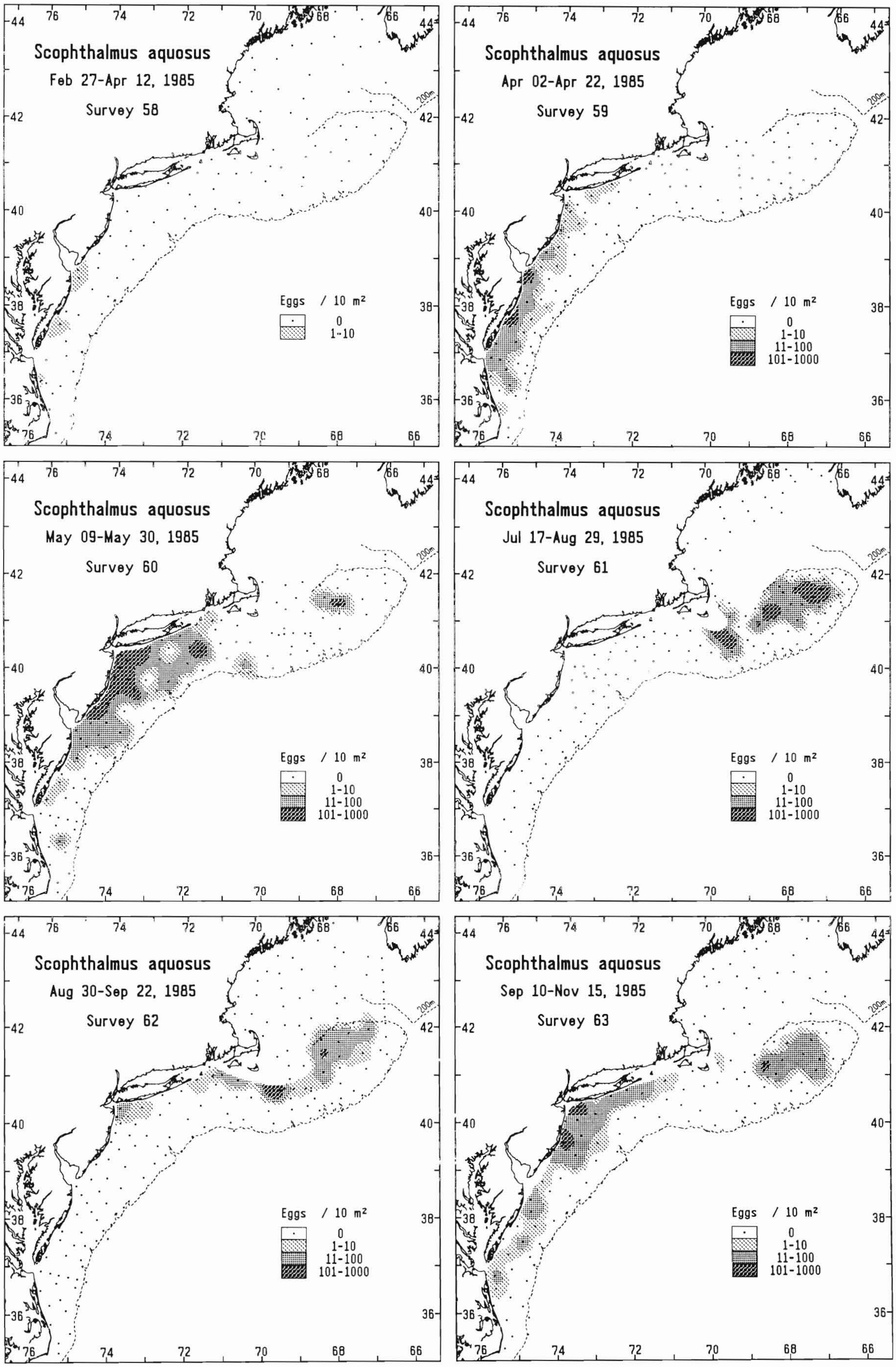

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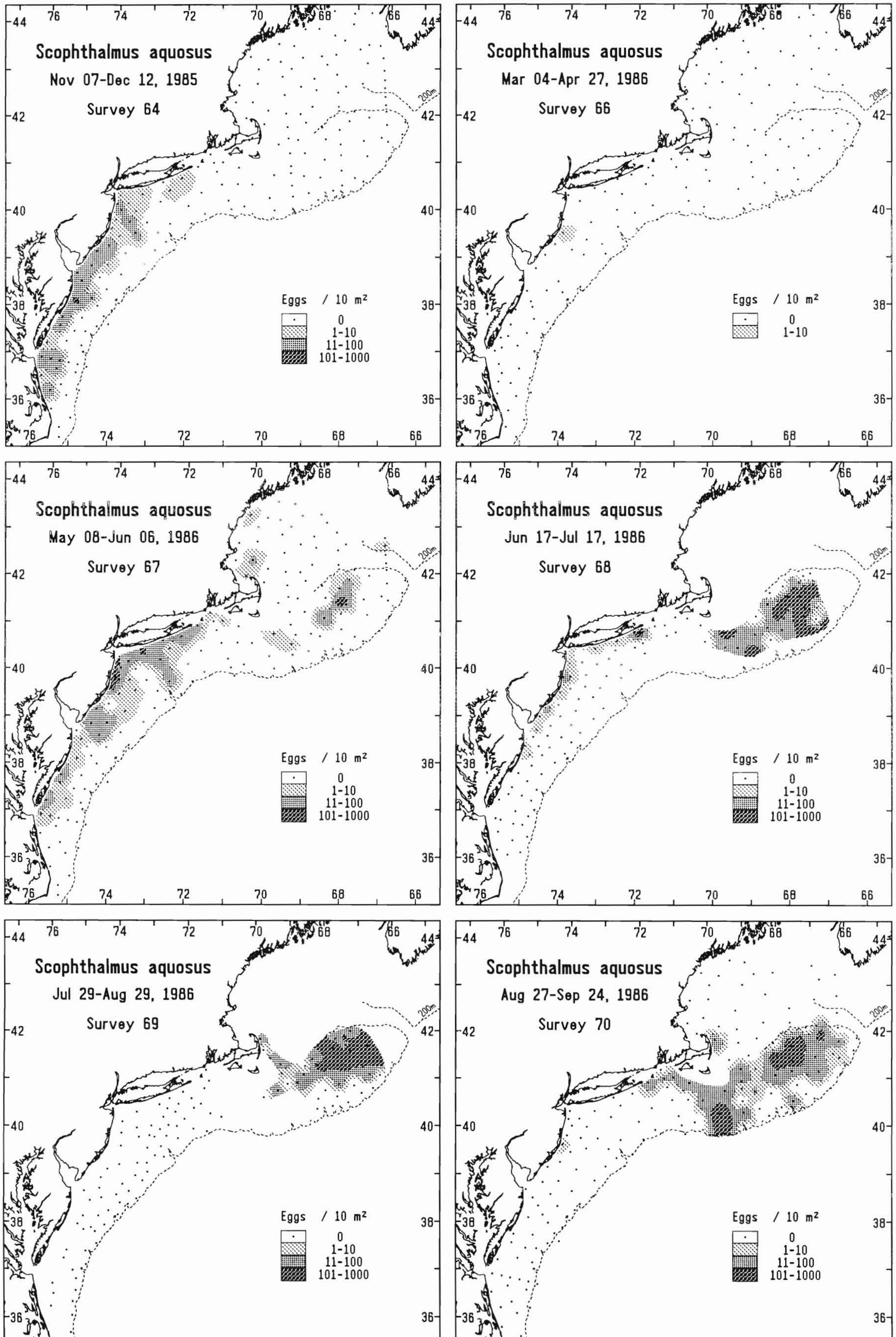

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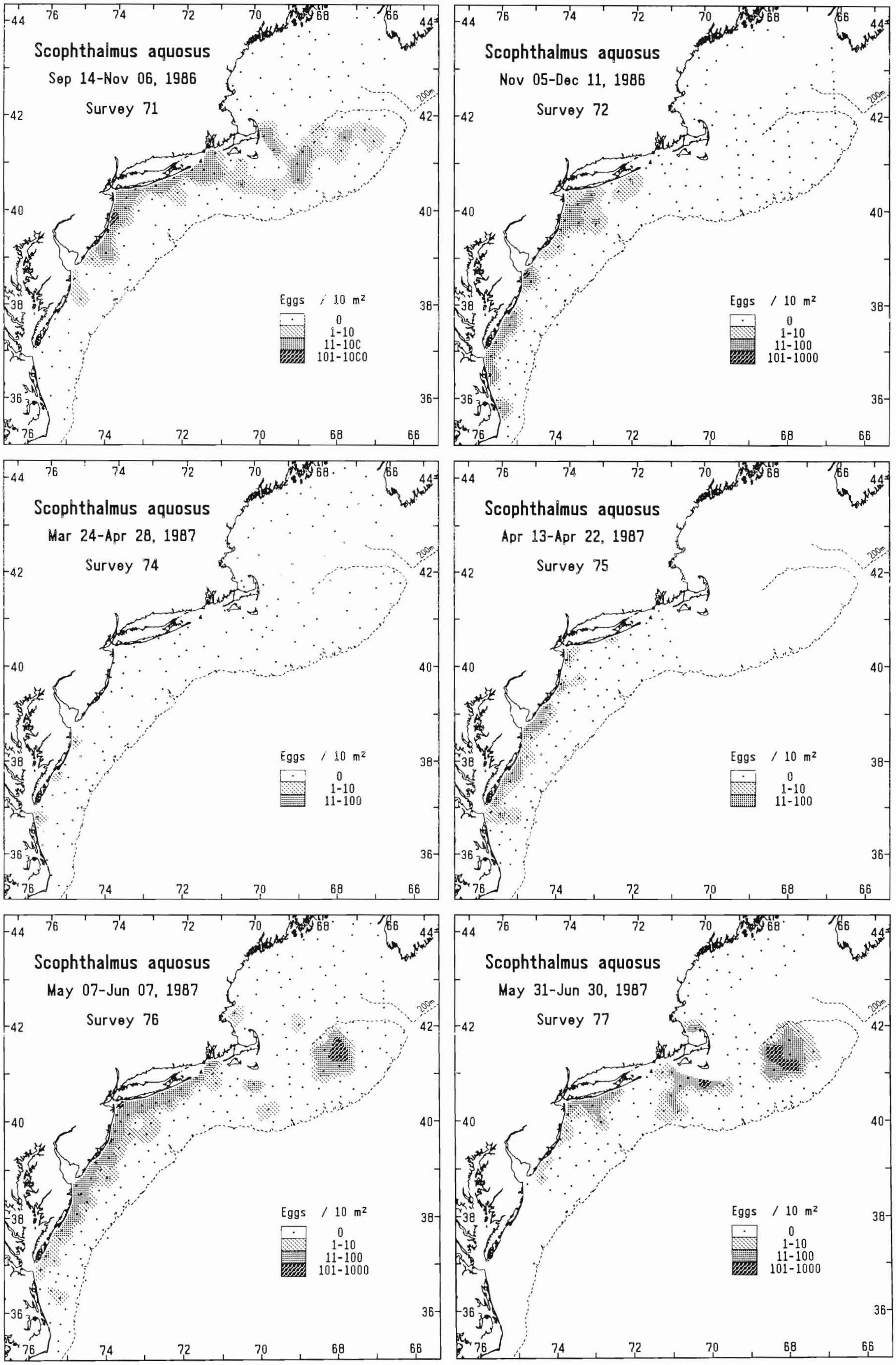

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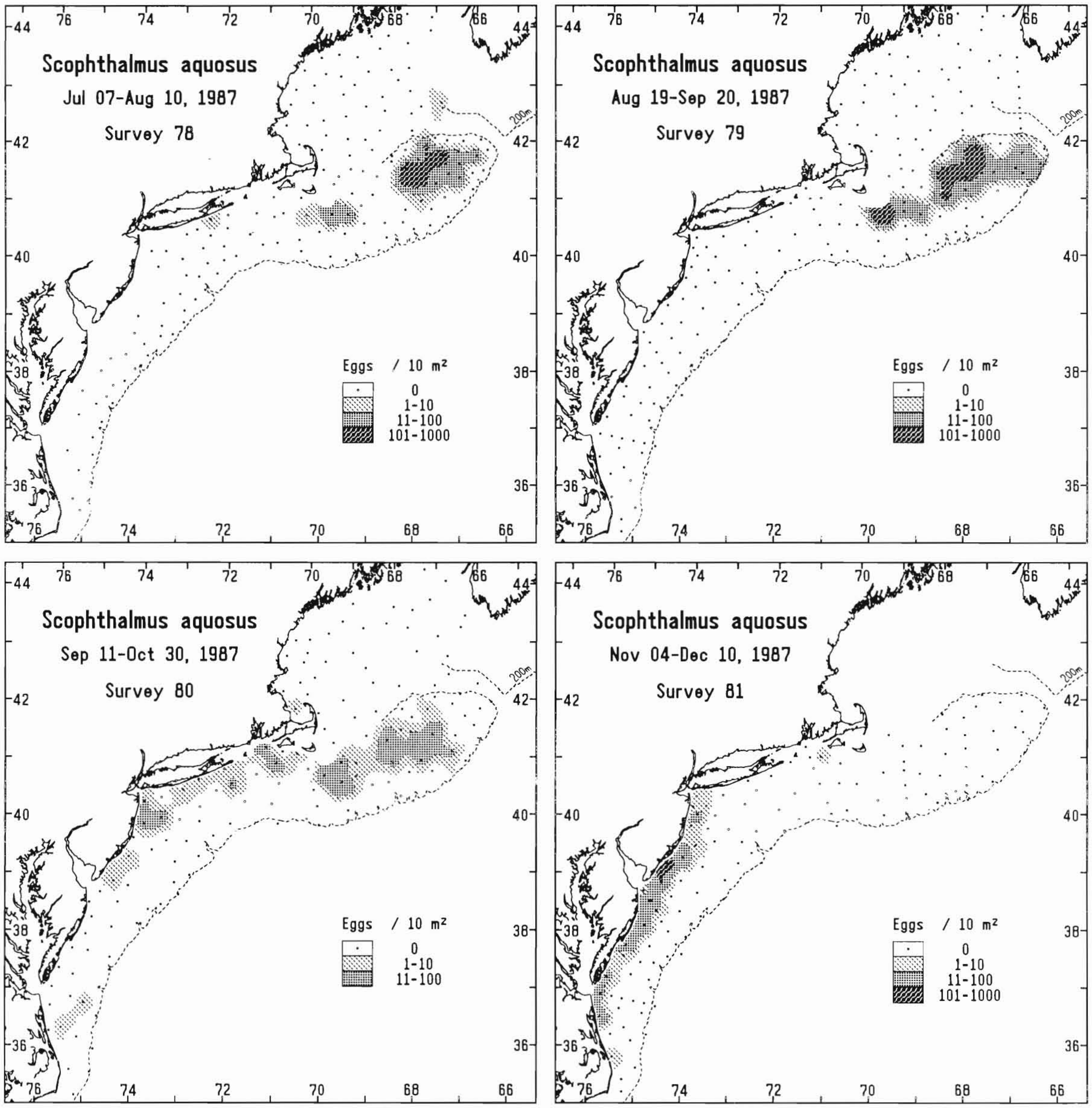


Figure 95 (continued)

Glyptocephalus cynoglossus, witch flounder (Figs. 96–98)

Glyptocephalus cynoglossus eggs were collected from February to October. A seasonal cycle in egg abundance was observed with a peak in June (Fig. 96). Eggs occurred across the entire breadth of shelf waters in the Middle Atlantic, southern New England, and Georges Bank subareas, but in the Gulf of Maine they usually were only in the nearshore or shoal areas (Fig. 97).

Spawning began in the south, expanded northward through spring and summer, and subsequently receded from south to north. Eggs first occurred in February or March in the vicinity of Chesapeake Bay, expanded northward into southern New England in April, and onto Georges Bank and in the Gulf of Maine in May. During peak spawning in June, eggs occurred at scattered locations in the Middle Atlantic and in the western portion of the southern New England subarea, were widespread in shelf waters south of Nantucket Shoals and on south-central Georges Bank, and were heavily concentrated in western, northern, and eastern Gulf of Maine. From July through October, egg abundance declined and eggs were centered at the northern and western Gulf of Maine and western Georges Bank.

The absence of *G. cynoglossus* eggs on the Scotian Shelf during July and August could be attributed to a lack of sampling (Fig. 97). Similarly, the decrease in mean egg density in July, as compared to May, June, and August (Fig. 96), was probably influenced by partial sampling coverage in the Gulf of Maine during July.

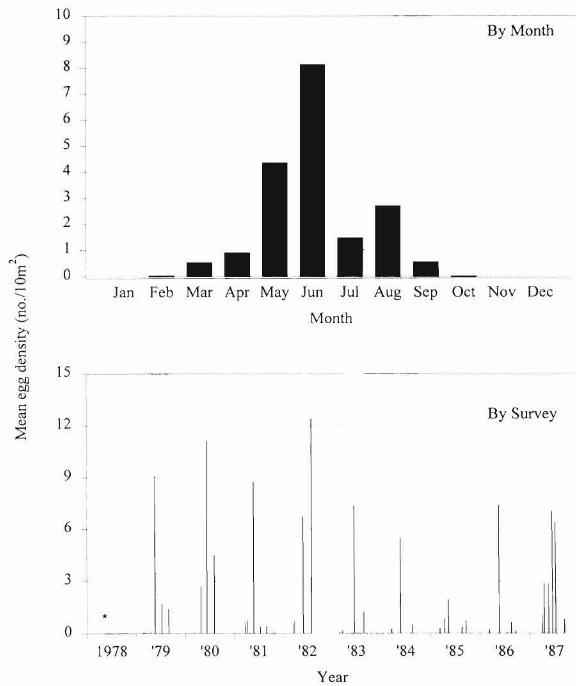


Figure 96
Glyptocephalus cynoglossus; mean-egg-density graphs by month (top) and by survey (bottom) for the total MARMAP area. (*Samples from the first four surveys in 1978 were not analyzed for *G. cynoglossus* eggs.)

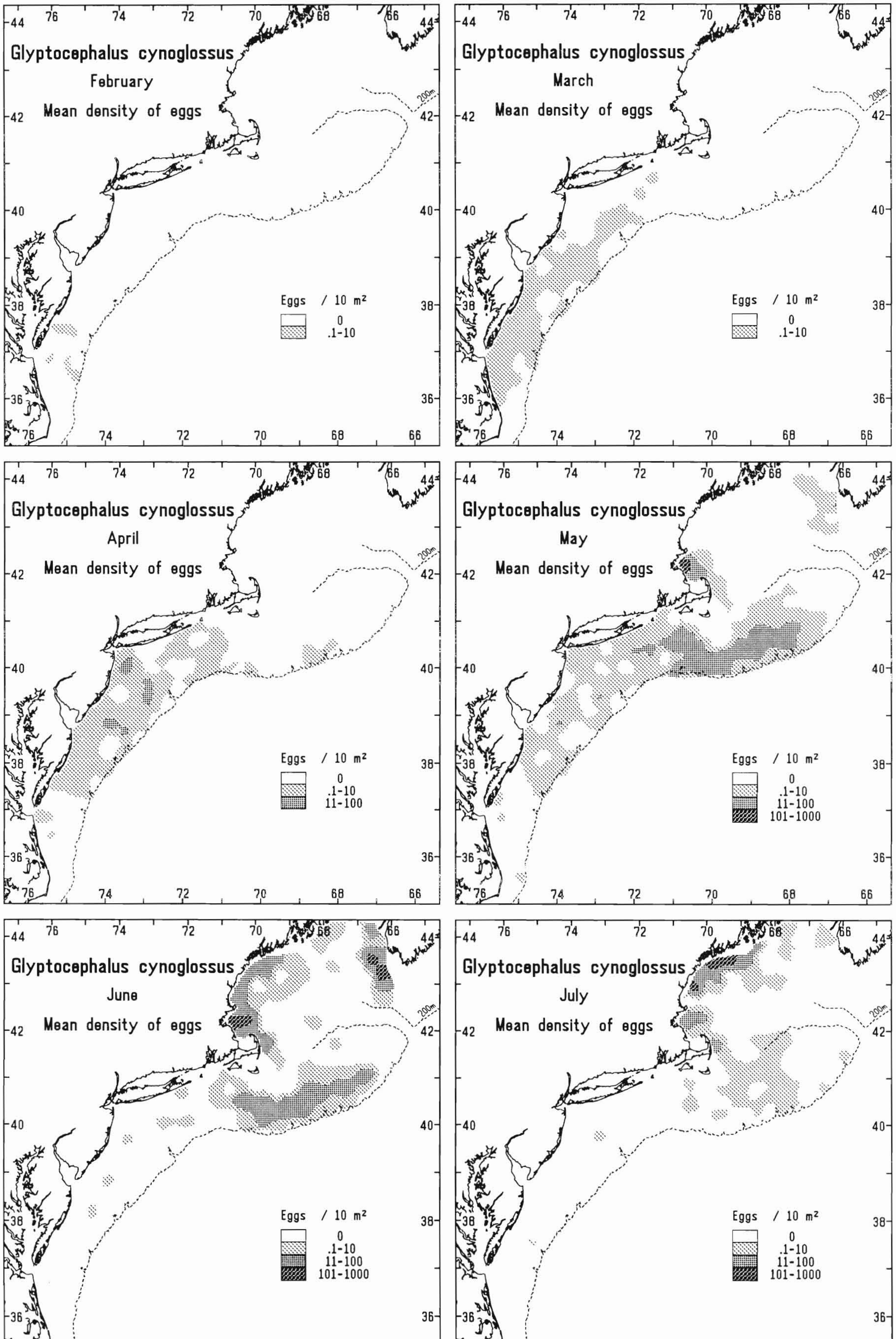


Figure 97

Glyptocephalus cynoglossus; composite monthly areal plots of mean egg densities (no./10 m²).

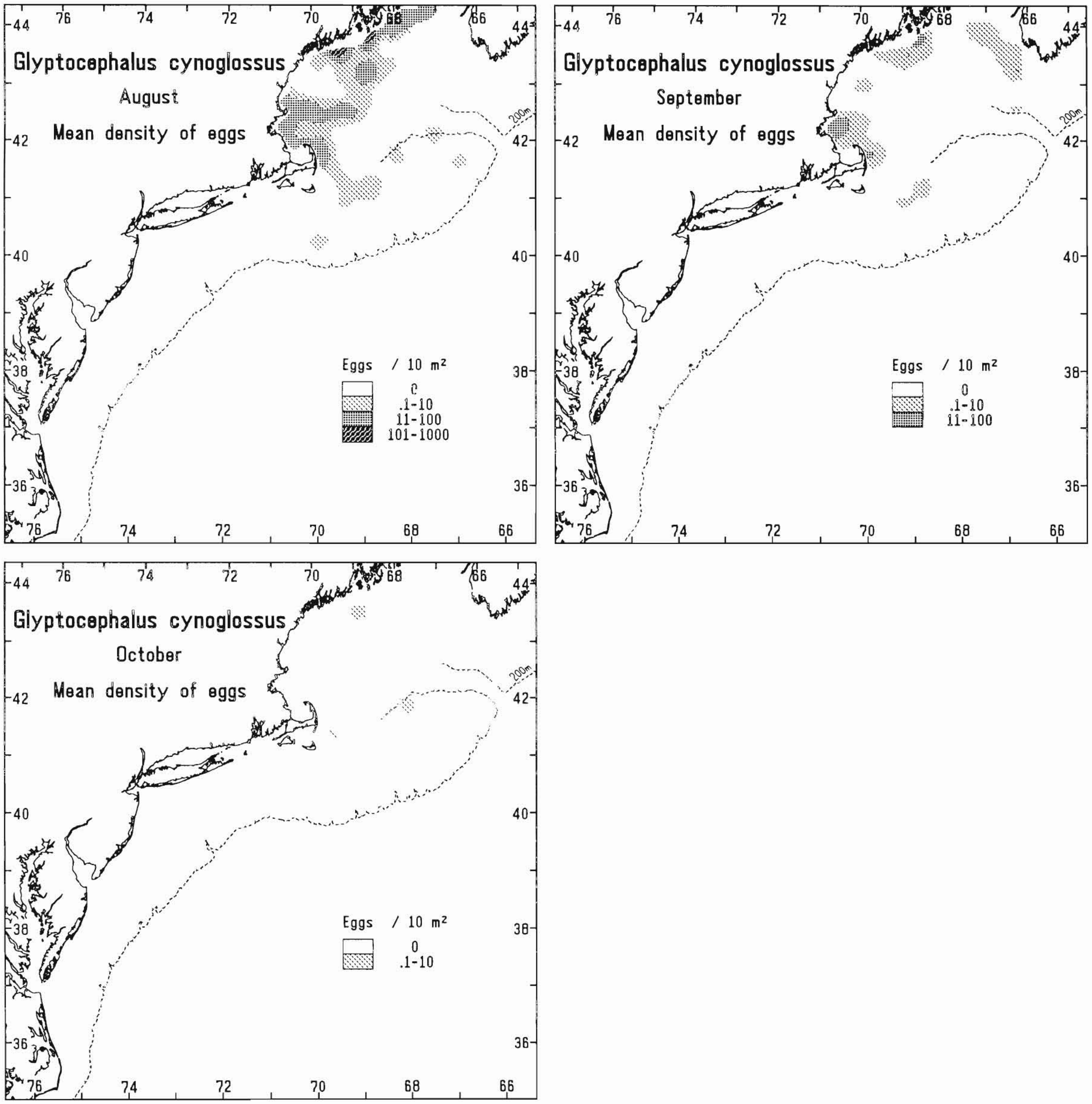


Figure 97 (continued)

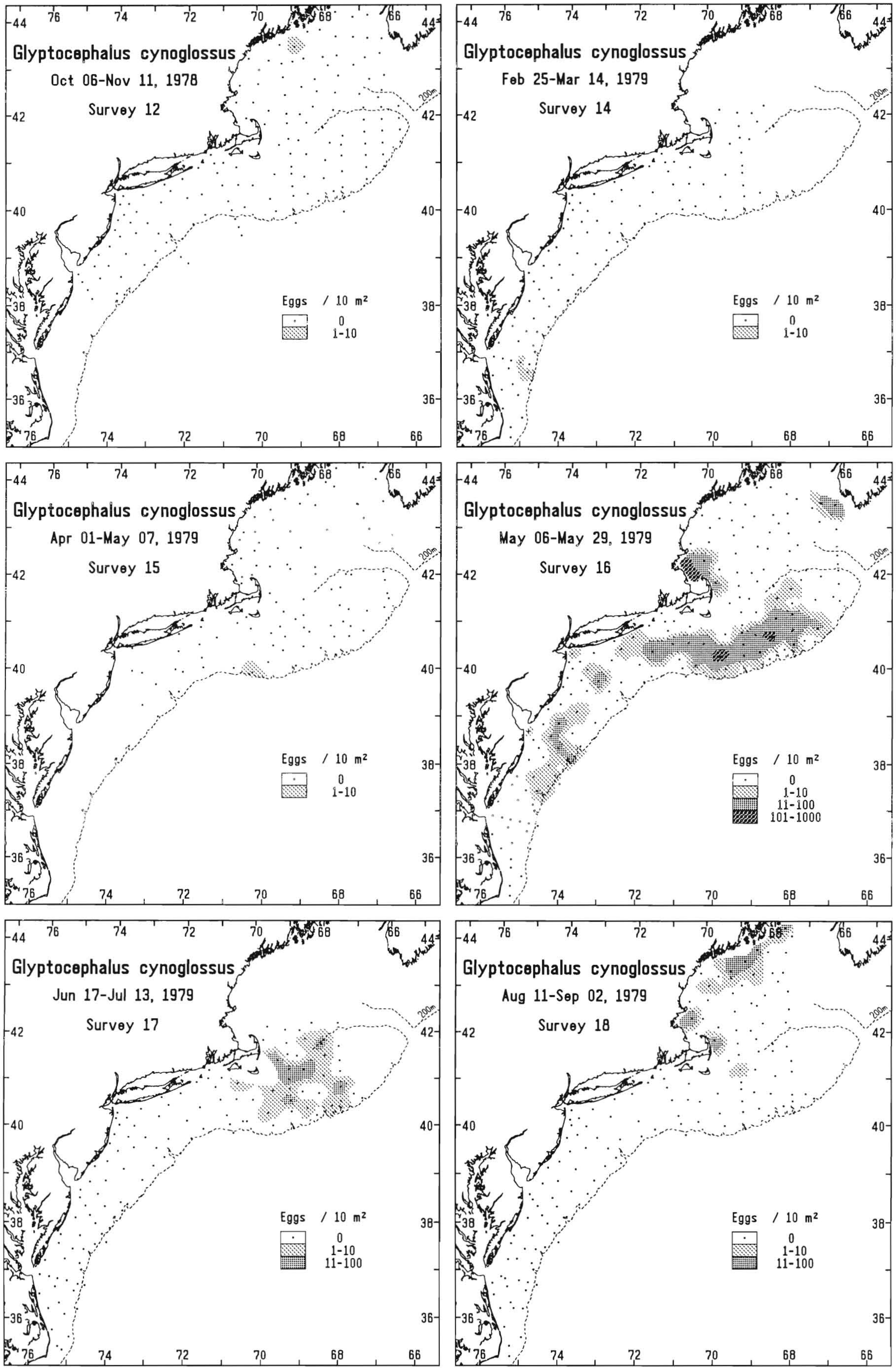


Figure 98

Glyptocephalus cynoglossus; survey areal plots of egg densities (no./10 m²).

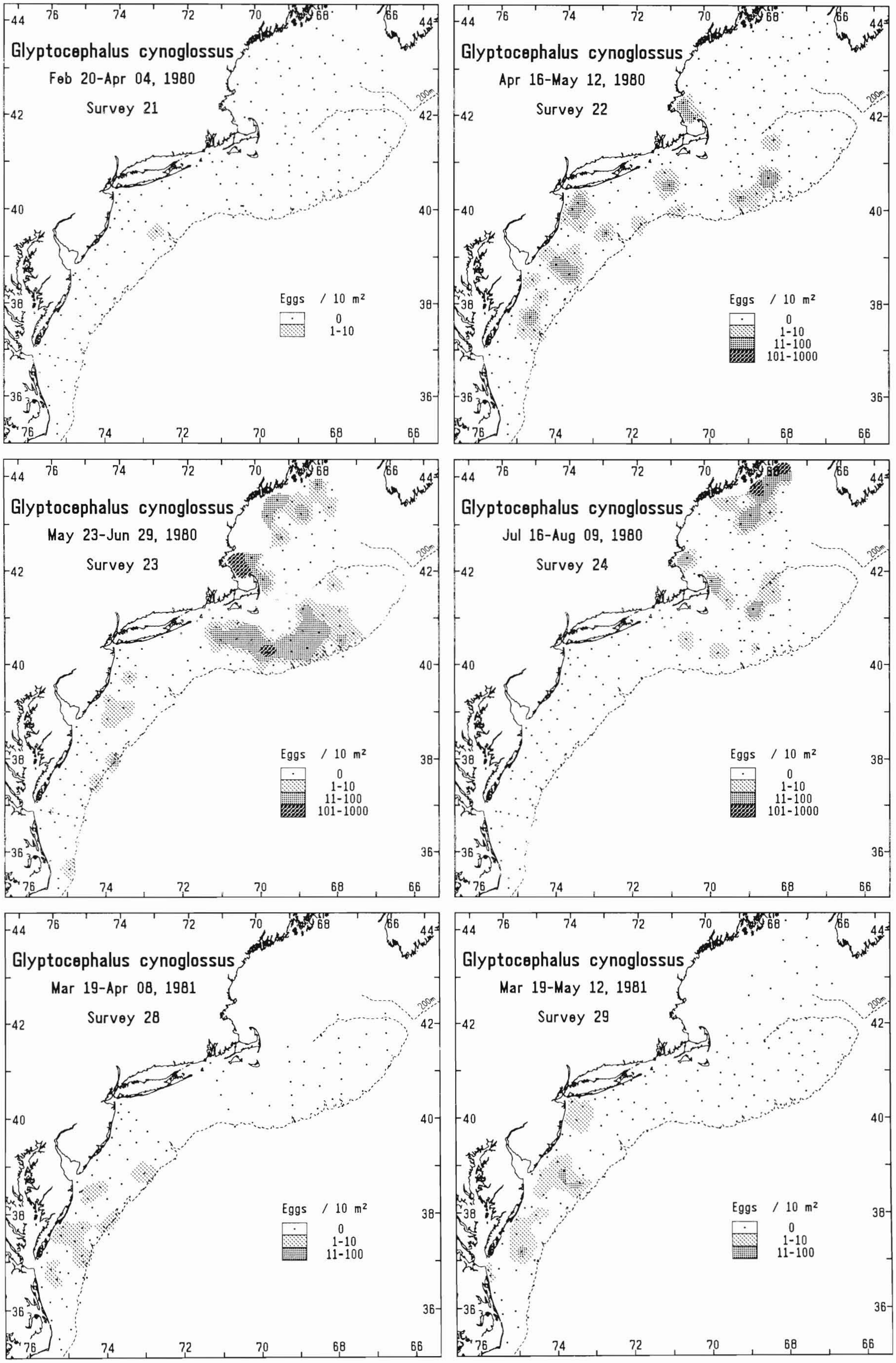


Figure 98 (continued)

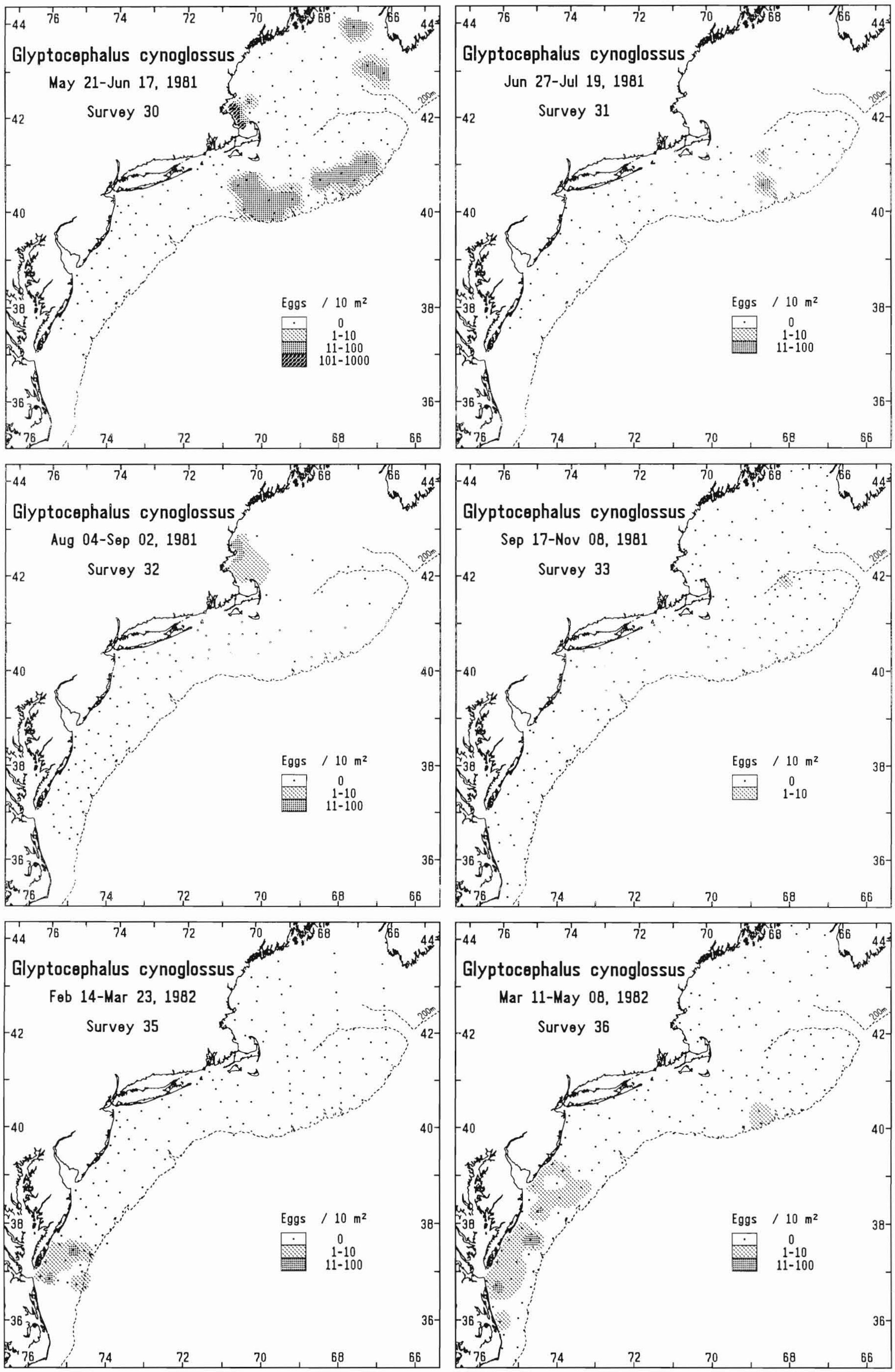
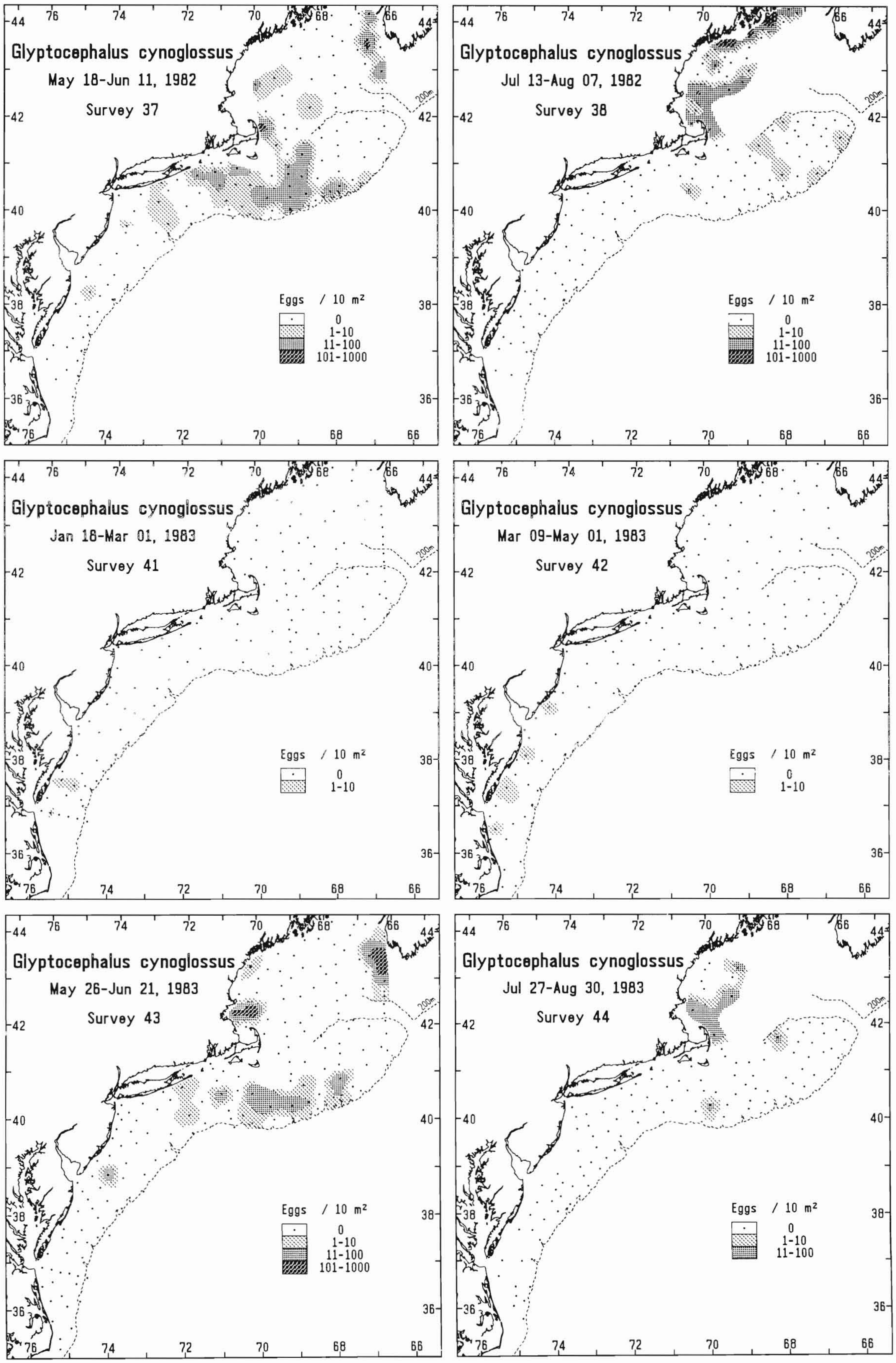


Figure 98 (continued)



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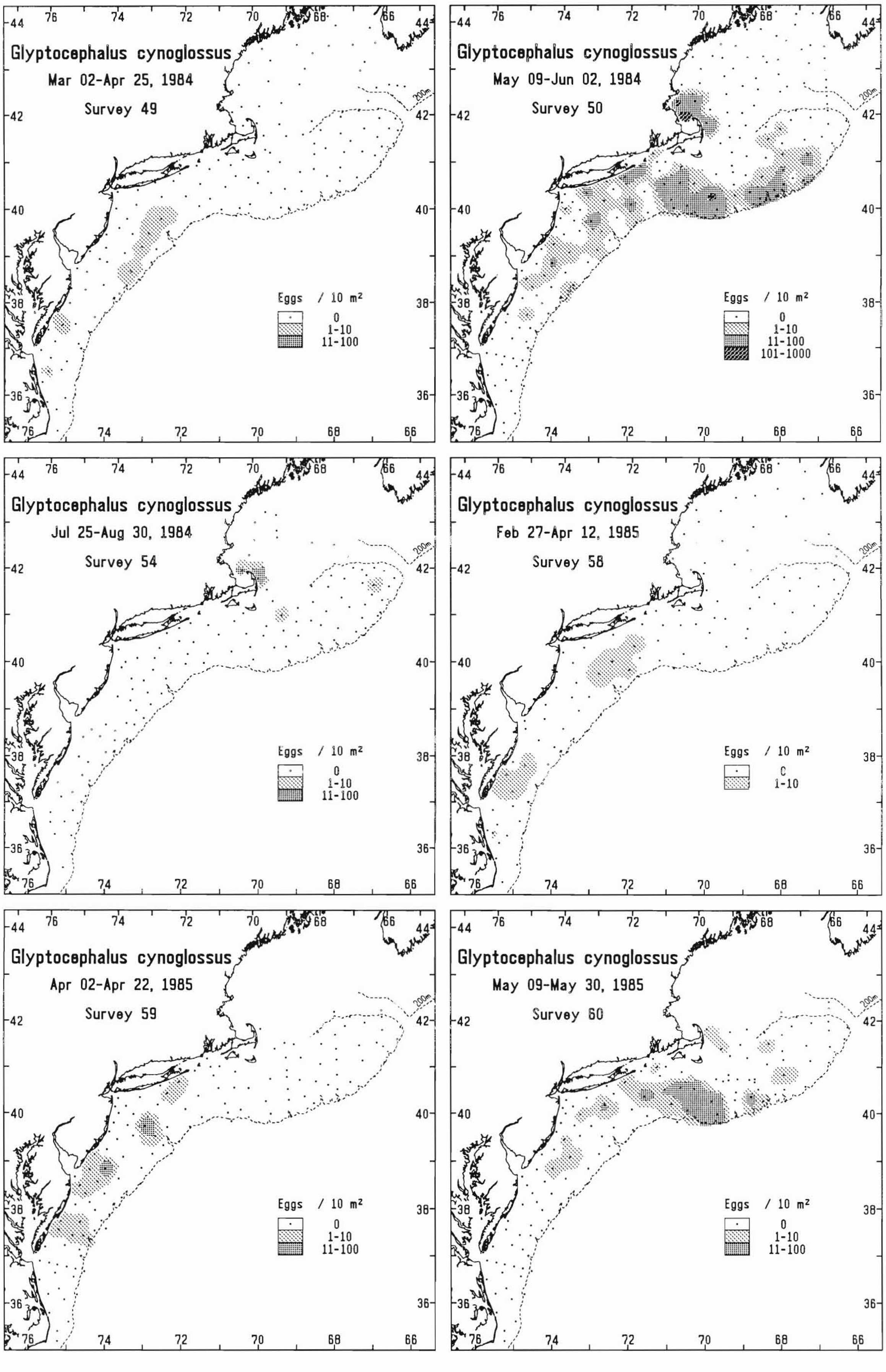


Figure 98 (continued)

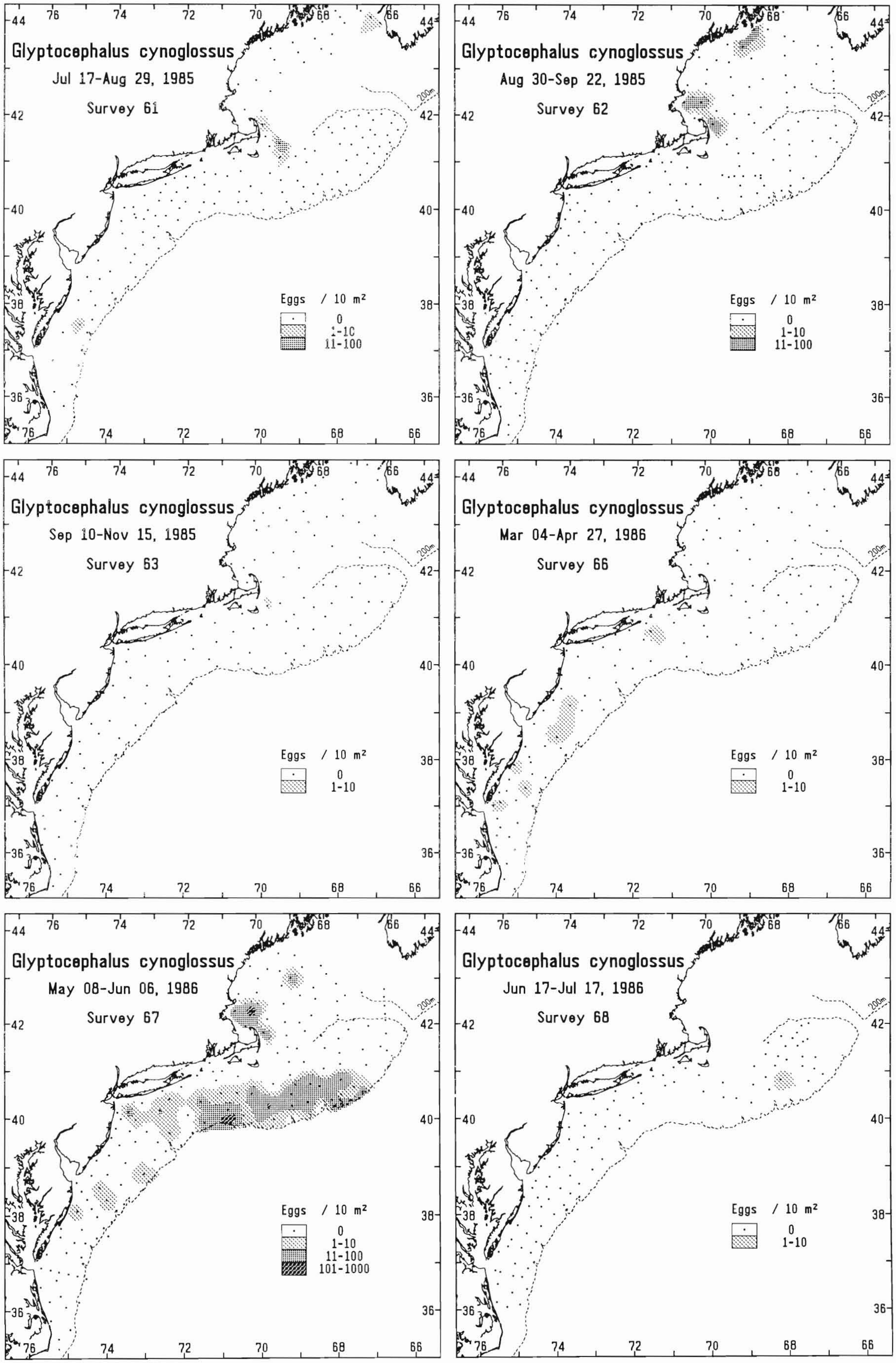
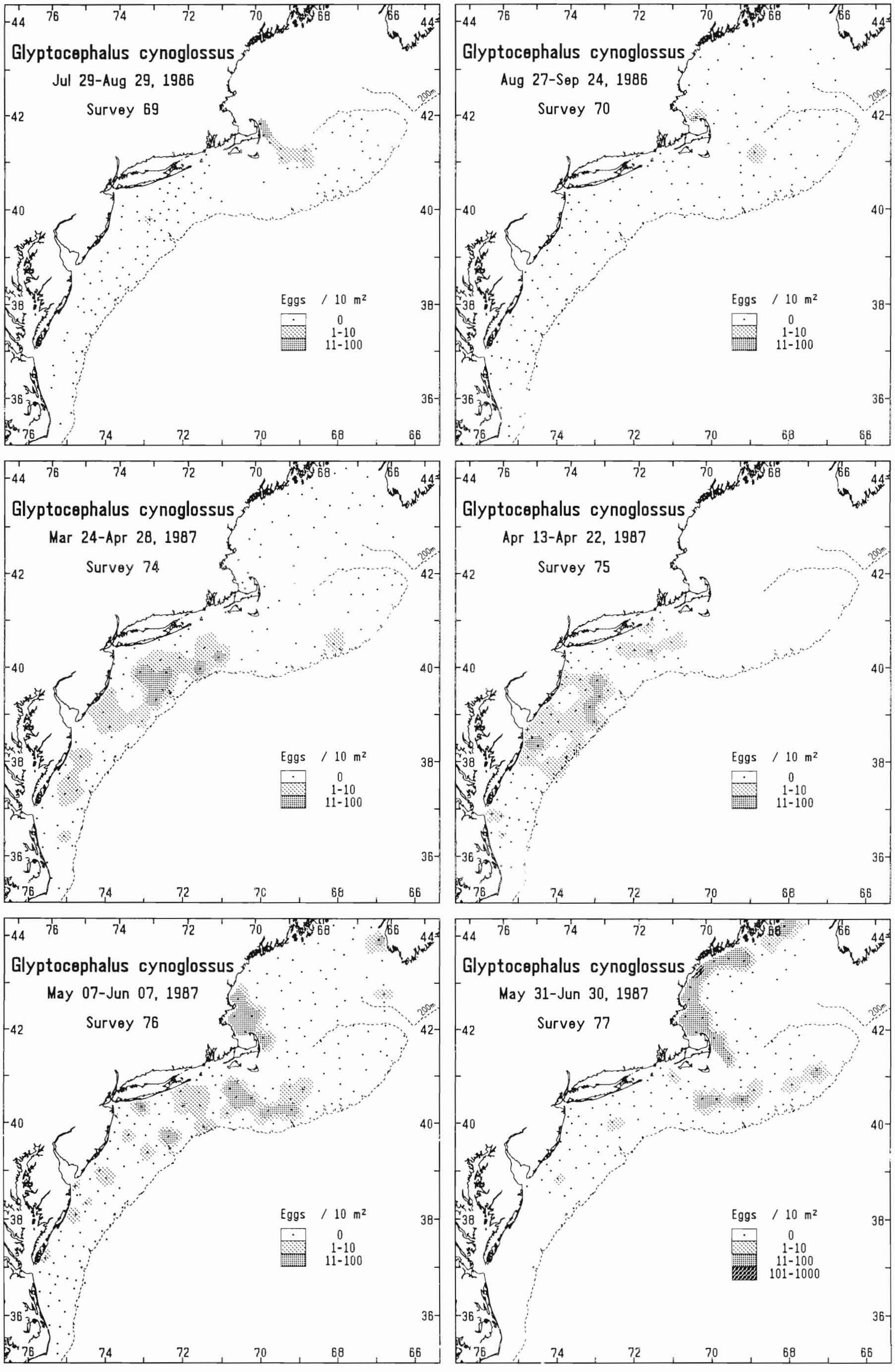


Figure 98 (continued)



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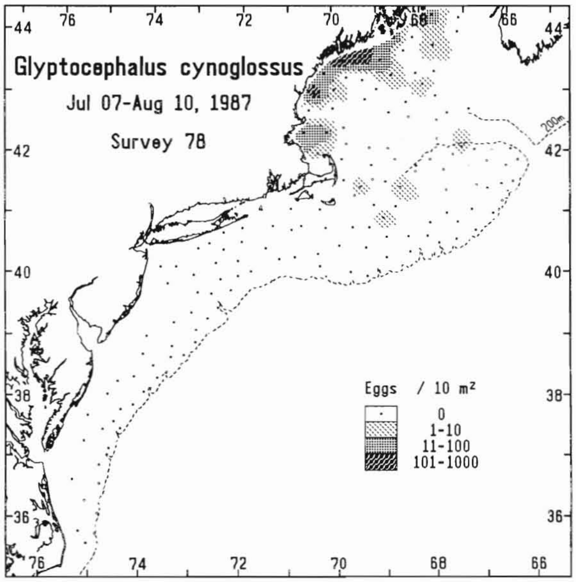
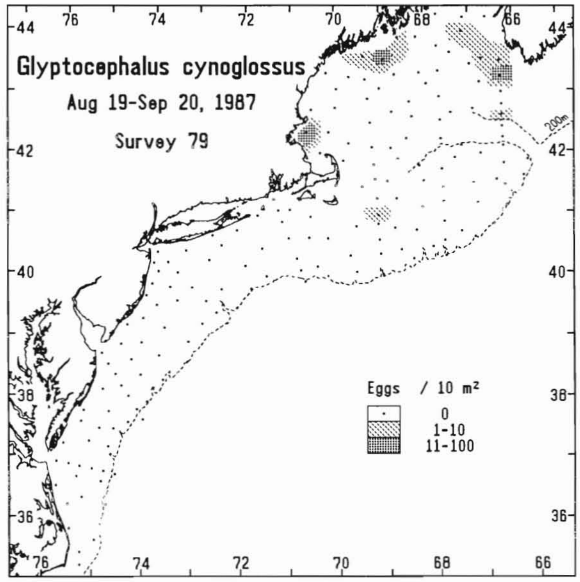




Hippoglossoides platessoides, American plaice (Figs. 99–101)

Although eggs of *Hippoglossoides platessoides* were collected year-round, there was a strong seasonal cycle in egg abundance, with fewest eggs occurring in autumn and early winter, and peak densities during spring and early summer (Fig. 99). They were most abundant in shallower portions of the Gulf of Maine and Georges Bank (Fig. 100).

Spawning was minimal from September to January, followed by a rapid increase from February to April. Egg densities in March in the Gulf of Maine were probably underestimated due to a lack of sampling (Fig. 2). During April and May the distribution of *H. platessoides* eggs was most extensive and mean densities were highest (Figs. 99 and 100). Thereafter (from June to September) spawning diminished and receded to isolated locations in western and northern Gulf of Maine.

A downward trend in survey mean-egg-density was observed (Fig. 99). But the highest survey mean-egg-density (in 1979) probably overestimated the true mean density because sampling coverage during that survey was lacking in the Middle Atlantic subarea, an area where eggs were not expected to occur (survey 15, Fig. 101).

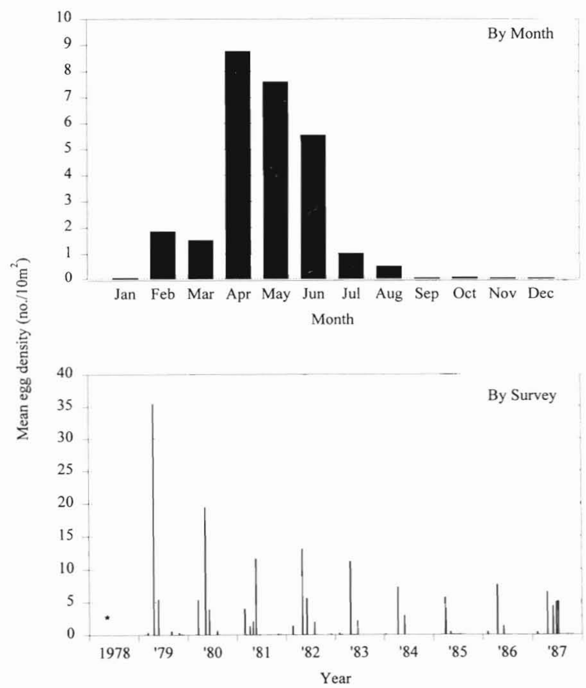


Figure 99
Hippoglossoides platessoides; mean-egg-density graphs by month (top) and by survey (bottom) for the total MARMAP area. (*Samples from the first four surveys in 1978 were not analyzed for *H. platessoides* eggs.)

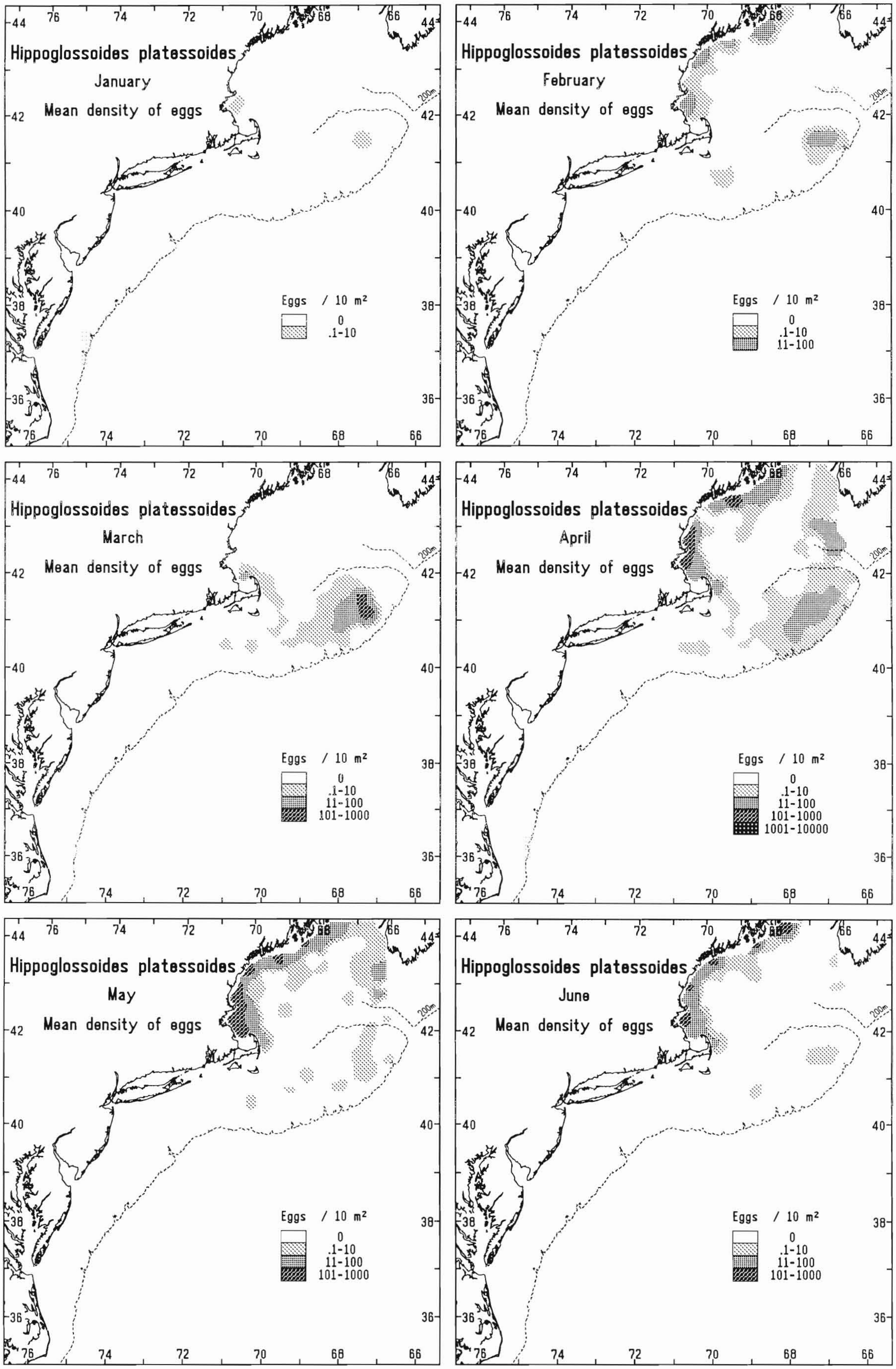


Figure 100

Hippoglossoides platessoides; composite monthly areal plots of mean egg densities (no./10 m²).

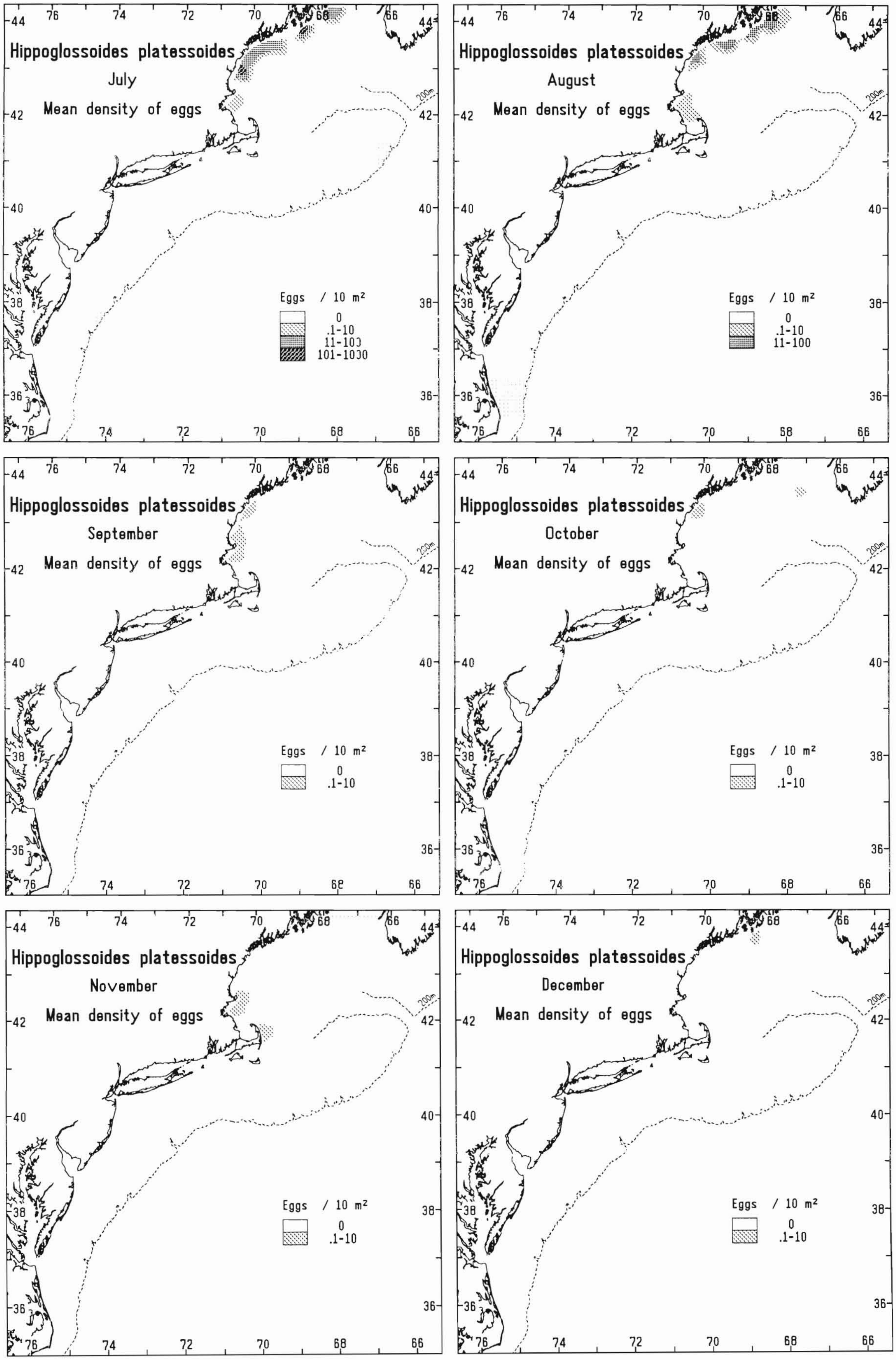


Figure 100 (continued)

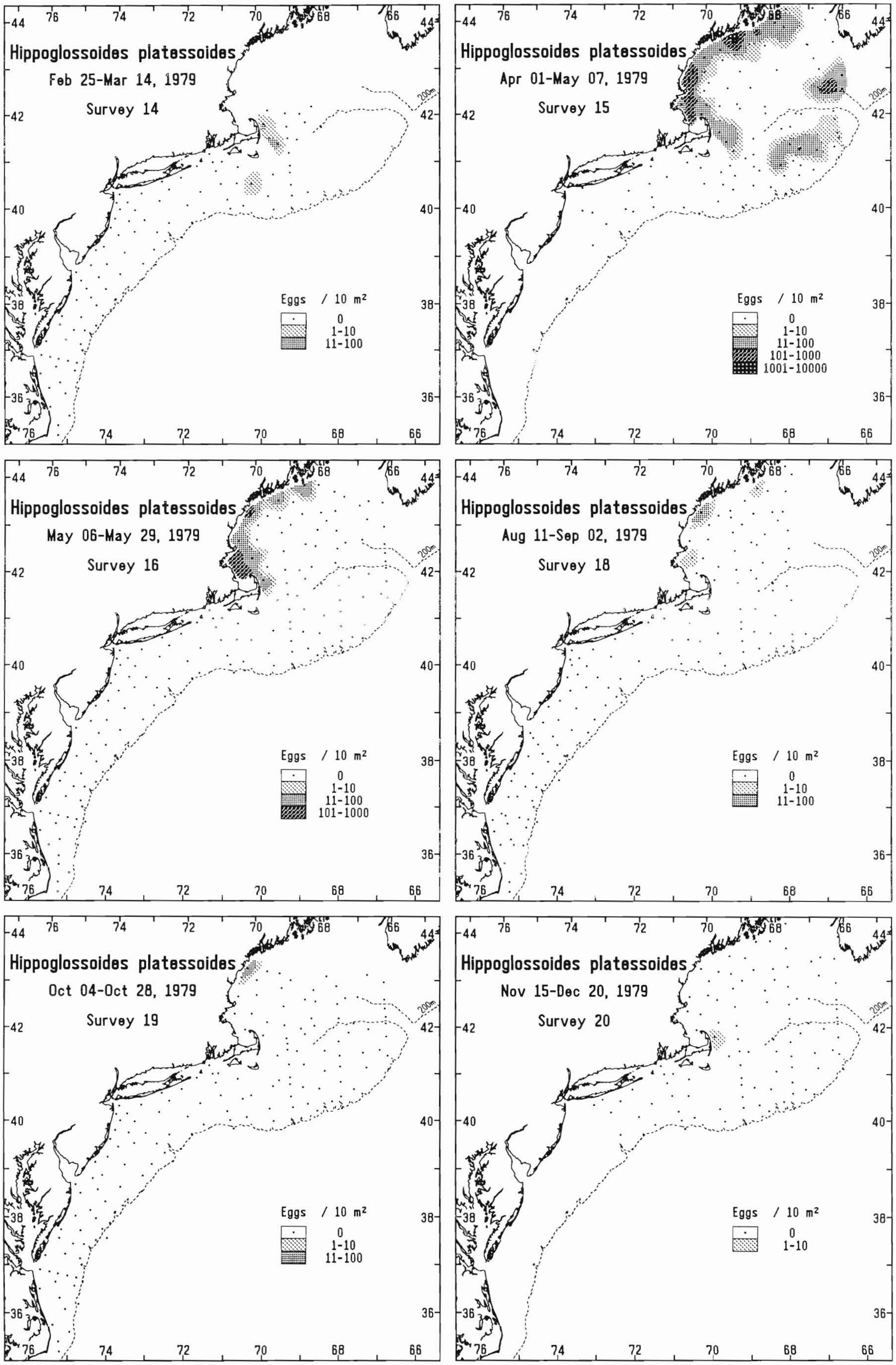


Figure 101

Hippoglossoides platessoides; survey areal plots of egg densities (no./10 m^2).

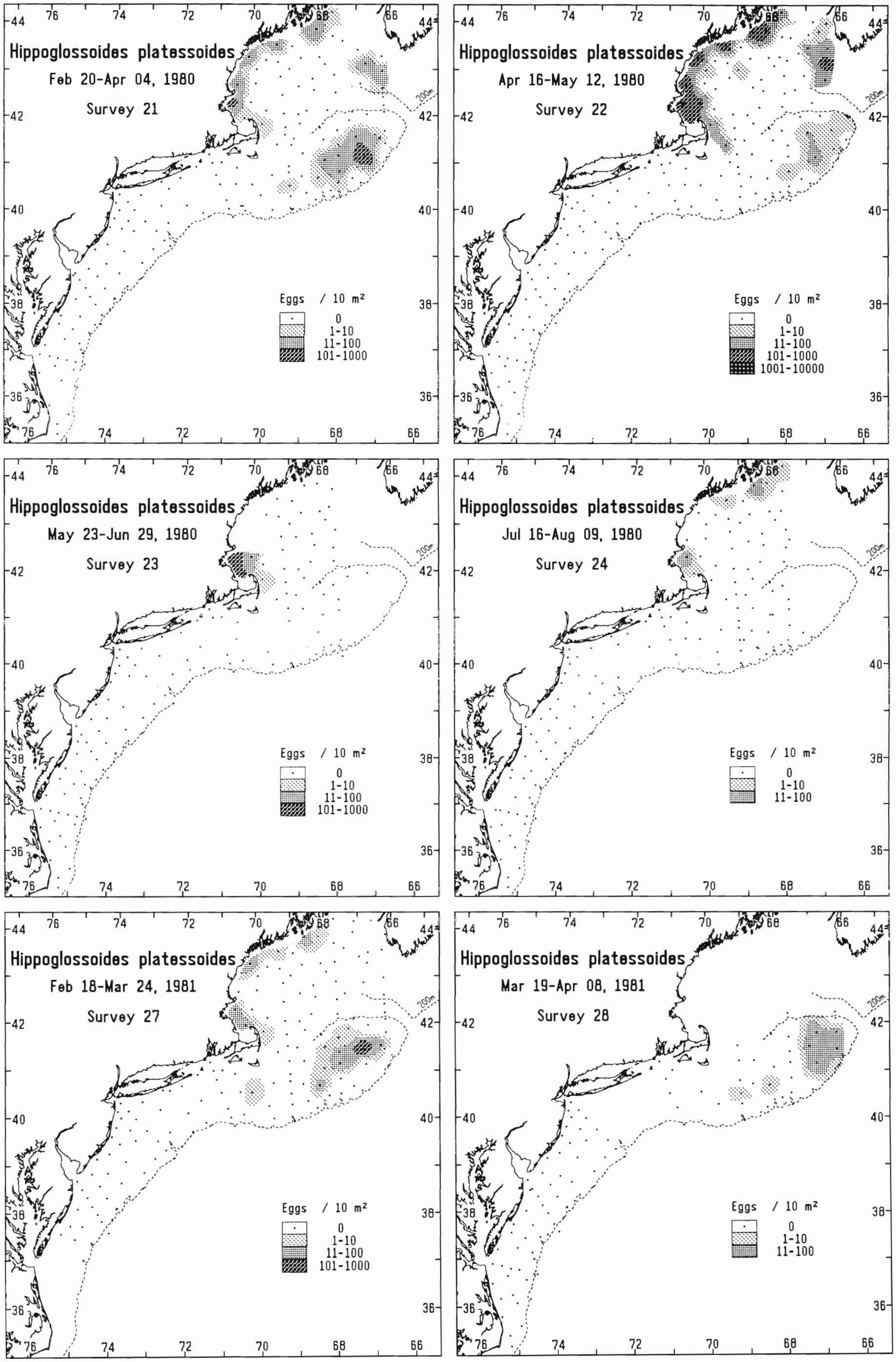


Figure 101 (continued)

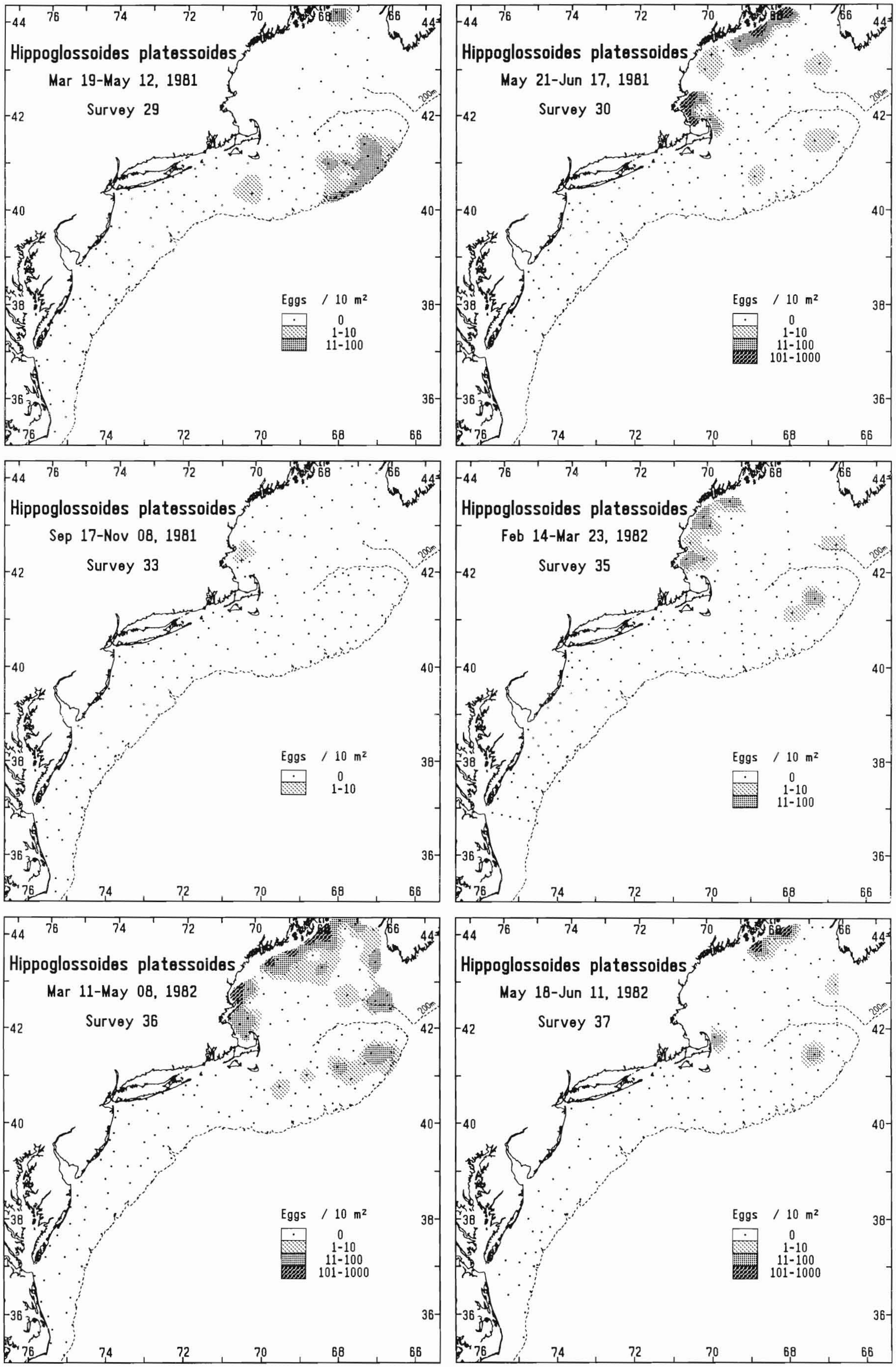
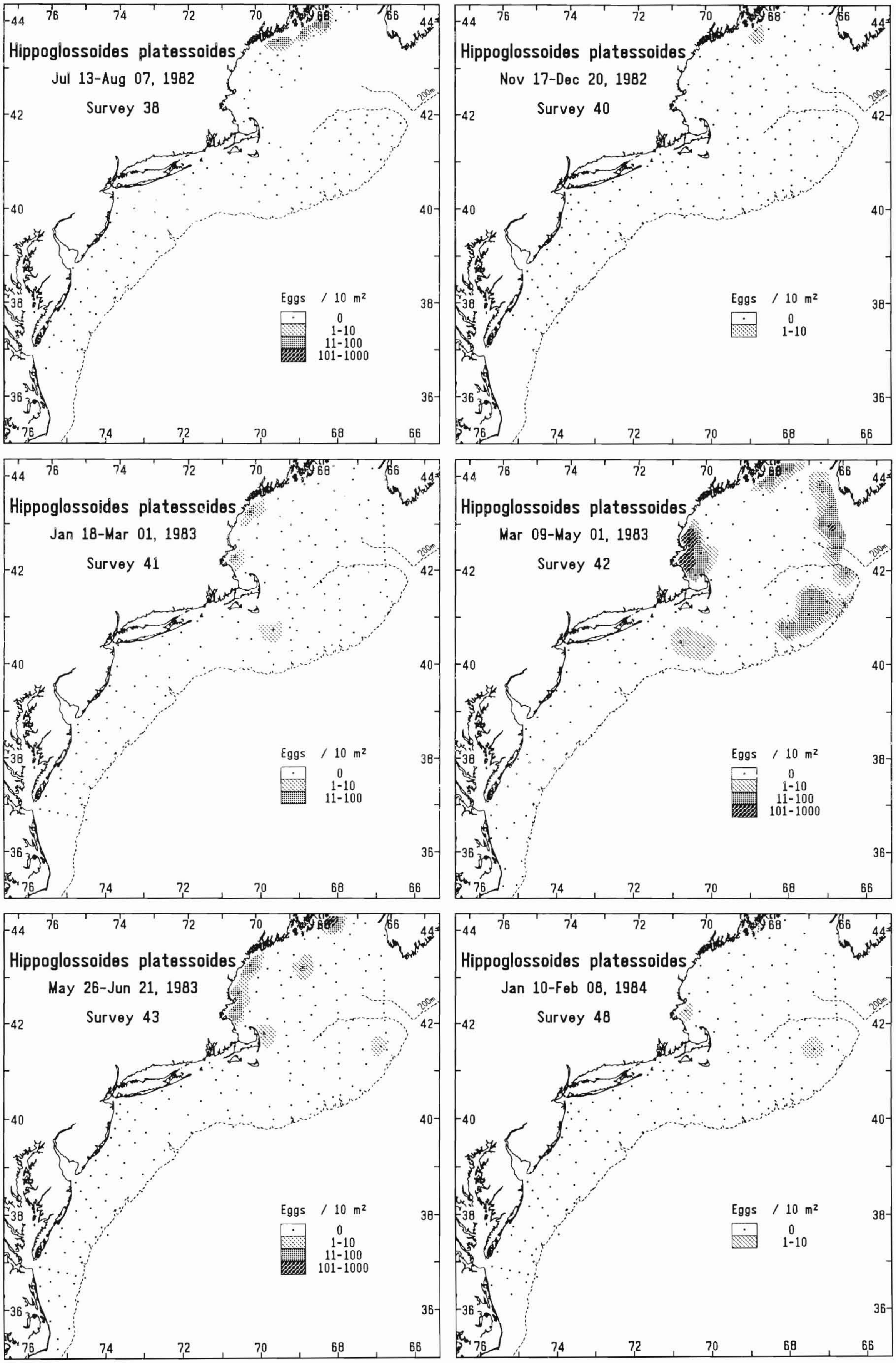


Figure 101 (continued)



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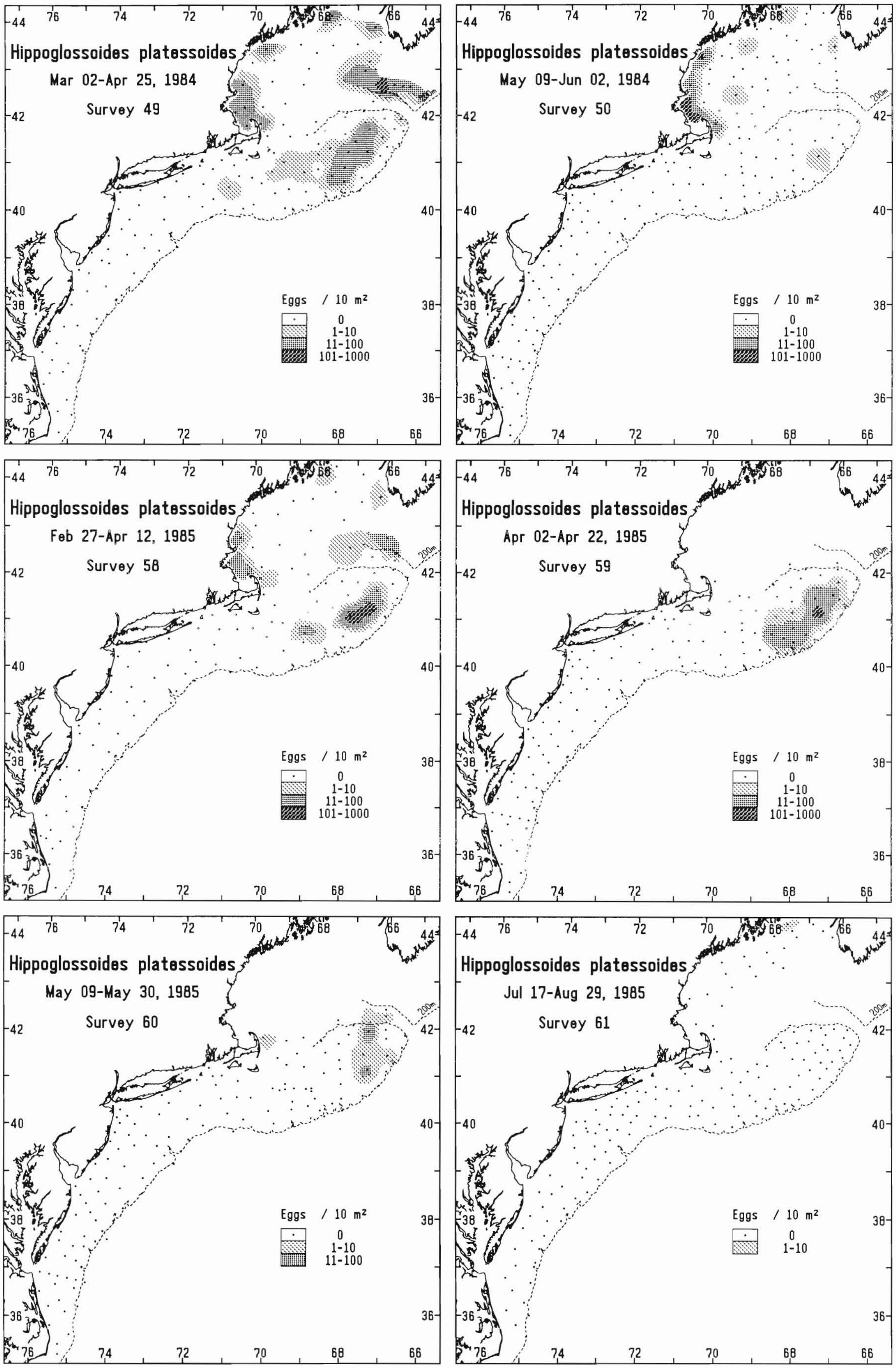
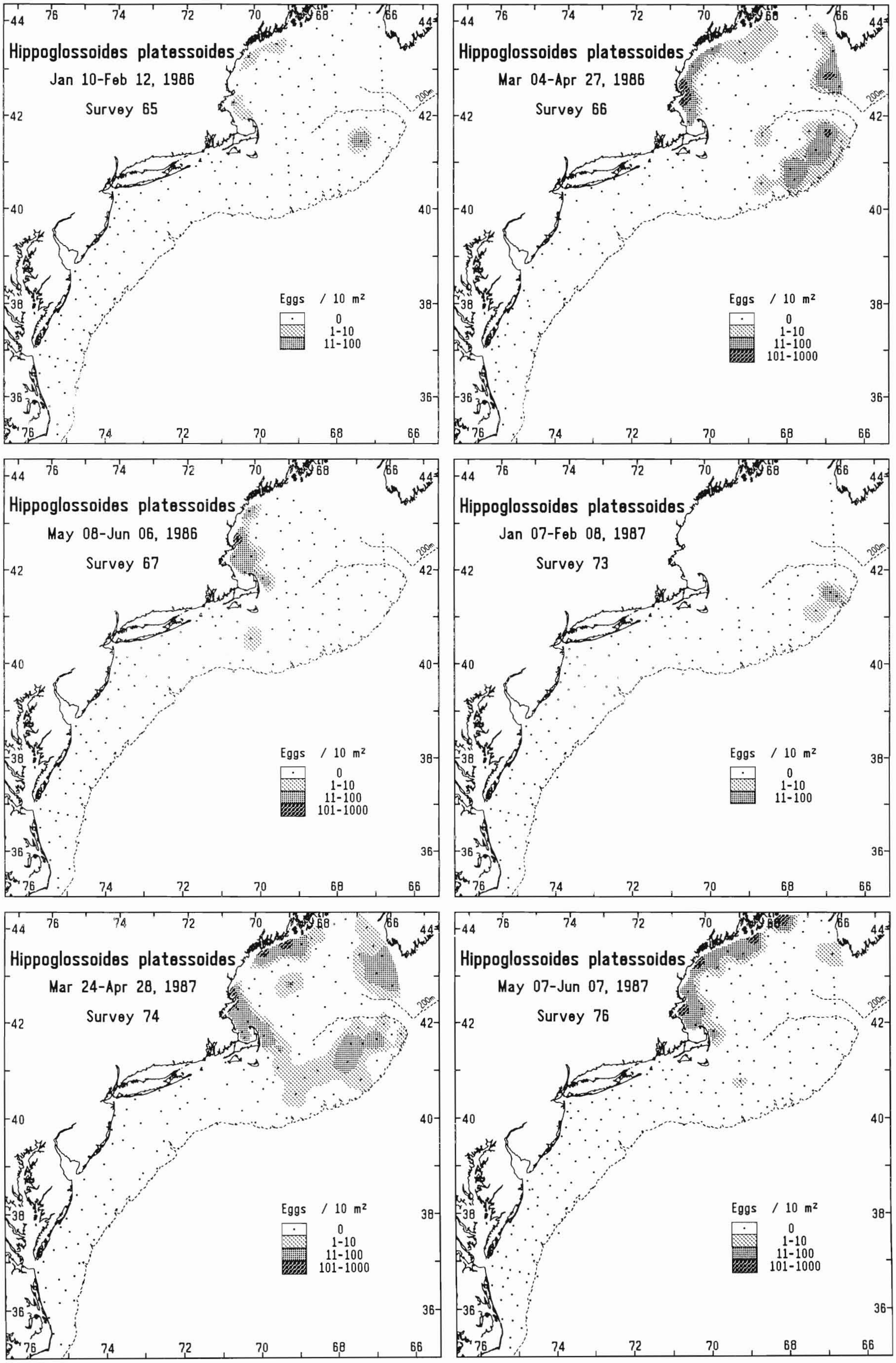


Figure 101 (continued)



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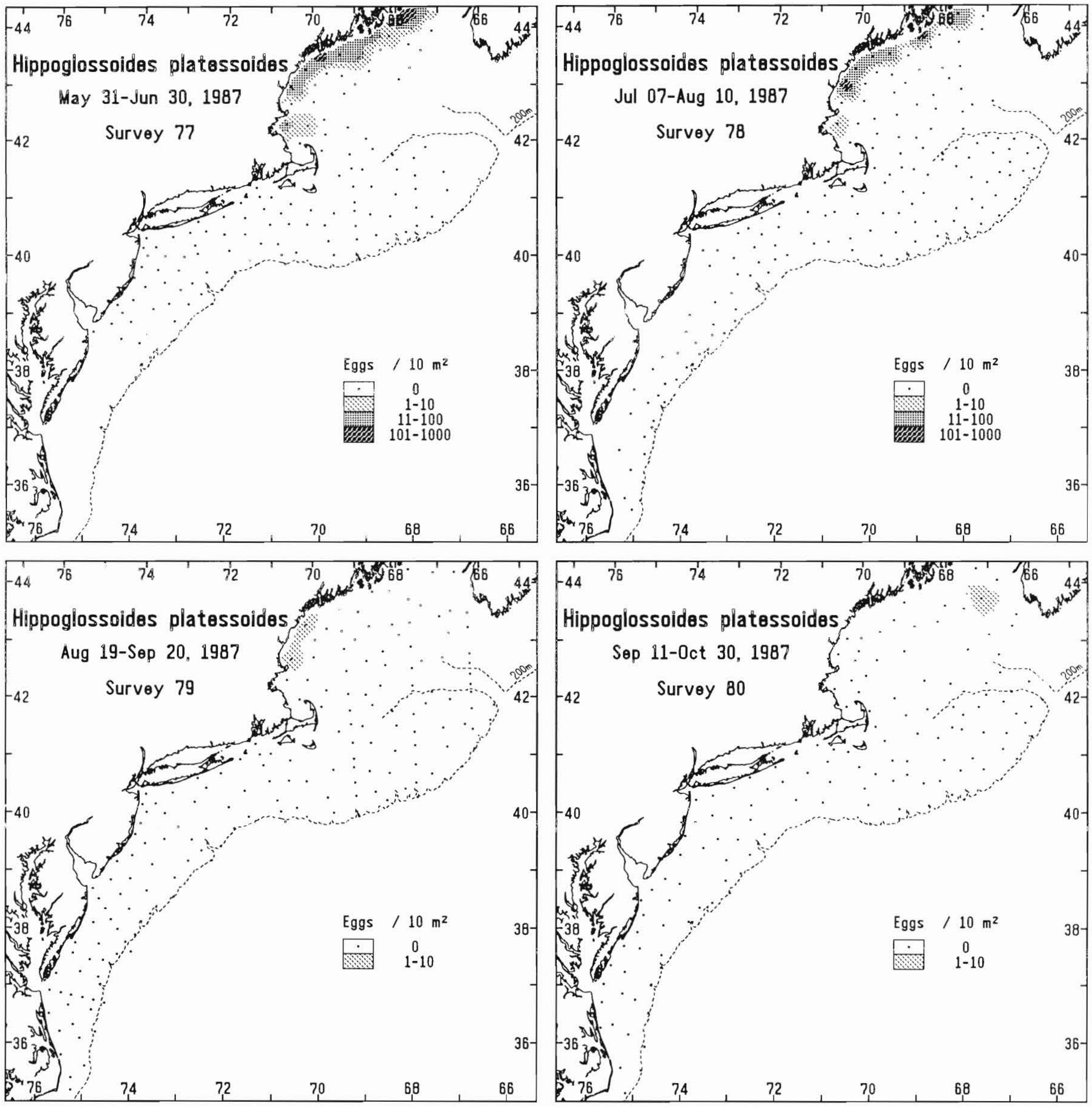


Figure 101 (continued)

Pleuronectes ferrugineus, yellowtail flounder (Figs. 102–104)

Pleuronectes ferrugineus eggs were collected from February to September, with peak abundances from April to June (Fig. 102). During months of high abundance, eggs were widespread across most of the shelf, with concentrations in the inner shelf. Areas of high egg density occurred from New York Bight to eastern Georges Bank and in western and Scotian Shelf portions of the Gulf of Maine.

Spawning began in February or March, occurring first in the northern half of the Middle Atlantic subarea, then extending rapidly into southern New England and Georges Bank (Fig. 103). In April and May spawning increased in intensity in the same areas plus the Gulf of Maine. While the overall level of spawning remained high in June, spawning intensity and the areal distribution of eggs receded in Middle Atlantic waters. Thereafter spawning diminished rapidly in July and ended in August or September. The mean egg density for July (Fig. 102) was probably underestimated due to a lack of sampling on the Scotian Shelf (Fig. 2).

A downward trend in spawning level was observed (Fig. 102), with peak egg abundances lower during the last three years (1985–87).

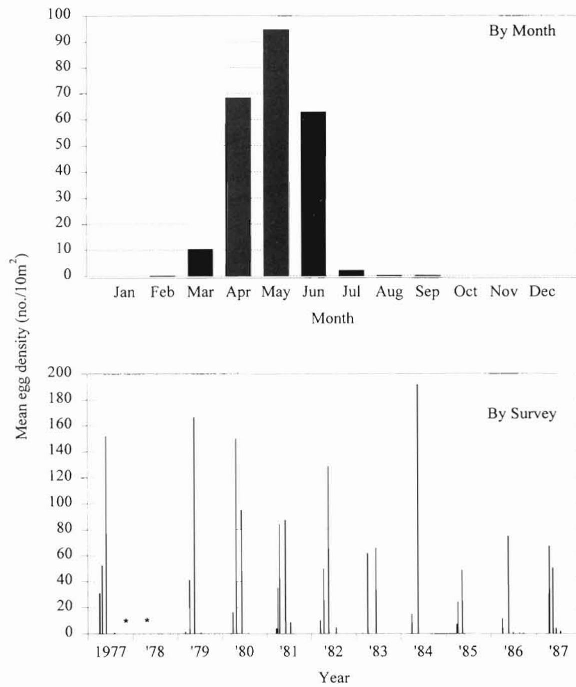


Figure 102
Pleuronectes ferrugineus; mean-egg-density graphs by month (top) and by survey (bottom) for the total MARMAP area. (*Samples from the first four surveys in 1978 were not analyzed for *P. ferrugineus* eggs.)

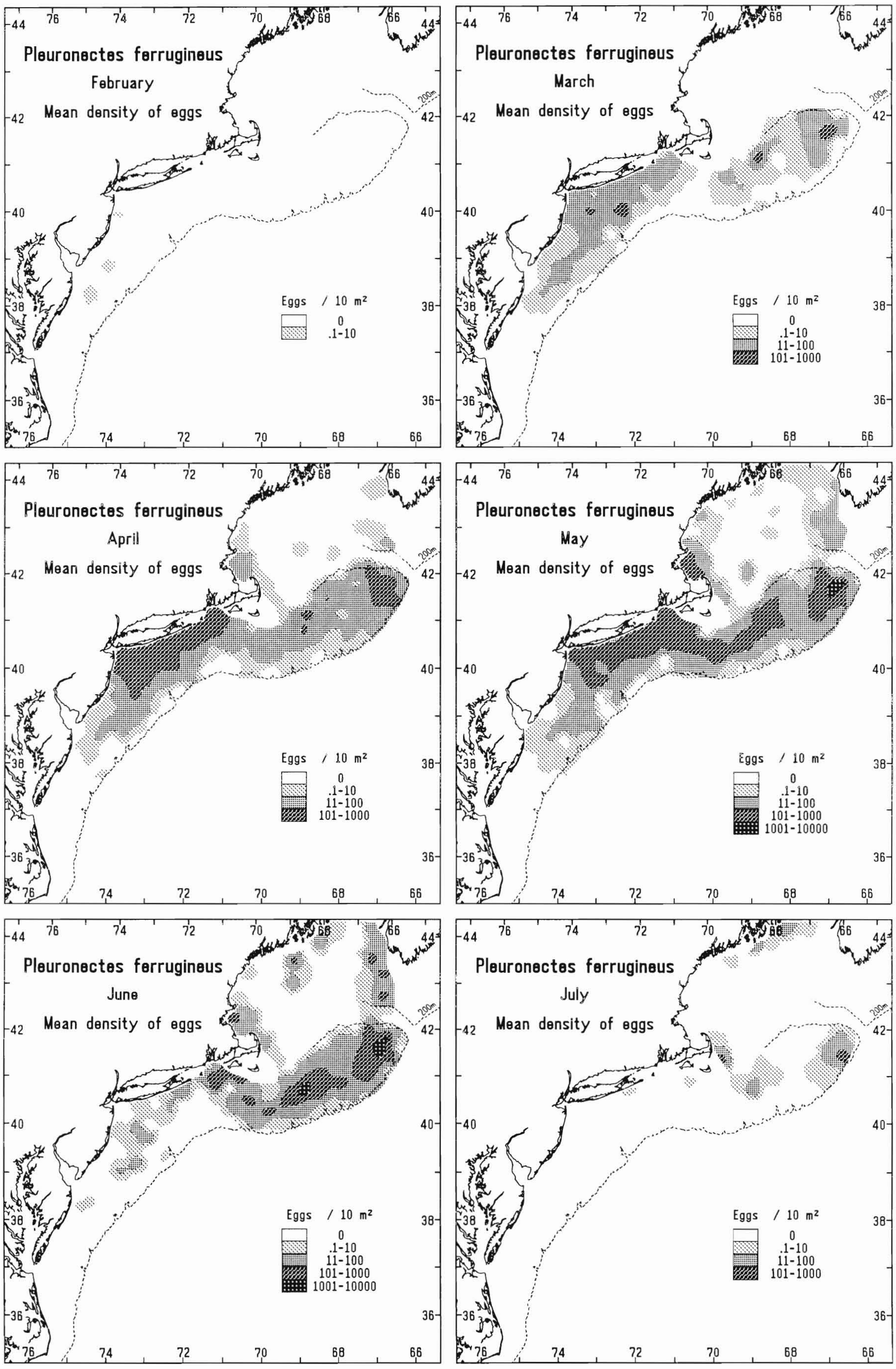


Figure 103

Pleuronectes ferrugineus; composite monthly areal plots of mean egg densities (no./10 m²).

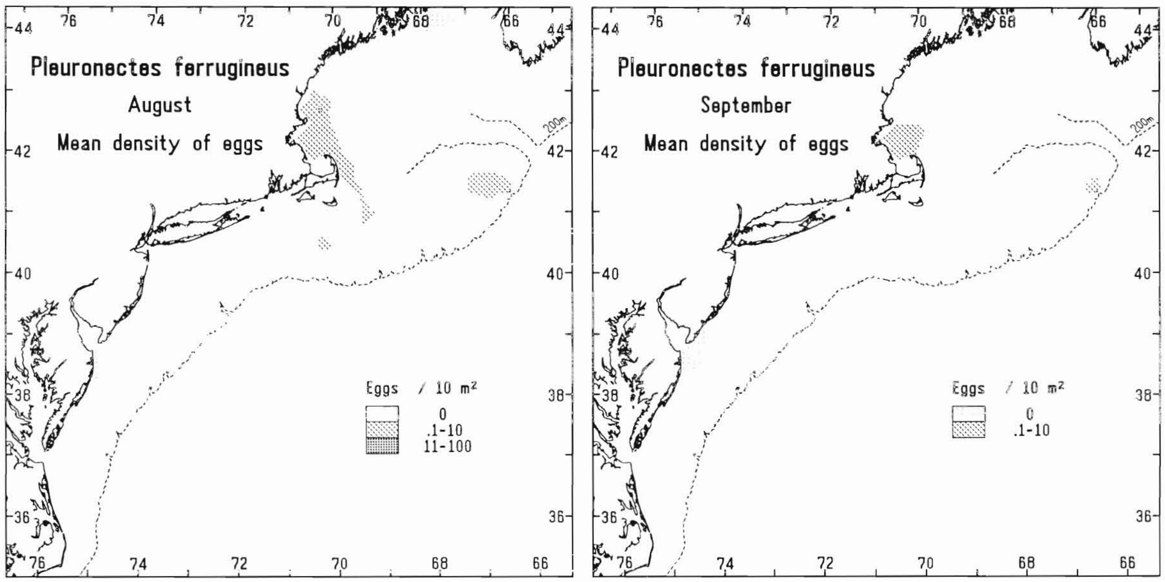


Figure 103 (continued)

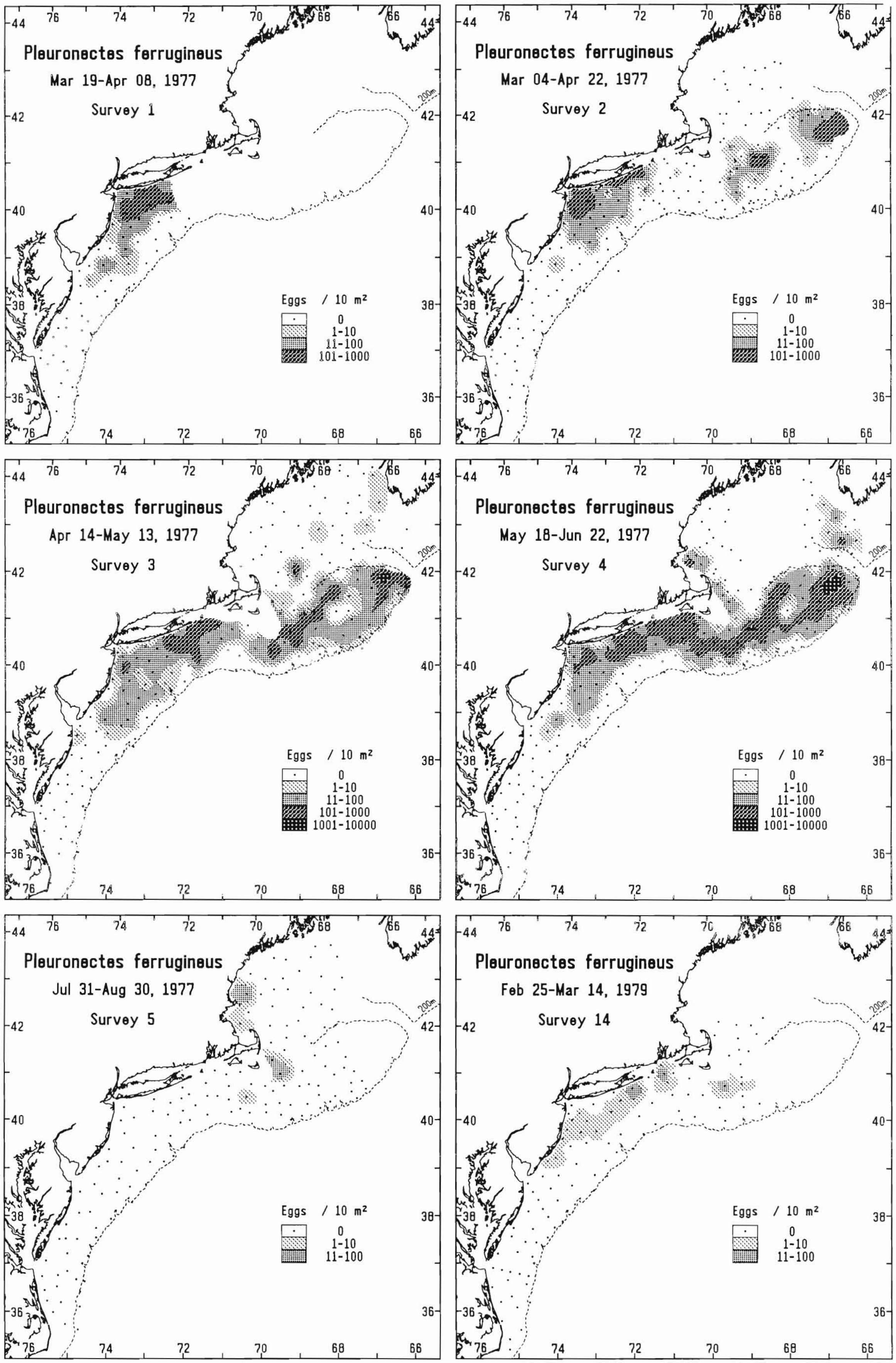


Figure 104

Pleuronectes ferrugineus; survey areal plots of egg densities (no./10 m²)

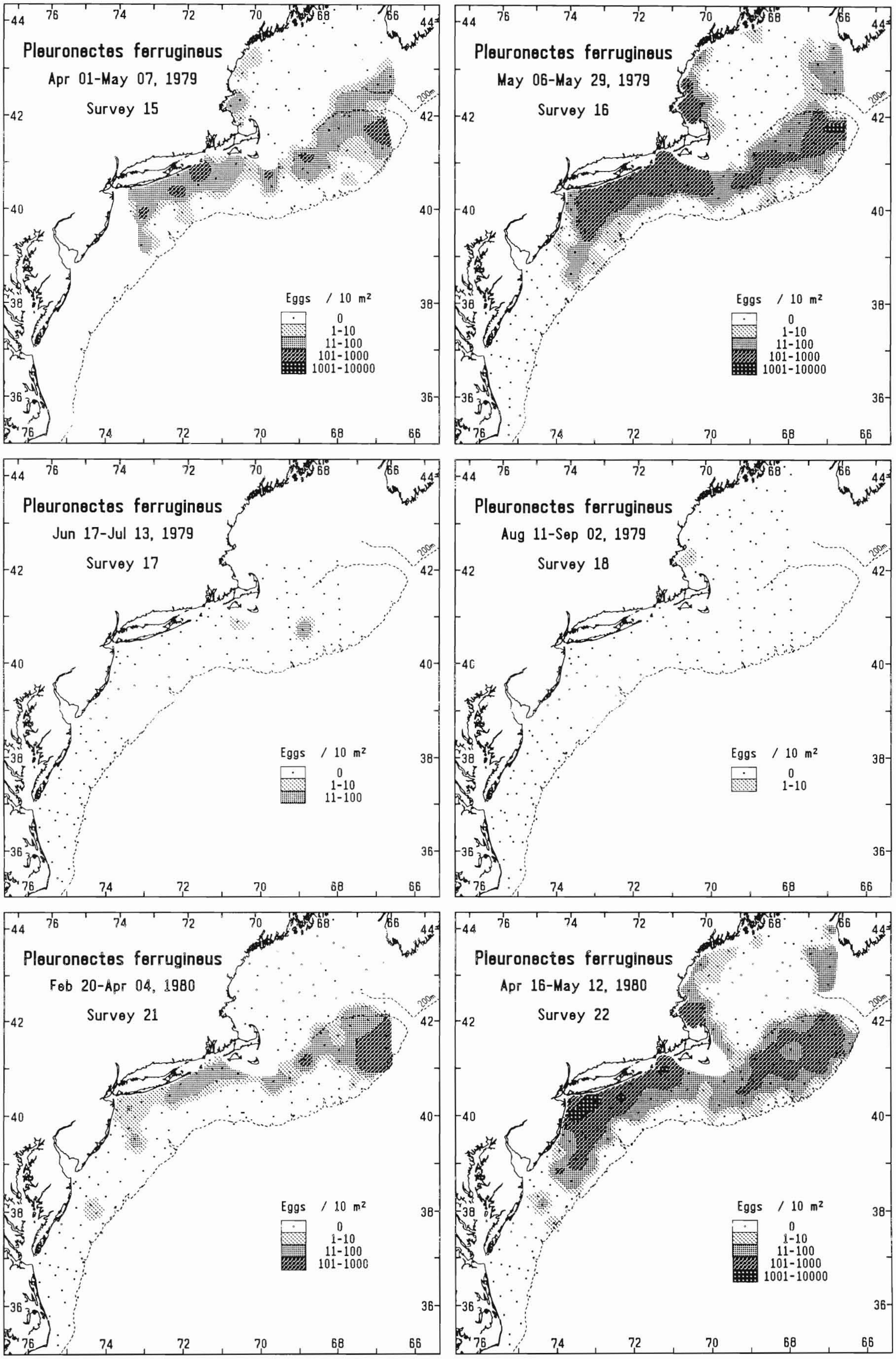


Figure 104 (continued)

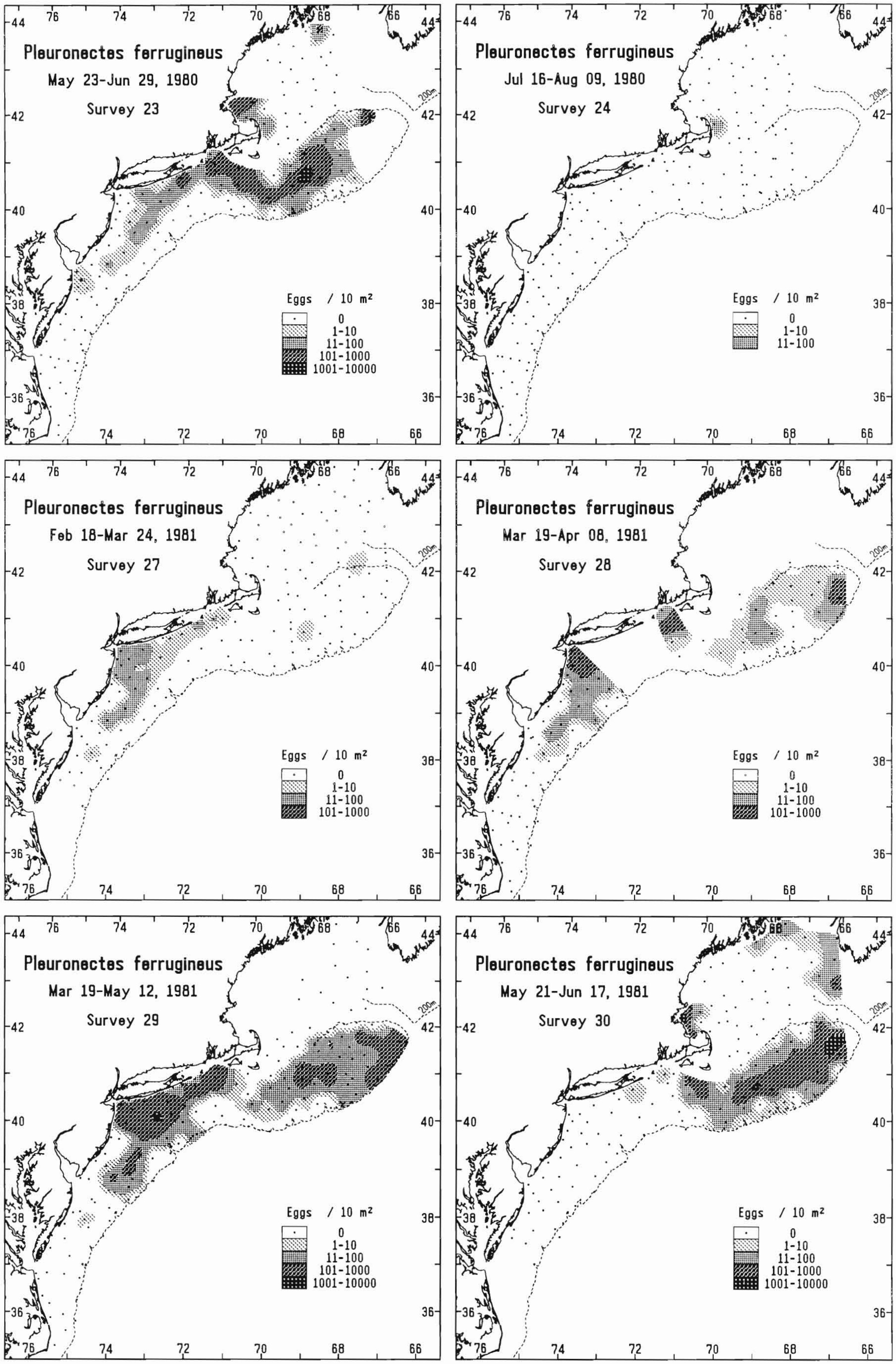


Figure 104 (continued)

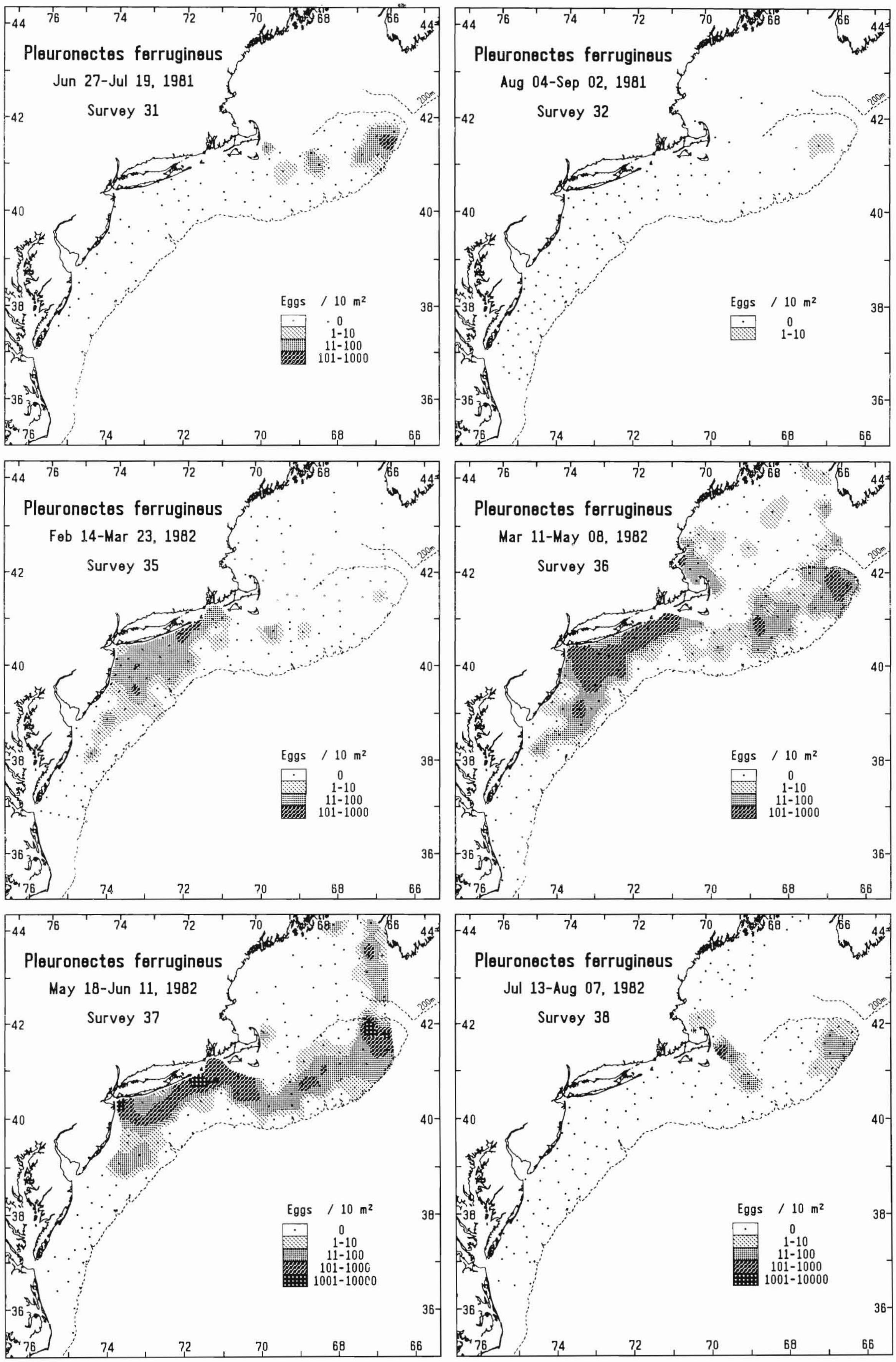


Figure 104 (continued)

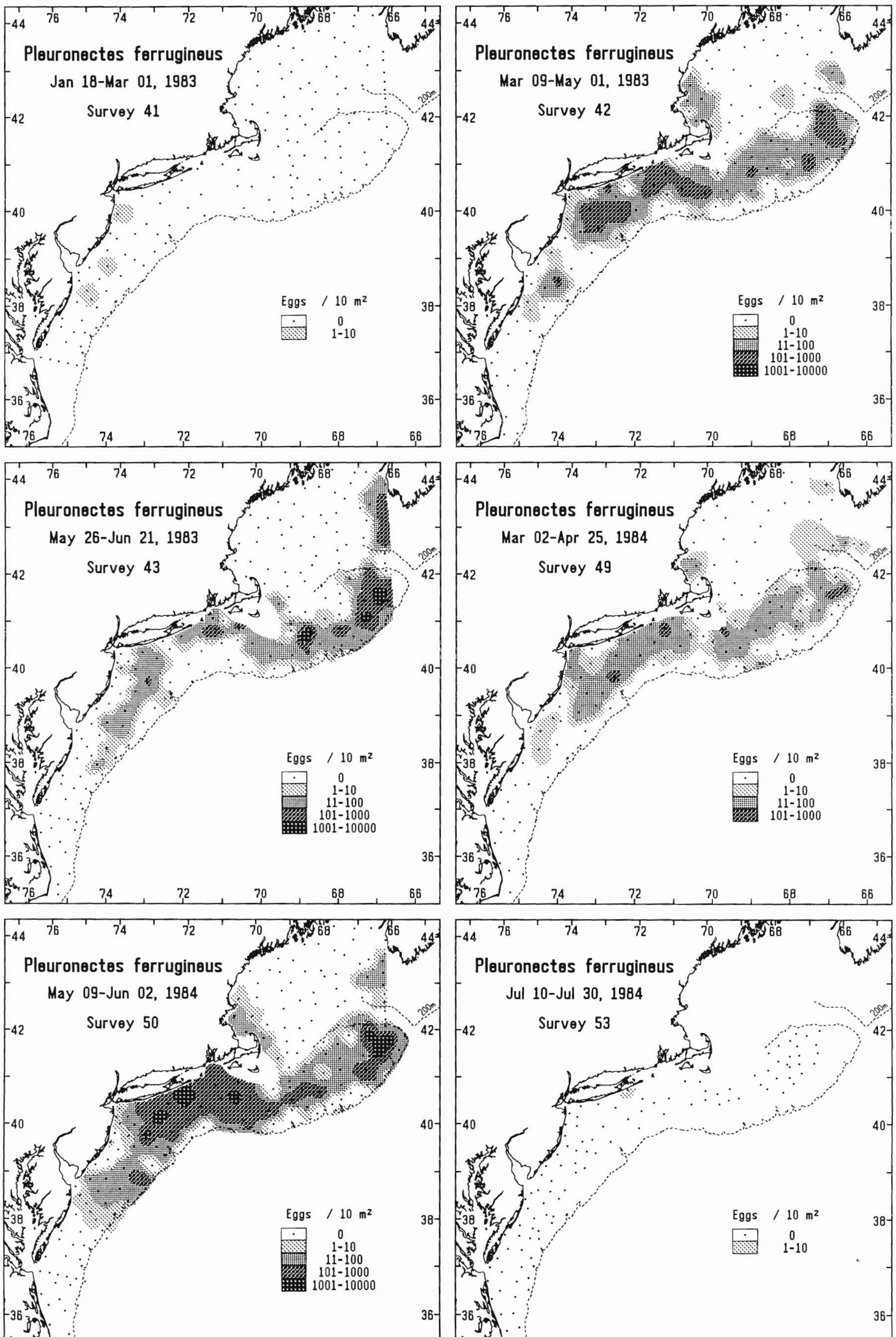
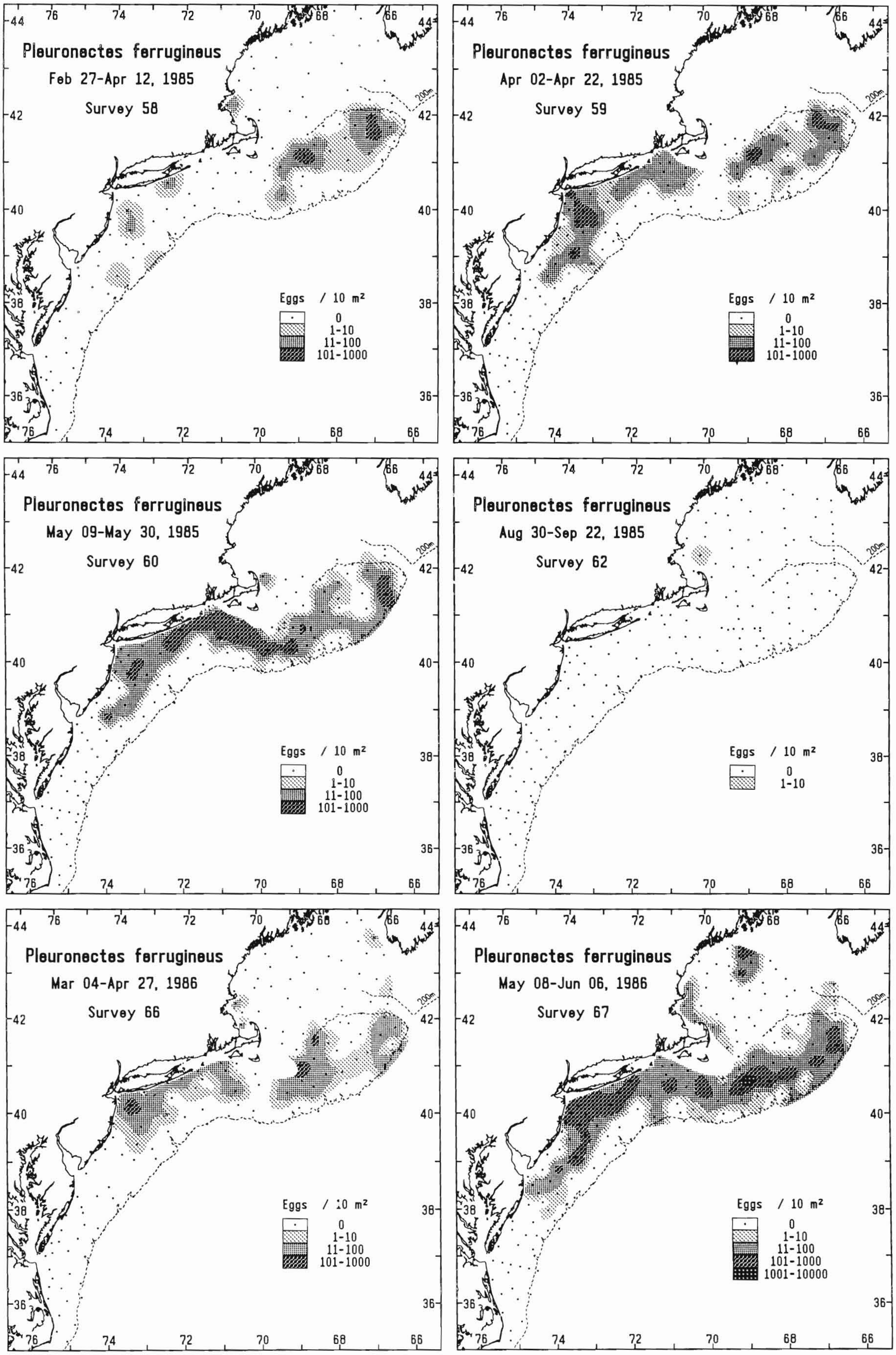


Figure 104 (continued)



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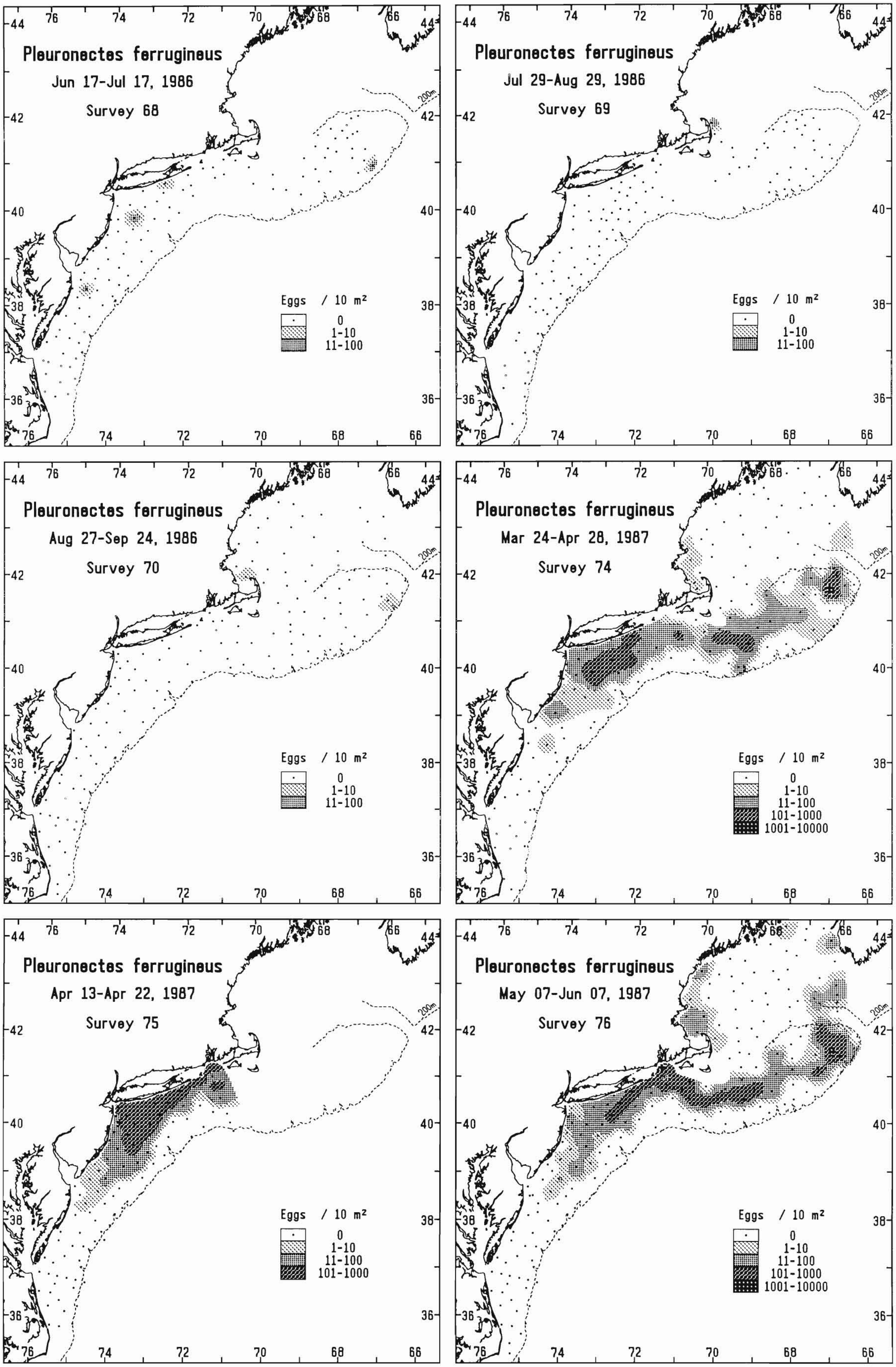

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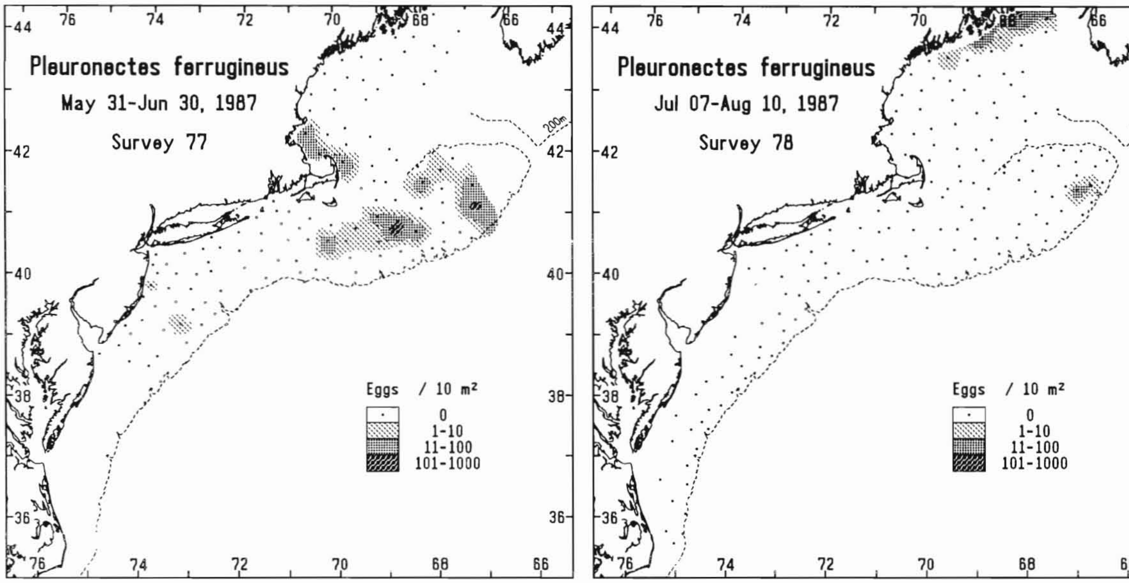

Figure 104 (continued)

Acknowledgments

We extend our thanks to the many people who worked on the MARMAP program over several years. We thank the vessel crews of the *R/V Albatross IV* and *R/V Delaware II*; the many sea-going technicians and biologists who collected plankton samples and data; and the laboratory technicians at Sandy Hook and at the Sorting Center in Szczecin, Poland, who helped sort, identify, count, and stage slightly more than two million fish eggs. We also thank Wallace Smith and Kenneth Sherman who supported this effort over the years, Jay O'Reilly for use of his Fortran program which enhanced the contoured distribution maps, two anonymous reviewers, and Dave Packer whose comments helped make this paper readable. Completion of this document was supported in part by funds from the NOAA Office of Global Programs.

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Appendix Table 1

Mean temperatures (°C), by survey, of continental shelf waters off the U.S. northeast coast, 1977–87; "N" refers to total number of stations, "J Date" to Julian date, "SD" to standard deviation, and "anomaly" to the deviation (°C) from the 11-year mean at the given date.

			Surface			0–15 m depth			0–200 m depth		
Survey no.	N	Mean J Date	Mean	SD	Anomaly	Mean	SD	Anomaly	Mean	SD	Anomaly
1	183	63.35	5.47	2.80	0.55	5.46	2.88	0.37	5.78	2.66	–0.02
2	188	90.83	7.46	3.52	1.88	6.94	3.22	1.31	6.78	2.87	0.70
3	189	122.39	9.39	4.30	0.90	8.75	3.97	0.69	7.74	3.23	0.29
4	205	149.53	12.70	3.66	–0.02	11.40	3.24	–0.26	9.22	2.91	–0.10
5	160	225.49	20.02	3.55	–0.78	18.35	3.85	–1.06	13.04	4.04	–0.91
6	142	300.71	13.99	2.60	–0.19	13.93	2.65	–0.39	13.03	2.95	0.10
7	90	329.13	10.68	1.54	–0.25	10.77	1.60	–0.43	10.21	2.03	–0.89
8	166	57.26	4.20	2.62	–0.79	4.28	2.63	–0.88	4.71	2.56	–1.16
9	172	125.79	7.42	1.73	–1.61	7.15	1.68	–1.36	6.60	1.86	–1.09
10	145	185.23	17.79	3.80	–0.30	16.08	3.15	–0.39	11.21	3.58	–0.65
11	152	234.43	20.78	4.68	0.10	19.50	4.54	0.03	13.10	3.82	–1.10
12	155	292.00	14.04	2.56	–1.27	13.96	2.56	–1.38	12.14	3.02	–1.25
13	72	325.18	10.87	2.11	–0.49	10.82	2.06	–0.81	9.95	2.19	–1.44
14	102	62.20	4.18	2.02	–0.75	4.08	2.14	–1.02	4.34	2.46	–1.47
15	102	106.57	5.19	0.97	–1.61	5.11	0.98	–1.53	5.17	1.57	–1.49
16	170	136.96	11.13	2.46	0.49	10.18	2.19	0.30	8.28	2.57	–0.12
17	123	183.82	18.49	2.50	0.53	17.29	2.81	0.94	12.61	3.52	0.82
18	145	233.30	19.58	3.36	–1.13	18.84	3.56	–0.63	13.46	4.63	–0.72
19	158	289.13	15.57	3.31	–0.12	15.55	3.28	–0.12	13.90	3.88	0.37
20	102	334.55	10.47	1.64	0.15	10.61	1.62	0.03	10.32	2.16	–0.34
21	170	72.03	4.93	2.26	–0.02	5.01	2.35	–0.10	5.42	2.59	–0.36
22	175	118.77	7.90	2.22	–0.21	7.67	2.13	–0.08	7.23	2.34	–0.04
23	148	157.97	14.45	2.70	0.42	13.04	2.36	0.23	9.84	2.99	–0.07
24	153	208.80	20.46	3.33	0.12	18.28	3.79	–0.45	12.24	3.74	–1.05
25	174	285.69	16.65	4.48	0.59	16.60	4.44	0.60	13.96	4.30	0.30
26	137	338.90	9.73	2.49	–0.20	9.76	2.51	–0.43	9.92	2.44	–0.45
27	151	66.64	4.59	1.75	–0.33	4.65	1.78	–0.43	5.08	2.10	–0.70
28	99	87.05	6.03	2.20	0.65	5.92	2.32	0.46	6.08	2.47	0.10
29	143	106.47	6.53	1.29	–0.17	6.37	1.29	–0.19	6.40	1.73	–0.22
30	143	156.12	13.53	4.83	–0.18	12.32	4.08	–0.20	9.16	3.00	–0.61
31	78	189.53	18.96	3.36	0.27	17.66	3.26	0.61	13.21	2.64	1.02
32	94	227.19	22.33	3.80	1.53	21.40	3.84	1.96	15.70	3.93	1.69
33	169	288.98	14.34	4.23	–1.35	14.39	4.17	–1.28	12.80	3.98	–0.73
34	88	341.27	8.32	1.41	–1.42	8.54	1.37	–1.45	8.53	1.54	–1.69
35	145	67.39	4.20	2.01	–0.72	4.26	1.96	–0.82	5.07	2.49	–0.71
36	166	102.52	5.80	1.92	–0.63	5.43	1.88	–0.91	5.76	2.28	–0.73
37	132	149.57	10.89	4.26	–1.83	10.31	3.63	–1.35	8.40	2.68	–0.92
38	123	207.71	19.46	4.38	–0.82	17.31	3.95	–1.36	12.66	3.71	–0.58
39	149	287.06	15.65	4.47	–0.29	15.58	4.48	–0.31	13.61	4.07	–0.01
40	152	339.07	10.53	1.81	0.60	10.74	1.80	0.55	10.54	2.14	0.17
41	148	35.43	6.54	2.03	0.87	6.63	2.02	0.81	6.82	1.83	0.32

continued on next page

Appendix Table 1 (continued)

Survey no.	N	Mean J Date	Surface Mean	Surface SD	Surface Anomaly	0–15 m depth Mean	0–15 m depth SD	0–15 m depth Anomaly	0–200 m depth Mean	0–200 m depth SD	0–200 m depth Anomaly
42	139	94.97	6.43	1.69	0.60	6.28	1.72	0.45	6.50	2.07	0.30
43	170	158.75	13.29	3.00	–0.91	12.20	2.68	–0.75	9.43	2.91	–0.56
44	116	222.37	19.86	4.14	–0.92	18.95	3.87	–0.39	13.09	2.97	–0.76
45	62	235.94	22.32	2.65	1.70	21.48	2.41	2.03	17.42	3.15	3.18
46	160	285.34	16.28	4.62	0.09	16.44	4.58	0.33	13.83	4.25	0.13
47	149	334.78	11.02	2.49	0.70	11.08	2.49	0.50	11.20	2.51	0.54
48	159	24.32	5.84	2.23	–0.38	5.92	2.22	–0.44	6.45	2.32	–0.56
49	151	87.70	5.27	2.09	–0.16	5.35	2.28	–0.15	5.91	2.70	–0.09
50	177	141.36	10.48	2.71	–0.78	10.11	2.61	–0.30	8.60	3.08	–0.08
51	41	171.82	21.24	2.10	4.98	18.98	2.54	4.19	14.41	4.14	3.46
52	68	191.31	19.74	2.79	0.94	18.22	3.38	1.06	13.14	2.89	0.88
53	106	201.48	19.61	3.20	–0.17	17.79	3.23	–0.34	14.33	3.16	1.47
54	119	221.00	20.90	2.91	0.13	19.01	3.08	–0.30	12.86	2.93	–0.95
55	158	281.98	16.21	3.78	–0.35	16.20	3.79	–0.22	13.87	3.67	0.05
56	144	320.58	14.01	3.70	2.21	14.14	3.62	2.08	13.90	3.38	2.23
57	125	26.30	6.62	2.63	0.51	6.87	2.68	0.62	7.32	2.93	0.41
58	120	80.50	6.14	2.83	0.99	5.97	2.85	0.70	6.35	2.78	0.48
59	130	101.79	8.45	3.60	2.10	8.11	3.08	1.84	8.23	2.83	1.78
60	134	136.80	12.14	4.37	1.50	11.74	4.10	1.86	10.63	3.43	2.23
61	150	216.48	19.50	4.02	–1.15	18.41	4.19	–0.71	13.18	3.49	–0.43
62	173	253.41	19.67	4.31	0.04	19.35	4.30	0.50	15.09	4.63	0.70
63	140	290.52	16.39	4.98	0.95	16.54	4.87	1.09	14.75	4.43	1.31
64	179	326.68	12.27	4.10	1.13	12.74	3.95	1.33	12.65	3.73	1.41
65	173	25.81	7.09	3.51	0.98	7.43	3.51	1.18	7.90	3.38	0.99
66	145	91.27	6.66	2.55	1.08	6.79	2.47	1.16	6.89	2.53	0.81
67	161	142.58	11.41	3.36	–0.17	11.00	3.46	0.32	9.86	3.25	1.04
68	105	184.49	18.50	3.43	0.54	17.09	3.28	0.74	13.92	2.33	2.13
69	116	223.11	21.61	4.89	0.82	19.74	4.25	0.37	14.22	2.64	0.34
70	155	252.44	17.99	3.26	–1.72	17.93	3.39	–0.98	14.75	4.04	0.36
71	147	283.80	15.87	4.44	–0.44	15.85	4.39	–0.36	14.00	4.04	0.26
72	159	323.18	12.63	3.66	1.05	12.77	3.62	0.93	12.70	3.57	1.17
73	132	22.49	7.34	3.55	1.01	7.60	3.65	1.13	7.95	3.44	0.83
74	152	101.79	6.09	2.05	–0.26	5.82	2.14	–0.45	6.08	2.31	–0.37
75	91	106.72	7.70	1.97	0.90	7.75	2.02	1.11	7.79	2.17	1.13
76	193	138.50	9.58	2.10	–1.37	9.17	1.94	–0.97	8.08	2.25	–0.46
77	129	160.86	13.39	2.12	–1.14	12.05	1.89	–1.19	8.97	2.39	–1.17
78	155	199.90	18.88	4.28	–0.81	16.59	3.91	–1.45	10.24	3.14	–2.56
79	179	244.80	19.04	4.76	–1.16	18.32	4.40	–0.90	13.19	5.07	–1.18
80	144	277.20	16.46	5.22	–0.70	16.27	4.98	–0.66	13.17	4.76	–0.82
81	124	321.57	12.10	2.99	0.41	11.94	2.90	–0.01	11.79	2.81	0.19