Report on the distribution and abundance of menhaden (*Brevoortia spp*.) larvae captured in ichthyoplankton samples during fishery-independent resource surveys in the Gulf of Mexico

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Gulf of Mexico

Submitted by

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Introduction

Plankton survey activities were initiated in the Gulf of Mexico (GOM) by NMFS in 1977 as part of the Marine Resources Monitoring Assessment and Prediction program or MARMAP (Sherman et al. 1983; Richards 1987). Most of the plankton sampling during those early annual surveys (1977 – 1981) was conducted in open GOM waters in April and May using essentially the same gear and methods as are in use today (see following sections for details). The success of these initial surveys in providing a useful fishery-independent index of the western Atlantic bluefin tuna spawning stock furnished the motivation and justification for all subsequent plankton survey activities in the GOM. Starting in 1982 resource surveys including plankton surveys carried out by the NMFS /Mississippi Laboratories were incorporated into the Southeast Area Monitoring and Assessment Program or SEAMAP (Sherman et al. 1983; Stuntz et al. 1983). Through this joint Federal-State program coordinated through the Gulf States Marine Fisheries Commission the NMFS and the states of Louisiana, Mississippi, Alabama and Florida conduct plankton sampling cooperatively during resource surveys in the GOM.

The goal of plankton surveys under SEAMAP has been to assemble a time series of data on the occurrence, abundance and geographical distribution of fish eggs and larvae, as well as, to collect data on selected physical properties of their pelagic habitat. These data can then be used to more precisely describe/define the spawning times and areas of GOM fishes and the relationship of their early life stages to environmental (abiotic) factors. Furthermore it was anticipated (and shown now to be true) that this time series of annual abundance estimates could eventually provide a valuable fishery-independent index of spawning stock size for additional GOM species as was first demonstrated for tuna from pre-SEAMAP plankton surveys. Larval indices of abundance based on SEAMAP plankton survey data have been developed for Atlantic bluefin tuna (Scott et al. 1993), king mackerel (Gledhill and Lyczkowski-Shultz 2000), red snapper (SEDAR7-DW-14; Hanisko et al. 2007), vermilion snapper (SEDAR9-DW24) and gray triggerfish (SEDAR9-DW25). After larval identifications have been verified (as necessary) nominal and model-generated indices of larval abundance over the SEAMAP time series are now routinely provided to SEFSC stock assessment scientists.

Previous studies of menhaden planktonic life stages in the GOM were presented by Fore (1970) and Shaw et al. (1985). This report represents the first data summary for menhaden larvae captured in GOM plankton samples during pre-SEAMAP, SEAMAP and NMFS resource surveys over the time period 1982 to 2009. Analyzes are ongoing to determine the feasibility of a SEAMAP larval menhaden index of relative abundance. These results will be presented in a subsequent report.

Methods

Survey Design

Area and station layout (spatial considerations)

The overall SEAMAP sampling area covers the entire northern GOM from the 10 m isobath out to the U.S. EEZ, and comprises approximately 300 designated sampling sites i.e. 'SEAMAP' stations. Most stations are located at 30-nautical mile or 0.5^{o} (~56 km) intervals in a fixed, systematic, 2-dimensional latitude-longitude grid of transects across the GOM. Some SEAMAP stations are located at < 56 km intervals especially along the continental shelf edge, while others have been moved to avoid obstructions, navigational hazards or shallow water. The majority of SEAMAP plankton samples have been taken during dedicated plankton surveys and shrimp/bottomfish (trawl) surveys at these stations but over the years additional samples were taken using SEAMAP gear and collection methods at locations other than designated SEAMAP stations and/or outside established SEAMAP surveys, e.g. during Louisiana seasonal trawl surveys, SEAMAP Squid/Butterfish survey; and other serendipitous or special projects/surveys.

Timeframe (temporal considerations)

The original plan for SEAMAP plankton surveys was for sampling to be conducted in both continental shelf (10-200 m depth range) and open GOM waters (shelf edge, i.e. 200 m to the limits of the EEZ) at least once during each season. This ambitious goal could not be achieved due to logistic constraints; neither all areas, nor all seasons, could be sampled every year Gulf-wide. As a result SEAMAP plankton surveys have yet to encompass the spawning seasons of all fish species; with a particular deficiency of sampling during winter months.

As a consequence SEAMAP plankton data have been collected primarily during four survey periods: spring (April to early June, annually, 1982 to present), summer (June and July, annually, 1982 to present), late summer/early fall (typically in September, annually, 1986 to present) and fall (October and November, annually, 1982 to present). The spring survey covers only open GOM waters (within the U.S. EEZ), while the summer and fall (trawl) surveys encompass only continental shelf waters from south Texas to Mobile Bay. The late summer/early fall survey encompasses the continental shelf waters from south Texas to south Florida.

Gear

The standard sampling gear and methodology used to collect plankton samples during SEAMAP surveys are similar to those recommended by Kramer et al. (1972), Smith and Richardson (1977) and

Posgay and Marak (1980). Plankton sampling protocols and guidelines for the two standard SEAMAP gear using during resource surveys (bongo and neuston nets) are described in detail in the SEAMAP Field Operations manual (2007). A 61 cm (outside diameter) bongo net fitted with 0.335 mm mesh netting is fished in an oblique tow path from a maximum depth of 200 m or to 2-5 m off the bottom at station depths less than 200 m. A single or double, 2x1 m pipe frame neuston net fitted with 0.950 mm mesh netting is the other primary (standard) gear employed and it is towed at the surface with the frame half-submerged for 10 minutes.

Maximum bongo tow depth is calculated using the amount of wire paid out and the wire angle at the 'targeted' maximum tow depth or is directly observed using a SBE 19 or Seacat to view and record bongo net depth in real time throughout the tow. A mechanical flowmeter is mounted off-center in the mouth of each bongo net to record the volume of water filtered. During surveys in 1982 and 1983 (in part) a flowmeter was placed in only one side of the bongo gear. Water volume filtered during bongo net tows ranges from ~20 to 600 m^3 but is typically 30 to 40 m^3 at the shallowest stations and 300 to 400 m^3 at the deepest stations.

Post Survey Data Collection (Plankton Sample Processing and Identification)

Essential elements of SEAMAP plankton survey activities include sample processing (sorting and identification), specimen archival and re-examination of selected taxa. Since the inception of the SEAMAP program most plankton samples have been sorted for fish eggs and larvae, and specimens have been initially identified (mostly to the family level) at the Sea Fisheries Institute, Plankton Sorting and Identification Center (MIR ZSIOP), in Gdynia and Szczecin, Poland under a Joint Studies Agreement between the NMFS and the Sea Fisheries Institute. During the period 1989 to 2002 plankton samples collected by the Louisiana Department of Wildlife and Fisheries were processed by Louisiana state biologists following SEFSC/SEAMAP protocols in use at MIR ZSIOP.

Vials of eggs and identified larvae, plankton displacement volumes, total egg counts; and counts and body length measurements of identified larvae are sent to the SEAMAP Archive at the Fish and Wildlife Research Institute, Florida Fish and Wildlife Conservation Commission, St. Petersburg, FL. At the SEAMAP Archive data are entered into the SEAMAP database and specimens are curated and loaned to researchers upon request. Data files containing specimen identifications and lengths are sent to the NMFS Mississippi Laboratories where these data are combined with field collection data, edited and maintained in the SEAMAP data base. Examination and re-identification of the larvae of selected taxa by SEFSC ichthyoplankton specialists are routinely undertaken in order to assure accurate and consistent identifications over the time series. No attempt has been made to identify menhaden larvae to species although the larvae of all three Gulf species have now been described. Re-examination of Brevoortia spp. larvae has not been undertaken for this summary. Identification of menhaden larvae (to the genus level) has been possible over the entire time series of SEAMAP collections.

Results and Discussion

Menhaden larvae were consistently caught in both bongo and neuston nets but only data from bongo net samples are presented in this report. Menhaden larvae were taken during 18 of 23 types of resource surveys (including pre-SEAMAP, SEAMAP and NMFS surveys) comprising 154 individual cruises conducted from 1982 to 2008 (and 2009 only for most recent SEAMAP Winter Plankton survey; Tables 1 & 2). Per cent frequency of occurrence ranged from < 1 to 89.6 and mean abundance for surveys with a sample size (N) greater than 45 and percent menhaden occurrence > 15 ranged from 9 to 466 larvae under 10 sq. m sea surface (Table 2).

Distribution and abundance of larvae and sampling effort for select surveys conducted during months when Gulf menhaden are known to spawn (Fore 1970; Shaw et al. 1985) are depicted on maps in Figures 1 - 13. Menhaden were consistently captured and abundant from October through April from western Louisiana to Mobile Bay in coastal and continental shelf waters out to the 200 m isobath. Menhaden larvae were captured in waters east of Mobile Bay off the Florida panhandle and west Florida shelf during surveys in fall and winter months especially in February and March during Gulfwide SEAMAP winter surveys in 2007-2009 (Figure 12). During these recent cruises larvae were found in abundance off the south Texas coast and beyond the 200 m isobath east of the Mississippi River.

Menhaden larvae were found primarily in samples from October through March with a few occurrences in April, May, June, July and September (Table 3). The specimens indentified in June and July samples may be problematic and will be re-examined to confirm their identification. Highest mean monthly abundances were observed in November, 181.0±48.1 (n=563), and March, 223.2±31.9 (n=324). Discontinuity in the progression of mean monthly abundances from October through March is likely due to reduced sampling effort in December, January and February, i.e. fewer years sampled relative to October and November.

Menhaden larvae were taken over a wide range of surface water temperatures (Figure 14). Most menhaden larvae were taken at stations where water temperatures ranged from 18 to 25 ° C. But relatively high numbers of larvae were also found at temperatures between 14 and 16 degrees. Menhaden larvae were captured over a relatively narrow range of water depths; rarely being taken at stations where water depth was > 120 m (Figure 15).

The potential for a SEAMAP larval menhaden index of relative abundance is being explored based on Louisiana Winter (LA-LW) and SEAMAP Fall Trawl (FS-FS) surveys. These two surveys represent the longest, continuous time series within the timeframe and region of historically, high menhaden spawning activity (Fore 1970; Shaw et al. 1985).

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Table 1. Explanation of survey type abbreviations used in this report. Month or year in parenthesis indicates minor contribution to overall temporal coverage.

Survey Type Abbreviation	Survey Type Name	Months	Years
US-MG	MEXUS-Gulf	Jan & Feb	1990
WP-LO	Winter Plankton (offshore)	Jan & Feb	1993
WP-WP	SEAMAP Winter Plankton (recent years)	Feb & Mar	2007, 2008, 2009
US-WG	Winter Groundfish	(Feb)Mar	1982-1985
LA-LP	Louisiana Spring	Mar, Apr, (May)	1986-1995
SP-SP	SEAMAP Spring Plankton (Gulfwide offshore)	Apr, May, (Jun)	1982-2008
MS-SP	Mississippi Spring	May & Jun	2005 & 2007
MS-SQ	Mississippi Squid/Butterfish	May & Aug	1985 & 1986
SS-SS	SEAMAP Summer Trawl	Jun & Jul	1982-2008
LA-CS	Louisiana Coastal Summer	Jul	1990 & 1991
US-PL	NMFS Pelagic Longline	(Jul) Aug	1988
US-SQ	NMFS Squid/Butterfish	(Jul) Aug	1985
FP-FP	SEAMAP Fall Plankton (Gulfwide on shelf)	Aug, Sep, Oct	(1984)-2008
LA-LF	Louisiana Fall Plankton	(Sep) Oct	1985-2005
FS-FS	SEAMAP Fall Trawl	Oct & Nov	1986-2006
US-FG	Pre-SEAMAP Fall Groundfish	Oct & Nov	1982-1985
MS-RD	Mississippi Red Drum survey	Oct & Nov	1983 & 1985
US-LL	NMFS Longline	Oct (Nov)	2005
LA-CF	Louisiana Coastal Fall	Nov	1989-1991
FL-FG	Florida Fall Early Groundfish	Nov	1986
LA-LW	Louisiana Winter	Nov & Dec	1985-2006
WP-EO	Winter Plankton (early years)	Nov & Dec	1983 & 1984, 1996
MS-MW	Mississippi Winter	Dec & Jan	2001 & 2004

Table 2. Resource surveys used to document the occurrence, distribution and abundance of menhaden larvae in bongo samples from the Gulf of Mexico over an annual monthly cycle. SURVEY_TYPE (see Table 1 for description); NYEARS=number of years survey was conducted; SDAY = start month and day of survey; EDAY=end month and day of survey; Z_0050=% of stations in ≤50 m; Z_0100=% of stations in >50 and ≤100 m; Z_0200=% of stations in >100 and ≤200 m; Z_G0200=% of stations in >200 m; N=number of sorted samples; ABUNDANCE= number of larvae under 10 m^2 sea surface; SUMA= sum of menhaden abundances; PTA = % abundance menhaden larvae of total larval fish abundance; SUM_FO= number of menhaden occurrences; FO= % menhaden frequency of occurrence.

SURVEY_TYPE	NYEARS	SDAY	EDAY	Z_0050	Z_0100	Z_0200	Z_G200	N	ABUNDANCE	SUM_A	PTA	SUM_FO	FO
US-MG	1	01/06	02/02	49.2	20.0	15.4	15.4	65	71.6	4651.1	8.0	10	15.4
WP-LO	1	01/06	02/11	0.0	28.7	11.9	59.4	101	8.9	898.6	0.8	17	16.8
WP-WP	3	02/05	03/28	32.6	21.1	16.1	30.1	279	105.0	29285.7	10.5	83	29.7
US-WG	4	02/24	03/29	61.8	32.4	0.0	5.9	136	465.8	63348.5	53.6	121	89.0
LA-LP	10	03/09	05/20	100	0.0	0.0	0.0	96	97.7	9375.9	12.6	41	42.7
SP-SP	26	04/15	06/29	2.6	3.9	11.1	82.5	2473	0.0	19.9	0.0	3	0.1
MS-SP	2	05/11	06/09	66.7	11.1	0.0	22.2	9	0.0	0.0	0.0	0	0.0
MS-SQ	2	05/20	08/24	14.6	29.3	22.0	34.1	41	0.0	0.0	0.0	0	0.0
SS-SS	27	06/01	08/02	74.7	17.0	4.1	4.2	1467	0.3	470.1	0.0	11	0.7
LA-CS	2	07/09	07/11	100	0.0	0.0	0.0	9	0.0	0.0	0.0	0	0.0
US-PL	1	07/29	08/19	0.0	0.0	0.0	100	16	0.0	0.0	0.0	0	0.0
US-SQ	1	07/30	08/26	4.3	6.4	14.9	74.5	47	0.0	0.0	0.0	0	0.0
FP-FP	23	08/02	10/18	57.8	19.1	14.1	9.1	2618	0.0	91.0	0.0	9	0.3
LA-LF	21	09/16	10/30	100	0.0	0.0	0.0	175	9.5	1666.6	1.6	43	24.6
FS-FS	21	10/02	11/22	67.4	22.7	9.0	1.0	837	117.5	98318.0	8.6	261	31.2
US-FG	4	10/10	11/23	56.3	16.7	4.2	22.9	96	26.7	2558.9	4.3	23	24.0
MS-RD	2	10/18	11/14	100	0.0	0.0	0.0	5	8.5	42.5	5.6	2	40.0
US-LL	1	10/22	11/01	35.6	22.2	20.0	22.2	45	600.5	27020.4	36.3	15	33.3
LA-CF	3	11/05	11/20	97.9	2.1	0.0	0.0	47	2.1	96.7	42.7	15	31.9
FL-FG	1	11/15	11/21	64.3	17.9	14.3	3.6	28	0.3	9.5	0.1	2	7.1
LA-LW	20	11/17	12/19	100	0.0	0.0	0.0	164	119.2	19554.7	46.9	147	89.6
WP-EO	3	11/18	12/21	4.7	6.2	12.4	76.7	129	78.0	10058.0	10.1	15	11.6
MS-MW	2	12/04	01/15	54.5	18.2	0.0	27.3	11	271.9	2991.3	25.7	4	36.4

Table 3. Larval menhaden mean monthly abundance and frequency of occurrence in plankton samples taken during resource surveys in the Gulf of Mexico. N= number of bongo samples; ABUNDANCE= mean number of larvae under 10 m^2 sea surface; SE_A= standard error of the mean abundance; SUM_FO= mean number of menhaden occurrences; FO= % frequency of occurrence; SE_FO= standard error of mean occurrence.

MONTH	N	ABUNDANCE	SE_A	SUM_FO	FO	SE_FO
1	133	54.4	22.3	22	16.5	3.2
2	175	171.0	34.2	86	49.1	3.8
3	324	223.2	31.9	164	50.6	2.8
4	698	0.1	0.0	5	0.7	0.3
5	1698	< 0.1	0.0	1	0.1	0.1
6	892	0.0	0.0	6	0.7	0.3
7	736	0.6	0.4	5	0.7	0.3
8	348	0.0	0.0	0	0.0	0.0
9	2222	0.3	0.2	12	0.5	0.2
10	840	37.6	31.8	131	15.6	1.3
11	563	181.0	48.1	253	44.9	2.1
12	265	98.8	23.5	137	51.7	3.1

Louisiana Fall (LA-LF)

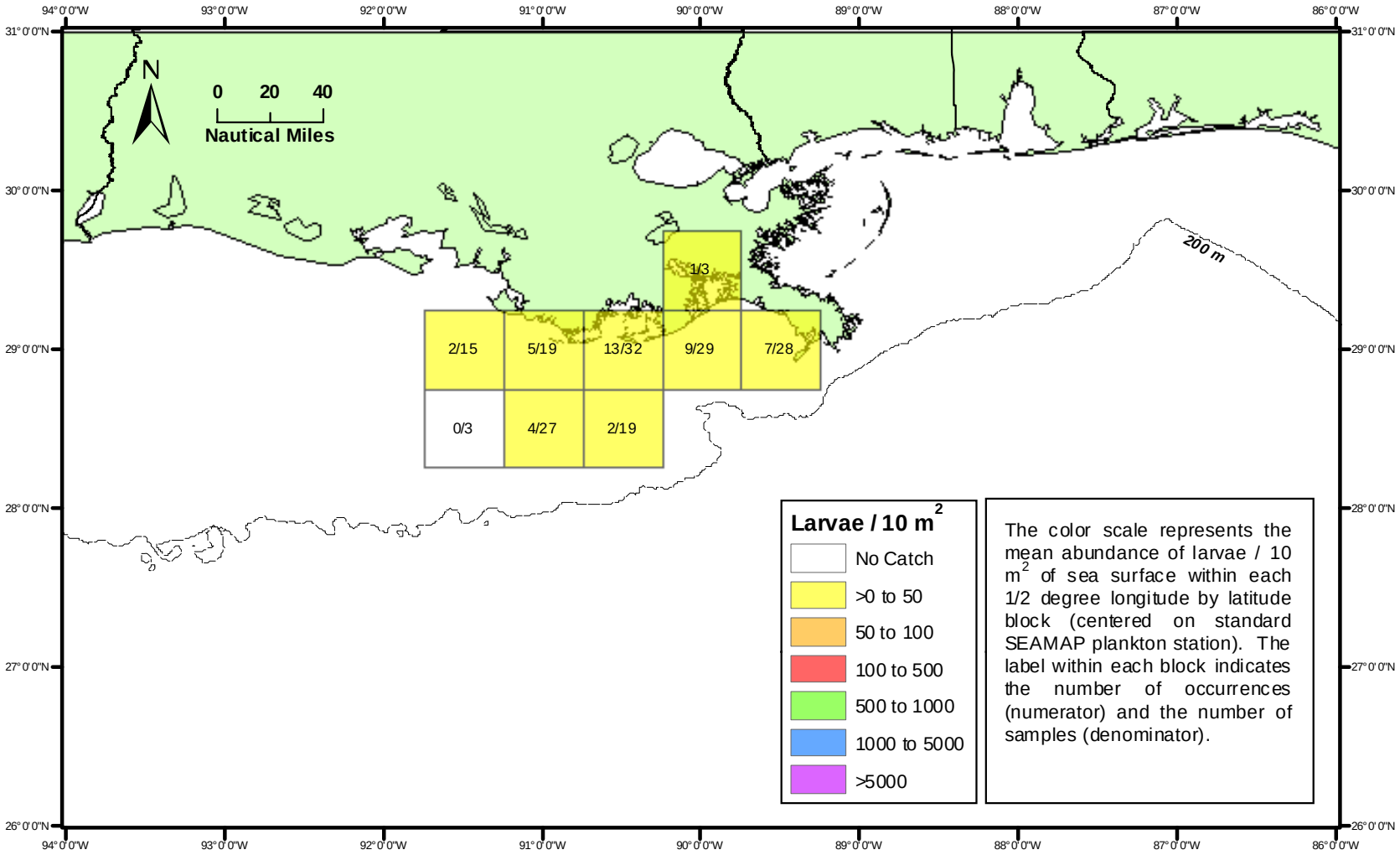

Figure 1. Louisiana Fall Plankton (LA-LF), September and October, 1985-2005. Abundance and occurrence of *Brevoortia* spp. larvae captured in bongo net samples (n=175).

Fall Groundfish Pre-SEAMAP (US-FG)

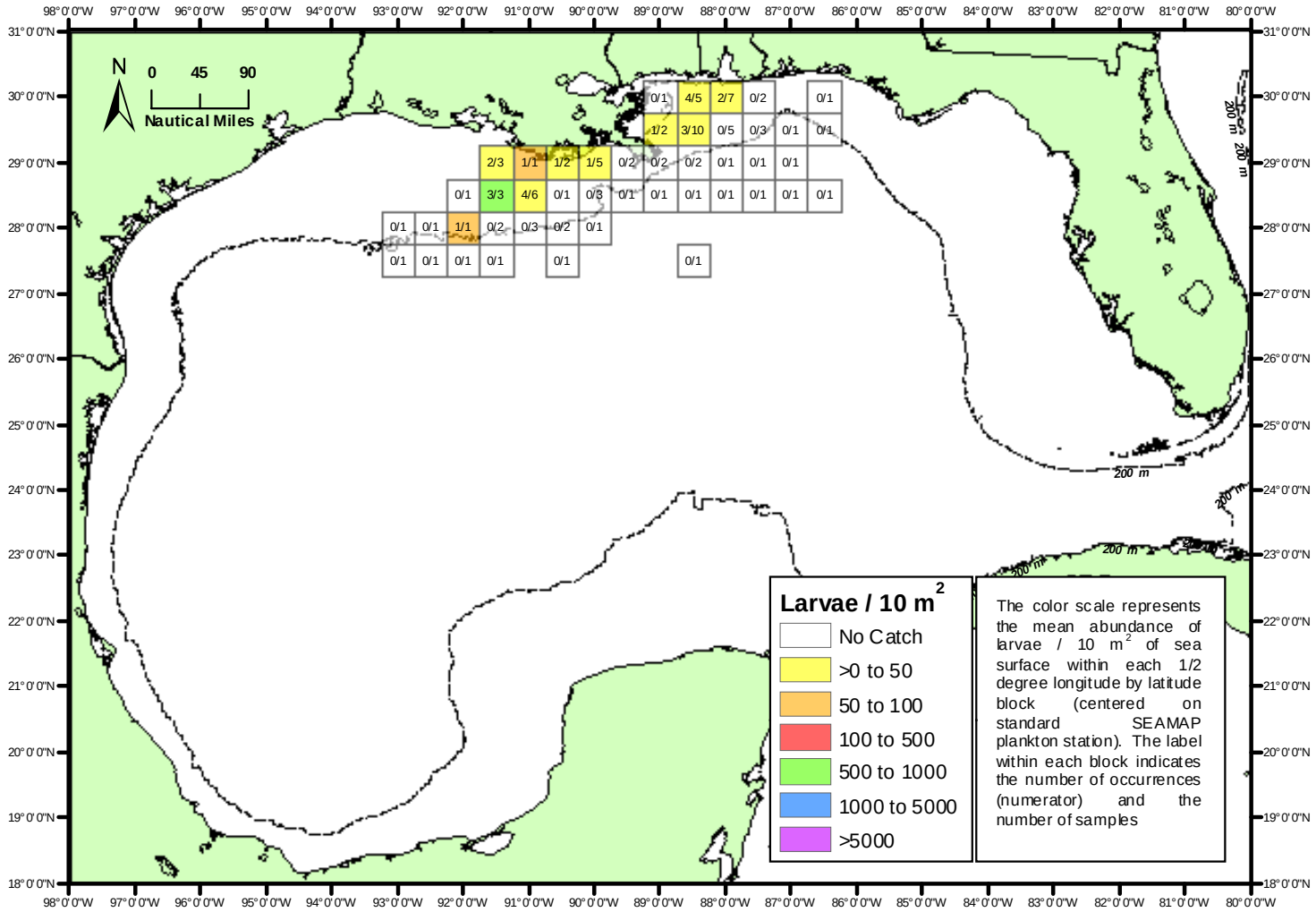

Figure 2. Fall Groundfish Pre-SEAMAP (US-FG), October and November, 1982-1985. Abundance and occurrence of *Brevoortia* spp. larvae captured in bongo net samples (n=96).

SEAMAP Fall Trawl (FS-FS)

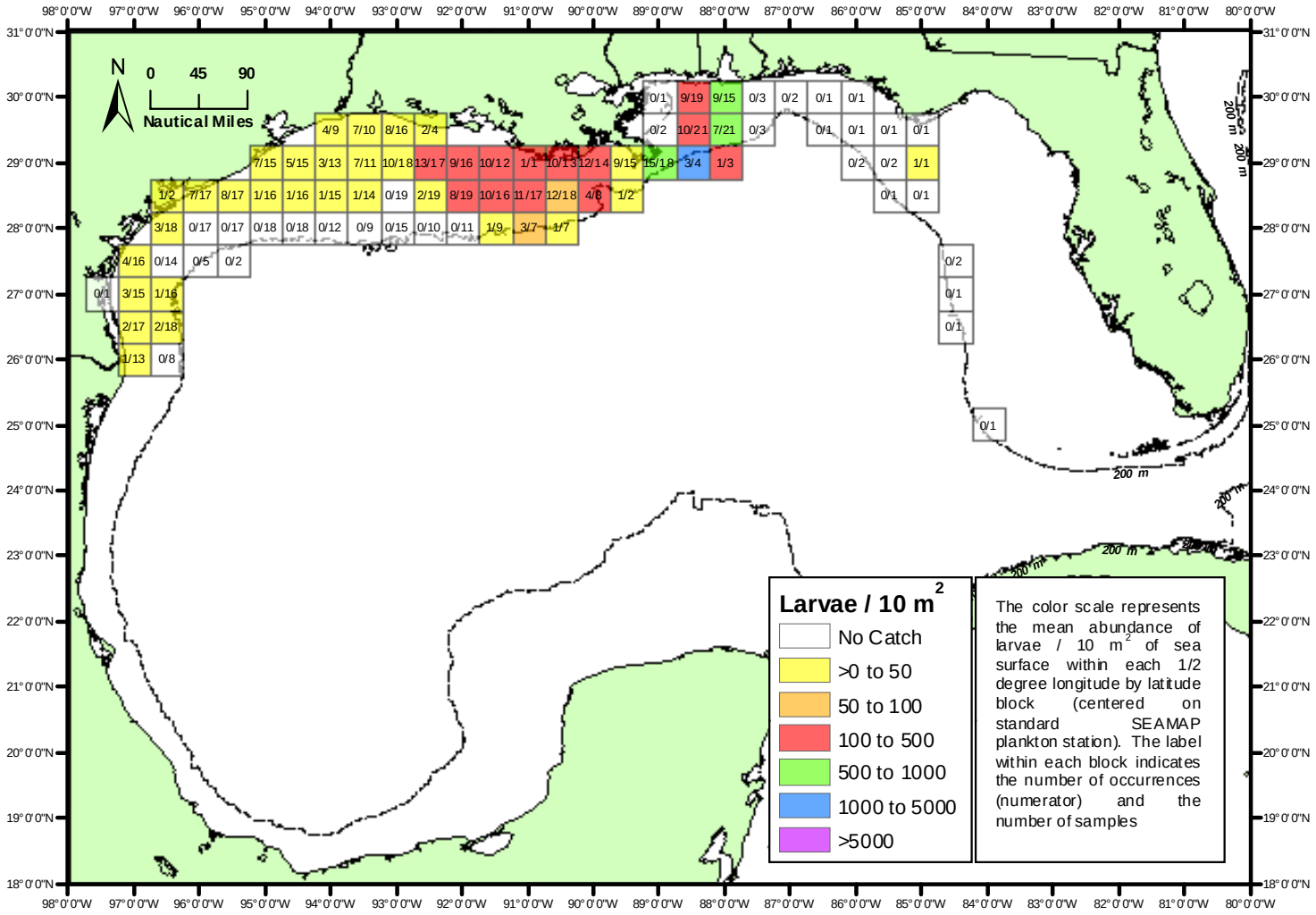

Figure 3. SEAMAP Fall Trawl (FS-FS), October and November, 1986-2006. Abundance and occurrence of *Brevoortia* spp. larvae captured in bongo net samples (n=837).

Longline Survey (US-LL)

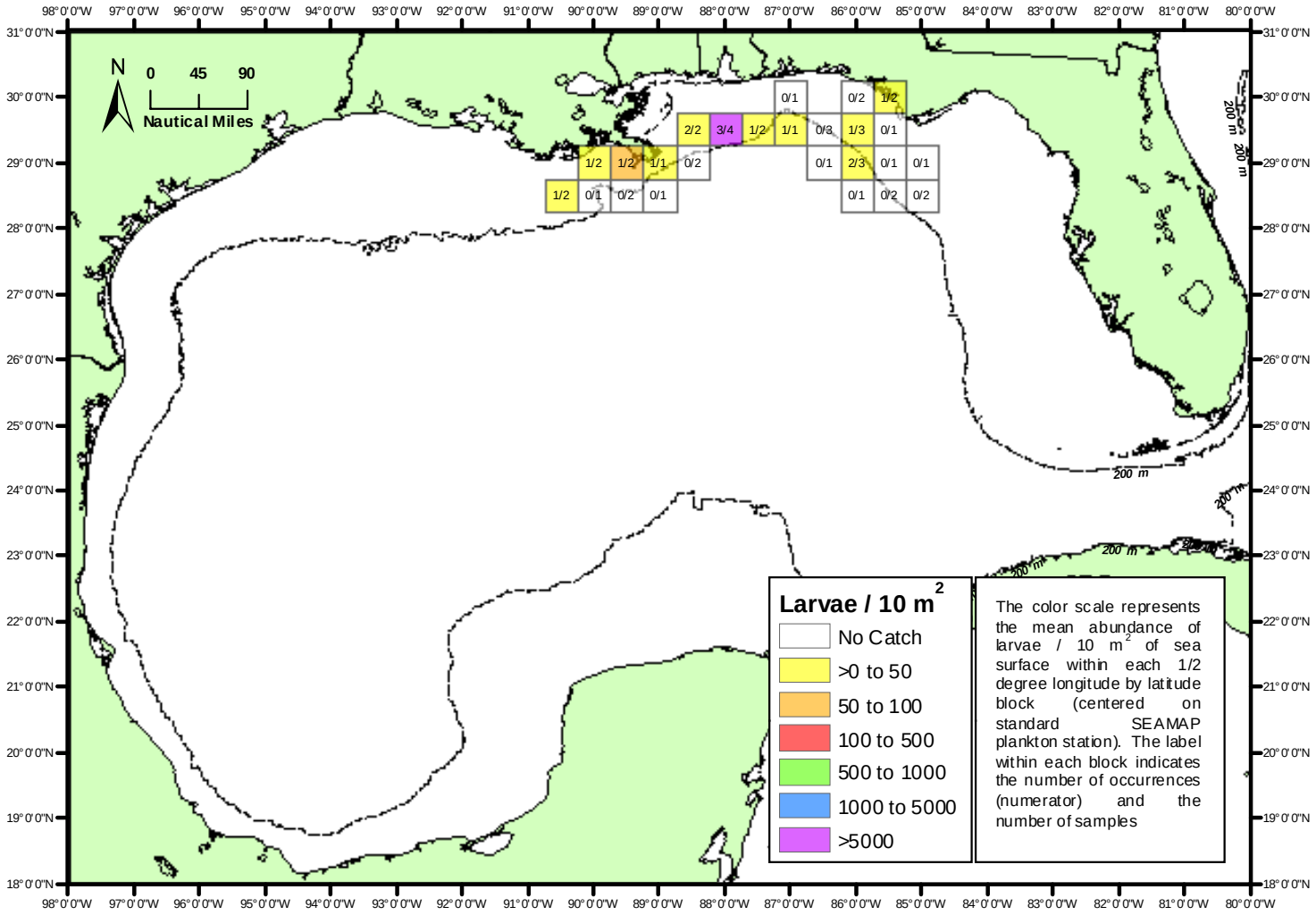

Figure 4. Longline Survey (US-LL), October and November, 2005. Abundance and occurrence of *Brevoortia* spp. larvae captured in bongo net samples (n=45).

Louisiana Coastal Fall (LA-CF)

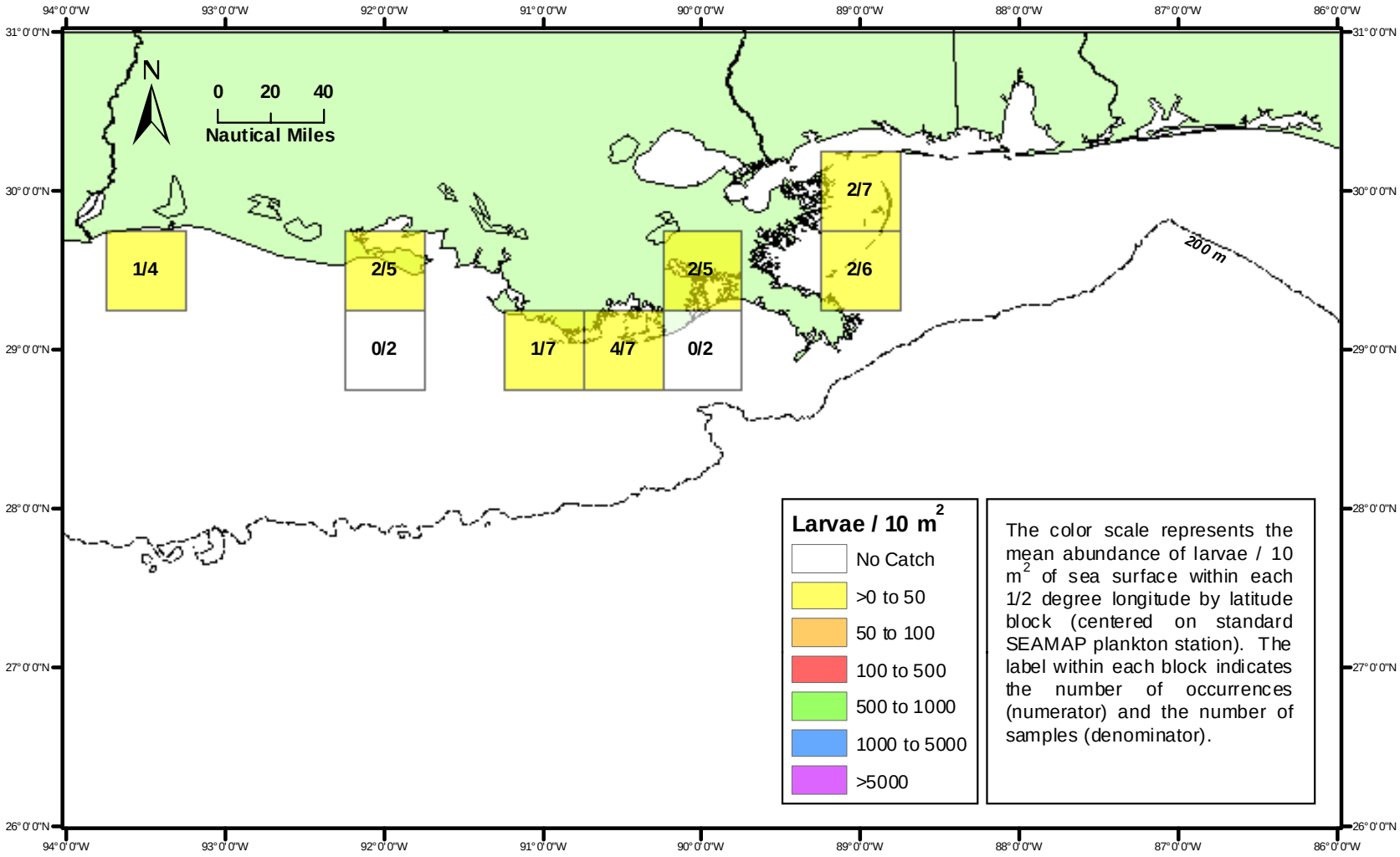

Figure 5. Louisiana Coastal Fall (LA-CF), November, 1989-1991. Abundance and occurrence of Brevoortia spp. larvae captured in bongo net samples (n=47).

Louisiana Winter (LA-LW)

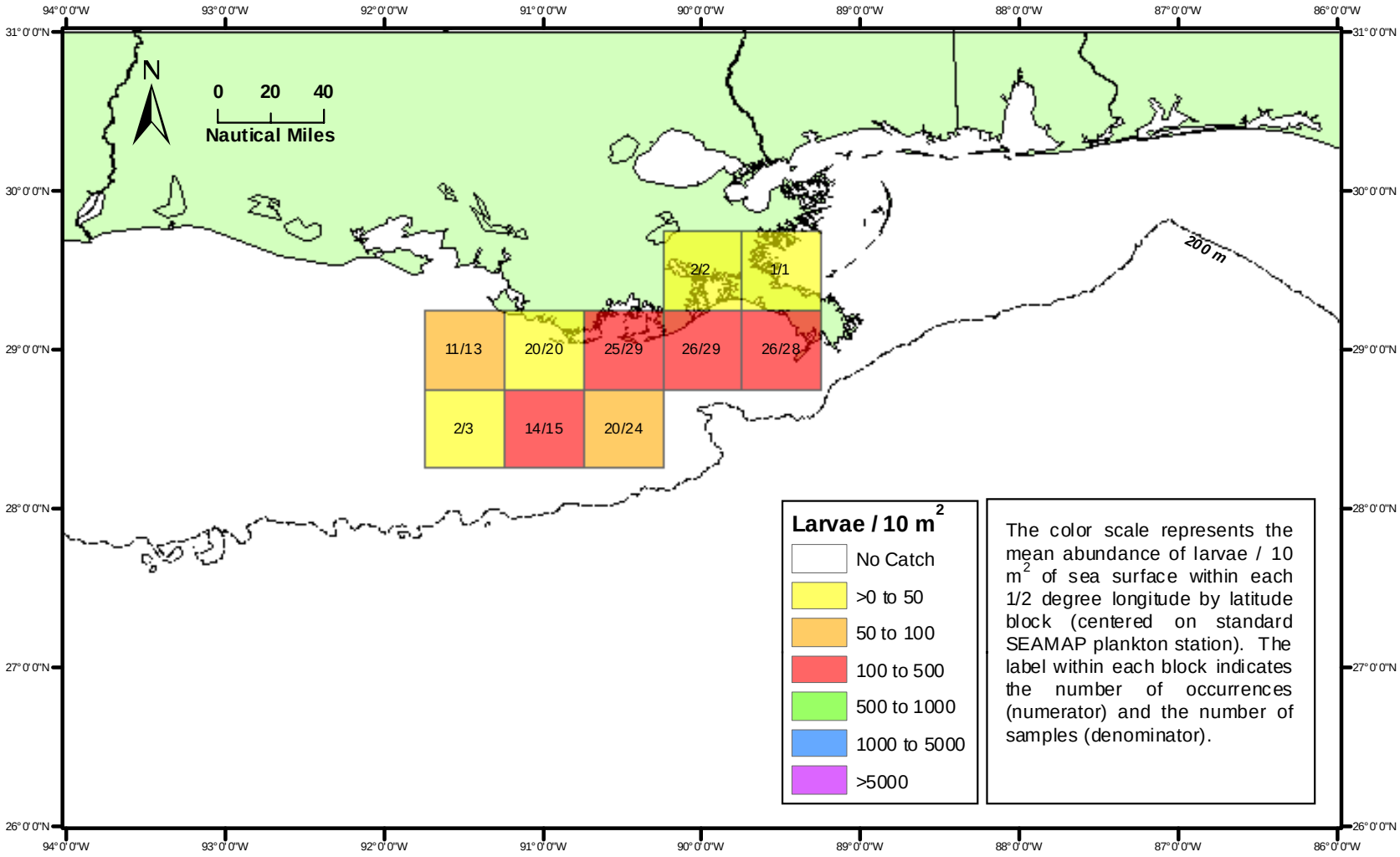

Figure 6. Louisiana Winter (LA-LW), November and December, 1985-2006. Abundance and occurrence of *Brevoortia* spp. larvae captured in bongo net samples (n=164).

Winter Plankton Early Offshore (WP-EO)

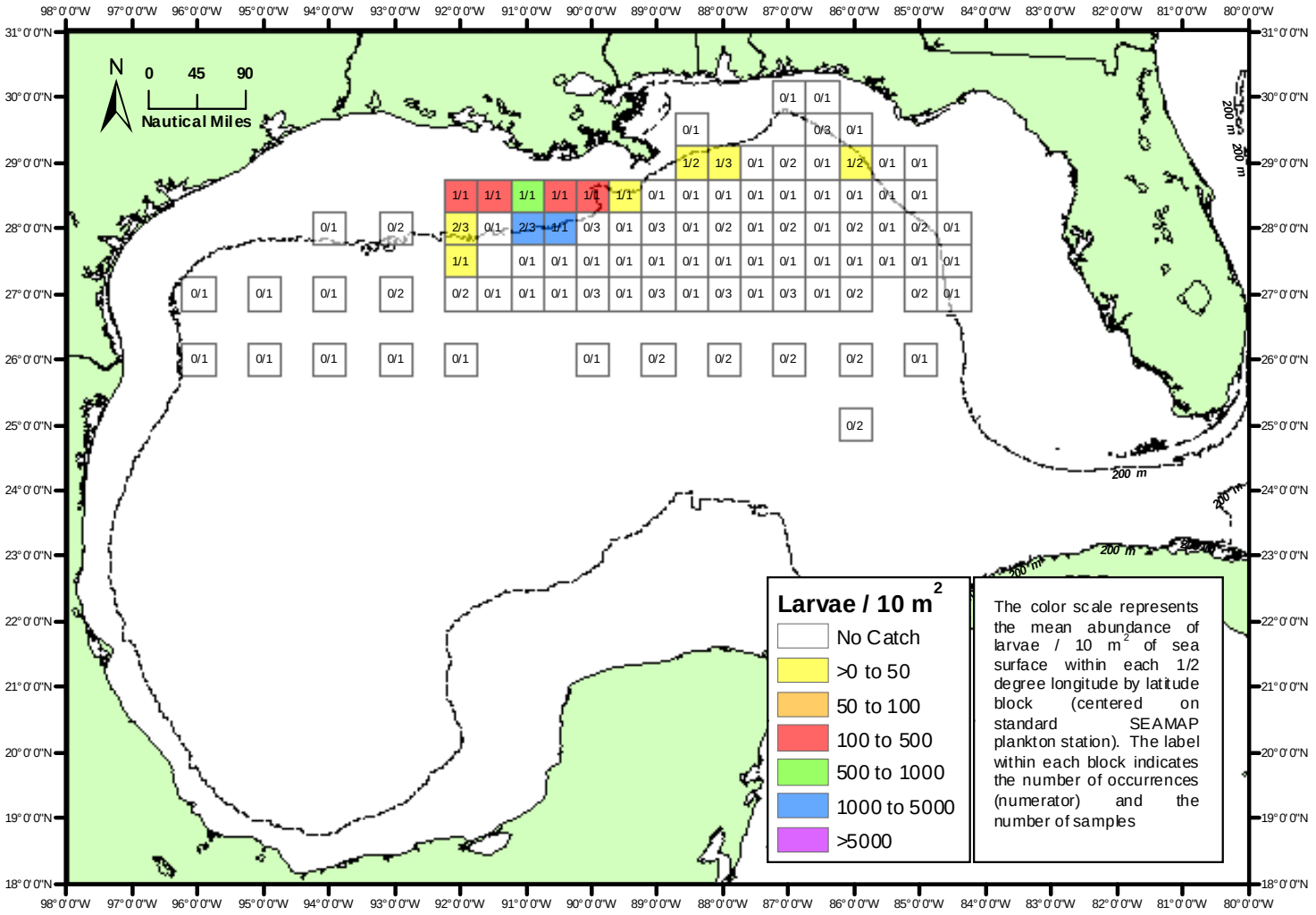

Figure 7. Winter Plankton Early Offshore (WP-EO), November and December, 1983, 1984, 1996. Abundance and occurrence of *Brevoortia* spp. larvae captured in bongo net samples (n=129).

Mississippi Winter (MS-MW)

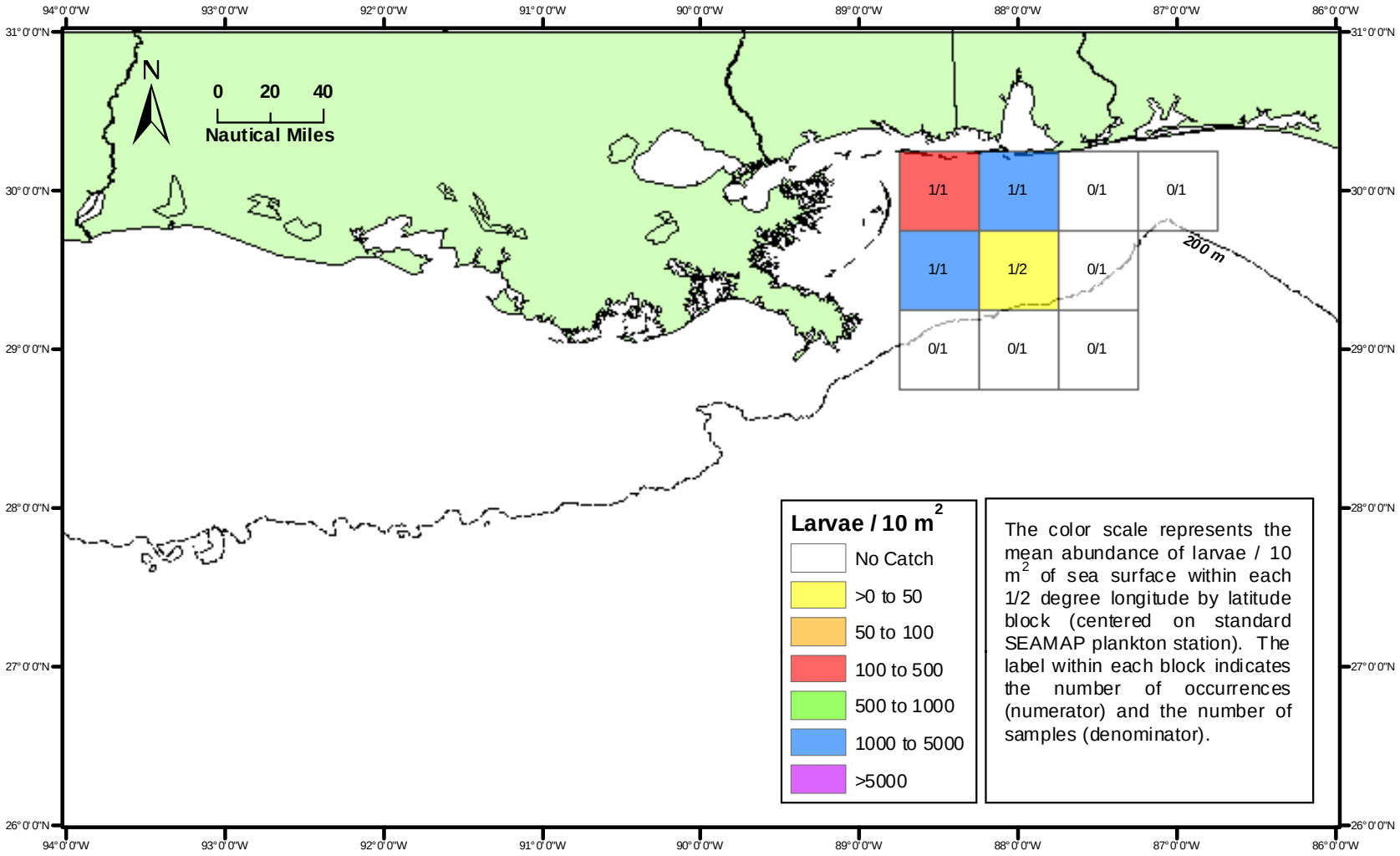

Figure 8. Mississippi Winter (MS-MW), December and January, 2001 and 2004. Abundance and occurrence of *Brevoortia* spp. larvae captured in bongo net samples (n=11).

MEXUS-Gulf Survey (US-MG)

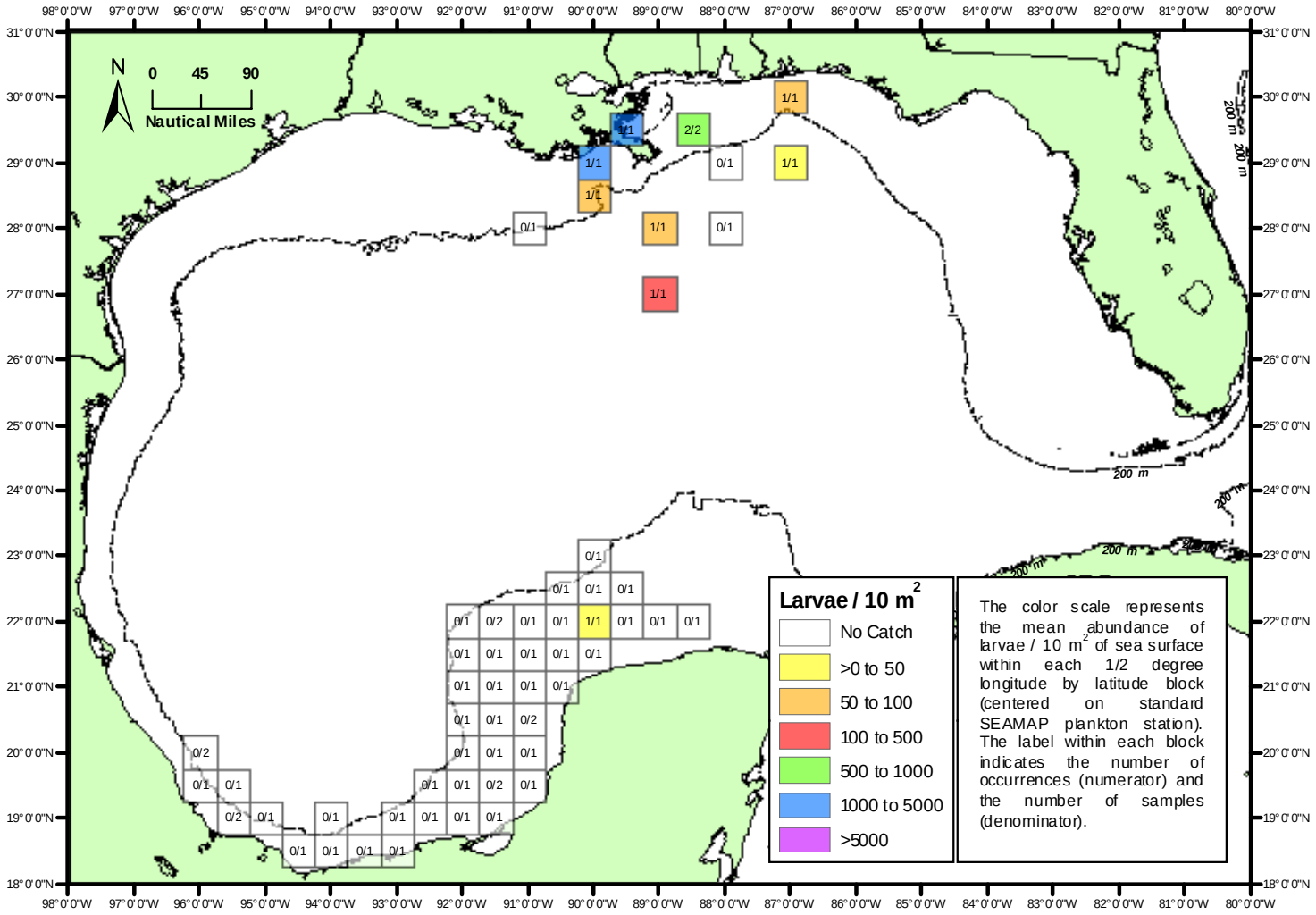

Figure 9. MEXUS-Gulf Survey (US-MG), January and February, 1990. Abundance and occurrence of *Brevoortia* spp. larvae captured in bongo net samples (n=65).

Winter Plankton Late Offshore (WP-LO)

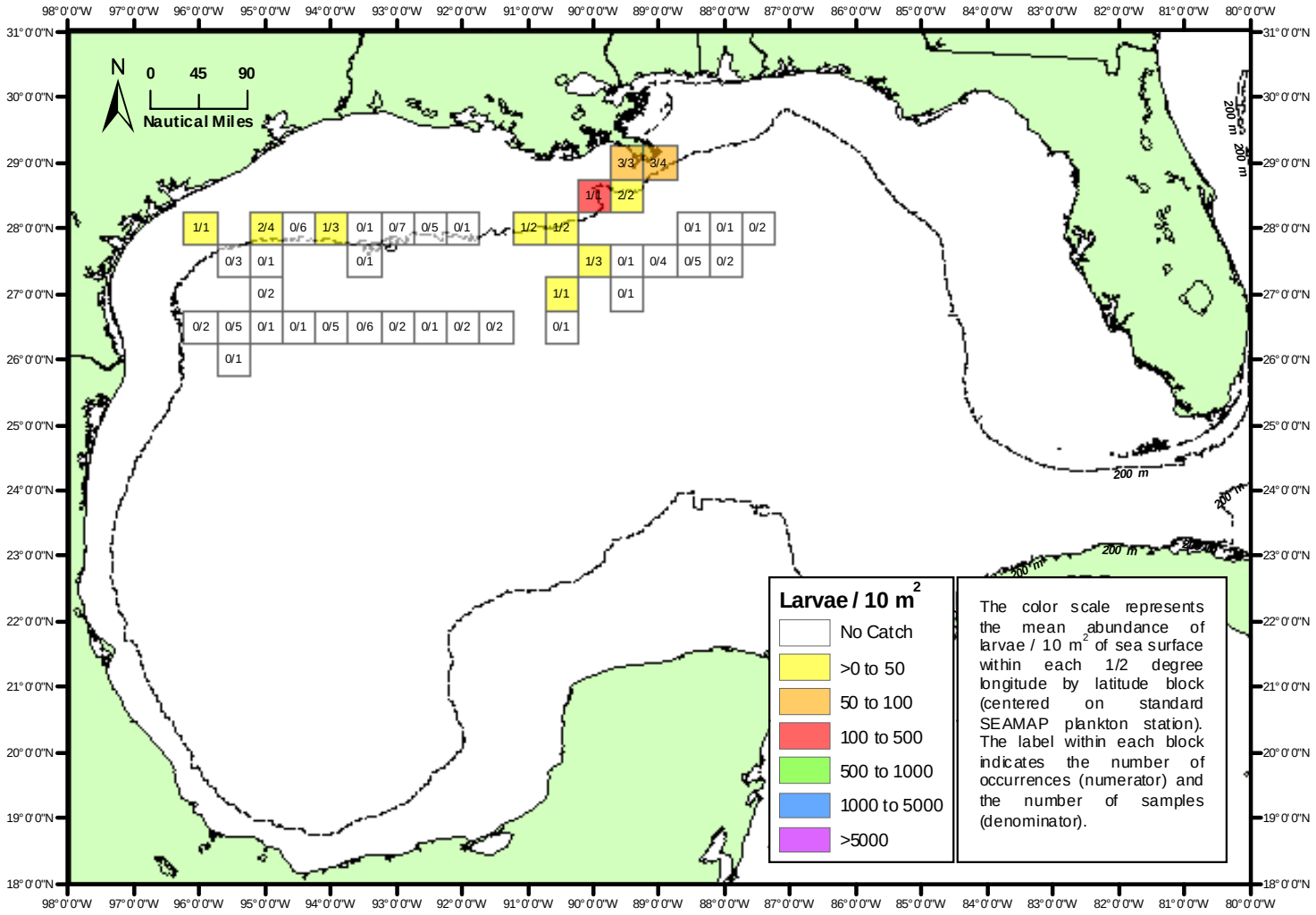

Figure 10. Winter Plankton Late Offshore (WP-LO), January and February, 1993. Abundance and occurrence of *Brevoortia* spp. larvae captured in bongo net samples (n=101).

Winter Groundfish (US-WG)

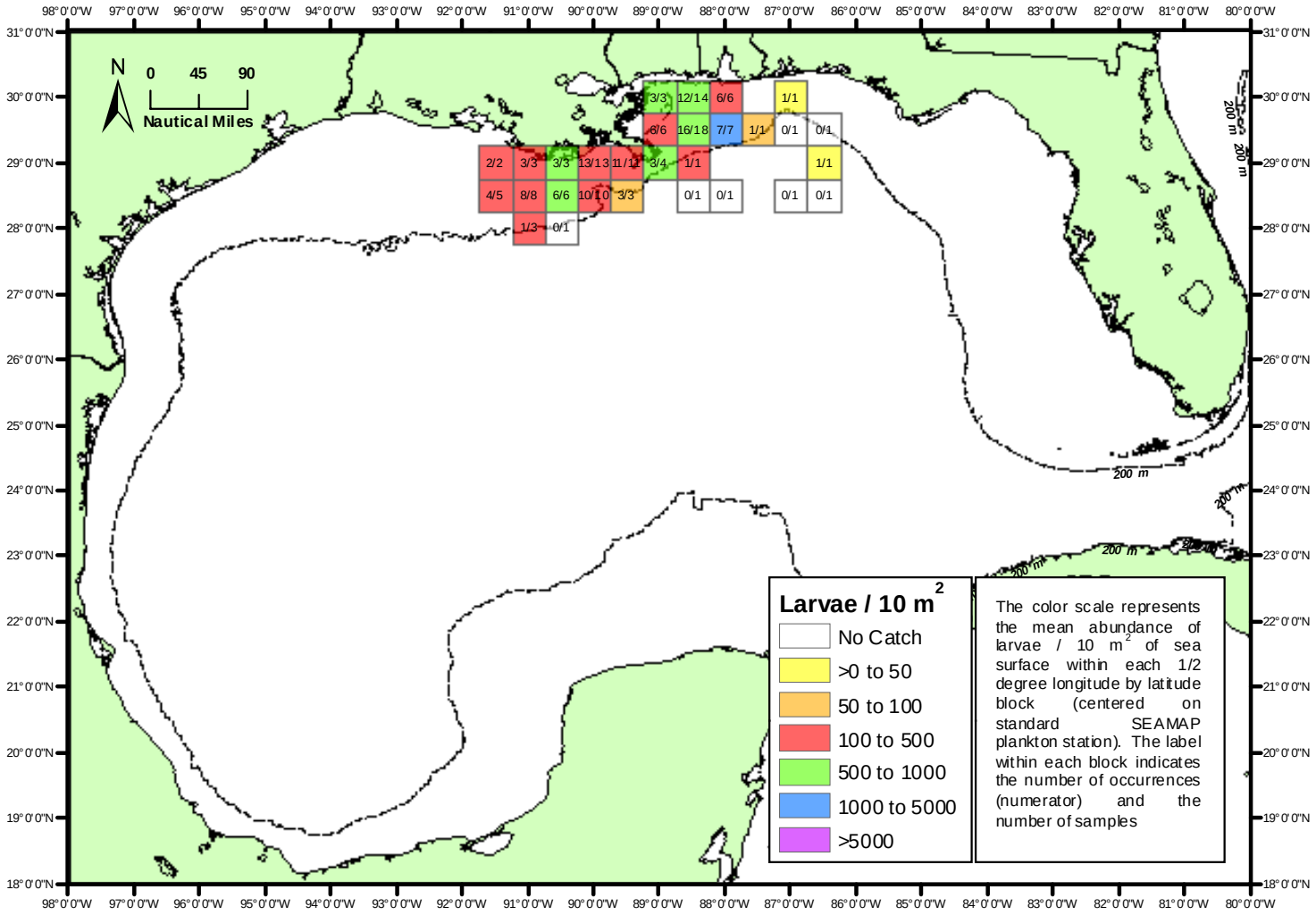

Figure 11. Winter Groundfish (US-WG), February and March, 1982-1985. Abundance and occurrence of *Brevoortia* spp. larvae captured in bongo net samples (n=136).

SEAMAP Winter Plankton (WP-WP)

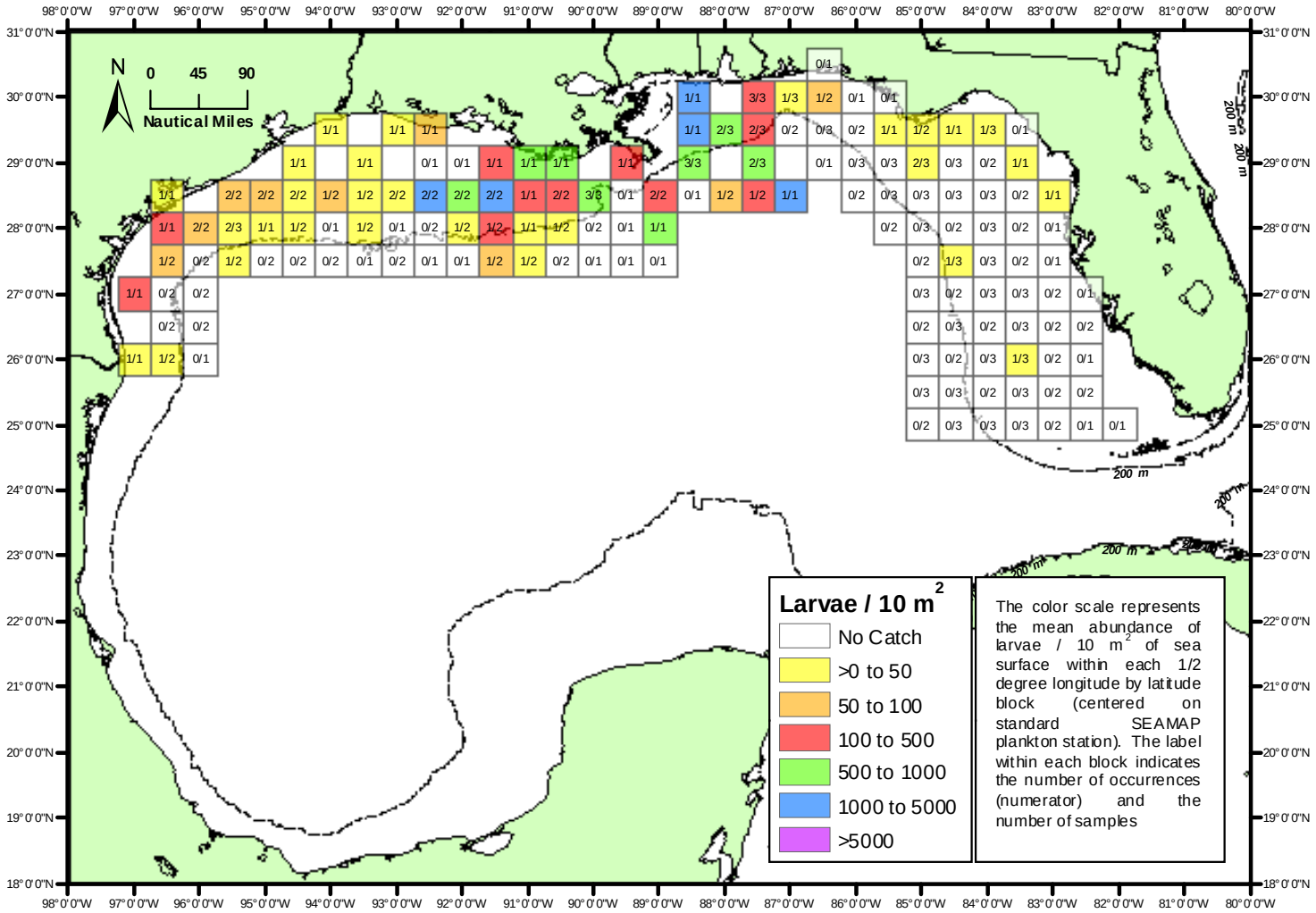

Figure 12. SEAMAP Winter Plankton (WP-WP), February and March, 2007-2009. Abundance and occurrence of *Brevoortia* spp. larvae captured in bongo net samples (n=279).

Louisiana Spring (LA-LP)

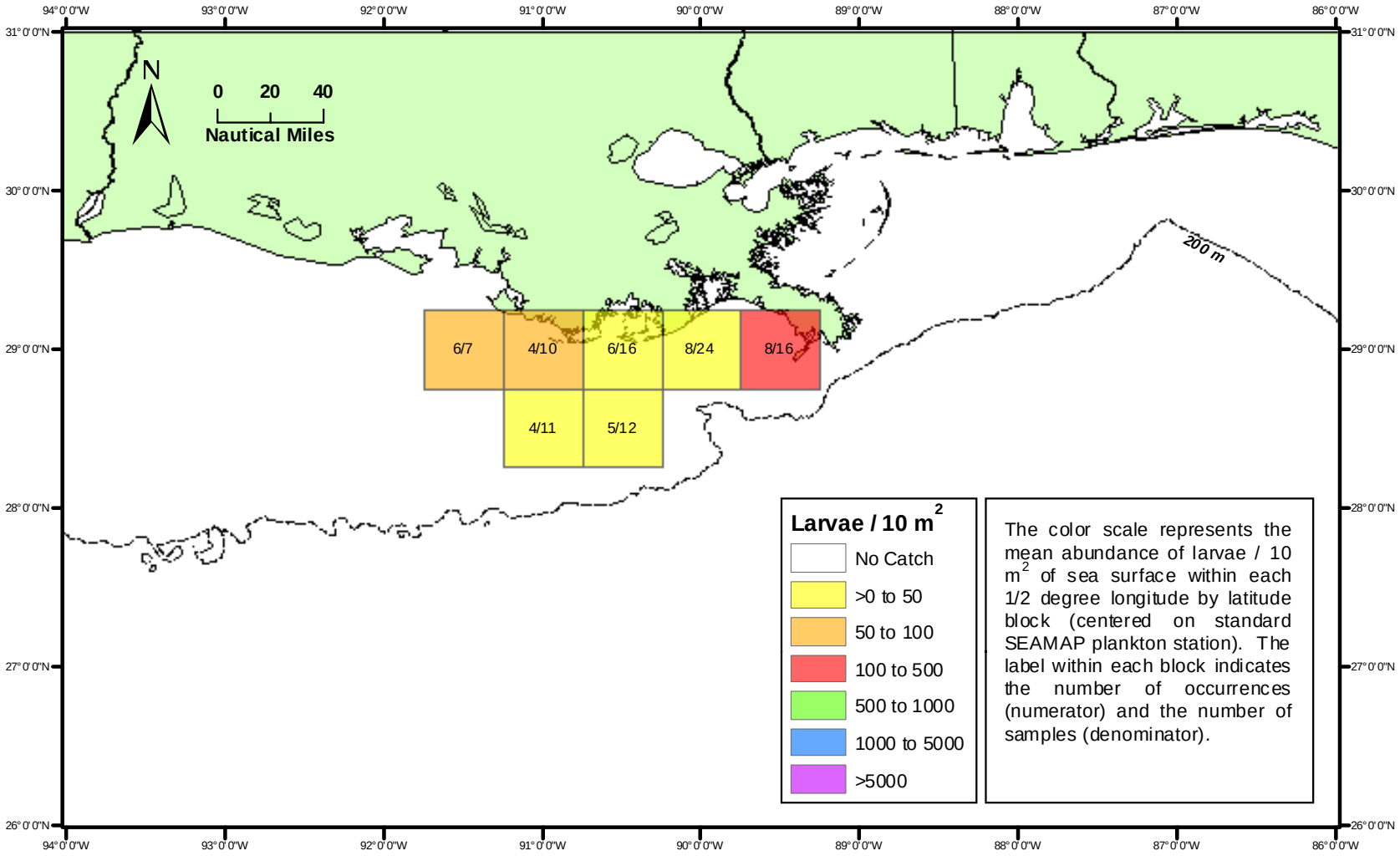

Figure 13. Louisiana Spring (LA-LP), March, April, May, 1986-1995. Abundance and occurrence of Brevoortia spp. larvae captured in bongo net samples (n=96).

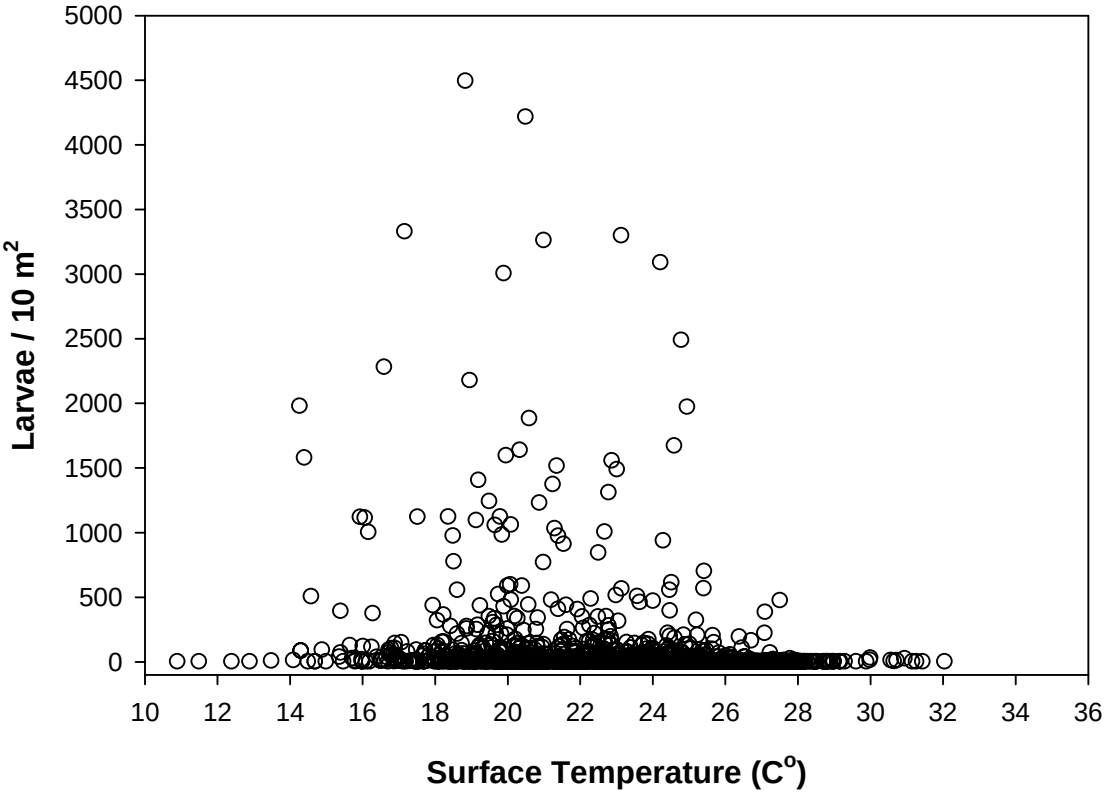

Figure 14. Larval menhaden abundance (n=1880 bongo samples) by sea surface temperature, three observations with abundances > 5000 are not shown.

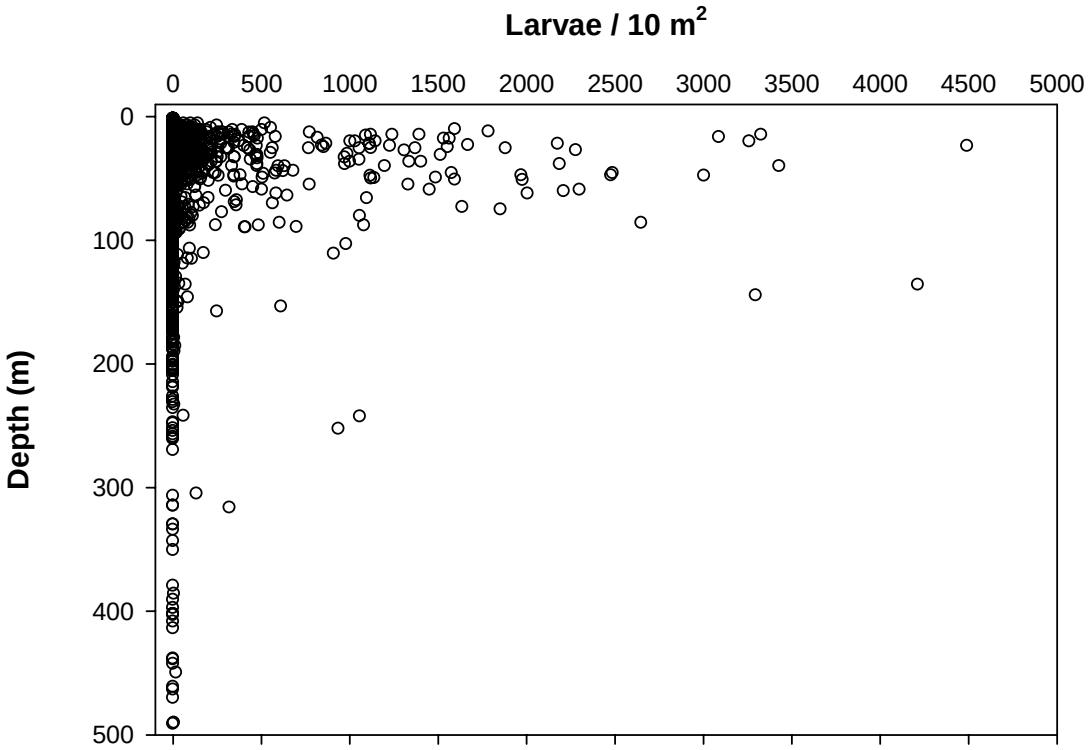

Figure 15. Larval menhaden abundance (n=2181 bongo samples) by depth. Five observations with abundances greater than 5000 are not shown; and 155 samples taken at stations where depth > 500 are not shown. Larvae were present in only nine of the 155 samples.