SCRS/1985/032 Rev.

Col.Vol.Sci.Pap. ICCAT, 24 : 182-195 (1986)

DISTRIBUTION AND ABUNDANCE OF BLUEFIN TUNA (THUNNUS THYNNUS) LARVAE IN THE GULF OF MEXICO IN 1982 AND 1983 WITH ESTIMATES OF THE BIOMASS AND POPULATION SIZE OF THE SPAWNING STOCK FOR 1977, 1978 AND 1981-1983

M. F. McGowan, W. J. Richards
Cooperative Institute for Marine and Atmospheric Science
University of Miami and NMFS Southeast Fisheries Center
75 Virginia Beach Drive, Miami, FL 33149, U.S.A.

SUMMARY

Estimated abundance of bluefin larvae in the Gulf of Mexico in 1982 was 2.00×10^{12} with coefficient of variation 0.28. Abundance in 1983 was 2.22×10^{12} or 3.70×10^{12} depending on assumptions of spawning duration and area. Coefficient of variation in 1983 was 0.40. Assuming larval mortality rate 0.1 per day, fecundity of 60.3×10^{6} eggs per female, and mean weight of spawning fish of 242 kg, the spawning stock in 1982 was 100,338 fish with total biomass of 2.43×10^{4} metric tons. The 1983 spawning stock was 78,610 (188,094) fish with biomass of 1.90×10^{4} (4.55×10^{4}) tons. Spawning duration and area were apparently smaller in 1983 than in previous years. Estimated larval abundance was lower in 1982 and 1983 than in 1977, 1978, and 1981. The population estimates based on ichthyoplankton are similar to, and follow the same trend as fishery-dependent estimates based on virtual population analysis (VPA).

RESUME

L'abondance estimée des larves de thon rouge dans le golfe du Mexique en 1982 était de 2.00×10^{12}, avec un coefficient de variation de 0.28. En 1983, l'abondance était de 2.22×10^{12} ou 3.70×12^{12}, selon les hypothèses sur la durée et la zone de ponte. Le coefficient de variation de 1983 était de 0.40. En suposant un taux de mortalité larvaire de 0.1/jour, une fécondité de 60.3×10^{6} oeufs/femelle, et un poids moyen du poisson reproducteur de 242 kg, le stock géniteur de 1982 était de 100.338 poissons avec une biomasse totale de 2.43×10^{4} TM. Le stock reproducteur de 1983 était de 78.610 (188.094) poissons, avec une biomasse de 1.90×10^{4} (4.55×10^{4}) TM. La durée et la zone de ponte étaient apparemment plus réduites en 1983 que les années précédentes. L'abondance larvaire estimée était plus faible en 1982 et 1983 qu'en 1977, 1978 et 1981. Les estimations de la population basées sur l'ichthyoplancton sont semblables aux estimations en fonction de la pêcherie basées sur l'analyses des populations virtuelles (VPA), dont elles suivent les tendances.

RESUMEN

La abundancia estimada de larvas de atún rojo en el Golfo de México en 1982 era de 2.00 x 10^{12}, con un coeficiente de variación de 0.28. En 1983, la abundancia era 2.22 x 1012 ó 3.70 x 10^{12}, según las hipótesis establecidas sobre duración y zona del desove. El coeficiente de variación en 1983 era de 0.40. Suponiendo una tasa de mortalidad de larvas de 0.1 por día, una fecundidad de 60.3 x 10^{6} huevos por hembra y un peso medio de pez reproductor de 242 kg, la población reproductora era en 1982 de 100.338 peces, con una biomasa total de 2.43 x 10^{4} t. La población reproductora de 1983 era de 78.610 (188.094) peces, con una biomasa de 1.90 x 10^{4} (4.55 x 10^{4}) t. La duración y la zona de desove eran aparentemente inferiores en 1983 que en años anteriores. La abundancia estimada de larvas era menor en 1982 y 1983 que en 1977, 1973 y 1981. Las estimaciones de población, basadas en el ictioplancton siguen la misma tendencia y son similares a las estimaciones dependientes de la pesquería y basadas en el análisis de población (VPA).

INTRODUCTION

Ichthyoplankton surveys can delimit the spawning areas and spawning seasons of fishes. Fishery independent estimates of the size of the spawning stock can be made from estimates of egg or larval abundance given estimates of fecundity, sex ratio and larval mortality. Previous estimates of western North Atlantic bluefin tuna stock size were made from larval surveys for 1977 and 1978 (Richards et al. 1981) and for 1981 (Richards, McGowan, and Ortner 1982; NMFS, SEFC, Miami Laboratory Reference Document). In this report we describe the distribution and abundance of bluefin larvae in the Gulf of Mexico in 1982 and 1983 and we present estimates of bluefin spawning stock biomass and population size based on the ichthyoplankton data.

The 1982 and 1983 estimates use different values for some life-history parameters than were used for previous estimates. Therefore we recalculated the stock size estimates for 1977, 1978 and 1981 using the new parameters in order to compare all years on the same basis. The time series of stock estimates is presented as a fishery-independent index of bluefin population dynamics. This index is, in fact, an estimate whose precision is presently limited by inadequate knowledge of the batch fecundity of bluefin, of temperature and age dependent growth and mortality rates of larvae, of rates of extrusion and escapement of larvae from plankton nets, of shrinkage of larvae due to capture and preservation, and by incomplete sampling of the spawning area and season.

METHODS

Collection and larval bluefin identification were done following Richards and Potthoff (1980).

Catch of bluefin larvae per station was standardized to numbers under 10 square meters of sea surface. Estimates of the mean and variance of the standardized catch per station were calculated from the log transformed values for stations at which bluefin larvae were present. These transformed values did not differ statistically from a normal distribution (Kolmogorov-Smirnov test; p=0.507:1982; p=0.904:1983), so the data follow the Delta-distribution (Aitchison and Brown 1957). The unbiased estimators

of the mean and variance were calculated using formulae in Pennington (1983). The estimate of larval production was calculated as:

$$P=(l)\,(s)\,(d/a)$$

where P = total larvae produced

l = mean catch/area

s = total area surveyed

d = duration of the spawning season in days

a = mean age in days of larvae captured

(estimated from Fig. 3 in Brothers et al. 1983)

Spawning stock population size was calculated as:

$$N = P/(F \times R)$$

where N = number of spawning fish

P = total larvae produced

F = relative fecundity (60.3 million eggs/female, Baglin 1982)

R = sex ratio as proportion of females in the population,

(0.565, mean of ratios for April, May, June; Baglin 1982)

Biomass of the spawners was calculated based on a mean weight of 242kg per fish (Table 4 in Baglin 1982; mean of fish actually weighed).

Survival of 40.8% to age 9 days (Richards et al. 1981) equals an exponential daily mortality of 0.0996 (=0.1). This rate was used to estimate the number of eggs originally spawned from the total larval catch and the mean age of the larvae. The mean age was used in the calculation of total larvae produced to adjust for the duration of spawning represented by the range of ages of larvae susceptible to capture.

RESULTS

The locations of sampling stations and relative standardized abundances of larvae are shown by month (April-July) and year (1982, 1983) in Figures 1-16. Dates and numbers of samples and numbers of samples with bluefin larvae present are shown in Table 1.

Abundance estimates were based on catches in bongo nets only, although the positive neuston stations were used with the bongo stations to delimit the spawning area. There was no statistical difference between day and night mean catches in 1982 or 1983. There was a difference in length distributions between years (Kolmogorov-Smirnov test, p=0.002). Mean length in 1982 was 4.15mm (bongo tows). Mean length in 1983 was 3.75mm (bongo tows). Mean length of larvae caught in neuston tows was 5.48mm in 1982 and 5.36mm in 1983.

The spawning area sampled in 1982 was 3.94×10^{11} square meters. The area sampled in May 1983 was 2.21×10^{11} square meters in the eastern and central Gulf of Mexico. No larvae were caught in April 1983 when 1.47×10^{11} square meters in the western Gulf of Mexico was sampled. For the smaller estimate we assume that spawning was restricted to the eastern Gulf in 1983 and that it did not begin there until May. We also assume that the 1983 spawning ended June 15 although one specimen was reported collected near the mouth of the Mississippi river on July 2. The identification of this larvae will be checked. For the larger estimate of larval abundance for 1983 we assumed Gulf-wide spawning May through July 2.

The mean number of larvae under 10 square meters of sea surface was 5.066 in 1982 with standard error = 1.43, n = 121. The mean number in 1983 was 10.038 with standard error = 4.01, n = 67. Estimates of total larvae were calculated as the produce of the mean standardized catch and the area sampled, adjusted for days in the spawning season and mean age of the larvae as described in the methods section. The mean age was estimated from the mean lengths in bongo tows in 1982 and 1983 using the age-length relationship: Age (days) = -8.04 + 3.67 Length (mm). This relationship was calculated from the mean lengths at age in Brothers et al. (1983, Fig. 3).

Biomass and population estimates were made from the larval index by adjusting the estimate of larvae initially spawned for mortality, 0.1 per day (Richards et al. 1981), and by using the relationships of 60.3×10^6 eggs per female, sex ratio of .565 females, and mean weight of 242 kg per spawning fish (Baglin 1982). These estimates and re-estimates for 1977, 1978, and 1981 using these parameters are presented in Table 2. The larval abundance-based spawning population estimate, and VPA population estimate (age 10+ fish, Table 8a in SCRS/84/31) are shown in Fig. 17. Confidence

intervals for the biomass and population estimates are proportional to the intervals for the estimate of larvae but are approximate because variances of the mortality rate, fecundity, and weight per fish are not included.

DISCUSSION

The distributions of bluefin larvae in the Gulf of Mexico in 1982 and 1983 were similar to that in previous years. They were generally found off-shore of the 200m depth contour. In 1982, when both the eastern and western Gulf were sampled in April and again in May, larvae were widely distributed within the sampled area in both months. In 1983, larvae were absent from the western Gulf in April when they were expected to be present based on previous estimates of the spawning season (April 15-June 15). Larvae were relatively abundant in the eastern Gulf in May 1983 but, because of the limited sampling caused by bad weather, it is uncertain whether spawning began in the eastern Gulf in April, whether it extended into the Western Gulf in May. The single larva caught in July 1983 may indicate that the spawning season extended later in the year, after starting later than usual.

The estimates of larval abundance for 1982 and 1983 (smaller estimate) were lower than estimated abundance in 1977, 1978, and 1981. This trend resulted in lower estimates of spawning stock biomass and population size. The sampling coverage was similar if not exactly equivalent across years. Sampling may have been better than usual in 1982 when the United States EEZ waters were sampled twice. Therefore the decrease relative to 1978 and 1981 appears to be real. There was little or no bluefin spawning in Mexican waters in 1982 and 1983 (Olvera L., ms.). Therefore the estimate of total abundance would not be changed substantially by including the area of the Mexican EEZ.

The estimates could be improved if more precise estimates of fecundity, larval mortality, sampler bias, and preservation artifacts could be obtained. For example, Baglin (1982) reported that there was no statistical relationship between fecundity and weight in bluefin from the Gulf of Mexico. He used estimates of all eggs > 0.32mm diameter to estimate fecundity although it was uncertain whether eggs this size would be spawned. There was, however, a significant relationship in his data between eggs >0.46mm and fish weight (linear regression, $p=0.013$, $r^1=0.224$, $n=27$). The eggs >0.46mm were those he judged would definitely be spawned. If fecundity were estimated from the larger eggs then the estimated number of fish would double. But if the bluefin spawn several batches of eggs, not all readily counted at one time, then the population estimate should be revised down.

Comparing the larval index to the estimate of 10 year and older fish from virtual population analysis (VPA), the trends are similar (Fig. 17) except that in 1977 and perhaps in 1983 the larval index is proportionally low. The adequacy of sampling in both of these years was questionable. Therefore the larval survey data can be an index of an estimate of stock size, given complete sampling coverage, better knowledge of life-history parameters of the bluefin, and estimates of plankton net sampling bias for bluefin larvae.

ACKNOWLEDGEMENTS

We thank the Southeast Area Monitoring and Assessment Program (SEAMAN) for access to 1982 and 1983 inchthyoplankton data. We also thank M. Farber, P. Phares, and J. Scott for advice on statistical methods. This work was supported in part by the National Oceanic and Atmospheric Administration under Cooperative Agreement #NA 84-WC-H-06098.

LITERATURE CITED

Aitchison, J. and J.A.C. Brown. 1957. The lognormal distribution. Cambridge University Press, Cambridge.

Baglin, R.E., Jr. 1982. Reproductive biology of western Atlantic bluefin tuna. Fish. Bull. U.S. 80:121-134.

Brothers, E.B., E.D. Prince, and D.W. Lee. 1983. Age and growth of young-of-the-year bluefin tuna, Thunnus thunnus, from otolith microstructure. Pages 49-59 in E.D. Prince and L.M. Pulos (editors), Proceedings of the international workshop on age determination of oceanic pelagic fishes: tunas, billfishes, and sharks. NOAA Tech. Rep. NMFS 8.

Olvera L., R.M. 1983. Distribucion, abundancia y biomasa reproductora de tres especies de tunidos, que desovan en la zona economica exclusiva del Golfo de Mexico y Caribe Mexicano. (ms. report of Mexus-Golfo ichthyoplankton cruises 1982-1983).

Pennington, M. 1983. Efficient estimators of abundance, for fish and plankton surveys. Biometrics 39:281-286.

Richards, W.J. and T. Potthoff. 1980. Distrbution and abundance of bluefin tuna larvae in the Gulf of Mexico in 1977 and 1978. International Commission for the Conservatio of Atlantic Tunas. Collective Volume of Scientific Papers 9(2):433-441.

Richards, W.J., M.F. McGowan, and J.A. Ortner. 1982. Summary of Gulf of Mexico ichthyoplankton research 1977-1982 with bluefin tuna population estimates and preliminary analyses of larval bluefin distribution and ichthyoplankton assemblages. NMFS, Miami Laboratory Reference Document.

Richards, W.J., T. Potthoff, and E.D. Houde. 1981. Abundance of bluefin tuna larvae and estimates of spawning stock sizes in the Gulf of Mexico in 1977 and 1978. International Commission for the Conservation of Atlantic Tunas. Collective Volume of Scientific Papers 15(2):273-277.

Table 1. Sampling effort and catch of bluefin larvae in 1982-1983. (Bongo net tows in areas sampled in which bluefin larvae occur.)

YEAR	DATES	N SAMPLES	SAMPLES WITH BLUEFIN	CATCH OF BLUEFIN
1982	4/15-7/30	121	27	79
1983	4/22-7/19	67(92)	19	71

Note: 1983 sample size in parentheses include those taken in the western Gulf in April when no larvae were taken.

Table 2. Summary of catches of bluefin larvae in the Gulf of Mexico and estimates of total larval production and spawning stock population and biomass 1977,1978,1981-1983.

	1977	1978	1981	1982	1983	
Catch	34	292	51	79	71	
Samples	48	147	65	121	67	
Positive	15	53	13	27	19	
Mean of ln(positives)	2.434	2.853	2.824	2.621	2.7615	
Variance ln(positives)	0.456	1.126	0.639	1.06	1.767	
Mean catch per 10m^2	4.397	10.802	4.498	5.066	10.038	
Variance	1.5237	4.9311	2.306	2.0388	16.095	
S. E.	1.234	2.221	1.519	1.428	4.012	
Coef. Var. = S.E./Mean	0.281	0.206	0.338	0.282	0.400	
Survey Area x 10^11 m^2	7.327	7.383	8.78	3.94	2.209	3.681
Larvae x10^12 (mean x area)	3.222	7.975	3.949	1.996	2.217	3.695
Season (days)	60	60	60	60	39	56
Age of Larvae (days)	8.842	7.007	8.4016	7.1905	5.7225	
Mean Length (mm)	4.6	4.1	4.48	4.15	3.75	
P=LxS/A	21.862	68.290	28.204	16.655	15.112	36.159
N fish assuming larval mortality= 0.1/day = P/(F x R)	155353	403925	191785	100338	78611	188094
Fecundity	60300000	60300000	60300000	60300000	60300000	60300000
Ratio female	0.565	0.565	0.565	0.565	0.565	0.565
Biomass tons 242kg/fish	37596	97750	46412	24282	19024	45519

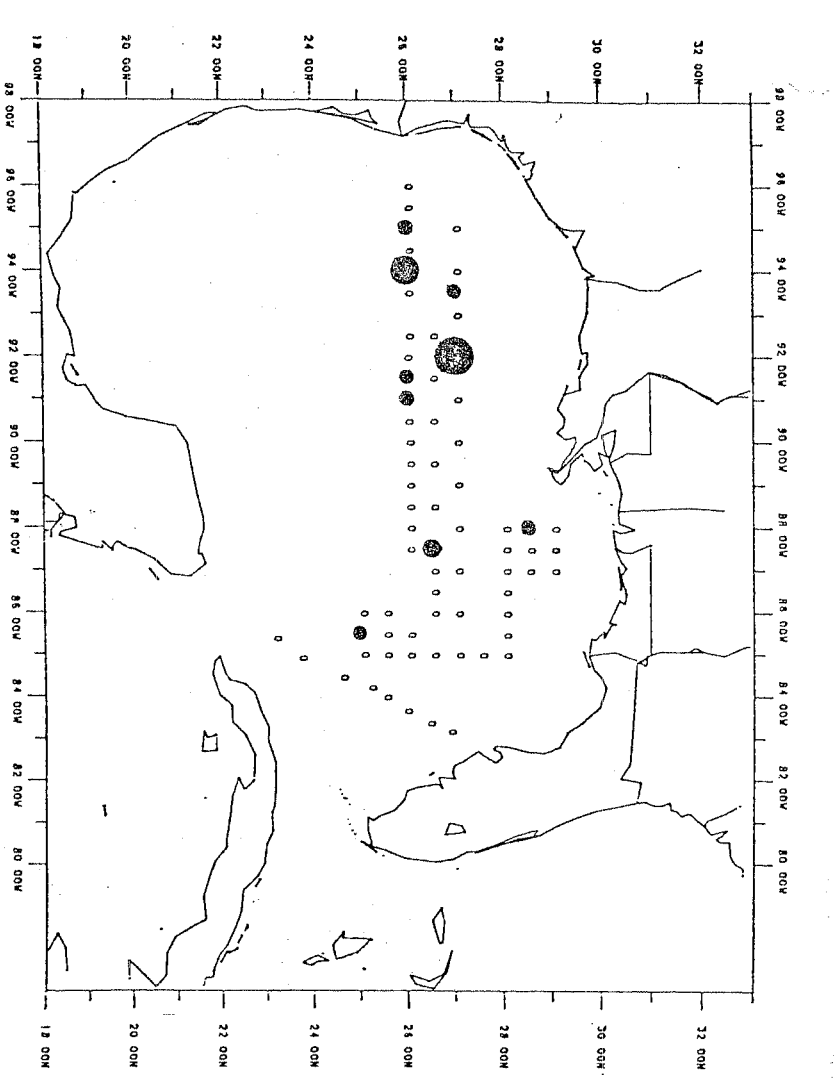

FIG. 1 BLUEFIN TUNA LARVAE. RELATIVE ABUNDANCE IN BONGO NET. APRIL 1982

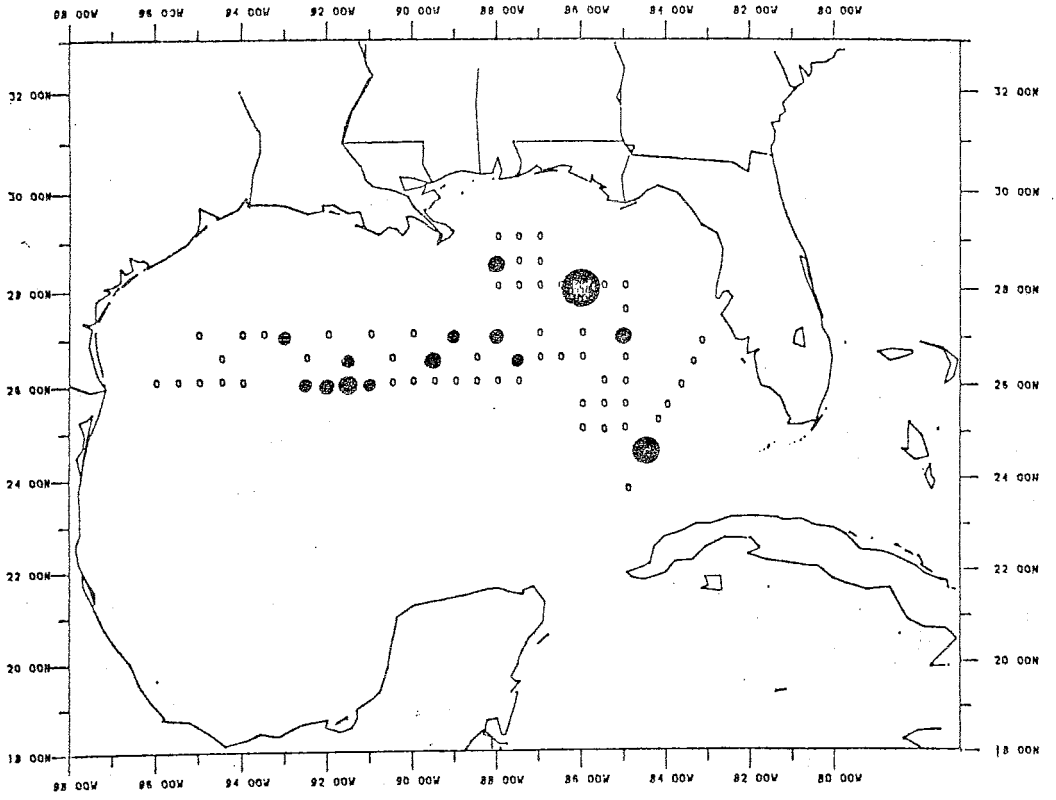

FIG. 2 BLUEFIN TUNA LARVAE..RELATIVE ABUNDANCE IN NEUSTON NET. APRIL 1982

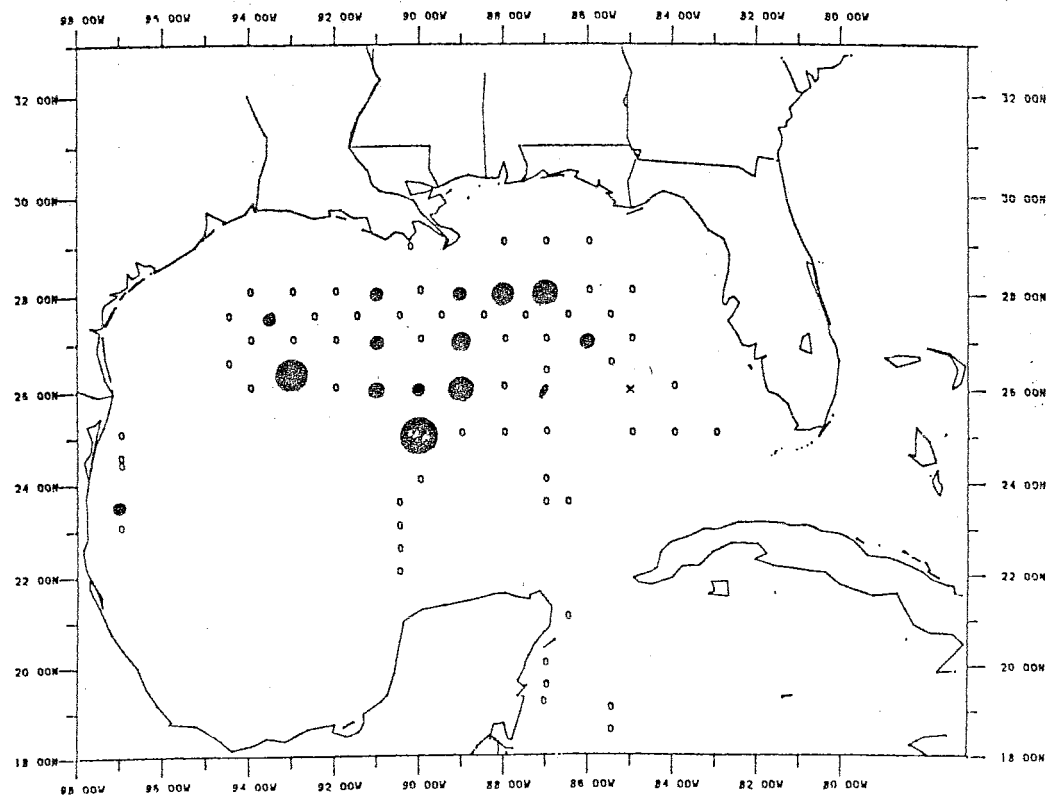

FIG. 3 BLUEFIN TUNA LARVAE. RELATIVE ABUNDANCE IN BONGO NET. MAY 1982

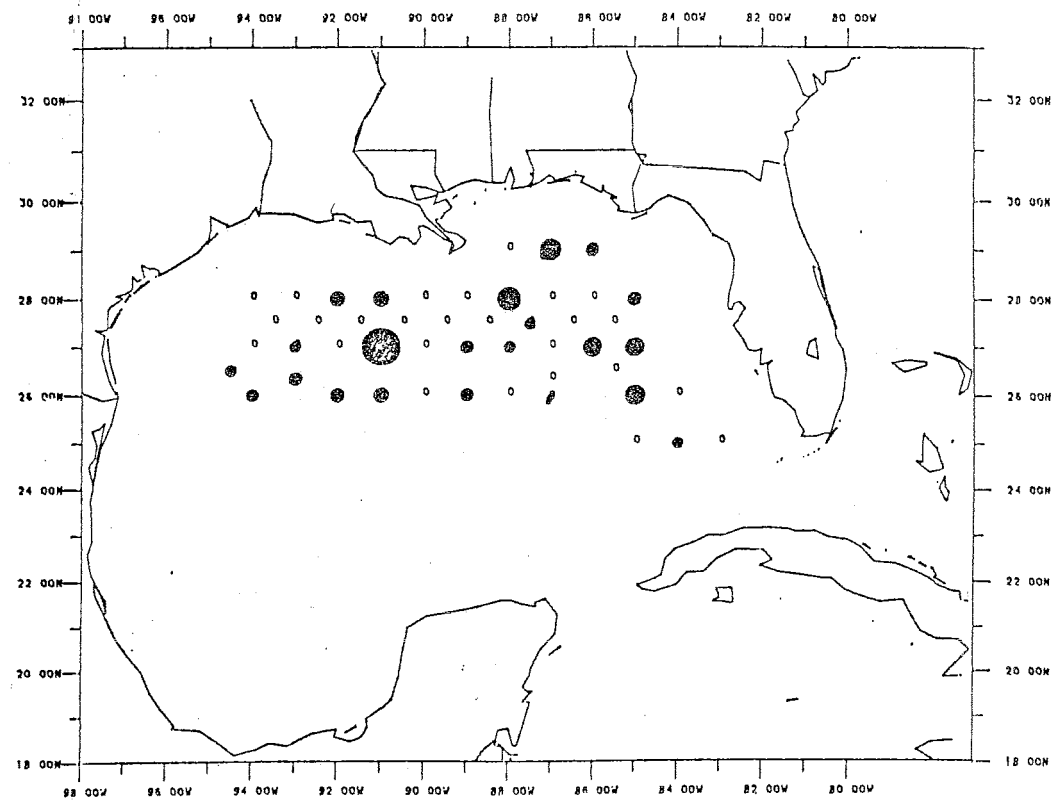

FIG. 4 BLUEFIN TUNA LARVAE. RELATIVE ABUNDANCE IN NEUSTON NET. MAY 1982

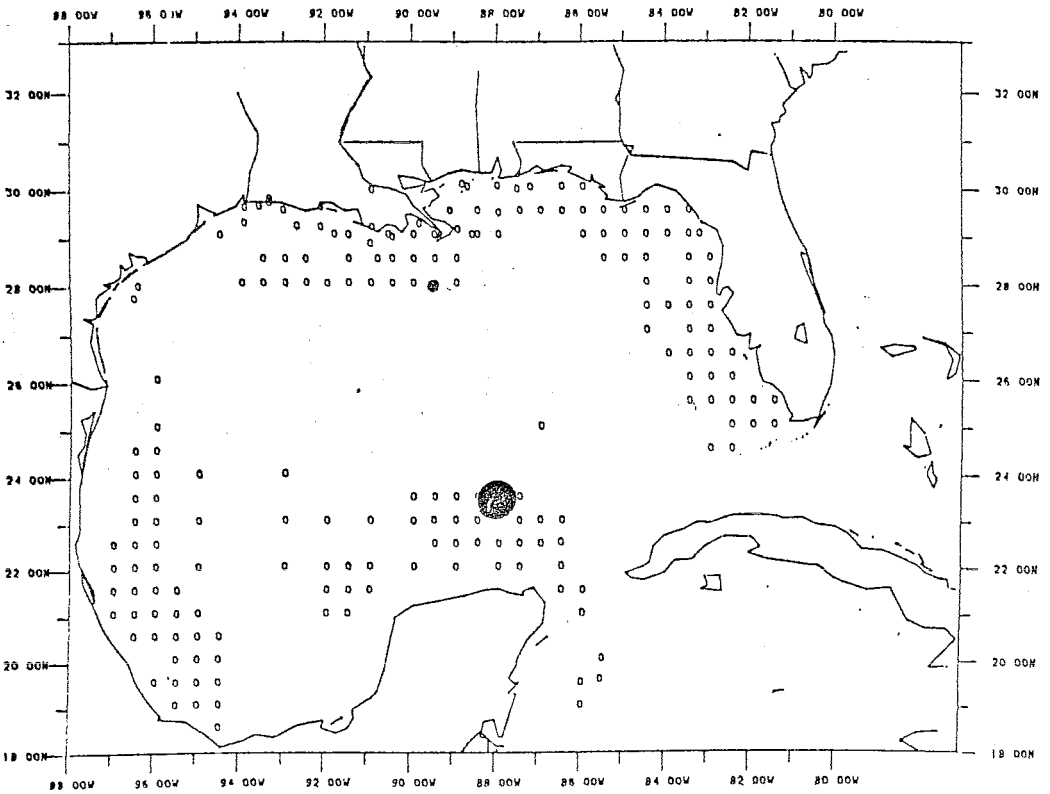

FIG. 5 BLUEFIN TUNA LARVAE. RELATIVE ABUNDANCE IN BONGO NET. JUNE 1982

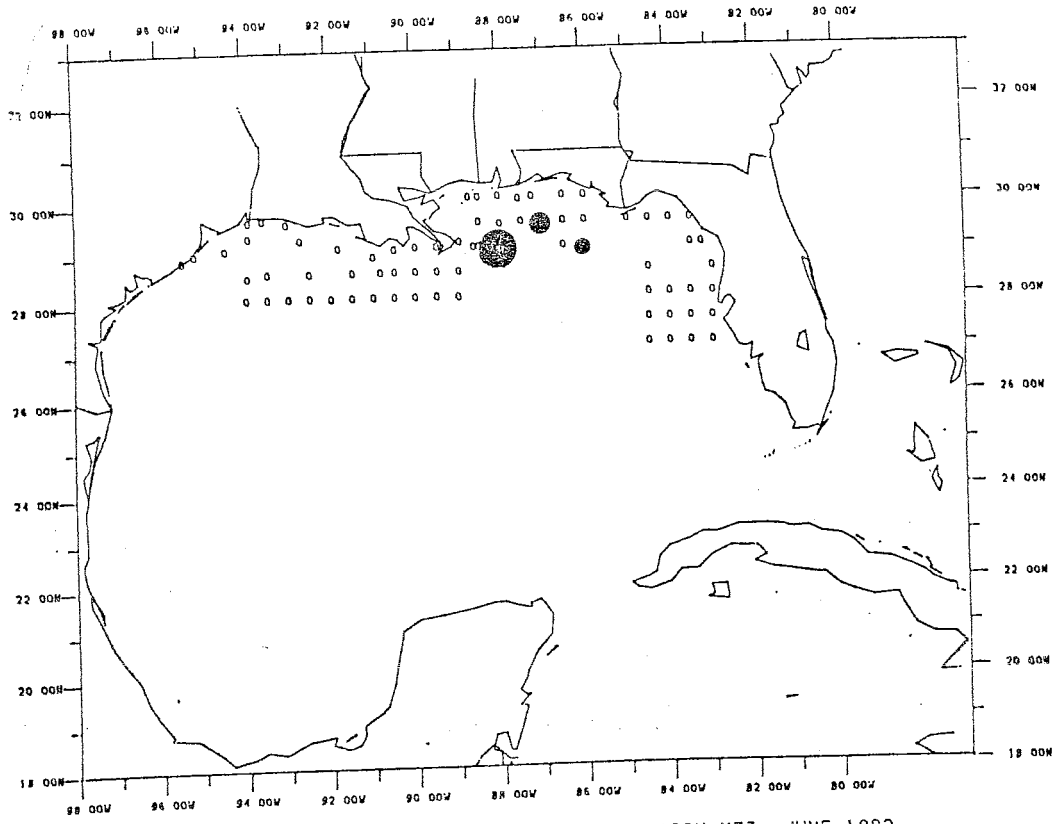

FIG. 6 BLUEFIN TUNA LARVAE. RELATIVE ABUNDANCE IN NEUSTON NET. JUNE 1982

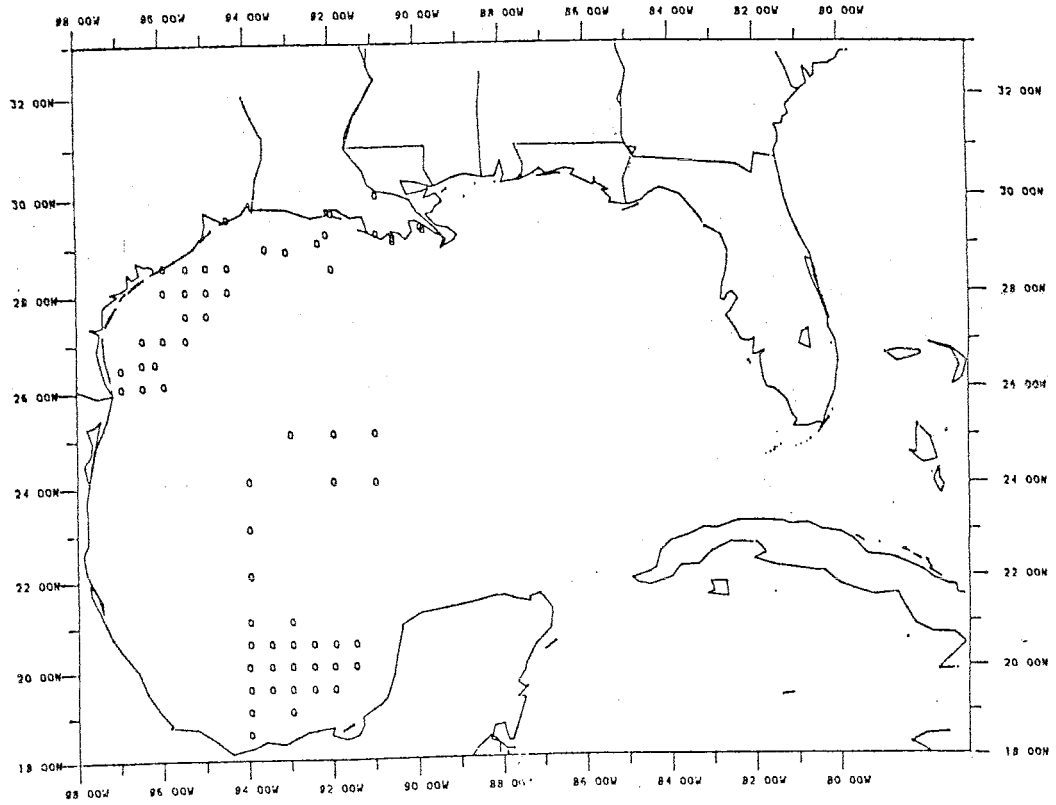

FIG. 7 BLUEFIN TUNA LARVAE. RELATIVE ABUNDANCE IN BONGO NET. JULY 1982

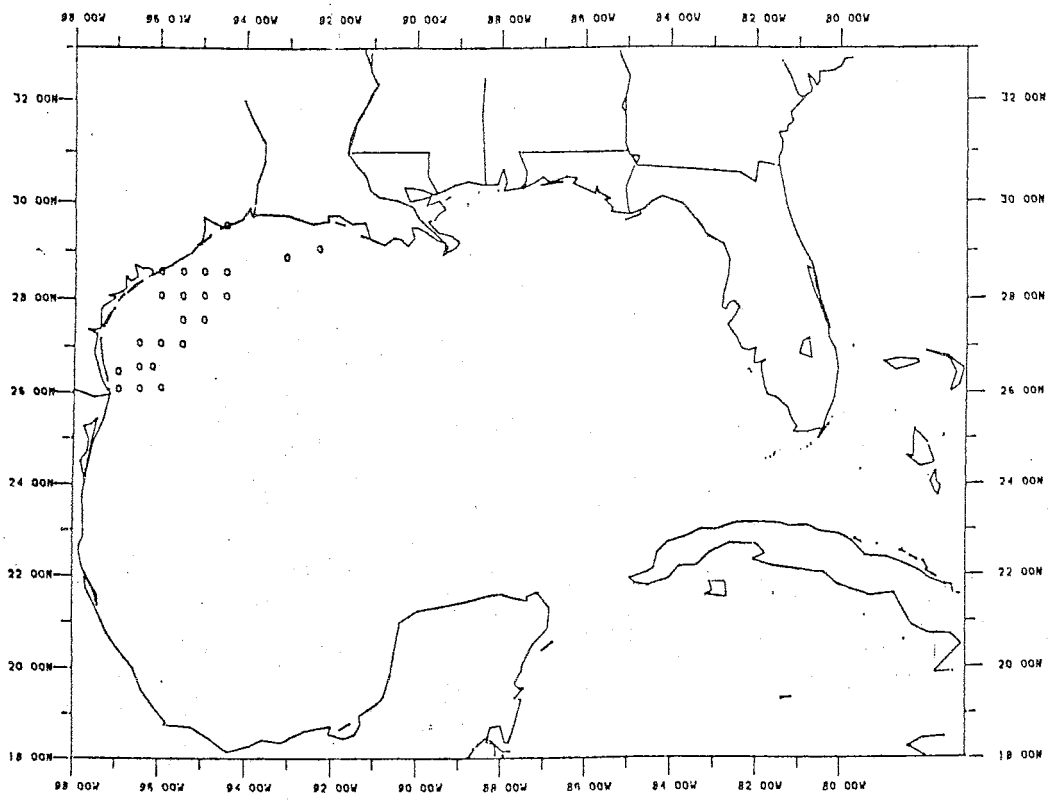

FIG. 8 BLUEFIN TUNA LARVAE. RELATIVE ABUNDANCE IN NEUSTON NET. JULY 1982

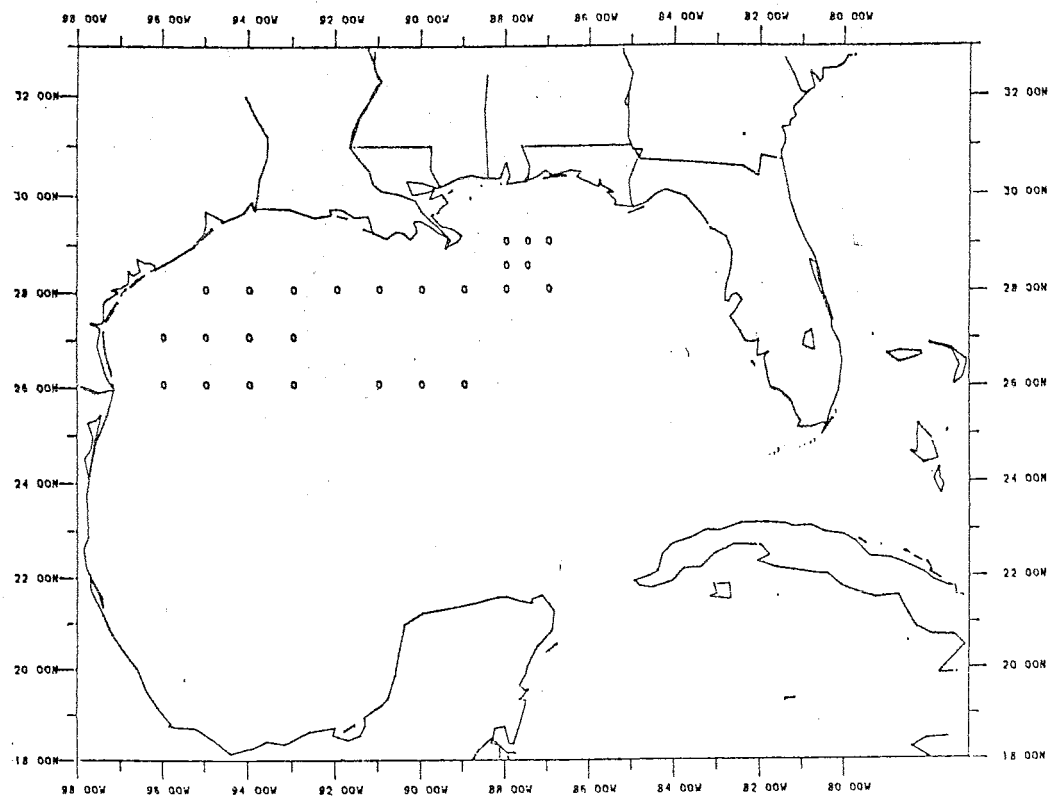

FIG. 9 BLUEFIN TUNA LARVAE. RELATIVE ABUNDANCE IN BONGO NET. APRIL 1983

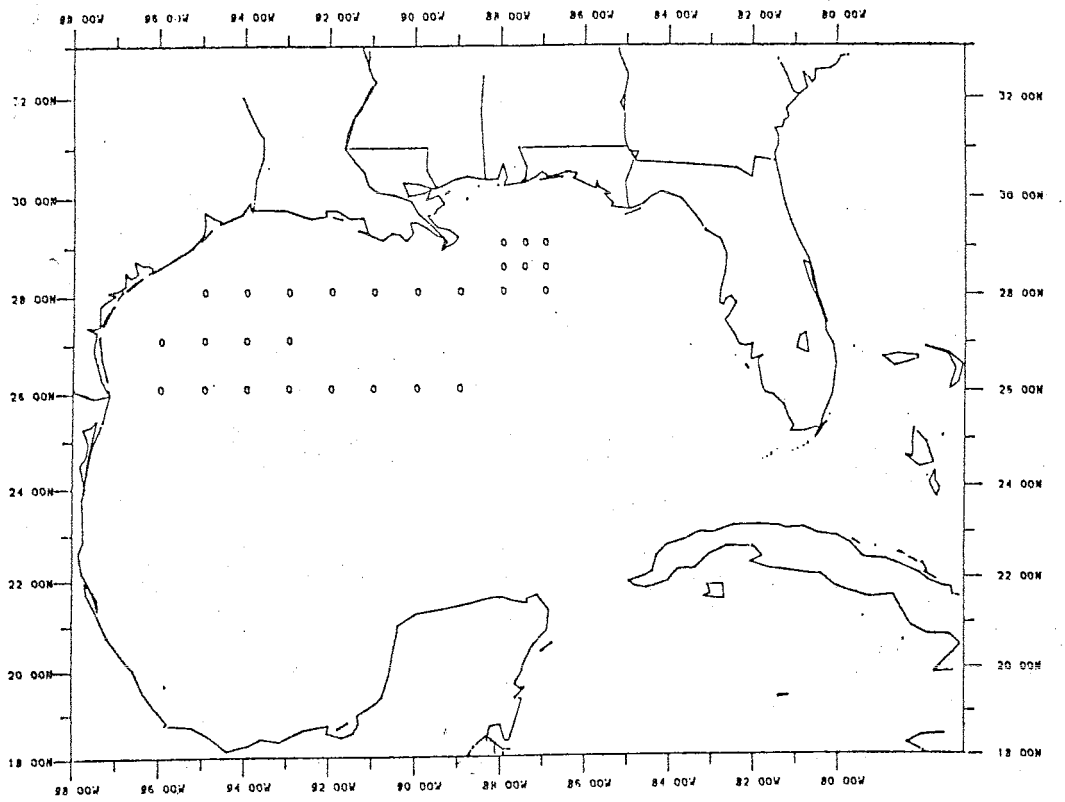

FIG. 10 BLUEFIN TUNA LARVAE. RELATIVE ABUNDANCE IN NEUSTON NET. APRIL 1983

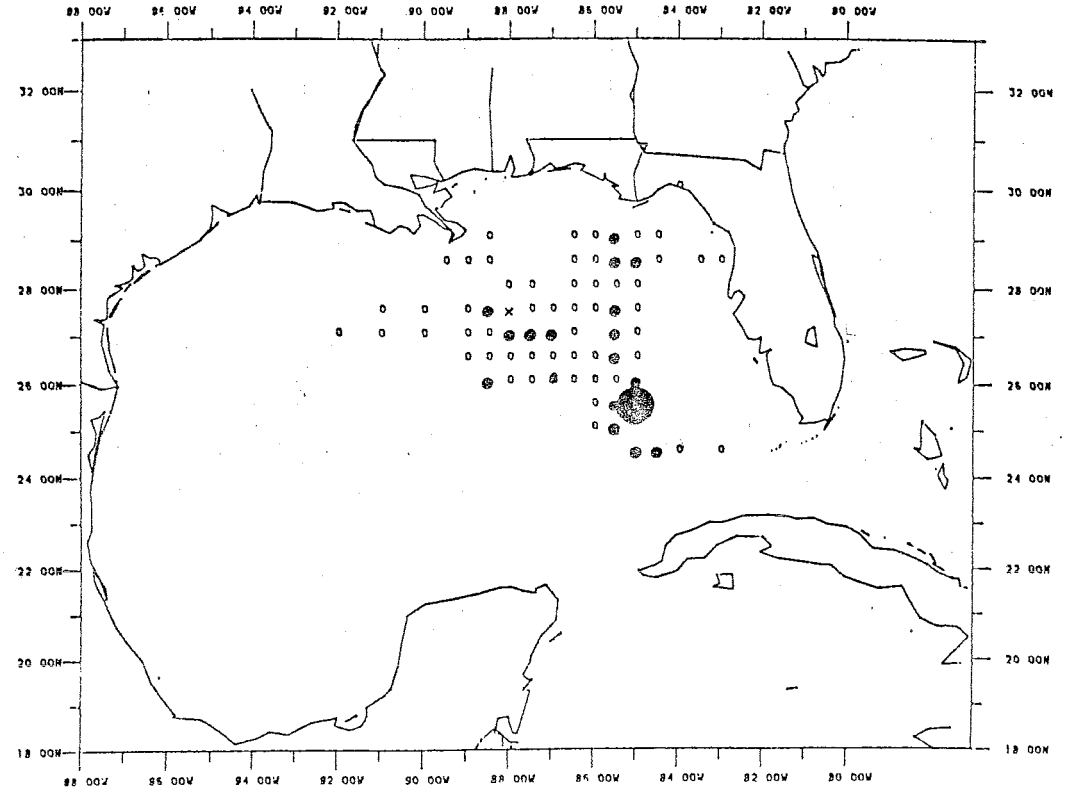

FIG. 11 BLUEFIN TUNA LARVAE. RELATIVE ABUNDANCE IN BONGO NET. MAY 1983

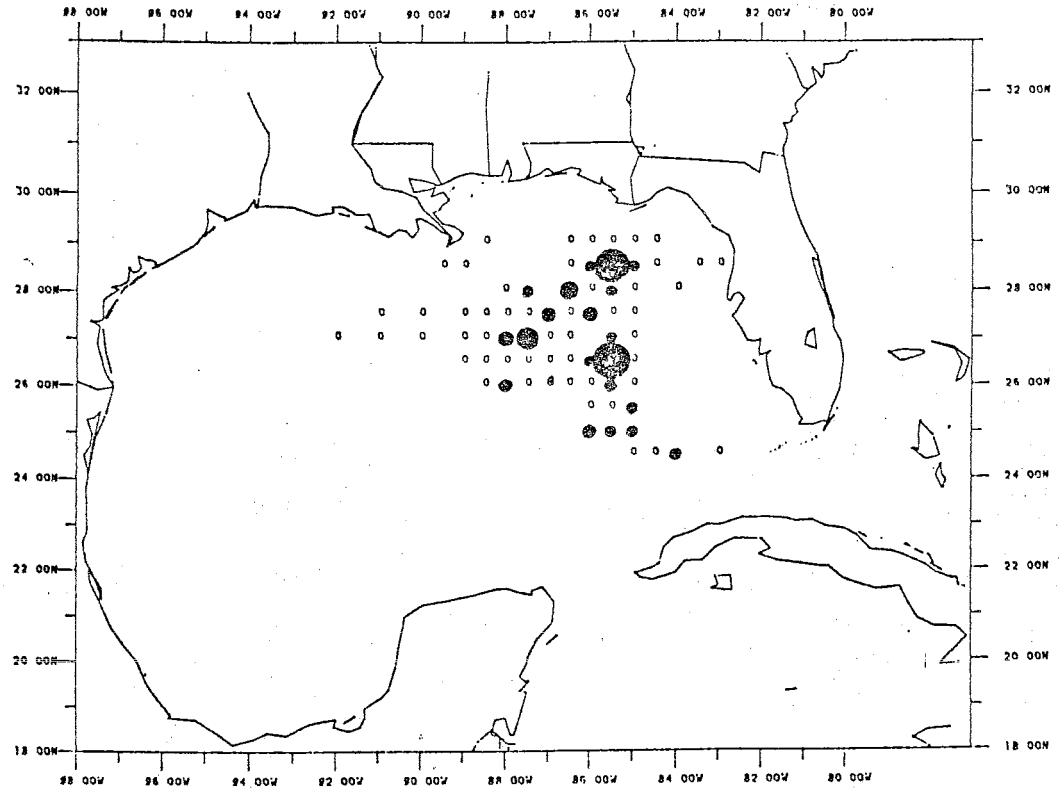

FIG. 12 BLUEFIN TUNA LARVAE, RELATIVE ABUNDANCE IN NEUSTON NET, MAY 1983

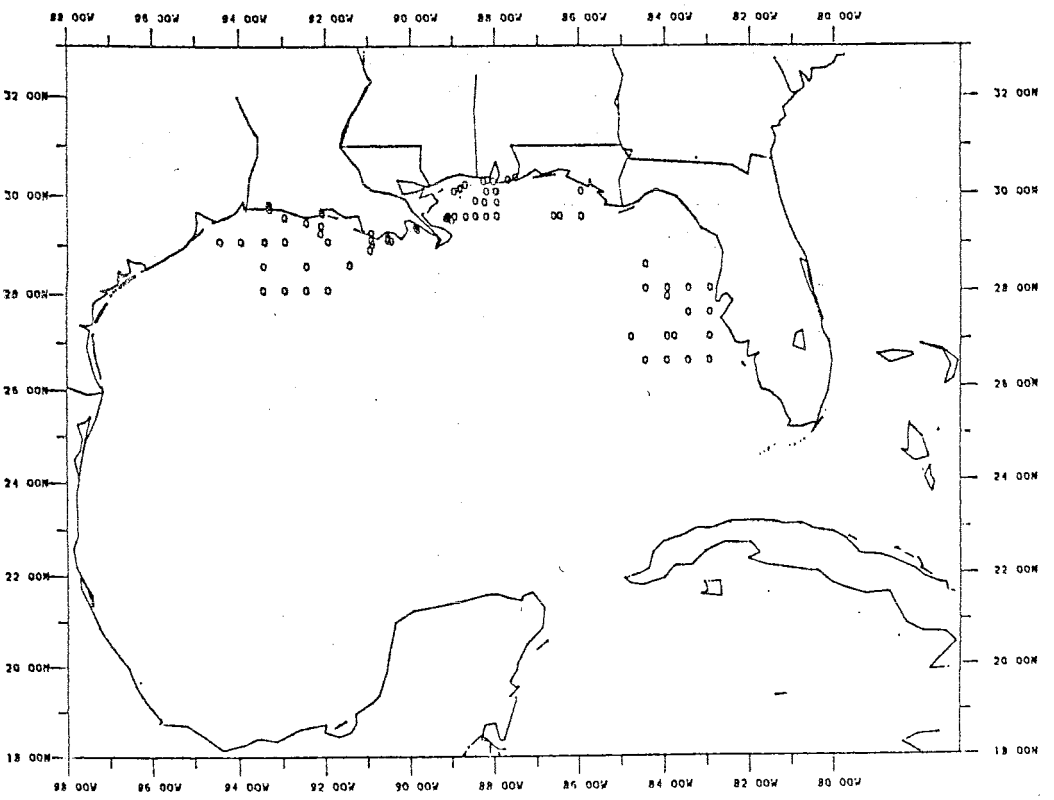

FIG. 13 BLUEFIN TUNA LARVAE, RELATIVE ABUNDANCE IN BONGO NET, JUNE 1983

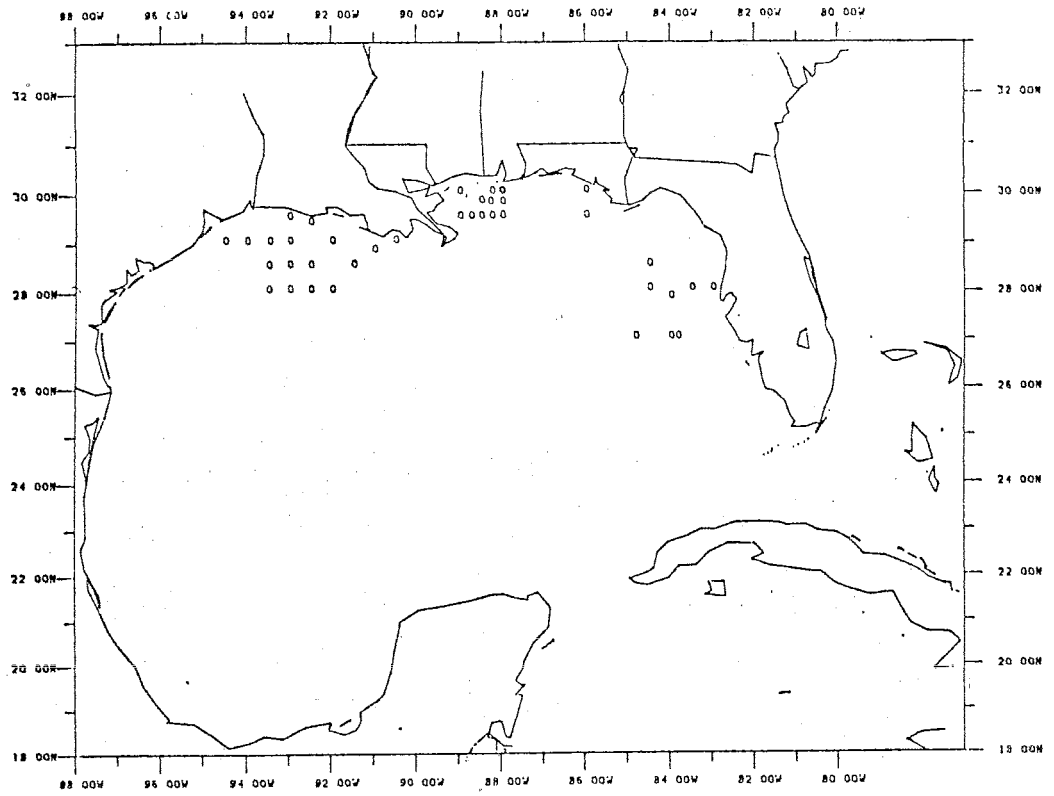

FIG. 14 BLUEFIN TUNA LARVAE. RELATIVE ABUNDANCE IN NEUSTON NET. JUNE 1983

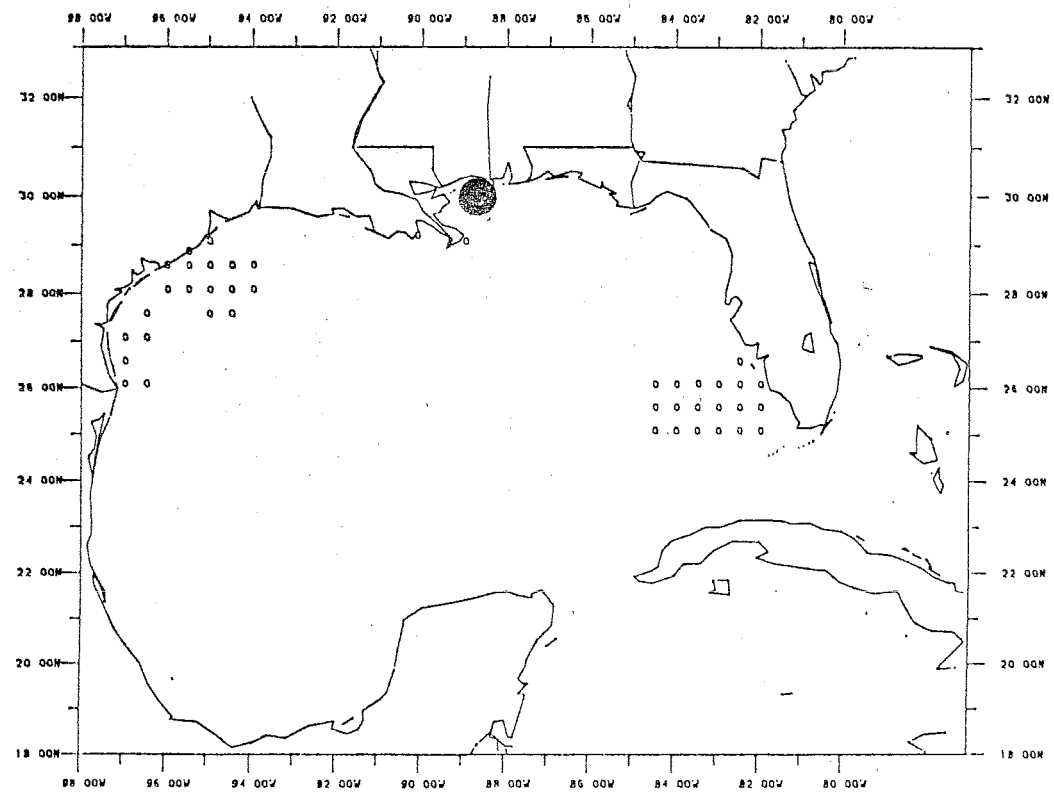

FIG. 15 BLUEFIN TUNA LARVAE. RELATIVE ABUNDANCE IN BONGO NET. JULY 1983

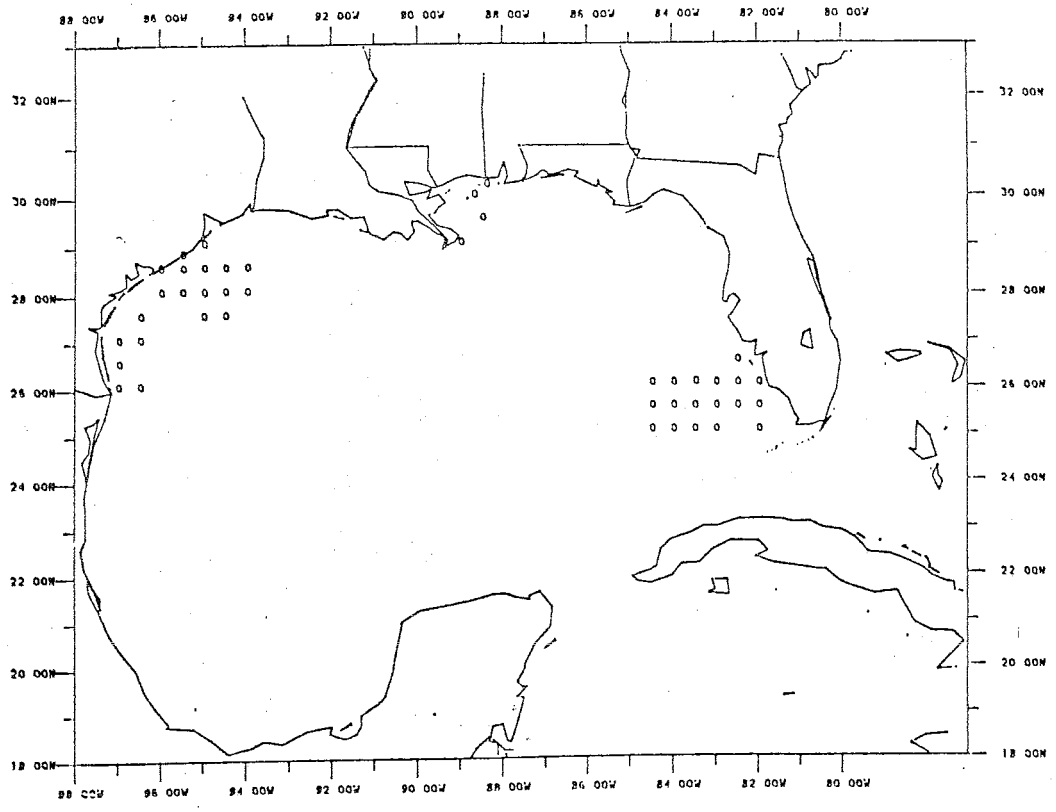

FIG. 16 BLUEFIN TUNA LARVAE. RELATIVE ABUNDANCE IN NEUSTON NET. JULY 1983

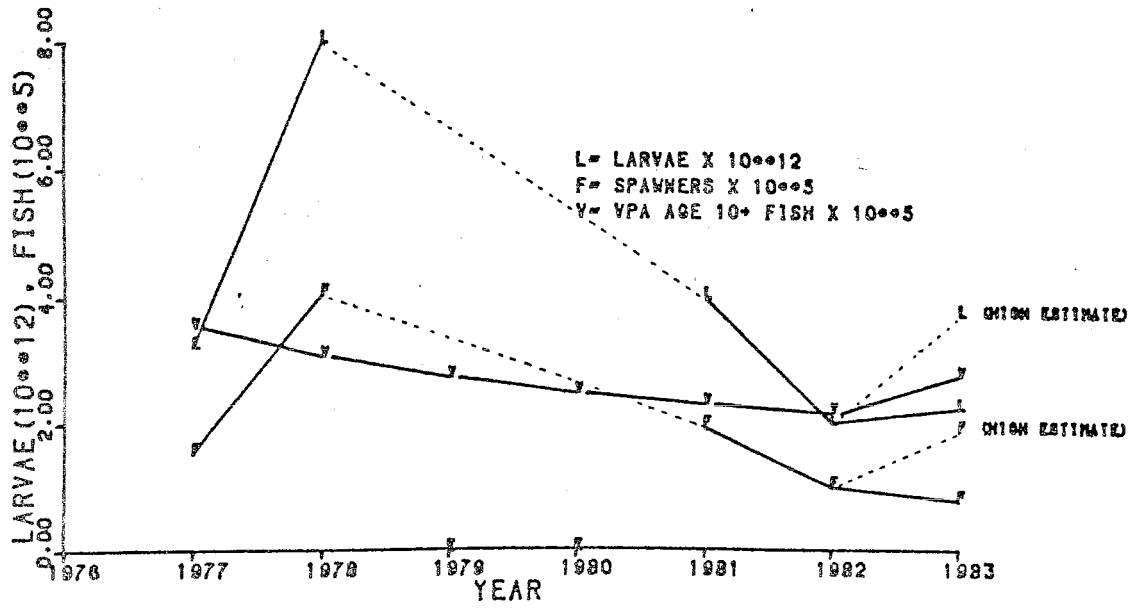

FIG. 17 COMPARISONS OF ESTIMATED TOTAL ABUNDANCE OF LARVAE WITH SPAWNING STOCK POPULATION ESTIMATED FROM LARVAL ABUNDANCE AND WITH NUMBERS OF AGE 10+ ADULTS ESTIMATED BY VIRTUAL POPULATION ANALYSIS. NO ICHTHYOPLANKTON SURVEYS WERE MADE 1979-1980. THE LOW ESTIMATES IN 1983 ARE BASED ON REDUCED SPAWNING AREA AND SEASON. THE HIGH ESTIMATES ARE BASED ON HISTORIC DURATION AND EXTENT OF SPAWNING.