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Scomber scombrus spawning stock estimates in ICNAF Subarea 5 and Statistical Area 6, based on egg catches during 1966, 1975 and 1976

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Abstract

Estimates of Scomber scombrus spawning stock size, based on egg catches during two series of surveys within the Mid-Atlantic Bight, are presented. Egg catches from oblique plankton tows with Gulf V and 61-cm bongo samplers were adjusted to account for depth and volume filtered and egg mortality. Total egg production and the number of spawners was calculated for each survey. Due to timing and geographic coverage, only one (May 1975) of the seven surveys considered provides a realistic but minimum estimate of spawning stock size within the Bight (392 million fish). This and other estimates from both SA 5-6 and the Gulf of St. Lawrence (SA 4) were compared and discussed.

Introduction

Recent estimates of Scomber scombrus population size within ICNAF Subarea 5 and Statistical Area 6 have been based on commercial catch compositions (e.g. Paciorkowski et al.,1973; Anderson,1975a; and Falk et al., 1975) with estimates of relative abundance between years provided by Anderson (1973, 1974, and 1975b). An alternative and independent population estimate can be provided by sampling eggs and calculating the spawning stock necessary to have produced them. This has been done on Atlantic mackerel in the Gulf of St. Lawrence during 1968 (MacKay,1973) and south of Cape Cod in 1932 (Sette, 1943). MacKay concluded that the northern population spawning stock consisted of about 1.6 billion fish in 1968. Sette calculated a total of 6.4×10^{13} eggs and 320 million spawners south of Cape Cod in 1932.

This paper presents similar information resulting from the 1965-66 R/V Dolphin ichthyoplankton survey of the Mid-Atlantic Bight and the 1974-76 ERDA-funded (Energy Research and Development Administration) monthly survey in the New York Bight; both series of surveys were conducted by the Sandy Hook Laboratory.

Materials and Methods

Stations occupied during the 1965-66 survey of the Mid-Atlantic Bight are shown in Figure 1. Plankton sampling procedures and gear used were described by Clark et al. (1969). Gulf V samplers were towed for 30 min at a speed of 9.3 km/hr (5 kt) in a step-oblique pattern. Normally two nets were towed, one sampling at 0 to 15 m in six steps, the other from 18 to a maximum of 33 m. When there was insufficient water to allow lowering either net to its standard maximum depth, the towing scheme was altered. Fahay (1974) explained in detail this procedure and consequent adjustments to the data. Flowmeters were not used; therefore, a theoretical value (495 m^2) of water strained by each Gulf V sampler was used in the calculations. This value was based on the dimensions of the sampler and the mesh and a reported 85% efficiency for this design (Tranter and Smith, 1968). Catches of eggs were expressed as eggs/m^2 ocean surface.

Plankton sampling was conducted almost monthly between July 1974 and June 1976 in the New York Bight at stations shown in Figure 2. A pair of 61-cm bongo nets, fitted with 0.505 and 0.333-mm mesh netting, were towed at approximately 90 cm/sec (1.75 kt) at each station, sampling from the surface to near the bottom and back to the surface in a smooth oblique pattern according to standard MARMAP (Marine Resources Monitoring, Assessment, and Prediction) procedures outlined by Jossi et al. (1975). These nets were equipped with flowmeters in their mouths, and a bathykymograph was attached to the towing wire just below the nets.

Early-stage Scomber scombrus eggs were counted in each sample and a corresponding number of eggs per m^2 of ocean surface was calculated which accounted for the volume of water filtered, the maximum sampling depth, and (for 1966 Gulf V catches) contamination of the deeper sampler. Numbers of eggs at the time of spawning were calculated by assuming a 5% per day mortality rate (Sette,1943) and development rates at various temperatures reported by Worley (1933). The early stage of egg development extends from fertilization to complete epiboly and constitutes 35% of the egg incubation time (Worley, 1933). The duration (days) of the early-stage eggs at each station was therefore determined knowing the surface temperature at the station (Tables 1-2). To account for continuous spawning and development of eggs, only one-half of the 35% rate was used in back-calculating the initial numbers of eggs spawned at each station. Ocean surface areas corresponding to each station were measured on navigation charts and were defined by lines perpendicular to, and passing through mid-points of, lines connecting adjacent stations. Egg densities were expanded to estimate the numbers of eggs in the areas surrounding each station, and these products were summed to derive a cruise total of eggs spawned which produced the early-stage eggs sampled.

Since this estimate of spawned eggs corresponds to the early stage and because the duration of this stage differs from the time-interval between spawning batches, a further adjustment was necessary to estimate the eggs spawned in a single batch by the entire population. The number of eggs spawned at one time (i.e. eggs per batch) has been reported to average 40,000 to 50,000 (Brice, 1898; Moore, 1899; Bigelow and Welsh, 1925), with a yearly fecundity of 360,000 to 450,000 eggs per female (Bigelow and Welsh, 1925), implying about nine batches in one season. The time-interval between batches is unknown and can only be approximated. Several authors referring to either western Atlantic or eastern Atlantic populations note that S. scombrus females spawn in batches over a considerable period of time but are not able to set limits on that time period or the batch intervals for individual fish (Brice, 1898; Moore, 1899, Bigelow and Welsh, 1925; Steven and Corbin, 1939; Steven, 1949; Bigelow and Schroeder, 1953). However, in calculating point estimates of spawning stock for this species based on egg abundance estimates, a batch size and interval must be assumed. The bulk of the spawning migration between Chesapeake Bay and southern Massachusetts occurs for about 8 weeks, beginning in the south around mid-April and extending to Cape Cod around mid-June. Individual fish apparently do not spawn over that entire time span; some are believed to join the migration as it proceeds along the coast (Sette, 1950). Therefore, the spawning season for an individual fish can be expected to be less than 8 weeks, and is assumed in this paper to average from 4 to 6 weeks. In order for 9 batches to be produced within 4-6 weeks, the batches must be spaced an average of 3.5 to 5.25 days apart. In computing estimates of cruise totals of eggs spawned in one batch, the mid-point of these two values (4.4 days) was assumed to be the batch interval. The batch interval was divided by the average early-stage duration for the cruise to provide a staging factor which was multiplied by the cruise total of eggs sampled to determine the total number of eggs spawned in one batch. In other words, the calculated total number of eggs sampled corresponding to the mean early-stage egg duration time for the cruise was expanded upwards to estimate the total number of eggs spawned (population egg batch) during the assumed batch interval of 4.4 days (Table 3). The number of spawners in the survey area was then calculated by dividing the population batch size by the individual female batch size and multiplying by 2.0 to include the males (assuming a 1:1 sex ratio).

Since there were no replicate tows during either series of surveys, sampling variance or confidence limits were not calculated for these egg and stock estimates.

Estimates of spawning stock were calculated, applicable only to the times and areas of each survey. Total seasonal estimates were not determined because the times and areas sampled during both series were inadequate for this purpose, as discussed below.

Results

Within the 1965-66 series of ichthyoplankton surveys, those during May and June 1966 provided S. scombrus egg data. There was no survey during July, and no eggs were taken during the April and August surveys of this series. During May, sampling extended over almost the entire geographic extent of spawning which extended from the eastern shore of Virginia and Maryland to Martha's Vineyard and was most concentrated off Delaware Bay, New Jersey and western Long Island. In June, early-stage eggs were collected off Montauk Point, N.Y. and Martha's Vineyard; these eggs apparently representing the westerly extreme of the spawning area at that time. Calculated egg densities and resultant cruise totals for May and June are presented in Table 1 and estimated numbers of spawners are given in Table 3. Despite the large difference in the areas of egg distribution between the two surveys, the spawning stock estimates are similar primarily because the average egg density sampled in May was much lower than that in June.

Atlantic mackerel eggs were taken during five surveys of the 1974-76 series in the New York Bight (Table 2). The greatest numbers of eggs were caught during May in both years; however, considerably more were taken during May 1975 than May 1976. The resulting numbers of spawners represented by the May surveys in 1975 and 1976 were 392 million and 7 million, respectively (Table 3).

Discussion

Among the estimates of S. scombrus spawning stock south of Massachusetts, Sette's (1943) calculation for 1932 appears to be less subject to error. Sette sampled frequently throughout the spawning season and included what appeared to be most of the spawning area. His smooth oblique tows were capable of sampling all portions of the water column with equal intensity and the catches were quantitative because net flowmeters were employed.

The 1965-66 and 1974-76 data reported in this paper are subject to considerable error which would result in underestimates of the spawning stock. Survey timing and frequency within the spawning period and a lack of flowmeters in the nets are sources of error in the 1966 data. While the May 1966 survey encompassed the geographic range of spawning and obtained eggs over a wide area, compared to June, the egg density within the area of egg distribution was lower than that in June. The lower egg density in May implies that sampling occurred before the peak in spawning that season. The June survey sampled egg densities greater than in May and, therefore, was closer to the peak in spawning for 1966; however, the June survey apparently missed a significant portion of the spawning area east of Martha's Vineyard. It was not possible to measure the volume of water sampled by the Gulf V nets, so theoretical values were assumed. Since clogging of the nets was observed to be substantial at times, the egg densities and resulting stock estimates presented here are undoubtedly underestimated. In addition, using the assumed 4.4-day batch interval for both series of surveys may bias the stock estimates one way or the other.

Sampling techniques in the New York Bight surveys of 1974-76 were more refined than those of 1965-66 in that smooth oblique tows were made which sampled the entire water column, and the catches were quantitative because flowmeters were suspended in the mouths of the bongo nets. The bongo nets are more efficient and less prone to clogging than conical nets such as the Gulf V (Tranter and Smith, 1968). These surveys, however, were geographically restricted, their results applicable to approximately 30,000 km^2, whereas Sette (1943) surveyed 86,000 km^2 in 1932, and the 1965-66 surveys covered 98,000 km^2. Because of the more restricted area sampled in 1974-76, the timing of these surveys was very important in determining egg abundance and spawning stock size. Judging from egg abundance estimates for all surveys in the New York Bight, the sampling in May 1975 was closer to the peak of spawning than during any other survey. Therefore, a better estimate of spawning stock size (392 million fish) is derived from that survey. However, the area sampled represented only part of the total spawning area at that time, so 392 million spawners is an underestimate from the standpoint of area sampled. Neither estimate from the two 1976 surveys approaches the magnitude of that from May 1975. Based on increased temperatures during the

1976 season, the spawning intensity was already decreasing by the time of the May survey. Unfortunately, there was no sampling during April when the bulk of spawning probably occurred.

The 1975 estimate of 392 million spawners and Sette's (1943) estimate of 320 million in 1932 suggest similar levels of biomass in the two years. However, the 1932 estimate was based on sampling which covered 86,000 km^2 whereas the 1975 sampling was limited to only 30,000 km^2. The only indicator of stock abundance in 1932 is catch and catches during 1925-49 were relatively steady averaging 23,500 tons per year (Anderson, 1976). The total commercial catch in 1975 in SA 5-6 was 250,978 tons. The size of the spawning stock in SA 3-6 at the beginning of 1975 was estimated from cohort analysis to be 1.184 billion fish (Anderson et al., 1976). Part of the SA 3-6 mackerel stock spawns in SA 5-6 and part spawns in the Gulf of St. Lawrence (SA 4). MacKay (1973) estimated the number of spawners in the Gulf of St. Lawrence in 1968 to be 1.6 billion fish. The cohort analysis estimate for SA 3-6 in 1968 was 2.1 billion fish (Anderson et al., 1976) suggesting, based on MacKay's (1973) estimate, that the majority of the fish in the population spawned in the Gulf of St. Lawrence. Sette (1943) earlier concluded from egg density estimates that the Gulf of St. Lawrence accounted for only about 10% of the total spawning. Changes in environmental conditions in the Gulf since that time could have resulted in an increased proportion of the stock spawning there. Recent estimates of mackerel egg production in the Georges Bay portion of the Gulf of St. Lawrence range from 3.4×10^{12} in 1973 to 7.2×10^{12} in 1975 (D. M. Ware[1], personal communication). Georges Bay represents only 1-2% of the potential spawning area for mackerel in the Gulf of St. Lawrence, but it is unlikely that the Georges Bay egg estimates can be expanded to accurately reflect the entire egg production in the Gulf of St. Lawrence. Assuming fecundity of 400,000 eggs per female and a 1:1 sex ratio as in MacKay's (1973) estimate, the number of mackerel spawning in Georges Bay ranged from 17 million in 1973 to 36 million in 1975. These represent minimal estimates, but it is not known how much they could be expanded to account for the total number of spawners in the Gulf of St. Lawrence. Although MacKay's (1973) estimate suggests that the bulk of the SA 3-6 stock spawned in the Gulf of St. Lawrence in 1968, quantitative data from egg surveys are presently lacking to accurately assess the size of the two spawning groups.

The estimates of spawners presented in this paper are subject to considerable variation; many of the sources of bias were discussed. Although confidence limits were not calculated directly from the data reported, if it can be assumed that the accuracy of these estimates is similar to that reported for other pelagic egg surveys, then the actual cruise totals of eggs may be expected to be from one-half to double the estimates (Saville, 1964).

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Table 1. Scomber scombrus early-stage egg abundance estimates from sampling in Mid-Atlantic Bight, 1966.

Cruise Sta.	Surf. temp. (°C)	Early-stage duration (days)	Eggs/m^2	Station area (km^2)	Eggs in station area X 10^9
D-66-5 May 12-24, 1966					
A-2	7.4	3.94	0.036	780.3	0.028
B-1	8.3	3.69	2.199	270.1	0.594
B-2	7.7	3.87	5.120	1023.8	5.242
B-3	7.5	3.92	1.271	1517.7	1.929
B-4	7.6	3.89	0.258	1937.9	0.500
B-5	7.6	3.89	0.110	2315.2	0.256
B-6	7.0	4.05	0.104	2611.0	0.270
C-1	8.8	3.49	11.334	557.4	6.318
C-2	8.7	3.54	5.309	725.4	3.851
C-3	8.4	3.67	1.710	1633.3	2.793
C-4	7.9	3.84	1.295	2085.4	2.700
C-5	7.8	3.86	0.309	2448.3	0.757
C-6	7.5	3.92	0.033	2695.9	0.090
D-1	10.8	2.69	35.737	493.2	17.625
D-2	9.8	3.11	68.578	715.1	49.040
D-3	9.2	3.33	24.520	1165.5	28.578
D-4	8.9	3.44	2.151	1509.2	3.247
D-5	8.7	3.54	1.734	1826.4	3.168
D-6	8.1	3.74	0.235	2057.9	0.483
D-7	6.3	4.21	0.037	1939.6	0.072
E-1	11.8	2.32	12.000	377.3	4.528
E-2	10.0	2.98	55.779	677.4	37.784
E-3	9.5	3.24	6.914	1013.5	7.008
E-4	9.2	3.33	3.992	1327.4	5.299
E-6	8.8	3.49	0.106	1296.5	0.137
F-1	12.7	2.01	1.059	120.0	0.127
F-2	12.2	2.18	2.166	466.5	1.010
F-3	12.2	2.18	69.498	882.2	61.312
F-4	10.8	2.69	29.802	1275.9	38.025
F-5	10.4	2.84	0.104	1599.0	0.166
F-6	10.0	2.98	0.108	1908.7	0.206
F-7	8.2	3.72	0.103	1903.6	0.195
G-1	13.8	1.69	8.176	392.7	3.211
G-2	12.5	2.08	3.414	622.5	2.125
H-1	15.0	1.44	0.063	571.8	0.036
H-2	13.4	1.80	1.460	665.4	0.971
H-3	11.9	2.28	0.257	970.0	0.249
Total				46379.0	289.930
D-66-7 June 17-29, 1966					
A-3	14.1	1.61	11.022	840.3	9.261
A-4	14.5	1.51	109.137	1209.0	131.947
A-5	15.0	1.44	1.390	1972.2	2.742
A-7	14.1	1.61	0.347	2160.8	0.751
B-2	14.0	1.64	0.338	1023.8	0.346
Total				7206.1	145.047

Table 2. Scomber scombrus early-stage egg abundance estimates from sampling in New York Bight, 1975 and 1976.

Cruise Sta.	Surf. temp. (°C)	Early-stage duration (days)	Eggs/m^2	Station area (km^2)	Eggs in station area X 10^9
D-75-4 April 2-10, 1975					
F-5	7.6	3.89	0.636	1585.5	1.009
Total				1585.5	1.009
D-75-5 May 6-12, 1975					
A-2	8.5	3.65	2504.254	1057.0	2646.996
A-4	11.3	2.47	115.810	1585.5	183.617
B-3	12.0	2.24	772.238	1585.5	1224.383
B-5	10.4	2.84	682.002	1585.5	1081.314
C-2	7.9	3.84	297.866	1585.5	472.267
C-4	10.4	2.84	127.268	1585.5	201.784
C-6	10.0	2.98	2.299	1585.5	3.645
D-1	8.2	3.72	61.111	1057.0	64.594
D-3	8.5	3.65	60.762	1585.5	96.338
D-5	10.5	2.80	15.192	1585.5	24.088
E-2	8.1	3.74	394.531	1585.5	625.529
E-4	9.0	3.39	1.178	1585.5	1.868
E-6	9.5	3.24	0.838	1585.5	1.329
F-1	8.1	3.74	403.847	1585.5	640.299
F-3	7.9	3.84	1.129	1585.5	1.790
F-5	9.3	3.30	1.194	1585.5	1.893
G-4	9.0	3.39	5.328	1585.5	8.448
Total				25896.5	7280.181
D-75-6 June 3-9, 1975					
F-3	15.1	1.42	9.060	1585.5	14.365
F-5	15.0	1.44	1.730	1585.5	2.743
G-2	16.5	1.21	172.172	1585.5	272.979
G-4	17.5	1.07	0.621	1585.5	0.985
Total				6342.0	291.072
D-76-7 May 17-24, 1976					
A-2	13.7	1.72	0.267	1057.0	0.282
C-2	10.9	2.65	1.725	1585.5	2.735
C-6	13.6	1.76	3.918	1585.5	6.212
D-3	12.6	2.05	1.850	1585.5	2.933
D-5	13.5	1.78	1.616	1585.5	2.562
E-2	12.3	2.14	0.488	1585.5	0.774
E-4	13.2	1.85	2.101	1585.5	3.331
E-6	12.5	2.08	6.572	1585.5	10.420
F-5	13.0	1.89	0.777	1585.5	1.232
G-2	11.9	2.28	12.375	1585.5	19.621
G-4	12.4	2.11	18.706	1585.5	29.658
Total				16912.0	79.760
D-76-10 June 9-12, 1976					
C-6	15.5	1.35	0.662	1585.5	1.050
D-5	16.4	1.22	0.953	1585.5	1.511
E-4	16.4	1.22	0.589	1585.5	0.934
Total				4756.5	3.495

Table 3. Estimates of *Scomber scombrus* spawning population during 1966, 1975 and 1976.

Cruise	Weighted mean surf. temp. (^{o}C)	Mean early-stage duration (days)	Staging factor	Sampled egg total X 10^{9}	Population egg batch X 10^{9}	Spawning adults X 10^{6}
D-66-5	10.4	2.84	1.55	289.930	449.189	17.97
D-66-7	14.5	1.51	2.91	145.047	422.654	16.91
D-75-4	7.6	3.89	1.13	1.009	1.141	0.05
D-75-5	9.4	3.27	1.35	7280.181	9795.990	391.84
D-75-6	16.4	1.22	3.61	291.072	1049.770	41.99
D-76-7	12.4	2.11	2.09	79.760	166.324	6.65
D-76-10	16.1	1.26	3.49	3.495	12.205	0.49

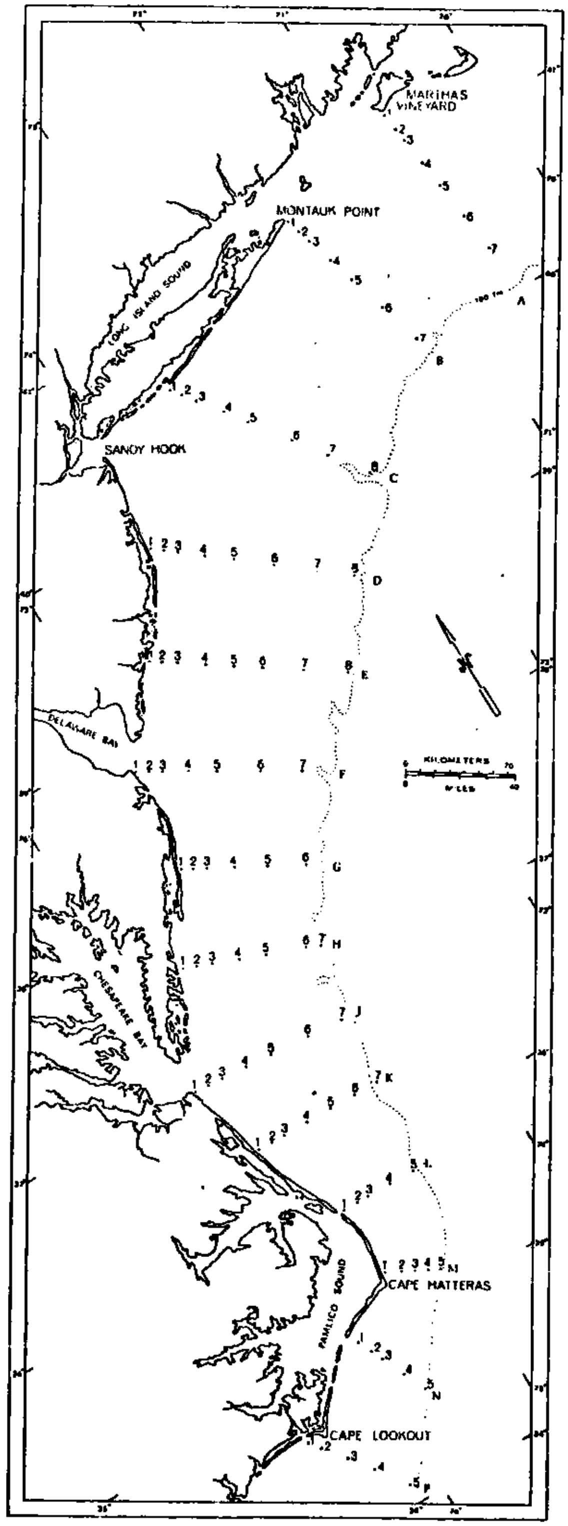

Fig. 1. Stations sampled with Gulf V plankton nets during cruises from December 1965 to December 1966 (from Clark _et al._, 1969).

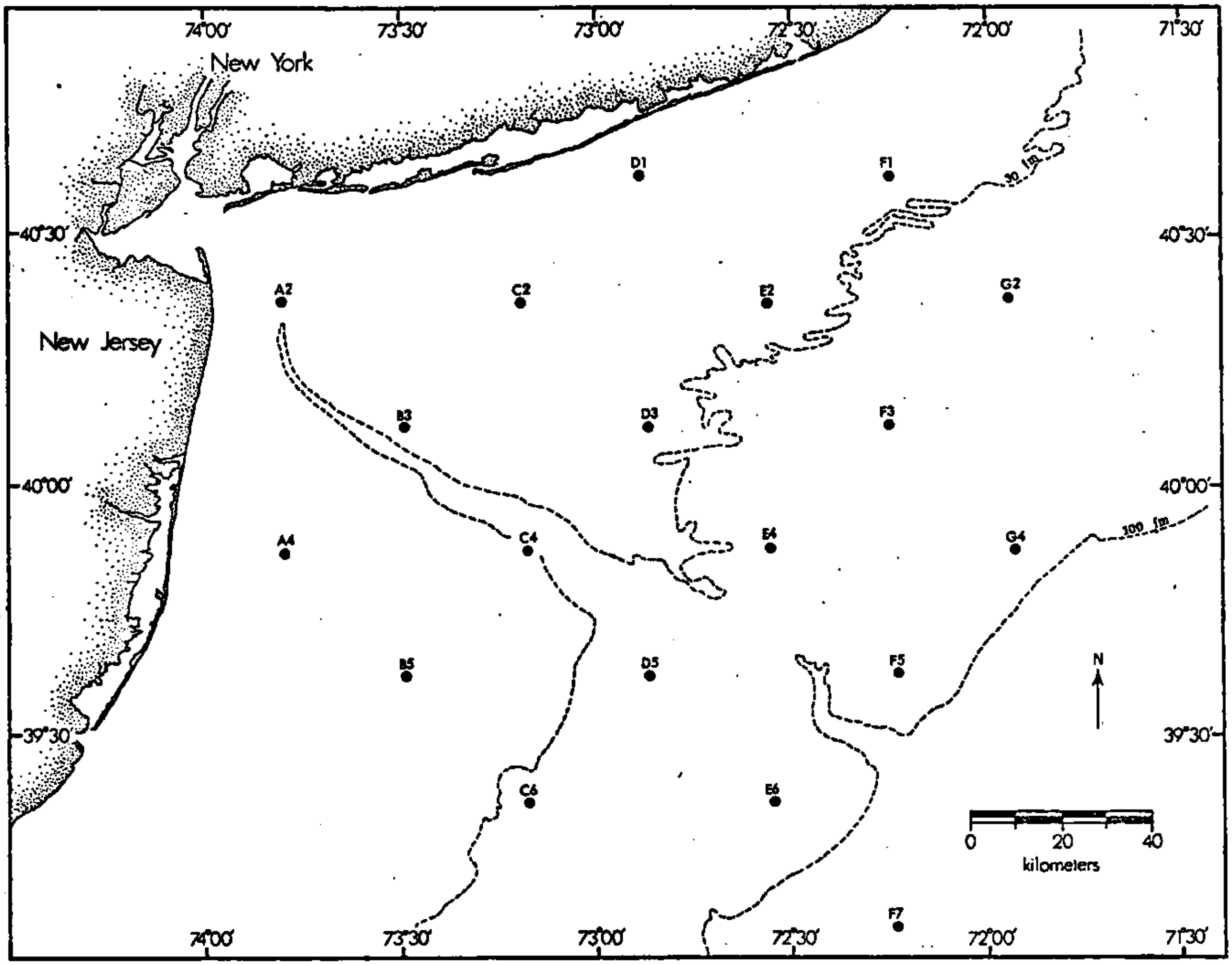

Fig. 2. Stations in New York Bight sampled for ichthyoplankton with 61-cm bongo nets, between July 1974 and June 1976.