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Contrasts in Distribution Patterns of Larval Atlantic Herring in the Georges Bank Area, Early 1970's vs Early 1980's *

by

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ABSTRACT

Information on distribution patterns of Atlantic herring, *Clupea harengus*, larvae is summarized from an ongoing 10-year time series of ichthyoplankton surveys conducted in coastal waters from Cape Hatteras, North Carolina to Cape Sable, Nova Scotia. Results show that the once-productive spawning beds on Georges Bank were relatively non-productive in 1977 and 78, and dormant since 1979. Where abundance estimates in excess of 1000 larvae 10 m^{-2} surface area were commonplace in autumn months of the early 1970s, we caught just 10 larvae in the past seven years. Late winter surveys produced nine additional post larvae. Since 1979 larval abundance has been greatest in Cape Cod Bay and the Lurcher Shoals area off western Nova Scotia. Highest abundance estimates occurred off Massachusetts in 1981 and 82; in Canadian waters around Lurcher Shoals in 1984.

SPECIAL SESSION ON RECRUITMENT

INTRODUCTION

The Northeast Fisheries Center (NEFC) is completing the 10th consecutive year of plankton surveys in coastal waters off northeastern United States as part of a comprehensive fisheries ecosystem study designed to investigate recruitment mechanisms (Sherman 1986). Surveys are conducted at monthly to bimonthly intervals and cover the entire continental shelf from Cape Hatteras, North Carolina to Cape Sable, Nova Scotia, an area of some 260,000 km^2. They provide a description of the interannual variability in temporal and spatial patterns of mesoscale distribution, abundance, production and mortality of fish eggs and larvae along with measurements and/or collections of neuston, zooplankton, phytoplankton, chlorophyll a, temperature and salinity. In

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addition to their contribution to NEFC's recruitment initiative, ichthyoplankton data are used to derive fishery-independent estimates of adult spawning biomass (Berrien et al., 1984). Through the spring of 1986 this decadal time series had occupied 10,436 stations and collected more than 25,000 bongo samples for ichthyoplankton/zooplankton analysis (Table 1).

Smith et al., 1980; 1981 summarized the occurrence of Atlantic herring larvae during the autumn/winter periods of 1977-81, the first 4 years of the time series that, for Atlantic herring, represents a continuation of the 1971-78 ICNAF larval herring surveys on Georges Bank. This paper updates Smith et al., 1980;1981 and contrasts spawning patterns in the early 1980s, some 6 to 10 years after the stock collapsed and the directed fishery ended on Georges Bank, with information from the early 1970s, a period when Georges Bank represented the principal spawning grounds for herring in the western North Atlantic and the herring stock (age 3+) was estimated at 400,000 to 600,000 mt, with annual landings ranging from 150,000 to 200,000 mt (Anthony and Waring 1980).

METHODS

Fish eggs and larvae are collected on two types of cruises: those dedicated to broadscale plankton surveys; and those with a primary mission of assessing the distribution and abundance of fish and mollusk populations using trawls or dredges, respectively. Station plans on plankton surveys remain largely unchanged between cruises. Sampling sites are spaced at 8 to 18-km intervals along 7 transects. Others are uniformly distributed over the shelf at 25 to 35-km intervals. The survey area is sectioned into four subareas for analytical purposes. (Figure 1). Ichthyoplankton stations on trawl and dredge surveys are selected from stratified random station plans and change with each survey (Grosslein 1969). Sampling intensity on these cooperative cruises in late winter/early spring, summer and early autumn is similar to that on plankton surveys.

Survey methods and collections through 1983 are described by Sibunka and Silverman 1984. Double oblique tows are made with a 61-cm bongo which is lowered to within a few meters of bottom or to a maximum depth of 200 m at 50 m min^{-1} and retrieved at 20 m min^{-1}. Ship speed varies between 1 and 2 kts to maintain a 45° wire angle during the tow. One side of the sampler is fitted with a 0.505-mm mesh net for ichthyoplankton studies, the other with a 0.333-mm mesh net for zooplankton monitoring. Initial processing of the 61-cm samples is completed at the Morski Instytut Rybacki, Szczecin, Poland. Larvae are identified and measured at the institute, then returned to NEFC's Sandy Hook Laboratory, along with appropriate logs and fish eggs. Quality control procedures are completed at Sandy Hook and the data are entered into VAX (S1032) at Woods Hole. Fish eggs of some 50 taxa, used largely for assessment purposes, are identified and staged at Sandy Hook with results subsequently entered into the computer.

When contouring larval distributions for this paper, we plotted all stations occupied during three bimonthly intervals from September through February, beginning with our early autumn 1981 survey and continuing through winter 1984. Results are included from the two 1985 autumn surveys for Georges Bank (east of 69°N) but not for the other subareas. We then entered larval herring catches for each bimonthly time period. If larvae occurred at a station only once in a given 2-month interval, that single occurrence was used for contouring. When larvae occurred at the same location more than once, the highest abundance estimate was used. By treating the results in this way, we present bimonthly composites depicting the most extensive distribution and maximum density of larvae encountered during the 4-year period. This technique was adopted because of the limited spatial and temporal distribution of herring larvae during the 9-year reporting period and the interannual similarity in the locations of their occurrence.

RESULTS

Spatial and temporal distribution patterns of Atlantic herring larvae within the survey area have remained essentially unchanged for the 1981-85 reporting period, reflecting a pattern that began in 1979. We found young herring restricted to shallow coastal waters around the Gulf of Maine with densest concentrations consistently occurring off western Nova Scotia, particularly in the Lurcher Shoals area, and in Cape Cod Bay and along the eastern face of Cape Cod. Abundance estimates were highest in Canadian waters in 1984; in coastal waters off Massachusetts in 1981 and 82. Some spawning continues annually on Nantucket Shoals but at significantly reduced levels from those observed there by Lough et al. 1981 during the 1971-77 period (Figure 2).

Whereas we found low levels of larval production on the west and northwest parts of Georges Bank in 1977 and 78 (Smith et al. 1980), the ensuing seven years provided no evidence of spawning anywhere on the bank. From 1979 through 1985, we caught only 10 larvae at 426 stations occupied on

14 surveys of the bank east of 69° N longitude. None was taken in 1980, 81 and 83. Nine late-stage larvae (22 to 32 mm) were collected in the 39,000 km^2 area on annual winter surveys conducted in the January/February time period. All of the autumn caught larvae were collected on November/December surveys, or about a month later than the period of peak larval abundance during the early 1970s. Lough et al. 1981 reported that spawning occurred progressively later in their time series, ranging from mid September to mid October in the 1971-73 seasons and late October to early November by 1977.

DISCUSSION

Our survey results during the early 1980s contrast sharply with those of a decade earlier when larval herring abundance estimates over the Georges Bank spawning beds routinely exceeded 1000 10 m^{-2} surface area and occasionally exceeded 10,000 10 m^{-2} (Figure 3). Larval production estimates for the 1973 and 74 spawning seasons were 78 x 10^{12} and 203 x 10^{12}, respectively (Lough et al. 1985). By 1979 there was no measureable production on the bank east of 69°N longitude. Although poor recruitment followed the high larval production in 1973 and 74, chances of good recruitment are infinitely better with high larval production than with essentially none, which is the current situation on the bank. As Overholtz et al. 1986 demonstrated with haddock, when spawning stock biomass falls below a threshold level poor year classes can be expected. Our survey results indicate that the herring stock on Georges Bank is below that critical biomass. NEFC trawl records substantiate our plankton surveys. Autumn trawl surveys have taken 37 herring on Georges Bank since 1979.

It is clear from our ongoing time series of plankton surveys that the spawning beds on Georges Bank, the principal spawning beds in the entire Gulf of Maine region from the mid 1950s through the mid 1970s (Tibbo, et al. 1958; Tibbo and Legare 1960; Boyar et al. 1973; Lough et al. 1985) have been dormant for the past 7 years and perhaps longer. Lough et al. 1985 found little or no evidence of larval production in the final years of their 8-year time series and speculated that the population collapsed in 1976. Their catches increased in 1977 but nearly all of this production was on Nantucket Shoals. Our results agree with those of Lough et al. 1985. The larvae we caught on the bank in 1977 and 78 occurred mostly along the western edge and could have originated on Nantucket Shoals (see Smith et al. 1980).

Iles and Sinclair (1982) reported that herring larvae in the western

North Atlantic are retained by hydrographic conditions in areas where little or no mixing takes place with young herring from other spawning grounds. They further recognized the strong homing instincts of adults prior to spawning, an observation supported by Wheeler and Winters (1984) who found homing rates approaching 90% for herring in Newfoundland waters. Sherman et al. (1984) considered gyre-influenced spawning areas such as Georges Bank ecologically advantageous in that they hold developing larvae in areas of high prey concentration and decrease the potential for advection to inimical environments. However, when adult spawning biomass is reduced through overfishing to economically extinct levels, which is the current situation with herring on Georges Bank, coupling of the above behavioral characteristics and circulation patterns works against stock rejuvenation. Adult spawning stocks are not replinished by mature fish of different geographic origin and gyres block the influx of larvae from other spawning grounds through advective processes.

A great deal has been written about the Georges Bank herring stock since the fishery began in 1961 but what were the fortunes of the stock prior to the period of intense exploitation that lasted through the mid 1970s? Our efforts to answer this question through a review of the literature were largely unsuccessful. We eventually concluded that information is not at hand to piece together a clear picture of the status of the Georges Bank herring stock during the first half of this century. A few temporally disjointed accounts provide only a vague and fragmented historical summary.

Bigelow and Schroeder (1953) reported that herring were far less abundant on the offshore banks than in coastal waters of the Gulf of Maine from 1912 to 1922. They recognized that early dory fishermen sometimes set drift nets on the bank to catch herring for bait, and that the trawlers that replaced the longline fishery occassionally made large catches of herring on both Georges and Browns banks, but their records showed such catches to be unusual. Draggers working the banks normally picked up few to none and stomachs from the cod they caught seldom contained herring remains. Furthermore, Bigelow and Schroeder (1953) found no definite records of herring spawning on Georges Bank, nor did they see early life stages in their autumn plankton samples from the bank during their pioneer surveys of the Gulf of Maine region in the early part of the century. They did, however, catch 30 to 50 mm herring in the spring of 1920 near Cashes Ledge, on the northern and eastern parts of Georges Bank, off Seal Island and Yarmouth which they considered wayward drifters from inshore spawning grounds. We suspect that these late stage larvae originated closer to their point of capture but conclude from the account of Bigelow and Schroeder (1953) that the herring stock on Georges Bank was not very large during the early 1900's.

Our search of the literature turned up nothing during the 1930s and early 40s. Files of the NEFC and a report by Tiller (1949) reveal that R/V *Albatross III* caught more than 6000 herring on summer(2) and autumn(1) surveys of Georges Bank in 1948 and 49 but Tibbo et al. 1958 is the earliest account we could find that provides evidence of major spawning on the bank. Their report is based on a cooperative study by Canadian and U. S. scientists in the mid to late 1950s, initiated in response to a decline in spawning and the occurrence of adults over the once-extensive spawning grounds along the Grand Manan, New Brunswick and Maine coasts. At the time of this survey herring were known to spawn on Georges Bank but the magnitude of spawning was not known. Results showed that the principal spawning grounds were located off the southwest coast of Nova Scotia and along the northern edge of Georges Bank (Tibbo et al. 1958; Tibbo and Legare, 1960).

The boom/bust scenario that occurred on Georges Bank after 1960 is a familiar story with herring stocks around the world. Both historical and recent literature abound with similar accounts. Some stocks rebuild within expected time frames, others do not. For example, North Sea herring stocks rose and declined on a temporal scale that is remarkably similar to that on Georges Bank. Strong year classes in 1956 and 1960 contributed to increased spawning biomass in both areas. Subsequent landings increased on Georges Bank from 67 thousand tons in 1961 to 374 thousand tons in 1968 (Anthony and Waring 1980). In the North Sea they exceeded a million metric tons during the mid 1960s, up from the 600 to 800 thousand mt landed annually during most of the century (Daans 1986). Both fisheries were at or near the point of collapse by 1977. Sherman et al. 1981 reported dramatic increases in the abundance of sand eels, *Ammodytes* spp., with the decline in herring in the two ecosystems. But here the similarities end. North Sea herring stocks rebounded by 1982 and the fishing moritorium declared 5 years earlier was lifted. Off the east coast of the United States, passage of the Fisheries Conservation and Management Act in 1977 ended the exploitation of Georges Bank herring by distant water fleets but by then the stock had been reduced to such low levels that most fishing had ceased. As those familiar with literature on the appearance/disappearance of herring know, there is no certainty as to how long the rebuilding process on Georges Bank will take.

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Table 1. Summary of data collections on NEFC ichthyoplankton/zooplankton surveys in shelf waters off northeastern United States.

Vessel	Cruise	Date	Vessel Days	No. Sta.	PLANKTON SAMPLES 0.61-m bongo 0.505	0.333	Other	0.20-m bongo 0.253	0.165	0.165	0.053	Other	Neuston	XBT	WATER BOTTLES No. Casts	No. Bottles	Temp. (°C)	o/oo	18O	D.O.	Cl	Phyto.	Nut.	14C	Secchi	Weather
Delaware II	77-03	3/19-4/8	21	69	69	69	-	-	-	-	-	-	69	69	67	269	69	269	-	269	-	-	-	-	-	69
Goerlitz	77-01	3/3-4/7	36	109	109	109	-	29	29	-	-	-	94	-	-	-	109	-	-	-	-	-	-	-	-	109
Delaware II	77-04	4/12-4/29	18	151	151	151	-	-	-	-	-	-	151	151	151	822	151	822	-	426	-	-	-	-	-	151
Albatross IV	77-02	4/13-5/16	34	123	122	122	-	2	-	-	-	-	120	122	113	702	123	702	-	-	-	-	-	-	-	123
Delaware II	77-05	5/3-5/27	22	192	183	183	-	-	-	-	-	-	177	192	190	864	192	864	-	486	523	121	395	-	-	192
Nogliki	77-02	5/22-6/6	16	95	95	95	-	95	95	-	-	-	95	95	95	185[1]	285[1]	280[1]	-	-	-	-	-	-	39	95
Delaware II	77-07	6/9-6/30	20	133	133	133	-	-	-	-	-	-	133	132	132	828	133	828	-	445	665	-	-	-	-	133
Delaware II	77-09	7/27-8/6	11	15	15	15	-	-	-	-	-	-	15	15	15	15	30	30	-	15	-	-	-	-	-	15
Yubileiniy	77-09	7/30-9/3	35	190	169	169	-	43	43	-	-	31	169	169	190	1210	1210	1188	-	1030	762	-	605	-	101	190
Argus	77-01	10/15-11/11	28	142	144	144	-	24	24	-	-	-	140	142	142	1226	1224	1366	-	226	850	-	-	-	16	142
Mt. Mitchell	77-11	11/12-11/19	8	37	37	37	-	17	17	-	-	-	36	37	37	382	382	382	-	180	297	-	-	-	11	37
G.B. Keles	77-11	11/25-12/13	18	58	57	57	-	12	12	-	-	-	76	54	54	510	444	554	-	147	405	-	-	-	16	58
TOTALS			267	1314	1284	1284	-	222	220	-	-	31	1225	1178	1186	7013	4352	7295	-	3232	3502	121	1000	-	183	1314
Delaware II	78-02	2/14-3/1	33	132	132	132	2	26	26	-	-	-	132	134	132	1264	590	1380	-	218	1105	-	-	-	54	132
Argus	78-04	4/13-5/24	42	149	149	149	-	29	29	-	-	38	148	154	150	1346	1346	1489	-	1311	1288	-	970	28	78	154
Albatross IV	78-04	4/26-5/16	21	40	39	39	-	20	20	-	-	-	39	40	-	-	40	40	-	-	-	-	-	-	-	40
Aliot	78-01	6/20-7/31	42	137	137	137	-	47	47	-	-	-	137	137	-	-	137	137	-	-	-	-	-	-	-	137
Albatross IV	78-07	6/22-7/17	26	149	149	149	3	29	29	-	-	-	149	149	149	1439	1223	1439	-	1233	1260	98	-	-	73	149
Belogorsk	78-01	8/9-9/6	28	154	154	154	-	29	29	-	-	52	154	156	154	1612	1612	1612	-	1612	1370	-	254	41	77	156
Belogorsk	79-03	10/5-11/2	29	130	126	126	6	31	31	-	-	40	125	49	131	1379	1379	1379	-	640	1196	324	264	42	61	30
Delaware II	78-06	10/24-11/25	20	14	14	14	-	-	-	-	-	-	14	14	-	-	14	14	-	-	-	-	-	-	-	14
Belogorsk	78-04	11/15-11/30	16	78	74	74	-	20	20	24	24	-	63	35	78	910	910	910	-	434	727	182	143	24	30	78
TOTALS			257	983	974	974	11	231	231	24	24	130	961	368	794	7950	7251	8400	-	5448	6947	504	1646	139	398	990
Delaware II	79-03	2/23-3/15	21	111	102	102	8	19	24	-	-	-	102	41	111	924	770	924	-	261	862	51	23	-	48	111
Albatross IV	79-03	3/31-5/12	34	52	52	52	-	21	21	-	-	-	52	57	-	-	52	52	-	-	-	-	-	-	-	52
Delaware II	79-04	4/11-4/30	20	53	53	53	-	-	-	-	-	-	-	53	-	-	53	53	-	-	-	-	-	-	-	53
Eisbar	79-01	4/24-5/7	14	58	58	58	-	-	-	-	-	-	42	58	-	-	-	-	-	-	-	-	-	-	-	58
Delaware II	79-05	5/4-5/29	26	175	170	170	4	33	33	30	30	-	170	60	175	1591	1166	1591	-	693	1479	79	36	566	91	175
Albatross IV	79-06	6/12-7/14	33	130	125	125	-	25	25	26	26	-	125	47	130	-	710	1171	-	1010	1138	64	29	499	74	130
Belogorsk	79-01	8/9-9/13	26	151	146	146	-	30	30	15	15	44	146	61	151	1151	1159	1151	-	644	1366	72	40	579	95	151
Belogorsk	79-03	9/10-10/10	31	52	59	59	-	59	59	51	51	-	60	108	52	582	573	582	-	477	495	51	31	313	36	52
Albatross IV	79-11	10/1-10/29	29	166	161	161	-	31	31	69	69	-	159	62	166	1127	1456	1683	-	720	1364	301	39	563	78	166
Wiecano	79-03	11/13-11/28	9	33	33	33	-	-	6	-	-	-	33	33	33	66	66	66	-	66	-	-	-	-	-	33
Albatross IV	79-13	11/14-12/21	38	88	76	76	-	15	15	16	16	-	74	44	82	955	947	955	-	433	798	36	18	291	33	88
Belogorsk	79-05	11/21-11/28	8	16	15	15	-	15	15	15	14	-	16	16	16	179	174	179	-	179	154	33	11	138	-	16
TOTALS			289	1085	1050	1050	12	248	259	222	221	44	979	635	916	6975	7526	8807	-	4483	7656	687	227	2949	455	1085
Wiecano	80-02	2/18-3/11	23	92	80	80	-	30	30	-	-	-	60	48	87	949	617	617	-	617	808	60	-	-	25	92
Albatross IV	80-02	2/27-3/5	34	158	148	148	-	25	25	37	37	-	145	65	156	1618	1590	1618	-	608	1428	120	42	532	79	158
Evrika	80-01	4/15-5/15	33	164	164	164	-	28	28	61	61	-	150	57	155	1661	1560	1573	-	882	2918	144	51	565	91	164
Albatross IV	90-03	4/24-5/2	9	11	11	11	-	-	-	-	-	-	11	-	-	-	-	11	-	11	-	-	-	-	-	11
Delaware II	80-02	4/30-5/8	9	12	12	12	-	-	-	-	-	-	12	-	-	-	-	12	-	12	-	-	-	-	-	12
Delaware II	80-03	5/21-6/30	28	149	148	148	-	17	17	40	40	-	148	52	149	1508	1423	1507	-	1506	1348	123	41	503	77	149
Evrika	80-04																									
Evrika	80-06	7/14-8/11	27	160	157	157	-	29	29	44	44	-	158	56	160	1700	1613	1646	-	1187	2917	194	44	607	88	160
Delaware II	80-05	7/28-8/8	12	1	1	1	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	1
Albatross IV	80-10	9/24-10/30	32	175	174	174	-	31	31	34	34	5	174	61	175	1824	1720	1741	-	718	1601	226	44	613	74	175
Albatross IV	80-12	11/17-12/23	30	138	137	137	-	28	28	29	29	-	138	25	138	1351	1260	1351	-	577	1213	117	30	491	47	138
TOTALS			237	1060	1032	1032	-	188	188	245	245	5	974	387	1020	10611	9806	10074	-	6095	12233	984	252	3311	482	1060
Albatross IV	81-01	2/17-3/26	33	153	153	153	-	25	25	39	39	5	152	21	150	1590	1528	1577	-	655	1393	194	39	564	63	153
Delaware II	81-02	3/17-5/14	50	147	147	147	-	-	-	-	-	-	-	147	-	-	147	147	-	-	-	-	-	-	-	147
G.B. Keles	81-03	3/18-4/9	19	99	99	99	-	16	16	28	28	-	98	25	97	918	836	909	-	419	769	78	25	366	41	97
Delaware II	81-03	5/20-6/18	27	147	145	145	-	16	16	24	24	5	145	57	147	1584	1495	1603	-	433	1441	206	25	407	83	147
Delaware II	81-04	6/27-7/2	18	78	78	78	-	-	-	-	-	-	-	78	-	-	149	149	-	-	-	-	-	-	-	78
Albatross IV	81-07	7/7-7/21	15	17	17	17								17												17
Delaware II	81-05	8/3-8/21	19	72	72	72	-	-	-	-	-	-	-	72	-	-	72	72	-	-	-	-	-	-	-	72
Albatross IV	81-10	8/26-9/4	10	24	24	24								24												24

Vessel	Cruise	Date	Vessel Days	No. Sta.	PLANKTON SAMPLES: 0.61-m bongo 0.505	0.61-m bongo 0.333	0.61-m bongo Other	0.20-m bongo 0.253	0.20-m bongo 0.165	0.20-m bongo 0.165	0.20-m bongo 0.053	Other	Neuston	XBT	WATER BOTTLES: No. Casts	No. Bottles	Temp. (°C)	o/oo	^{18}O	D.O.	Cl	Phyto.	Nut.	^{14}C	Secchi	Weather
Delaware II	81-06	9/15-11/13	54	167	167	167	-	-	-	-	-	-	-	167	-	-	167	167	-	-	-	-	-	-	-	167
Albatross IV	81-13	11/2-11/13	26	26	26	25	-	-	-	-	-	-	-	26	-	-	26	26	-	-	-	-	-	-	-	26
Albatross IV	81-14	11/16-12/22	31	96	97	97	-	21	21	34	34	4	89	31	89	1051	994	1049	1049	524	922	63	29	306	31	96
TOTALS			302	1026	1025	1025	-	78	78	125	125	14	484	665	483	5143	5414	5699	1049	2031	4525	541	118	1643	218	1024
Albatross IV	82-02	2/16-3/25	32	146	146	146	-	29	29	35	35	5	144	39	145	1518	1415	1509	1481	673	1364	126	516	36	43	146
Delaware II	82-02	3/8-5/8	43	166	166	165	-	-	-	-	-	-	-	166	-	-	166	166	-	-	-	-	-	-	-	166
Delaware II	82-03	5/17-6/11	23	110	102	102	-	22	22	27	27	27	5	102	111	1238	1182	1235	1235	511	1104	90	360	29	59	110
Albatross IV	82-06	6/1-6/11	11	38	38	38	-	-	-	-	-	-	-	38	-	-	38	38	-	-	-	-	-	-	-	38
Albatross IV	82-08	7/12-8/6	24	89	89	89	-	-	-	-	-	-	-	89	-	-	89	89	-	-	-	-	-	-	-	89
Delaware II	82-05	7/26-8/12	19	51	51	51	-	-	-	-	-	-	-	51	-	-	51	51	-	-	-	-	-	-	-	51
Albatross IV	82-11	9/13-11/12	55	156	155	156	-	-	-	-	-	-	-	156	-	-	156	156	-	-	-	-	-	-	-	156
Delaware II	82-09	11/15-12/22	32	161	151	152	-	28	28	36	36	-	152	47	162	1765	1660	1645	1645	789	1562	138	-	36	49	161
TOTALS			239	917	897	900	-	79	79	98	98	18	398	603	418	4521	4757	4889	4361	1973	4030	354	876	100	151	917
Delaware II	83-01	1/17-2/4	24	105	102	102	-	15	15	22	22	-	102	18	105	1210	1160	1210	1210	441	1040	60	327	25	39	105
Delaware II	83-02	2/14-2/24	11	39	39	39	-	8	8	-	-	-	-	39	-	-	39	39	-	-	-	-	-	-	-	39
Albatross IV	83-01	2/25-3/3	8	16	16	16	-	6	6	-	-	-	16	16	-	-	-	16	-	-	-	-	-	-	-	16
Albatross IV	83-02	3/7-5/6	55	140	140	140	-	-	-	-	-	-	-	140	-	-	140	140	-	-	-	-	-	-	-	140
Albatross IV	83-04	5/23-6/22	29	177	176	176	-	31	31	41	41	-	176	46	176	1852	1732	1812	1852	712	1639	138	-	42	102	177
Albatross IV	83-07	7/26-9/2	33	118	118	118	-	-	-	-	-	-	-	118	-	-	118	118	-	-	-	-	-	-	-	118
Delaware II	83-07	8/15-9/7	23	62	62	62	-	-	-	-	-	-	-	62	-	-	62	62	-	-	-	-	-	-	-	62
Albatross IV	83-08	9/12-11/10	54	165	165	165	-	-	-	-	-	-	-	165	-	-	165	165	-	-	-	-	-	-	-	165
Delaware II	83-09	11/14-12/21	31	152	151	151	-	29	29	38	38	-	151	40	152	1556	1453	1554	1554	656	1387	151	-	35	58	152
TOTALS			268	974	969	969	-	89	89	101	101	-	445	644	433	4618	4885	5100	4616	1809	4066	349	327	102	199	974
Delaware II	84-01	1/9-2/10	31	161	160	160	-	31	31	40	40	-	159	39	161	1684	1578	1683	1683	213	1492	158	654	38	67	161
Albatross IV	84-02	2/29-4/27	52	155	155	155	-	-	-	-	-	-	-	155	-	-	155	155	-	-	-	-	-	-	-	155
Albatross IV	84-03	5/7-6/3	26	181	178	178	-	30	30	36	36	-	178	42	181	1905	1795	1905	1904	704	1687	173	-	38	80	181
Delaware II	84-05	5/17-6/24	39	41	41	41	-	-	-	-	-	-	-	41	-	-	41	-	-	-	-	-	-	-	-	41
Albatross IV	84-06	7/2-7/19	18	70	70	70	-	-	-	-	-	-	-	70	-	-	70	-	-	-	-	-	-	-	-	70
Delaware II	84-06	7/9-8/1	24	107	107	107	-	-	-	-	-	-	-	107	-	-	107	107	-	-	-	-	-	-	-	107
Albatross IV	84-07	7/24-8/31	34	119	119	119	-	-	-	-	-	-	-	119	-	-	119	119	-	-	-	-	-	-	-	119
Albatross IV	84-08	9/10-11/9	52	158	158	158	-	-	-	-	-	-	-	158	-	-	158	158	-	-	-	-	-	-	-	158
Delaware II	84-09	10/29-12/7	32	146	144	144	-	25	25	32	32	-	144	32	142	1422	1313	1422	1421	509	1278	140	-	30	60	146
TOTALS			308	1138	1132	1132	-	86	86	108	108	-	481	763	484	5011	5336	5549	5008	1426	4457	471	654	106	207	1138
Delaware II	85-01	1/7-2/8	30	132	131	131	-	30	30	24	24	-	129	27	132	1334	1231	1332	1332	451	1188	131	-	24	57	132
Albatross IV	85-02	2/25-4/13	44	140	140	140	-	-	-	-	-	-	-	140	-	-	140	140	-	-	-	-	-	-	-	140
Delaware II	85-03	4/1-5/2	30	191	190	190	-	24	24	-	-	-	190	28	191	1848	1706	1848	1848	254	-	189	-	-	-	191
Oregon II	85-01[2]	4/23-5/28	36	158	158	158	-	-	-	-	-	-	158	5	153			348	-	151	87	-	-	-	58	158
Albatross IV	85-04	5/8-6/6	29	173	168	168	-	23	23	33	33	-	163	16	173	1660	1558	1660	1659	439	1410	162	-	37	83	173
Gyre	85-07	7/16-7/25	9	22	22	22	-	-	-	-	-	-	-	-	21				-			-		-	-	22
Albatross IV	85-07	7/22-8/31	30	126	126	126	-	-	-	-	-	-	-	126	-	126	126	-	-	-	-	-	-	-	-	126
Delaware II	85-07	8/26-9/22	26	193	192	192	-	31	31	-	-	-	187	13	193	2016	1893	1964	1946	279	-	189	-	-	-	193
Albatross IV	85-08	9/9-11/16	18	58	58	58	-	-	-	-	-	-	-	58	-	-	58	58	-	-	-	-	-	-	-	58
Delaware II	85-08	9/30-11/26	24	78	78	78	-	-	-	-	-	-	-	78	-	-	78	78	-	-	-	-	-	-	-	78
Delaware II	85-10	11/5-12/12	30	180	179	179	-	31	31	-	-	-	179	2	180	1880	1767	1878	1878	-	339[3]	-	-	-	-	180
TOTALS			306	1451	1442	1442	-	139	139	57	57	-	1006	493	1043	8738	8557	9432	8663	1574	3024	671		61	198	1451
Delaware II	86-01	1/7-2/12	32	174	174	174	-	32	32	-	-	-	173	15	174	1823	1712	1822	1822	-	312	95	-	-	-	174
Albatross IV	86-02	3/3-4/27	46	150	150	150	-	-	-	-	-	-	-	150	-	-	-	150	-	-	-	-	-	-	-	-
Delaware II	86-03	5/6-6/7	30	164	160	160	-	29	29	-	-	-	180	42	167	1741	1636	1740	-	30	290	164	46	-	-	164

[1]Includes surface measurements and samples.
[2]Staffed by SEFC personnel. Area coverage is from off Palm Beach, Fla. to off Chesapeake Bay, Va.
[3]Number of samples taken to calibrate the continuous underway fluorometry system.

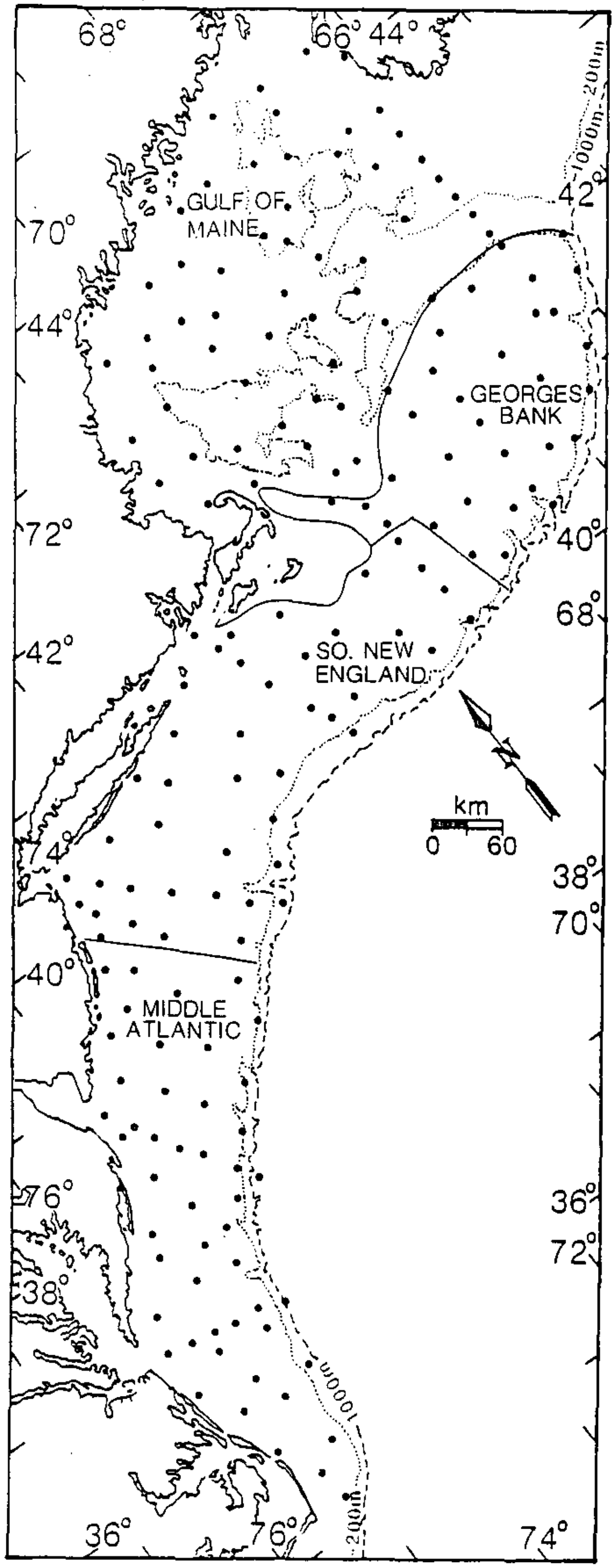

Figure 1. Standard station plan and four subareas for NEFC ichthyoplankton surveys.

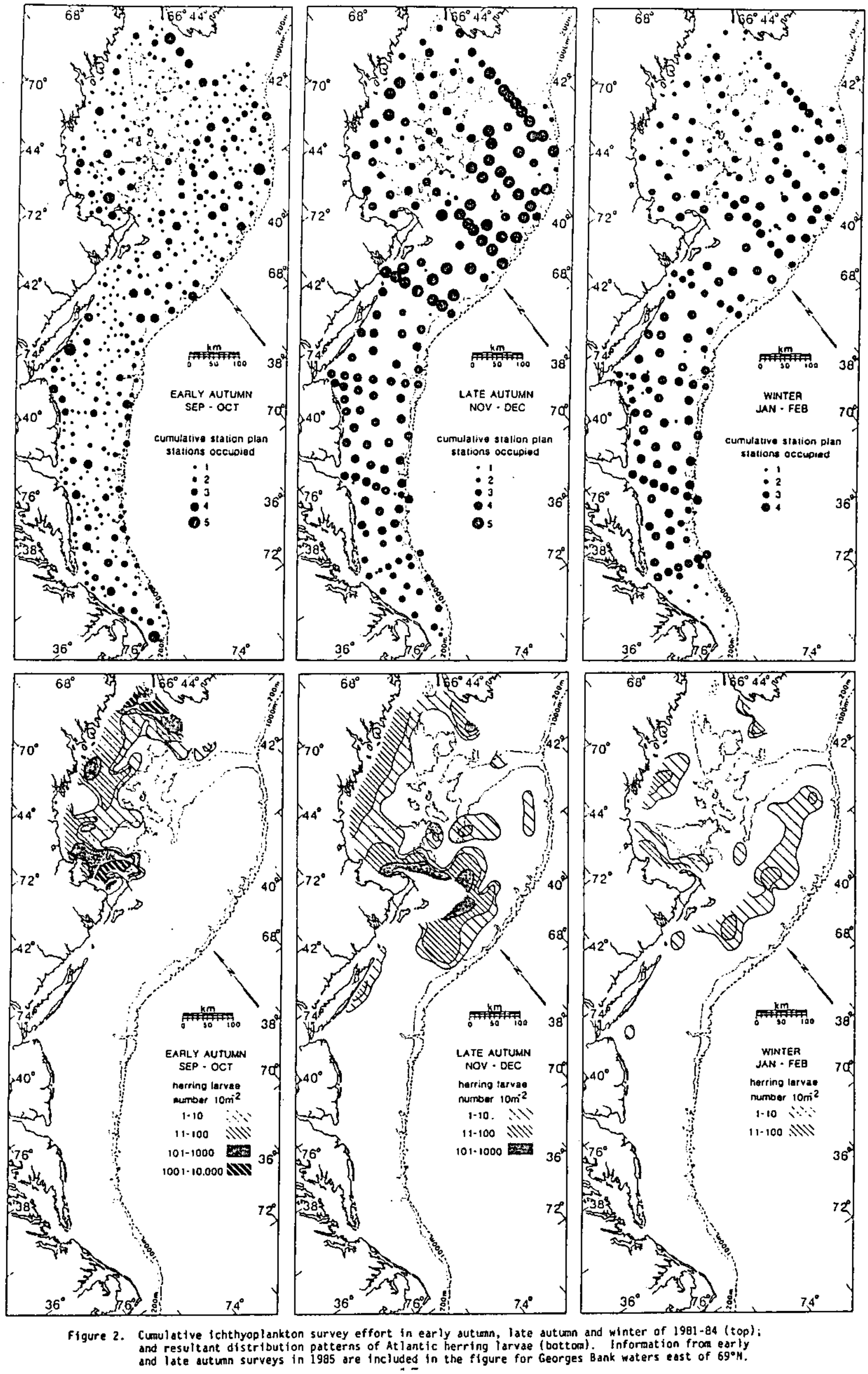

Figure 2. Cumulative ichthyoplankton survey effort in early autumn, late autumn and winter of 1981-84 (top); and resultant distribution patterns of Atlantic herring larvae (bottom). Information from early and late autumn surveys in 1985 are included in the figure for Georges Bank waters east of 69°N.

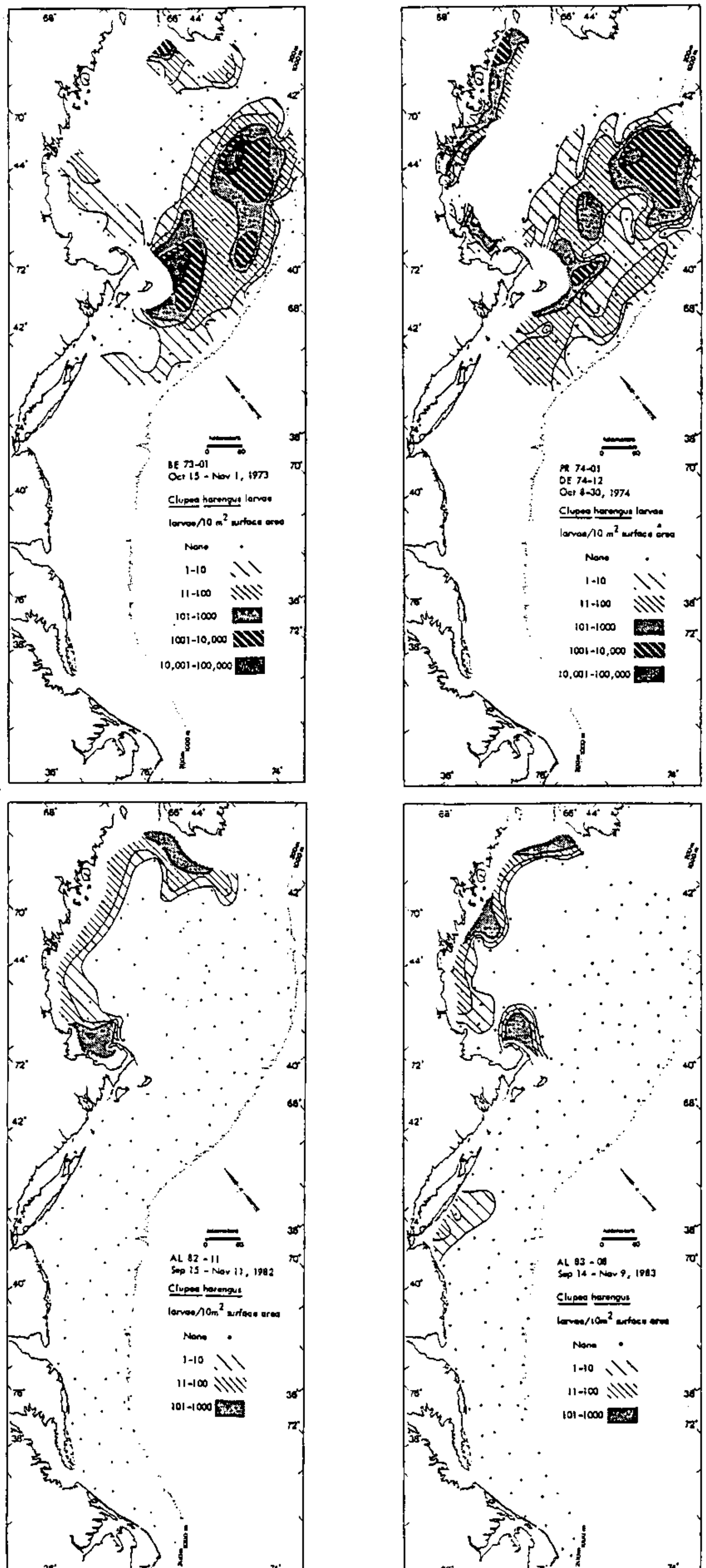

Figure 3. Contrast in distribution and abundance of herring larvae on Georges Bank, early 1970's (see Lough et al. 1985) vs. early 1980's.