Distribution and Abundance of Haddock (*Melanogrammus aeglefinus*) and Atlantic Cod (*Gadus morhua*) Eggs and Larvae in the Waters off Southwest Nova Scotia[1]

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Hurley, P. C. F., and S. E. Campana. 1989. Distribution and abundance of haddock (*Melanogrammus aeglefinus*) and Atlantic cod (*Gadus morhua*) eggs and larvae in the waters off southwest Nova Scotia. Can. J. Fish. Aquat. Sci. 46(Suppl. 1): 103–112.

Synoptic ichthyoplankton surveys conducted at monthly intervals during the winter–spring of 1983–85 were used to determine the location, timing, and magnitude of spawning by haddock (*Melanogrammus aeglefinus*) and Atlantic cod (*Gadus morhua*) off southwest Nova Scotia. There was a marked similarity in the spawning locations of the two species: primary spawning occurred on Browns Bank, although lower levels of spawning were observed on adjacent banks and in the inshore region. Cod egg abundance peaked in April in all years, while that of haddock varied between April–June.

À l'hiver et au printemps de 1983 à 1985, des relevés synoptiques de l'ichtyoplancton ont été faits à intervalles mensuels afin de déterminer l'emplacement, le moment et l'importance de la fraie de l'aiglefin (*Melanogrammus aeglefinus*) et de la morue franche (*Gadus morhua*) au large de la rive sud-ouest de la Nouvelle-Écosse. On a observé une similarité marquée des emplacements choisis par les deux espèces : la fraie primaire a eu lieu sur le banc Browns, bien qu'une fraie moins importante ait été observée sur les bancs adjacents et vers la côte. Les oeufs de morue étaient les plus abondants au mois d'avril de chaque année alors que dans le cas de l'aiglefin, l'abondance maximale variait entre avril et juin.

Received April 19, 1989
Accepted October 11, 1989
(JA136)

Reçu le 19 avril 1989
Accepté le 11 octobre 1989

While many workers have reported spawning activity of haddock (*Melanogrammus aeglefinus*) and Atlantic cod (*Gadus morhua*) off Southwest Nova Scotia, none of the studies have been conducted in sufficient spatial or temporal detail to clearly delineate the spawning season or location. Previous work has shown that spawning of both species may occur anywhere between January and June, with peak spawning in April and May for cod and haddock, respectively (Bigelow and Schroeder 1953; Homans and Vladykov 1954; Serebryakov 1971; Grosslein and Hennemuth 1973; Scott 1983; Gagné and O'Boyle 1984; O'Boyle et al. 1984; Markle and Frost 1985; Koslow et al. 1985; Smith and Morse 1985; Sherman et al. 1987). The centre of spawning has generally been acknowledged to be Browns Bank, with lesser centres on adjacent banks.

An objective of the present study was to determine the timing and location of spawning of haddock and Atlantic cod off Southwest Nova Scotia, by examining the distribution and abundance of their eggs and larvae. A second objective was to assess the intraseasonal, interannual, and spatial variability in location, timing, and magnitude of spawning of these species.

Materials and Methods

A grid of 95 stations off Southwest Nova Scotia was sampled once a month from February to June during 1983 to 1985. Stations were spaced approximately 28 km apart, with additional stations in the vicinity of Browns Bank (Fig. 1). Two extra transects across Browns Bank were added to the grid in 1984 and 1985. Cruise dates and number of stations sampled are shown in Table 1.

At each station, an oblique tow was made with a paired 61-cm diameter bongo sampler, to a depth of 5 m off bottom or to a maximum depth of 200 m. Sampler depth was determined from a Guildline conductivity–temperature–depth (CTD) sensor attached just above the sampler. The bongo frame was fitted with 333-μm mesh Nitex nets and volume filtered was determined from calibrated General Oceanics flowmeters centred in the mouth of each net. Vessel speed was maintained at 2.5 knots (1.3 m/s) and wire rates in and out were 50 and 20 m/min, respectively. During 1984 and 1985, tows at each station were replicated immediately, using the same starting location and vessel heading. Samples were fixed in 5% buffered formalin in seawater. Marble chips were used as a buffer during 1983. In 1984 and 1985, sodium carbonate was used as a buffer and samples were transferred to 95% ethanol after 48 h.

Fish eggs and larvae were removed and identified from the preserved samples in the laboratory. Samples containing more than 200 eggs were subsampled using the beaker split method (Van Guelpen et al. 1982) to obtain a subsample containing between 100 and 200 eggs. Eggs were classified into the following four developmental stages (after Markle and Frost 1985): Stage I, from spawning until the visible formation of an embryonic axis about the midgastrula; Stage II, from the end of Stage

[1]Fisheries Ecology Program Contribution Number : 14.

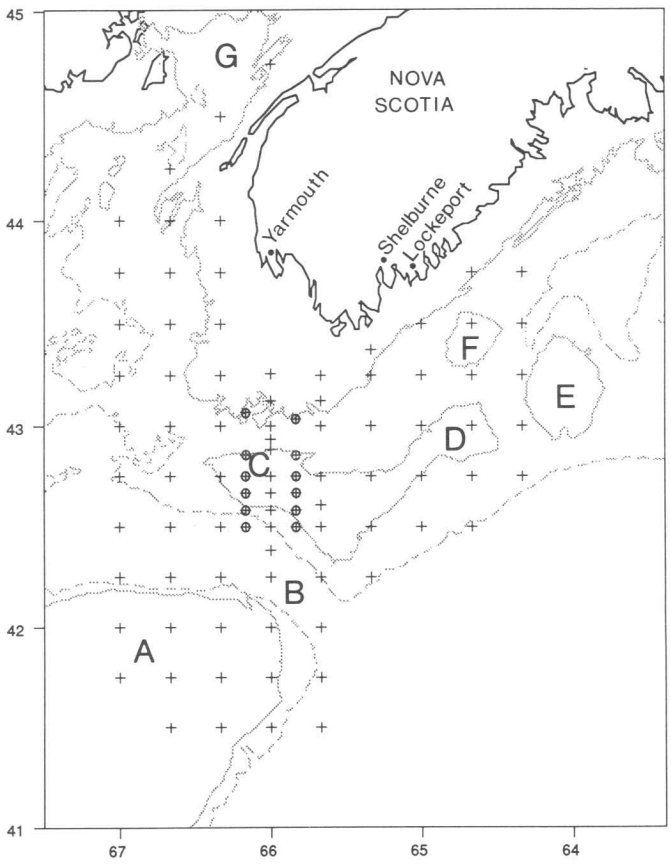

FIG. 1. Map of study area showing station locations and geographic features referred to in the text: (A) Georges Bank; (B) Fundian Channel; (C) Browns Bank; (D) Baccaro Bank; (E) La Have Bank; (F) Roseway Bank; and (G) Bay of Fundy. Stations added in 1984 and 1985 are indicated by circles (⊕). Contours are 100- and 200-m isobaths.

TABLE 1. Summary of cruise dates and number of stations sampled during this study.

Cruise	Start date	End date	*N*
H091	83-02-09	83-02-17	53
H093	83-03-06	83-03-16	50
P288	83-04-07	83-04-20	49
H097	83-05-04	83-05-13	78
H099	83-06-04	83-06-12	81
H112	84-02-08	84-02-15	74
H114	84-03-22	84-03-29	53
H116	84-04-17	84-04-25	62
H118	84-05-15	84-05-23	70
H120	84-06-12	84-06-21	83
H130	85-02-05	85-02-21	85
H132	85-03-14	85-03-27	48
H133	85-04-03	85-04-17	92
H135	85-05-07	85-05-14	57
H137	85-06-04	85-06-13	61

I until the embryo is half way around the yolk, approximately the time of blastopore closure; Stage III, from the end of Stage II until the tip of the tail reaches or could reach the snout; and Stage IV, from the end of Stage III until hatching. Early egg stages of cod, haddock and witch flounder (*Glyptocephalus cynoglossus*) could not be differentiated, and thus were artificially grouped as CHW (cod, haddock, witch). These species could only be identified after late Stage III, when diagnostic pigmentation had formed. Standard length of larvae (less than 18 mm) was measured to the nearest millimetre.

Sample abundance was calculated as the number per square metre using maximum tow depth; station abundance was calculated as the mean of all samples available for each station.

Results

Stage I CHW eggs off Southwest Nova Scotia were taken in all cruises, primarily on Browns Bank, but lower levels were encountered throughout the area, including the inshore (Fig. 2). Since Stage I eggs are less than 7 d old (Marak and Colton 1961; Fridgeirsson 1978; Page and Frank 1989), their distribution should provide a more accurate indication of spawning location than that of Stage IV. This assumes that the relative contribution of witch eggs is low, an assumption that is supported by studies showing that Stage IV witch eggs were largely absent from the Scotian Shelf prior to May (Markle and Frost 1985; Neilson et al. 1988). We found no Stage IV witch eggs prior to June in each of the 3 yr, with the exception of one station each in May 1984 and 1985.

The temporal distribution of Stage IV haddock eggs was more variable than that of cod (Figs. 3 and 4). During 1983, haddock eggs were not observed off Southwest Nova Scotia until April, in contrast to their first appearance in March 1984 and February 1985. Cod eggs were present in February in all 3 yr. Peak haddock egg abundance was observed in April, May, and June of 1983, 1985, and 1984, respectively, but substantial numbers were evident in June of all 3 yr. Peak cod egg abundance was observed in April of all 3 yr.

Haddock larvae off Southwest Nova Scotia appeared 1 mo after eggs were first observed, while cod larvae were observed in all cruises (Figs. 5 and 6). Only 10 haddock larvae were taken off Southwest Nova Scotia in 1983, while 450 were taken in 1984 (almost all in June) and 1335 in 1985 (in April, May, and June) (Table 2). Cod larvae (Table 3) were infrequently captured in 1983 and 1984 (total of 15 and 27, respectively), some of which hatched from eggs spawned the previous November, December, and January (Campana and Hurley 1989). The abundance of larval cod was highest in 1985, with a total of 408 larvae taken.

Maximum egg and larval station abundances of both cod and haddock were generally higher on Georges Bank than on Browns Bank (Figs. 3, 4, 5 and 6). Although coverage of stations on Georges Bank was sporadic, eggs of both species tended to appear 1 to 2 mo earlier there than off Southwest Nova Scotia.

Discussion

Our study confirms earlier reports that Browns Bank is the principle spawning ground of both cod and haddock in Southwest Nova Scotia (Scott 1983; Gagné and O'Boyle 1984; O'Boyle et al. 1984; Koslow et al. 1985; Waiwood and Buzeta 1989). Lower levels of spawning were observed on Baccaro, Roseway, and La Have banks for both species. The marked similarity between cod and haddock ichthyoplankton distributions implies that the two species utilize the same spawning sites, and that the same physical forces may be influencing the subsequent distribution of their eggs and larvae (Campana et al. 1989a,b). Repeated observations of Stage I eggs in the nearshore region are most consistent with inshore spawning, since

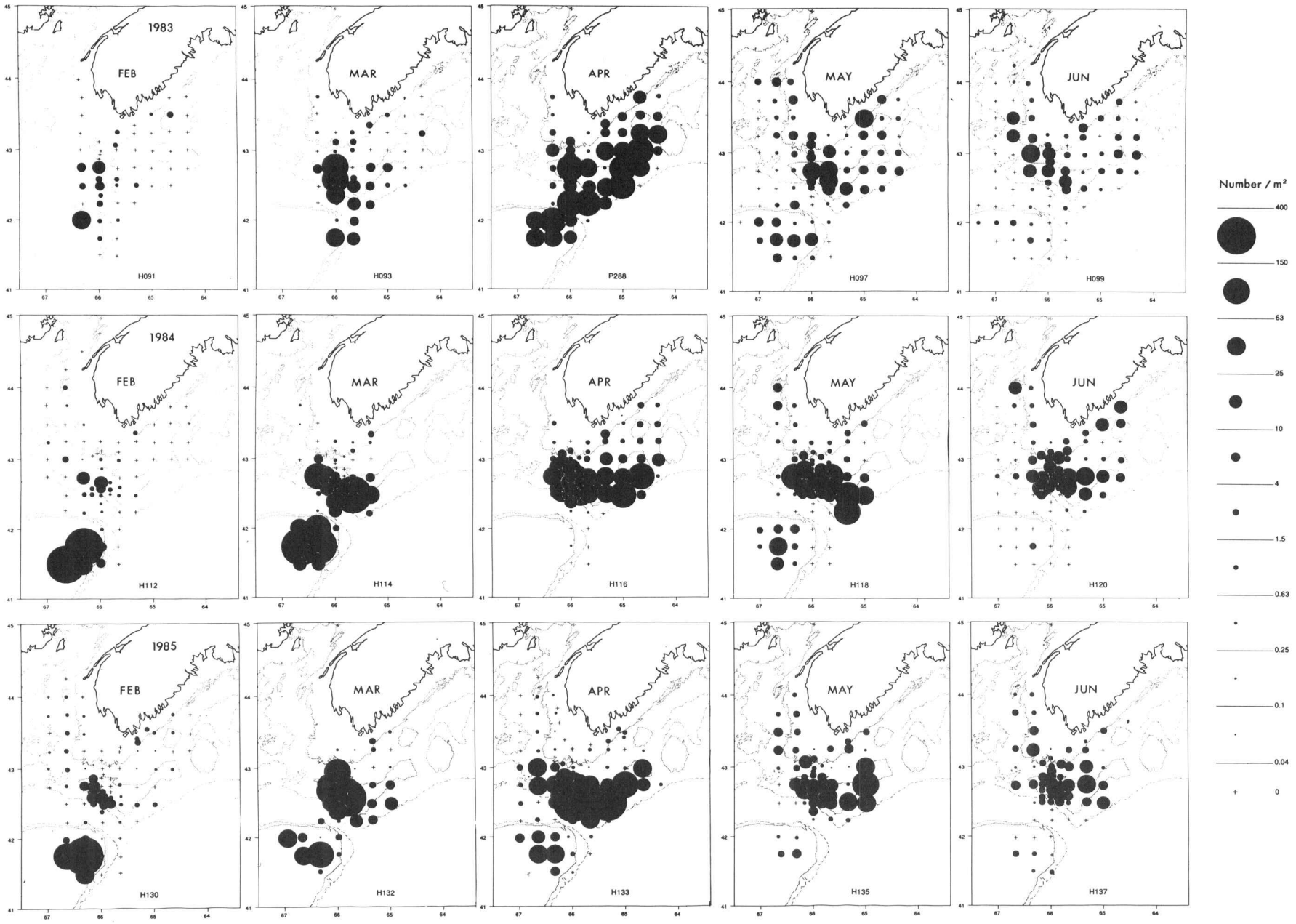

FIG. 2. Distribution of Stage I CHW (cod/haddock/witch) eggs by month and year, 1983–85 (number/m^2).

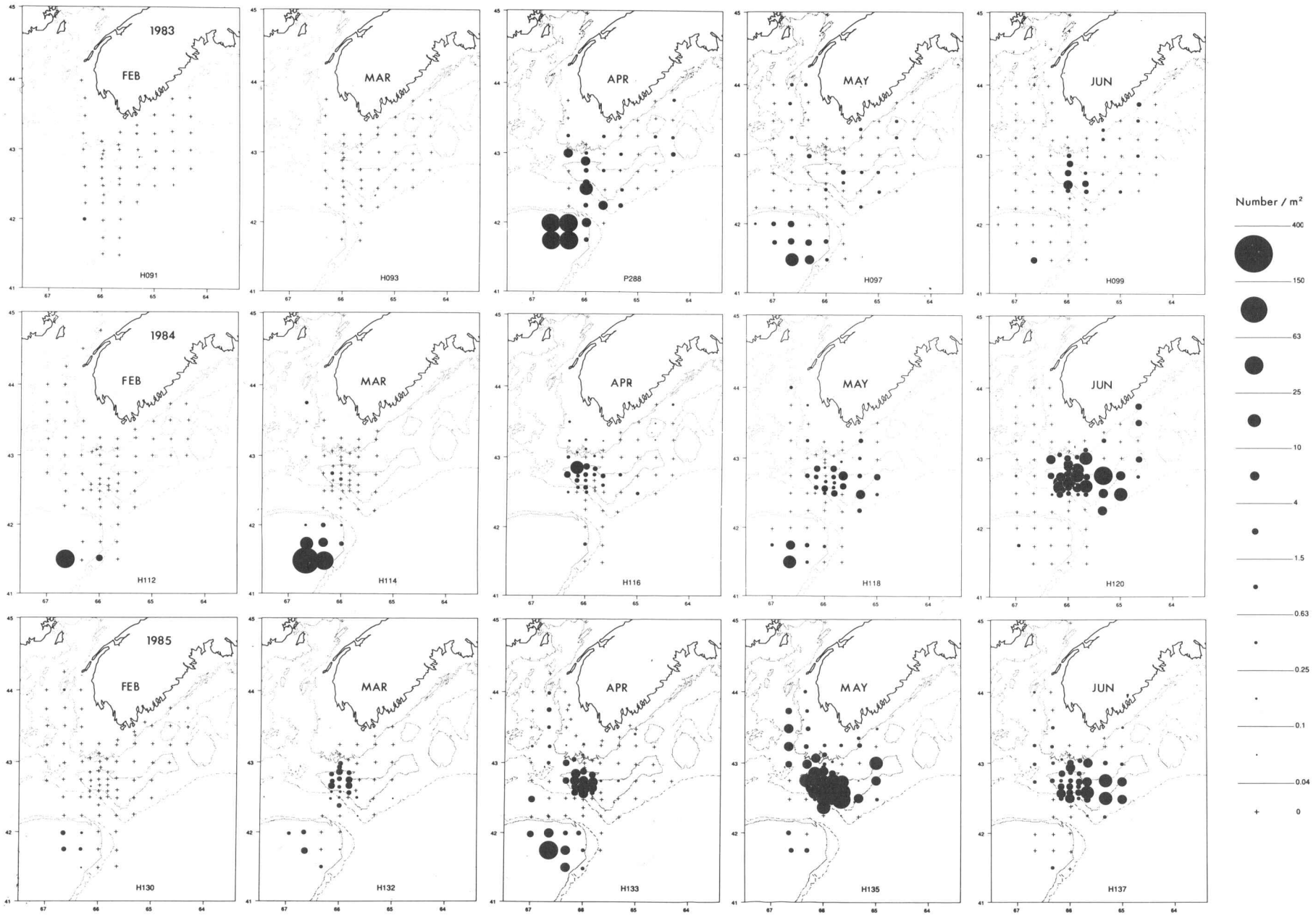

FIG. 3. Distribution of Stage IV haddock eggs by month and year, 1983–85 (number/m^2).

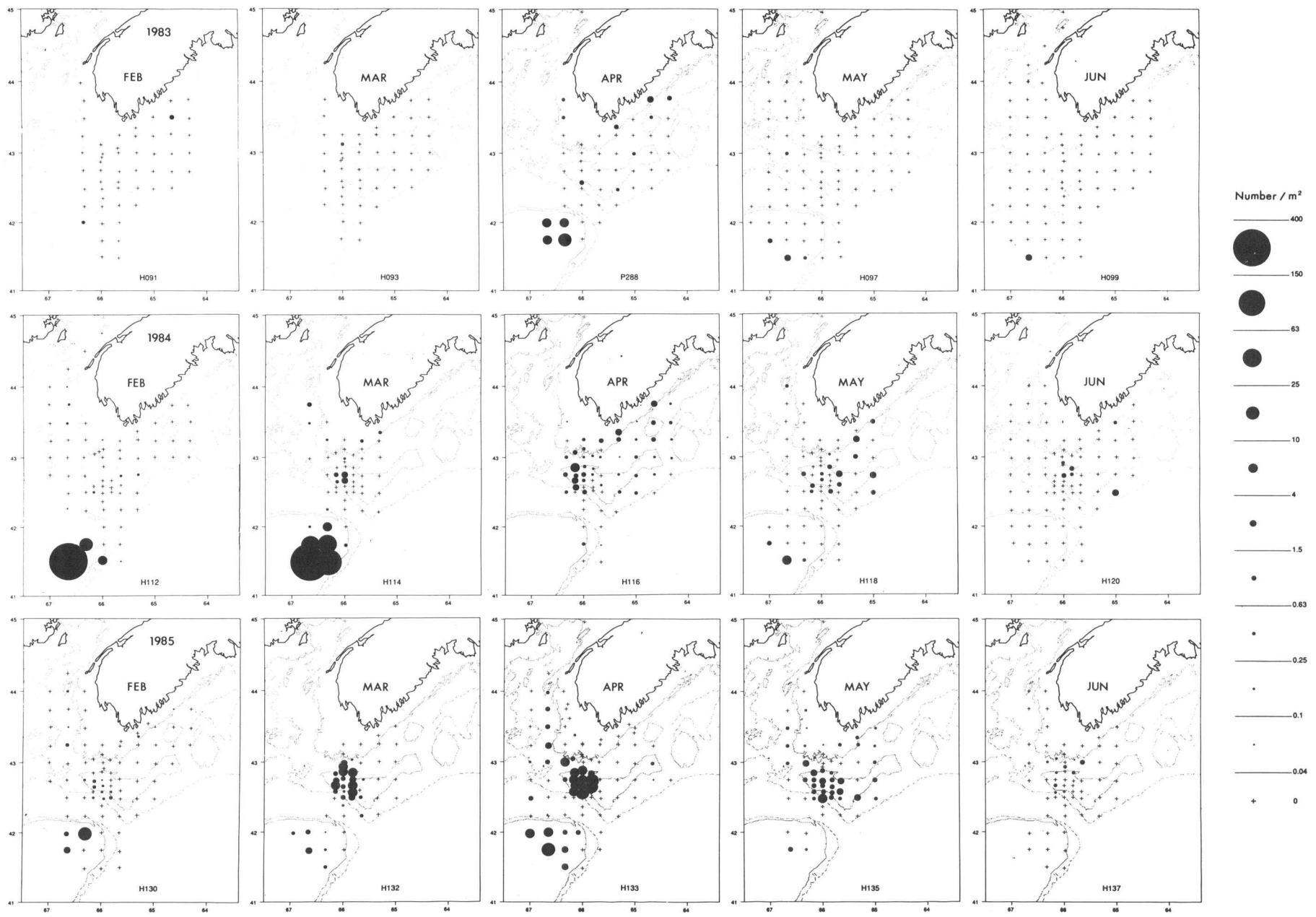

FIG. 4. Distribution of Stage IV cod eggs by month and year, 1983–85 (number/m^2).

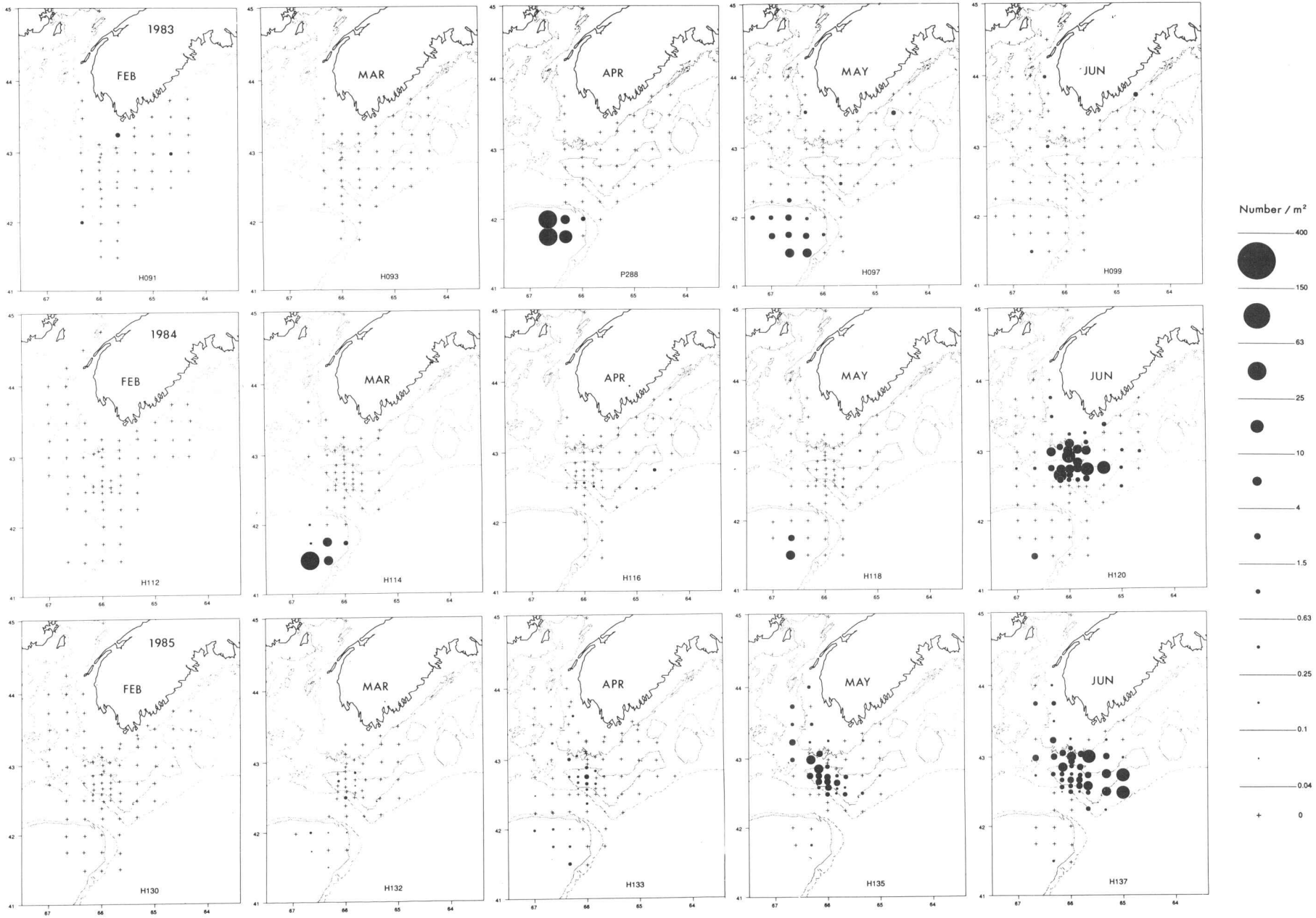

FIG. 5. Distribution of haddock larvae by month and year, 1983–85 (number/m^2).

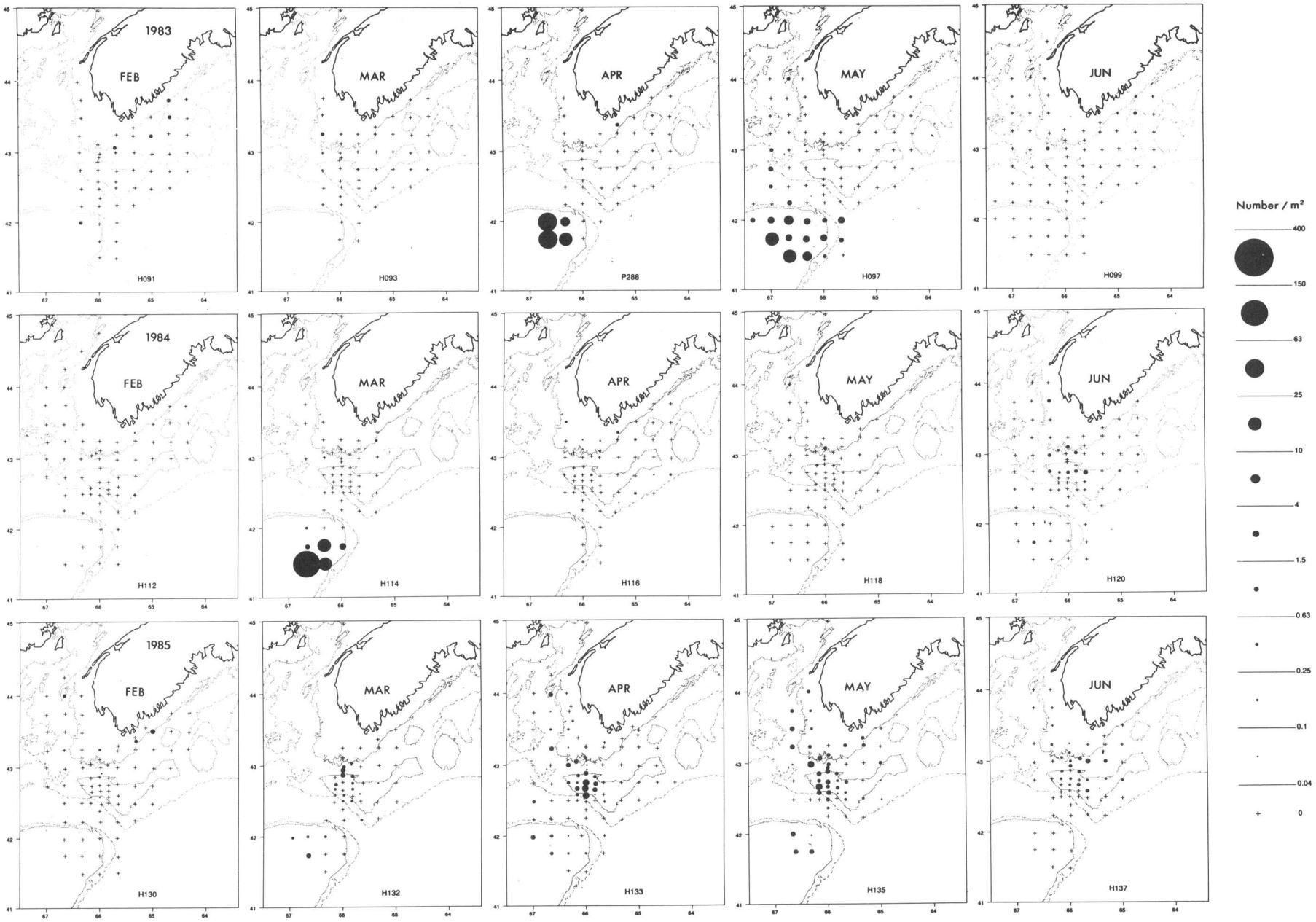

FIG. 6. Distribution of cod larvae by month and year, 1983–85 (number/m^2).

TABLE 2. Length frequency (numbers) of haddock larvae taken off Southwest Nova Scotia and on Georges Bank, by month and year 1983–85.

	Standard length (mm)																
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	Total
Southwest Nova Scotia																		
Feb. 83	—	—	—	—	—	—	—	2	—	—	—	—	—	—	—	—	—	2
Mar. 83	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0
Apr. 83	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0
May 83	—	1	1	1	—	1	—	—	—	—	—	—	—	—	—	—	—	4
Jun. 83	—	—	2	1	1	—	—	—	—	—	—	—	—	—	—	—	—	4
Feb. 84	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0
Mar. 84	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0
Apr. 84	—	—	1	5	2	1	2	—	1	—	—	—	—	—	—	—	—	12
May 84	—	—	1	—	1	—	—	—	—	—	—	—	—	—	—	—	—	2
Jun. 84	—	1	25	187	136	50	26	9	—	2	—	—	—	—	—	—	—	436
Feb. 85	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0
Mar. 85	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0
Apr. 85	—	—	23	20	1	—	—	—	—	—	—	—	—	1	—	—	—	45
May 85	—	44	217	67	11	6	1	—	—	—	—	—	—	—	—	—	—	346
Jun. 85	—	49	272	236	195	114	64	9	3	1	—	—	—	—	1	—	—	944
Georges Bank																		
Feb. 83	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	1
Mar. 83	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0
Apr. 83	—	4	59	83	18	12	5	2	—	—	—	—	—	—	1	—	—	184
May 83	—	—	8	21	11	3	5	3	2	4	4	6	5	5	2	2	2	83
Jun. 83	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	1
Feb. 84	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0
Mar. 84	—	5	65	108	40	3	—	—	—	—	—	—	—	—	—	—	—	221
Apr. 84	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0
May 84	—	—	4	2	—	—	—	—	—	—	—	—	—	—	—	—	—	6
Jun. 84	—	—	—	4	—	2	—	—	—	—	—	—	—	—	—	—	—	6
Feb. 85	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0
Mar. 85	—	1	1	1	1	—	—	—	—	—	—	—	—	—	—	—	—	4
Apr. 85	—	1	5	2	—	—	—	—	—	—	—	—	—	—	—	—	—	8
May 85	—	—	1	1	—	—	—	—	—	—	—	—	—	—	—	—	—	2
Jun. 85	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	1

reported current speeds (Lawrence and Trites 1983; Smith 1983, 1989) are of insufficient magnitude to have carried the eggs from Browns Bank during the 6-d (maximum) stage duration (Marak and Colton 1961; Page and Frank 1989). However, the magnitude of inshore spawning appeared to be low relative to the total. While inshore spawning of cod has been reported previously (Bigelow and Schroeder 1953; Gagné and O'Boyle 1984; O'Boyle et al. 1984), the inshore distribution of Stage IV haddock eggs suggests that haddock may also spawn inshore. Note that earlier reports of apparent inshore haddock spawning (McKenzie 1940; Kohler 1960) were based on inconclusive data.

There was a marked consistency among the apparent spawning sites for both cod and haddock. Aside from differences in relative abundance, the stage IV eggs of both species were characterized by similar distributions, despite differences in spawning times and associated circulation pattern changes. There was little or no evidence of interannual shifts in spawning location. If, as Waiwood and Buzeta (1989) have suggested, spawning location of haddock is linked to sediment type, this may explain the observed interannual consistency. An equally viable explanation is the correspondence between spawning sites and bottom topography, which is itself correlated with sediment type. Apparent geographic shifts in spawning location, from west to east, within a spawning season, were consistent across years, and were probably linked to patterns in vernal warming (Drinkwater and Trites 1987). A similar trend in flatfish spawning on the Scotian Shelf was reported by Neilson et al. (1988). Reexamination of the cod egg data presented by Gagné and O'Boyle (1984) suggests that the same may apply to cod along the entire Scotian Shelf.

The time of peak spawning for cod (April) and haddock (April–June) off Southwest Nova Scotia is similar to that reported elsewhere for eastern Scotian Shelf stocks (Gagné and O'Boyle 1984; O'Boyle et al. 1984). It is also consistent with estimates of peak spawning activity derived from observations of spawning fish (Scott 1983) and examination of otolith microstructure (Campana 1989). However, our data indicate that haddock spawning is more prolonged than was previously described. Further, the timing of peak spawning varied among years, occurring in each of the months April through June. The source of these interannual differences is not immediately evident, nor were similar variations observed in relation to cod spawning. Cod spawning was usually initiated earlier than that of haddock, but the lag between their peak times was not always of the same duration (0–2 mo). While this study was not designed to examine any contribution by fall spawners (Gagné and O'Boyle 1984), some fall progeny were evident among the

TABLE 3. Length frequency (numbers) of cod larvae taken off Southwest Nova Scotia and on Georges Bank, by month and year 1983–85.

	Standard length (mm)																	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	Total
Southwest Nova Scotia																		
Feb. 83	—	—	—	1	1	—	1	—	—	—	—	—	—	—	1	—	1	5
Mar. 83	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	1	2
Apr. 83	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	1
May 83	—	—	—	—	1	—	—	—	—	—	—	—	1	1	1	—	1	5
Jun. 83	—	—	—	1	—	1	—	—	—	—	—	—	—	—	—	—	—	2
Feb. 84	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	1
Mar. 84	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	1
Apr. 84	—	—	1	2	1	2	2	—	—	—	—	—	—	—	—	2	—	10
May 84	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	1
Jun. 84	—	1	—	4	6	2	—	—	—	—	—	1	—	—	—	—	—	14
Feb. 85	—	1	2	3	1	2	—	2	—	—	1	—	—	—	—	—	1	13
Mar. 85	—	—	4	21	6	—	—	—	—	—	1	—	—	—	—	—	—	32
Apr. 85	—	4	59	89	21	5	—	1	—	—	—	—	—	—	—	—	1	180
May 85	—	5	38	41	34	13	8	5	—	2	1	—	—	1	1	—	—	149
Jun. 85	—	2	7	8	1	3	2	3	1	—	4	—	—	—	—	2	1	34
Georges Bank																		
Feb. 83	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	1
Mar. 83	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0
Apr. 83	—	—	13	51	34	36	40	25	11	5	2	2	1	—	—	—	—	220
May 83	—	—	—	—	—	3	2	6	3	14	8	11	18	23	28	13	16	145
Jun. 83	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0
Feb. 84	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0
Mar. 84	—	13	79	196	95	16	4	—	—	1	—	—	—	—	—	—	—	404
Apr. 84	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0
May 84	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0
Jun. 84	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	1
Feb. 85	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0
Mar. 85	—	—	3	9	1	—	—	—	—	—	—	—	—	—	—	—	—	13
Apr. 85	—	5	8	2	2	—	—	—	—	—	—	—	—	—	—	—	—	17
May 85	—	—	—	—	1	—	—	—	—	1	—	2	3	6	2	2	3	20
Jun. 85	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0

larvae collected in this study. Peak spawning on Georges Bank occurred 1–2 mo earlier than on Browns Bank for both species, in keeping with other published findings (Grosslein and Hennemuth 1973; Colton et al. 1979; Sherman et al. 1987).

Interannual and interspecific comparisons of egg and larval production are beyond the scope of this paper, and in any case, have been addressed elsewhere (Campana et al. 1989c). However, on the basis of visual inspection of the data, there appears to be little evidence of either synchrony in relative abundance or exchange of ichthyoplankton between Browns and Georges banks (Smith and Morse 1985; Perry and Hurley 1986).

Acknowledgements

We sincerely thank the many individuals involved in the collection of the samples, including the officers and crew of the *Lady Hammond*, but particularly Jim Reid for all his efforts. Thanks also go to the staff of Marine Research Associates for sorting and identification services, Lou Van Guelpen and the Huntsman Marine Science Centre for training, advice, and confirming ichthyoplankton identifications, M. Fowler for editing the volumes of data, P. Simpson for assistance in the data analysis and J. Hamel for preparing the figures. We appreciate the constructive reviews of an earlier draft of this manuscript by K. T. Frank, K. G. Waiwood, R. N. O'Boyle, and an anonymous reviewer.

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