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Spawning Time of Haddock and Cod on Georges Bank as Indicated by the MARMAP Icthyoplankton Data Set.

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ABSTRACT

Spawning times for cod and haddock have been estimated from the MARMAP data set for fisheries statistical areas 5Zg-o. When the dates of cod stage III egg appearance are adjusted for an egg age of 15d, ninety percent of the spawning occurs after February 8 (December 5), 70% after March 11 (February 16) and 50% after March 14 (March 20) based on an abundance (presence-absence) weighting. When the date of haddock stage III egg appearance are adjusted for an egg age of 15d, ninety percent of the haddock eggs appear after March 11 (January 22), 70% after March 14 (March 18) and 50% after March 20 (March 25) based on an abundance (presence-absence) weighting. These estimates are consistent with previous estimates for the area.

RÉSUMÉ

Les périodes de frai de la morue et de l'aiglefin des zones statistiques des pêches 5Zg-0 ont été estimées à partir de la série de données du MARMAP. Lorsque les dates d'apparition des oeufs de morue de stade III sont corrigées pour l'âge de 15 jours, on obtient, après pondération pour l'abondance (présence-absence), que 90 % du frai a eu lieu après le 8 février (5 décembre), 70 % après le 11 mars (16 février) et 50 % après le 14 mars (20 mars). Lorsque la date d'apparition des oeufs d'aiglefin de stade III est corrigée pour l'âge de 15 jours, après pondération pour l'abondance (présence-absence), 90 % des oeufs apparaissent après le 11 mars (22 janvier), 70 % après le 14 mars (18 mars) et 50 % après le 20 mars (25 mars). Ces estimations sont conformes aux estimations antérieurement faites pour cette région.

Introduction

For fishery management purposes, the Georges Bank area has been divided into several statistical areas. The boundaries of presently used areas are shown in Figure 1. A review of the development of these areas is given in Halliday and Pinhorn (1990). The management units used by Canada for the assessment of Georges Bank cod and haddock is NAFO Subarea 5Zj,m (Gavaris and Van Eeckhaute 1997, Hunt 1989, Hunt and Buzeta 1997). The management units used by the United States, for Georges Bank cod and haddock are NAFO Subareas 5Z and 6 (Hunt and Buzeta 1997, Mayo 1995). In both countries the major cod and haddock spawning areas are considered to be on the eastern portion of Georges Bank with minor spawning occurring on the eastern portion of Nantuckett Shoals and along the Maine coast (Mayo 1995).

One of the tools for managing fishery resources is the use of spawning season and area closures. On Georges Bank, the closed area was instituted by ICNAF in 1970 to protect haddock spawning activity and to reduce catches during the spawning period (Halliday 1988). The area was closed from March through April. In 1972 the closure period was expanded to March through May. In 1984, the international boundary between Canada and the United States as defined by the International Court of Justice in 1984 was implemented. In 1985 the dates for the American portion of the closed area were further extended to February through May and in 1993 they were expanded to Jan. 1 through June 30. The dates for the Canadian portion remained unchanged. In 1994 the American portion of the closure was extended to year round and the Canadian closure was expanded to Jan. 1 through May 31. The rationale for the closures in discussed in Halliday (1988) and changes to the closure dates since 1977 are given in Gavaris and VanEeckhaute (1997).

The rationale for the closures, in addition to potentially protecting the spawning activity itself, is to reduce the catches of fish, primarily haddock, and to spread the catch out over the year (Halliday 1988). The latter rationale is the primary reason for continued support of the use of the closed areas (Halliday 1988).

In 1997 some members of the Canadian fishing industry indicated to DFO that they would like the dates of the closure period to be modified so fishing could be conducted during the early part of the year (January, etc.) when the catch rates and market prices for cod and haddock are relatively high. In particular, they would like to have the beginning date of the Canadian closure moved ahead to sometime later in January or in February or March.

In partial response to this industry request, an analysis of the National Marine Fisheries Service, Marine Resources Monitoring, Assessment and Prediction (MARMAP) data set was requested. The analyses was to focus on the spatial and temporal distribution of cod and haddock eggs on Georges Bank. The results of this analysis are presented below. The data source and analyses methods are described, along with the resulting composite spatial and temporal distributions of stage III cod and haddock eggs. This is

followed by a discussion of the results. The emphasis is placed on statistical unit area 5Z, and particularly 5Zjmno and 5Zjm.

Materials and Methods

The MARMAP Data set

The spatial and temporal distribution of cod and haddock spawning has been estimated from the presence-absence and abundance (#/10m^2) of stage III eggs recorded in the plankton samples collected during the MARMAP program. These data include estimates of the abundance of cod and haddock eggs at stations within the Georges Bank area for about 80 cruises that were conducted between 1977 and 1987 (Fig. 2). Typically, there were 6 to 9 surveys per year. The dates of the surveys varied interannually, although efforts were made to ensure at least quarterly sampling. Each plankton survey sampled a series of geographically fixed stations that were located 8 to 18 km apart along 7 transects that crossed Georges Bank. Additional stations, located at 25 to 35 km intervals apart, were spread throughout the survey domain to ensure a representative broadscale coverage (Smith and Morse 1985).

As part of the MARMAP protocol eggs were separated into three stages and identified to species where possible. The first egg stage covers from just spawned to before blastopore closure. The second stage covers blastopore closure to before the tail bud lifts free from the yolk sac. The third stage covers tail bud free to before hatching. It is not until the third stage that cod and haddock eggs can be identified as separate species. The abundance of eggs per tow was calculated as numbers per 10m^2 of sea surface. Additional details of the MARMAP sampling methods and identification protocols are given in Berrien and Sibunka (1994) and Sibunka and Silverman (1984, 1989).

Analyses

In the present analyses only the abundance of stage III eggs is used. Stage III eggs are the first stage that cod and haddock can be differentiated. At temperatures typical of Georges Bank during the cod and haddock spawning season the eggs take approximately 10 to 20 days to hatch (Page and Frank 1989). The age of stage III eggs is approximately 15d (Lough et al. 1994).

Since, the number of surveys within a year is low and the timing of the surveys is different every year, a composite picture of the spatial and temporal distribution of spawning has been compiled for each species by aggregating the data from all years (1977-87) together. In the aggregation each survey was given an equal weighting.

The composited data were analyzed from both a presence-absence and abundance point of view. Absolute and relative cumulative frequency distributions were calculated from these composites. These plots indicate the cumulative proportion of the total egg

abundance that appears up to and including the corresponding date. At the request of industry representatives, the cumulative frequencies have also been plotted as 1 minus the relative cumulative frequencies. These indicate the proportion of the total egg abundance that has yet to be spawned at a given date.

Results

Cod

The composite distribution map of the presence of stage III cod eggs indicates that cod eggs occur throughout the 5Ze area in waters shallower than 100m (Fig. 3a). The composite distribution of the abundance of the stage III cod eggs indicates that spatial variation in the concentrations of eggs exists, with the highest concentrations occurring in 5Zj,m (Fig. 3b).

The cumulative frequencies of stage III eggs (Fig. 4a,b) within 5Zjm, indicate the presence of a single large catch that dominates the frequency distributions. They also indicate that spawning occurs during the beginning (winter-spring) and end (fall) of the year, but not in the middle (summer). Therefore, the frequencies were recalculated after removing the outlier and by shifting the dates from day 1 to 214 to begin on day 366.

The revised cumulative frequencies (Fig. 5a,b) indicate sampling effort was evenly distributed throughout the year. Stage III cod eggs first appear on day 299 (Oct 26). The last day of appearance is day 559 (Jul. 13). Percentiles of spawning time are listed in Table 1a. The median date of stage III egg appearance based on presence-absence (abundance) criteria is 459 (453). This day corresponds to April 4 (Mar. 29). Sixty percent of the spawning occurs between days 401-480 (Feb. 5 - Apr. 25) when based on presence-absence criteria and 419-461 (Feb. 23 - Apr. 6) when based on abundance criteria (Table 1).

The plots of 1 minus the relative cumulative frequencies (Fig. 5c) indicate that on June 1, the day when the 5Zc closed area opens, 1 to 4 percent of the stage III cod eggs have yet to appear. Ninety percent of the eggs appear after February 23 (December 20), 70% after March 26 (March 3) and 50% after March 29 (April 4) based on the abundance (presence-absence) weighting (Table 2a). When the dates are adjusted for an egg age of 15d (Table 2b), ninety percent of the spawning occurs after February 8 (December 5), 70% after March 11 (February 16) and 50% after March 14 (March 20) based on the abundance (presence-absence) weighting.

In 5Zhjmn the cumulative frequencies (Fig. 6a,b) indicate sampling effort was also evenly distributed throughout the year. Stage III cod eggs first appear on day 238 (Aug. 26). The last day of appearance is day 559 (Jul. 13). The median date of spawning based on presence-absence (abundance) criteria is 452 (453). This day corresponds to Mar 28 (Mar. 29). Sixty percent of the spawning occurs between days 378- 471 (Jan, 13

- Apr. 16) when based on presence-absence criteria and 419-460 (Feb. 23 - Apr. 5) when based on abundance criteria (Table 1).

The dates of the first and last appearance of stage III cod eggs for each of the statistical unit areas suggests spatial variability in the timing of spawning (Fig. 7). Spawning appears to begin along the southern flank of Georges Bank and progresses toward the north and west. Spawning ends earliest along the Great South Channel side and latest on the eastern side of the Bank.

Haddock

The composite distribution map of the presence of stage III haddock eggs indicates that, with the exception of 5Zg, which has almost no eggs, haddock eggs occur throughout the 5Ze area in waters shallower than 100m (Fig. 8a). The composite distribution of the abundance of the eggs indicates that spatial variation in the concentrations of eggs exists, with the highest concentrations occurring in 5Zj,m (Fig. 8b).

The cumulative frequencies for 5Zjm (Fig. 9a,b) indicate sampling effort was evenly distributed throughout the year. Stage III haddock eggs first appear on day 12 (Jan. 12). The last day of appearance is day 194 (Jul. 13). The median date of spawning based on presence-absence (abundance) criteria is day 99 (94) which is April 9 (April 4). Sixty percent of the spawning occurs between days 63 and 118 (Mar. 4 - Apr. 28) when based on presence-absence criteria and 88-108 (Mar. 29 - Apr. 18) when based on abundance criteria (Table 1).

The plots of 1 minus the relative cumulative frequencies (Fig. 9c) indicate that on June 1, the day when the 5Zc closed area opens, 2 percent of the stage III haddock eggs have yet to appear. Ninety percent of the eggs appear after March 26 (February 6), 70% after March 29 (April 2) and 50% after April 4 (April 9) based on the abundance (presence-absence) weighting (Table 3a). When the dates are adjusted for an egg age of 15d (Table 3b), ninety percent of the eggs are spawned after March 11 (January 22), 70% after March 14 (March 18) and 50% after March 20 (March 25) based on the abundance (presence-absence) weighting.

In 5Zhjmn the cumulative frequencies (Fig. 10a,b) indicate sampling effort was also evenly distributed throughout the year. Stage III cod eggs first appear on day 12 (Jan. 12). The last day of appearance is day 194 (Jul. 13). The median date of spawning based on presence-absence (abundance) criteria is 95 (94). This day corresponds to Apr. 5 (Apr. 4). Sixty percent of the spawning occurs between days 83-115 (Mar. 24-Apr. 25) when based on presence-absence criteria and 88-112 (Mar.29-Apr.22) when based on abundance criteria (Table 1). The 1-percentiles were not calculated for 5Zhjmn, since the cumulative frequency distributions for 5Zjm and 5Zhjmn are similar.

The dates of the first and last appearance of stage III haddock eggs for each of the statistical unit areas suggests spatial variability in the timing of spawning (Fig. 11).

Spawning appears to begin first in 5Zm and last in 5Zg. Spawning ends earliest in 5Zg and latest in 5Zm.

Discussion

The location of spawning within the 5Z area as indicated by the MARMAP data is consistent with indications from previous icthyoplankton surveys. Haddock spawning is primarily on the northeastern portion of Georges Bank (Colton and Temple 1961, Posgay and Marak 1970, Grosslein and Hennemuth 1973) and cod spawning is spread over the bank.

The time of cod and haddock spawning on Georges Bank has been estimated several times in the past. Colton et al. (1979) used available icthyoplankton data to estimate the months in which eggs or larvae occurred and the months of peak spawning for many species within the Gulf of Maine and Middle Atlantic Bight region. They estimated cod spawning on Georges Bank to occur during December through April, with peak spawning in March. Haddock spawning was estimated to be during February, March and April, with peak spawning in February and March.

In the recent stock assessment literature only coarse estimates of spawning times are provided. Cod is considered to spawn during the winter and spring (Mayo 1995) and haddock during January and June, with peak activity during late March and early April (Mayo 1995).

The use of the composited MARMAP data, cumulative frequency distributions and percentiles to define spawning times has given more precise estimates of spawning time for cod and haddock on Georges Bank than has been previously available and has suggested some spatial variability on the time of spawning. As such the approach may prove useful for the basis of more extensive analyses of the cod and haddock as well as other species and areas.

The present estimates of the time window and time of peak spawning for cod are similar to those of Colton et al. (1979). During the MARMAP period (1977-87), stage III cod eggs within 5Zghjmno appeared between day 238 and 559 (Aug. 26 - Jul. 13). Ninety percent of the eggs appeared between days 327 and 511 (Nov. 23 - May 26) and 60% between days 378 and 480 (Jan 13 - Apr. 25). The median date of appearance is day 452-459 (Mar. 28 - Apr. 4). If the 15 day incubation period for stage III eggs is taken into consideration, the majority of cod spawning occurred during mid-November to mid May (90%) or January to mid-April (60%), which is similar to the Dec-Apr. indicated by Colton et al. (1979). The mid-point of mid-March agrees with Colton et al.'s (1979) estimate of March.

The present analyses give a broader time window for haddock spawning and a narrower time of peak spawning than Colton et al. (1979). During the MARMAP period (1977-87),

the haddock stage III eggs within 5Zghjmno appeared between day 12 and 194 (Jan. 12 - Jul. 13). Ninety percent of the eggs appeared between days 21 and 143 (Jan. 21 - May 23) and 60% between days 63 and 118 (Mar. 4 - Apr. 28). The median date of appearance is day 94-99 (Apr. 4-9). If a 15 day incubation period for stage III eggs is taken into consideration (Grosslein and Hennemuth 1973), the majority of haddock spawning occurred during mid-January to the mid-May (90%) or mid-February to mid-April (60%). This is similar to the Feb.-Apr. indicated by Colton et al. (1979). The date of peak spawning, mid-March, is relatively narrow, although consistent with Colton et al.'s (1979) estimate of February-March.

As indicated in the introduction, the rationale behind the use of spawning area closures is not solely to prevent the disruption of the spawning process, of particular importance during times of low stock size. The authority by which spawning closures is used, involves the definition of the closed area and season on the basis of the distribution and timing of spawning activity. However, there is little information documenting the impact of fishing during the spawning period on the spawning process, other than it lets mature fish spawn before they are caught and if there is a disruption of the spawning act this possibility is precluded. The main rationale supporting the use of spawning closures is to limit catches of fish during the time of the year when the fish are most aggregated and hence catch rates are the greatest. (Halliday 1988).

The distribution of the stage III eggs gives only an indication of the spatial and temporal distribution of spawning aggregations. The egg distributions must be modified to account for the age of the eggs, which is temperature dependent, and their displacement during development if a better indication of the distribution of spawning adults is desired. Also, the aggregation behavior and pattern of the adult fish prior to the actual release of eggs should be considered if the goal of controlling catches is to be balanced with the desire to achieve high catch rates.

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Table 1: Consecutive days (Jan. 1= 1, Feb. 1=32, etc.) of stage III egg abundance percentiles for statistical unit areas within 5Z as estimated from the presence-absence and abundance of stage III cod and haddock eggs in the MARMAP data set. Dates have not been corrected for the age of the eggs.

Species and Unit Area	PERCENTILES						
	First Recorded Presence	5th	20th	50th	80th	95th	Last Recorded Presence
Cod							
5Zhjmn							
presence-absence	238	327	378	452	471	497	559
abundance	238	382	419	453	460	477	559
5Zjm							
presence-absence	299	336	401	459	480	511	559
abundance	299	401	419	453	461	477	559
Haddock							
5Zhjmn							
presence-absence	12	23	83	95	115	140	194
abundance	12	61	88	94	112	115	194
5Zjm							
presence-absence	12	21	63	99	118	143	194
abundance	12	59	88	94	108	119	194

Table 2: Consecutive days and dates corresponding with the amount of spawning remaining, i.e. the abundance weighted and presence/absence weighted 1 minus cumulative relative percentiles of stage III cod egg abundance, for statistical unit area 5Zjm as estimated from the MARMAP data set (1977-87). Consecutive days for year 1 are Jan. 1= 1, Feb. 1=32, etc. and for the consecutive year 2 are Jan. 1 = 366, Feb. 1 = 397, etc.). Days in brackets refer to the unadjusted day of the year. Dates have not been corrected for the age of the eggs.

1-PERCENTILE	Cod 5Zjm			
	Abundance Weighted		Presence - Absence Weighted	
	Consecutive Day	Date	Consecutive Day	Date
100	299 (299)	Oct. 26	299 (299)	Oct. 26
90	419 (54)	Feb. 23	354 (354)	Dec. 20
80	420 (55)	Feb. 24	401 (36)	Feb. 5
70	450 (85)	Mar. 26	427 (62)	Mar. 3
60	452 (87)	Mar. 28	457 (92)	Apr. 2
50	453 (88)	Mar. 29	459 (94)	Apr. 4
40	458 (93)	Apr. 3	466 (101)	Apr. 11
30	458 (93)	Apr. 3	473 (108)	Apr. 18
20	461 (96)	Apr. 6	480 (115)	Apr. 25
10	468 (103)	Apr. 13	495 (130)	May 10
1 , 4*	516 (151)	May 31	516 (151)	May 31
0	559 (194)	Jul. 13	559 (194)	Jul. 13

* Note: percentile corresponding to May 31, the date the seasonal closure on the Canadian side of Georges Bank ends. The 1th percentile corresponds with the abundance weighted and the 4th percentile with the presence-absence weighted estimates, respectively.

Table 2b: Days and dates adjusted for a cod stage III egg age of 15d.

	Unadjusted for Egg Age		Adjusted for Egg Age of 15d	
Percentile of Stage III Cod Eggs yet to be spawned	**Abundance Weighted Date**	**Presence - Absence Weighted Date**	**Abundance Weighted Date**	**Presence - Absence Weighted Date**
100	Oct. 26	Oct. 26	Oct. 11	Oct. 11
90	Feb. 23	Dec. 20	Feb. 8	Dec. 5
80	Feb. 24	Feb. 5	Feb. 9	Jan. 21
70	Mar. 26	Mar. 3	Mar. 11	Feb. 16
60	Mar. 28	Apr. 2	Mar. 13	Mar. 18
50	Mar. 29	Apr. 4	Mar. 14	Mar. 20
40	Apr. 3	Apr. 11	Mar. 19	Mar. 27
30	Apr. 3	Apr. 18	Mar. 19	Apr. 3
20	Apr. 6	Apr. 25	Mar. 22	Apr. 10
10	Apr. 13	May 10	Mar. 29	Apr. 25
1, 4*	May 1	Jun. 3	Apr. 16	May 19
0	Jul. 13	Jul. 13	Jun. 28	Jun. 28

* Note: percentile corresponding to May 31, the date the seasonal closure on the Canadian side of Georges Bank ends

Table 3a: Days and dates (consecutive days, Jan. 1= 1, Feb. 1=32, etc.) corresponding with the amount of spawning remaining, i.e. the abundance weighted and presence/absence weighted 1 minus percentiles of stage III haddock egg abundance, for statistical unit area 5Zjm as estimated from the MARMAP data set (1977-87). Dates have not been corrected for the age of the eggs.

1-PERCENTILE	HADDOCK 5Zjm			
	Abundance Weighted		Presence - Absence Weighted	
	Consecutive Day	Date	Consecutive Day	Date
100	12	Jan. 12	12	Jan. 12
90	85	Mar. 26	37	Feb. 6
80	88	Mar. 29	63	Mar. 4
70	88	Mar. 29	92	Apr. 2
60	93	Apr. 3	94	Apr. 4
50	94	Apr. 4	99	Apr. 9
40	96	Apr. 6	104	Apr. 14
30	102	Apr. 12	112	Apr. 22
20	108	Apr. 18	118	Apr. 28
10	115	Apr. 25	139	May 19
2*	151	May 31	151	May 31
0	194	Jul. 13	194	Jul. 13

* Note: percentile corresponding to May 31, the date the seasonal closure on the Canadian side of Georges Bank ends

Table 3b: Days and dates adjusted for a haddock stage III egg age of 15d.

	Unadjusted for Egg Age		Adjusted for Egg Age of 15d	
Percentile of Stage III Haddock Eggs Yet to be Spawned	**Abundance Weighted Date**	**Presence - Absence Weighted Date**	**Abundance Weighted Date**	**Presence - Absence Weighted Date**
100	Jan. 12	Jan. 12	Dec. 28	Dec. 28
90	Mar. 26	Feb. 6	Mar. 11	Jan. 22
80	Mar. 29	Mar. 4	Mar. 14	Feb. 17
70	Mar. 29	Apr. 2	Mar. 14	Mar. 18
60	Apr. 3	Apr. 4	Mar. 19	Mar. 20
50	Apr. 4	Apr. 9	Mar. 20	Mar. 25
40	Apr. 6	Apr. 14	Mar. 22	Mar. 30
30	Apr. 12	Apr. 22	Mar. 28	Apr. 7
20	Apr. 18	Apr. 28	Apr. 3	Apr. 13
10	Apr. 25	May 19	Apr. 10	May 4
2*	May 31	May 31	May 16	May 16
0	Jul. 13	Jul. 13	Jun. 28	Jun. 28

* Note: percentile corresponding to May 31, the date the seasonal closure on the Canadian side of Georges Bank ends

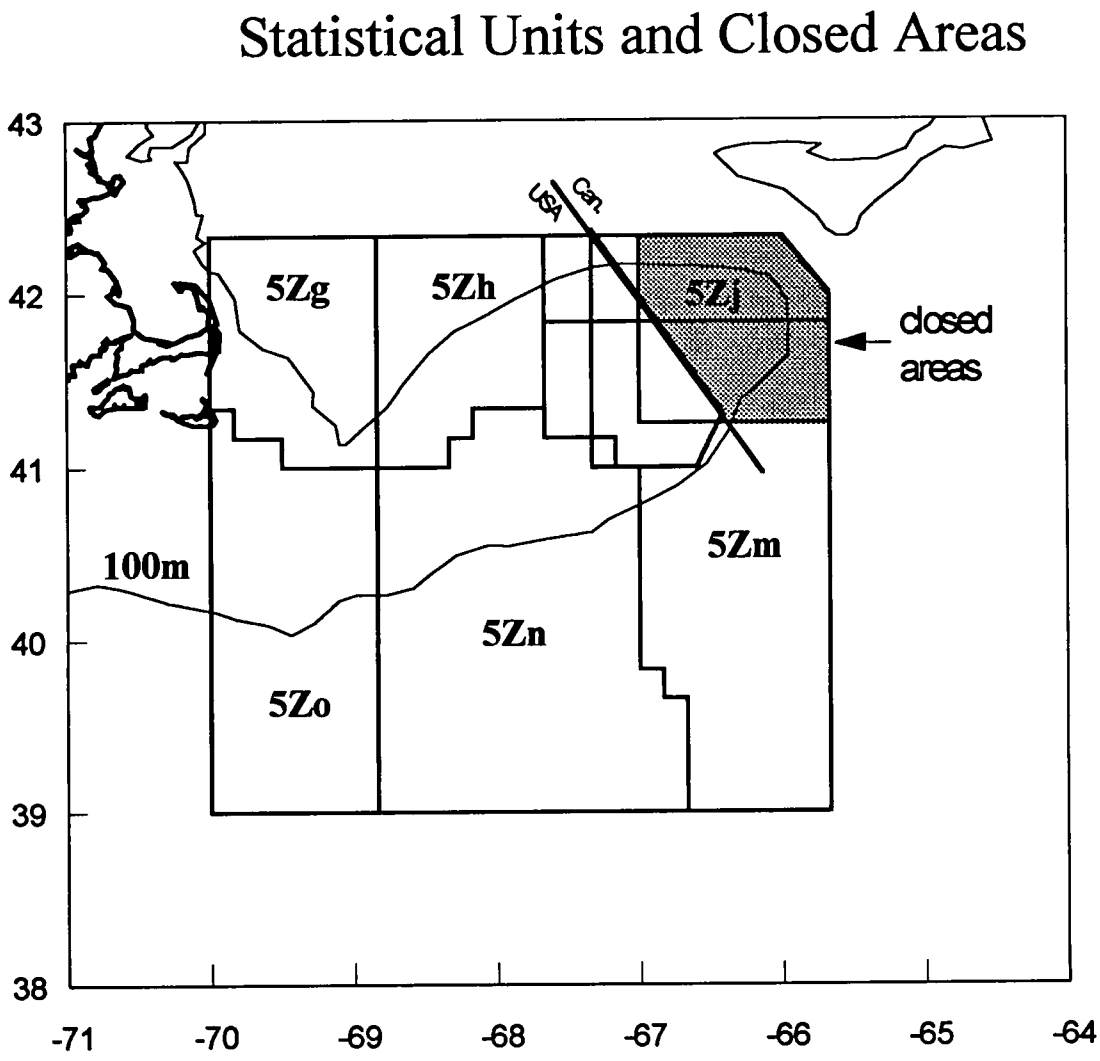


Figure 1: Map showing the boundaries of the statistical unit areas within the Georges Bank region.

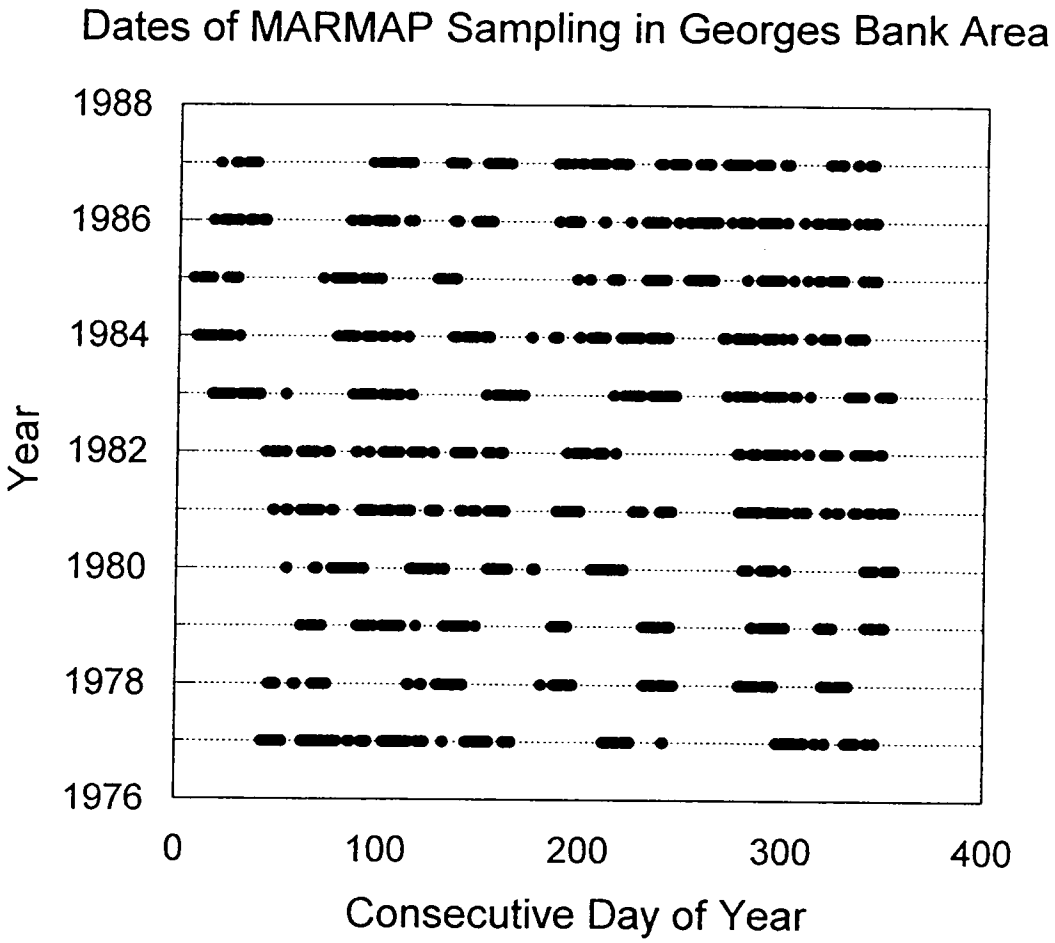
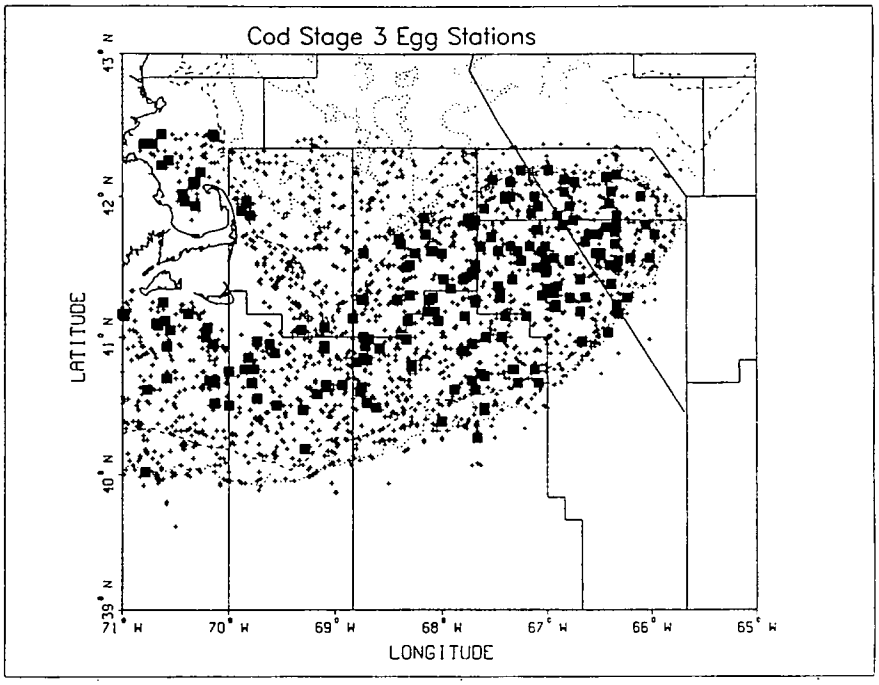


Figure 2: The temporal distribution of MARMAP sampling effort in the Georges Bank area.



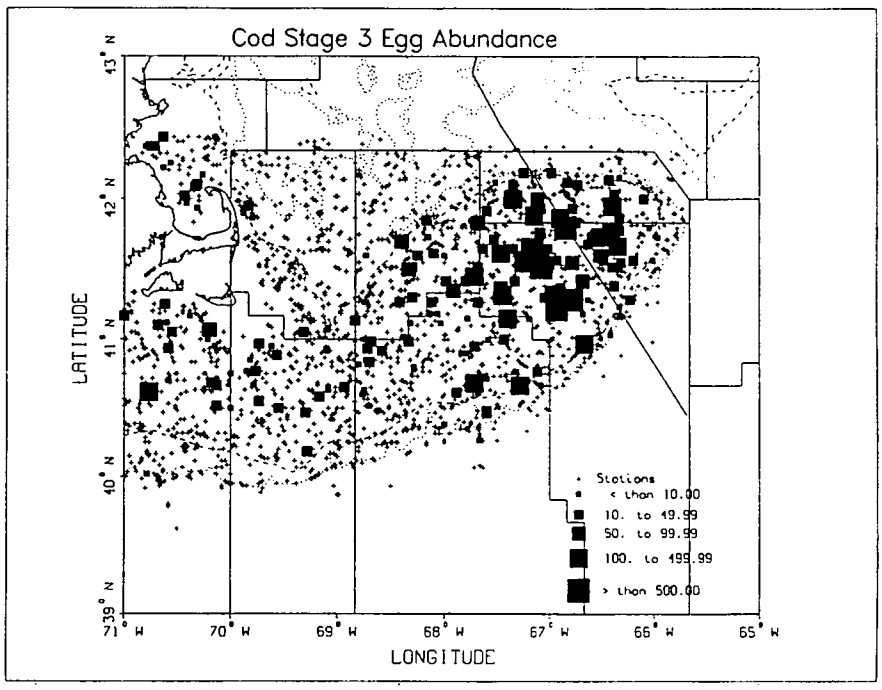
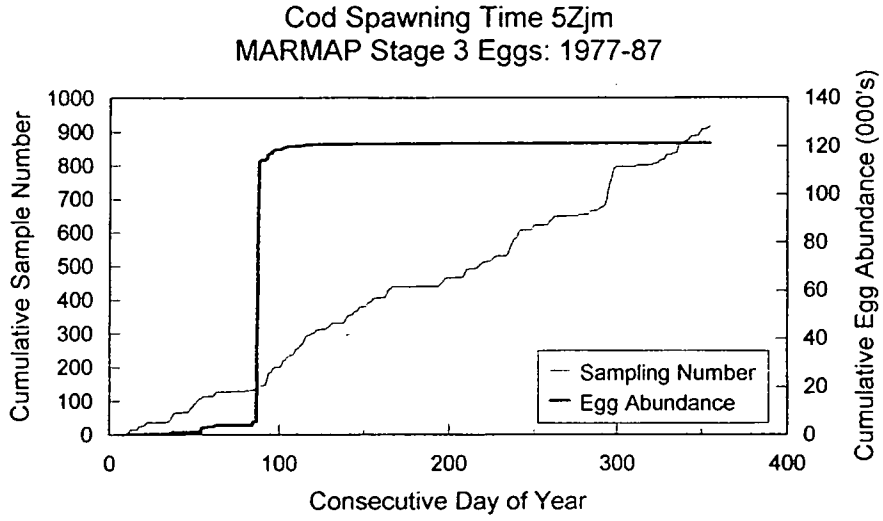


Figure 3: The composite (1977-87) spatial distribution of the presence-absence (top) and abundance (bottom) of stage III cod eggs in the Georges Bank area based on the MARMAP sampling stations within the Georges Bank.



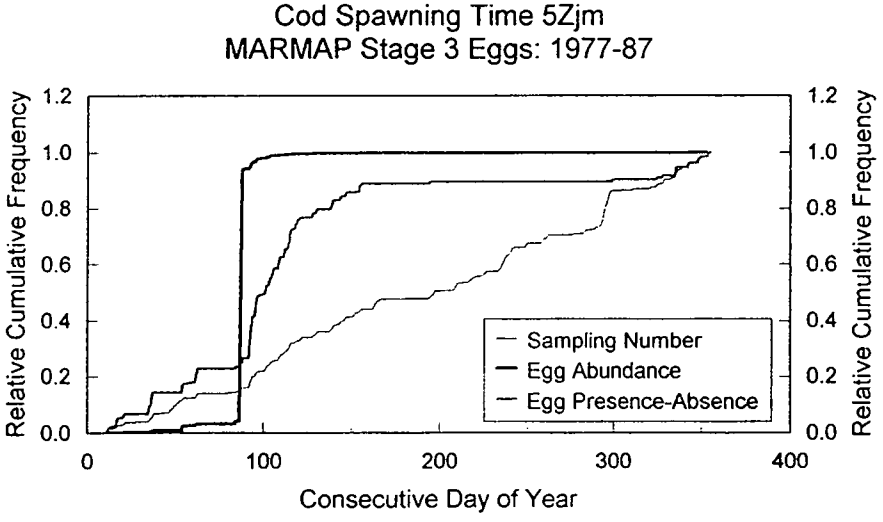


Figure 4: Composite cumulative frequency distributions of sampling effort, presence and abundance of stage III cod eggs in statistical unit area 5Zjm when on all of the data are included in the analyses. The upper panel shows absolute frequencies and the lower panel shows relative frequencies.

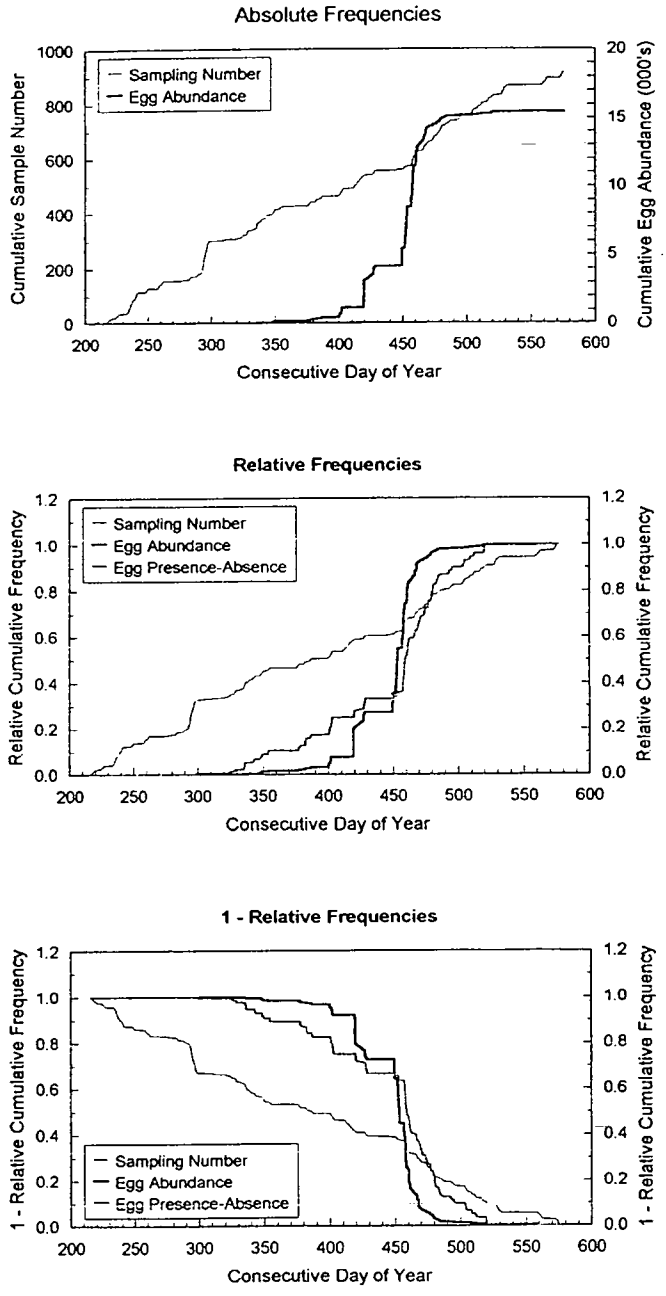


Figure 5: Composite cumulative frequency distributions of sampling effort, presence and abundance of stage III cod eggs in statistical unit area 5Zjm when a large catch outlier has been removed and the sampling dates have been shifted to begin on day 215 (Aug.1). The upper and middle panels show the absolute and relative frequencies of the proportion of eggs that have been released. The lower panel shows 1-relative frequencies or the proportion of eggs yet to be released.

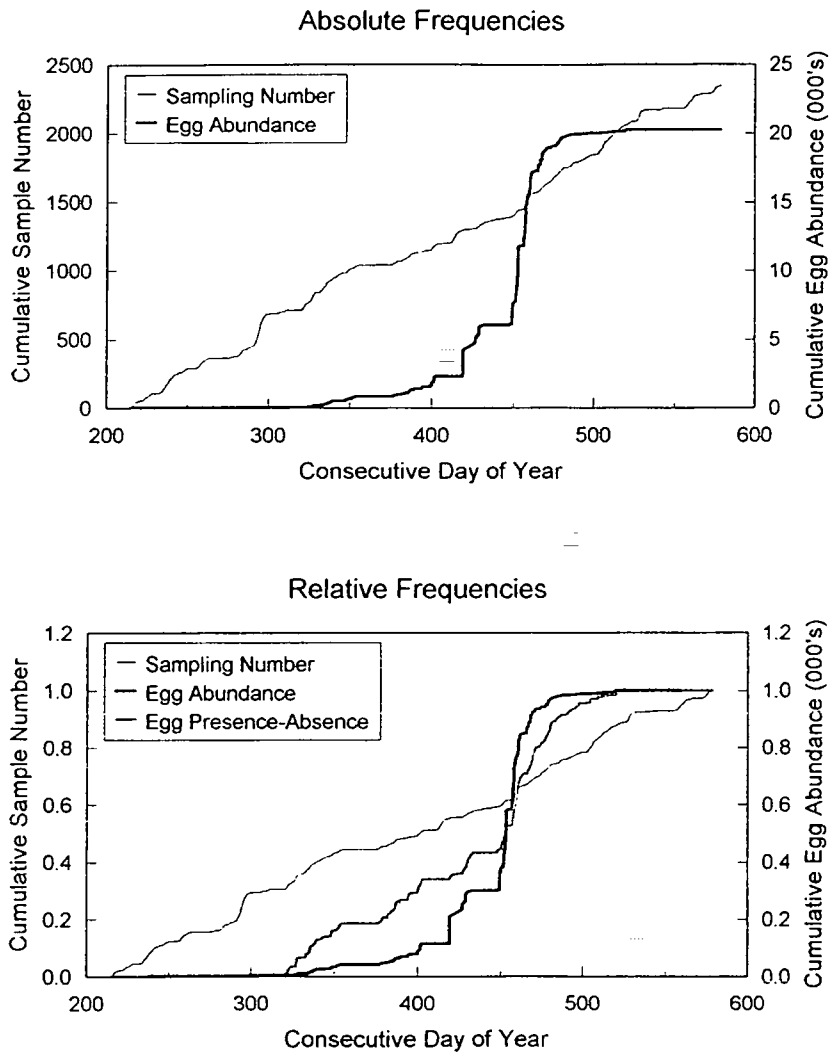
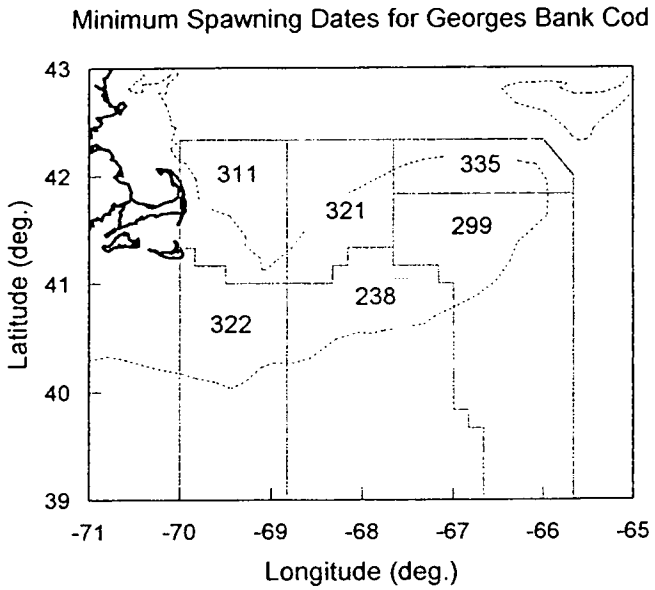


Figure 6: Composite cumulative frequency distributions of sampling effort, presence and abundance of stage III cod eggs in statistical unit area 5Zhjmn when a large catch outlier has been removed and the sampling dates have been shifted to begin on day 215 (Aug.1). The upper panel shows absolute frequencies and the lower panel shows relative frequencies.



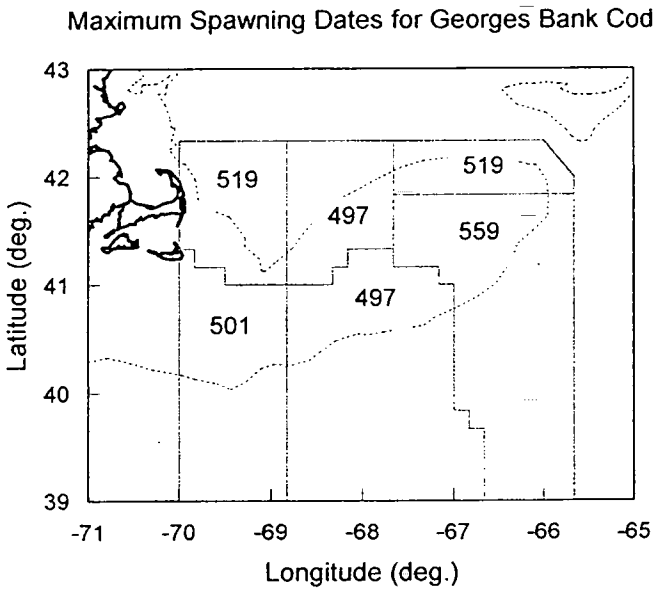
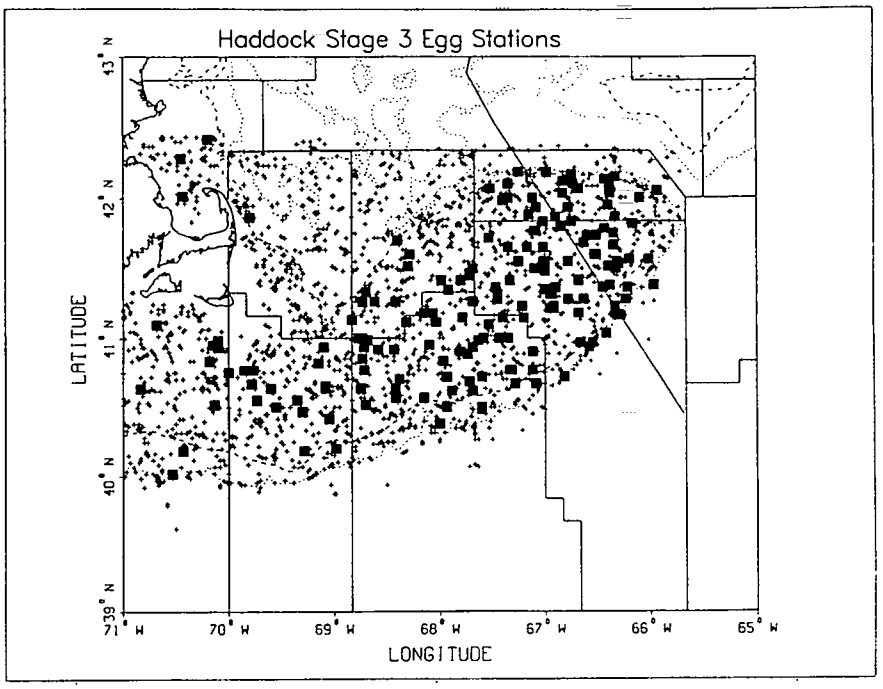


Figure 7: The dates of the first (top) and last (bottom) appearance of stage III cod eggs in statistical unit area 5Zghjmno based on the 1977-87 MARMAP dataset.



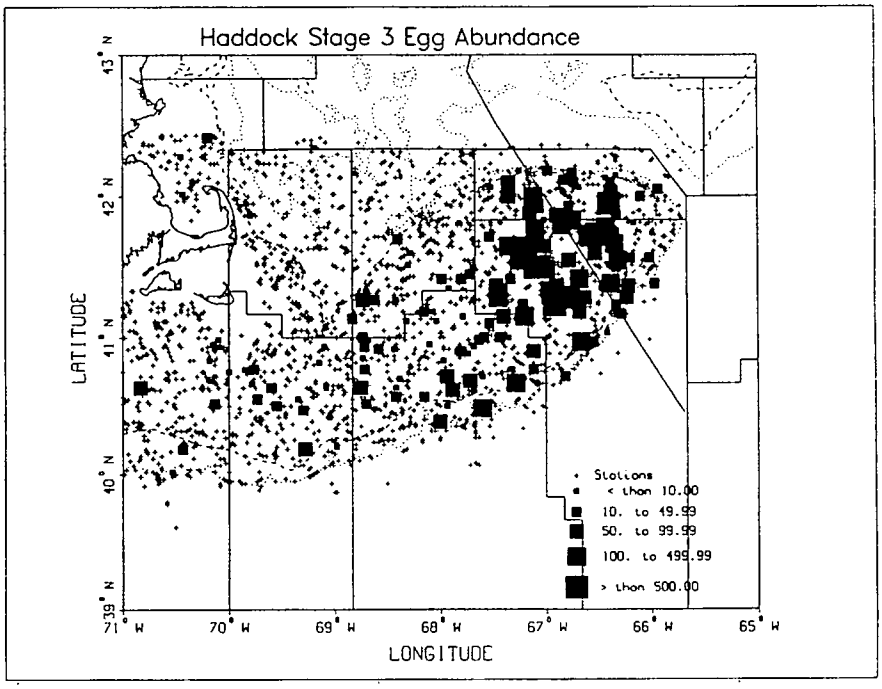


Figure 8: The composite (1977-87) spatial distribution of the presence-absence (top) and abundance (bottom) of stage III haddock eggs in the Georges Bank area based on the MARMAP sampling stations within the Georges Bank.

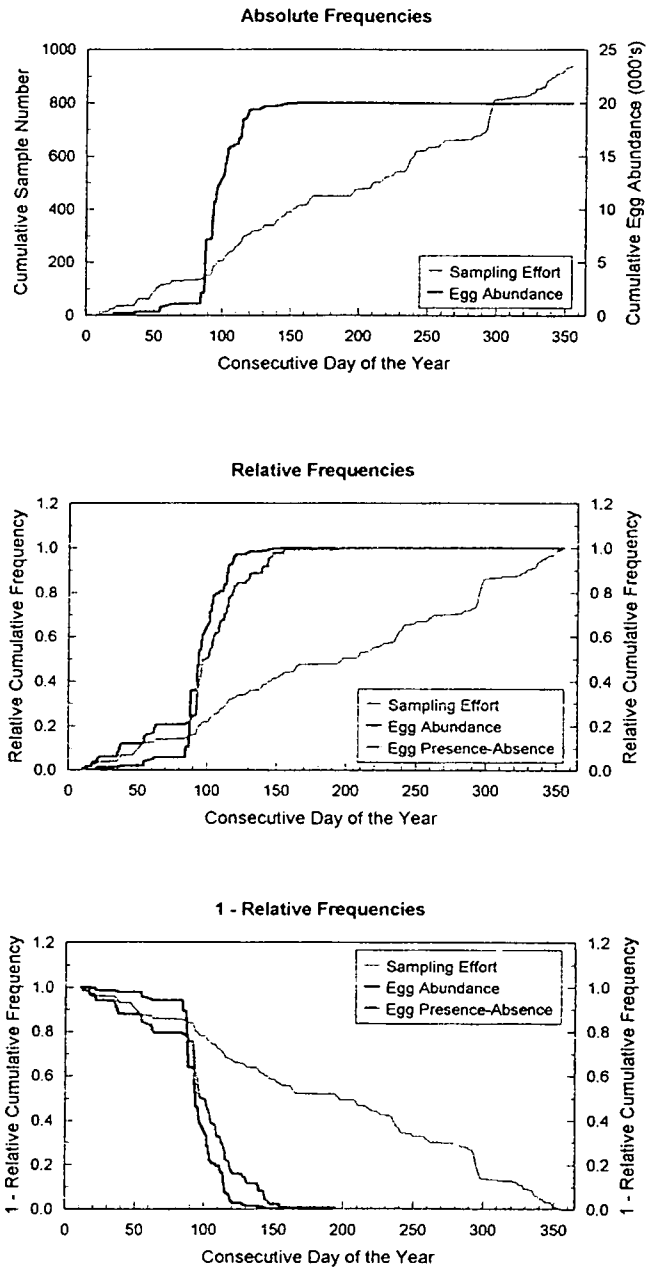


Figure 9: Composite cumulative frequency distributions of sampling effort, presence and abundance of stage III haddock eggs in statistical unit area 5Zjm when on all of the data are included in the analyses. The upper and middle panels show the absolute and relative frequencies of the proportion of eggs that have been released. The lower panel shows 1-relative frequencies or the proportion of eggs yet to be released.

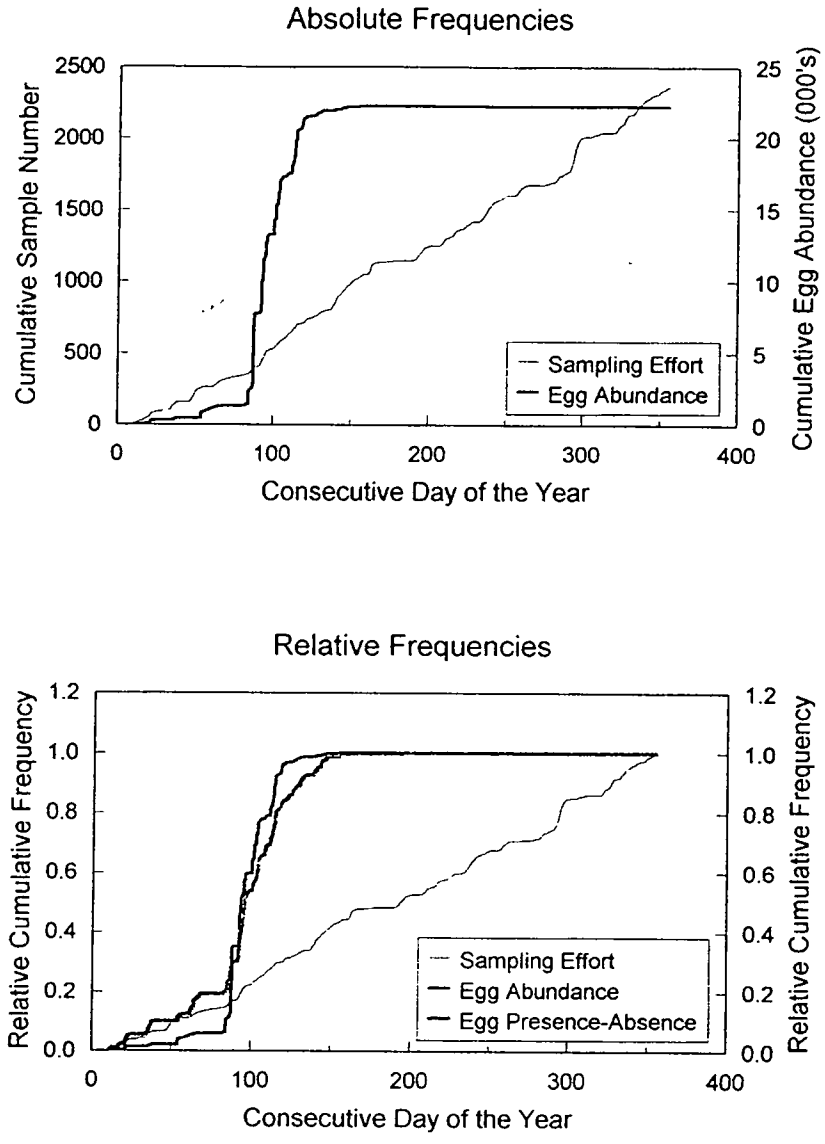
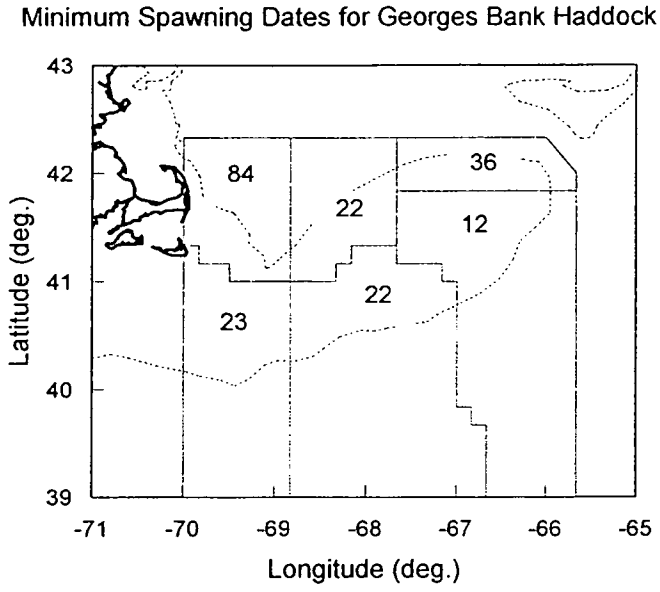


Figure 10: Composite cumulative frequency distributions of sampling effort, presence and abundance of stage III haddock eggs in statistical unit area 5Zhjmn when on all of the data are included in the analyses. The upper panel shows absolute frequencies and the lower panel shows relative frequencies.



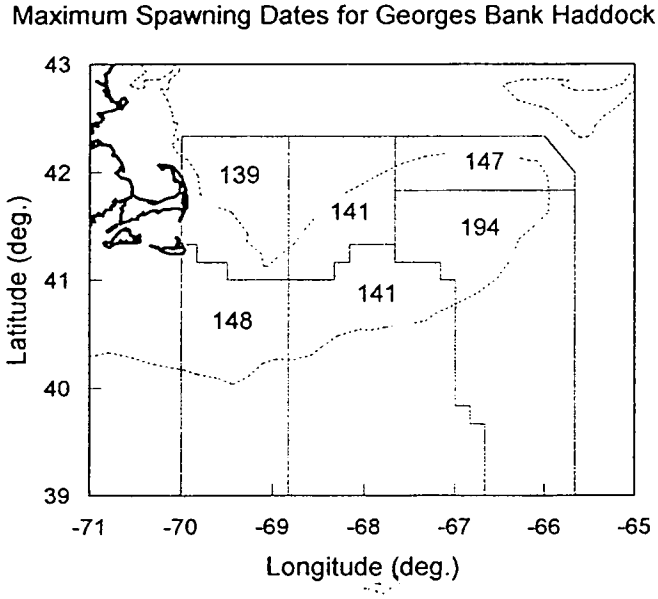


Figure 11: The dates of the first (top) and last (bottom) appearance of stage III haddock eggs in statistical unit area 5Zghjmno based on the 1977-87 MARMAP dataset.