Northwest Atlantic Fisheries Organization

Serial No. N864

NAFO SCR Doc. 84/VI/75

SCIENTIFIC COUNCIL MEETING - JUNE 1984

Comparison of Cod and Haddock Spawning in 1982 and 1983 on Georges Bank

by

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Introduction

That there is no correlation between larval abundance and subsequent year-class strength over thefull range of values is widely accepted (Sissenwine, in press). However, spawner-recruit considerations show that extremely low production of eggs and larvae generally results in a poor year-class. This has some predictive value in that a bad year-class can be predicted earlier than with a pre-recruit survey. In addition, it may offer an opportunity to identify the specific effects of the environment on ichthyoplankton.

In 1982 there was extremely poor cod and haddock larval production on Georges Bank which offers an excellent chance to examine specific effects on eggs and larvae.

We examine bottom temperature, average salinity (0-50 m), warm core ring (WCR) and major storm activity on Georges Bank in relation to the distribution and abundance of cod and haddock larvae in the springs of 1982 and 1983 for clues to the cause of extremely low production and/or survival of larvae in 1982.

Data on egg and larval abundance is from a series of MARMAP ichthyoplankton surveys in 1982 and 1983 (Table 1). Temperature, salinity and WCR activity is from four cruises in 1982 (Table 1). Additional WCR and temperature records were obtained from satellite imagery supplied by the Atlantic Environmental Group

(AEG, NMFS, NEFC, Narragansett, R.I.). Wind data and current meter records are from ENDECO Inc. in cooperation with the Mobil Research Development Corporation. The current data are from two moorings (Figure 1) which had instruments at 5 m and at half the water depth. Wind measurements were made on site 1 from the R/V ROWAN MIDLAND (Figure 1).

Information on the abundance and stage of the reproductive cycle for spawners is based on the spring bottom trawl survey (Table 1).

Results

The mean abundance of cod and haddock larvae in 1982 is one to two orders of magnitude lower than in 1983 (Tables 2 & 3). Morse (unpublished ms.) has estimated the total number of haddock larvae hatched for each year from 1977-1982 (Table 4) and, 1982 stands out as the year of lowest larval production.

Bottom Temperature

The average bottom temperatures on the eastern part of Georges Bank have been determined from data obtained on NEFC MARMAP and groundfish survey cruises. The specific area used is 41°-42°N, 66°-67°W where water depth is less than 100 m. Figure 2 shows the bottom temperature as a function of Julian day for the spring periods of 1964-1983. The average data for 1982 are shown by an open circle with the bars indicating the range of values observed. The average values for 1972-1983 are shown by solid circles with the range of observations indicated by the dashed envelope.

On 4 March 1982 (Day 63) the average bottom temperature was 3.4°C and was more than 1°C colder than in any other years shown. By 19 April (Day 109) the average temperature was 4.1°C, again about 1°C colder than average and 2°C colder than observations on the same date in 1983. It should be noted that similar cold spring bottom temperatures did occur from the mid-1960's through 1971.

Salinity

The average salinity on Georges Bank (Figure 7, 0-50 m from all MARMAP stations on the Bank) varies both seasonally and between years. Generally the maximum occurs in the winter and the minimum in the summer. In 1982, however, the salinity began the year at a low value - about 0.5% below the other years shown. This was due to a drop in salinity that began in the Gulf of Maine in late 1980 with the influx of low salinity water around Cape Sable. Throughout 1981 the surface layers of the Gulf showed a progressive decrease in salinity which was first evident on Georges Bank in the late fall of 1981. The low salinity on Georges in early 1982 does not appear related to a large influx of water directly from the Scotian Shelf and probably has little bearing on the larval survival on the Bank.

Warm Core Ring Entrainment

The only cod or haddock larvae found on Georges Bank were at three stations on the southern edge of the Bank between 66-67°W occupied on 19-20 April 1982. The contours of larval density (Figure 3) were open at the edge of the survey area suggesting that the distribution may have extended off the southern side of the Bank. Frontal analysis charts issued by AEG show that for the month preceding the larval observations, Warm Core Ring 82-A was nearly stationary south of the Bank near 67°W. A large amount of water from Georges Bank appeared to be entrained off the Bank by the ring from March through the time of the larval observations. The entrained water (shaded in Figure 3) appeared to be leaving the Bank in the same area that the larval distribution appeared to extend off the Bank. After 19 April the ring decreased in size and by early May disappeared from the AEG charts. A CTD/MOCNESS survey of the entrainment feature around ring 82-A was made on 25-26 April, including the area of the Bank where the larvae had been observed on 19 April. The survey showed that the entrainment contained water of Georges Bank hydrographic characteristics, but no cod or haddock larvae were found in the entrainment or on the southern edge of the Bank as far west as 68°W.

In the spring of 1983 a large entrainment feature was again observed off the southern side of Georges Bank in late March, in the vicinity of significant larval concentrations as shown from surveys carried out between 6-19 April. By mid-April both the ring and the entrainment appeared much reduced in size and by the end of April only a small deformation of the shelf/slope front remained. The larval distribution did not extend to the edge of the Bank and did not appear to extend off the Bank into the entrainment.

Storm Events

During April 6-9, 1982 (Julian Day 96-99) an intense storm passed through the Georges Bank region. The wind record (Figure 5A) indicates strong SW winds rotating to NW winds with speeds of 34-64 knots and gusts of up to 88 knots. The current records during the storm (Figure 5B) indicate that the normal southwestward flow abruptly changed to the southeast for a period of three days during the storm with a net horizontal displacement of about 25 nautical miles at 5 m depth and somewhat less at the deeper observation. The temperature and salinity records from the mid-depth instrument (68 m) on the deeper mooring (Figure 6) suggests that at the beginning of the storm period (Day 96) the shelf-slope front was located at the mooring, as indicated by the large variations in temperature and salinity over each tidal cycle. During and just after (Day 98-103) the storm, cooler, fresher water from Georges Bank was present.

A review of satellite images from the storm period indicates that the surface edge of the shelf-slope front moved offshore about 12 miles from 3 April to 10 April (Figure 1). This is consistent with the current measurement. The front off southeastern Georges Bank (66°W) appeared to move about 35 miles, but the picture is complicated by the entrainment feature associated with Warm Core Ring 82-A and the lack of satellite imagery any further east.

The implication from these results is that a significant movement of water off the Georges Bank occurred in response to the April 6-9 storm accompanied by a seaward displacement of the shelf-slope front. There is no indication, however, of how much shelf water might have been permanently exchanged or mixed into the slope region.

Discussion

There are several possibilities that may have caused the extremely low production and abundance of eggs and larvae on Georges Bank. Perhaps the simplest explanation would be that there was an extremely low spawning biomass in 1982. Both the survey index and VPA estimates of haddock biomass were low in 1982 (Figure 8) but not at historical minima, although the survey index for cod (Figure 9) is at the lowest level since 1963. Low spawning biomass undoubtedly contributes to poor recruitment but it is not the complete explanation. A regression analysis done on haddock numbers at age 1 against spawning biomass and average temperature during the larval period (April, May and June) explains about 43% of the variance in the recruitment from 1946 to 1980. The regression model used is ℓn (Temp) + ℓn (Spawner Biomass) + ℓn error. The regression was done using the stepwise regression program BMDP2R (BMDP, 1981). Good year classes are associated with warmer temperatures and larger spawning biomass. Spawning biomass accounts for the majority of the variance that is explained (25%). Results agree with that of Edwards (1984) who looked at a recruitment index (no. recruits/no. spawners) vs. average temperature in January-March.

Another possibility is that the MARMAP surveys missed the spawning period. This is not likely as ichthyoplankton surveys continued in the area through June. Spawning stage data obtained on the NEFC bottom trawl surveys in 1981 and 1982 show more pre-spawning adults in 1982 than 1981 (data is not yet available for

1983). However, the number of post-spawning fish was much higher in 1981. The 1981 spring bottom trawl survey was later than the survey in 1982 and presumably the timing of the cruises is the cause of the difference. What is most striking about the results is that about 50% more spawners were sampled (reflecting the abundance in the trawl survey in 1981 than in 1982.

It is generally assumed that fecundity rates are fairly consistent year to year. However, as Ware (1980) pointed out, "the empiricists, led by Nikolski (1969) and Bagenal (1973), have reported significant time variability in the annual size-specific fecundity rates of different species..." Ware (1980) cites fluctuations of 22-61% in herring (Nikolski, 1969) and 39-144% in haddock (Hodder, 1965). Similar interannual differences have been reported for Georges and Browns Banks (Halliday, personal communication).

The physical environment may contribute to egg and larval loss in several ways. The large storm on Georges Bank in 1982 may have been responsible for advection of a large number of eggs and larvae off the Bank. While storms may occur in every year the exact timing and magnitude of a particular storm are the critical elements in egg and larval survival. Storms of the magnitude of the 1982 storm are quite rare in April. Another possibility is that the colder than normal bottom water temperature on Georges Bank (when compared to recent years) may have contributed to the lack of eggs and larvae. Low temperature may result in increased predation mortality on eggs and larvae as the hatching time is greater and the growth of larvae is slower. Low temperatures may also reduce the fecundity of the spawners. The larvae that were observed on 19 April appear to have disappeared by 26 April and certainly by mid-May when the entire Bank was surveyed. The entrainment of water by Ring 82-A appears a likely cause of this disappearance. The entrainment could also be responsible for the low abundance of larvae observed on 19 April, having already removed eggs and larvae spawned early in March and April.

The difference between 1982 and 1983 may be in part related to differences in the entrainment processes. The 1982 event apparently removed water from the Bank proper, while in 1983, only water from the edge of the Bank was affected. The larval distribution during 1983 was not perturbed or deformed near the entrainment feature. Satellite images do suggest that the entrainment process is quite complicated and that the source of water entering an entrainment feature can vary spatially with respect to the ring.

There is as yet no data available to examine the possibility of increased predation mortality by either vertebrate or invertebrate predators as the cause of the low egg and larval abundance.

There are several possible mechanisms operating in 1982, cold water temperature, advection of eggs and larvae off the Bank during a large storm or through WCR activity and low numbers of spawners that could be the cause of the very poor 1982 year-class. The 1982 haddock year-class is equal to the poorest observed (Overholtz et al., 1983). However, 1981 is equally as bad as 1982 and preliminary data indicate 1983 is also poor (Overholtz et al., 1983). Since the temperatures in 1981 and 1983 are not anomalously low, is is probable that low temperature is not the sole cause of the poor recruitment in those years. It appears that while there are numerous possible mechanisms regulating year-class strength, different ones act to varying degress year to year. We are left with a situation that is very similar to the enigma of the lack of haddock larvae on Browns Bank in 1983 (Koslow et al., unpublished ms.). We can only reiterate that understanding of the mechanisms responsible for the poor recruitment on Georges Bank in 1982 and Browns Bank 1983 will take a concerted comparative effort on the physical and biological processes in the two areas.

Acknowledgements

We wish to thank W. Morse and L. O'Brien for their extreme helpfulness in supplying unpublished data on total haddock larval production and maturity stages, respectively. Thanks to M. Grosslein and S. Ramp for helpful comments and discussion on this paper.

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Table 1. List of Cruises in 1982 and 1983 on Georges Bank

Cruise	Date
ALBATROSS IV 82-02	2-11 March
DELAWARE II 82-02	12-23 April
DELAWARE II 82-03 ?	14 February - 9 March
ALBATROSS IV 82-04	19 April - 4 May
ALBATROSS IV 82-05	10-21 May
DELAWARE II 82-06	22-28 September
DELAWARE II 82-09	15-24 November
DELAWARE II 83-01	17-28 January
ALBATROSS IV 83-01	25 February - 3 March
ALBATROSS IV 83-02	28 March - 22 April
ALBATROSS IV 83-04	6-22 June

Table 2. Density (k=larvae/10m[2]) and abundance estimates (no. x 10^9) for haddock larvae, based on collections in four subareas of the western North Atlantic from Cape Hatteras, North Carolina to the Gulf of Maine, 1982-83. ND = no data (not sampled).

Year	Cruise	Date	Subarea	No. of Sta.	Positive Sta.	Mean Abundance (k)[1]	Standard Error (Sx)	Abundance (no. x 10^9)
1981	ALB 81-14	Nov-Dec	GOM	40	0	0	0	0
			GB	30	0	0	0	0
			SNE	19[2]	0	0	0	0
			MA	ND	ND	ND	ND	ND
1982	ALB 82-02	Feb-Mar	GOM	37	0	0	0	0
			GB	27	0	0	0	0
			SNE	44	0	0	0	0
			MA	38	0	0	0	0
	DEL82-02	Mar-May	GOM	44	1[3]	0.023	0.023	0.223
			GB	36	3	1.635	1.100	6.837
			SNE	40	0	0	0	0
			MA	45	0	0	0	0
	DEL82-03 ALB 82-06	May-Jun	GOM	37	8	11.799	6.255	115.664
			GB	30	5	0.899	0.391	3.759
			SNE	35	3	0.454	0.256	2.721
			MA	30	0	0	0	0
	DEL 82-09	Nov-Dec	GOM	51	0	0	0	0
			GB	30	0	0	0	0
			SNE	43	0	0	0	0
			MA	28	0	0	0	0
1983	DEL 83-01 ALB 83-01 DEL 83-02	Jan-Feb	GOM	51	0	0	0	0
			GB	28	4	2.556	1.287	10.686
			SNE	36	2	0.422	0.304	2.529
			MA	38	-	0	0	0
	ALB 83-02	Mar-May	GOM	38	0	0	0	0
			GB	29	12	63.997	36.837	267.563
			SNE	34	4	2.342	1.446	14.032
			MA	38	0	0	0	0
	ALB 83-04	May-Jun	GOM	54	0	0	0	0
			GB	30	4	1.102	0.580	4.608
			SNE	42	5	1.937	0.984	11.603
			MA	50	0	0	0	0

[1]k = mean number of larvae/10 m^2 surface area. Refer to Berrien et al. (in press) for discussion of rationale and procedures for use of Δ-distribution which appears to describe these data. Abundance is expansion of k to reflect subarea size.

[2]Incomplete coverage.

[3]When n_1=1, the mean is estimated by x/n, and its variance by x^2/n^2, where x is the single non-zero value; both are unbiased estimators (Berrien et al., in press).

Table 3. Density (k=larvae/10 m^2) and abundance estimates (no. x 10^9) for Atlantic cod larvae, based on collection in four subareas of the western North Atlantic from Cape Hatteras, North Carolina to the Gulf of Maine, 1982-83. ND = no data (not sampled).

Year	Cruise	Date	Subarea	No. of Sta.	Positive Sta.	Mean Abundance (k^1)	Standard Error (Sx)	Abundance (no. x 10^9)
1981	ALB 81-14	Nov-Dec	GOM	40	3	0.582	0.343	5.703
			GB	30	3	1.576	0.886	6.589
			SNE	19[2]	4	2.479	1.359	14.850
			MA	ND	ND	ND	ND	ND
1982	ALB 82-02	Feb-Mar	GOM	37	2	0.445	0.315	4.361
			GB	27	3	0.473	0.263	1.979
			SNE	44	5	0.936	0.519	5.608
			MA	38	1[3]	0.058	0.058	0.336
	DEL 82-02	Mar-May	GOM	44	3	0.396	0.224	3.886
			GB	36	5	2.504	1.443	10.471
			SNE	40	1[3]	0.025	0.025	0.150
			MA	45	2	0.141	0.104	0.825
	DEL 82-03	May-Jun	GOM	37	5	1.799	0.774	11.513
			GB	30	1[3]	0.033	0.033	0.139
			SNE	35	3	0.371	0.215	2.220
			MA	30	0	0	0	0
	DEL 82-09	Nov-Dec	GOM	51	2	0.361	0.266	3.535
			GB	30	1[3]	0.033	0.033	0.139
			SNE	43	2	1.266	1.053	7.582
			MA	28	0	0	0	0
1983	DEL 83-01	Jan-Feb	GOM	51	0	0	0	0
	ALB 83-01		GB	28	7	8.625	3.852	36.059
	DEL 83-02		SNE	36	13	4.715	1.706	28.243
			MA	38	2	0.153	0.107	0.890
	ALB 83-02	Mar-May	GOM	38	0	0	0	0
			GB	29	15	130.527	73.883	545.722
			SNE	34	7	5.994	3.996	35.909
			MA	38	1[3]	0.026	0.026	0.153
	ALB 83-04	May-Jun	GOM	54	2	0.869	0.767	8.514
			GB	30	6	3.550	1.918	14.844
			SNE	42	2	0.307	0.215	1.840
			MA	50	1[3]	0.020	0.020	0.117

[1] k = mean number of larvae/10 m^2 surface area. Refer to Berrien et al. (in press) for discussion of rationale and procedures for use of Δ-distribution which appears to describe these data. Abundance is expansion of k to reflect subarea size.

[2] Incomplete coverage.

[3] When n_1=1, the mean is estimated by x/n, and its variance by x^2/n^2, where x is the single non-zero value; both are unbiased estimators (Berrien et al., in press).

Table 4. Total abundance of haddock larvae ($x10^9$) for Georges Bank 1977-1982. Data from W. Morse (NEFC, Sandy Hook Laboratory)

Year	Larvae Production ($x10^{-9}$)
1977	2578.6
1978	4475.7
1979	7467.4
1980	5505.5
1981	4608.3
1982	202.2

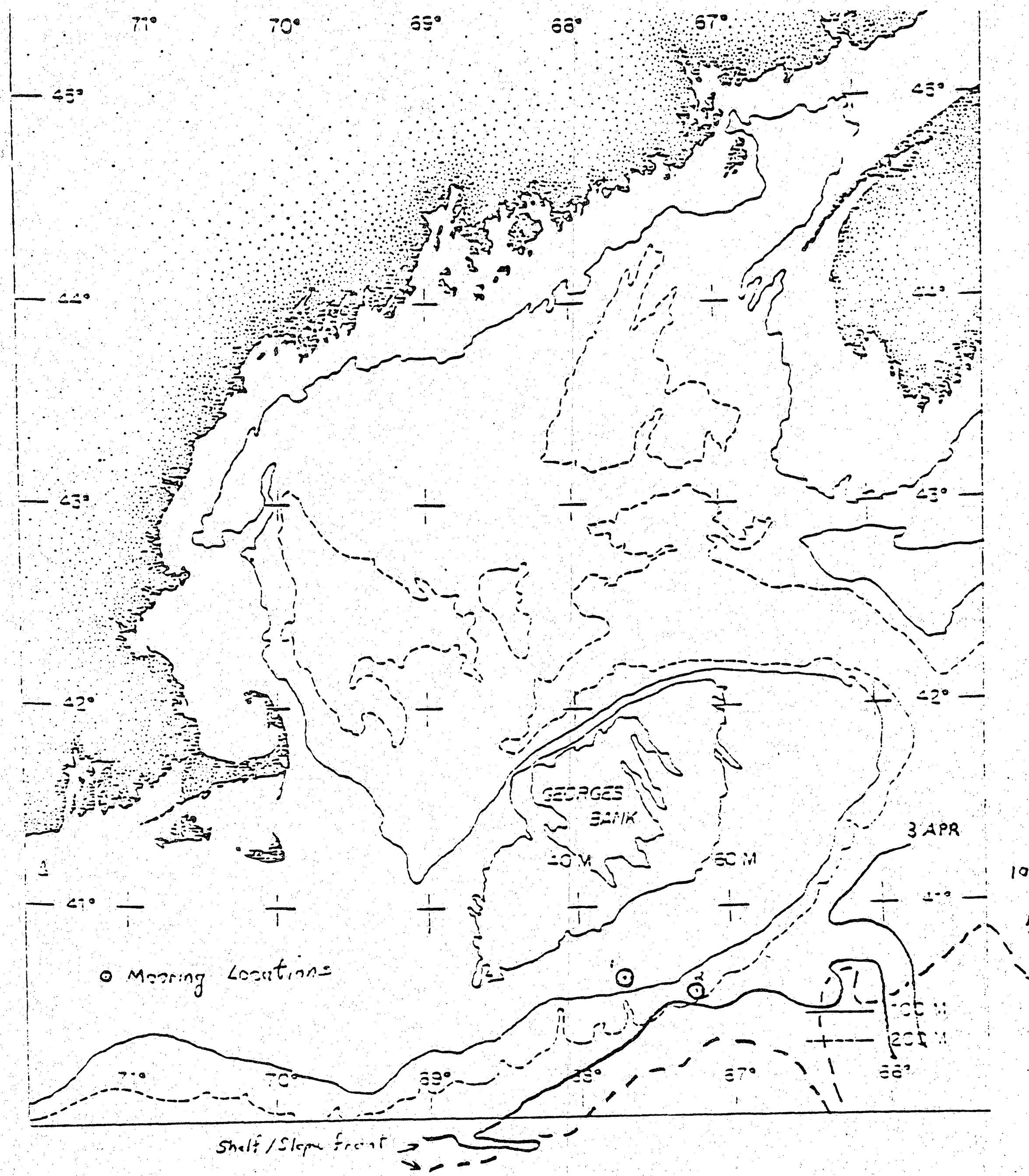

Figure 1. Georges Bank with the positions of the shelf-slope front before (3 April 1982) and after (10 April 1982) a major storm.

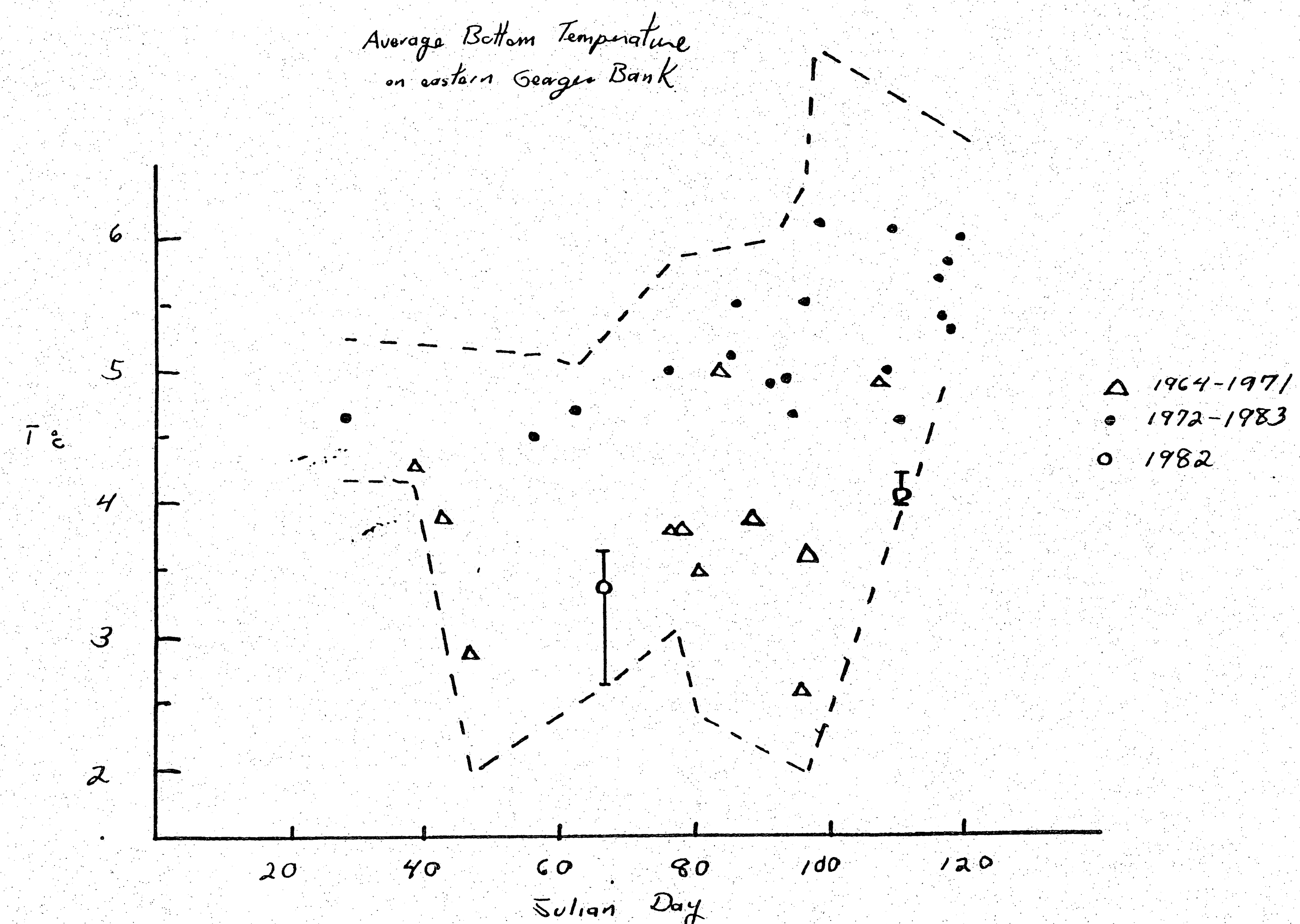

Figure 2. Average bottom temperature on eastern Georges Bank. The range of temperature is indicated by the envelope (dashed line) around the data.

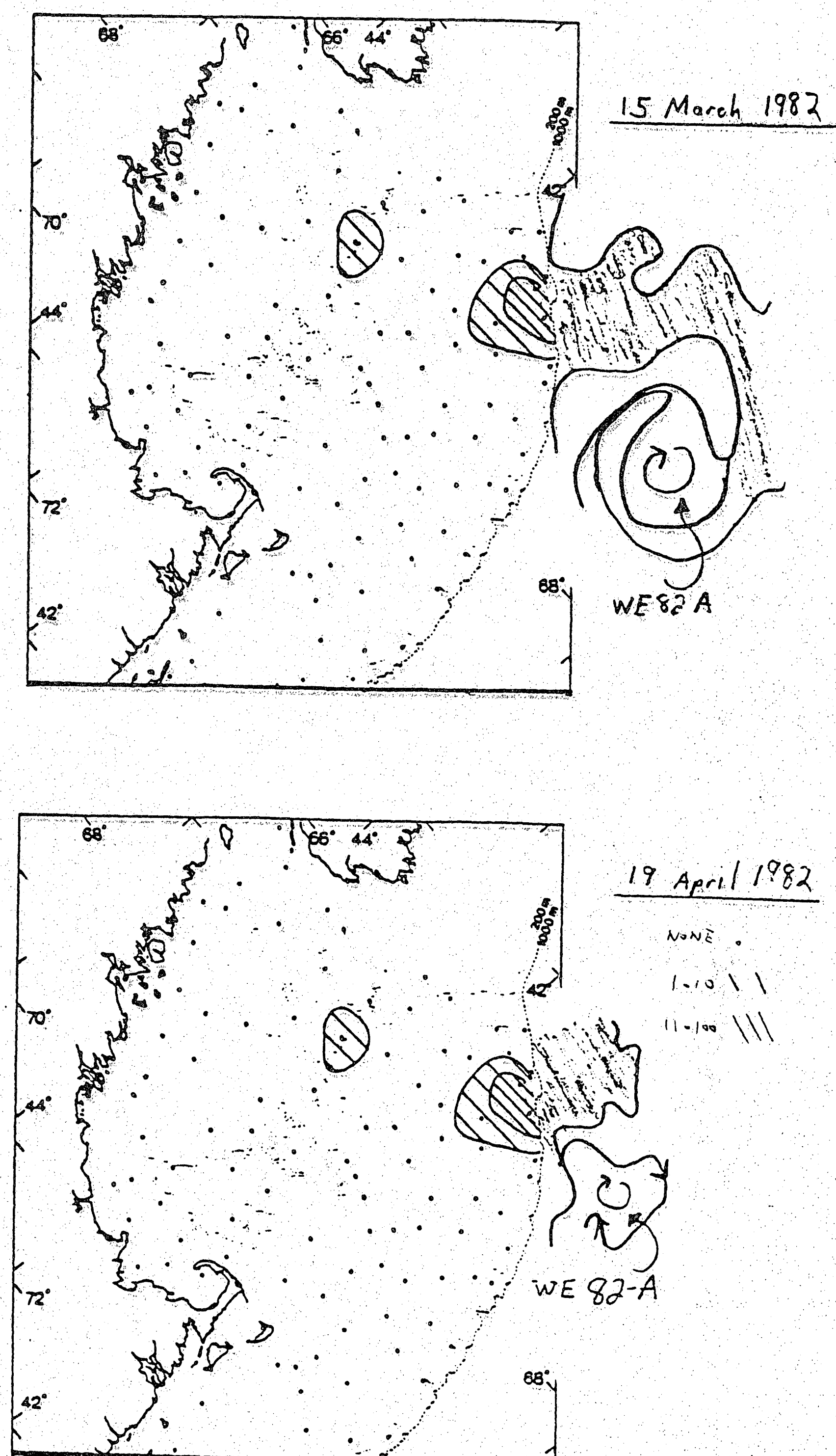

Figure 3. Warm Core Ring WE 82-A with associated entrainment feature of shelf water (shaded area) and open contours of larval density on Georges Bank.

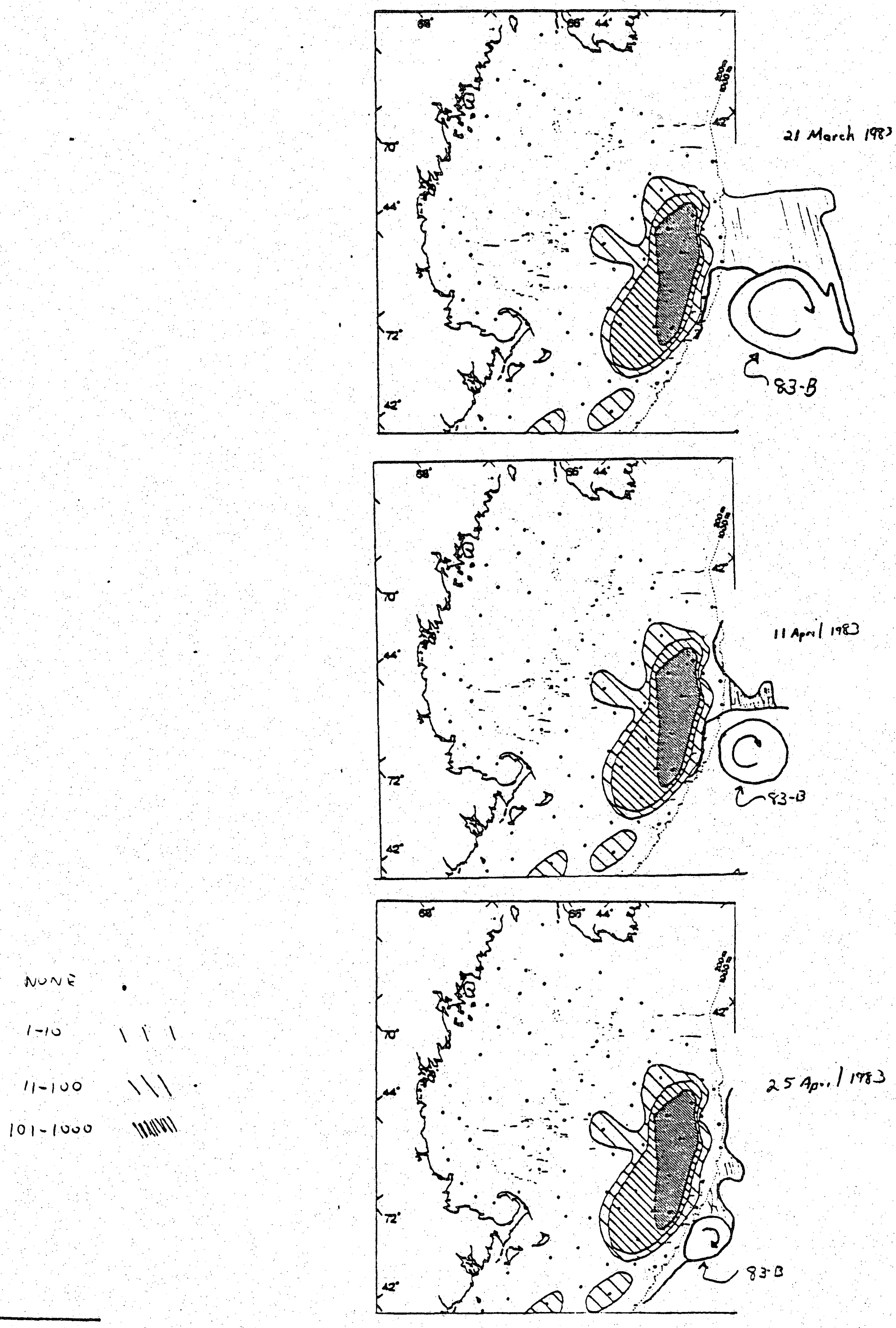

Figure 4. Warm Core Ring 83-B with associated entrainment of shelf water (shaded area) and closed contours of larval density.

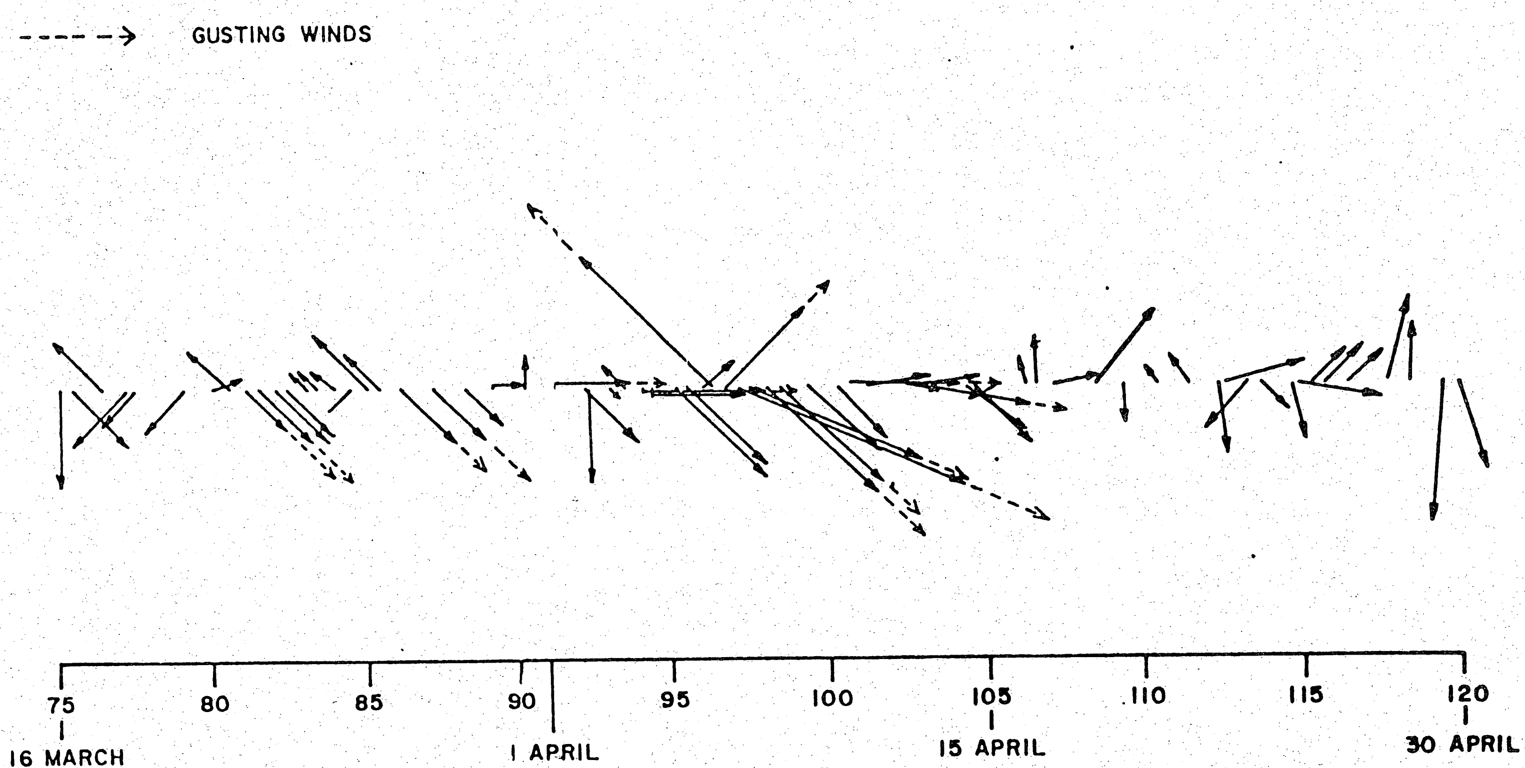

Figure 5A. Wind data for ENDECO deployment #3. From Ramp (1982). Arrows indicate direction wind is blowing in the direct of the arrow.

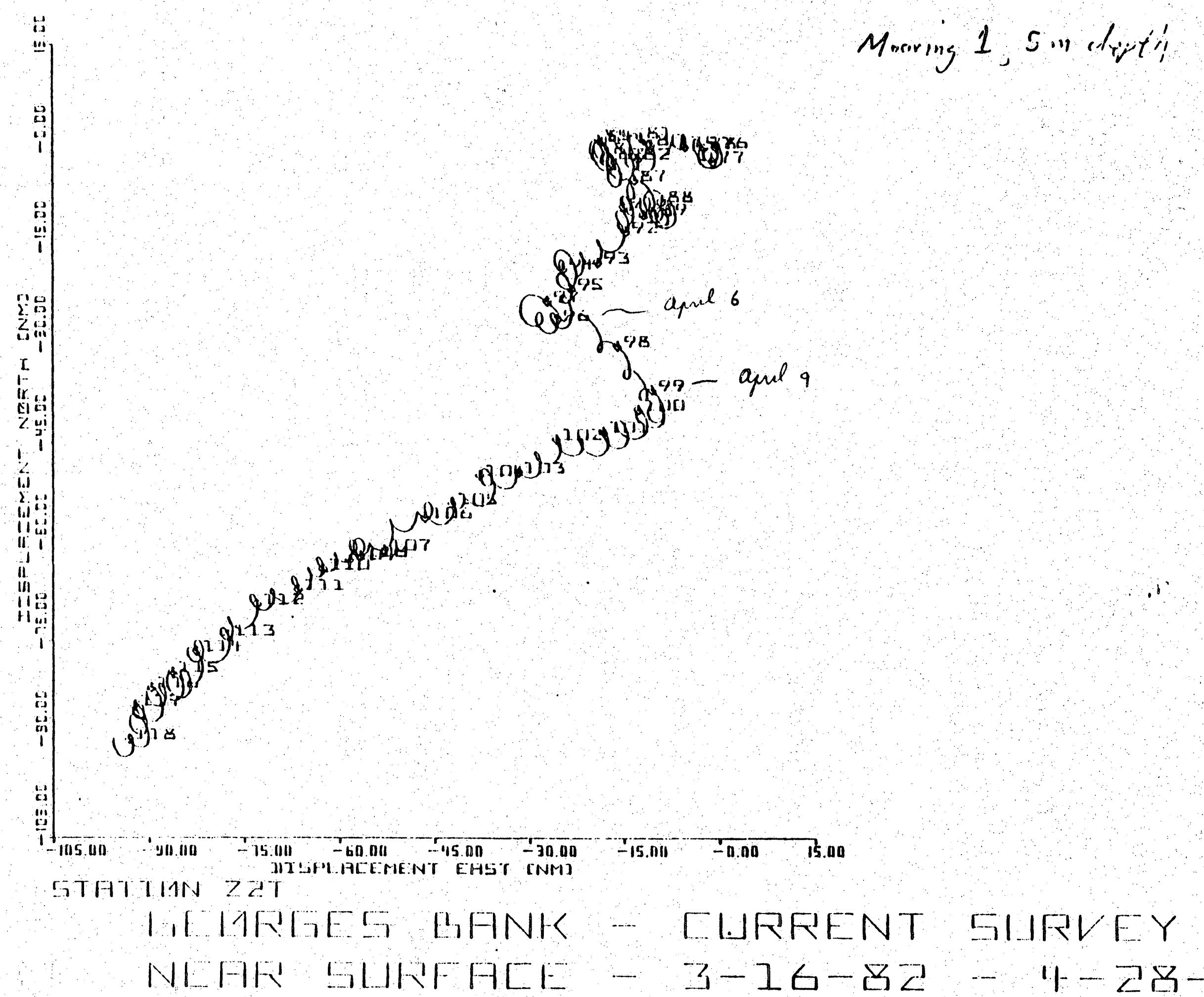

Figure 5B. Current meter data from ENDECO deployment, site 1, 5 m instrument showing the striking change in current direction at the time of the storm, April 6-9.

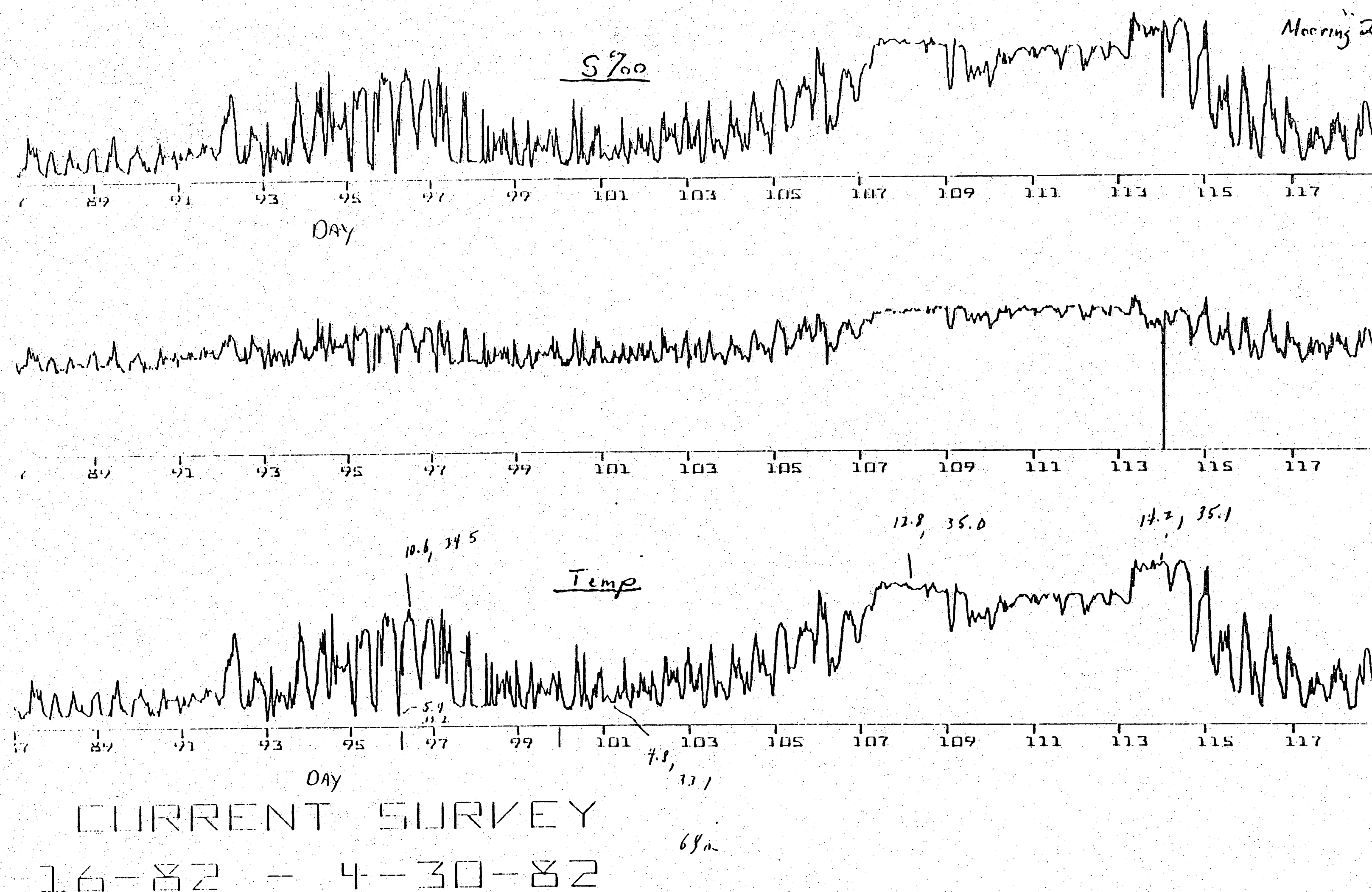

Figure 6. Salinity and temperature records from mid-depth instrument (68 m). Temperature and salinity records indicate movement of the front.

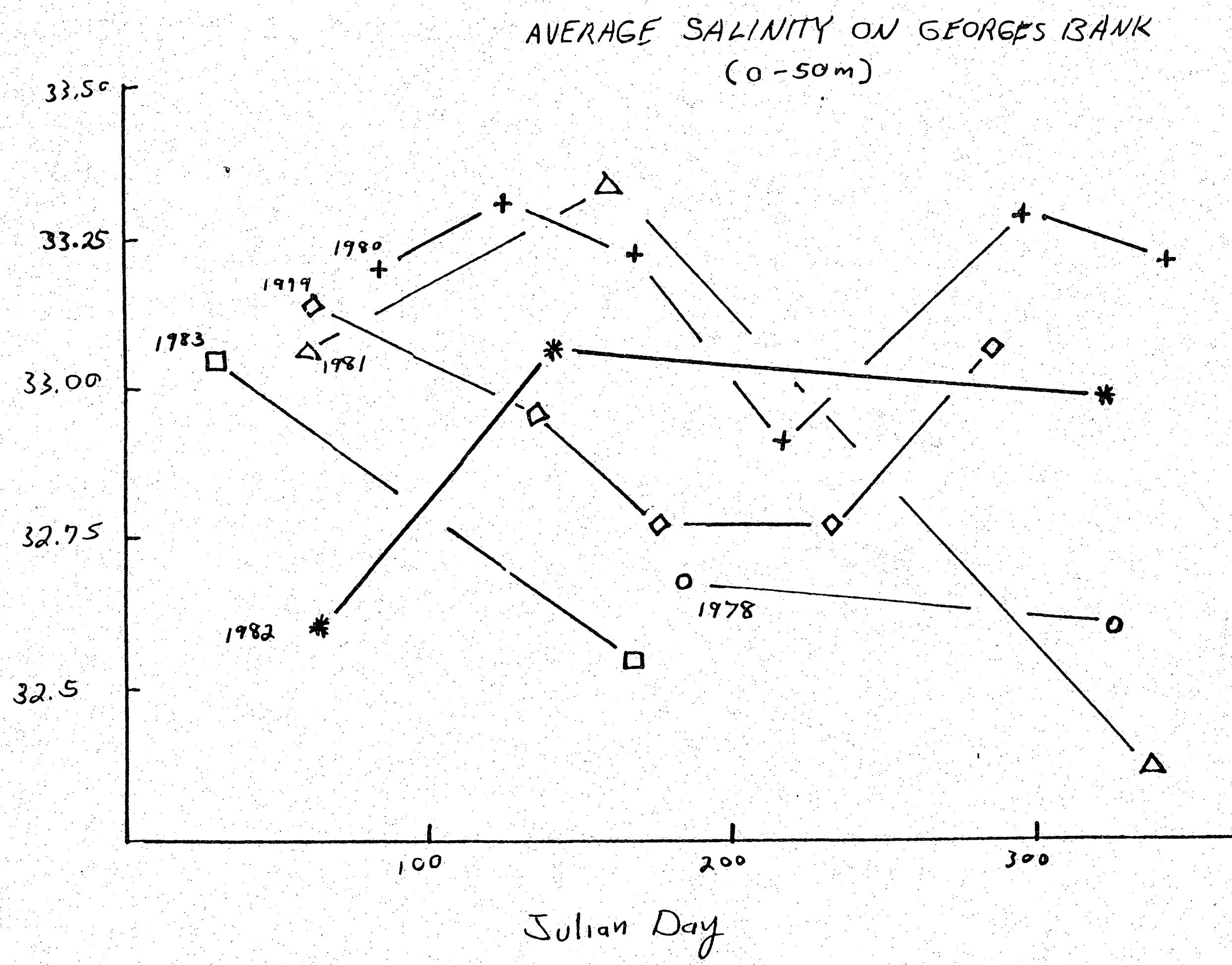

Figure 7. Average salinity (0-50 m) on Georges Bank for 1978-1983.

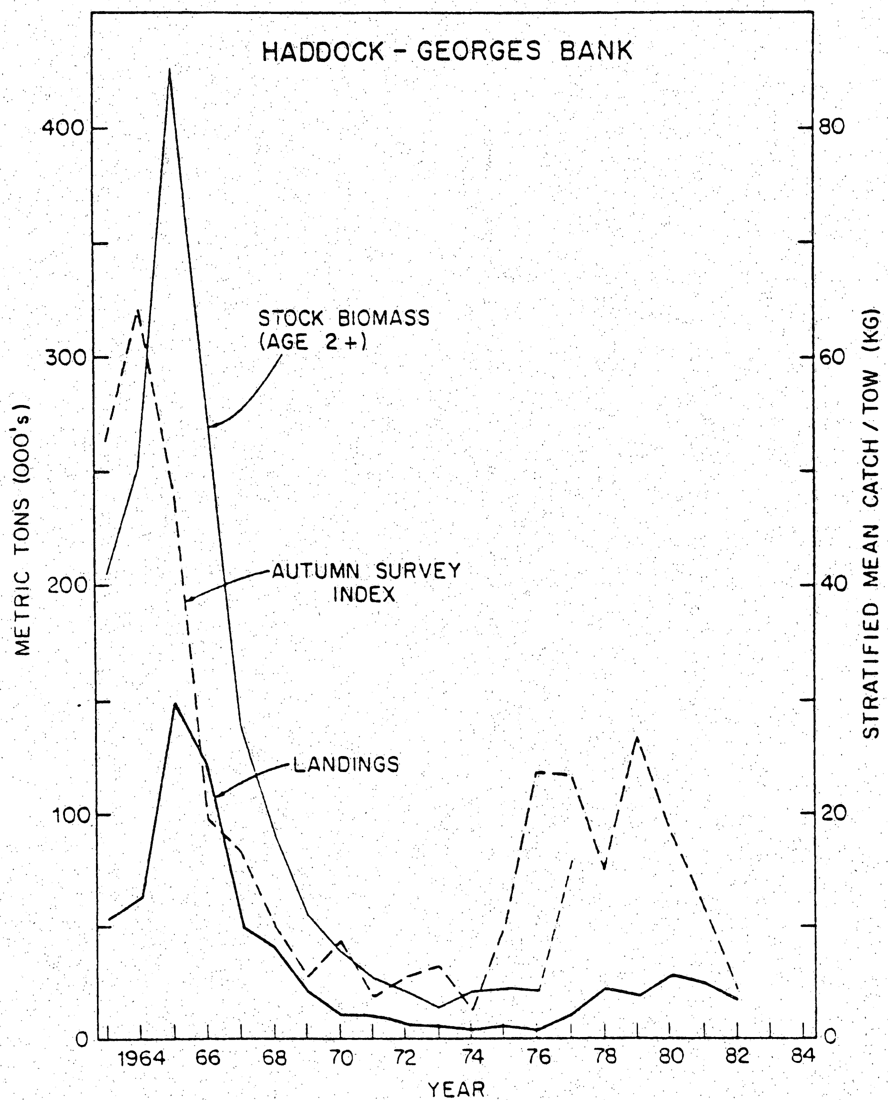

Figure 8. Nominal catches, stock biomass and NMFS survey index of abundance for Georges Bank haddock. From Status of the Stocks Rept. 1983.

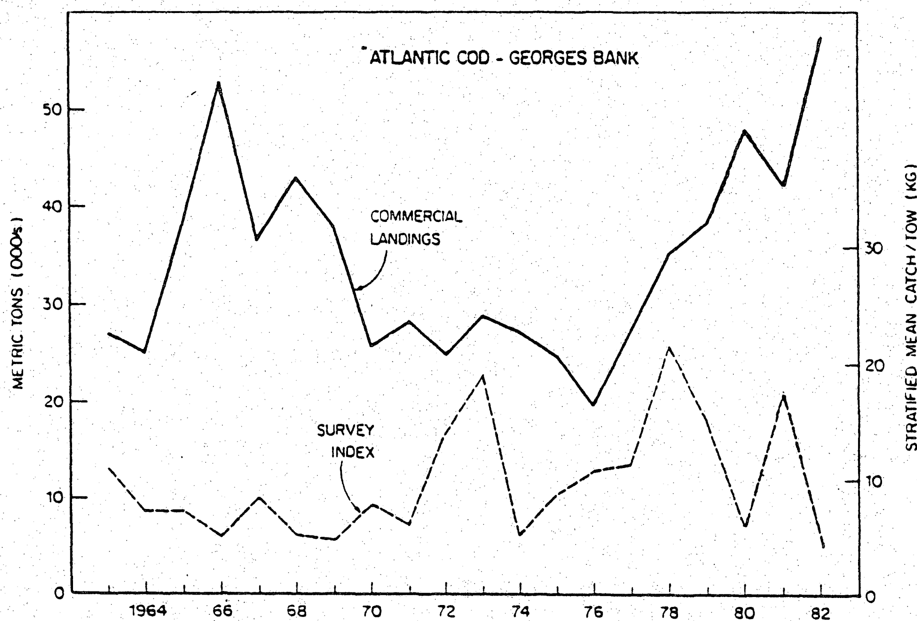

Figure 9. Nominal total commercial catches and indices of abundance from NMFS autumn research vessel bottom trawl surveys for Atlantic cod on Georges Bank.