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DISTRIBUTION AND ABUNDANCE OF O-GROUP REDFISH IN THE IRMINGER SEA AND AT EAST-GREENLAND IN 1970-94 AND IT'S RELATION TO *SEBASTES MARINUS* ABUNDANCE INDEX FROM THE ICELANDIC GROUNDFISH SURVEY

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ABSTRACT

Annual variations in abundance and distribution of 0-group redfish in the Irminger Sea have been recorded since 1970. These are reviewed for the time period 1972 to 1994 and relation are investigated between abundance indices based on the 0-group survey, a groundfish survey and the CPUE in the fishery.

The abundance of 0-group redfish in the Irminger Sea and at Iceland varies considerably from year to year. At Iceland, the abundance is generally low and depends on the influx of warm Atlantic water into the area north of Iceland. The upper layer temperatures in the Irminger Sea are normally 7° - 9°C.

The 0-group redfish off North Iceland belongs to *Sebastes marinus*. In the Irminger Sea, the proportion of this species is highest in the sub-areas East Greenland North and Central Irminger Sea North.

Length-based abundance indices from the Icelandic groundfish survey (which cover the Icelandic shelf) are available for *S. marinus* from 1985 to 1994. From these indices, a recruitment index (in relation to the Icelandic fishery) was constructed, representing the abundance of 31-35 cm *S. marinus*. Possible relationships between the recruitment index and the 0-group were investigated by considering different time-lags (10-15 years) between the 0-group appearance and it's recruitment to the fishery. A significant relationship with r^2 from 0.60 to 0.68 was found by assuming a time-lag of 13 years between the 0-group and the recruitment index.

INTRODUCTION

At the Statutory Meeting of ICES in 1969 it was decided to initiate an 0-group survey of the waters around Iceland, the Irminger Sea and off East Greenland employing similar techniques as used in the Barents Sea O-group surveys since 1965. In the beginning, these surveys which started in 1970 were carried out jointly by various ICES member states, but from 1976 onwards Iceland has conducted the survey with two research vessels operating simultaneously.

The known "spawning" areas of redfish are in the southeastern part of the Irminger Sea, extending far to the southwest. The redfish fry is carried by the current system of the region into the Irminger Sea towards East Greenland and southwards along the East Greenland coast and, to some extent, to the west and north of Iceland.

The distribution and abundance of 0-group fish in the Iceland- East Greenland area have been investigated annually in August since 1970. The preliminary results were presented as annual reports at the ICES Statutory Meetings (1-3,5,7,9,11,14,15,17,32-40,46-51,53) and in Annales Biologiques (4,6,8,10,12,13,16,18-20,32,41,45). The main purpose of the survey was to obtain an indication of the relative year class strength at the 0-group stage of species of commercial importance *e.g.* cod, haddock, capelin and redfish. A first review of the results of the 1970 - 1975 surveys, including the above mentioned species was presented in 1976 (52). Special studies have been carried out on 0-group cod based on material from the 0-group surveys (23, 25). However, no such studies have so far been carried out on 0-group redfish.

Several authors have reported on the occurrence of 0-group redfish in the Irminger Sea and adjacent waters, *e.g.* Tåning 1949 (44),Henderson 1961 (26) and Magnússon 1968 (28). The month of August was selected for the remaining 0-group surveys following initial experiments in July-September of 1970 and 1971. In August, 0-group redfish are distributed pelagically in the upper water layers throughout the Irminger Sea while cod, haddock and capelin are mainly observed in the upper water layers of the shelf areas off Iceland and to some extent also off East Greenland.

Three species of redfish inhabit the Iceland - East Greenland - Irminger Sea area, *i.e.* *Sebastes viviparus*, *S. marinus* and *S. mentella*. Recently, the last named species has been identified as two stocks, *i.e.* an oceanic and a deep-sea stock. However, in the presentation of the annual abundance indices, of 0-group fish, 0-group redfish have been collectively reported as one group, although 0-group redfish have been identified into *Sebastes marinus* and *S. mentella* since 1980 (31). The occurrence of 0-group *S. viviparus* has always been negligible and is omitted in this paper.

It has always been the intention to link the O-group abundance indices to the abundance of redfish later in their lives. This became possible with the implementation of the Icelandic groundfish surveys, in 1985. These annual groundfish surveys cover the entire Icelandic shelf by a dense net of trawl stations down to the 500 m isobath, in March. Although the surveys are mainly designed for assessing the cod stock, data are collected on all other species inhabiting this area and depth range. Since *Sebastes marinus* are mainly observed at depths of less than 500 m, the groundfish survey data on that species can be used in this study. Data on *S. mentella* , which live mainly at depths exceeding 500 m, had to be excluded.

The main aims of this paper are:

1. To present the results of the 0-group surveys for the time period 1972-1994 as distribution charts and time-series of abundance indices for the various sub-areas.
2. To answer the question whether there is a connection between the 0-group indices and the catch per unit of effort (CPUE) in the Icelandic commercial redfish fishery by comparing a recruitment abundance index from the Icelandic groundfish surveys with 0-group indices.

Materials and Methods

The Design of the 0-group Survey

The sampling strategy has remained more or less unchanged during the whole period of investigation. On the other hand, the survey coverage has been quite variable.

Echo sounders (38 and 120 KHz) were used to monitor changes of fish abundance and distribution. Trawl stations were not fixed but trawling was carried out at a depth of about 5 to 50 meters following changes of the echo records. Thus, the distance between the trawl stations could vary according to the nature and strength of the echo traces. Since 1976, trawling has, nevertheless, been undertaken every 20 to 30 nautical miles even in the absence of echo traces. The trawl used was a Harstad pelagic trawl, with a nominal 18 m x 18 m opening and a mesh size of 0.5 cm x 0.5 cm, in the codend. A headline transducer and/or a Scanmar depth recorder were used for measuring the trawling depth. The general tow length of 0.5 nautical mile was sometimes extended, depending on the acoustic traces but all hauls were finally adjusted to catch in number per one nautical mile towed.

The catch was analyzed to species (redfish unsorted), subsamples were counted, raised to the total catch per nautical mile, and the total length of the specimens was measured in mm. Since 1980, redfish subsamples were identified into *Sebastes marinus* and *S. mentella* as described by Magnússon (31).

The area of distribution was divided into sub-areas as shown in Figure 1. Density charts of 0-group redfish were drawn, based on the CPUE and on echo traces (Figs. 2a,b,c and d). For calculating the abundance indices of 0-group fish, the catch per unit of effort data were converted for each species into the average number of fish per square nautical mile, the catches grouped into several density strata and multiplied by the area of each stratum (in square nautical miles). The method was described by Vilhjálmsson and Fridgeirsson (52). The abundance indices of O-group redfish are given by areas in Table 1.

The total distribution area of 0-group redfish was never covered during any of the surveys. Therefore, the abundance indices of 0-group redfish were presented as number of fish x 10^6 per square nautical mile.

The Icelandic groundfish survey

Abundance indices, by 1 cm length groups, were derived for *S. marinus* from the annual Icelandic groundfish survey, conducted in March. The survey was described in Pálsson *et al.* 1989 (42). The number of stations taken each year range from approximately 580-600, most of them taken at less than 500 m depth on the Icelandic shelf (All stations are inside the Icelandic sub-areas shown in Fig. 1). The raw data for a given year consist of the number of fish caught per station, along with length measurements. The observed length distribution of each station was scaled in accordance with the number caught and towing length. The resulting length distributions were integrated by averaging, within each length group, in statistical rectangles (of same sizes) and then summing across rectangles, resulting in indices of the annual number of fish in each length group.

Exploring the possible relationship between the 0-group- and *S. marinus* recruitment indices

If age-based indices for recruiting *S. marinus* were available, it would be rather straightforward to test whether there was a relationship between the 0-group abundance of a year class and it´s strength as a recruiting year class to the fishery. But this is not the case. Because of the uncertainty in age-determinations of *S. marinus* (and of other *Sebastes* species), only length-based indices were available.

An example of the length distribution of *S. marinus* in the commercial fishery at Iceland is a rough indication of abundance and is given below for the years 1993 and 1994:

	5% is below:	25% is below:	50% is below:	75% is below:	95% is below:	Total number
1993	29.8 cm	34.4 cm	37.8 cm	40.2 cm	45.2 cm	12,994
1994	30.0 cm	33.2 cm	37.0 cm	40.5 cm	46.0 cm	11,557

It is believed that the length distribution for these two years is characterized by an unusual amount of 'small' fish. The fishery has been regulated in such a way that a fishing area is closed if 20 % of the *S. marinus*catch consists of smaller fish than 33 cm. With both the length distribution in the fishery and it's regulation, it was decided to construct an annual recruitment index for redfish from the Icelandic groundfish survey by using the total abundance of 31 to 35 cm *S. marinus* . This time series of the this index is given in Figure 3.

As shown in Figure 4 (groundfish survey indices), an appearance of a year class in the survey area is indicated in the years 1986-88 and another year class in the years 1991-93. The year class appearing in 1986 is peaks at approximately 7 cm and two years later (1988) at about 11.5 cm, a growth of about 2.3 cm per annum. The year class appearing in 1991, peaks at 8 cm and at about 13 cm two years later (in 1993). This also indicates a growth of about 2.5 cm per annum. By comparing these appearances in the groundfish survey to the 0-group survey, it is seen that in 1985, there was some amount of 0-group redfish on the Icelandic Shelf and again in 1989 (and even in 1988, which has it's correspondence in a small peak in the 1989 groundfish survey). It is tempting to assume that at age one*S. marinus* is approximately 7.5 cm long and at that time growing about 2.5 cm per year. At age 4 it would then be about 15 cm long and approximately 30 cm at age 10. These calculations are based on a linear growth of 2.5 cm per year for the first years which is probably an overestimation. We then could conclude that 31-35 cm *S. marinus* (recruiting to the Icelandic fishery) is probably at least 11 years old. Similar results were reported by Magnusson *et al.* 1988 (30).

In order to compare the groundfish survey redfish recruitment index (31-35 cm) to the 0-group survey indices, we first estimated the correlation between different series of 0-group indices, all with different year range, to the groundfish survey index. As an example we estimated the correlation between a 1972-81 0-group series and the 1985-94 groundfish survey indices. This corresponds to a 13 years time-lag between the 0-group and the recruitment to the fishery. Two methods were applied: (1) Estimate the correlation coefficient (r) by the method of Minimum Volume Ellipsoid Covariance. This was done within the S-plus statistical package (for reference see the S-plus manuals and reference therein). (2) Estimate the significance of the slope (β) in the model:

> $R_y = \mu + \beta I_{r,y-l}$ where μ and β are estimated and:
> R_y is the length-based recruitment index from the groundfish survey for year y. $I_{r,y-l}$ is an 0-group index for region r in year y-l, where l is the time-lag between the 0-group and the recruitment to the fishery.

This model assumes an average recruitment index, μ, and fluctuation around that average caused by the abundance of the 0-group year class in question, $I_{r,y-l}$, and the estimated slope, β. Naturally we are most interested in seeing a positive significant value for β. The reasion for using the method of Minimum Volume Ellipsoid Covariance to estimate the correlation coefficient is that this method is less sensitive to outliers than the traditional one. The time-lags tested were from 10 years (1975-1984 0-group series, at most 10 observations) to 15 years (1972-79 0-group series and 1987-94 recruitment series, at most 8 observations). Series with fewer than 8 observations were not treated.

The second step was to extend the above model to include more than one 0-group index, *i.e.* 0-group indices from two or more year classes and/or from more than one sub-area. These are estimate models of the type:

$$R_y = \mu + \beta I_{r,y-l} + \gamma I_{r,y-l-1} + \cdots$$

To test which of the extensions were significant, the Akaike Information Criteria statistic (AIC), see *e.g.*Chambers 1992 (24) was used.

RESULTS

Distribution and Abundance of redfish in the 0-group Survey

The annual distribution and abundance of 0-group redfish in the Irminger Sea, at East Greenland and at Iceland is shown in Figures 2 a, b, c, and d, for the period 1972 to 1994. For several reasons the coverage of the area was very variable, *e.g.* due to weather and ice conditions, participation of vessels and availability of vessel time. During the period 1984 to 1990, the survey area in the Irminger Sea had to be severely restricted, in particular in 1984. In general, only the northernmost part of the Irminger Sea was covered during this period. Further restrictions were implemented in 1987 when the area off South Iceland was excluded. However, this area was again included to some extent in the survey of 1994.

The distribution charts show fairly variable abundance patterns. Until 1975, the main abundance of 0-group redfish was indicated both at East Greenland and in the Central Irminger Sea. During the period 1976 to 1982, the main densities were observed off East Greenland. The 1979 survey was carried out somewhat later than in the other years (August-September) and obviously a great part of the 0-group fish had already descended to the deeper layers. Thus, *e.g.* cod and redfish, caught with bottom trawl off East Greenland were in some areas feeding heavily on 0-group redfish. In 1983, the distribution was unusual. 0-group redfish were almost totally lacking off East Greenland and their abundance was exceptionally low. Little can be said on the general distribution and abundance of redfish in the Irminger Sea in 1984 because of the extremely limited coverage of the possible distribution area. However, the charts for the years 1985 to 1990 might indicate a similar density distribution pattern to that of 1976 to 1982. In the period 1991 to 1994 the distribution pattern seemed to have changed again and resembled that of the years prior to 1976. Time-series of 0-group indices for five sub-areas are given in Figure 5.

In Icelandic waters, redfish are generally poorly represented in the 0-group catches and the distribution is irregular. In some years, *e.g.*in 1984, they were almost totally lacking in the Icelandic area while in some of the other years, *e.g.*in 1980, they were fairly common.

The identification of 0-group redfish into *Sebastes marinus* and *S. mentella* was carried out for the sub-areas East Greenland North, Central Irminger Sea North and Dohrn Bank, from 1980 to 1991 and, additionally, for the sub-areas East Greenland South and Central Irminger Sea South, from 1992 to 1994. However, during 1984 to 1990, when the survey area was greatly restricted, the sub-area Central Irminger Sea North was only partly covered. The proportion of *S. marinus* varied greatly within each sub-area from year to year but *S. marinus* dominated in sub-areas East Greenland North and Central Irminger Sea North, in most years. In the southern sub-areas (East Greenland South and Central Irminger Sea South), *S. mentella* dominated. In the Icelandic area, the 0-group redfish consisted almost entirely of *S. marinus*.

The temperature of the Irminger Sea was somewhat variable in the upper water layers from year to year, in August. The dominating temperatures at 20 m depth were between 7° and 9°C, except for the year 1983 which was colder (4°-8°C) than the preceding (7°-11°C) and the following year (7°-10°C). Along the East Greenland shelf, the temperature declines rapidly towards the shore. The distance of the temperature front to the East

Greenland coast line varied considerably from year to year. Concentrations of 0-group redfish were frequently observed at the temperature front.

The temperature off the north coast of Iceland depends largely on the influx of warm Atlantic water into the area from the west. The annual variation in temperature is even more pronounced in this region than in the Irminger Sea. The dominant temperatures in this area were between 5° and 7°C in most years, increasing to 8° even 9° in some years, *e.g.* in 1990. However, in years with little or no influx of Atlantic water, the temperature can decrease greatly, in extreme cases from 0° to 6°C as in 1993.

The relationship between 0-group- and *S. marinus* recruitment indices

The *S. marinus* abundance indices based on the annual Icelandic groundfish survey are presented in Figure 4 (in 1 cm groups for the years 1985-94). Figure 3 shows the time-series of the recruitment index (length-groups 31-35 cm).

The estimated correlation coefficient (r) between 0-group series from the five sub-areas, with different time-lag (years) and the groundfish survey recruitment index are given in Table 2. Similarly, Table 3 holds the p-values for the significance of the slope-coefficient (β) in the model: $R_y = \mu + \beta I_{r,y-l}$

The sub-areas Central Irminger Sea North and the East Greenland North are best covered by the 0-group survey and have, probably, the highest proportion of *S. marinus* 0-group. Therefore, it is not surprising to find a positive trend over a range of time-lags for these two areas and in both cases peaking with 13 years lag between the 0-group and the recruitment index (Table 3).

Figure 6 is a scatter plot of the recruitment indices vs. the 0-group series with 13 years time-lag for E-Greenland North and Central Irminger Sea North. There is a positive trend in both figures, but this is somewhat curved and not far from the shape of the logarithmic function. It was therefore decided to estimate models of the form:

$$R_y = \mu + \beta \log(I_{r,y-l} + 1)$$

i.e. transforming the 0-group indices, I, to log(I+1). The resulting p-values for the significance of the slope β are in Table 4 (similar to Table 3).

As seen when comparing Table 4 to Table 3, there is a slight improvement in the regression when transforming the 0-group indices, I, to log(I+1).

The next step would be to estimate models of the form:

$$R_y = \mu + \beta \log(I_{r,y-l} + 1) + \gamma \log(I_{r,y-l-1} + 1) + \cdots$$

This implies using more than one series of 0-group indices to predict recruitment. When using the AIC statistic to test whether a given 0-group series should be included in the model or not, the results were such that there was only one series included in the above model, *i.e.* the 0-group index for the Central Irminger Sea North with 13 years time-lag. The p-value for the slope was < 0.01 (which is significantly different from zero at the 1% level) and the R-squared value was about 0.68, *i.e.* explaining about 68% of the variance in the recruitment index.

From Table 4 it is seen that the relationship between the recruitment and 0-group indices peaks with 13 years time-lag, both for the Central Irminger Sea North and E-Greenland North. In addition, some positive trend was observed for the series with 12 and 14 years time-lag. By a simple ad-hoc method, two new '0-group indices' were constructed, (1) by adding the indices with 13 years time-lag from the sub-areas E-Greenland North and Central Irminger Sea North and (2) in addition to (1), half of the indices from these sub- areas with 12 and 14 years time-lag were added. Thus:

$$I_{1,y} = I_{N\text{-}Gr,y-13} + I_{N\text{-}Ir,y-13}$$

and

$$I_{2,y} = 0.5\,(I_{N\text{-}Gr,y-12} + I_{N\text{-}Ir,y-12}) + (I_{N\text{-}Gr,y-13} + I_{N\text{-}Ir,y-13}) + 0.5\,(I_{N\text{-}Gr,y-14} + I_{N\text{-}Ir,y-14})$$

The latter index can be looked upon as a 'smoothed' (running weighted mean) trend in 0-group abundance. These indices were used in the model:

$$R_y = \mu + \beta \log(I_{.,y}+1)$$

The resulting R-squared values were about 0.61 for the first series (only 0-group indices with 13 years time-lag) and 0.59 for the latter one. The scatter plot of the recruitment index vs. these combined 0-group indices is given in Figure 7 (with the fitted relationship) and the time-series of the predicted recruitment indices is given in Figure 8 along with the values observed in the groundfish survey. As can be seen in Figure 8, the recruitment index has been at a low level in the years 1992-94. This is reflected in a relatively low CPUE in the *S. marinus* fishery in late years (22). All the O-group models predict a recovery in 1997-1998, but the degree of the recovery differs slightly depending on which model is used.

DISCUSSION

The annual variation in the distribution pattern of 0-group redfish in the Irminger Sea might to some extent be explained by the different timing in the release of the larvae. It has been shown that the peak of the "spawning" period of oceanic redfish can vary considerably, *i.e.*up to three weeks from one year to another (43) resulting in a differently advanced drift and size of 0-group redfish. However, the main impact on the drift pattern is the variation in strength and direction of the current system. This is clearly reflected in the distribution pattern of 0-group redfish in Icelandic waters and in the distribution pattern off East Greenland.

In spite of the relative scarcity of 0-group redfish in Icelandic waters, juvenile bottom stages of *S. marinus,* mainly originating from relatively few year classes are abundant , in particular off the north coast.

Considering the known distribution of oceanic redfish in the southern part of the survey area, it is likely that the 0-group redfish observed there belong to this species. However, it must be pointed out that the main distribution area of 0-group oceanic redfish most probably lies south of the area covered by the 0-group surveys.

The extremely low abundance of 0-group redfish in the Irminger Sea in 1983 coincides with exceptionally low water temperatures in the upper layers. This indicates that the temperature may have an impact on the survival of the fry. However, after having descended to the bottom young redfish seem to be less vulnerable to low temperatures. Young redfish have been observed to be abundant at Iceland, East Greenland and in the Davis Strait at temperatures of 2 - 3°C and even below 0°C (29,30,54).

In this study of the relationship between the recruitment index and the 0-group indices, no attempt was made to adjust 0-group indices which were clearly down-biased because of part-covered areas in some years. The simplest process would have been to remove such observations from the data, but because of the limited number of observations (10 years recruitment series) this was not considered a feasible choice.

R-squared values of 0.6-0.7 possibly indicate a higher correlation than could be expected between the recruitment index and 0-group indices, bearing in mind the time it takes for the 0-group to grow to recruitment size (on the average 13 years according to this study).

The three 0-group series indicate O-group/recruitment time lag as follows: (1) Central Irminger Sea North with 13 years time-lag, (2) Central Irminger Sea North + E-Greenland North with 13 years time-lag and (3) Central Irminger Sea North + E-Greenland North with 12, 13 and 14 years time-lag (with weights 0.5, 1, 0.5). The first series is probably the most sensitive one to variation in the 0-group survey design (one sub-area, one survey) and the third series is the least sensitive one (two sub-areas, three surveys).

According to these recruitment models, an increased recruitment to the adult stock of redfish would be expected in 1997-1998 and maintained at a similar level for several years onwards. This is supported by an increased number of small redfish in the commercial catches during the most recent years and by the increased occurrence of small redfish in areas where they have been rather scarce during previous years, *e.g.* west and southwest of Iceland. Furthermore, in the summer of 1995, a large area west of Iceland was closed to the trawl fishery because of a high proportion of small redfish in the catches.

Thus, there is a brighter prospect for the redfish fishery at Iceland towards the end of the century.

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Table 1. Redfish O-group abundance indices by subareas (see Figure 1). NA = area not covered.

Year	East-Greenland, North	Dohrn Bank	Central Irminger Sea, North	East-Greenland, South	Central Irminger Sea, South
1970	0.86	3.78	1.36	0.75	0.08
1971	NA	1.56	12.70	NA	NA
1972	17.03	5.41	20.38	26.84	0.96
1973	17.93	2.22	43.70	13.04	3.50
1974	9.75	9.67	18.02	1.84	0.06
1975	1.95	1.26	4.77	0.31	7.02
1976	3.30	0.10	4.03	0.59	0.28
1977	5.18	0.69	11.48	0.25	0.14
1978	3.21	1.69	1.66	0.47	0.13
1979	1.27	0.06	0.01	0.23	NA
1980	2.49	0.77	0.18	0.80	0.01
1981	4.88	1.84	2.39	2.90	0.17
1982	2.43	0.01	0.10	0.40	0.03
1983	0.19	0.01	0.46	0.01	0.01
1984	0.05	0.03	4.22	NA	NA
1985	15.43	1.30	5.86	NA	NA
1986	5.39	0.78	5.90	NA	NA
1987	2.08	0.64	20.14	NA	NA
1988	7.92	5.16	3.94	NA	NA
1989	7.45	1.14	5.74	NA	NA
1990	9.70	0.69	6.94	NA	NA
1991	5.33	0.30	7.80	7.72	5.25
1992	1.63	0.01	0.97	4.97	3.99
1993	1.50	0.01	1.05	0.94	0.47
1994	3.47	0.01	1.64	0.31	0.36

Table 2. Estimated correlation coefficient between the groundfish survey recruitment index and O-group series with different time-lag (years). The Minimum Volume Ellipsoid Method was used to estimate correlation (non-sensitive for outliers in data).

Time-lag (years)	E-Greenl North	E-Greenl. South	Centr.Irm. Sea North	Centr.Irm. Sea South	Dohrn Bank
10	0.55	0.82	0.09	0.41	0.35
11	-0.23	0.00	0.35	0.36	0.05
12	0.18	-0.34	0.43	0.11	0.44
13	0.52	0.03	0.91	0.24	0.15
14	0.68	-0.01	0.57	0.75	0.45
15	0.16	0.35	0.77	# obs < 8	0.32

Table 3. P-values of the slope in the linear regression: $R_y = \mu+\beta\, I_{r,y-l}$, where R_y is the length-based recruitment index from the groundfish survey in year y *and* $I_{r,y-l}$, is an 0-group index for region r in year $y-l$, where l is the time-lag (in years) between the 0-group and the recruitment index. The p-value may be positive or negative depending on the sign of the estimated slope.

Time-lag (years)	E-Greenl North	E-Greenl. South	Centr.Irm. Sea North	Centr.Irm. Sea South	Dohrn Bank
10	0.41	-0.90	0.80	0.78	0.83
11	-0.94	-0.38	0.68	0.03	0.72
12	0.30	0.77	0.27	0.81	0.06
13	0.07	0.36	0.02	0.79	0.69
14	0.24	0.12	0.41	0.54	0.71
15	0.71	0.69	0.74	# obs. < 8	0.29

Table 4. P-values of the slope in the linear regression: $R_y = \mu + \beta \log(I_{r,y-l}+1)$, where R_y is the length-based recruitment index from the groundfish survey in year y and $I_{r,y-l}$ is an 0-group index for region r in year $y-l$, where l is the time-lag between the 0-group and the recruitment index. The p-value may be positive or negative depending on the sign of the estimated slope.

Time-lag (years)	E-Greenl North	E-Greenl. South	Centr.Irm. Sea North	Centr.Irm. Sea South	Dohrn Bank
10	0.23	0.87	0.86	0.72	0.67
11	0.97	-0.48	0.64	0.03	0.68
12	0.21	0.80	0.07	0.77	0.04
13	0.05	0.35	0.00	0.56	0.63
14	0.26	0.17	0.15	0.38	0.69
15	0.75	0.64	0.42	# obs. < 8	0.23

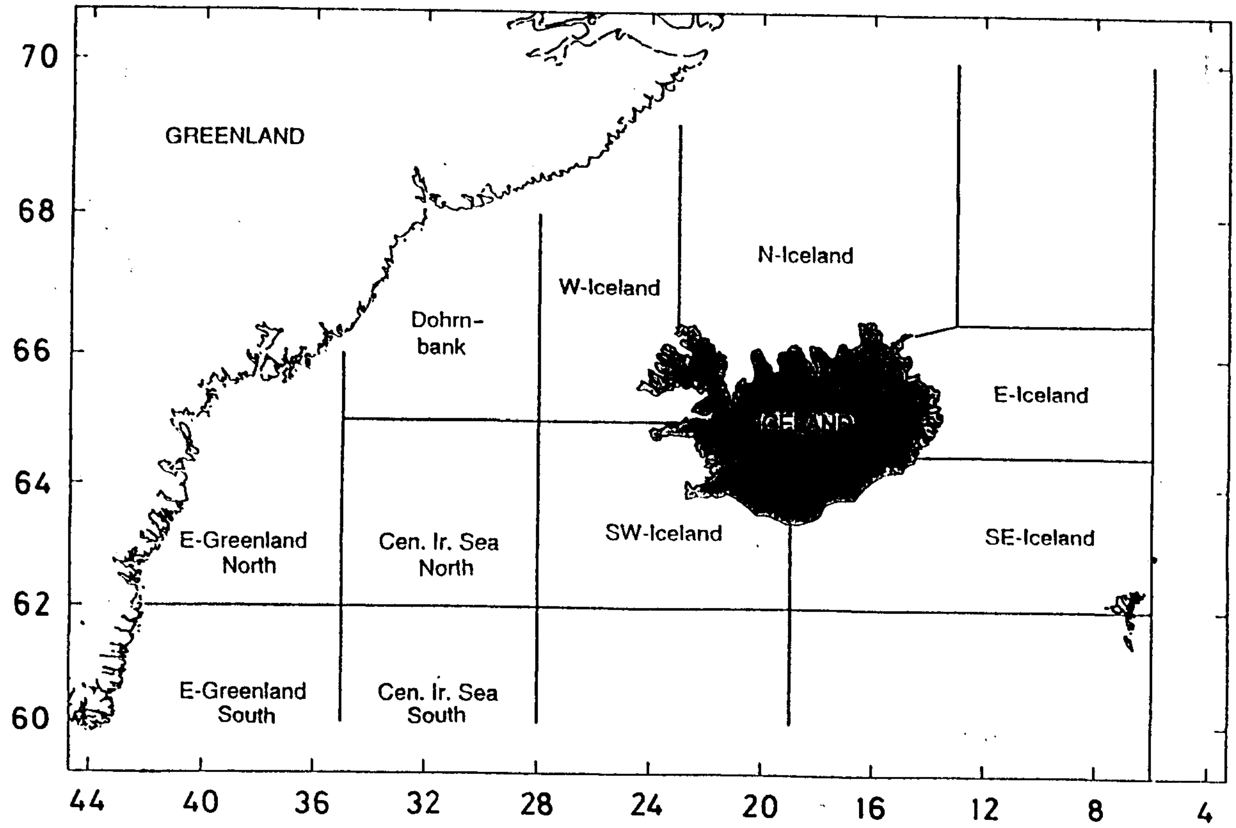


Figure 1.
Sub-areas used for the evaluation of O-group indices.

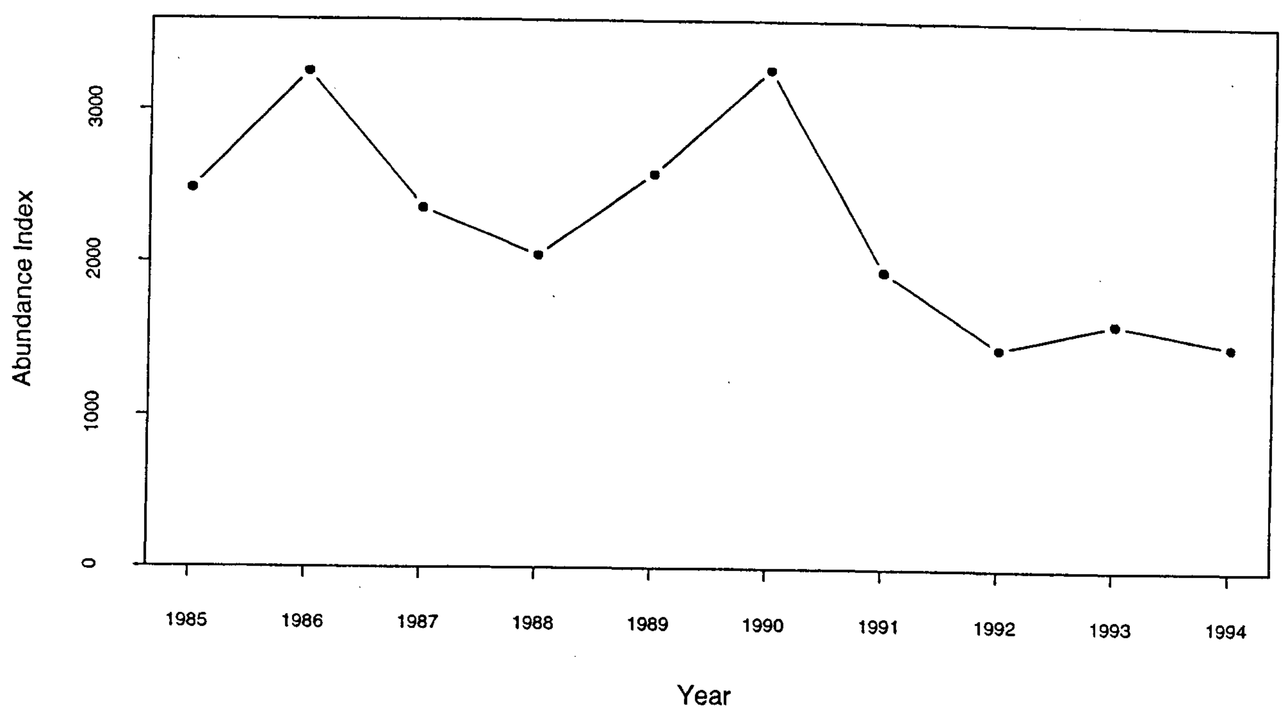
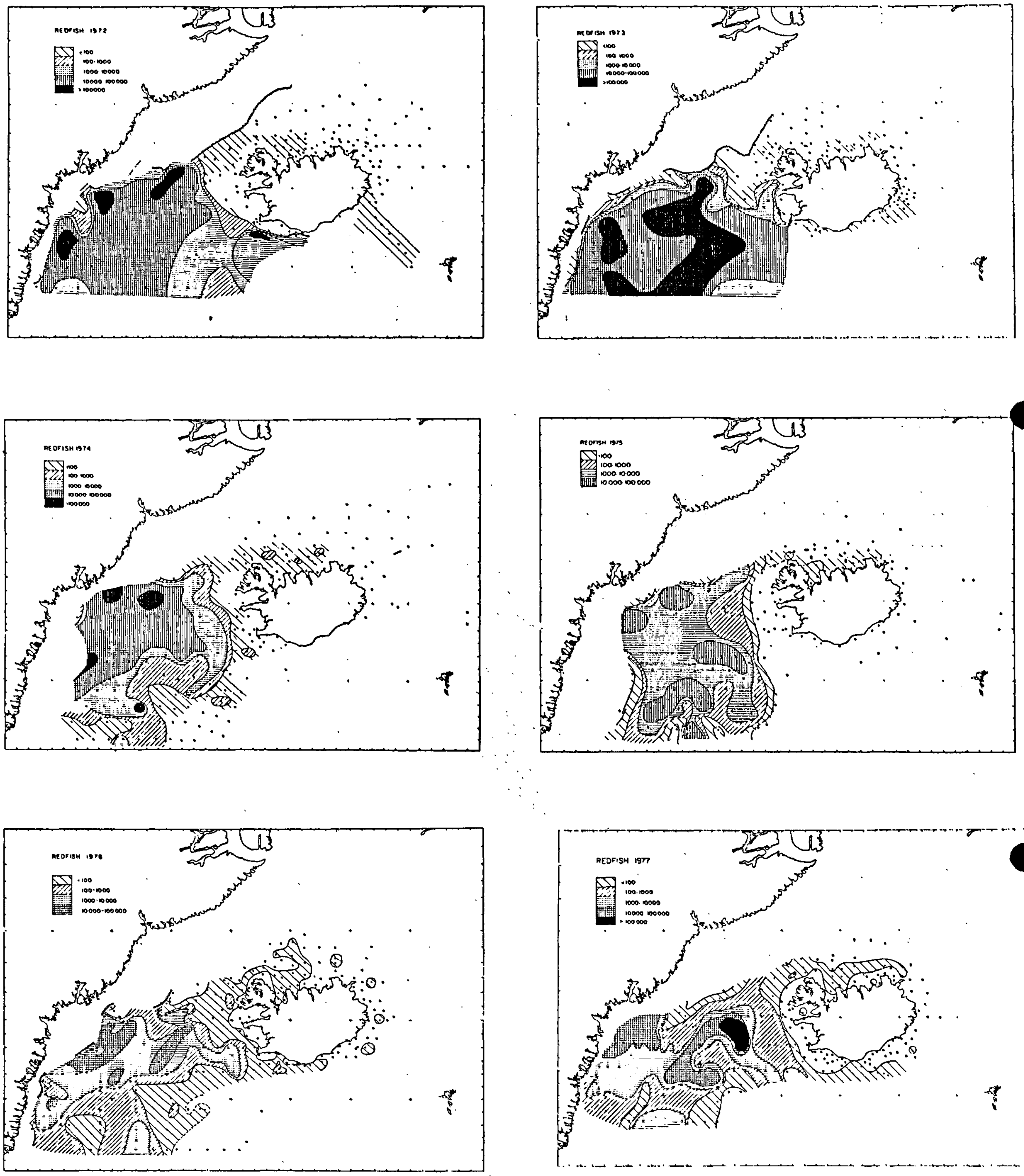
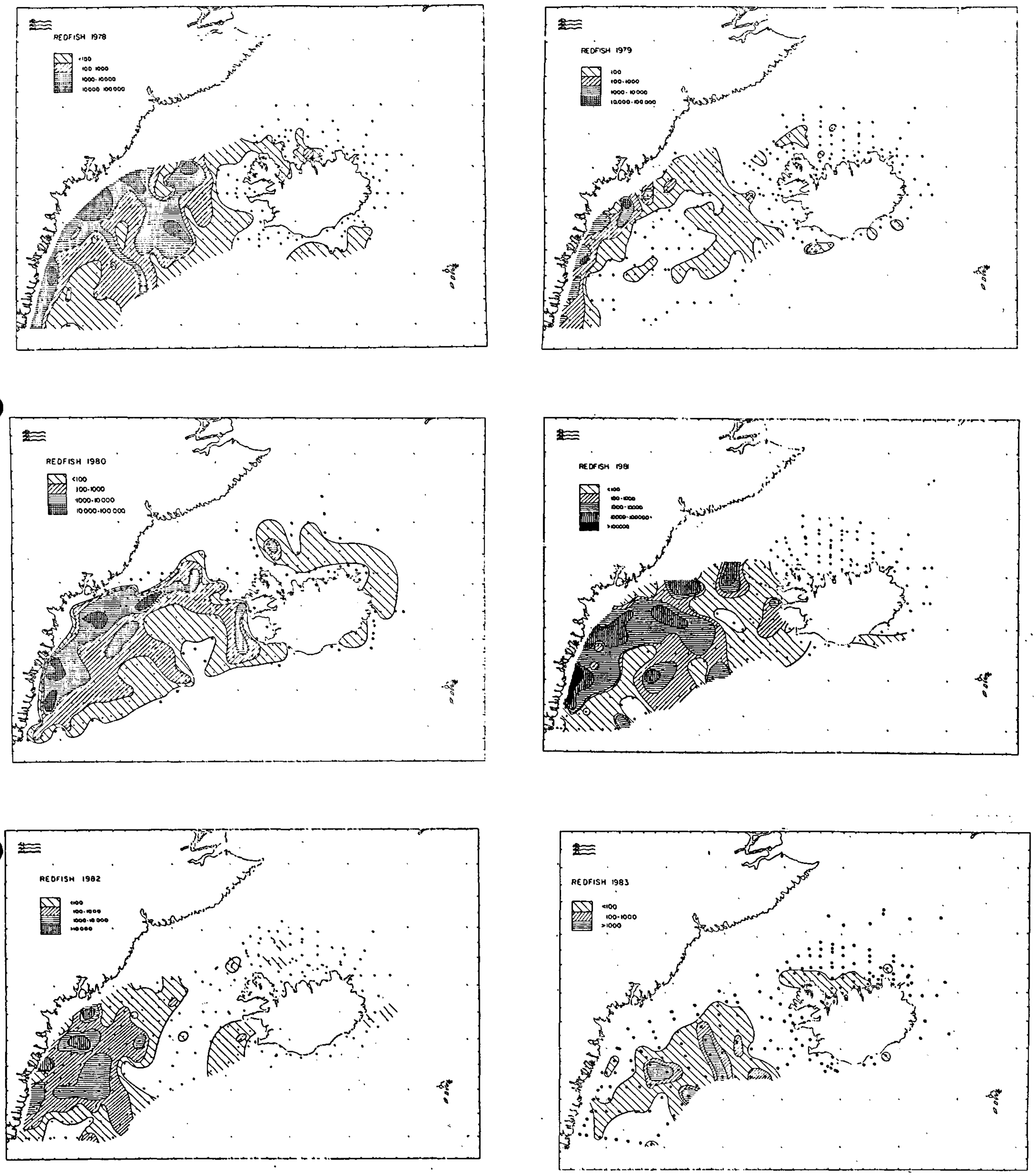


Figure 3.
Time series of the abundance of 31-35 cm *S. marinus* in the Icelandic groundfish survey.



a: 1972-1977

Figure 2.
Annual distribution and density of O-group redfish for the period 1972 - 1994.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100 1000
1000-10000
10000 100000
REDFISH 1979
100
100-1000
1000-10000
10,000-100000
REDFISH 1980
<100
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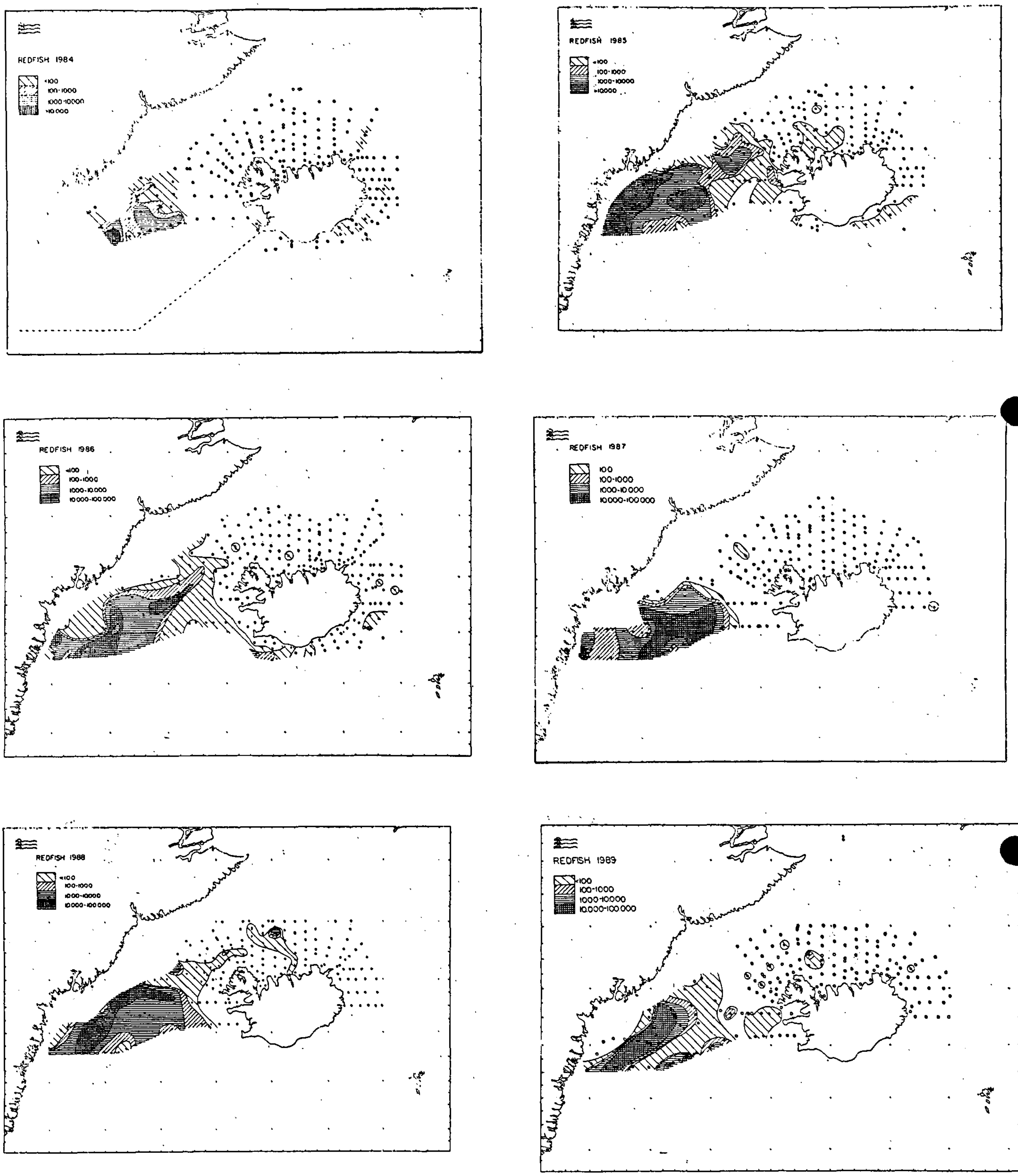
1000-10000
10000-100000
REDFISH 1981
<100
100-1000
1000-10000
10000-100000
>100000
REDFISH 1982
<100
100-1000
1000-10000
>10000
REDFISH 1983
<100
100-1000
>1000

b: 1978-1983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1000-10000
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REDFISH 1988
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REDFISH 1989
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1000-10000
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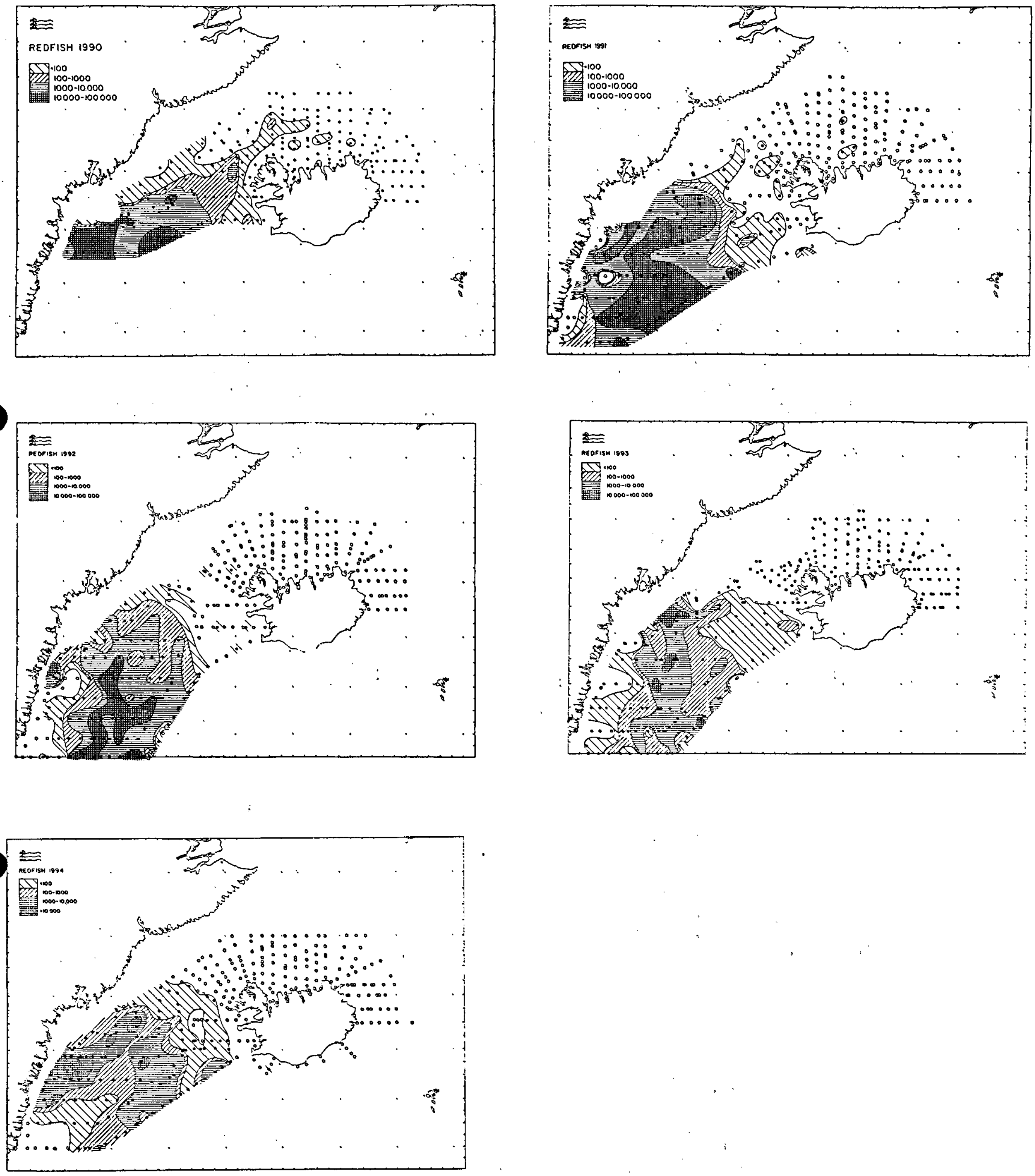
c: 1984-1989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100-1000
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100-1000
1000-10 000
10 000-100 000
REDFISH 1992
REDFISH 1993
REDFISH 1994
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100-1000
1000-10,000
>10 000

d: 1990-1994

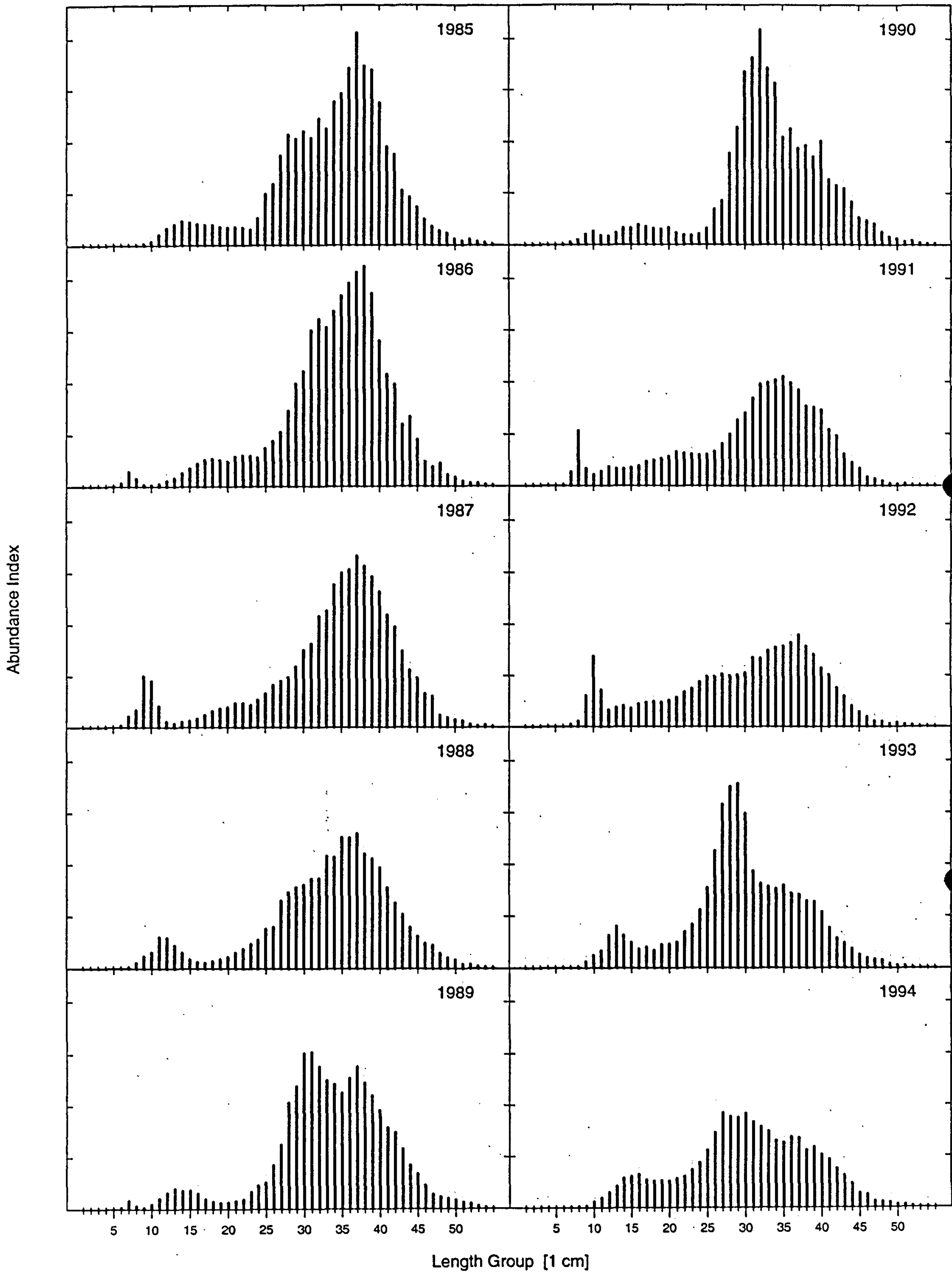

Figure 4.
Abundance indices of *S. marinus* from the Icelandic groundfish survey by length groups (1 cm) for 1985-1994.

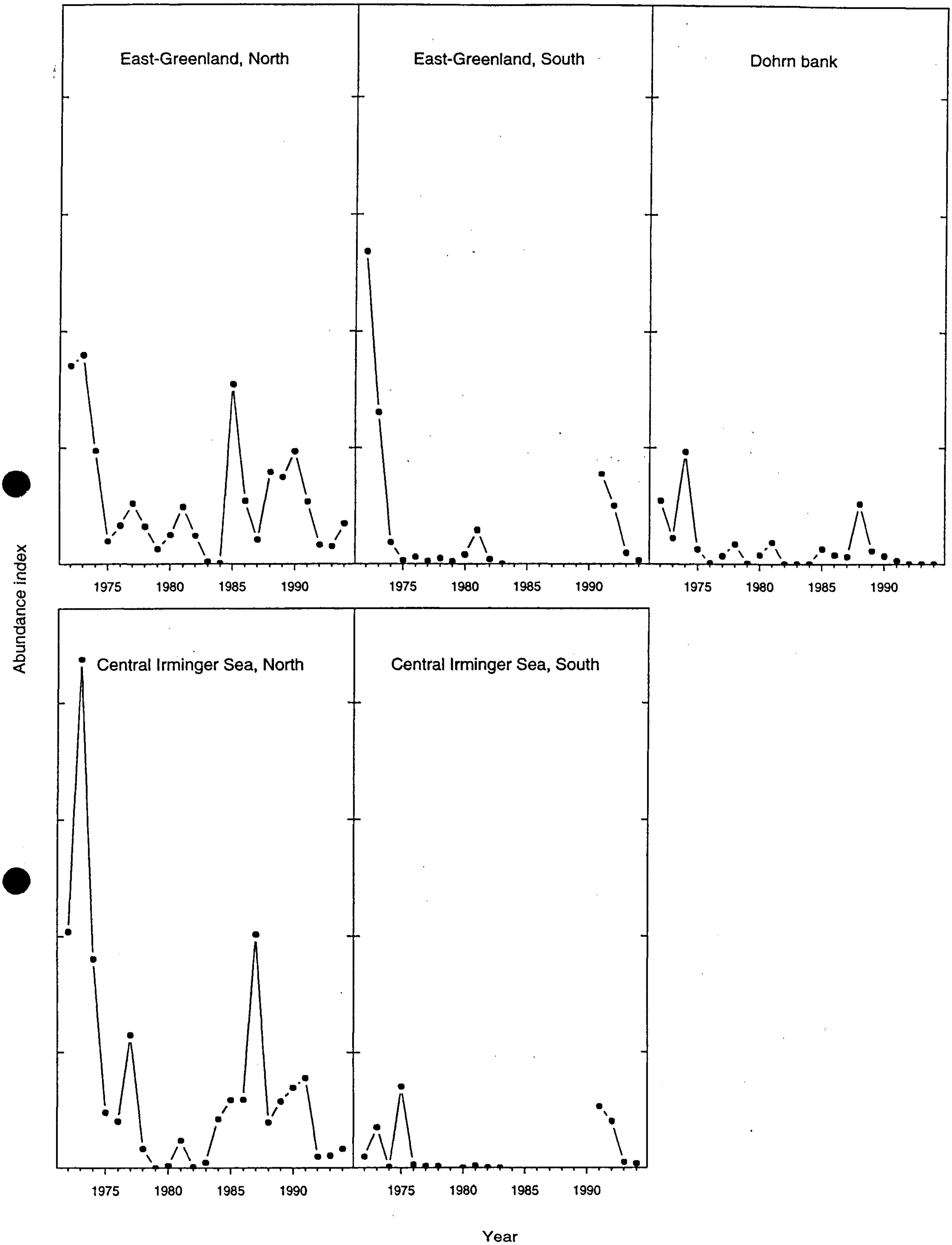

Figure 5.
Time series of O-group redfish abundance indices by sub-areas.
The sub-areas East Greenland South and Central Irminger Sea South were not covered by the survey in the years 1984-1990.

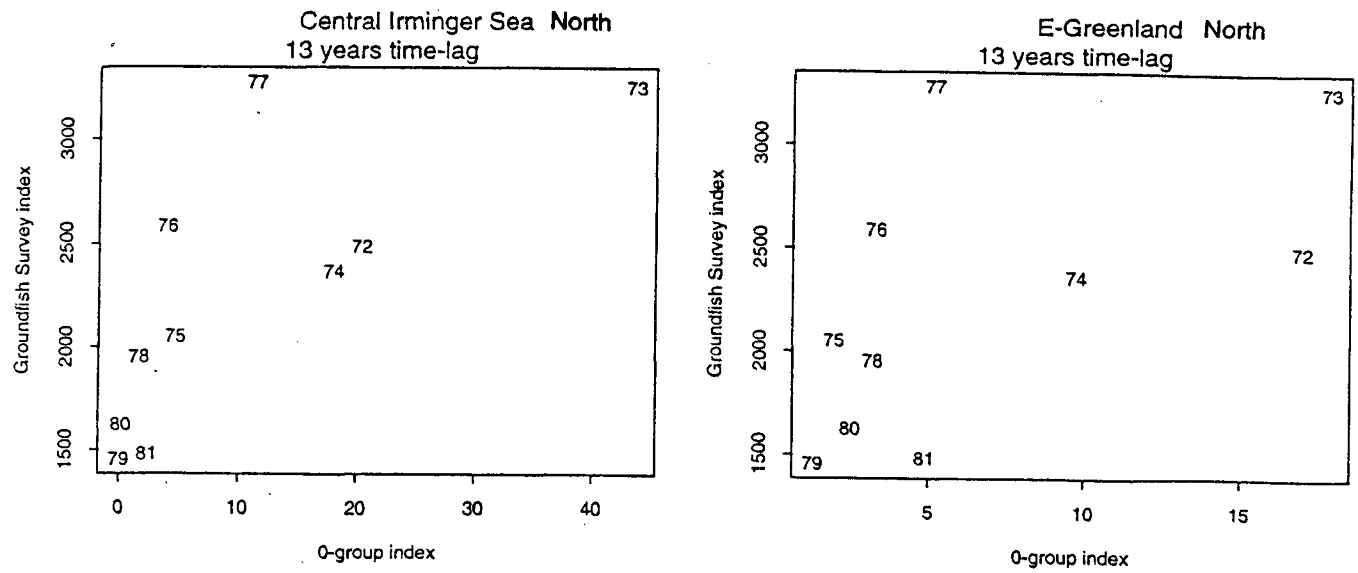

Figure 6.
Scatter plot of the groundfish survey recruitment index vs O-group indices for the sub-areas Central Irminger Sea North and East Greenland North with 13 years' time lag. Points on the plot are year classes.

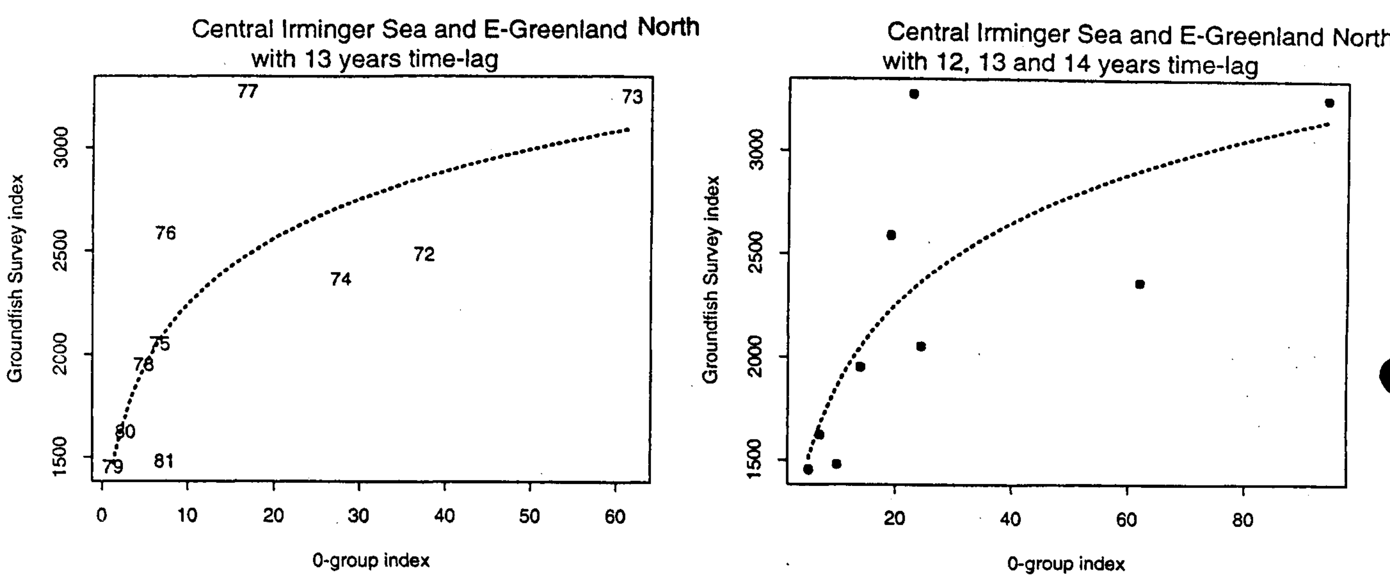

Figure 7.
Scatter plot of the groundfish survey index vs. two O-group indices along with the fitted relationship (for explanations, see text).

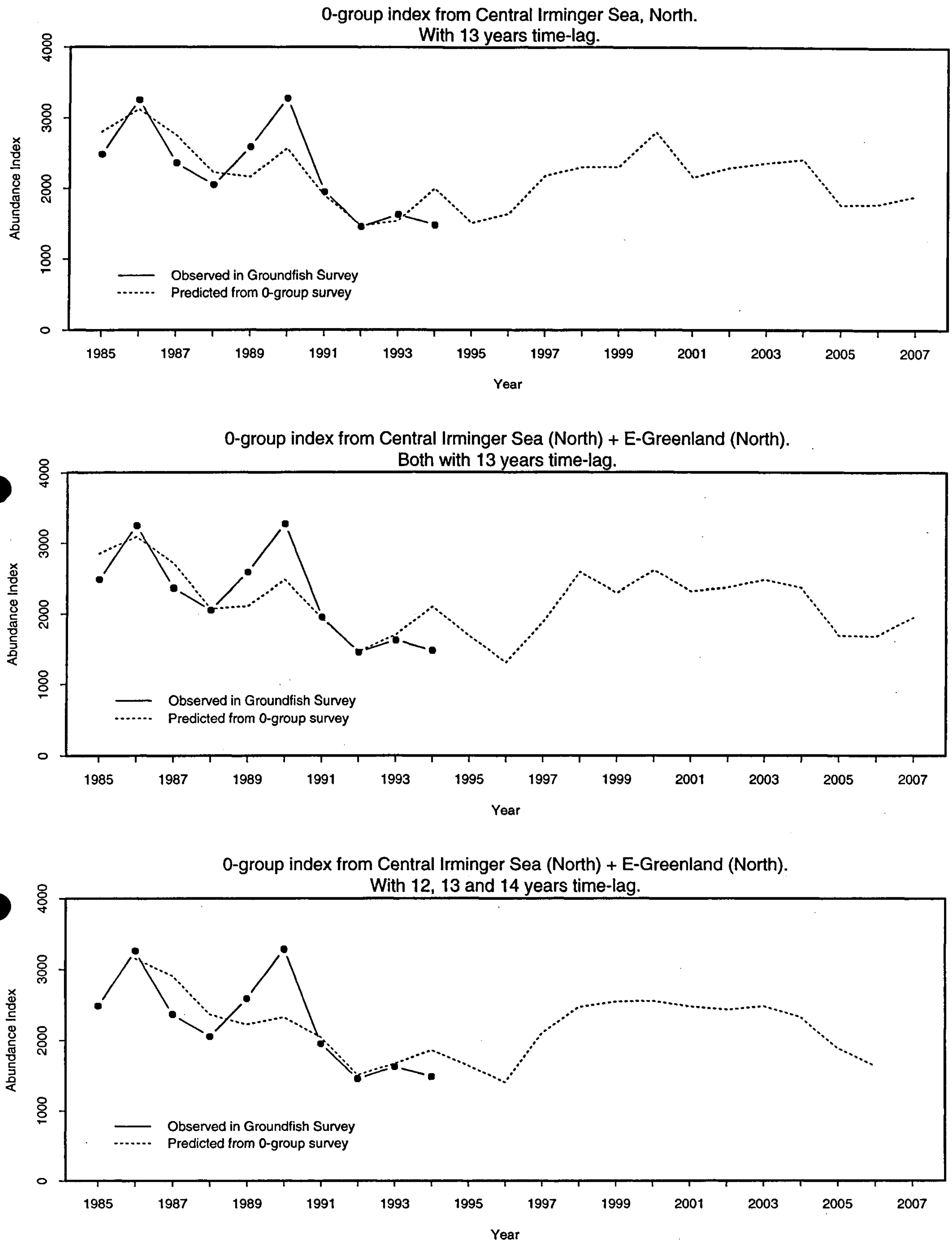

Figure 8.
Observed recruitment index for *S. marinus* from the Icelandic groundfish survey plotted along with predicted values from O-group indices.