Northwest Atlantic Fisheries Organization

Serial No. N956 NAFO SCR Doc. 85/16

SCIENTIFIC COUNCIL MEETING - JUNE 1985

The Effect of Changing Effort Patterns of Catch Composition in the Roundnose Grenadier Fishery, 1978-83

by

D. W. Kulka

Fisheries Research Branch, Department of Fisheries and Oceans
P. O. Box 5667, St. John's, Newfoundland, Canada A1C 5X1

Introduction

Roundnose grenadier, Coryphaenoides rupestris (Gunnerus 1765), the most plentiful and only commercial macrourid in the Northwest Atlantic, inhabits slope waters exceeding 350 m (Savvatimskii 1969, Parsons 1976, Eliassen 1983). Its distribution and abundance remained virtually unknown in the western sector of the North Atlantic until Soviet research vessels in the mid 1960's located large feeding concentrations in 500-1300 m off the Labrador Shelf (Pechenik and Troyanovskii 1971). These explorations indicated that commercially viable catch rates could be achieved, prompting the formation in 1967 of a directed roundnose grenadier fishery along the Contintental Slope, off Labrador north of 50° of latitude.

Annual catches for the early period of the fishery, 1967-77 ranged from 12,000 to 75,000 t, the USSR being the dominant participant (Fig. 1). However, USSR effort diminished significantly between 1978 and 1983 and catches dropped from 21,000 to 3,600 t. Two main reasons have been cited for the decline. Atkinson (1982, 1983, and 1984) noted a drop in the standardized hourly catch rates from 1.4 t in 1970 to 0.5 t in 1983 suggesting that the stock had been depleted or that problems may have existed with the reported catch and effort information. Alternatively, Chumakov and Savvatimskii (1983) attributed the lower catch rates and declining effort (down by 60% over the past 6 years) more to an increasing abundance of Greenland halibut in areas where grenadier were concentrated. Regulations restricting bycatch of a regulated species to 10% of total weight caught when using small mesh gear was said to have prevented full exploitation of the stock. The implication was that increasing overlap in distribution of the two species was forcing the fleet to fish less productive grenadier grounds in order to avoid the Greenland halibut (Reinharditus hippoglossoides).

Several analyses of bycatch have been done in an attempt to define the Greenland halibut/grenadier problem but none provided a clear picture of the recent situation. Also, none of the studies addressed the problem of high redfish (Sebastes sp.) catches taken in the shallow, southern area. Zilanov (1976) and Chumakov and Savvatimskii (1983) presented information on catch composition at depth, by area for the period prior to the decline. For more recent years, a study by Bowering (1983) included only average depths fished for each NAFO Division, while Chumakov and Savvatimskii (1984) provided detailed information on proportions of Greenland halibut in all commercial sets in depths between 500 and 1100 m, during 1970-83. However, for the latter paper, Greenland halibut bycatch figures were inflated by the inclusion of data from the deep water Greenland halibut directed fishery and exclusion of data from depths below 1100 m. Therefore reasons for the evolving structure and decline of the grenadier fishery require further clarification. A large Canadian fishery observer data base contained sufficient detailed information to investigate further the reasons for the declining fishery after 1978 by examining patterns and changes in the fishing effort and species assemblages of catches from the roundnose grenadier fishery.

Methods

A set by set collection scheme provided data in a form appropriate for examining effect of depth, area, and time of year on catch rates and species composition for the 1978 to 1983 grenadier fisheries. Catch and effort data were obtained from 12% of the total directed fishery in NAFO Subareas 2 and 3 (Labrador Shelf and northern Grand Bank) in 1978 and an average of 48% in subsequent years. Information collected by Canadian fisheries observers (Observer Program - Resource Management, Department of Fisheries and Oceans) stationed on 63 USSR and GDR stern trawlers during 1673 days of fishing provided a detailed picture of the deep water fishery. Coverage was not selective of season, area fished or fleet and therefore is also considered representative for the fishery. Data from 4638 sets included relevant effort information such as set duration, position, date, and depth fished. The catch weight for each set had to be estimated by an indirect multistage procedure described in Kulka (1983) and Kulka and Firth (1985) because commercial operations precluded direct weighing of the fish. The estimated weight was then matched with the appropriate effort information for each set.

The data were then sorted and compiled into year, country, area, month, and 50 m depth groupings. Areal effort distribution was illustrated on charts by shading the areas where sets had occurred. Catches (tonnes) at depth were plotted for each nationality and year separately to illustrate changes in species assemblages of the catches of each fleet over time. The percent of fishing activity in three broad depth ranges: shallow (<751 m), midrange (751-1050 m), and deep (>1050 m) and in each NAFO Div. 2G, 2H, 2J and 3K were determined. These categories were then plotted as histograms to show yearly shifts in distribution of fishing effort by depth and area.

Prior to calculating interval or variance estimates of percent of catch or catch per hour, sample distributions were examined for normality to ensure that underlying assumptions for such calculations were met. Distribution of bycatch percentages were found to be normal. On the other hand, distributions of catch per hour for grenadier were often found to be significantly skewed to the right; however, sample sizes were large enough to avoid problems associated with small non-normally distributed samples (Snedecor and Cochrane 1978, p. 51). The following procedures were then used to detect differences in bycatch levels among years, months, areas, and depth. Percent of catch of roundnose grenadier, Greenland halibut, redfish, and other species combined, by 50 m depth zones were plotted for each of the 6 years to provide an overview of species mix in catches from the directed roundnose grenadier fishery. No statistically significant differences were found by analysis of variance (GLM procedure, SAS User Guide: Statistics 1982 Ed.) for percent of catch, between countries, therefore USSR and GDR data were combined. For this and all subsequent analyses, cells of data were checked for homogeneity utilizing Bartletts procedure (Ostle and Mensing 1975). Finally, interval estimates of catch per hour specified at the 95% level for each 50 m depth range were plotted for each of the years to show relative abundance of the directed species at depth. If average catch per hour within each depth range were not significantly different between countries, then they were combined.

Mean values of percent of catch for Greenland halibut and redfish were compared between years, countries, months, areas and 50 m depth ranges in a five level analysis of variance procedure described below. This method was used rather than a factorial design utilizing all of the variables as separate classes because of the many missing cells . The actual ANOVA was done by placing all variables into a single class incorporating year, country, month, area, and depth interval. Means of all possible combinations from this super class were compared at the 0.01 level and if at each stage, a significant difference was not detected, then a variable was dropped from the class and the test was repeated using the remaining combination of categories. Each decreasing combination was analysed in a similar fashion and all orders of variables were tested. The less stringent 0.01 level of significance was chosen because certain categories with large sample sizes tended to imply differences between means which were biologically speaking very similar. However, in the majority of tests of significance, probability levels were extremely high rather than just borderline, strengthening the implication of the test. Where appropriate, data were consolidated and the pooled means were plotted with 95% confidence intervals to display yearly and areal patterns at depth. Comparisons of the corresponding means for both redfish and Greenland halibut at the 0.01 level confirmed that NAFO Div. 2G and 2H were not significantly different and therefore were combined. Given similar findings, redfish in 2J and 3K were also combined.

For 1981, 1982, and 1983 the distribution of percent of catch at depth showed an elevated central area, diminishing extremes, a zero baseline and non-tilted form suggesting a three parameter, normal distribution. The following Gaussian model (Gauch and Chase 1974) was fitted for each of the above years by a nonlinear iterative method (Nlin Procedure, SAS Users Guide: Statistics 1982 Ed.).

$$B = M_e^{-(C-d)^2/V^2}$$

B = percentage of total catch
d = depth of tow
M = maximum
C = mode
V = standard deviation

The program computed estimates of the Gaussian parameters mode (C), maximum (M), and standard deviation (V). A similar fit could not be achieved for the other three years because the range of data did not include the maximum (M) and, therefore, the iterative process of the non-linear procedure was unable to converge. For these years, curves were fitted by eye to the truncated but otherwise similarly shaped data, for the purposes of comparison to the other years.

Percent of bycatch was used to describe patterns of bycatch by area and depth for the major species. However it was also useful for describing relative abundance of the bycatch species. A regression of ℓn catch per hour on ℓn percent of catch for Greenland halibut and redfish for each year was performed on the curvelinear data. Analysis of covariance revealed no significant differences between slopes for the different years for both species therefore, data were combined and a single model sufficed for both redfish and Greenland halibut.

Results

Cumulatively over the past six years, the USSR and GDR grenadier fishing grounds in the Northwest Atlantic extended in a long, narrow, and intermittent band straddling the 1000 m depth contour, from 50° to 61°N (Fig. 2). However, during this period the fishery was in a state of change and showed considerable variation in the patterns of catch and effort. In particular, shifts occurred in areal distribution and average depths fished, as indicated by Fig. 3. Effort distribution by depth of gear (equivalent to bottom depth) not only changed from year to year but was substantially different between the two countries in all but the two most recent years. In 1978 and 1980 GDR fished almost exclusively at depths not exceeding 750 m but gradually shifted into deeper water from 1981 to 1983. Conversely, 60 to 70% of USSR fishing effort in 1978 and 1979 took place at depths exceeding 1050 m. However, by 1982 GDR and USSR fleets fished a very similar cross section of the depths. Each country fished in separate areas up until 1981, the USSR fleet located mainly to the south. Only two small areas in 2H and 3K (indicated by arrows in Fig. 2) were fished consistently throughout most of the observed period. Over the past six years, the season was usually short, with an average of 83% of the fishing occurring in September through December. Effort also shifted in a fairly consistent pattern within each fishing period. Particularly during the most recent years examined, the fleets tended to shift north and onto shallower grounds as the season progressed.

Shifting fleet distribution patterns, both yearly and seasonly within each year contributed to the pronounced variability of the observed bycatch levels and to a lesser extent catch rate of the directed species. Tables 1 and 2, listing monthly percent bycatch averages for the dominant species by NAFO division and country, show a very wide and unpatterned spectrum of values. Fluctuating yearly bycatch averages for redfish ranging from 0.1 to 17.1% and turbot from 4.1 to 52.9% suggest that a combination of factors not related to time have substantially influenced configurations of the major bycatch species in this fishery.

Over the short seasons of recent years, temporal trends in bycatch levels of either species were not apparent but there did appear to be a correlation with average depth and to a lesser extent area fished. The depth related structure of the catches of each fleet was more apparent from data stratified into 50 m depth categories. Figure 4 (GDR) and Fig. 5 (USSR) indicate substantial differences between years and countries in the distribution of total catch at depth, reflecting a shift of effort. However, catch breakdown from sets grouped by 50 m depth interval consistently showed an increasing proportion of turbot in the midrange fished until 1981 and from then on a stabilized pattern of species proportions at depth. Higher yearly bycatch rates for GDR was related to greater effort in shallow depths particularly in the first four years.

The similarity in depth-related bycatch patterns between GDR and USSR, apparent in Fig. 4 and 5, was confirmed by a series of t-tests comparing percent bycatch by species, for each depth category. Levels were found not to be significantly different between countries at the

0.01 level in 100% of the cases for redfish and 87% for Greenland halibut. In most instances, probabilities exceeded 0.20 reinforcing the conclusion that bycatch patterns were similar between fleets. Therefore, with respect to bycatch data, countries were combined. Yearly catch compositions for combined fleets, illustrated in Fig. 6, suggest a temporally stable mix of species at depth, particularly during the last three years. Except in 1980, roundnose grenadier constituted less than 50% of the catch at depths less than 750 m, even though effort associated with the grenadier fishery was considerable in this range. On the other hand, it dominated in the deepest part of the range, constituting about 80 to 90% of the total. Redfish was a major component only of the catch in depths less than 650 m whereas Greenland halibut peaked in abundance in the midrange, diminishing to a level of about 10% beyond 900 m in 1978 to 1980 and 1100 m in 1981 to 1983. The apparent shift in 1981 may reflect a change in the distribution of Greenland halibut at this time. Therefore, with the possible exception of the movement of Greenland halibut to greater depths in 1980, variations in compositions of the bycatches over the past six years appears to be related primarily to shifting patterns of effort.

An analysis of variance consisting of the variables years, months, areas (NAFO divisions) and depth suggested that only the latter two had a significant effect on redfish bycatch levels. For different years and months, significant differences were detected in 10% or less of the cases at the 0.01 level. Point estimate plots of percent of redfish in the catch, with 95% confidence intervals (Fig. 7), demonstrated that adjacent depth ranges were often not significantly different but over the whole range bycatch diminished rapidly from an average 45% at 500 m (years combined) to near zero at about 900 m. The rapidly diminishing level of bycatch with significantly different values at either end (solid dots for combined areas, Fig. 7) suggests the tail of a Gaussian curve with zero baseline similar to the pattern for Greenland halibut. The maximum (highest point with respect to the y axis) of such a curve would occur at some depth less than 500 m, outside the range of the observed data. Because maximum and mode parameters could not be mathematically estimated from the truncated data, its Gaussian configuration could not be confirmed. However, an attempt at fitting a log relationship to the data in order to approximate the tail of the curve resulted in a good fit above 700 m but with an increasingly biased estimate as depth decreased. This pattern of difference would be expected when attempting to fit a log relationship to Gaussian data therefore providing further evidence of its form. The dotted line in Fig. 7, for illustrative purposes simply represents an eyeball estimate of the normal fit.

Additional tests of significance suggested that redfish bycatch in areas 2J and 3K were consistent and could be considered a single area within each of the depth categories. This was also the case for 2G and 2H. Figure 7 shows, however that the two resulting areas, 2GH and 2J3K exhibited distinctly different levels of bycatch from each other as deep as 650 m. Beyond 700 m, the levels merged as they approached zero. A 55% difference at 500 m, suggested a considerably greater abundance of redfish in the southern shallow part of the grenadier grounds than in the northern part of the range.

According to Fig. 8 the maximum abundance of Greenland halibut was located about 300-400 m deeper than redfish, closer to the mid depths of the grenadier fishery. Also, a test of significance showed that the pattern was not consistent from year to year. As such, each year of the fishery is presented separately. In 1981, 1982, and 1983 the maximum levels of bycatch were centered well within the range of the data allowing for annual curves to be fitted to the Gaussian model:

$$B = M_e^{-(C-d)^2/2V^2}$$

where B is percent of catch, d is depth of tow and the matrix of yearly parameter estimates are:

Parameter/Year	1981	1982	1983
Maximum (M)	40.0	48.6	43.2
Mode (C)	706.5	774.4	691.6
Standard deviation (V)	369.0	251.1	458.9

Fitted curves for the total fishery are presented as solid lines in Fig. 8. F-tests indicated highly significant fits, but the mean square errors were improved only moderately by fitting the Gaussian as opposed to the straight line model. This was due to very large variation in the data as well as truncation of both tails. However, appropriateness of the normal curve for describing the Greenland halibut bycatch distribution was confirmed by the bell-shaped distribution of 50 m depth category means of percent bycatch which closely tracked the Gaussian form. The 95% interval estimates nearly always overlapped the fitted normal curves.

In 1978 through 1980 truncated depth ranges of observed data and location of mode (c) at shallower depths than sampled, prevented convergence in the iterative curve fitting process. Therefore, eyeball fits of the right tail only were possible for these years and they are presented as dashed lines in Fig. 8. The curve maxima (M) for 1981-83 show relatively little variation, rangeing from 40 to 49%. When directing for grenadier, average percent bycatch of Greenland halibut did not exceed 50% at depths of maximum abundance. The mode (C) however showed some variation shifting from the shallow end of the range in 1978-80 to 707 m in 1981, 774 m in 1982, and back to 692 m in the following year. Up to 1983 which may be a possible point of stabilization or reversion, there appears to be a movement of the mode to greater depths. Also, the standard deviation of the curves became sharply reduced in 1982 indicating a concentration of Greenland halibut into a narrower range of depths followed by a considerable widening again in 1983.

Tests of significance similar to those done for redfish also indicate differences in Greenland halibut bycatch levels between NAFO divisions over certain portions of the depth range. As well, comparison of 2G with 2H showed that their levels were not significantly different and, therefore, data were combined into a single category, as was done for redfish. Significant differences were found to occur between 2GH, 2J and 3K. Illustrated in Fig. 8, the areal percent bycatches for 3K versus 2GH merged at about 1100 m where levels had dropped to between 5% and 30%, depending on year. Values for the very limited 2J portion of the fishery, not presented in Fig. 8, were intermediate to data from the areas north and south. It was also apparent for 1981-83 that modes (C) and standard deviations (V) showed little change. For the maxima (M), the northern (2GH) area was substantially higher than the southern (3K) region. The separation was greatest in 1982 and 1983, at nearly 40% in 600 to 800 m.

The percent of a particular species in a catch is a measure of its relative abundance with respect to other species present. This value can be related to the more commonly used index of abundance, catch per hour, which is independent of other species. For redfish, all years of data were combined given that the yearly relationships were shown by analysis of covariance not to be significantly different. A similar test for Greenland halibut suggested marginally significant differences between years. However, they too were combined because for practical purposes the yearly patterns were very similar. This similarity was verified by the distribution of sum of squares amongst the various sources in the combined year model. Only 1.2% and 0.9% of the total SS could be attributed to year and interaction of catch per hour and year respectively while 23.4% was attributable to random error. Best fit for each species was obtained in the form of double ln relationship:

$$P = e^{(\beta_0+\beta_1 C\ )}$$

where P is percent of catch, C is catch per hour and the parameter estimates and r^2 values for each species are:

	Redfish	Turbot
β_1	0.93	0.79
β_0	4.45	4.42
r^2	0.88	0.75

In each case the model tends to overestimate percent of catch for high values of catch per hour. Given that high values are rare events, the models are adequate within the range of a large majority of the data. Therefore, this relationship implies that the distributions in Fig. 7 and 8 not only describes the relationship of Greenland halibut and redfish to other species present in the catch but also presents a picture of their relative abundance along the environmental gradient, depth.

It is useful to compare the depth-related abundance distribution of major bycatch species with the directed species, roundnose grenadier, in order to determine degree of overlap. The interval estimates (at the 95% level) in Fig. 10 for grenadier show a distinct pattern of increasing values over the shallow depth ranges but with considerable overlap due to large variation over the entire range. Only when comparing values for depths less than 500-600 m to those exceeding 1000 m is there no overlap of interval estimates. This suggests no significant difference in catch rates over all but the shallowest fishing areas. The catch rate leveled off in the mid to deep areas, possibly diminishing slightly below 1200 m in some years. Also, there appears to be a slight reduction in optimum hourly catch rates from about 0.8 in 1978 to 0.6 in 1983. Analysis of variance indicated no significant differences at the 0.01 level between countries, months, or areas. The tendency regardless of fleet, time of year or area fished was toward minimum overlap of grenadier with redfish but considerable overlap with Greenland halibut in the 600 to 1100 m range.

DISCUSSION

With respect to it's commercial distribution roundnose grenadier is unique because of its exceptionally wide scope of depth and latitude. Trawl depths for this fishery are distributed between 450 and 1600 m (1978-83), outside the range of all but two exploited commercial species. Grenadier directed catches are composed of a complex and highly variable assemblage of both shelf and slope species, with Greenland halibut and redfish constituting the most significant bycatches. These two species often occur in substantial proportions and have been recorded over the entire period of the fishery and during the early exploratory phase. Savvatimskii (1969) noted that grenadier made up only a minor to moderate bycatch in the Greenland halibut and redfish dominated deep water scouting cruises of the early 1960's, however, much of this work occurred at depths less than 700 m where bycatch was demonstrated in the present study to be highest. A significant observation from this early paper was the inverse relationship with respect to proportions of roundnose grenadier and Greenland halibut. Pechenik and Troyanovskii (1971) also noted from the 1965-66 explorations that concentrations of grenadier were intermittent, of low density, and unstable in the 500 to 650 m range. Also, corresponding to the months of the 1978-83 observed fishery (current study), records for the fall fishery of 1968 indicated high bycatch of Greenland halibut; 10-30% in the south (3K) and 10 to 40% in the north (2GH), averaged over the entire depth range fished (600 to 1370 m). These early records showed reasonably similar patterns of bycatch to those in the present study including the presence of denser, more stable concentrations of grenadier in the deepest portion of the range.

Other studies consisting of more recent commercial data are less concordant particularly with respect to the present study. While Zilanov (1976) for the early commercial period, 1967 to 1974, set forth estimates of no less than 92% roundnose grenadier in the catches in all depths and almost all areas, Chumakov and Savvatimskii (1983) listed substantially higher levels of Greenland halibut in the north for the same period; 23% in 901 to 1000 m, up to 52% in 501 to 600 m. Chumakov and Savvatimskii's (1984) breakdown of more recent catches by month and depth list high Greenland halibut bycatches (average 37.6%) for the 1973 to 1977 commercial fisheries over the entire range and an even higher value, 52.8% for 1978 to 1981. The commercial portion of these data, however, were not directly comparable to the present study because they not only included sets from Davis Strait but also catches in the study area containing any amount of grenadier, regardless of the directed fishery. This included considerable amounts of catch information from the period prior to start of the formal grenadier fishery in June or July. As well, only information from depths less than 1100 m was included although the 1100 m portion made up nearly one third of the observed fishery in 1978 to 1983. As such, these factors contributed to some of the differences observed between the present study and the work of Chumakov and Savvatimskii (1984). The latter study was in agreement in one aspect indicating higher Greenland halibut bycatches to the north and decreasing abundance with depth in 3K.

Recent studies while not all consistent with respect to bycatch levels nonetheless pointed to the dramatic decline of the roundnose grenadier fishery. Atkinson (1984) attributed the decline, at least in part to a reduced stock of grenadier as reflected in diminished catch rates. On the other hand, Chumakov and Savvatimskii (1984) suggested that increased abundance of Greenland halibut, particularly in the deeper areas overlapping grenadier grounds (and combined with current bycatch restrictions) was forcing fleets to fish away from areas of maximum genadier abundance. As such, avoidance of Greenland halibut was said to prevent full exploitation of the grenadier stocks. Attesting to this Bowering (1984) noted that older, larger individuals of Greenland halibut are distributed more deeply and (Bowering and Brodie 1984) found that the very abundant 1972-74 year-classes were now maturing and migrating to northern offshore areas . In the present study an outward shift was noted in the mode or centre of abundance of Greenland halibut between 1980 and 1981. In addition Burmakin (1978) and Ernst (1984) hypothesized that outwardly shifting and cooling water masses along the shelf break could affect species distributions, the latter author specifically suggesting the affect on Greenland halibut in the study area.

The present study revealed a third important factor not previously addressed. Effort location, specifically with respect to depth and area, was found to influence bycatch levels of both Greenland halibut and redfish in the catches and to a lesser extent, catch rates of grenadier. As such, sufficiently large changes in effort location alter species mixes in the grenadier catches. This occurs because the areal and depth distributions of grenadier, Greenland halibut, redfish, and other species incompletely overlap. In relation to depth, each of the species was distributed in Gaussian fashion typical of populations along environmental gradients (Gauch and Whittaker 1972). The mode or centre of abundance for the distribution of each species was differently located and the maxima, reflecting level of abundance at the mode, varied between areas north to south. Because of this, sets prosecuted in the shallowest sector of the grenadier grounds produced the largest amount of redfish particularly in the south. Mid-range sets yielded a varying mix of grenadier and Greenland halibut. Highest levels for the latter species were obtained at about 700-750 m in the north. The lowest levels of bycatch occurred at depths greater than 1100 m both in the north and south and there was a substantial drop in catch rates for grenadier at about 550-600 m. Therefore, while purely speculative it is possible that effort location differences for the years prior to this study may have influenced the increase in bycatch along with the other factors previously noted.

Period and span of the fishery with regard to season also affected the mix of species in grenadier catches because of an increasing overlap with Greenland halibut as the grenadier migrated into shallower waters from spring to autumn (Pechenik and Troyanovskii 1971). Since 1978, the majority of the fishery occurred during the fall months with no spring fishery and a relatively small summer effort in contrast to the years prior to 1978. Therefore the majority of the fishery of recent years took place when Greenland halibut bycatches would be greatest. The decline of the grenadier fishery is probably related in varying degrees to decreased stock abundance, a shift in the distribution of Greenland halibut to greater depths and changes in the patterns of effort location. All three combined to produce a complex and variable pattern of bycatch and catch rates from year to year.

REFERENCES

Anon. 1982. SAS users guide: Statistics 1982 Ed. SAS Inst. Cary N.C., 584 p.

Atkinson, D. B. 1982. Status of roundnose grenadier stocks in Subareas 0+1 and 2+3. NAFO SCR Doc 82/VI/55, 8 p.

1983. Roundnose grenadier in Subareas 0+1 and 2+3 NAFO SCR. Doc. 83/VI/37, 6 p.

1984. An update on the status of roundnose grenadier in Subareas 0+1 and 2+3 NAFO SCR Doc. 84/VI/20, 6 p.

Bowering, W. R. 1983. By-catch levels of Greenland halibut in the roundnose grenadier fishery of NAFO Subareas 2+3. NAFO SCR Doc. 83/VI/28, 4 p.

1984. Distribution and relative abundance of the Labrador-Eastern Newfoundland stock complex of Greenland halibut (Reinharditus hippoglossoides). NAFO SCR Doc. 84/VI/61, 14 p.

Bowering, W. R., and W. B. Brodie. 1984. An assessment of the Greenland halibut (Reinharditus hippoglossoides) stock complex in NAFO Subareas 2 and Division 3KL. NAFO SCR Doc. 84/VI/62, 19 p.

Burmakin, V. V. 1978. Influence of water temperature on the catches of roundnose grenadier and Greenland halibut of the Baffin Island. Can. Transl. Fish. Aquat. Sci. No. 4915, 7 p.

Chumakov, A. K., and P. I. Savvatimskii. 1983. On the Greenland halibut bycatch in the directed fishery for roundnose grenadier on the Labrador continental slope and in Davis Strait (NAFO Subareas 0, 1, 2, and 3K). NAFO SCR Doc. 83/IX/91, 12 p.

1984. Roundnose grenadier - Greenland halibut ratio in bottom trawl catches taken in NAFO area in 1970-83. NAFO SCR Doc. 84/VI/37, 15 p.

Eliassen, J. 1983. Distribution and abundance of roundnose grenadier (Corphaenoides rupestris Gunnerus) (Gadiformes, Macrouridae) in northern and mid-Norway. ICES C.M. 1983/G: 43, 24 p.

Ernst, P. 1984. A contribution to bycatch of Greenland halibut (Reinhardtius hippoglossoides Walb.) in the roundnose grenadier (Coryphaenoides rupestris Gunn.) directed fishery in NAFO Subarea 2. NAFO SCR Doc. 84/IX/96, 8 p.

Gauch, H. G., and G. B. Chase. 1974. Fitting the Gaussian curve to ecological data. Ecology 55: 1377-1381.

Gauch, H. G., and R. H. Whittaker. 1972. Coenocline simulation. Ecology, Vol. 53, No. 3, 446-451.

Kulka, D. W. 1983. Method for determination of fish production conversion factors on commercial factory trawlers. CAFSAC Res. Doc. 83/25, 32 p.

Kulka, D. W., and J. R. Firth. 1985. Observer program training manual, Newfoundland Region. Fish. Aquat. Sci. Tech. Rept. 1355: ix + 171 p.

Ostle, B., and R. W. Mensing. 1975. Statistics in research. Iowa State Univ. Press 596 p.

Parsons, L. S. 1976. Distribution and relative abundance of roundnose, roughhead, and common grenadier in the Northwest Atlantic. ICNAF Selected Papers, No. 1, 73-88.

Pechenik, L. N., and F. M. Troyanovskii. 1971. Trawling resources on the North-Atlantic continental slope, Israel Prog. Sci. Transl., 66 p.

Savvatimskii, P. I. 1969. The grenadiers of the North Atlantic. Fish. Res. Bd. Can. Transl. No. 2879, 86 p.

Snedecor, G. W., and W. G. Cochran. 1978. Statistical methods. Iowa State Univ. Press, Ames, Iowa U.S.A.

Zilanov, V. K. 1976. The problem of species composition and value of bycatch obtained in the course of a specialized grenadier, Macrourus rupestris, fishery in the Northwest Atlantic. ICNAF Res. Doc. 76/VI/112, 11 p.

Table 1. Catch, effort, and catch per unit effort for the observed USSR roundnose grenadier fishery, 1978-83.

Year	Month	Area	Days observed	% Fishery observed	Sets observed	Catch/ day	Catch/ hour	% Greenland halibut bycatch	% Redfish bycatch	Av. depth (m)
1978	July	2G	10		29	14.35	1.20	4.42	0.63	868
		3K	56		148	12.06	0.83	3.35	0.10	1330
		2+3	66		177	12.40	0.87	3.52	0.16	1256
	Aug.	3K (2+3)	26		53	12.86	0.98	6.77	0	1337
	Sept.	3K (2+3)	55		132	10.14	0.74	3.74	0	1145
	All	3K	137		333	11.43	0.81	4.12	0	1263
		2+3	147	11	362	11.63	0.83	4.14	0.10	1232
1979	June	3K (2+3)	15		48	9.97	0.72	4.57	0.01	1218
	July	3K (2+3)	27		96	12.90	0.84	4.44	0.01	1215
	Dec.	2G (2+3)	4		20	9.68	0.84	37.88	1.22	856
	All	3K (2+3)	42		144	11.58	0.80	4.47	0.01	1216
		2+3	58	10	164	11.30	0.84	18.94	0.10	1120
1980	Oct.	3K (2+3)	5	6	14	6.26	0.58	9.90	0.02	865
1981	July	3K (2+3)	16		56	10.36	0.77	7.22	0.65	1063
	Aug.	2G	32		98	6.65	0.55	46.89	0.08	982
		2H	79		288	8.15	0.74	37.75	8.32	769
		3K	37		118	12.51	1.04	7.32	2.45	1050
		2+3	148		504	8.92	0.79	31.39	5.30	874
	Sept.	2G	25		80	4.07	0.38	51.80	6.70	705
		2H	12		32	4.48	0.41	38.28	5.31	711
		3K	51		214	11.30	0.86	19.19	3.10	935
		2+3	88		326	8.37	0.70	27.36	2.25	849
	Oct.	2H (2+3)	4		13	10.28	0.84	27.48	3.75	742
	Nov.	3K (2+3)	15		45	9.86	0.81	11.36	0.26	1025
	All	2G	57		224	5.54	0.48	48.78	2.62	859
		2H	95		333	7.77	0.71	37.41	7.92	762
		3K	119		433	11.37	0.89	13.39	1.19	994
	All	2+3	271	50	944	8.90	0.76	27.97	3.86	882.6
1982	Aug.	2H	3		10	3.65	0.43	37.72	0	966
		2J	1		4	1.50	0.14	20.29	0	1000
		3K	30		109	9.12	0.69	5.48	0	1108
		2+3	36		129	8.0	0.64	7.57	0	1091
	Sept.	3K (2+3)	15		44	7.17	0.59	7.43	0	1037
	Oct.	2G	26		89	6.06	0.73	49.96	0	946
		2H	10		33	5.61	0.67	30.76	5.78	763
1982		2+3	36		122	5.93	0.72	46.01	1.51	897
	Nov.	2G	24		97	5.04	0.53	65.11	0.17	937
		3K	23		58	16.89	1.96	4.56	0	1043
		2+3	47		155	10.84	1.74	33.90	0.09	976
	All	2G	50		186	5.57	0.63	58.29	0.28	941
	All	2H	13		43	5.16	0.60	32.16	4.61	807
		3K	68		211	11.32	0.98	5.31	0	1073
		2+3	134	54	450	8.35	0.82	29.20	0.40	990
1983	Nov.	3K (2+3)	14		49	7.53	0.62	20.50	0.39	1109
	Dec.	2H	9		30	2.30	0.33	47.70	0.94	722
		2J	1		1	0	0	87.26	11.63	690
		3K	7		21	4.78	0.46	21.95	0.18	1027
		2+3	18		56	3.03	0.37	35.02	3.29	840
	All	3K	21		70	6.61	0.58	20.84	0.34	1082
		2+3	32	31	105	5.0	0.51	26.28	1.54	960
Midwater Fishery										
1981	All	2+3	4		9	11.03	0.71	0	0.13	894

Table 2. Catch, effort, and catch per unit effort for the observed GDR roundnose grenadier fishery, 1978-83.

Year	Month	Area	Days observed	% Fishery observed	Sets observed	Catch/ day	Catch/ hour	% Greenland halibut bycatch	% Redfish bycatch	Av. depth (m)
1978	Oct.	2G (2+3)	17		30	2.75	0.65	37.09	8.29	622
	Nov.	2G	4		15	1.52	0.13	84.70	0.24	568
		2H	22		71	3.18	0.46	53.71	3.45	605
		2J	7		24	1.01	0.09	52.46	34.75	586
		2+3	42		110	2.44	0.28	57.44	12.27	585
	All	2G	21		45	2.51	0.42	54.15	5.41	605
		2+3	59	22	140	2.54	0.35	52.85	11.37	591
1980	Oct.	2G	6		10	0.67	0.29	40.04	7.20	546
		2H	16		39	5.84	0.76	29.35	5.74	562
		2J	9		43	7.52	1.26	17.68	14.35	562
		2+3	43		111	6.08	0.89	28.95	8.95	563
	Nov.	2J (2+3)	44		123	8.14	0.98	16.73	12.24	680
	Dec.	2J (2+3)	4		16	8.69	0.86	27.66	6.61	647
	All	2J	57		182	8.08	1.0	17.88	12.02	659
		2+3	91	100	250	7.21	0.94	20.53	10.63	623
1981	Sept.	2H	8		25	5.93	0.67	21.02	7.57	569
		2J	6		26	1.20	0.10	15.4	49.17	656
		2+3	16		53	3.97	0.36	18.37	24.69	601
	Oct.	2G	50		154	3.70	0.38	45.17	4.70	684
		2H	27		56	1.10	0.15	50.93	18.02	666
		2J	16		42	2.42	0.23	33.02	9.84	810
		3K	13		37	3.27	0.27	35.04	14.94	737
		2+3	114		314	2.69	0.29	42.50	11.18	693
	Nov.	2H	34		114	5.52	0.54	40.15	0.64	875
		2J	22		59	3.84	0.50	26.70	0.05	871
		3K	21		71	0.83	0.08	10.73	65.0	698
		2+3	83		261	3.54	0.38	25.81	23.49	803
	Dec.	2H	9		29	2.25	0.22	65.10	0.23	900
		2J	1		1	1.10	0.44	39.49	4.39	1000
		2+3	10		30	2.12	0.23	64.08	0.40	903
	All	2H	78		224	3.70	0.42	42.39	4.23	787
		2J	45		124	2.92	0.32	16.66	25.30	814
		3K	24		75	1.36	0.12	13.94	48.58	726
		2+3	223	70	658	3.08	0.33	34.23	17.14	738
1982	Sept.	2J	4		3	0.04	0.02	4.47	91.90	785
		3K	10		28	7.15	0.64	13.57	3.76	1035
1982		2+3	16		36	4.77	0.54	10.28	27.72	923
	Oct.	2H	28		87	6.61	0.58	34.55	0.46	985
		2J	4		12	4.38	0.62	16.97	6.28	925
		2+3	32		99	6.32	0.58	33.41	0.84	978
	Nov.	2H	2		5	1.56	0.22	59.82	3.64	940
		2J	5		13	4.08	0.3	22.09	28.66	1029
		3K	51		155	9.09	0.72	14.05	1.22	1048
		2+3	59		177	8.27	0.68	14.92	7.30	1041
	Dec.	2H	6		16	1.05	0.11	80.24	1.71	652
		3K	31		74	12.67	1.23	7.51	4.33	1022
		2+3	38		91	10.44	1.0	13.83	11.40	963
	All	2H	36		107	5.37	0.48	40.51	0.71	942
		2J	14		30	2.93	0.41	11.79	45.69	927
		3K	92		257	10.06	0.84	11.62	2.58	1039
		2+3	145	50	403	8.04	0.72	18.39	8.64	997
1983	Aug.	3K (2+3)	2		2	0.21	0.13	26.94	0	823
	Sept.	2J	3		8	0.33	0.06	1.68	95.62	663
		3K	173		404	5.71	0.51	16.59	21.25	849
		2+3	176		412	5.61	0.50	16.16	23.36	845
	Oct.	2H	122		304	5.48	0.55	18.77	0.37	1108
		3K	3		4	2.5	0.37	25.68	1.13	921
		2+3	126		310	5.37	0.55	18.85	0.38	1103
	Nov.	2H (2+3)	108		295	2.30	0.23	46.48	7.24	852
	Dec.	2H (2+3)	32		95	1.04	0.09	72.40	0.87	910
	All	2H	262		694	3.63	0.36	36.71	2.79	972
		3K	178		435	5.59	0.51	16.65	21.10	849
		2+3	444	69	1114	4.38	0.42	26.99	12.48	922
Midwater Fishery										
1981	All	2+3	12	-	23	5.0	0.47	0	0.10	872

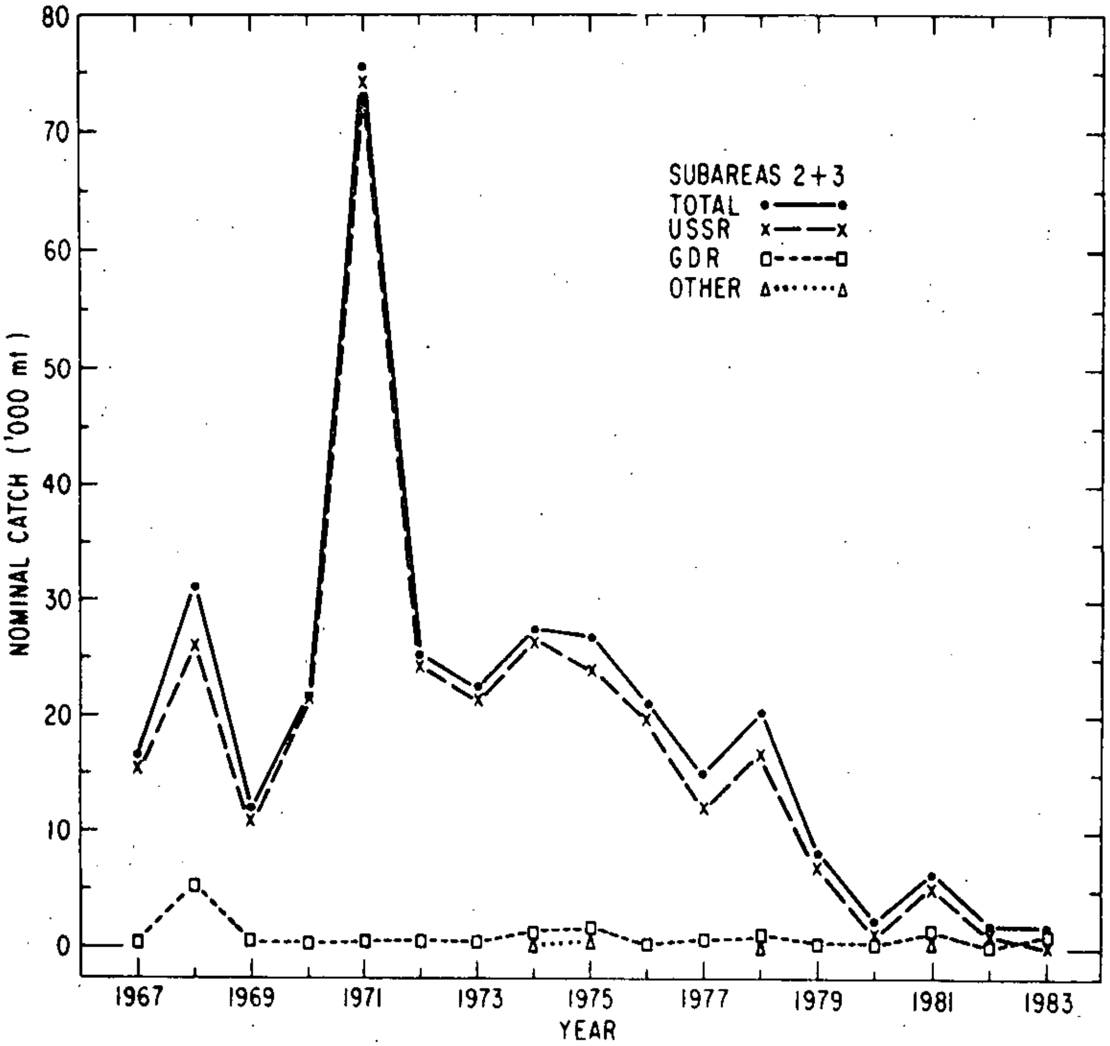

Fig. 1. Nominal catches of roundnose grenadier in Subarea 2+3 1967-83.

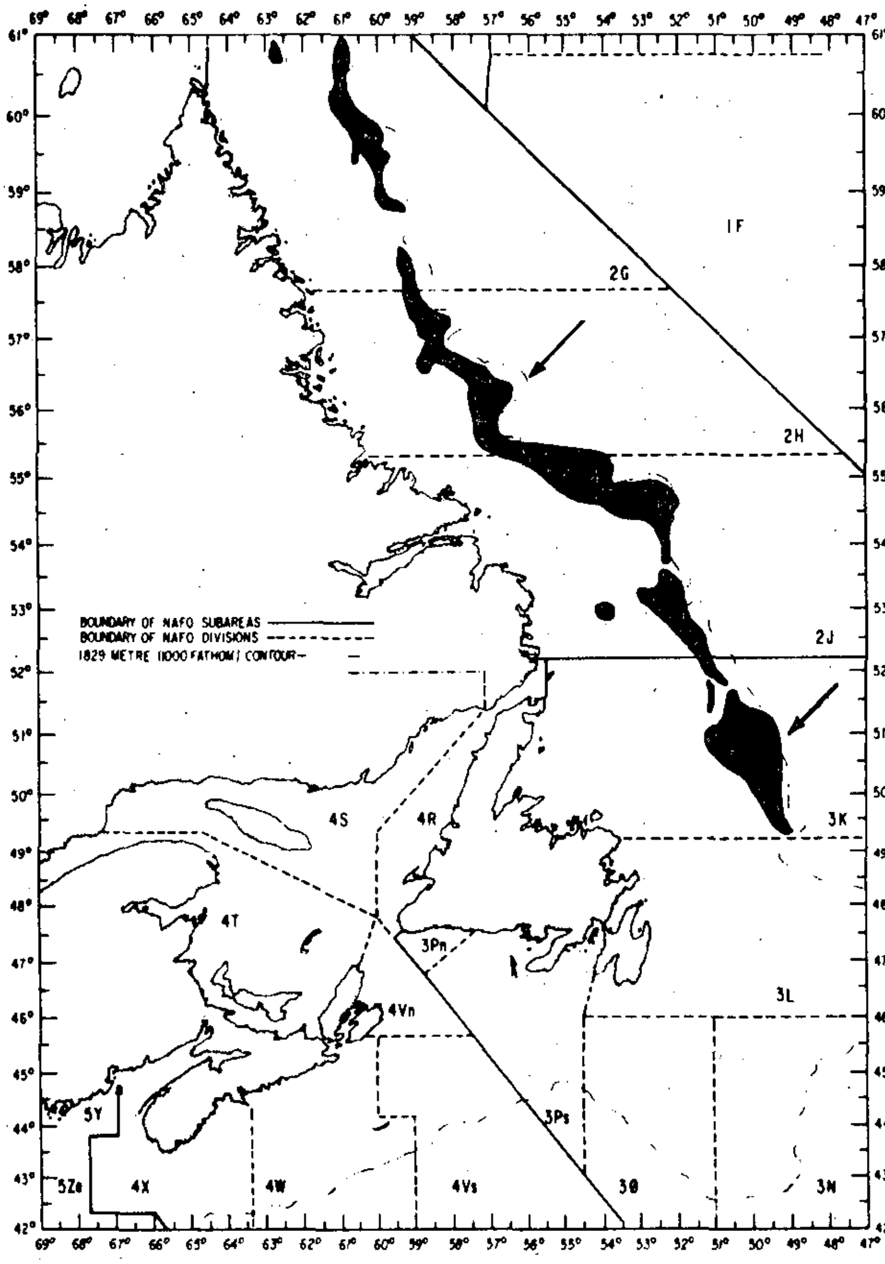

Fig. 2. Cumulative distribution of the fishing effort for roundnose grenadier in Subareas 2+3, 1978-83. Arrows indicate areas of concentrated fishing.

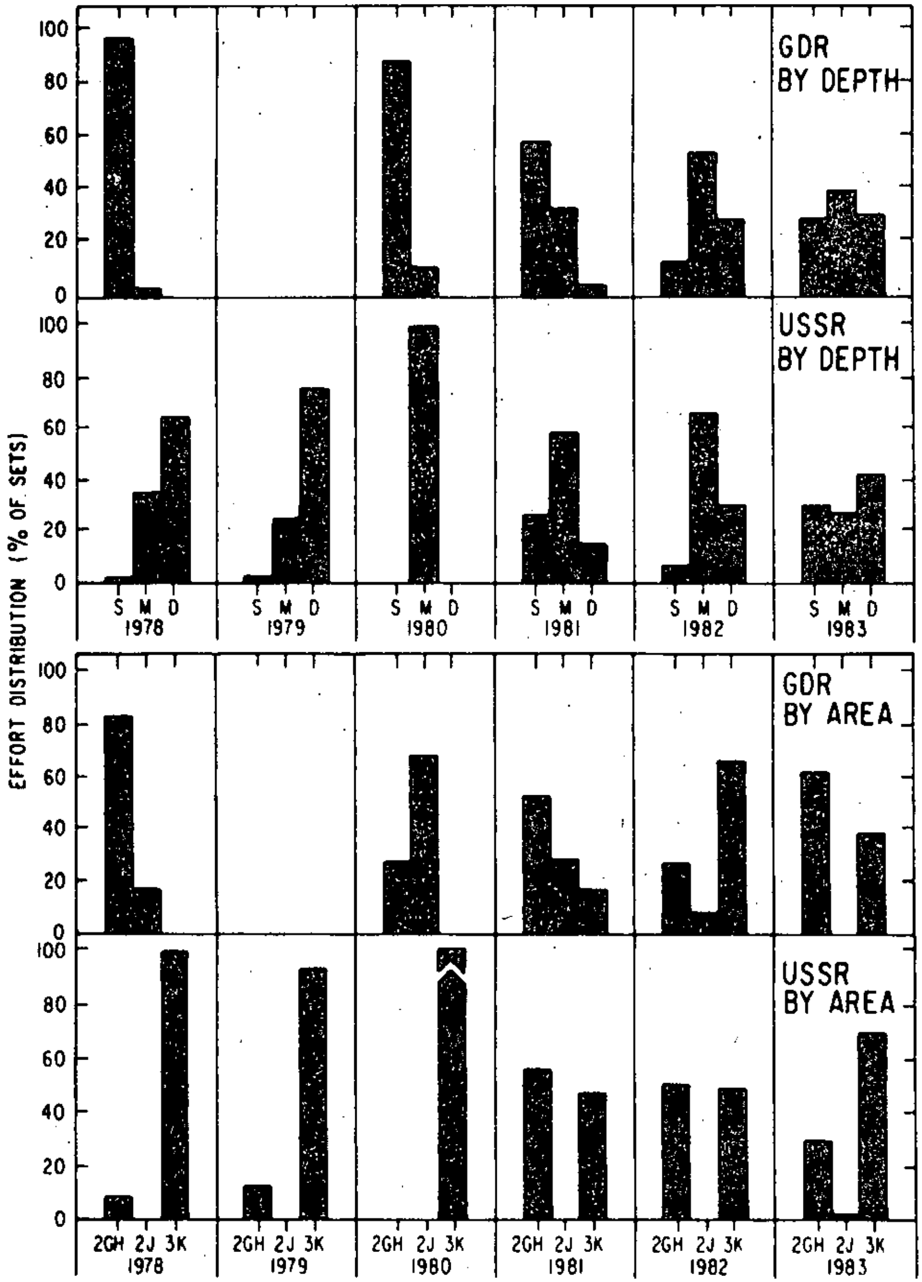

Fig. 3. Relative distribution of observed effort in the grenadier fishery, by depth and by NAFO Division. S, M, and D respectively denote shallow (less than 750 m), medium (751-1050 m) and deep (1051+m).

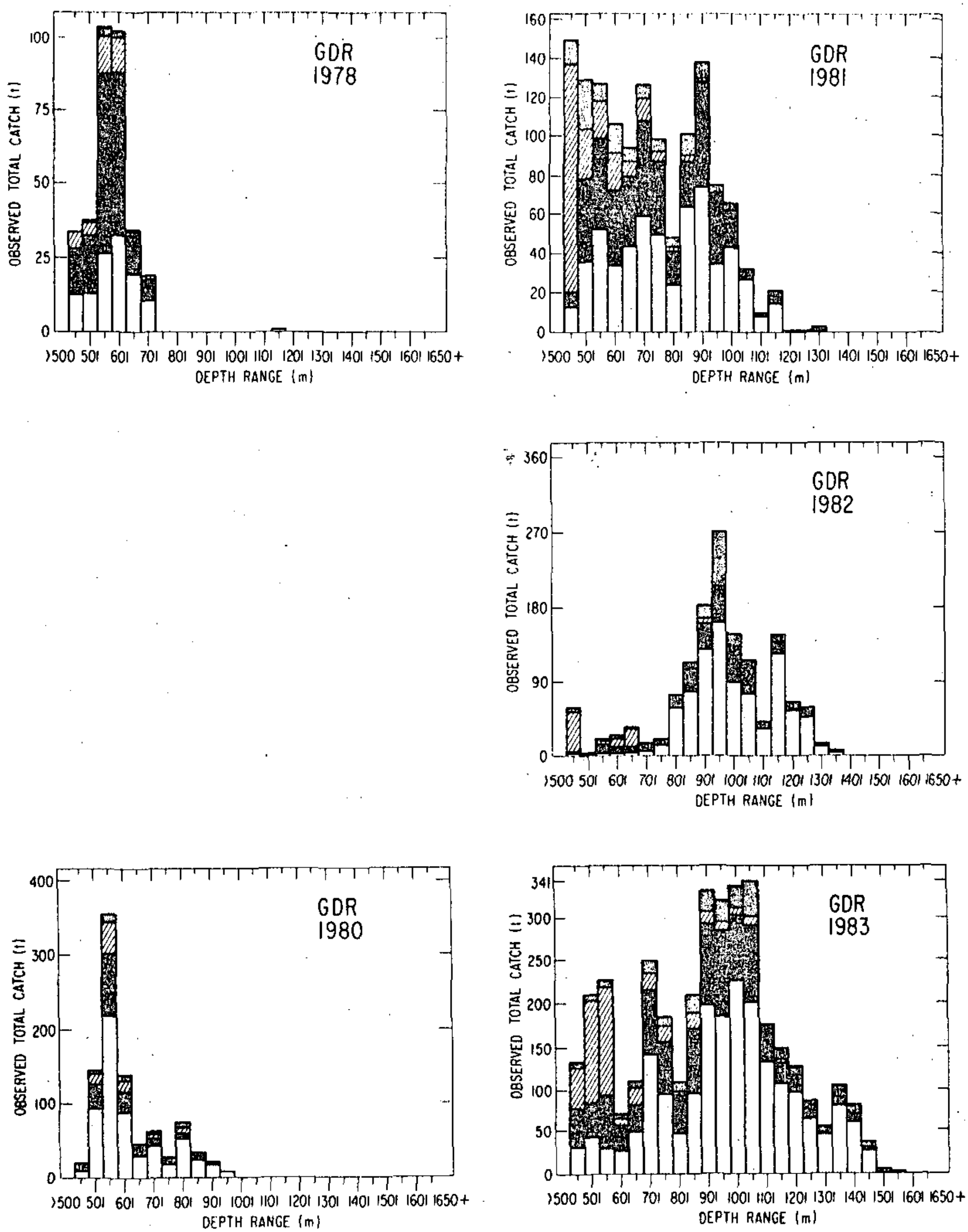

Fig. 4. Distribution of observed catch, by 50 m depth intervals for the GDR grenadier fishery.

[ ]-roundnose grenadier, [ ]-Greenland halibut, [ ]-redfish, [ ]-other.

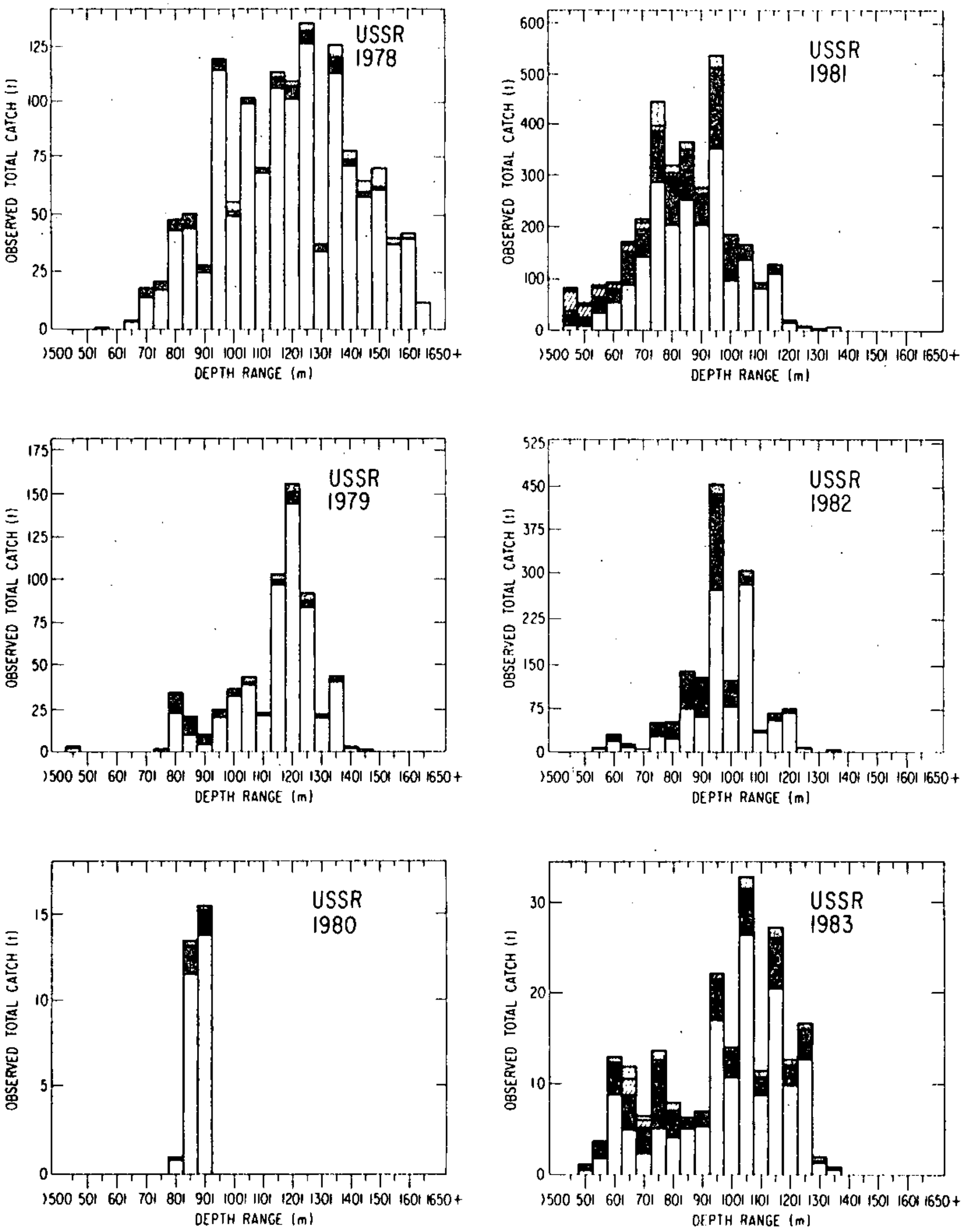

Fig. 5. Distribution of observed catch, by 50 m depth intervals for the directed USSR grenadier fishery.

-roundnose grenadier, -Greenland halibut, -redfish, -other.

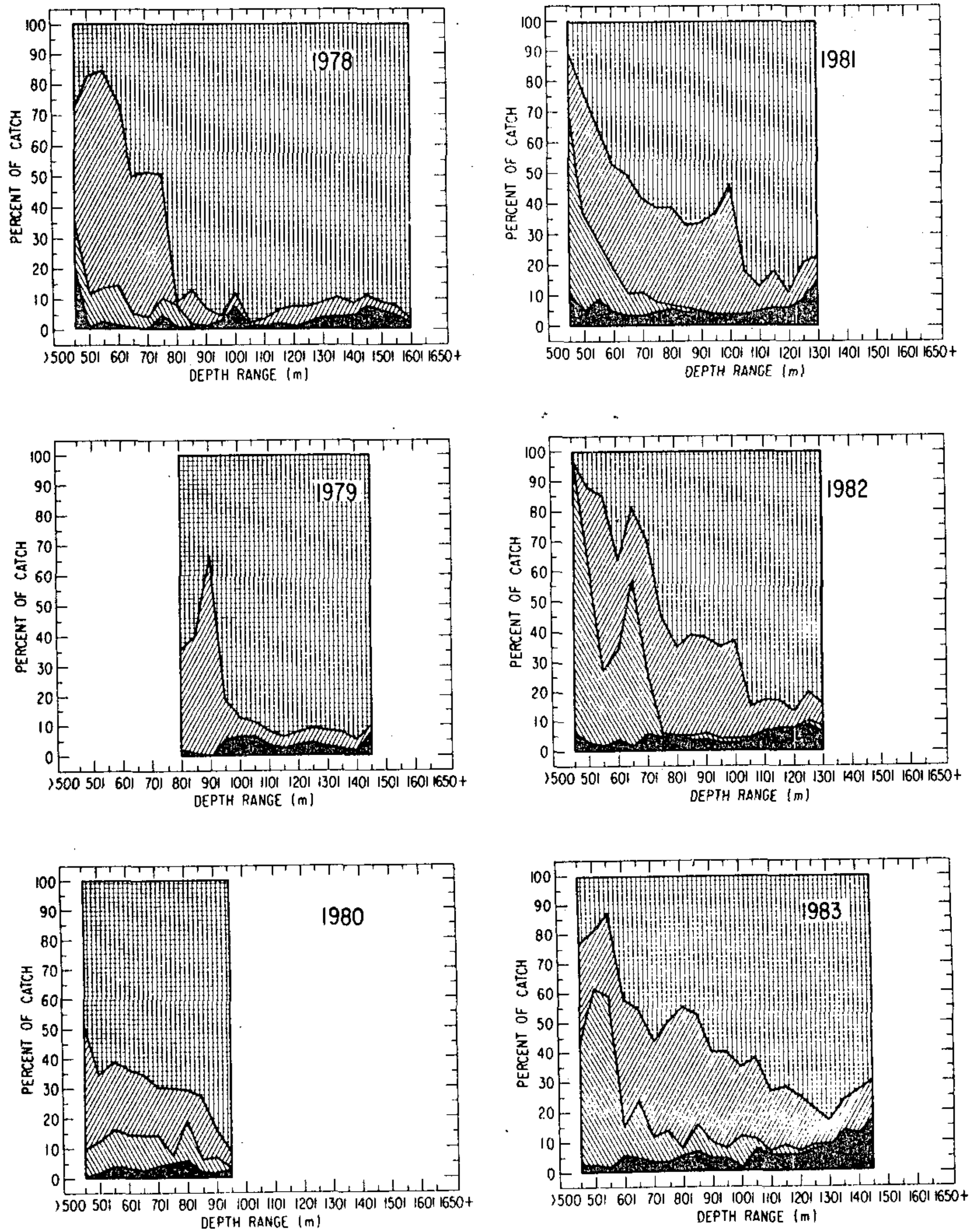

Fig. 6. Composition of all observed roundnose grenadier directed catches, 1978-83.

-roundnose grenadier, -Greenland halibut, -redfish, -other.

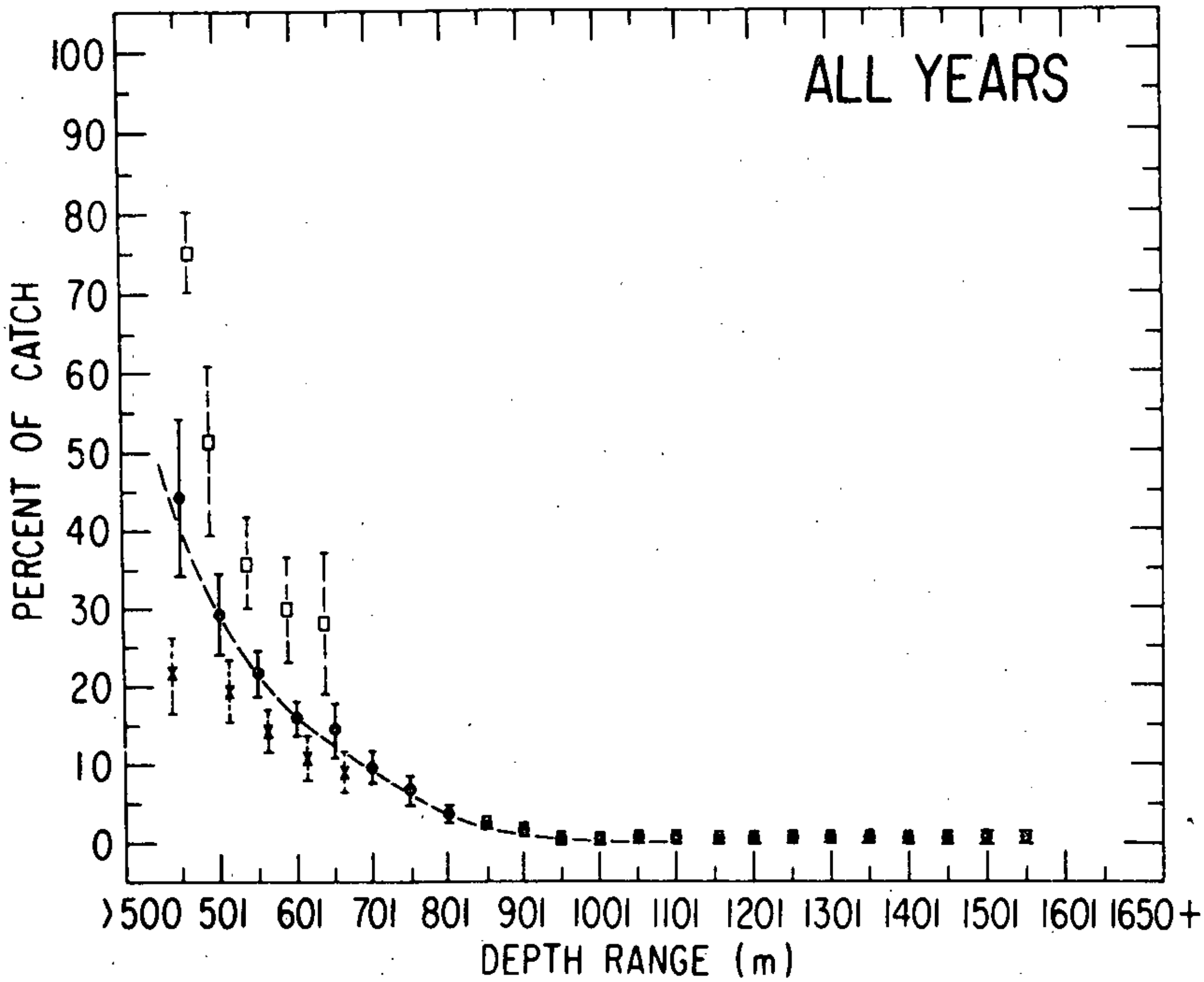

Fig. 7. Point and interval estimates for redfish as a percent of total catch in all years. □-2J3K, ◆-All areas, X-2GH

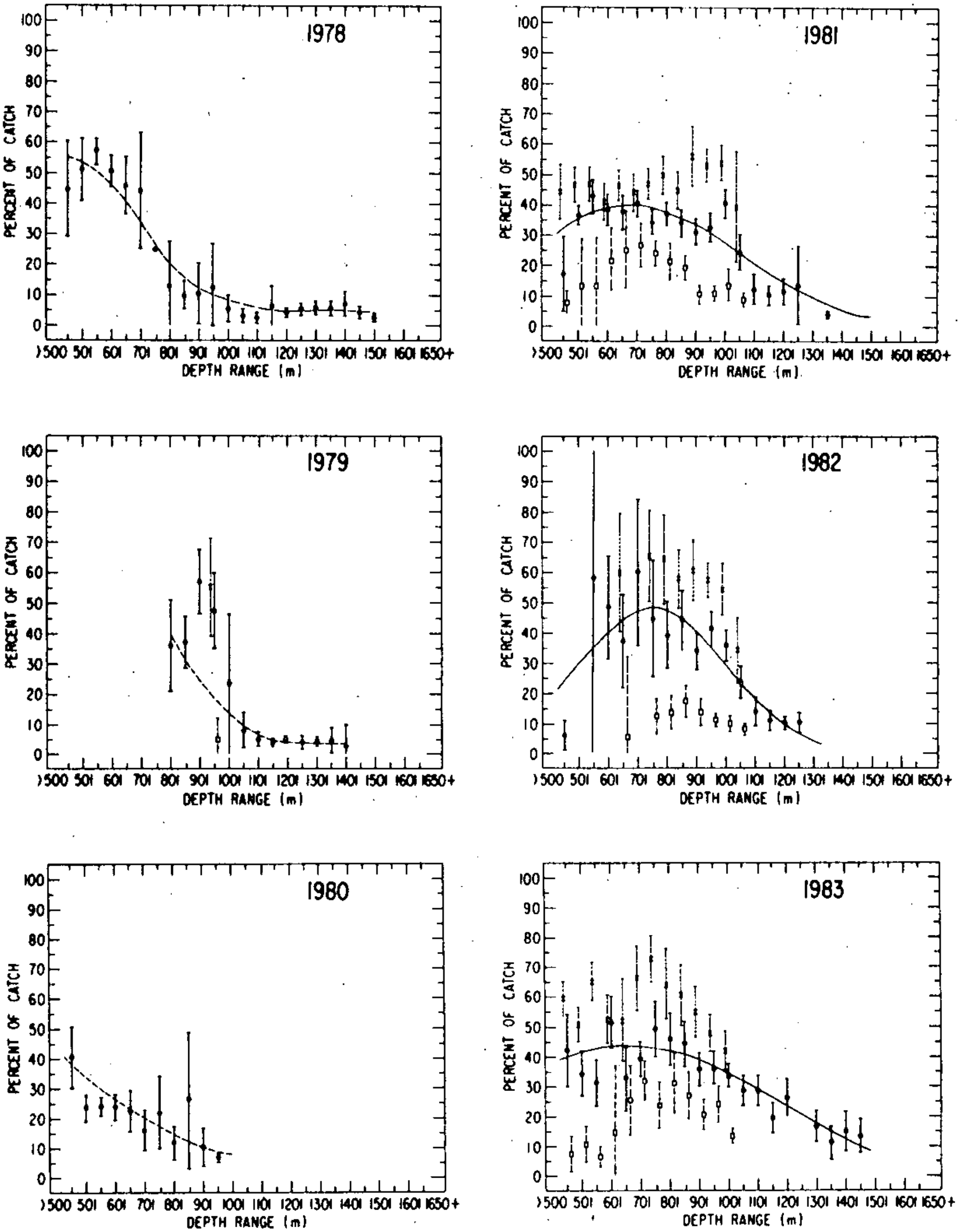

Fig. 8. Point and interval estimates for Greenland halibut as a percent of total catch, 1978-83.

-3K, -2GH, -all areas.

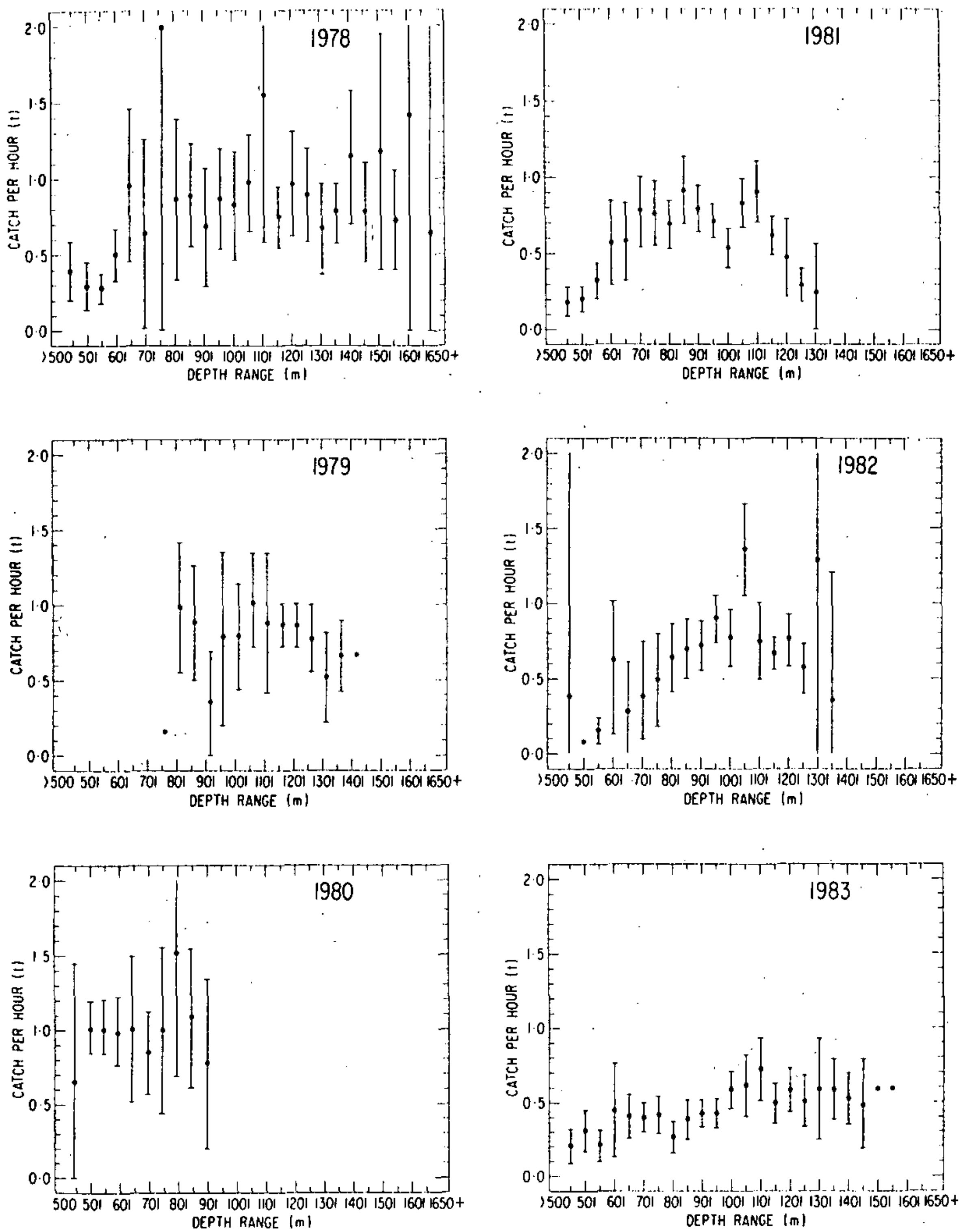

Fig. 9. Catch per hour point and interval estimates for roundnose greandier by 50 m depth categories and year.