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Some Observations on the Biomass and Abundance of Fish Captured During Stratified-Random Bottom Trawl Surveys in NAFO Divisions 2J and 3KL, Autumn 1981–1991

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Abstract

After dramatic declines in the biomass of northern (NAFO Div. 2J and 3KL) cod (*Gadus morhua*) were observed in 1991, questions were raised as to whether the observed declines had been compensated for by increases in biomass of other species of marine life. This study examined the biomass of various fish species captured during annual Canadian autumn research vessel stratified-random bottom trawl surveys to determine if increases of other species coinciding with the decline in cod biomass could be detected. Declines in biomass were observed for all species examined. In most cases, the declines were greater than that for cod, and the proportion of cod biomass to total biomass showed some increase over time, particularly in Div. 2J. The declines in biomass were paralleled in most cases, by declines in abundance. It is still possible that compensatory increases in biomass have taken place in Div. 2J and 3KL in pelagic fish species, or non-fish marine species.

Key words: Abundance, A. plaice, biomass, cod, distribution, grenadiers, groundfish, redfish, skates, surveys

Introduction

Results of 1992 assessments of northern (NAFO Div. 2J and 3KL) cod (*Gadus morhua*) carried out by both CAFSAC (Anon., 1992a) and NAFO (Anon., 1992b) indicated that the stock had not increased as was perceived based on the assessment of May, 1991 (Anon., 1991). This resulted in a discontinuation of the Canadian 3 year management plan for the stock, and a declaration, by the Minister of the Canadian Department of Fisheries and Oceans, on 2 July, 1992 of a 2 year moratorium. Of particular concern during this process was the dramatic decline in trawlable biomass observed during the 1991 Canadian stratified-random bottom trawl autumn survey as well as the disproportionate disappearance of larger mature fish.

The survey results noted above prompted the Steering Committee of the Canadian Atlantic Fisheries Scientific Advisory Committee (CAFSAC) to question whether there were indications of any other fish species increasing in proportion to the observed decline in cod, thus 'filling the void.' Specifically, the Committee **recommended** that *(a) Research into the species composition of research survey catches should be undertaken in the context of potential large scale changes in community structure in the Div. 2J and 3KL area (i.e. was there any compensatory response in other species in the ecosystem?). and questioned (b) Did abundance estimates of species other than cod also decrease in the 1991 survey?*

Annual autumn stratified-random bottom trawl surveys have been conducted by the Department of Fisheries and Oceans, Canada in all of Div. 2J and 3KL beginning in 1981. Results of these surveys have routinely been examined in conjunction with the assessments of a number of different species besides cod (e.g. redfish, Greenland halibut, witch flounder, American plaice and grenadiers). To 1992, there had been no attempts to bring the various estimates together as part of any holistic study.

The analyses presented are of an exploratory nature, and represent attempts to address the questions posed by the CAFSAC Steering Committee. Certain assumptions apply: there has been no systematic trend in catchability (q) over time, and there has been no systematic re-distribution of the various species between inside and outside the survey area over time. There has also been no consideration of the impact of commercial fisheries on any observed trends. For some species (e.g. redfish, Greenland halibut, American plaice), previous assessments have reported that the declines in biomass observed from the surveys cannot be explained by the fisheries.

Materials and Methods

Stratified-random bottom trawl surveys have been conducted by the Department of Fisheries and Oceans, Canada in Div. 2J, 3K and 3L annually during autumn beginning in 1981. The surveys in Div. 2J and 3K have consistently covered depths from 100 to 1 000 m, while those in Div. 3L were conducted from 50 to 200 fathoms (90–365 m) in 1981–1989 and 50–400 fathoms (90–730 m) in 1990–1991. Tows were routinely of 30 min. duration and a small mesh liner (50 mm) was used in the codend.

The data were extracted for a number of different fish species separately (cod, redfish, American plaice, Greenland halibut, witch flounder, roundnose grenadier, roughhead grenadier, skates [species combined]). The remainder of the species were grouped, and their catches totalled for each set.

Although the 'normal' procedure is to determine trawlable biomass or abundance using STRAP (Smith and Somerton, 1981), for this study, I used ACON (Black, MS 1991). This latter procedure uses contouring (Watson, 1982; Watson and Philip, 1985) and the summation of the volume of all defined triangles (Delaunay) under the contoured surface (integration) approximates the total volume. From this, biomass or abundance can be determined. This method was employed because it enabled simultaneous contouring (mapping) of the data as desired. There are some differences in the results obtained from STRAP and ACON (Fig. 1) but these are not considered to be sufficiently large to alter overall trends with time.

Trends in the biomass of cod compared to all other species separated and combined were examined for each division. The proportion of cod relative to the total trawlable biomass was also determined. The data were also partitioned to cod, other commercial species (COM) and non-commercial species (NONC). Least squares linear regressions of biomass on year were done for cod in all three divisions. For divisions with significant relationships for cod, regressions were also carried out of COM and NONC biomass on year. Slopes of the different significant regressions were compared. The 1981 point for COM in Div. 2J was excluded from the analysis because the point was considered an outlier resulting from two very large catches of redfish. Contour plots illustrating the distribution of trawlable fish biomass were also prepared.

It has been observed off West Greenland that although there have been declines in biomass for many species in recent years, the decline in numbers has not been so great (Rätz, 1991, MS 1992). This indicated that the proportion of smaller fish had increased. In order to investigate whether a similar phenomenon has been taking place in Div. 2J and 3KL, ACON was also used to determine the abundance of the species and groups noted above. Trends in biomass and abundance with time were then compared.

Results and Discussion

No species or group demonstrated any trend in biomass that contrasted sharply with that for cod (Fig. 2). Trends in the biomass of cod compared to all other species combined (Fig. 3) were not generally dissimilar. In Div. 2J there was a decline for both groups, while further south in Div. 3K and 3L, the decline in species other than cod seemed to have been greater.

Thus from the data, there is no indication of any compensatory increase in other species paralleling the decline in cod. Instead, there appears to have been a overall decline in all species. In each of the divisions, the proportion of cod to the total biomass actually appears to increase over the 11-year period (Fig. 4). This might suggest that cod itself is a compensatory species in the face of observed declines.

Regression analysis indicated that only in Div. 2J is the decline for cod significant ($p<0.05$) (Table 1). This relationship is not significant without 1990 and 1991. Regressions of COM and NONC were also significant for this division ($p<0.05$) (Table 2). Comparison of slopes of COM and NONC to that of cod in Div. 2J (Table 3, Fig. 5) indicated that the differences were not significant ($p<0.05$).

Contour plots (Fig. 6) of total trawlable biomass indicate wide scale distribution of densities >100 kg per tow during the early-1980s. There was a decline in density on top of some of the banks in the 1984/85 period, probably related to the cold water temperatures during that period. With time, however, it is also obvious that the amount of area with the >100 kg densities steadily declined. Even in 1986, a year identified as yielding anomalously high biomass estimates for cod and other species, this trend was sustained. The trends from 1989 through 1991 are particularly dramatic and suggest not only a decline, but a concentration of the remaining biomass in the offshore areas away from the coast.

Comparisons of trends in biomass and abundance for the various species indicate that abundance has declined simultaneously in many cases (Fig. 7, 8 and 9), but in some instances such as Greenland halibut in Div. 3K it did not. This may be related to recruitment of relatively strong year-classes of the mid-1980s. It also appears that the

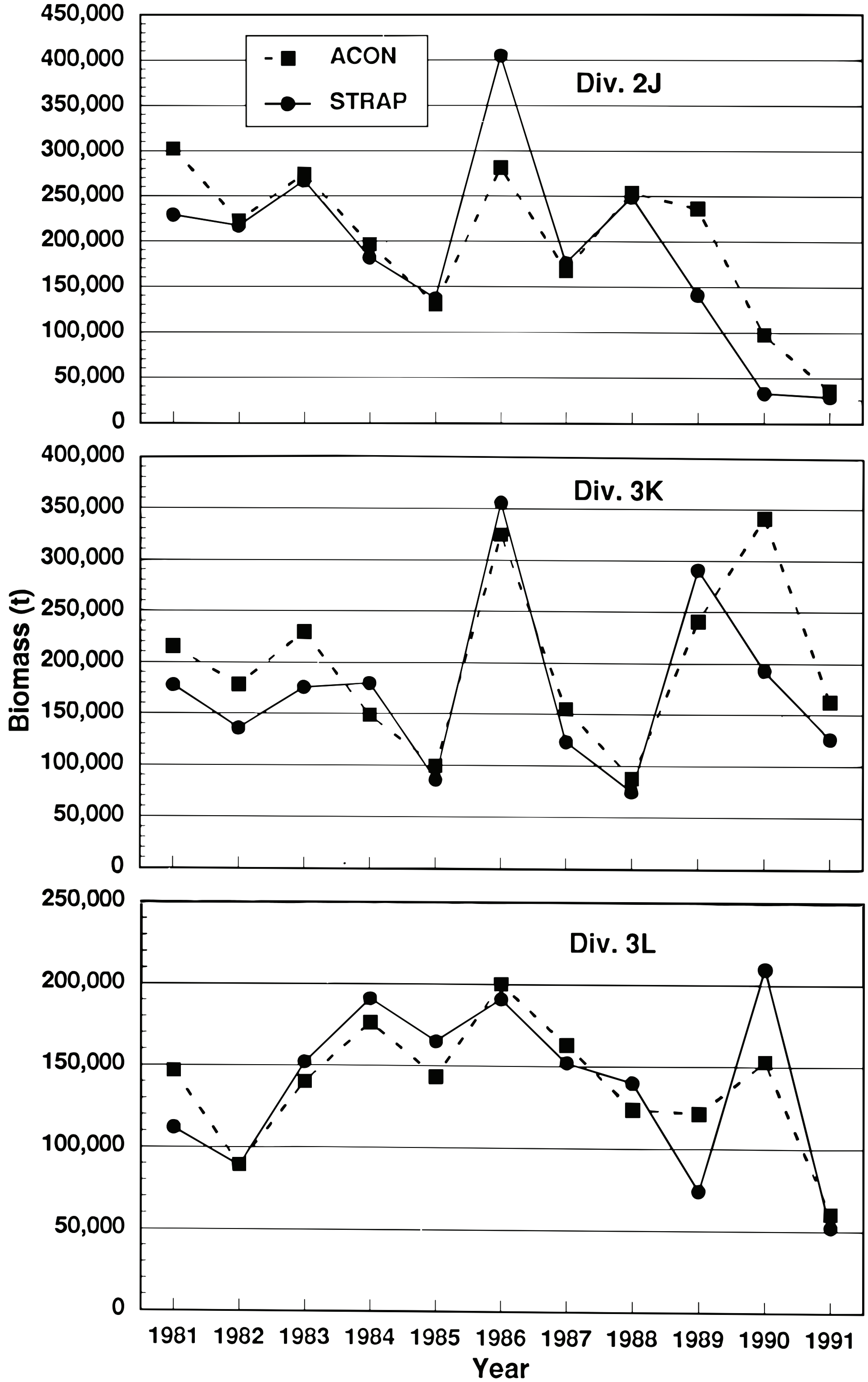


Fig. 1. Comparison of biomass estimates from STRAP and ACON for Div. 2J and 3KL cod.

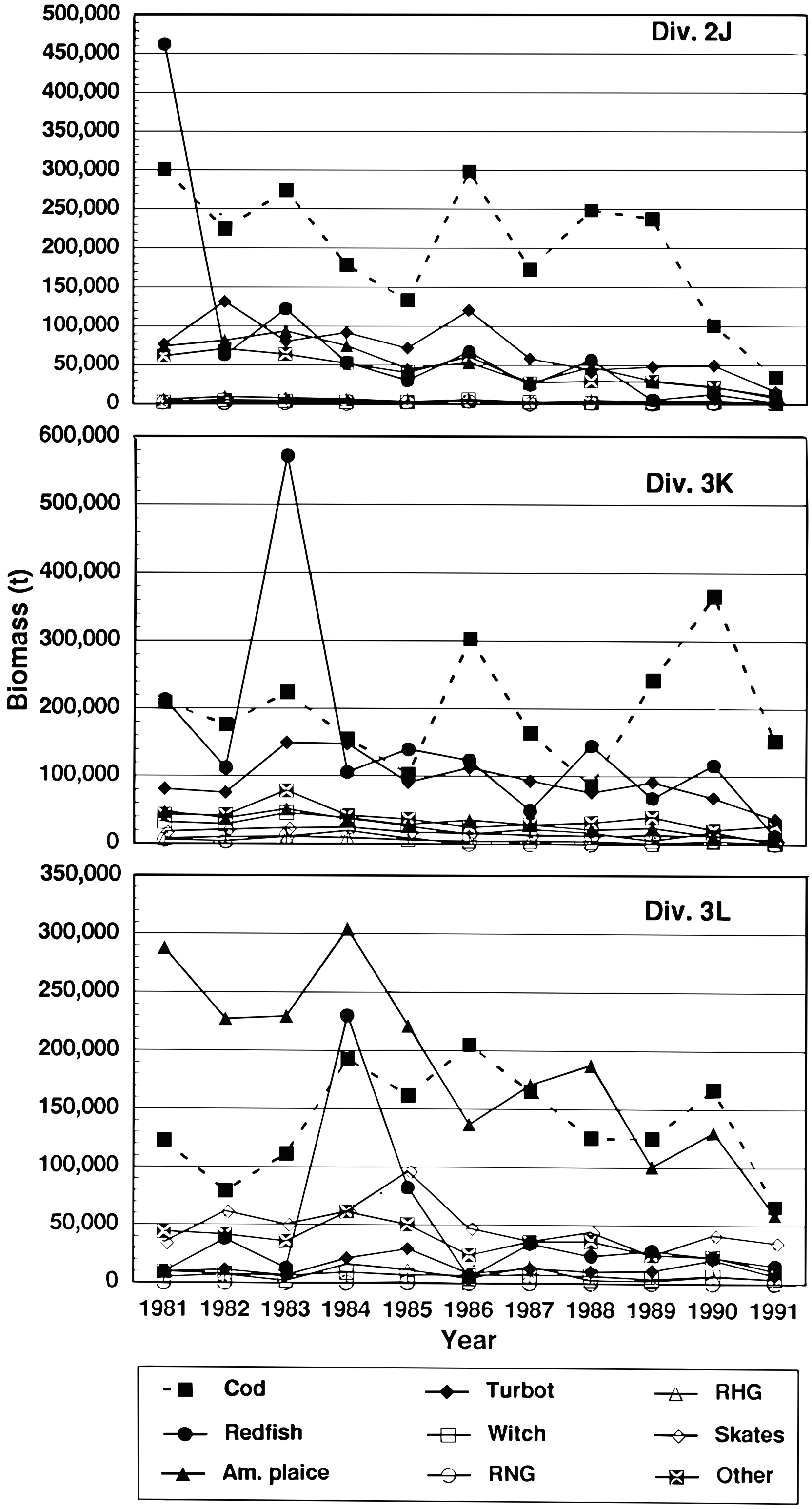


Fig. 2. Biomass estimates for the various species and species groups examined by NAFO Division.

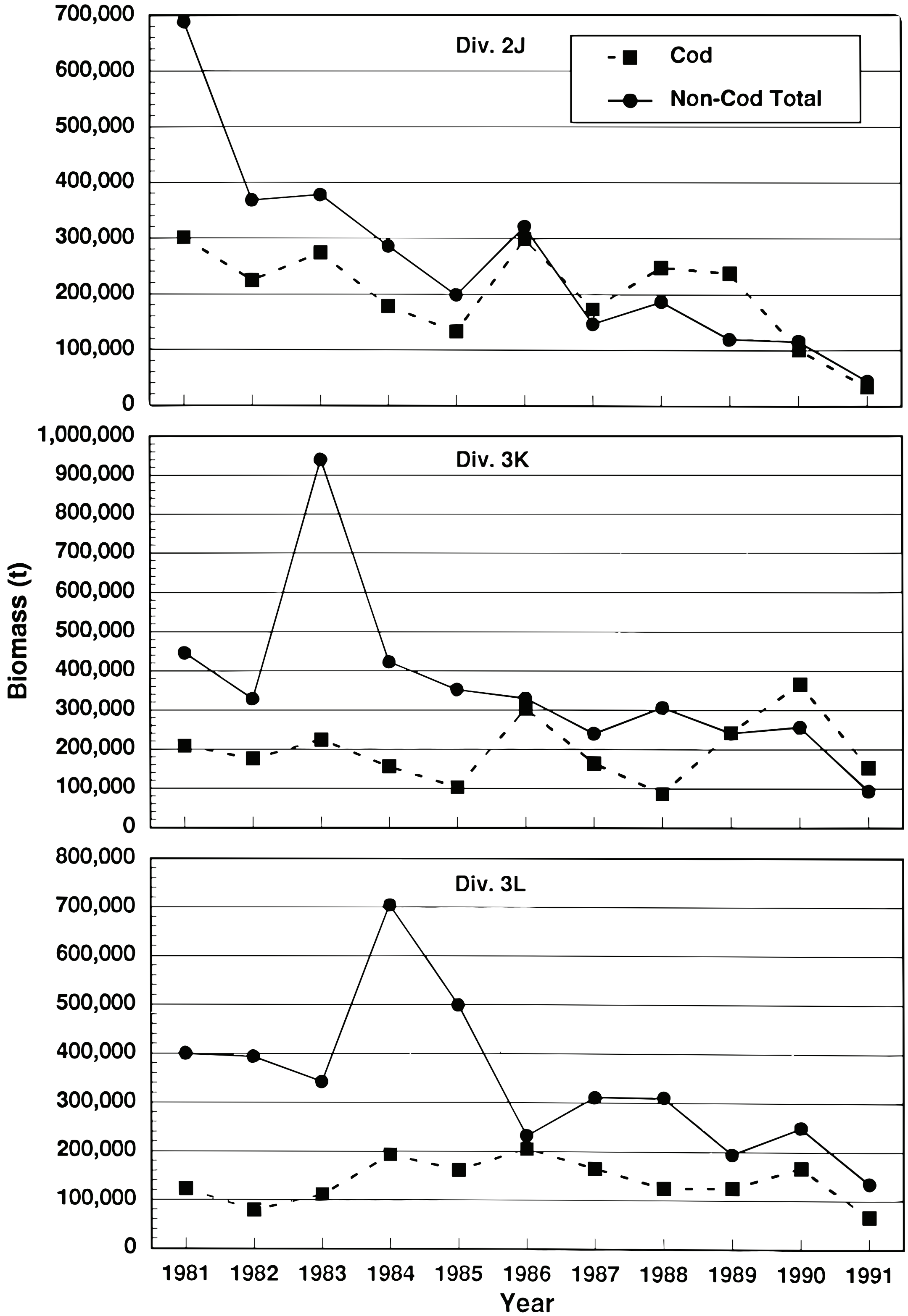


Fig. 3. Comparison of biomass for cod and non-cod species estimated by NAFO Division from the bottom trawl surveys, 1981–1991.

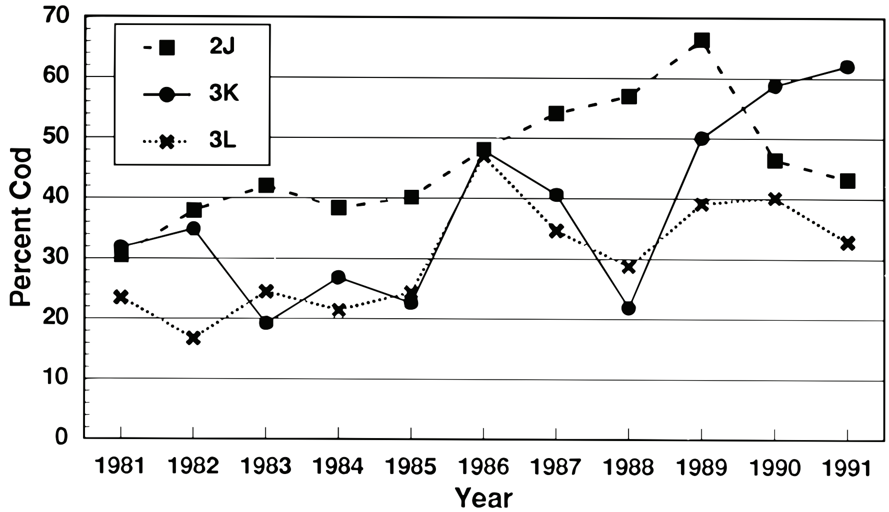


Fig. 4. Percentage of cod in total estimated fish biomass by NAFO Division.

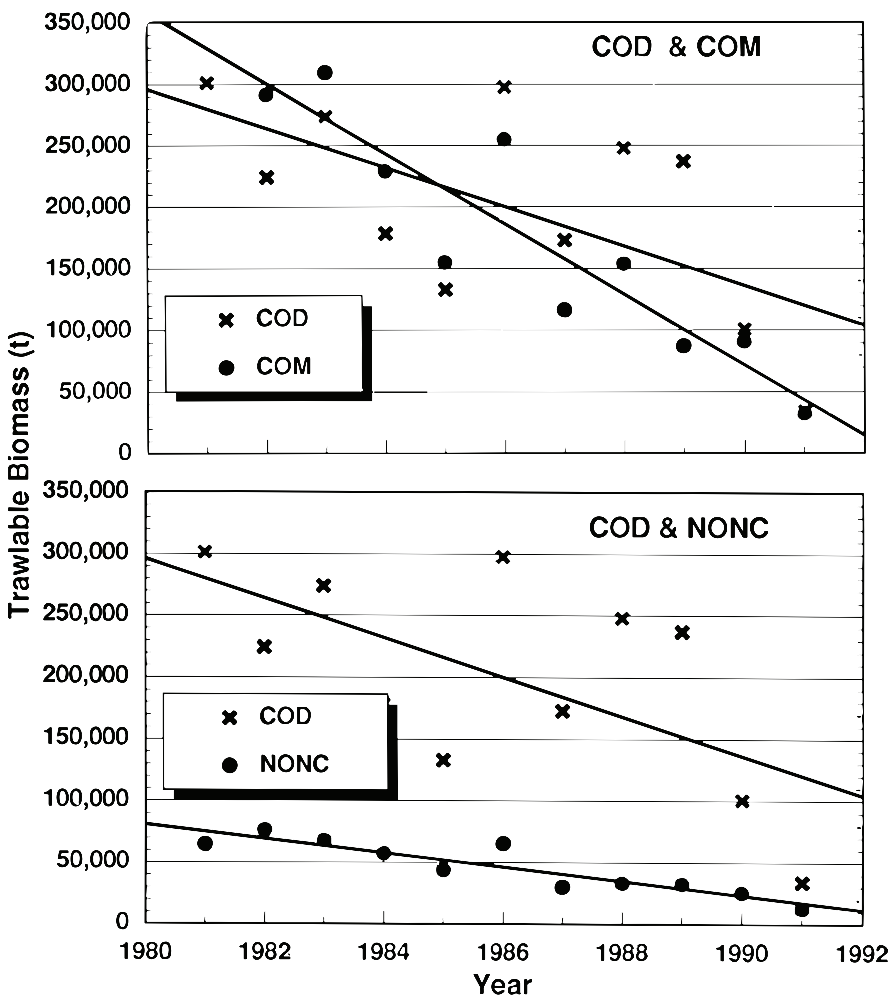


Fig. 5. Regression of biomass on year for cod and other commercial (COM) and non-commercial (NONC) species in Div. 2J.

TABLE 1. Results of regression analyses of cod biomass *vs* time.

Division 2J

DEP VAR: **COD** N: 11 MULTIPLE R: 0.623 SQUARED MULTIPLE R: 0.388 ADJUSTED SQUARED MULTIPLE R: 0.320
STANDARD ERROR OF ESTIMATE: 70296.2060

VARIABLE	COEFFICIENT	STD ERROR	STD COEF	TOLERANCE	T	P(2 TAIL)
CONSTANT	.319799E+08	.133111E+08	0.0000	.	2.4025	0.0397
YEAR	-16001.8091	6702.4803	-0.6227	1.0000	-2.3874	0.0407

ANALYSIS OF VARIANCE

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P	
REGRESSION	.281664E+11	1	.281664E+11	5.6999	0.0407	**SIG.**
RESIDUAL	.444740E+11	9	.494156E+10			

Division 3K

DEP VAR: **COD** N: 11 MULTIPLE R: 0.166 SQUARED MULTIPLE R: 0.028 ADJUSTED SQUARED MULTIPLE R: 0.000
STANDARD ERROR OF ESTIMATE: 86321.1675

VARIABLE	COEFFICIENT	STD ERROR	STD COEF	TOLERANCE	T	P(2 TAIL)
CONSTANT	-.805514E+07	.163456E+08	0.0000	.	-0.4928	0.6340
YEAR	4155.7727	8230.4004	0.1660	1.0000	0.5049	0.6257

ANALYSIS OF VARIANCE

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P	
REGRESSION	.189975E+10	1	.189975E+10	0.2550	0.6257	**N.S.**
RESIDUAL	.670621E+11	9	.745134E+10			

Division 3L

DEP VAR: **COD** N: 11 MULTIPLE R: 0.166 SQUARED MULTIPLE R: 0.028 ADJUSTED SQUARED MULTIPLE R: 0.000
STANDARD ERROR OF ESTIMATE: 86321.1675

VARIABLE	COEFFICIENT	STD ERROR	STD COEF	TOLERANCE	T	P(2 TAIL)
CONSTANT	-.805514E+07	.163456E+08	0.0000	.	-0.4928	0.6340
YEAR	4155.7727	8230.4004	0.1660	1.0000	0.5049	0.6257

ANALYSIS OF VARIANCE

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P	
REGRESSION	.189975E+10	1	.189975E+10	0.2550	0.6257	**N.S.**
RESIDUAL	.670621E+11	9	.745134E+10			

TABLE 2. Results of regression analyses of other commercial species (COM) and non-commercial species (NONC) biomass vs. time for Div. 2J.

DEP VAR: **COM (excl. 1981)** N: 10 MULTIPLE R: 0.916 SQUARED MULTIPLE R: 0.839 ADJUSTED SQUARED MULTIPLE R: 0.818 STANDARD ERROR OF ESTIMATE: 40298.1454

VARIABLE	COEFFICIENT	STD ERROR	STD COEF	TOLERANCE	T	P(2 TAIL)
CONSTANT	.569824E+08	.881347E+07	0.0000	.	6.4654	0.0002
YEAR	-28598.1576	4436.6798	-0.9157	1.0000	-6.4458	0.0002

ANALYSIS OF VARIANCE

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P	
REGRESSION	.674730E+11	1	.674730E+11	41.5489	0.0002	**SIG.**
RESIDUAL	.129915E+11	8	.162394E+10			

DEP VAR: **NONC** N: 11 MULTIPLE R: 0.909 SQUARED MULTIPLE R: 0.827 ADJUSTED SQUARED MULTIPLE R: 0.808 STANDARD ERROR OF ESTIMATE: 9209.3438

VARIABLE	COEFFICIENT	STD ERROR	STD COEF	TOLERANCE	T	P(2 TAIL)
CONSTANT	.114770E+08	.174386E+07	0.0000	.	6.5814	0.0001
YEAR	-5755.6455	878.0765	-0.9093	1.0000	-6.5548	0.0001

ANALYSIS OF VARIANCE

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P	
REGRESSION	.364402E+10	1	.364402E+10	42.9658	0.0001	**SIG.**
RESIDUAL	.763308E+09	9	.848120E+08			

TABLE 3. Results of comparison of slopes of cod with those of other commercial species (COM) and non-commercial species (NONC) in Div. 2J.

Commercial Species (excl. 1981)

LEVELS ENCOUNTERED DURING PROCESSING ARE:
CAT$
COD COM

DEP VAR: **BIOMASS** N: 21 MULTIPLE R: 0.797 SQUARED MULTIPLE R: 0.635

ANALYSIS OF VARIANCE

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P	
YEAR	.937745E+11	1	.937745E+11	27.7413	0.0001	
CAT$	.746962E+10	1	.746962E+10	2.2097	0.1555	
YEAR*CAT$	.748006E+10	1	.748006E+10	2.2128	0.1552	**N.S.**
ERROR	.574655E+11	17	.338033E+10			

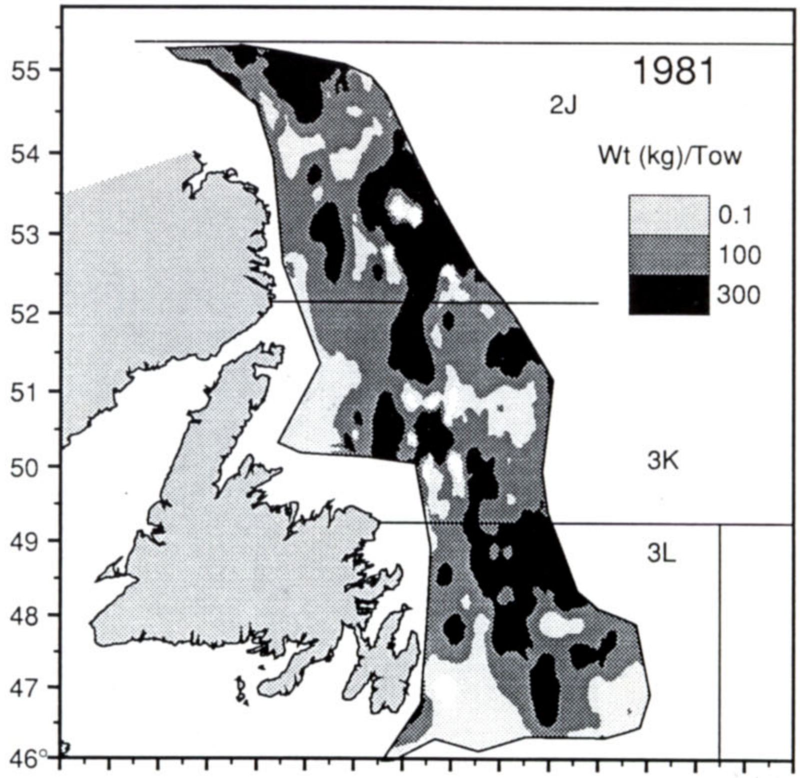
Non-Commercial Species

LEVELS ENCOUNTERED DURING PROCESSING ARE:
CAT$
COD NONC

DEP VAR: **BIOMASS** N: 22 MULTIPLE R: 0.884 SQUARED MULTIPLE R: 0.782

ANALYSIS OF VARIANCE

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P	
YEAR	.260363E+11	1	.260363E+11	10.3599	0.0048	
CAT$	.586180E+10	1	.586180E+10	2.3324	0.1441	
YEAR*CAT$	.577411E+10	1	.577411E+10	2.2975	0.1469	**N.S.**
ERROR	.452373E+11	18	.251318E+10			



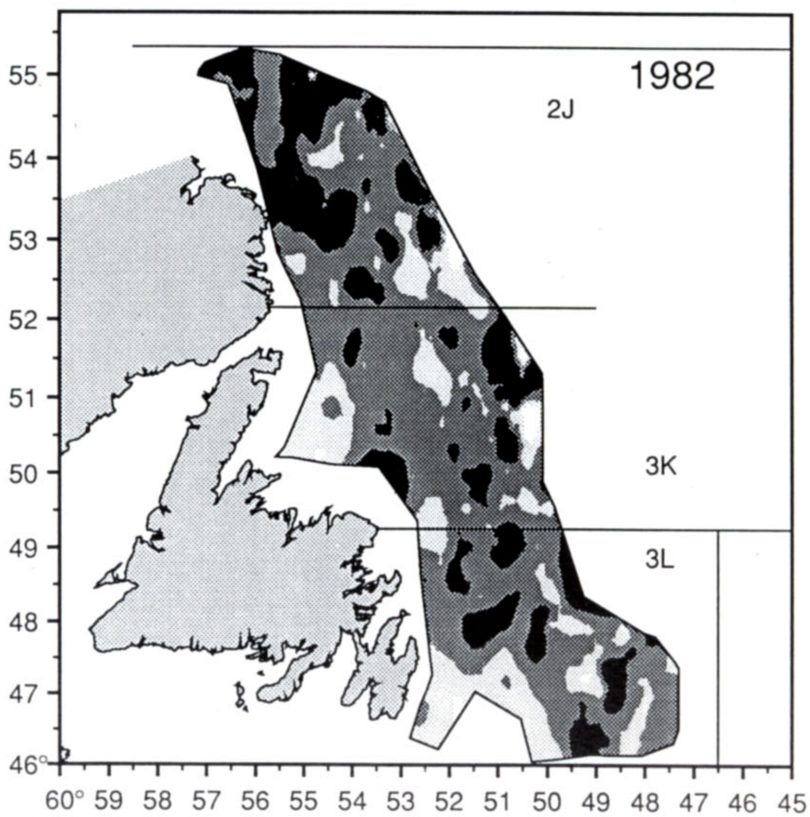
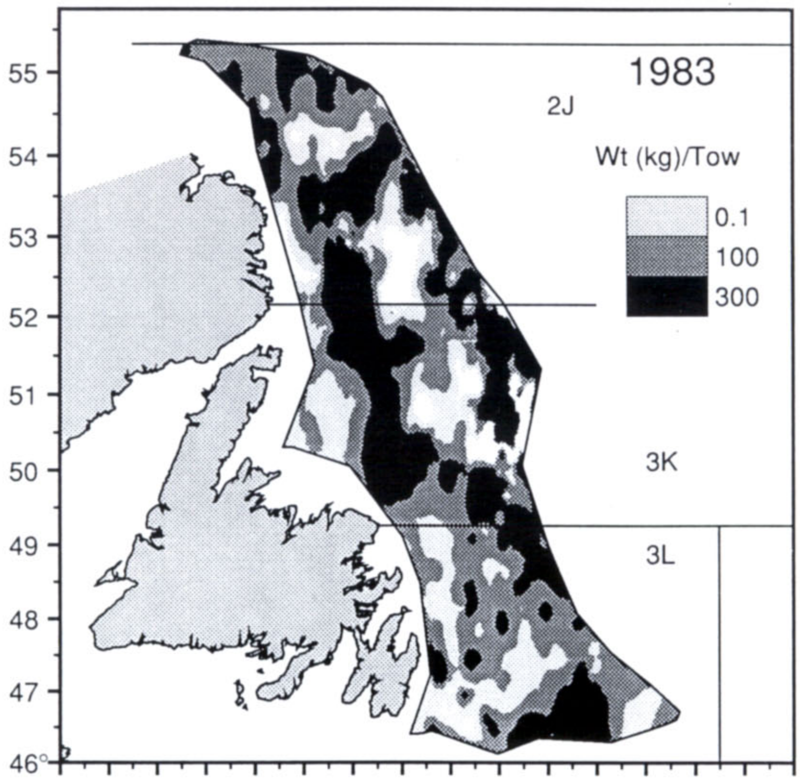


Fig. 6. Annual distributions of trawlable fish biomass in NAFO Div. 2J and 3KL from the bottom trawl surveys, 1981–1991.



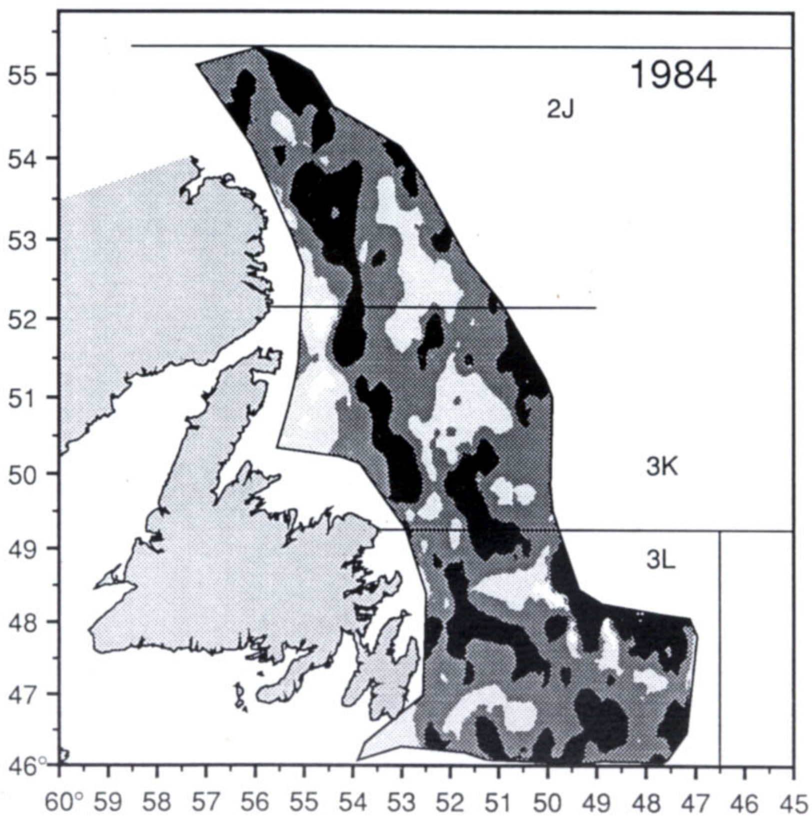
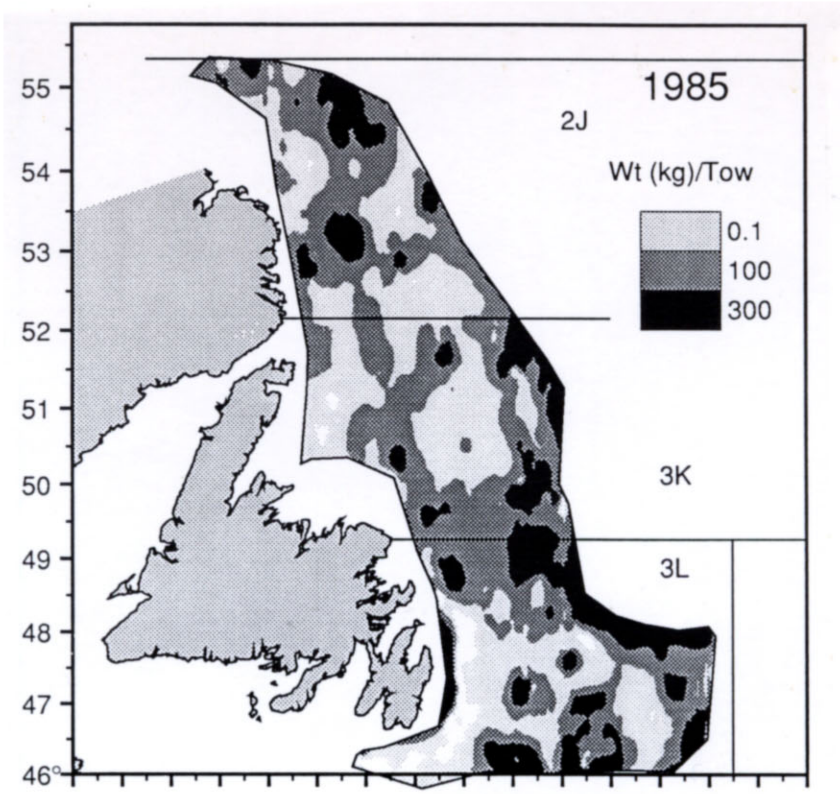


Fig. 6. (Continued). Annual distributions of trawlable fish biomass in NAFO Div. 2J and 3KL from the bottom trawl surveys, 1981–1991.



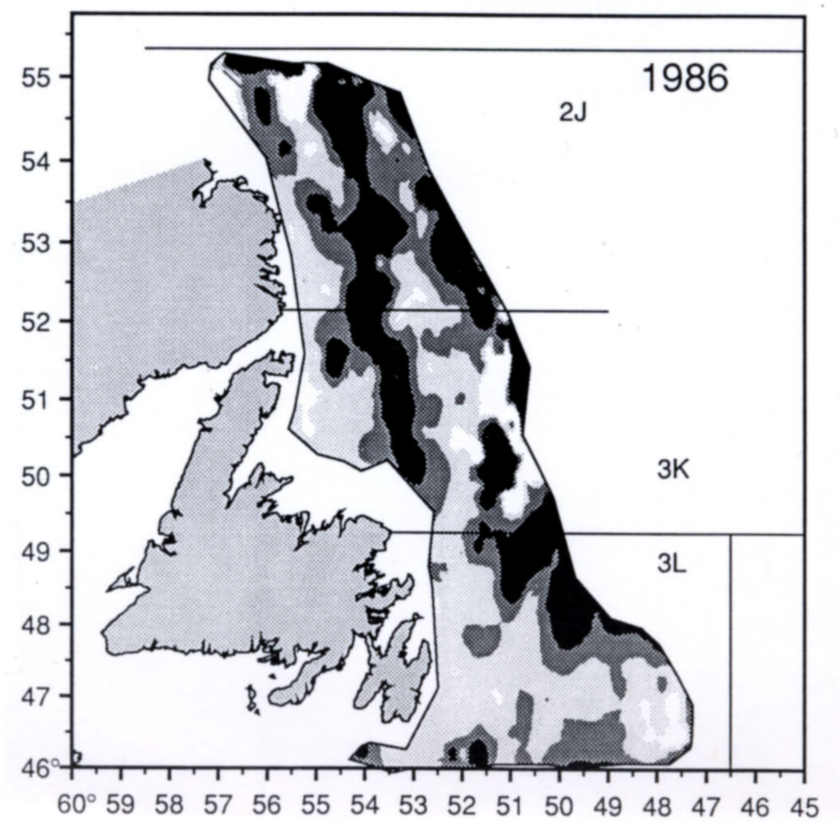
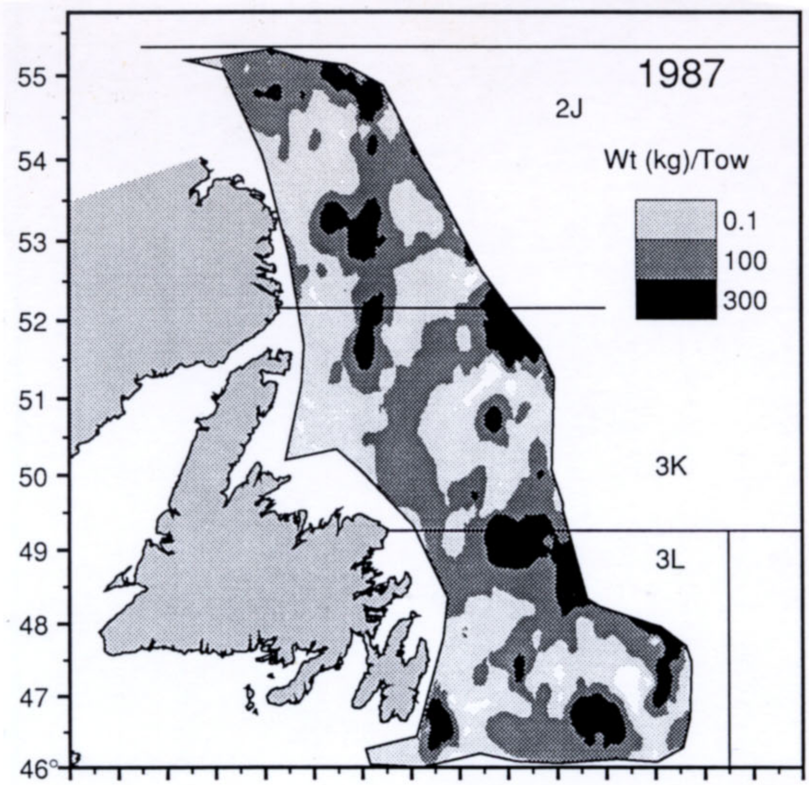


Fig. 6. (Continued). Annual distributions of trawlable fish biomass in NAFO Div. 2J and 3KL from the bottom trawl surveys, 1981–1991.



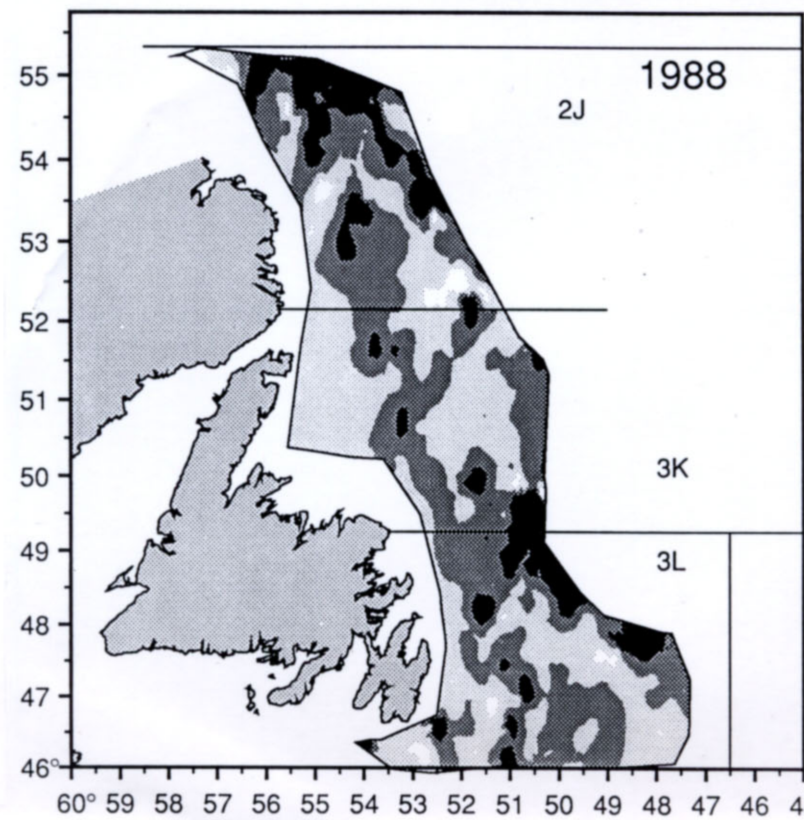


Fig. 6. (Continued). Annual distributions of trawlable fish biomass in NAFO Div. 2J and 3KL from the bottom trawl surveys, 1981–1991.

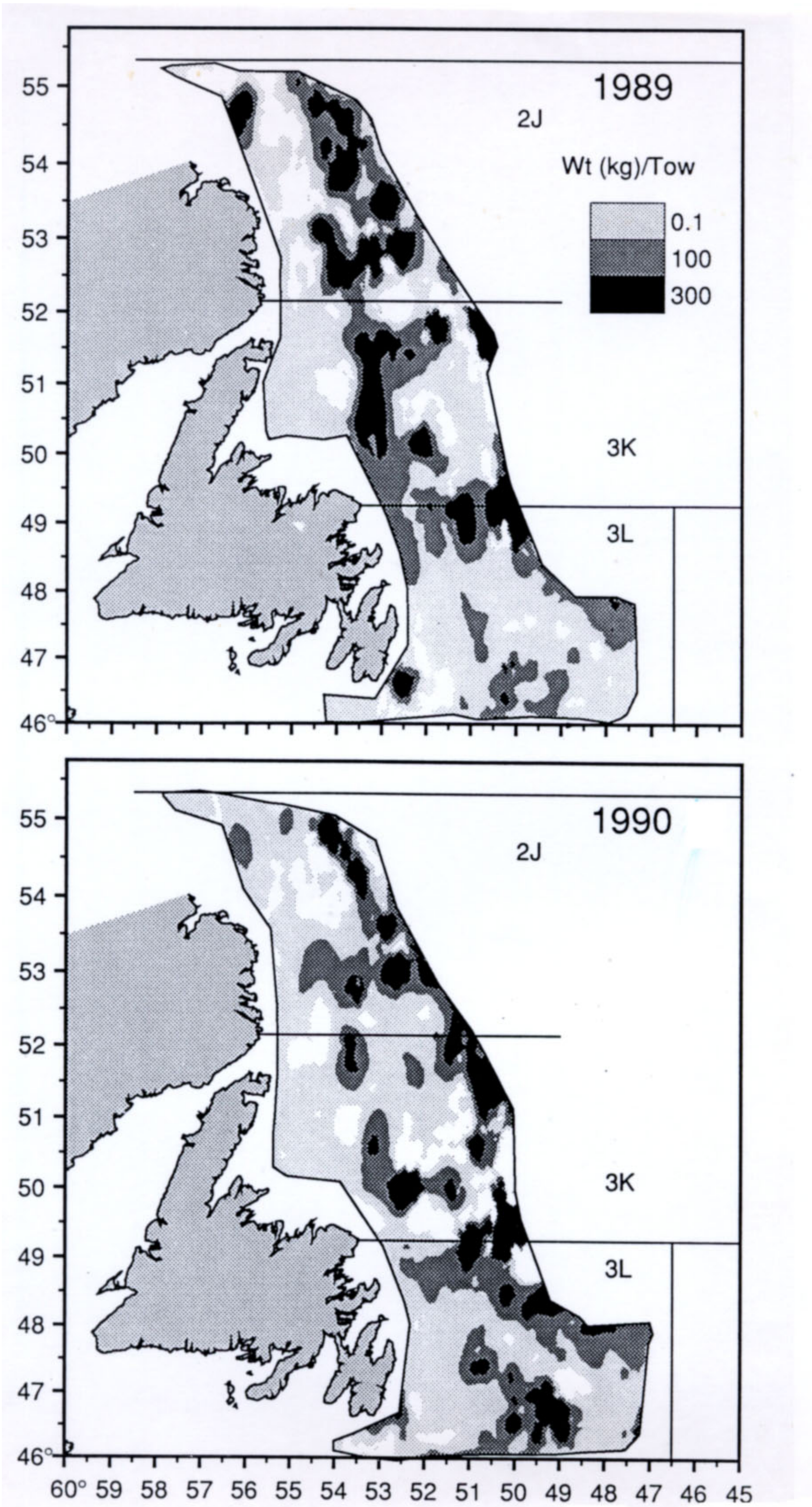


Fig. 6. (Continued). Annual distributions of trawlable fish biomass in NAFO Div. 2J and 3KL from the bottom trawl surveys, 1981–1991.

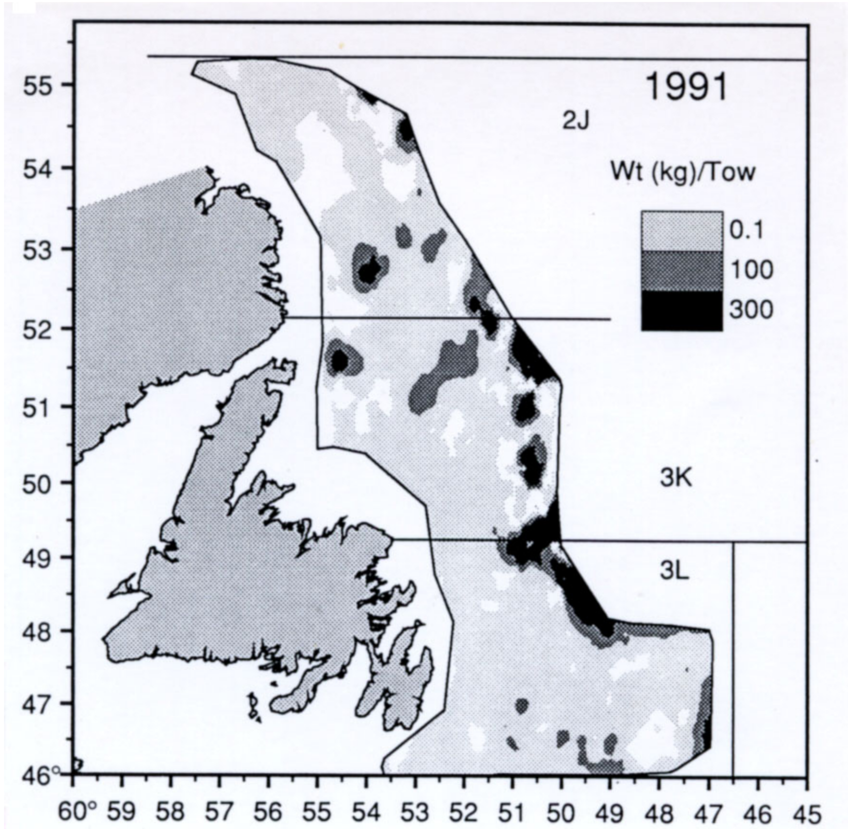


Fig. 6. (Continued). Annual distributions of trawlable fish biomass in NAFO Div. 2J and 3KL from the bottom trawl surveys, 1981–1991.

abundance of other species has increased although the overall biomass declined. This is most noticeable in Div. 3K and 3L. A closer examination of these data is required to determine if there has been a shift in species mix or from larger to smaller individuals within any one species.

Rätz (MS 1991) interpreted the declines in biomass off West Greenland to be indicative of "ecosystem stress". It is reasonable to believe that the wide spread declines observed in Div. 2J and 3KL may also be the result of ecosystem stress, although the nature of such a stress is unclear. It may encompass a number of factors including fishing pressure, environment and predator-prey relationships.

Summary and Conclusions

1. The declines observed for cod in Div. 2J and 3KL are not compensated for by increases in the biomass of other fish species caught during the annual autumn bottom trawl surveys. Instead, general declines in biomass were noted for all species or species groups examined. This does not preclude increases in biomass having occurred for pelagic fish species or non-fish species.

2. The proportion of cod to the total trawlable biomass of fish actually appeared to increase over the 11-year period perhaps indicating that cod itself is compensating to some degree for the decline in other species. (Although the increase in proportion in Div. 2J cannot be considered statistically significant since the slopes of the various declining biomasses were not statistically different.)

3. The declines observed for biomass were also reflected in fish abundance in most cases although a few exceptions were observed.

4. In order to properly address the issues and questions related to the observed decline in northern cod, we must ensure that our horizons are broad enough by:

   a) not focusing on the environmental events of 1991 and their possible impacts on cod alone. Large scale environmental events happening over broader periods of time must be considered.

   b) not focusing on any particular species (e.g. cod, or capelin, or salmon). Events may

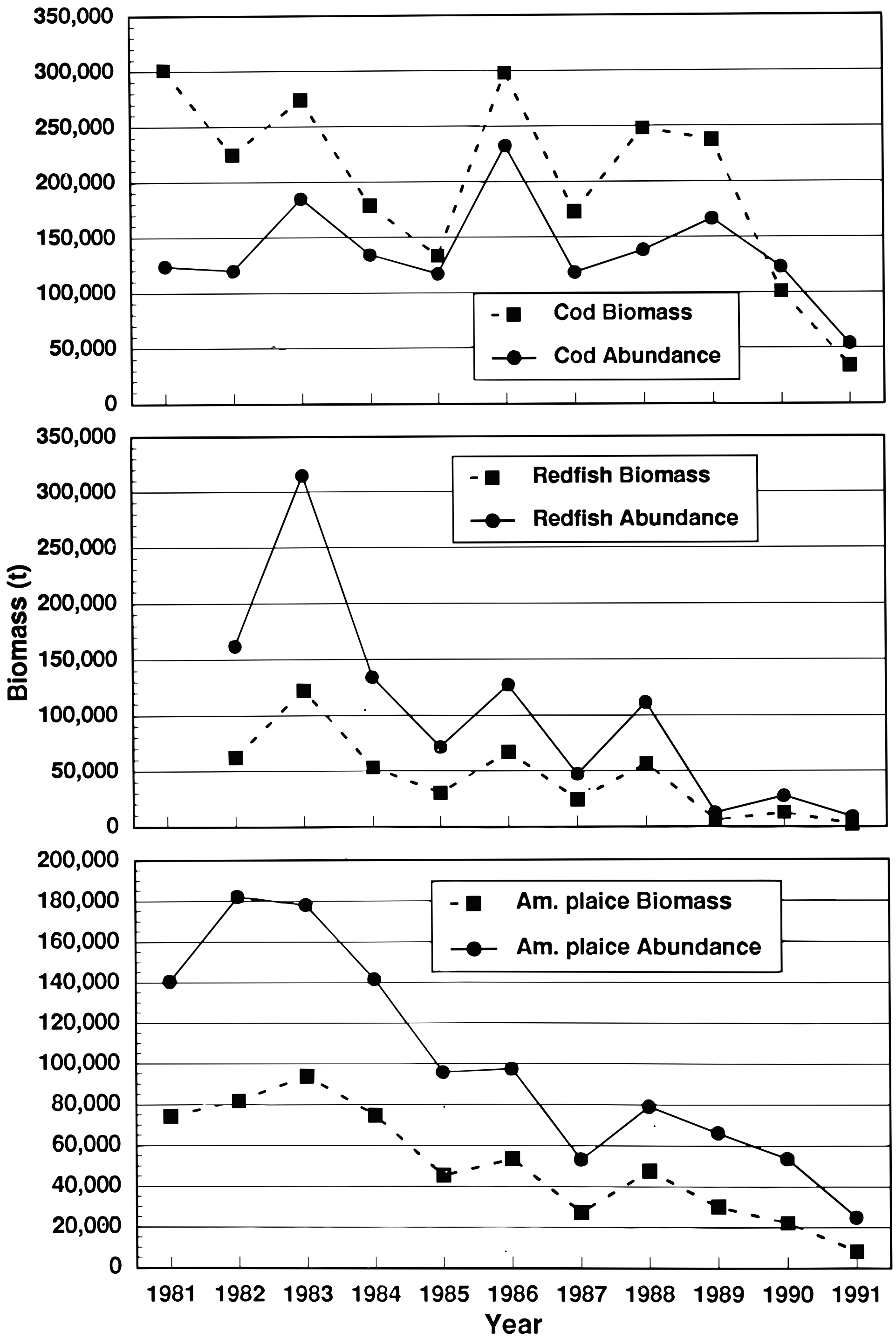


Fig. 7. Comparison of trends in estimated biomass and abundance for the various species and species groups in Div. 2J.

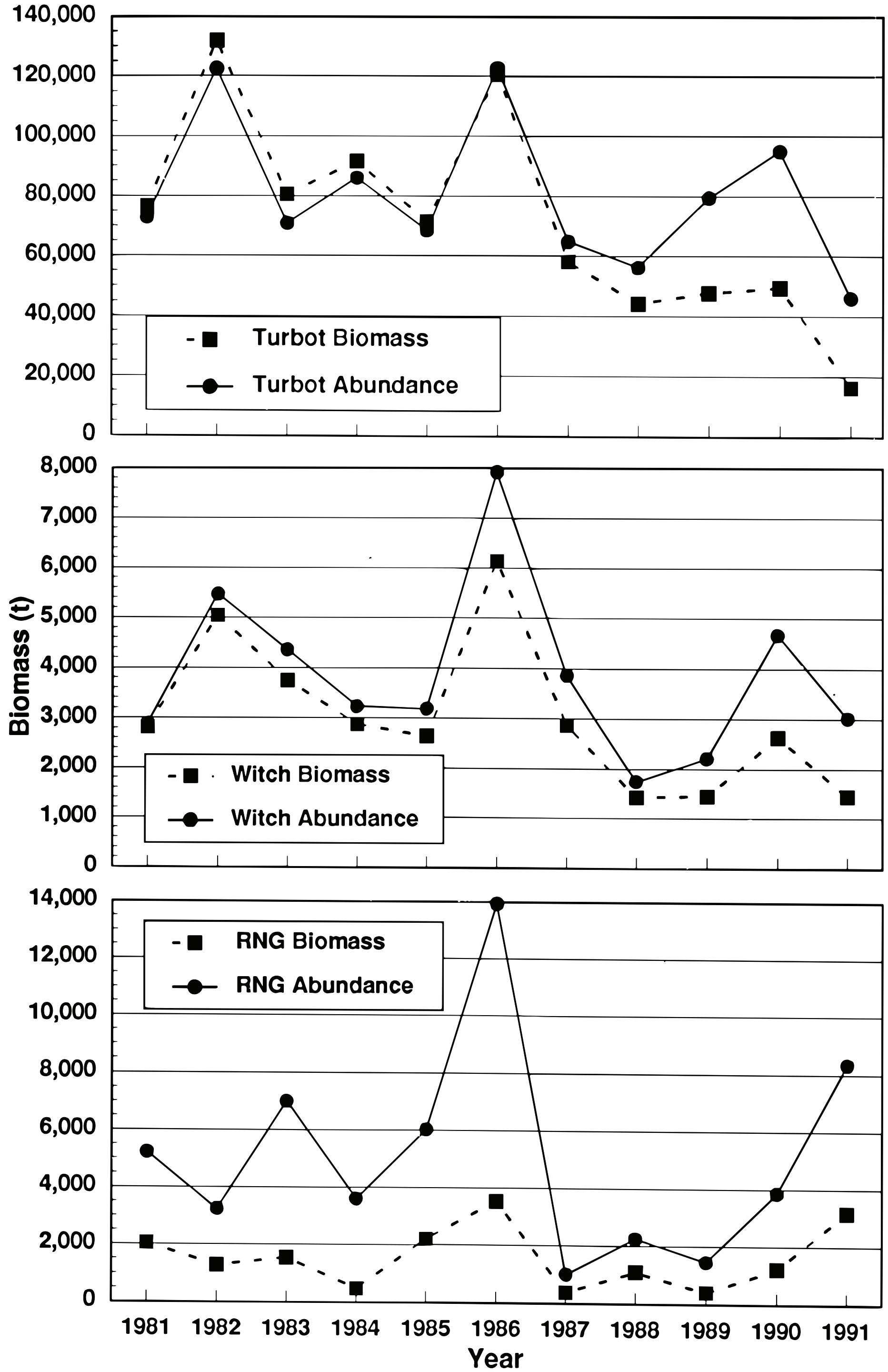


Fig. 7. (Continued). Comparison of trends in estimated biomass and abundance for the various species and species groups in Div. 2J.

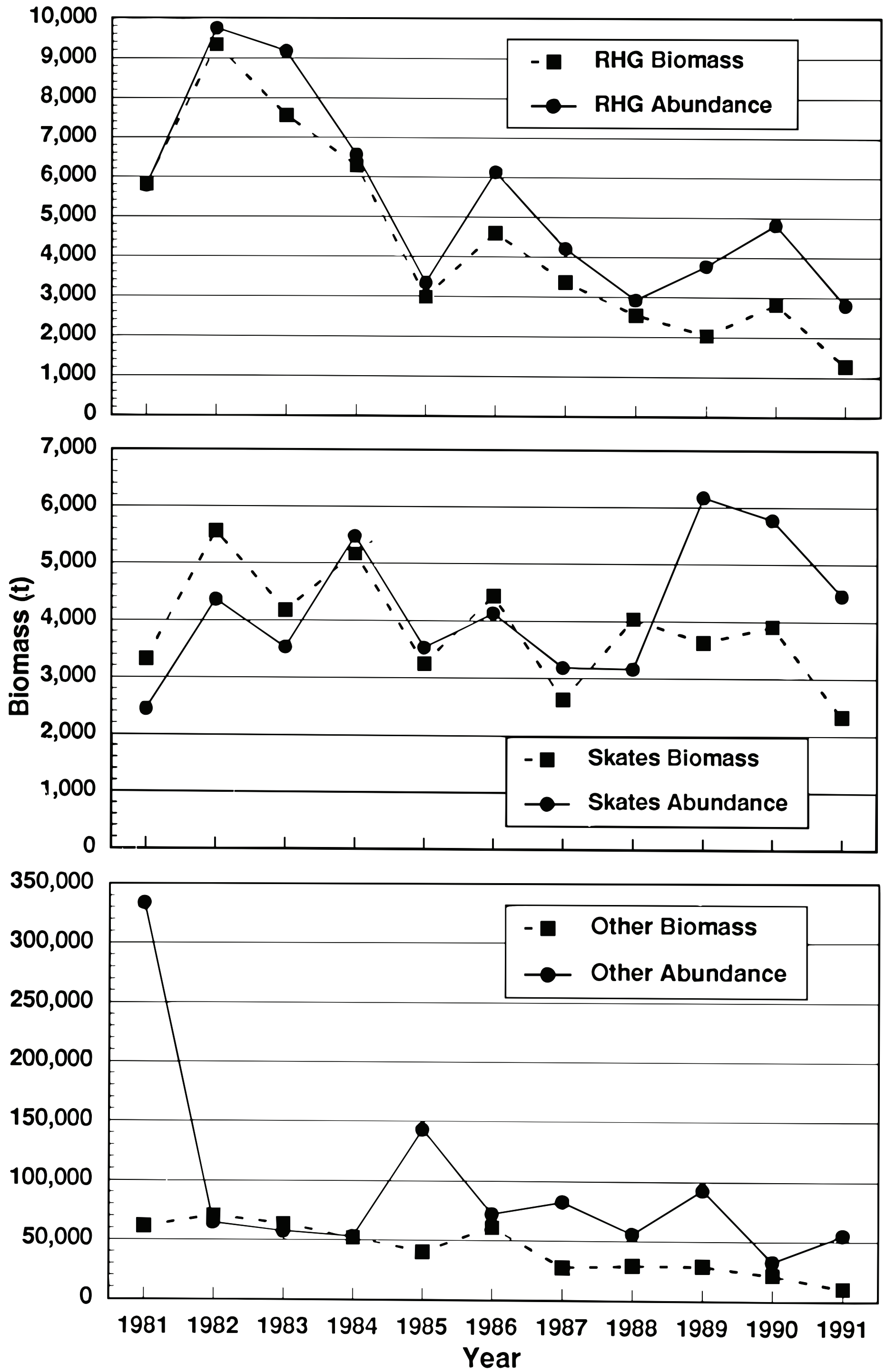


Fig. 7. (Continued). Comparison of trends in estimated biomass and abundance for the various species and species groups in Div. 2J.

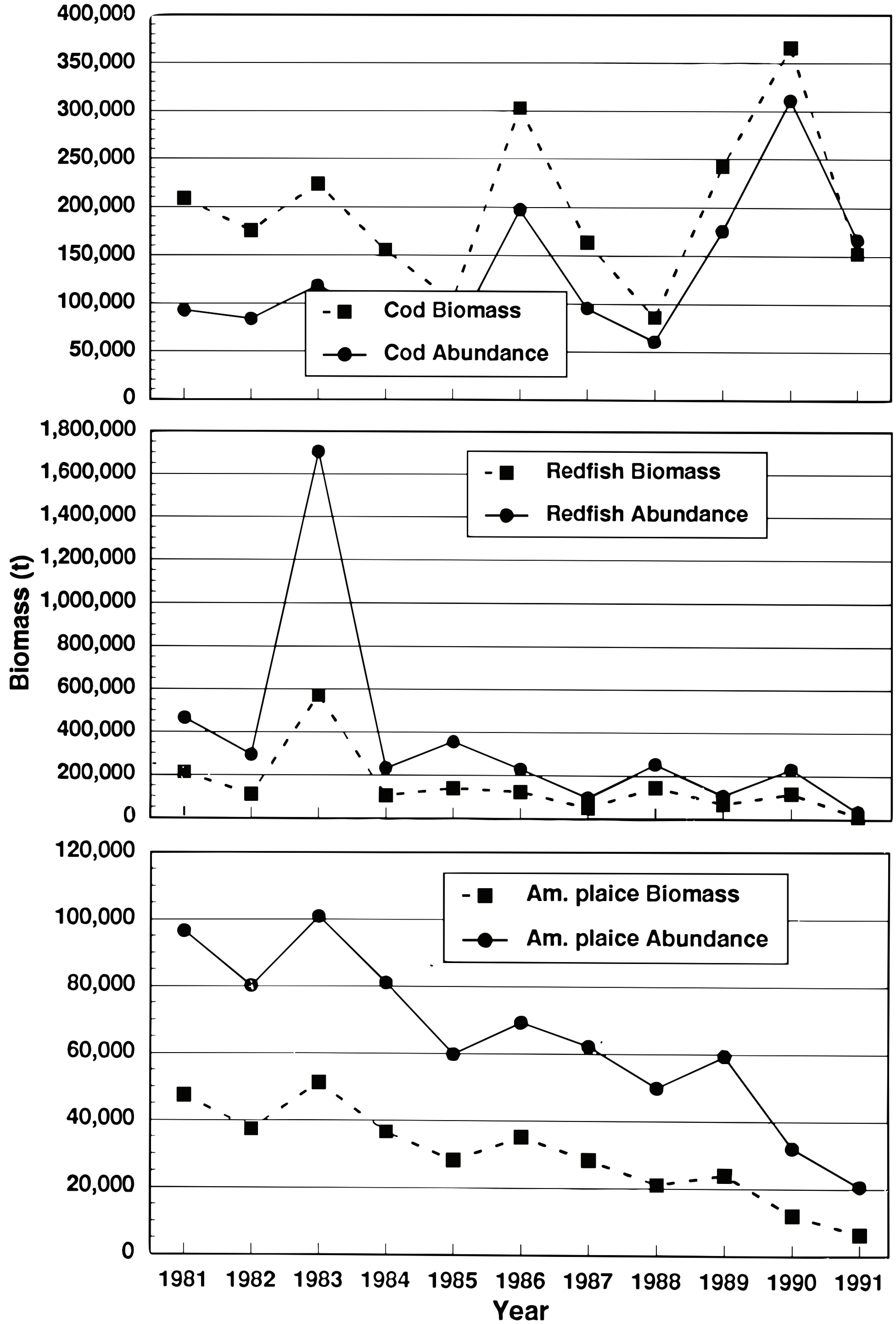


Fig. 8. Comparison of trends in estimated biomass and abundance for the various species and species groups in Div. 3K.

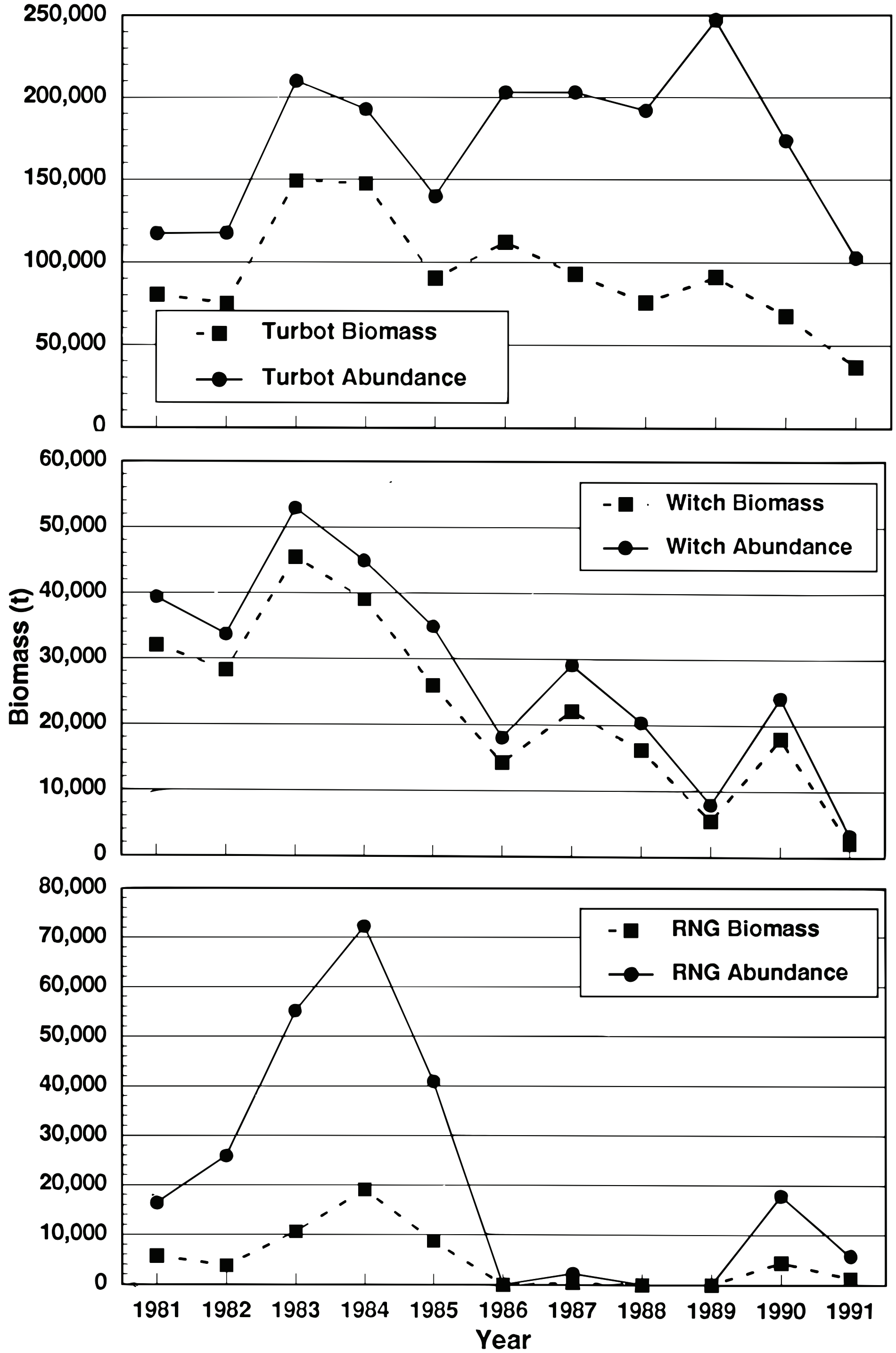


Fig. 8. (Continued). Comparison of trends in estimated biomass and abundance for the various species and species groups in Div. 3K.

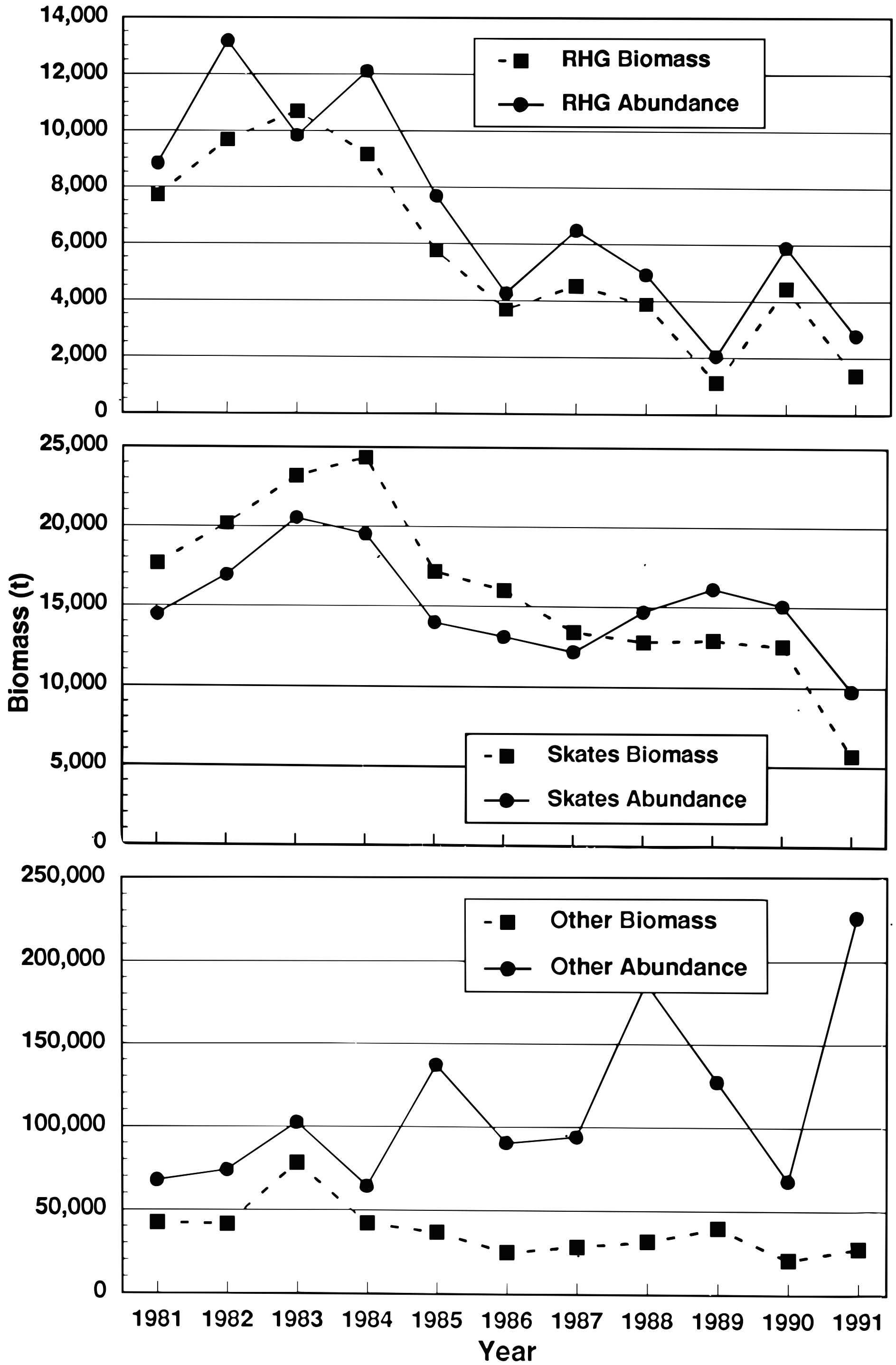


Fig. 8. (Continued). Comparison of trends in estimated biomass and abundance for the various species and species groups in Div. 3K.

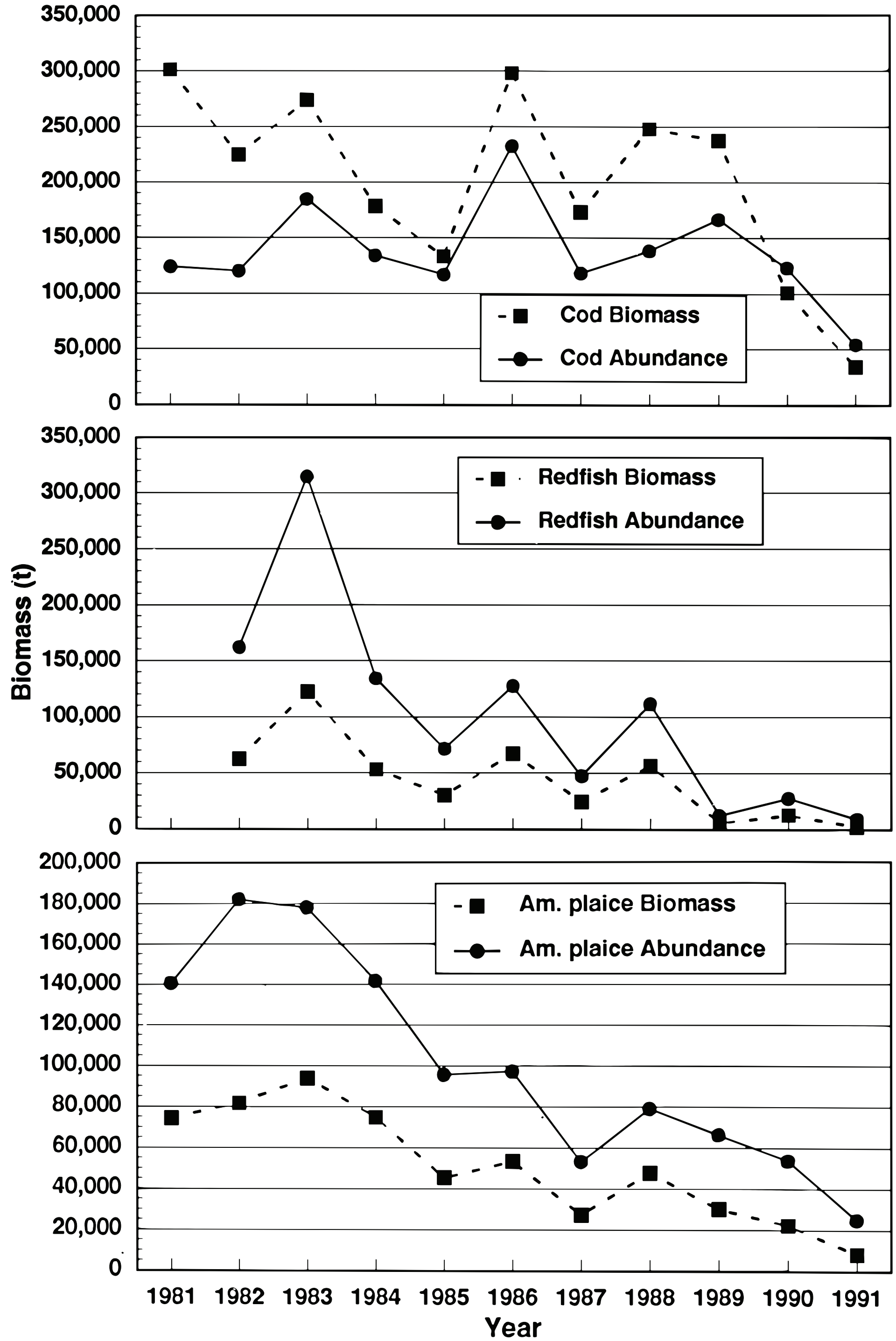


Fig. 9. Comparison of trends in estimated biomass and abundance for the various species and species groups in Div. 3L.

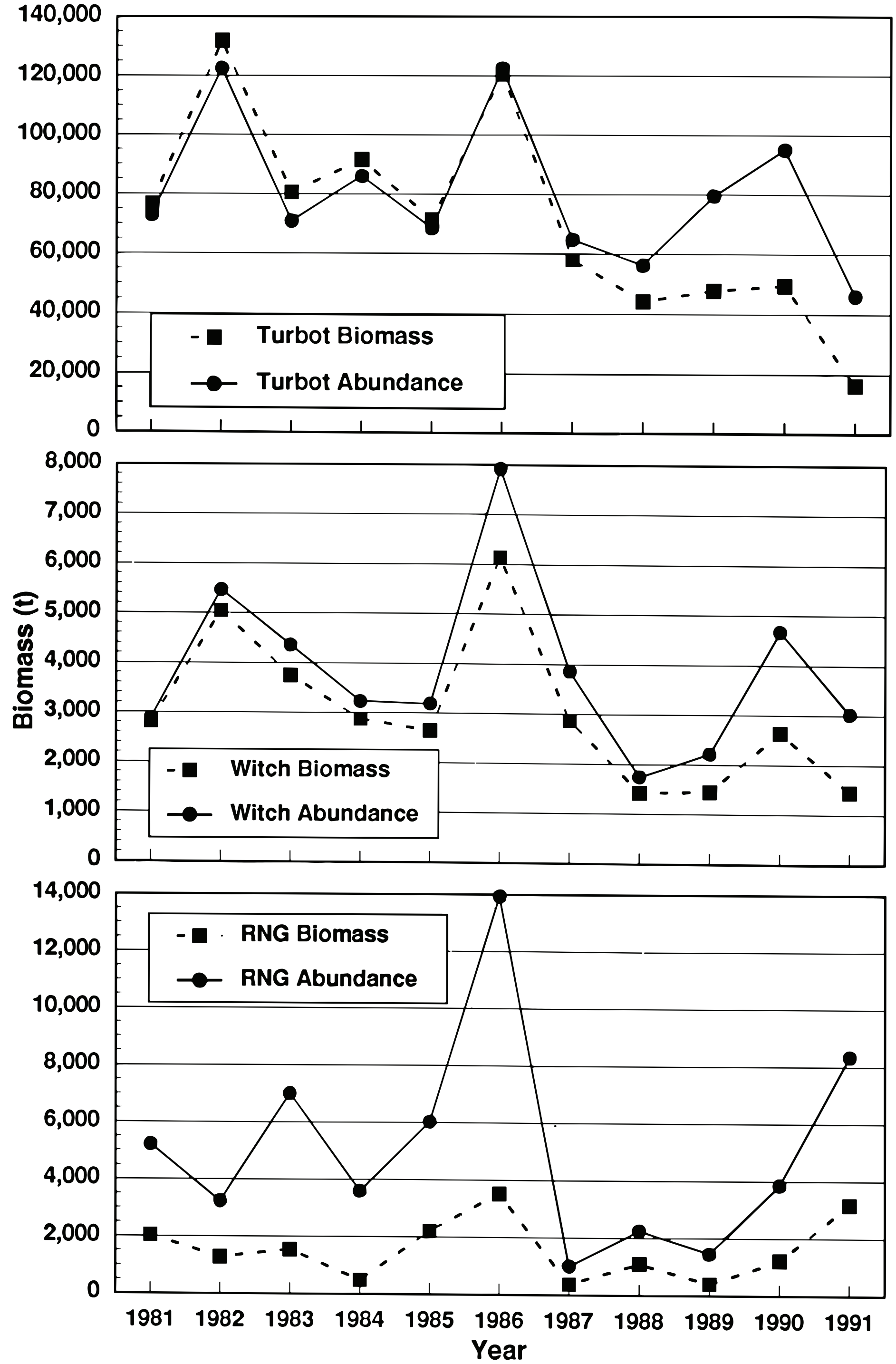


Fig. 9. (Continued). Comparison of trends in estimated biomass and abundance for the various species and species groups in Div. 3L.

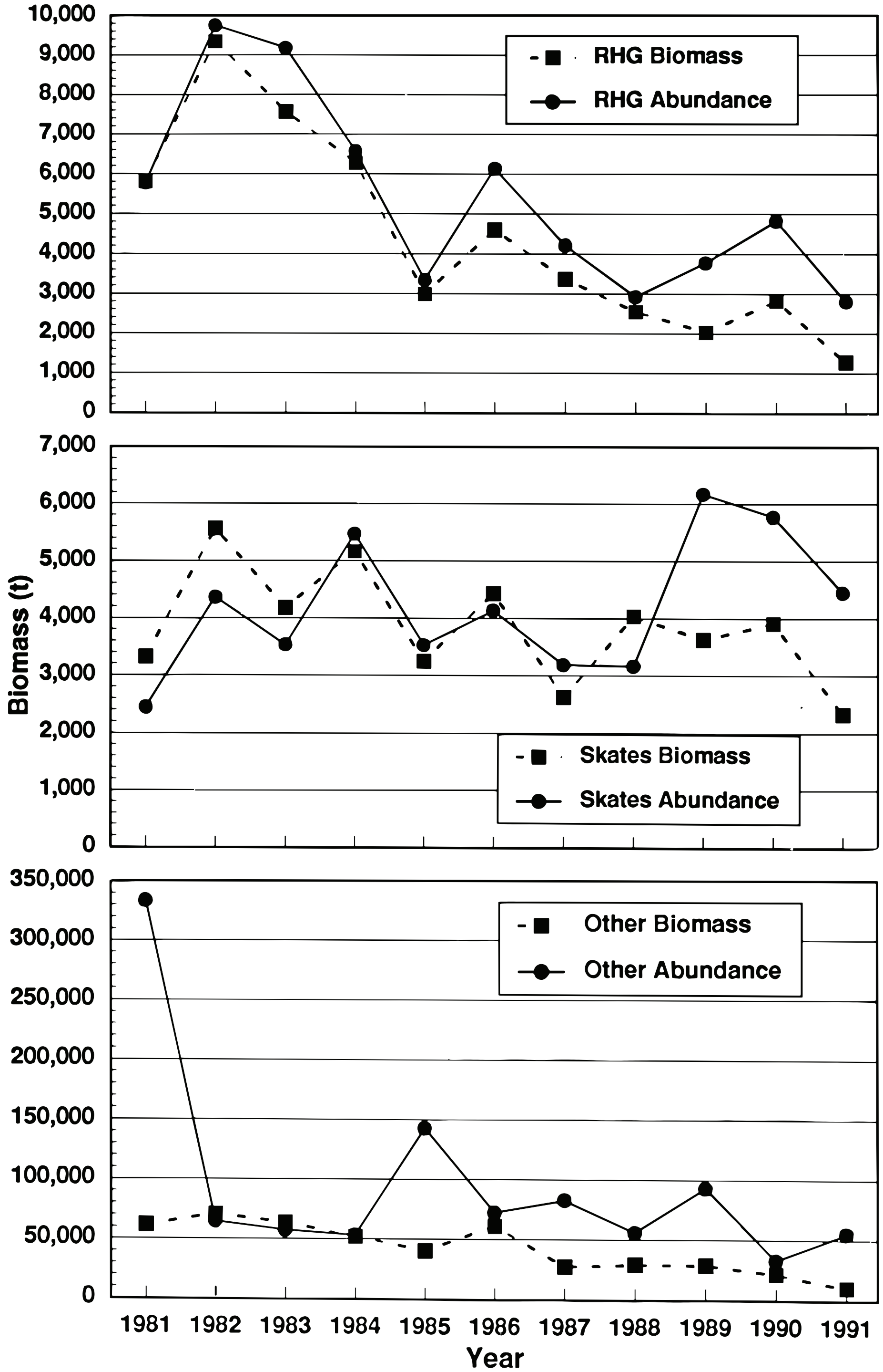


Fig. 9. (Continued). Comparison of trends in estimated biomass and abundance for the various species and species groups in Div. 3L.

have occurred which are impacting on a wide variety of fish species (and possibly other marine organisms as well). A more holistic approach is required (cf. Gomes *et al*. 1992, Villagarcía 1994).

References

ANON. 1991. Canadian Atlantic Fisheries Scientific Advisory Committee (CAFSAC) Annual Report (including Advisory Documents). Department of Fisheries and Oceans, P.O. Box 1006, Dartmouth, Nova Scotia, Canada B2Y 4A2.

1992a. Canadian Atlantic Fisheries Scientific Advisory Committee (CAFSAC) Annual Report (including Advisory Documents). Department of Fisheries and Oceans, P.O. Box 1006, Dartmouth, Nova Scotia, Canada B2Y 4A2.

1992b. Scientific Council Reports 1992. Northwest Atlantic Fisheries Organization, P.O. Box 638, Dartmouth, Nova Scotia, Canada B2Y 3Y9.

BLACK, G. A. P. MS 1991. ACON: Documentation for ACON Version 5.02. Unpubl. Manuscript. 148 p.

GOMES, M. C., R. L. Haedrich and J. C. RICE. 1992. Biogeography of Groundfish Assemblages on the Grand Bank. *J. Northw. Atl. Fish. Sci.*, **14**: 13–27.

RÄTZ, H-J. MS 1991. Notes of the Structure and Changes in the Ichthyofauna off West Greenland. *NAFO SCR Doc.*, No. 36, Serial No. N1916, 16 p.

MS 1992. Decrease in Fish Biomass off West Greenland (Subdivisions 1B–1F) Continued. *NAFO SCS Doc.*, No. 40, Serial No. N2088, 8 p.

SMITH, S. J., and G. D. SOMERTON. 1981. STRAP: A User-Oriented Computer Analysis System for Groundfish Research Trawl Survey Data. *Can. Tech. Rep. Fish. Aquat. Sci.*, **1030**: iv + 66 p.

VILLAGARCÍA, M. G. 1994. Structure and Distribution of Demersal Fish Assemblages on the Northeast Newfoundland and Labrador Shelf. M.Sc. Thesis, Department of Biology, Memorial University of Newfoundland, St. John's, Canada, 89 p.

WATSON, D. F. 1982. ACORD – Automatic Contouring of Raw Data. *Comp. & Geosci.*, **8**: 97–101.

WATSON, D. F., and G. M. PHILIP. 1985. A Refinement of Inverse Distance Weighted Interpolation. *Geo-Processing*, **2**: 315–327.