Northwest Atlantic Fisheries Organization

Serial No. N2692

NAFO SCR DOC. 96/19

SCIENTIFIC COUNCIL MEETING - JUNE 1996

A Combined Recruitment Index for Demersal Juvenile Cod (0, 1, and 2 Group) NAFO Divisions 3K and 3L

by

David C. Schneider
Ocean Sciences Centre and Biology Department
Memorial University of Newfoundland, St. John's, Newfoundland

and

Edgar L. Dalley and John T. Anderson
Science Branch, Newfoundland Region,
Department of Fisheries and Oceans
P. O. Nox 5667, St. John's, Newfoundland, Canada A1C 5X1

ABSTRACT

A variety of indices have been developed to assess the relative abundance of pre-recruit cod (age 0 to 3 years) in area 3KL. At the previous stock assessment (in 1995) these surveys were combined on an informal basis by comparing the ranking of each year class within each age group. The cohort projection model used for the Fleming data (LG1 = β LG0) could not be used to combine the several surveys because the slopes β were found to differ among three surveys: Fleming, inshore Campelen, and offshore Campelen. A second analysis was undertaken to determine the homogeneity of catches across surveys, based on the interation term in a two-way classification of catch, by year (4) and by survey (3). The interaction F-ratios tended to be small, often less than unity. This homogeneity in year to year change across surveys means that a single composite index could be constructed by averaging across surveys within each year. However, a simple average will give undue weight to the series that has the largest mean value, an undesirable characteristic. In the absence of an acceptable weighting, and in light of the similarity in trends of the indices, we constructed a narrative index that reports the evolution of each year class, as seen in the several surveys. This showed that two cohorts began weakly (1992 and 1993) but became somewhat stronger at age 1 and 2, with strong offshore shift in distribution. Two cohorts (1994 and 1995) began more strongly. Two cohorts (1993 and 1994) suffered substantial weakening in 1995 (as age 2 and age 1 fish respectively). Only the 1995 year class now appears promising.

INTRODUCTION

A variety of indices have been developed to assess the relative abundance of pre-recruit cod (age 0 to 3 years) in area 3KL. These include:

1. An inshore pelagic juvenile survey (Anderson and Dalley 1995)
2. An offshore pelagic juvenile survey (Anderson and Dalley 1995)
3. A coastal survey using bottom seines in coastal nursery habitat (Schneider et al 1995)
4. An inshore demersal juvenile survey using campelin trawls (Dalley and Anderson 1995)
5. An offshore demersal juvenile survey using campelin trawls (Dalley and Anderson 1995).

During the 1995 stock assessment these surveys were combined on an informal basis by comparing the ranking of each year class within each age group. This analysis showed that in general the ranking was 1994 > 1993 > 1992 for first year (LGO = length group 0+) fish. The ranking was 1994 > 1993 > 1992 for second year (LG1) fish. The ranking was 1994 > 1993 > 1992 for third year (LG2) fish. A multiplicative model of the same data set showed that the reliability of this index was as good as any index for cod in the North Atlantic. It was thus of interest to determine whether a composite index could be developed.

A series of analyses were undertaken. The first was to determine whether the cohort projection model (Ings et al in press) used with the coastal survey could be extended to the other surveys. As background for this, the coastal survey model was tested by adding the 1994 cohort and recomputing the parameter estimates for the model. The second analysis was to determine whether the observed pattern of similar rankings can be extended to a ratio scale: Is the change from year to year homogeneous across surveys ? The third analysis looked at the problems associated with constructing a single numerical index. A narrative index of cohort evolution as presented.

METHODS

Statistical analyses were carried out within the framework of the Generalized Linear Model (McCullagh and Nelder 1989) which has the advantage of permitting non-normal error structures.

RESULTS

Can the cohort projection model used in 1994 be extended to 1995 Fleming data ?

Data from the 1959-1964 and 1992-1994 coastal Fleming surveys were used to investigate whether a recruitment signal could be detected. These data are shown in Figure 1. A recruitment signal from one year to the next, on a ratio scale, was detectable when two successive years were used (Δdeviance = 6.474, df = 2, p = 0.04, gamma error structure; cf Schneider et al 1995).

An iterative weighting algorithm was used to estimate the parameters of the cohort projection model:

$$LG1 = \beta_{0->1}\ LG0$$

$$LG2 = \beta_{1->2}\ LG1$$

$\beta_{0->1}$ is the product of two quantities, the loss due to natural mortality $e^{-\mu t}$ during t = 1 year, and the ratio of catchabilities of LG1 and LG0 fish α_1/α_0. $\beta_{1->2}$ is the product of the loss due to natural mortality $e^{-\mu t}$ during t = 1 year, and ratio of catchabilities of LG2 and LG1 fish α_2/α_1. The estimates for the two composite parameters were

$$\beta_{0->1} = 0.7984 \quad se = 0.1112$$

$$\beta_{1->2} = 0.02019 \quad se = 0.00061$$

When the 1995 data was added, a normal error structure was found to be acceptable for both equations. The analysis of deviance showed a significant recruitment signal for the combined analysis, although not for the LG1-->LG2 component by itself.

$LG1 = \beta_{LGO} \cdot LGO$

Source	Deviance	df
β_o	13010	7
$\beta_0 + \beta_{LGO}$	1449	6
	11561	1

$LG2 = \beta_{LG1} \cdot LG1$

Source	Deviance	df
β_o	2.655	5
$\beta_0 + \beta_{LGO}$	1.234	4
	1.421	1

The change in deviance for the combined model was (Δdeviance = 11561 + 1.421) exceeds the degrees of freedom (df = 2) and is significant ($p < 0.001$). The addition of the 1995 data did not substantially change the parameter estimates.

$$\beta_{0->1} = 0.7785 \quad se = 0.08395$$

$$\beta_{1->2} = 0.01909 \quad se = 0.0058385$$

Can the cohort projection model be extended to the other surveys ?

This was tested by an analysis of covariance of the data in Figure 1 (age 0), Figure 2 (age 1), and Figure 3 (age 2). The analysis of deviance showed that the slopes were heterogeneous across surveys (Fleming, inshore Campelen, offshore Campelen) for the transition for LGO to LG1. A normal error structure was found to be acceptable for the first analysis, but not the second, where a gamma error structure was used.

$$LG1 = \beta_o + \beta_{LGO} + \beta_{svy} + \beta_{LGO*svy}$$

Source	Deviance	df
LGO + svy + LGO*svy	7146	10
LGO + svy	3644	9
LGO*svy	3502	1

$$LG2 = \beta_o + \beta_{LG1} + \beta_{svy} + \beta_{LG1*svy}$$

Source	Deviance	df
LG1 + svy + LG1*svy	5.29	10
LG1 + svy	5.07	8
LG1*svy	0.12	2

Analysis of deviance showed no heterogeneity across surveys for the transition from LG1 to LG2 fish. This suggests that the ratio of catchabilities of LG2 to LG1 cod is similar in all three surveys, while the ratio the ratio of catchabilities of LG1 to LG0 cod differs among the surveys. Examination of the data indicates that the Campelen trawl is substantially less efficient than the Fleming (bottom siene) in capturing LG0 fish, relative to LG1 fish. The cohort projection model could be to all surveys for LG1 or larger fish. The model would have to applied separately to each survey for the transition from LG0 to LG1.

Are year to year changes within a length group homogeneous across surveys ?

Analyses in previous assessments showed that rankings of years within length (age) group for one survey was similar to that of another. Homogeneity across surveys was tested by estimating the interation term in a two-way classification of catch, by year (4) and by survey (3). The data for this were only available as means and variances for each of the 3*4 = 12 cells in the two-way table and hence the iterative fitting scheme used for Generalized Linear Models could not be applied. Means (as in Figures 1, 2 and 3) and associated variances were therefore used to recontruct ANOVA tables, under that assumption that sample sizes were large enough to assume normal distribution of errors.

The analysis was carried out on data from the 1995 assessment of pelagic juveniles (Anderson and Dalley 1995) and from the 1996 assessement of demersal stages (Dalley and Anderson 1996, Schneider 1996).

LGO Demersal

	Inshore	Offshore
1992	7.59 (27)	0.03 (37)
1993	14.37 (27)	0.03 (36)
1994	59.96 (26)	0.08 (40)
1995	19.04 (25)	0.06 (39)

Comparison	F	p
svy*yr	1.57	0.21
yr	2.93	0.034
svy	12.51	<0.001

LGO Demersal

	Inshore	Fleming
1992	7.59 (27)	9.598 (46)
1993	14.37 (27)	13.250 (44)
1994	59.96 (26)	19.78 (40)
1995	19.04 (25)	13.264 (36)

Comparison	F	p
svy*yr	0.66	0.58
yr	3.6	0.014
svy	2.38	0.124

LG1 Demersal

	Inshore	Offshore
1992	34.22 (27)	1.24 (37)
1993	83.67 (27)	0.97 (36)
1994	136.0 (26)	3.05 (40)
1995	47.0 (25)	4.264 (39)

Comparison	F	p
svy*yr	1.03	0.46
yr	1.76	0.16
svy	17.54	<0.001

LG1 Demersal

	Inshore	Fleming	Comparison	F	p
1992	34.22 (27)	3.95 (46)	svy*yr	0.54	0.66
1993	83.67 (27)	10.22 (44)	yr	2.4	0.068
1994	136.0 (26)	16.45 (40)	svy	16.19	<0.001
1995	47.36 (25)	1.19 (36)			

LG2 Demersal

	Inshore	Offshore	Comparison	F	p
1992	54.07 (27)	7.3 (37)	svy*yr	1.69	0.17
1993	5.19 (27)	7.69 (36)	yr	2.85	0.38
1994	39.85 (26)	6.68 (40)	svy	9.74	0.002
1995	12.88 (25)	2.93 (39)			

LG2 Demersal

	Inshore	Fleming	Comparison	F	p
1992	54.07 (27)	0.391 (46)	svy*yr	1.66	0.176
1993	5.19 (27)	0.238 (44)	yr	3.19	0.024
1994	39.85 (26)	0.938 (40)	svy	17.67	<0.001
1995	12.88 (25)	0.264 (36)			

LGO Inshore

	Demersal	Pelagic	Comparison	F	p
1992	7.59 (27)	1.066 (18)	svy*yr	12.01	0.14
1993	14.37 (27)	1.047 (26)	yr	1.84	0.16
1994	59.96 (26)	1.506 (23)	svy	4.61	0.033

The interaction F-ratios tended to be small, often less than unity. This homogeneity in year to year change across surveys means that a single composite index could be constructed by averaging across surveys within each year.

Can a composite index be constructed ?

The problem that arises in constructing a single numerical index is that of weighting the contribution of each index to the composite estimate for the year. A simple average will give undue weight to the index that has the largest mean; extreme values within a series will also have a large influence. The choice of an appropriate weighting is not straightforward, as there are several possible--by area, by inverse of variance, etc. A further disadvantage of a composite number is that this leaves aside the biological differences among the surveys. One notable example is the change in distribution with age (according to Heincke's Law): small (0+) fish settle in coastal nurseries, then spread away from the coast at ages 1, becoming more widely distributed in deeper water at age 2 (Methven and Schneider, in prep).

Because of these problems, and in light of the similarity in trends of the indices, we propose a narrative index that reports the evolution of each year class, as seen in the several surveys. the narrative is based on cross product ratios, defined as R1 / R2, where

RA = Catch(cohort, Age 0) / Catch(same cohort, Age 1) for survey A

RB = Catch(cohort, Age 0) / Catch(same cohort, Age 1) for survey B.

The cross product ratio reflects the joint action of mortality, the ratio of catchabilties, and shifts in distribution. However, for many comparisons, some of these factors will cancel out of the cross product ratio. For example, the effects of differential catchability (Methven 1995) will cancel out of the cross product ratio for the campelen inshore/offshore comparison. It then becomes possible to use this information to constrain interpretation of the observed changes in catches from a cohort as it ages. With these constraints in mind, the following narrative of cohort evolution was constructed for the 3KL area for the period from 1989 to 1995. Note that the 1989 year class appears in the 1992 campelen survey (Figure 4).

1. The 1992 cohort was relatively weak during its pelagic stage, remaining weak just after settlement to the bottom. This cohort became somewhat stronger relative to other cohorts at age 1 and 2; this was especially true inshore. Howver, this cohort at age 3 still remained weak relative to the 1989 and 1991 cohorts.

2. The 1993 cohort began as a weak cohort in the plankton, remaining so upon settlement to the bottom. This cohort became stronger at age 1 especially inshore, but then suffered a substantial weakening in 1995, as two year old fish.

3. The 1994 cohort began more strongly than the two previous cohorts; it was also stronger than its predecessors upon settlement to the bottom, reaching densities in coastal nursery areas comparable to low values in the 1960s. This cohort suffered a substantial weakening in 1995, as 1 year old fish.

4. The 1995 cohort was comparable to the 1994 cohort in strength as pelagic larvae and just after settlement; there was some indication of distribution more restricted to coastal areas than the previous cohort.

5. In summary the narrative index shows two cohorts that began weakly (1992 and 1993) but became somewhat stronger at age 1 and 2, with strong offshore shift in distribution. Two cohorts (1994 and 1995) began more strongly. Two cohorts (1993 and 1994) suffered substantial weakening in 1995 (as age 2 and age 1 fish respectively).

References

Anderson, J.T. and E. L. Dalley. Spawning and recruitment of northern cod as measured by pelagic juvenile cod surveys following stock collapse 1991-1994. DFO Atlantic Fisheries Research Document 95/89.

Dalley, E. and J. Anderson. Geographic distribution of demersal juvenile cod (*Gadus morhua*) in inshore and offshore areas of northeast Newfoundland and the northern Grand Bank in the early 1990s. Canadian Journal Fisheries and Aquatic Sciences (in press).

Ings, D.W., D.C. Schneider and D.A. Methven. Detection of a recruitment signal in juvenile Atlantic cod (Gadus morhua L.) in coastal nursery areas. Canadian Journal Fisheries and Aquatic Sciences (in press).

McCullagh, P. and J.A. Nelder. 1989. Generalised Linear Models, 2nd edition. Chapman and Hall, London.

Methven, D.A. Gear dependent patterns of variation in catch of juvenile cod. (unpublished manuscript)

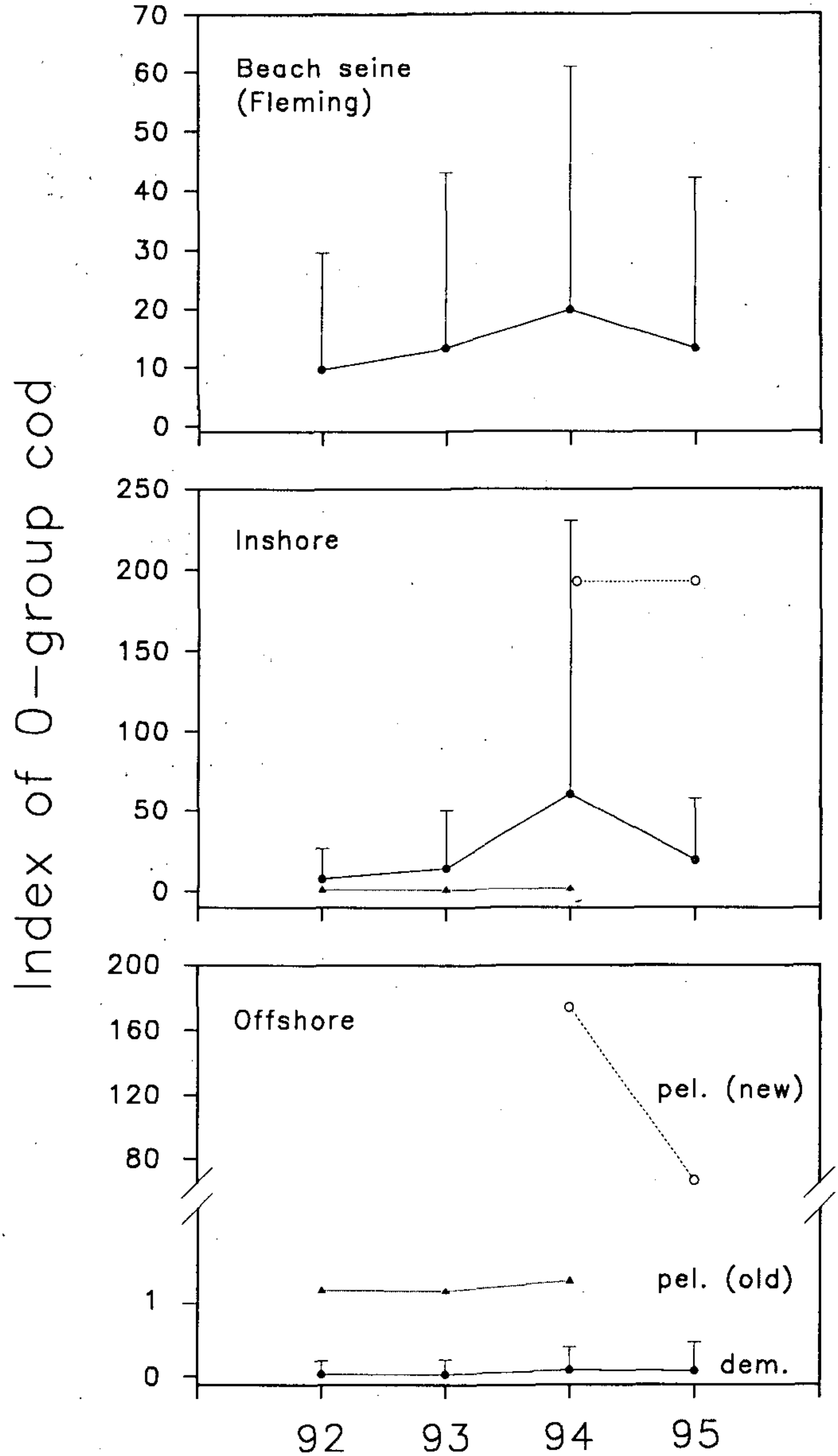
Methven, D.A. 1995. Early life history of juvenile cod (*Gadus morhua*): Spatial and temporal variability and variability due to gear. Unpublished final report, Northern Cod Science Program, Northwest Atlantic Fisheries Centre, St. John's.

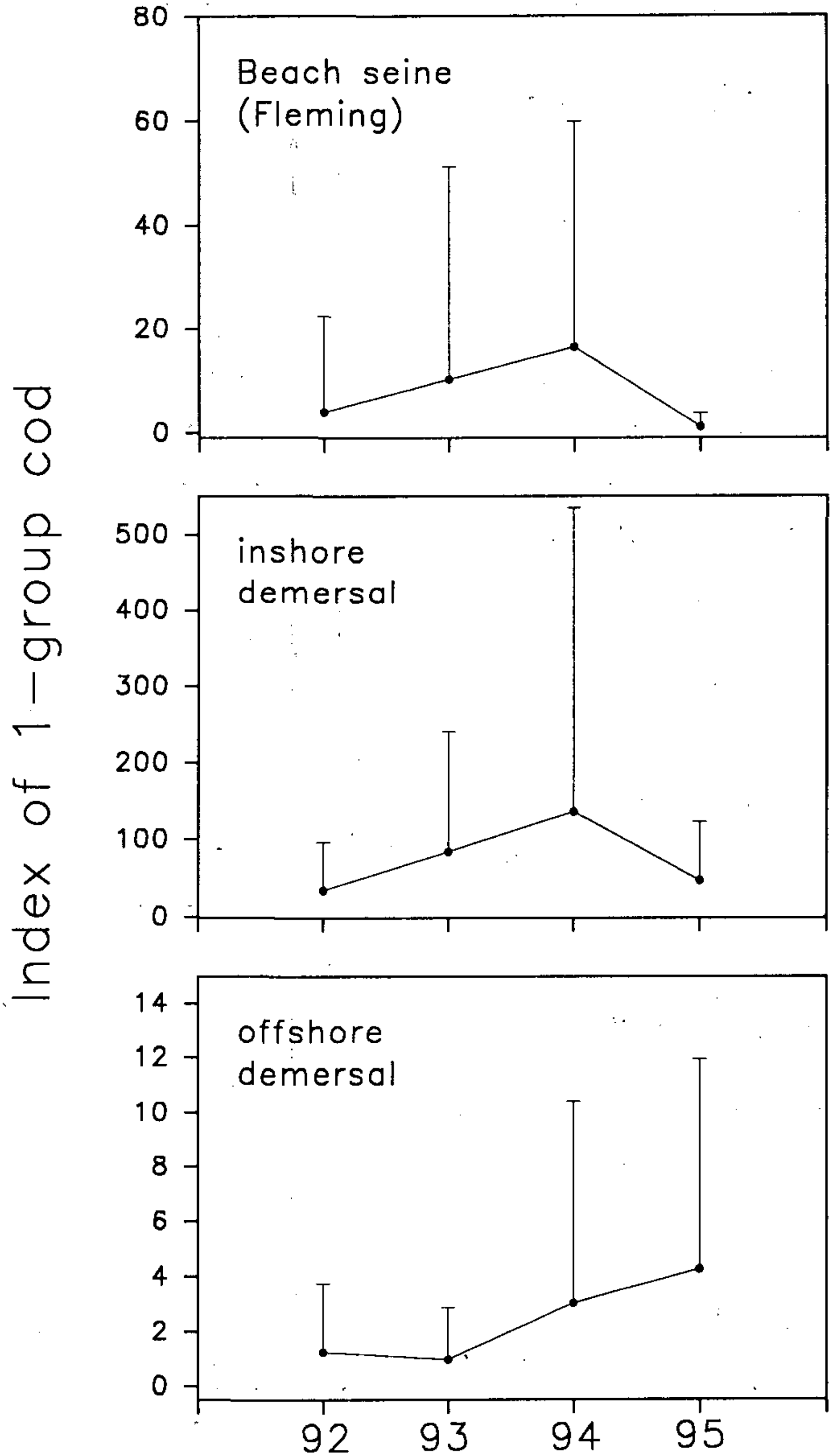
Schneider, D.C., D.A. Methven, D. Ings. 1995. Distribution of demersal cod (ages 0+, 1+, and 2+) in the coastal zone, NAFO Divisions 3K and 3L. DFO Atlantic Fisheries Research Document 95/68.

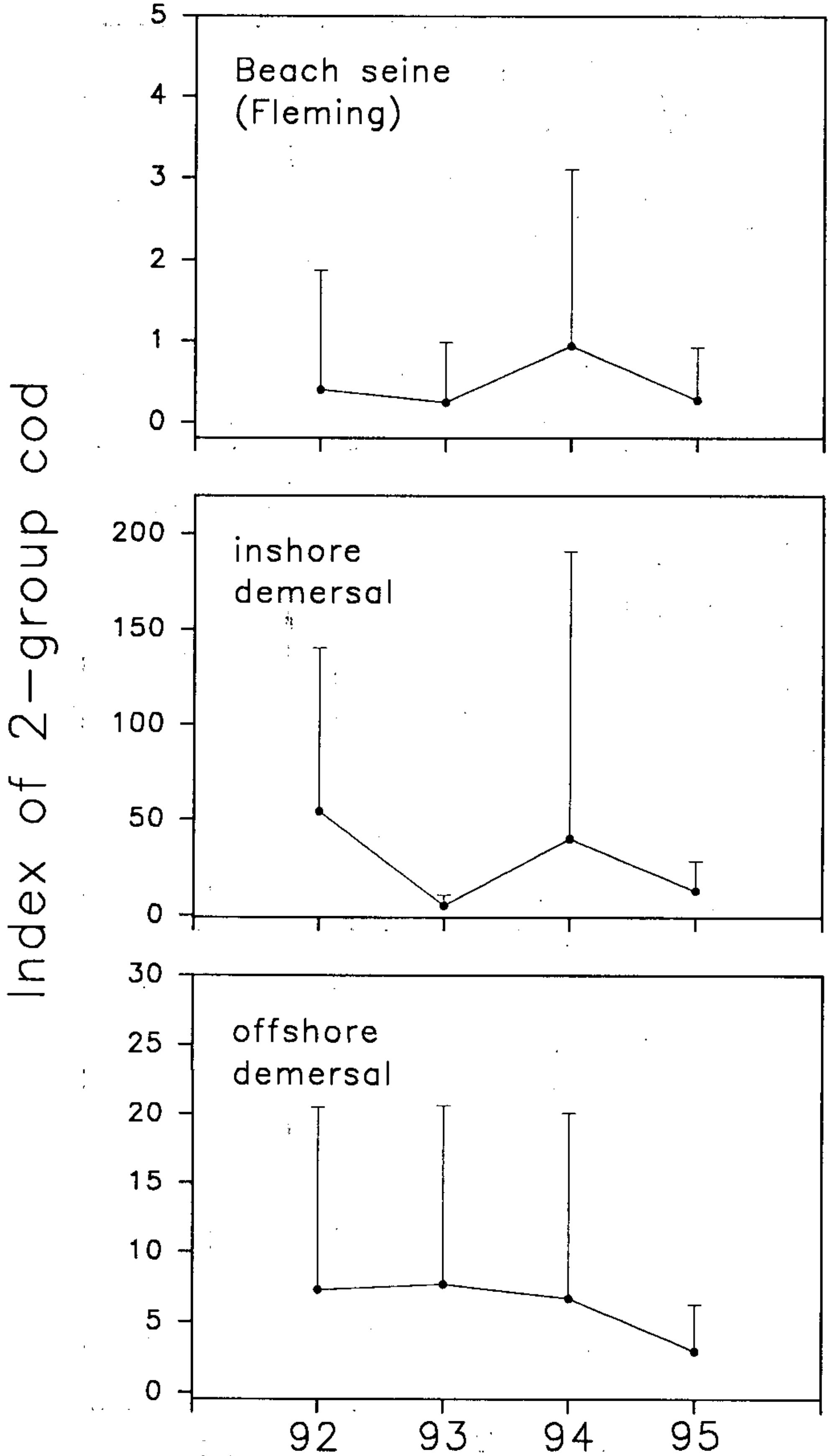
Summary

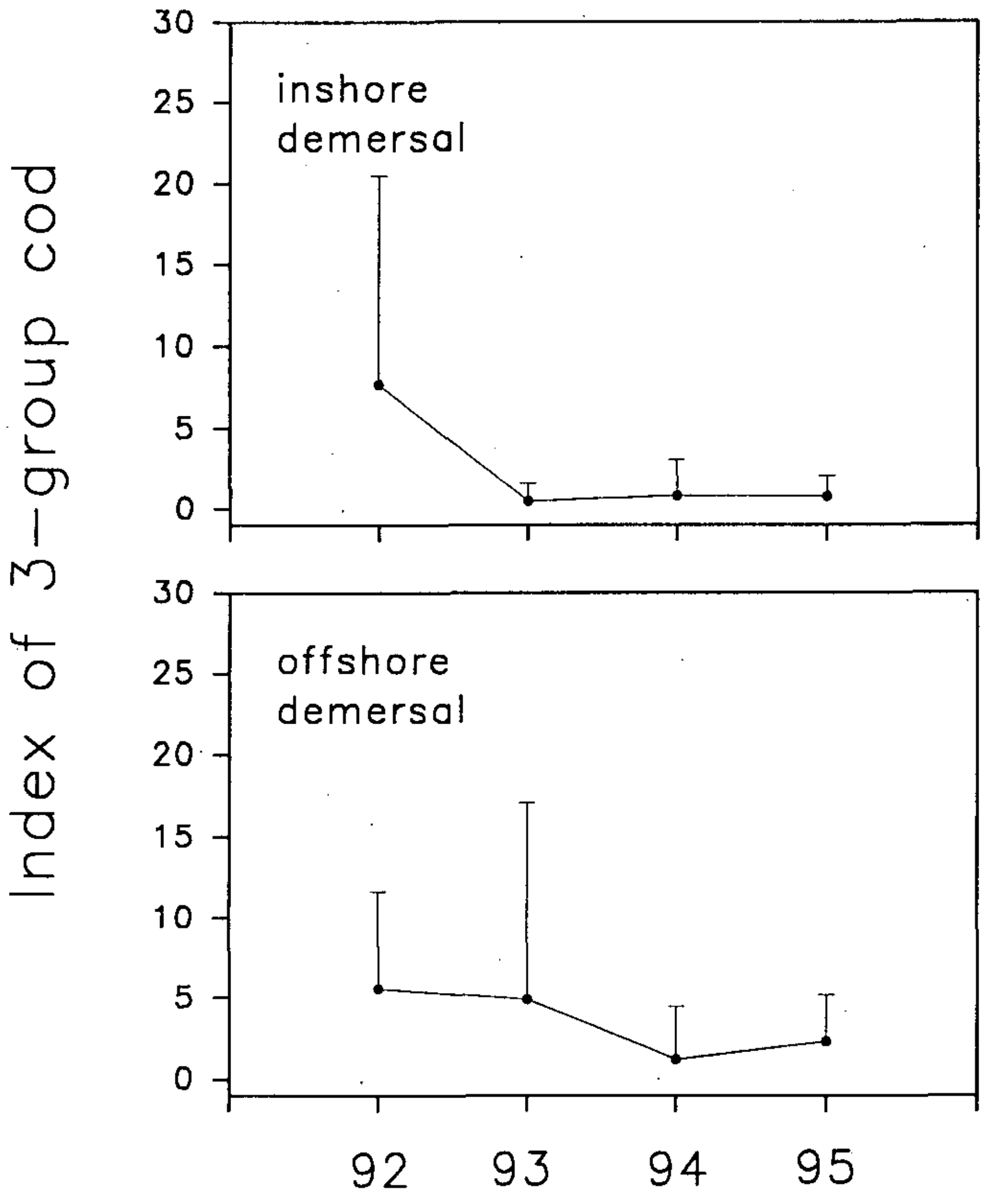
Cohort	pelagic	demersal 0	demersal 1	demersal 2	demersal 3
1992	weak	weak	strengthening	-----------------	
1993	weak	weak	strengthening	cut down	
1994	better	stable	cut down		
1995	better				

Comparison of pre-recruit time series




Index of 1-group cod
80
60
40
20
0
Beach seine
(Fleming)
500
400
300
200
100
0
inshore
demersal
14
12
10
8
6
4
2
0
offshore
demersal
92
93
94
95


Index of 2-group cod
Beach seine
(Fleming)
inshore
demersal
offshore
demersal
0
1
2
3
4
5
0
50
100
150
200
0
5
10
15
20
25
30
92
93
94
95


Index of 3-group cod
inshore
demersal
offshore
demersal
30
25
20
15
10
5
0
92
93
94
95