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An Account of the Annual Variability in 2J3KL Cod Trap Landings Relative to Stock Biomass and Sea Temperatures

by

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Abstract

I tested the hypothesis that variability in total cod trap landings in NAFO Div. 2J3KL not attributable to stock size variations would be positively correlated with near surface temperatures in the Labrador current and bottom temperatures in 3K and 3L immediately preceding and during the fishery. Total cod trap landings in NAFO Div. 2J3KL were positively correlated with the biomass of cod of ages 3, 4, and 5 as estimated by SPA for the years 1962-1990 (r = 0.74 for pooled ages 3-5). Landings were not correlated with the biomass of older fish. Landings were not correlated with near surface temperature anomalies at Station 27 (30 and 50 m) during the months of the inshore fishery (May-Aug). In multiple regressions, these temperatures did not reduce the error in landings predicted from biomass alone. Landings were not correlated with springtime bottom temperatures in 3K and 3L. Exploratory analyses led to the finding that trap landings were positively correlated with sea temperatures at Station 27 during the winter (Dec-Feb), and with bottom temperatures in 3K and 3L in the previous year (e.g., for Station 27, Jan 1962-1990, r = 0.51 at 30 m and r = 0.54 at 50 m). The best fit prediction of landings employing co-predictors ages 3-5 biomass and January temperatures at Station 27 was: (TRAP LANDINGS [log] = 3-5 YR-OLD BIOMASS [log] * 0.819 + STN 27 JAN. TEMP. ANOMALY AT 50 m * 0.211-1.442; for both predictors $P < 0.05$, $R^2 = 0.72$).

Résumé

J'ai éprouvé l'hypothèse selon laquelle la variabilité des débarquements de morue de trappe dans les divisions 2J3KL de l'OPANO qui n'est pas attribuable aux variations de la grosseur du stock serait directement liée aux températures régnant à proximité de la surface dans le courant du Labrador et dans les eaux profondes des divisions 3K et 3L immédiatement avant et durant la pêche. Il est apparu qu'une corrélation positive existait entre les débarquements totaux de morue de trappe dans les divisions 2J3KL de l'OPANO et la biomasse de morues de 3, 4 et 5 ans, telle qu'estimée selon l'ASP pour les années 1962-1990 (r = 0,74 pour le groupe d'âges 3-5). Aucune corrélation n'a été établie entre les débarquements et la biomasse de morues plus âgées, non plus qu'entre les débarquements et les anomalies de la température à proximité de la surface à la station 27 (30 et 50 m) au cours de la saison de pêche côtière (mai-août). L'utilisation de ces températures en régressions multiples n'a pas diminué l'erreur inhérente aux prévisions de débarquements fondées uniquement sur la biomasse. On n'a pu davantage dégager de corrélation entre les débarquements et les températures des profondeurs des divisions 3K et 3L au printemps. Des analyses exploratoires ont permis d'établir une corrélation positive entre les débarquements de morue de trappe et les températures de la mer à la station 27 au cours de l'hiver (décembre-février), ainsi qu'avec les températures des eaux profondes des divisions 3K et 3L l'année précédente (pour la station 27, janvier 1962-1990, r = 0,51 à 30 m et r = 0,54 à 50m). La meilleure prévision de débarquements fondée sur la biomasse aux âges 3-5 et sur les températures de janvier à la station 27 comme prédicteurs s'établissait comme suit : (Log DÉBARQUEMENTS DE MORUE DE TRAPPE = Log BIOMASSE AUX ÂGES 3-5 * 0,819 + ANOMALIE DE TEMPÉRATURE À LA STATION 27 EN JANVIER * 0,211-1,442, pour les deux prédicteurs $P < 0,05$, $R^2 = 0,72$).

Introduction

The poor inshore fishery during 1991 has elicited a new round of questions and many opinions about the nature and cause of the variability in the landings of the inshore fishery. Research on the cause of variations in cod trap landings has shown that two major factors affecting "bay-scale" catches are fish abundance and distributional variations associated with thermal conditions that modify availability (Rose and Leggett 1988, 1989a). At larger scales (whole stocks), a relationship between the biomass of cod of the ages caught by traps and trap catches has also been demonstrated (Pinhorn 1986, Rose 1992).

Thermal conditions influence cod distribution (e.g., Rose and Leggett 1989b). For 2J3KL cod, the strength and persistence of the inshore branch of the Labrador current has been hypothesized to influence cod migration and resultant inshore fishing success (Lear et al. 1986). However, recent acoustic studies on 2J3KL cod migration have shown that variability in the progressive movements of cod from the offshore to inshore, in relation to thermal conditions, can be observed well offshore from the "CIL boundary" (Rose unpublished). This suggests that the effects of thermal conditions on cod distributions and migrations may occur at much larger scales than those of the "CIL boundary" and that winter thermal conditions offshore may influence distributions and the "setting up" of the migration patterns and, hence, the spring and summer inshore fisheries.

In this paper, I examine the hypothesis that variability in sea temperatures accounts for annual variations in total trap landings (2J3KL scale) not attributable to stock size variations. I used Station 27 and Russian survey temperature data (Borovkov and Tevs 1990) to test the "thermal barrier hypothesis" - that warmer springtime near surface temperatures in the inshore branch of the Labrador current during the period of the migration from the offshore are associated with higher catches. I then investigated possible relationships between trap landings and Station 27 and shelf bottom temperatures to develop alternate hypotheses consistent with data and research findings on the migrations of northern cod.

Methods

Total trap landings and biomass of cod in NAFO Div. 2J3KL are for 1962-1990 from Baird, Bishop, and Murphy (1991). Temperature series were derived from two sources: (1) Labrador current averages (0-200 m, 1964-1988) from the Hamilton Bank area and spring (Mar-Jun, 1972-1988) bottom temperatures from NAFO Div. 3K and 3L (Borovkov and Tevs 1990); and (2) inshore Labrador current monthly average temperatures at 30 m and 50 m from Station 27 (1962-1991). All temperature series are anomalies from long-term averages. Standard multiple regression techniques were used in these analyses. Any autocorrelation in the series was ignored.

Results

Total trap landings were significantly and positively correlated with the biomass of cod of ages 3, 4, and 5 as estimated for January 1 of the same year

(Ps < 0.01) (Fig. 1). For ages above 5, no significant correlations were evident (Ps > 0.1). To enable the removal of the effects of stock size on trap landings with a single variable, biomasses of fish of ages 3-5 were pooled (Fig. 2). This pooled estimate of potentially available biomass had the strongest correlation (r = 0.74) with total trap landings over the full data range (the correlation with age 4 fish was marginally higher than with the pooled estimate over portions of the range of the data - consistent with Pinhorn 1986 - but the pooled estimate was judged to be superior in terms of removing the effect of potentially available biomass to the trap fishery).

Temperature anomalies from individual or combinations of months from the Labrador current (springtime) and at Station 27 during the months of the fishery (May-Aug, Fig. 3) were in no case significantly correlated with trap landings. Moreover, when included in multiple regressions with predictor variable 3- to 5-year biomass, temperatures during these months did not significantly reduce the error sum of squares of trap landings.

Springtime bottom temperatures in 3K and 3L (Fig. 4) were not significantly correlated with trap landings (max r = 0.12). However, in multiple regressions, both 3K and 3L bottom temperatures in the year previous to the fishery were significantly related to trap landings (P < 0.05). To derive an index of sea temperatures in the 12 months previous to the fishery, bottom temperatures were averaged from the previous and current springs for each year. This index of the anomaly of bottom sea temperatures in 3L during the previous winter contributed significantly to a reduction in the sum of squares in a multiple regression (with 3- to 5-year biomass, total $R^2 = 0.71$).

Sea temperatures during the winter (Dec-Feb, Fig. 4) at Station 27 were also correlated with the next season's trap landings (Fig. 2). January temperatures at Station 27 at both 30 m and 50 m were positively and significantly correlated with the full series of trap landings for 1962-1990 [r = 0.51 (30 m) and r = 0.54 (50 m), df = 28, Ps < 0.01]. Other depths have not yet been examined. February temperatures had probabilities of 0.06 at both depths. January temperatures at Station 27 were strongly correlated with the index of bottom temperature in 3L during the previous year (r = 0.85, df = 16, P < 0.01). When included in a multiple regression, January temperatures at Station 27 accounted for a significant reduction in the sum of squares (with predictor variable 3-5 year biomass) of trap landings ($R^2 = 0.72$). The fitted model [TRAP LANDINGS (log) = 3-5 YR-OLD BIOMASS (log) * 0.819 + STN 27 JAN. TEMP. ANOMALY AT 50 m * 0.211-1.442] is portrayed in Fig. 5.

Discussion

Although these analyses are preliminary and exploratory in nature, several conclusions are indicated:

1) The abundance (biomass) of 3- to 5-year-old fish is the strongest and most consistent predictor of the success of the trap fishery (accounts for > 50% of the variance).

2) The "thermal barrier" hypothesis - that thermal conditions in the Labrador current and the "cold intermediate layer" during the period of the migration of cod from the offshore spawning areas to the nearshore fishing grounds would account for a significant portion of the annual variability in trap landings - was not supported. Warmer years did not consistently coincide with better catches, nor did colder years consistently coincide with poorer catches. This finding does not support the oft-repeated contention that the "thermal barrier" dynamics of the Labrador current and the "CIL boundary" conditions greatly influence the availability of cod to the inshore fixed gear fishery. Akenhead et al. (1982) examined eight years of data from the 1970s and also found no relationship between these variables.

3) The positive correlation between winter thermal conditions and the forthcoming years' trap landings suggests that general thermal conditions in advance of the onshore migratory period may influence the migration and the resultant successes of the trap fishery. This hypothesis was supported both by the data derived from Borovkov and Tevs (1990) and from Station 27. I stress that this statistical relationship does not imply direct cause and effect - temperature may be a symptom of the causal phenomenon and not the cause itself. Also, temperature may be the cause; but the way in which thermal conditions affect fish migrations onshore, and the scales at which an effect operates, are still not clear. I believe that the only way to find out what is truly going on is to conduct directed fisheries oceanographic research on the mechanisms that determine fish distribution and migration (e.g., cod migration research of OPEN and the NCSP).

There is good and bad news here. The good news is that using two simple variables, 70% of the variance in annual trap landings can be accounted for. The bad news is that there remains 30% of the variability unaccounted for, and the mechanism underlying the temperature effect remains somewhat obscure. However, it should be pointed out that two years make up the major part of the unexplained variance (1981 catches are too low and 1988 too high for the present model). At present, I can offer no plausible explanation for the anomalous trap catches of 1981 and 1988 based on the measures of biomass and temperature used here. However, there are likely other factors at work (e.g., capelin distributions, nearshore oceanographic dynamics, slub, blackberry, variance in the catch data due to effort effects) that are not accounted for in the two predictive factors used here. Their influences may be highly non-linear, scale-dependent and may appear to be chaotic in nature; and it is reasonable to expect that they will remain difficult to detect without directed sea research.

The 1991 trap fishery

The moderate biomass levels of 3- to 5-year-old cod thought to exist at the beginning of 1991, coupled with the moderate negative temperature anomaly during January 1991, indicated an average to fairly good trap fishery for 1991 (roughly 36,000 t). The generality of the prediction - a relatively productive trap fishery - is directly at odds with the "thermal barrier hypothesis," given the severely cold temperatures present in the Labrador current and inshore during the fishery in 1991. It appears that this "prediction" has been borne out, in that the trap fishery statistics indicate that the final tally of trap caught cod will be in the range of 36,000-40,000 t.

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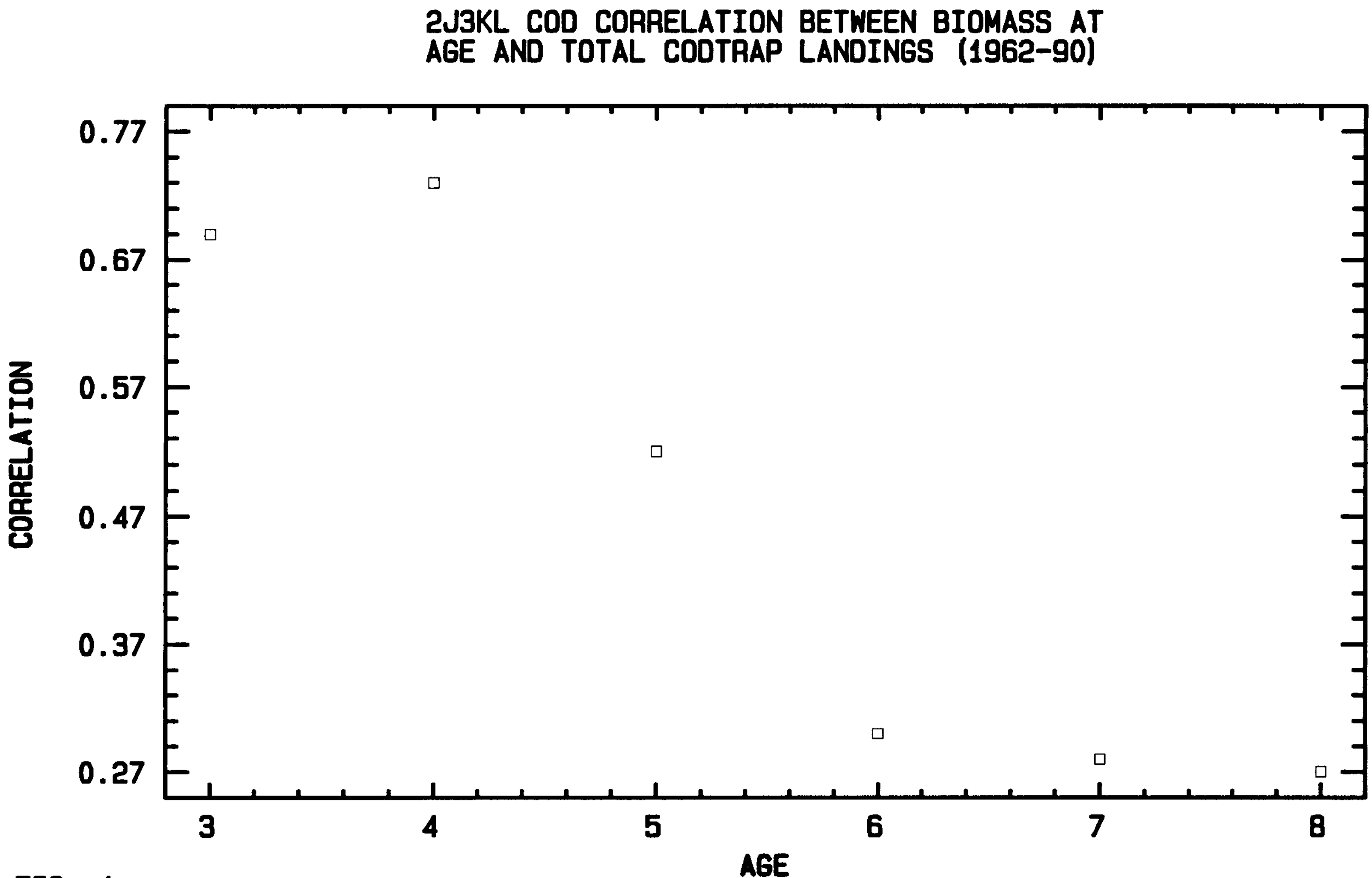

2J3KL COD CORRELATION BETWEEN BIOMASS AT
AGE AND TOTAL CODTRAP LANDINGS (1962-90)
CORRELATION
0.77
0.67
0.57
0.47
0.37
0.27
3
4
5
6
7
8
AGE

FIG. 1

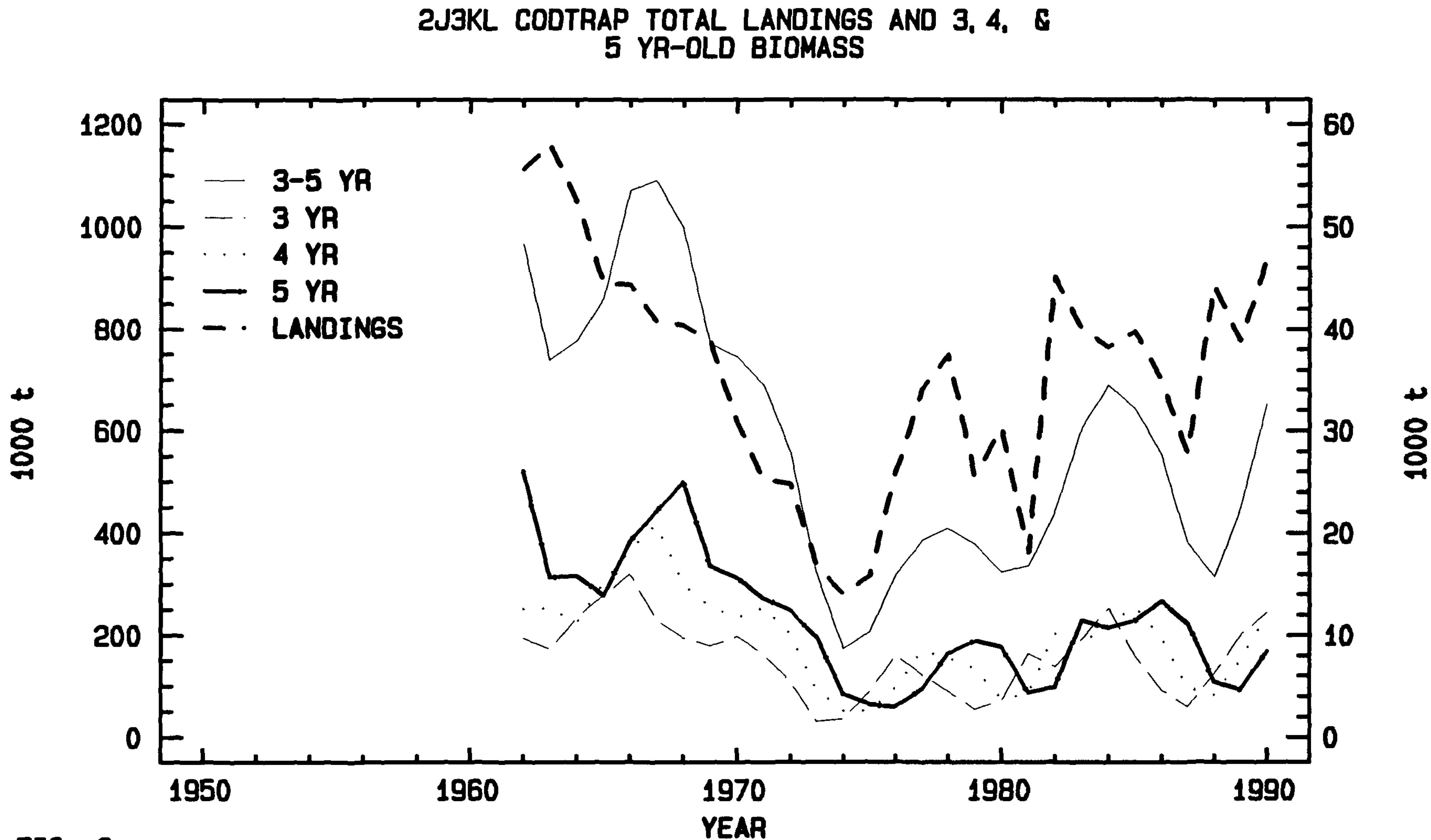
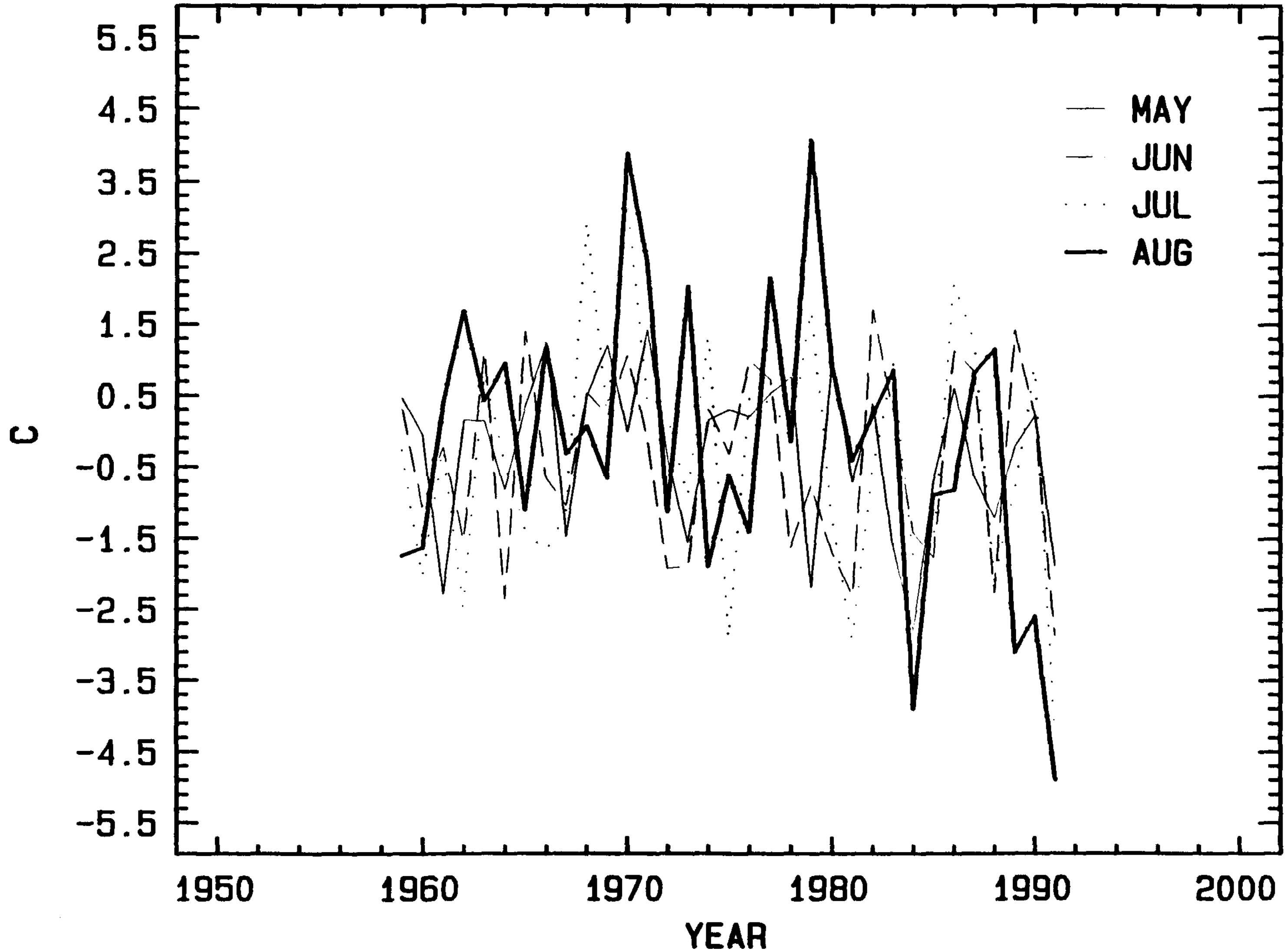
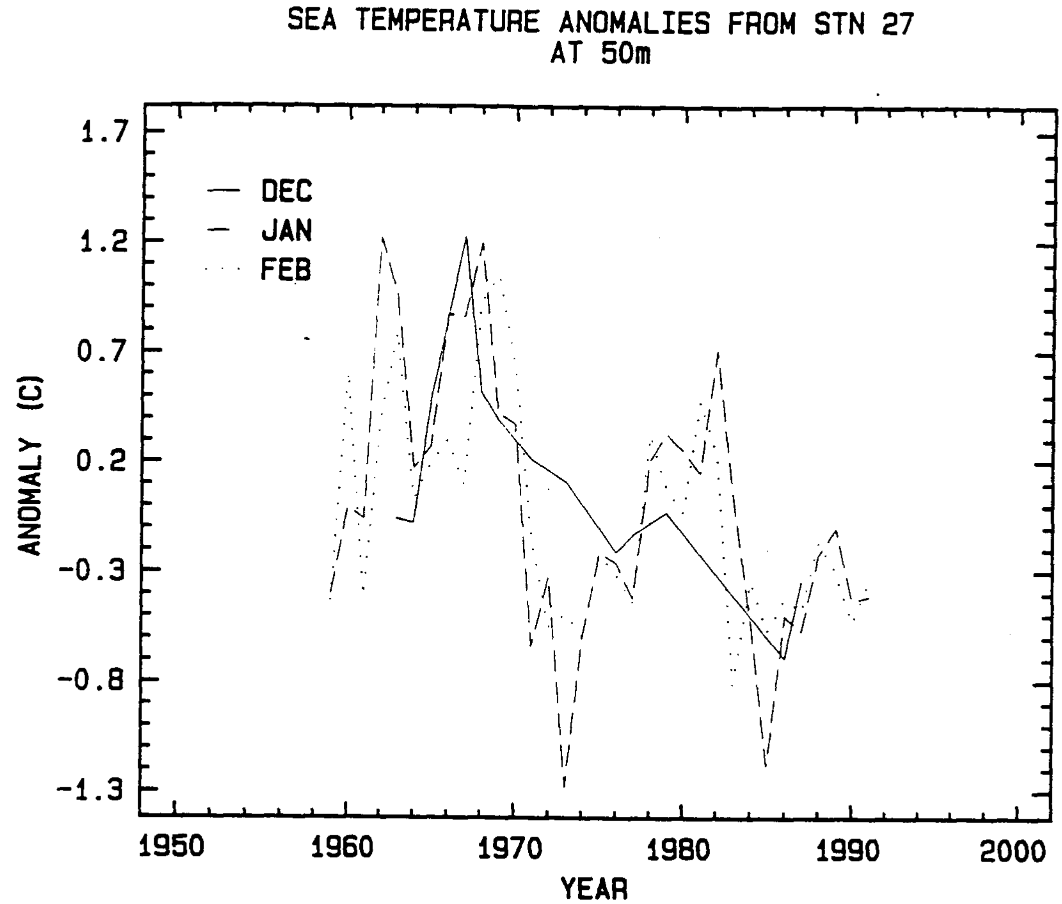

2J3KL CODTRAP TOTAL LANDINGS AND 3, 4, & 5 YR-OLD BIOMASS
3-5 YR
3 YR
4 YR
5 YR
LANDINGS
1000 t
1000 t
YEAR
0
200
400
600
800
1000
1200
0
10
20
30
40
50
60
1950
1960
1970
1980
1990

FIG. 2

Fig. 3. Monthly temperature anomaly from long-term average for May to August at Station 27 at 30 m depth, 1958-1991.





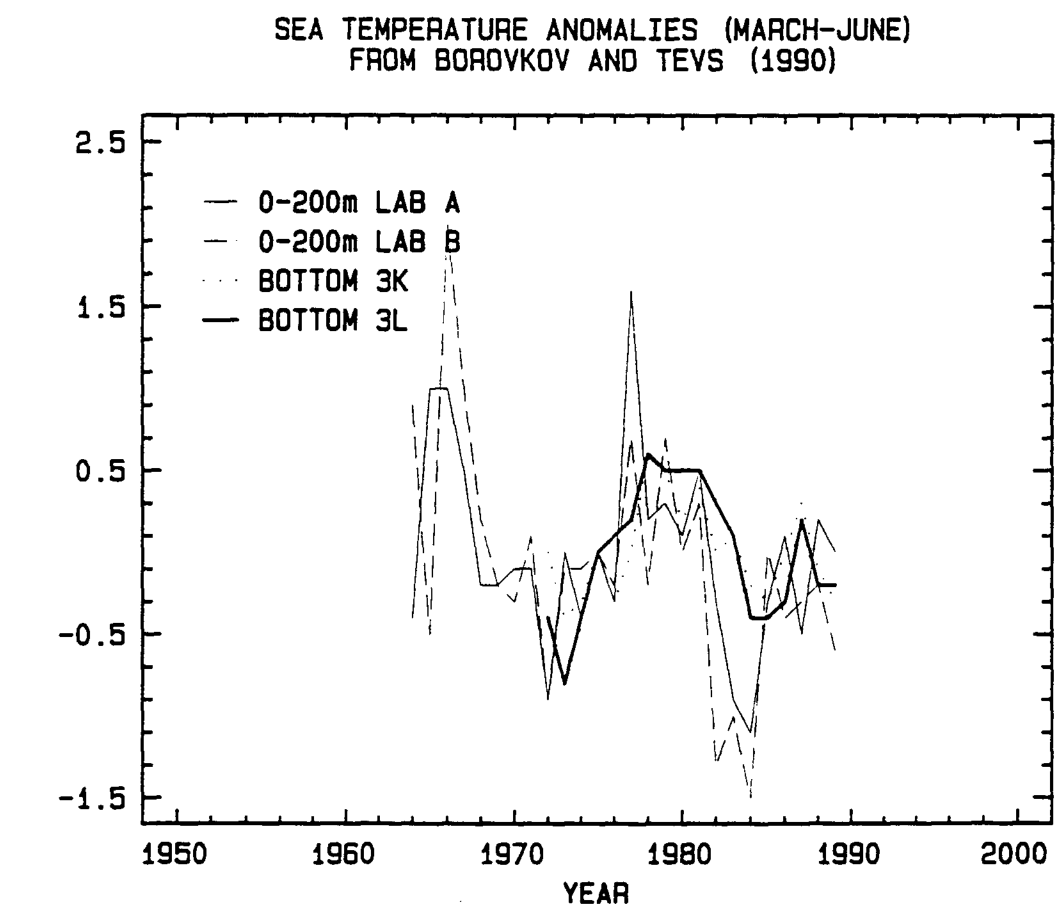


Fig. 4. Monthly temperature anomalies for December to January at Station 27 at 50 m depth, 1958-1991, and temperature anomaly series for Newfoundland and Labrador shelves derived from Borovkov and Tevs 1990.

Fig. 5. Total observed codtrap landings for 2J3KL and those predicted for 1973-1990 by the multiple regression with 3- to 5-year-old biomass and Station 27 January temperatures as predictors (see text for details).