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Environment-4VsW Cod Recruitment Relationships

by

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ABSTRACT

Earlier studies had established a relationship between RIVSUM, the freshwater discharge from the St. Lawrence River system, and 4VsW cod recruitment for the years from the late 1950s to the early 1980s. However, predictions from a RIVSUM-based regression equation were unable to forecast the apparent large decline in recruitment during the remainder of the 1980s. In this study, new estimates of recruitment, adjusted for seal predation, are tested against the RIVSUM predictions. A much better fit is obtained compared to the unadjusted recruitment index.

The relationship of recruitment to other environmental indices is also examined. Recruitment of 4VsW cod appears to covary with deep (200 m) Emerald Basin temperatures with colder temperatures corresponding to higher recruitment.

RÉSUMÉ

Des études précédentes avaient permis d'établir un lien entre le RIVSUM, écoulement d'eau douce en provenance du réseau hydrographique du Saint-Laurent, et le recrutement de morue dans 4VsW de la fin des années 1950 au début des années 1980. Toutefois, des prédictions établies au moyen d'une équation de régression fondée sur le RIVSUM n'ont pas su anticiper la baisse apparemment importante du recrutement durant le reste des années 1980. On compare ici de nouvelles estimations du recrutement, corrigées en fonction de la prédation par les phoques, aux prédictions fondées sur le RIVSUM. La concordance obtenue est bien supérieure à celle produite par l'indice de recrutement non corrigé.

On examine aussi les liens entre le recrutement et d'autres facteurs environnementaux. Le recrutement de la morue de 4VsW semble varier en fonction des températures des eaux profondes (200 m) du bassin Émeraude, les températures plus froides correspondant à un recrutement supérieur.

INTRODUCTION

In an exploratory analysis of the effects of environment on fish recruitment, Drinkwater (1987) found an apparent negative relationship (r=-0.87, 1958-1982) between the 3-yr running means of July discharge from the St. Lawrence River system (i.e. the combined flow from the St. Lawrence, Ottawa and Saguenay Rivers called RIVSUM by Sutcliffe et al., 1976) lagged 3 years and VPA estimates of recruitment for 4VsW cod expressed as numbers at age 3. A linear regression was used to calculate cod recruitment at age 3 based on the river discharge (Fig. 1). The effect of the river discharge was thought to be indirect, possibly on the larval stages through effects on stratification, mixing or by advection through generation of a buoyancy-driven flow. Sutcliffe et al. (1976) had earlier discussed the effects of RIVSUM on the Gulf of St. Lawrence and the Scotian Shelf.

Frank et al. (1994) revisited the relationship to determine if the RIVSUM-based regression predicted the large decline in the 4VsW cod population during the 1980s. Using age 1 abundance as the recruitment index and no running means, they confirmed the original relationship over the years 1957-79 using February RIVSUM (r=-0.77). The years refer to the birth year of cod, i.e the age 1 in 1958 have a birth date in 1957. Within the remainder of the paper, the years will refer to the birth year unless otherwise stated. Frank et al. (1994) went on to predict recruitment through the 1980s based upon a linear regression with RIVSUM. The large decline in recruitment estimated from the VPA was not predicted by the model (Fig. 2). This was not surprising as the river discharge showed no large increase during the 1980s.

Recent work by Mohn and Bowen (1994) on the effects of seal predation have lead to new estimates of 4VsW cod recruitment after adjusting for seal-based mortality. The question arose, how do the RIVSUM-based recruitment predictions compare with the seal-adjusted recruitment estimates? To investigate, the latter were obtained from R. Mohn (personal communication). The recruitment estimates were numbers at age one, assume M=0.2 and cover the period 1969 to 1989 (estimates from 1990 and 1991 were also available but are tentative and have not been used). In the following analysis these were combined with earlier recruitment estimates for the years prior to 1969. This was justified by the small difference between the unadjusted and the seal-adjusted estimates during the 1970s, due to the relatively low number of seals at that time.

RESULTS

The RIVSUM-based recruitment predictions for the 1980s are much closer to the seal-adjusted recruitment index (Fig. 3) than the unadjusted index (Fig. 2). The root-mean-square (rms) differences between the seal-adjusted and RIVSUM-based recruitment estimates are similar for 1957-78, the approximate period used to establish the original regression (rms=21.7×10^6), and the years since (1979-89;

rms=24.7x10^6). These rms values are not considered significantly different. While there was a slight tendency for the RIVSUM predictions to be high in the later period, still in 5 out of the 11 years the RIVSUM predictions were lower than the seal-adjusted estimates. This indicates that the RIVSUM-based recruitment predictions for the years 1979-89 matched the seal-adjusted estimates almost as well as for the years used to establish the relationship (1957-78). For comparison, the rms differences between the RIVSUM predictions and the unadjusted recruitment time series for the period 1979-89 was 45.7x10^6.

Although the rms values for 1979-89 were similar to those of the earlier period, the correlation between the RIVSUM-based and seal adjusted recruitment index during 1979-89 was low (0.1) and not significant. Thus, while there was relatively good agreement between the mean levels of recruitment predicted by RIVSUM and that for the seal-adjusted index, there was little similarity in their year-to-year variability. The reader must be cautioned that the seal-adjusted recruitment estimates are themselves preliminary, presently under scientific debate and may in future be revised.

OTHER ENVIRONMENTAL INDICES

As part of the investigations for the Frank et al. (1994) paper, an exploratory correlation analysis between 4VsW cod recruitment and 4 other environmental indices was also undertaken. These included monthly and annual means of Sable Island air temperatures, Halifax Harbour sea surface temperatures, positions of the shelf/slope front and Emerald Basin ocean temperatures. The shelf/slope frontal positions were obtained from digitized NOAA oceanographic analysis charts derived from satellite images (see Drinkwater et al. 1994 for details). Positions averaged between 57 and 62°W were estimated for comparison with 4VsW cod. The Emerald Basin temperatures were linearly interpolated to obtain a complete set of monthly values for the period 1947 to 1988. Data from 0, 100 and 200 m were used. Only relationships between recruitment and the environment during the first year of life, i.e. the year they were spawned, were considered. The recruitment time series used was that unadjusted for seal predation. In this study the analysis has been repeated using the seal-adjusted recruitment estimates.

In general, correlations of 4VsW cod recruitment with Sable Island air temperatures, the shelf/slope front and Halifax SSTs were low ($r < 0.35$). Correlations with Emerald Basin temperatures showed an increase with depth with values at 0 m near -0.4 while at 200 m they were near -0.6. Maximum r values occurred in the months of peak spawning (spring and autumn) but there was not considered to be any significant difference between the months. This is consistent with what we know about the deeper temperatures, i.e. they are highly persistent being dominated by long-period variability. A regression was estimated using the March and April

Emerald Basin temperatures. This regression together with the revised recruitment estimates adjusted for seal predation are plotted in Fig. 4. The regression model accounts for 52% of the variance in the recruitment time series over the years 1957-1988. A plot of the recruitment versus the average 200 m Emerald Basin temperature during March and April is provided in Fig. 5.

Why might the Emerald Basin deep temperatures correlate with 4VsW cod recruitment? Petrie and Drinkwater (1993) have shown that the deep temperatures in Emerald Basin are representative of the low-frequency thermal signal over the entire water column. At shallower depths there is more high-frequency "noise" (weather) which may not affect the cod recruitment as much as the low-frequency (climate) signal. It has also been shown that the deep Emerald Basin temperatures are coherent with low-frequency temperature variability over much of the Shelf (Petrie and Drinkwater, 1993). The negative correlation indicates that recruitment is high when temperatures are low. The highest recruitment occurred in the mid-1960s when temperatures were cold whereas the lower recruitment has occurred in times of relatively warm temperatures.

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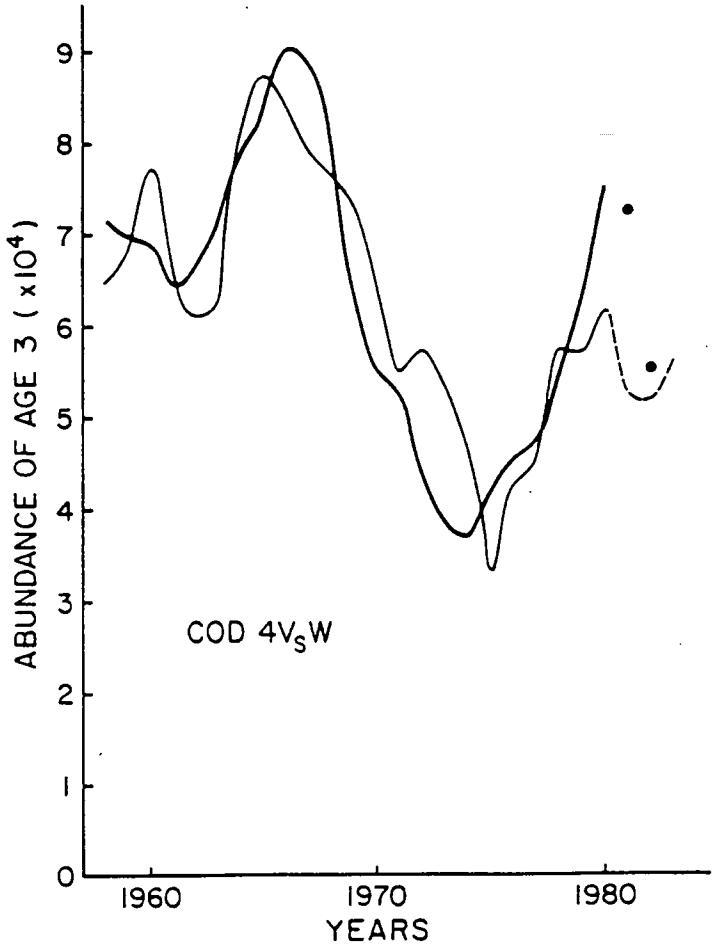

Fig. 1. The 3-yr running means of recruitment of 4VsW cod (measured as abundance at age 3) from VPA estimates (thicker line), estimated from regression relationship with RIVSUM established using the years 1958-80 (thin solid line), predicted by the RIVSUM regression for the years after 1980 (dashed line) and the then recent VPA estimates which had a high degree of uncertainty associated with them (dots). This has been taken from Drinkwater (1987).

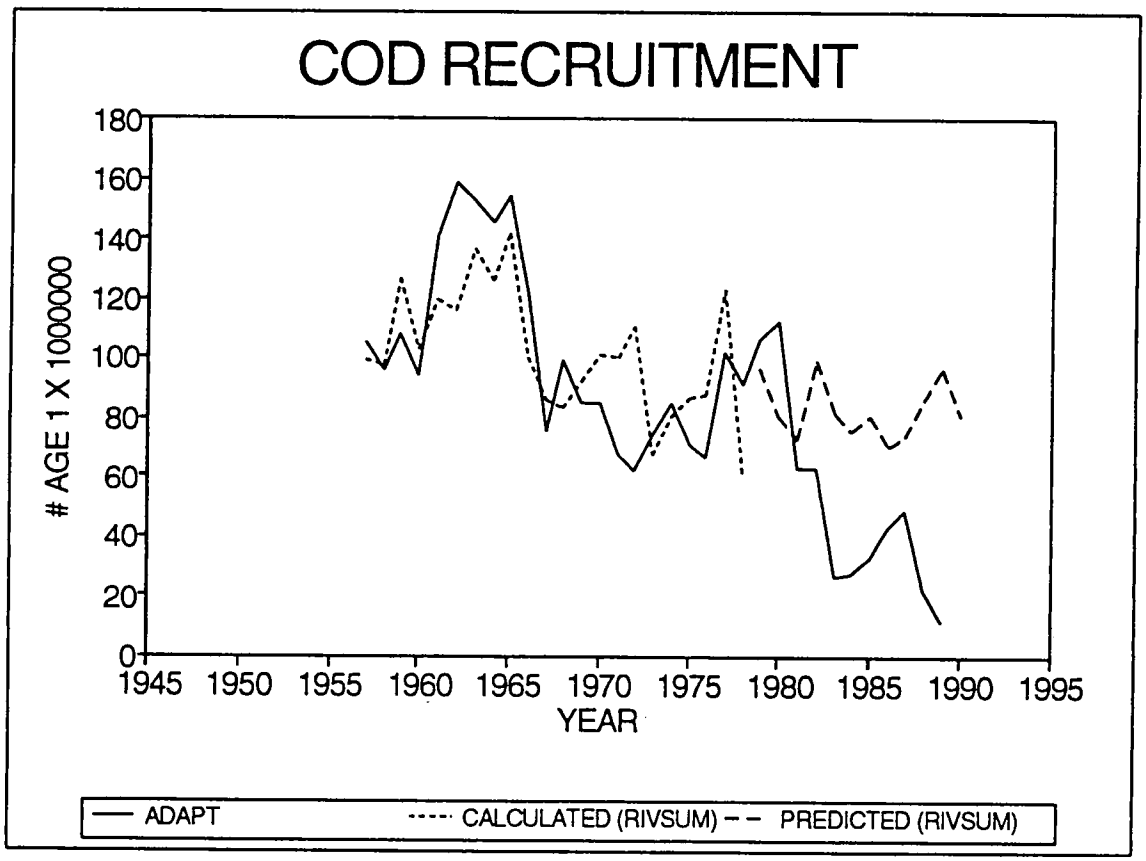

Fig. 2. Cod recruitment estimates from recent ADAPT runs (solid line), calculated from a regression with RIVSUM established for the years 1957-1979 (small dashes) and predicted for years from 1980 onwards (long dashes).

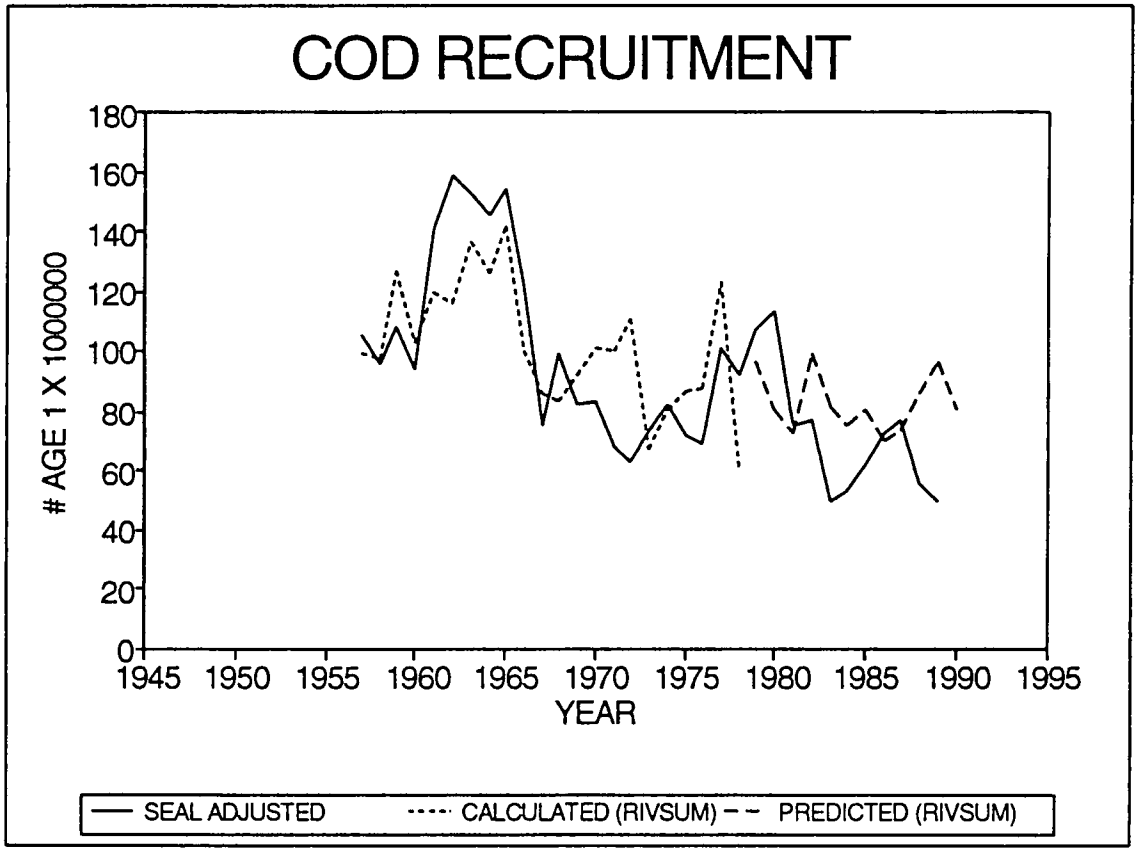

Fig. 3. Cod recruitment adjusted for seal predation (solid line), calculated from a regression with RIVSUM established for the years 1957-1979 (small dashes) and predicted for years from 1980 onwards (long dashes).

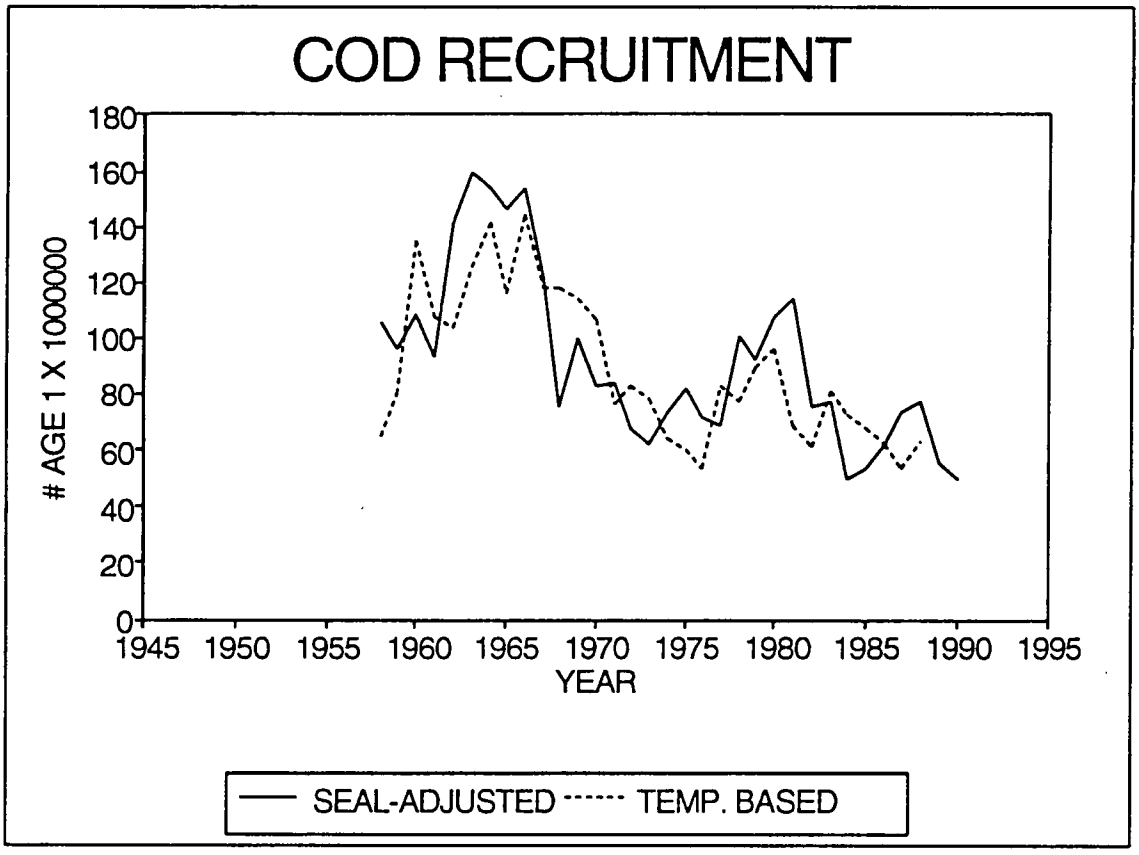

Fig. 4. Cod recruitment adjusted for seal predation (solid line) and calculated from a regression with Emerald Basin 200 m temperatures (dashed line) using all years (1957-1988).

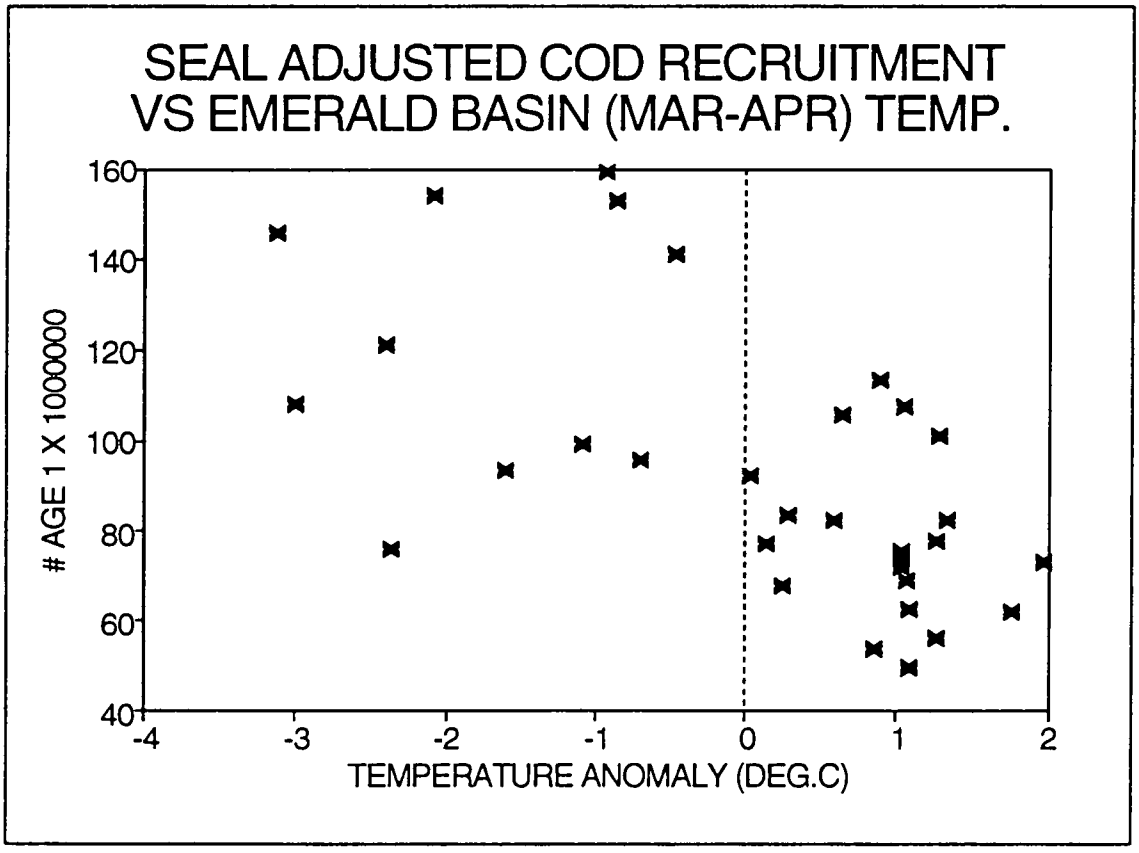

Fig. 5. Cod recruitment versus Emerald Basin 200 m mean temperature anomaly for March and April.