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# Prediction of Divisions 4WX Herring Year-class Strength

by

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## Abstract

Several pre-recruit abundance indices and environmental variables are considered in relation to the "best estimate" of 4WX herring year-class size from 1963 to 1975 (from cohort analysis. The pre-recruit indices include the spring Bay of Fundy larval survey, New Brunswick weir catch rates (ages 1, 2, 3 and ages 1 + 2 + 3) and Nova Scotia weir catch rates (ages 2, 3 and ages 2 + 3). All the environmental time series considered relevant to the area of larval drift and retention are considered. The spring larval survey abundance estimates do not look promising in that the very strong 1976 year-class is associated with average larval abundance. Market influences appear to affect the relationship between various weir catch rate indices and year-class strength. The best relationships are found with New Brunswick weir accumulated catch at ages 1, 2 and 3 (year-classes 1966 to 1975 considered) and with Nova Scotia catch at age 3 (year-classes 1964 to 1975 considered). The exceptional year-classes are reflected in all commercial pre-recruit indices. There is a highly significant relationship between year-class strength and two environmental variables (sea level and wind from the Southwest). However, plausible underlying biological interpretations have not as of yet been proposed. In sum, although there are several potential pre-recruit indices for this stock, the confidence limits associated with the assessment "predictions" of the size of incoming year-classes are broad.

## Recruitment variability from cohort analysis

For management purposes three major spawning stocks have been identified within NAFO SA 4, 5, and 6: the southwest Nova Scotian,[1] the Gulf of Maine and the Georges Bank. The details of the distribution at each life history phase are not equally well known for each spawning component, but some working hypotheses have tentatively been accepted.

[1] The Grand Manan stock, which appears biologically distinct, is included in the S.W. Nova Scotia management unit.

For each of the stocks the spawning areas and associated larval distributions are unique, but there is believed to be mixing (in unknown proportions) of the juvenile distributions, and during the adult overwintering and summer feeding migrations. Specifically there is mixing of "Gulf of Maine" and "S.W. Nova Scotia" juveniles along the coast of Maine and the Bay of Fundy. There is probably mixing of "Gulf of Maine" and "S.W. Nova Scotia" adults during summer feeding at the mouth of the Bay of Fundy. Finally there may be mixing of "Georges Bank" and "Gulf of Maine" adults during overwintering in SA 5 and 6.

The degree of mixing of the component stocks in the various fisheries and its year-to-year variability is not known. This uncertainty creates difficulties in the estimation of the population age structure and abundance of each stock using cohort analysis. In the present analysis of recruitment variability of the southwest Nova Scotia stock the option 2 cohort analysis from Sinclair and Iles (1980) is taken as the best estimate of the recent history of the population (1965 to present). The year-class strengths at age 1 from that analysis are shown in Table 1, along with comparative estimates from the literature for the Georges Bank and Gulf of Maine stocks. The accuracy of the time series of the S.W. Nova Scotian stock is critically dependent on the appropriateness of the catch matrix utilized. Temporal changes in the degree of mixing of the component stocks within Canadian waters, will induce biases both in the absolute values, as well as in the relative trends. The possibility of such biases should be kept in mind in considering the subsequent treatment of the recruitment time series.

There is some evidence for year-class strength parallelism between stocks (Figure 1). The 1974 Gulf of Maine and Georges Bank estimates are probably overestimates (G. Waring, personal communication). Without this point, the r value for the S.W Nova Scotia and Georges Bank stocks is 0.86. The temporal distribution in year-class strength for the southwest Nova Scotia stock is shown in Figure 2. Two points are noteworthy; the number of years between good year-classes (1963, 1966, 1970 and 1976), as well as the range between good and bad year-classes, is increasing. The coefficient of variability from 1964 to 1973 is 66% while that from 1974 to 1978 is 133% (it should be noted however that the three most recent years, 1976 on, are estimated using prerecruit indices rather than from cohort analysis).

Correlations with prerecruit indices

A. Juveniles of a mixture of stock components are caught by weirs on the New Brunswick side of the Bay of Fundy whereas juveniles of the S.W. Nova Scotia stock alone are thought to be fished by the Nova Scotia side weirs. Predominantly two-year olds are caught, but the percentage of one and three-year olds can be large in some months and years (Figure 3). The number of active weirs has been relatively constant over the time period covered in the recruitment series. However, market constraints influence the effective effort exercised by a weir during each season. This is thought to be particularly critical for the Nova Scotia weirs because of their distance from the major processing plants. An additional complication in the weir catch rate time series is the transformation from a meal and food fishery to a strictly food fishery in the early 1970's. The correlations between a variety of weir catch-at-age indices and cohort analysis year-class strengths are shown in Table 2, and two of the better relationships are graphed in Figure 4. Although the correlations are significant, they do not predict the moderate and poor year-classes well. The exceptional year-classes, however, do trend to stand out. There is the suggestion of a temporal discontinuity in the relationship between catch at age 3 in the Nova Scotia weirs and year-class strength, the correlation coefficients being somewhat higher for the shorter time series. Thus, this latter indice looks promising even though the year-class is not "predicted" until age 4. The smoothing out of market variability by using accumulative catch of each year-class in the respective weirs improves the correlations with the N.B. weirs, but not with the N.S. weirs.

B. A variety of environmental parameters have been considered as prerecruit indices. The best relationship (by a statistical and not necessarily biological criteria) is with Sable Island 240$^{o}$ wind and sea level (cm) at Halifax (Figure 5). The predictive regression is:

$$\text{Year-class strength } (\times 10^{-9}) = -1.80 + 1.35 \text{ Win } 230^{o} - 0.476 \text{ LEVHXR} \qquad (R^2 = 0.86)$$

The correlation (r) with Halifax sea level alone is 0.83. In an attempt to infer possible underlying mechanisms the sea level record has been decomposed into respectively wind driven, barametric, steric and residual components. The latter component is positively correlated (0.70) with calculated geostrophic currents along the coast of Nova Scotia and is interpreted as representing the relative strength of the Nova Scotia current.

The "Nova Scotia current" component is not however significantly correlated with the year-class strength time series. The barometric pressure component however is statistically correlated. The analysis suggests, if the correlations are not spurious, that large scale meteorological events may be important. Work is underway to analyse the sea level records in the vicinity of the larval distribution by amalgamating the Yarmouth and St. John records which individually are incomplete. In sum, although the environmental correlations are attractive, efforts to purpose underlying mechanisms have proven illusive to date. It is to be noted that the two exceptionally poor year-classes of 1974 and 1975 are well "predicted". This suggests that their poor strength might have been due to environmental factors rather than due to stock size feed back processes. Finally, the environmental regression predicts an exceptional 1976 year-class (6.96 billion) and a moderately good 1977 year-class (1.56 billion), both of which are in tune with fisheries related estimates.

C. A series of detailed spring larval surveys have been carried out since 1973 in the Bay of Fundy. The methodology used and some preliminary results are documented in Sinclair et al. (1979). It was concluded that, although there were only 4 data points in the relationship (1973 to 1975 year classes), spring larval abundance may well prove to be a valuable pre-recruit indice. Larval abundance for the whole Bay of Fundy was estimated using an aereal expansion approach. The mean station abundance (stations 14 to 99) indicates a similar relationship (fig. 6). However, the 1976 year class (for which there is no cohort analysis estimate, but from other indicators is predicted as very large) is associated with low spring larval abundance. Thus, when the above simple data treatments are used, the earlier optimism concerning the use of the spring larval surveys as a recruitment predictor is unwarranted. It is possible however that when the length frequency data and the distributional aspects are considered that a more detailed analysis will prove fruitful.

## Conclusions

Inspite of the variety of potential pre-recruit indices available for this stock there are still broad confidence limits associated with the assessment predictions. The juvenile fishery indices are influenced by variable market demands and perhaps variable stock mixture. The environmental regression at present lacks a plausible biological interpretation. The spring larval survey does not appear to be a useful recruitment predictor. The need for a juvenile survey to compliment the above approaches is clear.

## References

Anthony, V. 1977. June 1977 assessments of herring from the Gulf of Maine and Georges Bank areas. NFC Lab. Ref. 77-16.

Anthony, V. and G. Waring. 1980. Assessment and management of the Georges Bank herring fishery. Symp. Biological Basis of Pelagic Fish Stock Management (in press).

Sinclair, M. and T. D. Iles 1980. 1979 4WX herring assessment. CAFSAC Res. Doc. 80/47.

Sinclair, M., J. Black, T. D. Iles and W. Stobo. 1979. Preliminary analysis of the use of Bay of Fundy larval survey data in 4WX herring assessments.

Table 1. Best estimates of herring year class strengths for herring stocks in NAFO SA 4, 5 and 6.

| Year Class | S.W. Nova Scotia Age 1 abundance[1] (x $10^{-6}$) | Georges Bank Age 2 abundance[4] (x $10^{-6}$) | Gulf of Maine Age 3 abundance[5] (x $10^{-6}$) |
|---|---|---|---|
| 1964 | 3647 | 1585 | - |
| 1965 | 2858 | 1754 | - |
| 1966 | 6567 | 1909 | 269 |
| 1967 | 1441 | - | - |
| 1968 | 1943 | 855 | - |
| 1969 | 2282 | 759 | 73 |
| 1970 | 6697 | 3844 | 535 |
| 1971 | 1151 | 757 | 78 |
| 1972 | 2096 | 745 | 78 |
| 1973 | 1731 | 955 | 134 |
| 1974 | 273 | 1908 | 269 |
| 1975 | 671 | - | 73 |
| 1976 | (5870)[2] | | |
| 1977 | (2750)[2] | | |
| 1978 | (114)[3] | | |

1 Sinclair and Iles 1980. CAFSAC Res. Doc 80/47.

2 Estimated from pre-recruit indices.

3 Estimated using cohort analysis involving a questionable partial recruitment vector.

4 Anthony and Waring 1980. Aberdeen Symposium (in press).

5 Anthony 1977. NFC Lab. Ref. 77-16.

Table 2. Correlations (r) between weir catch rates and 4WX year-class strengths.

| | Year-classes 1964 to 1975. | Year-classes 1966 to 1975. |
|---|---|---|
| New Brunswick Weirs | | |
| Age 1 | 0.65 | 0.77 |
| Age 2 | 0.75 | 0.87 |
| Age 3 | 0.72 | 0.73 |
| Ages 1, 2 | 0.76 | 0.89 |
| Ages 1, 2, 3 | 0.79 | 0.90 |
| Nova Scotia Weirs | | |
| Age 2 | 0.46 | 0.56 |
| Age 3 | 0.86 | 0.88 |
| Ages 2, 3 | 0.68 | 0.75 |

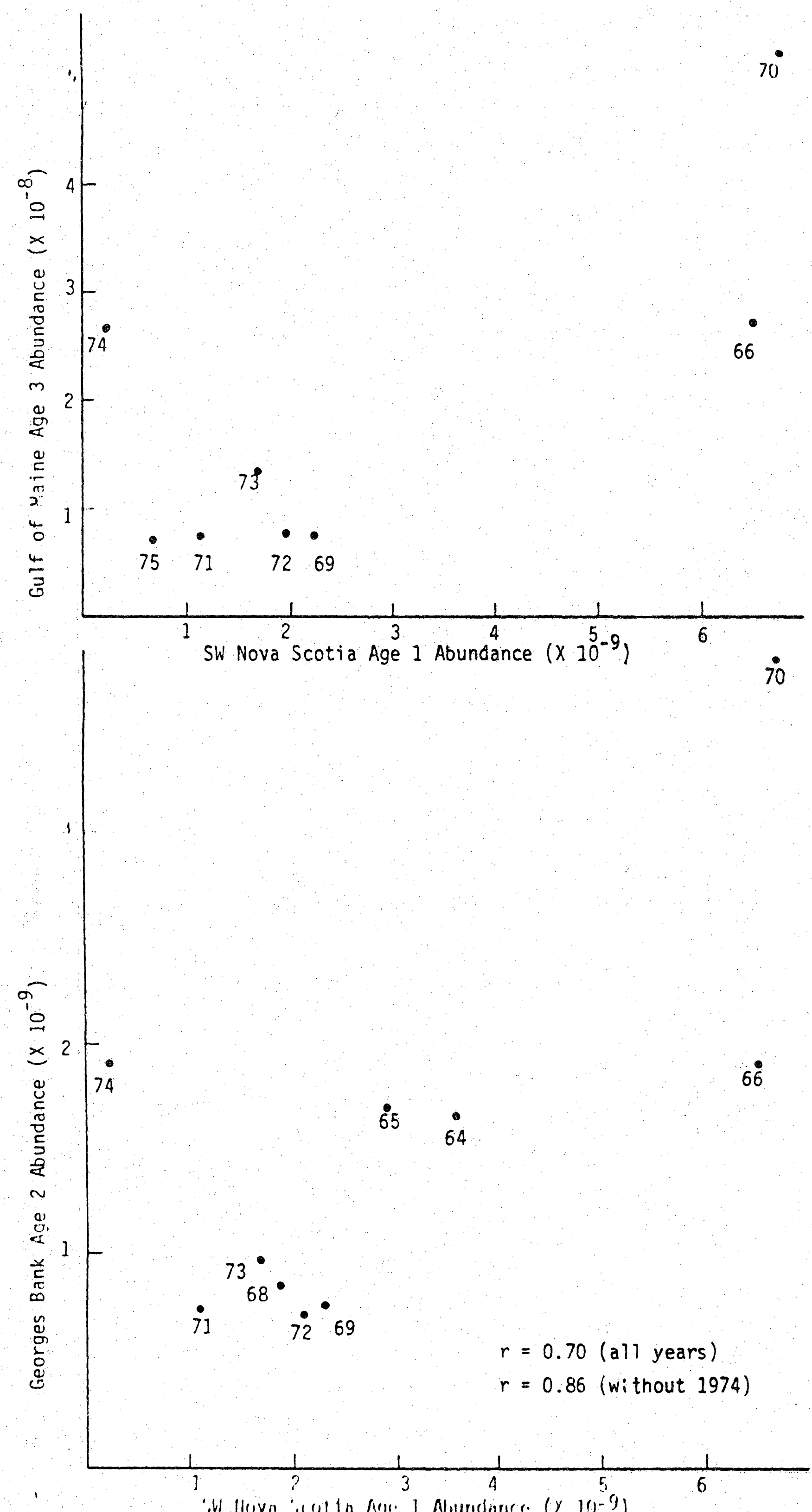


Figure 1. The relationships between year-class strengths for the three major herring stocks in NAFO SA 4, 5, 6.

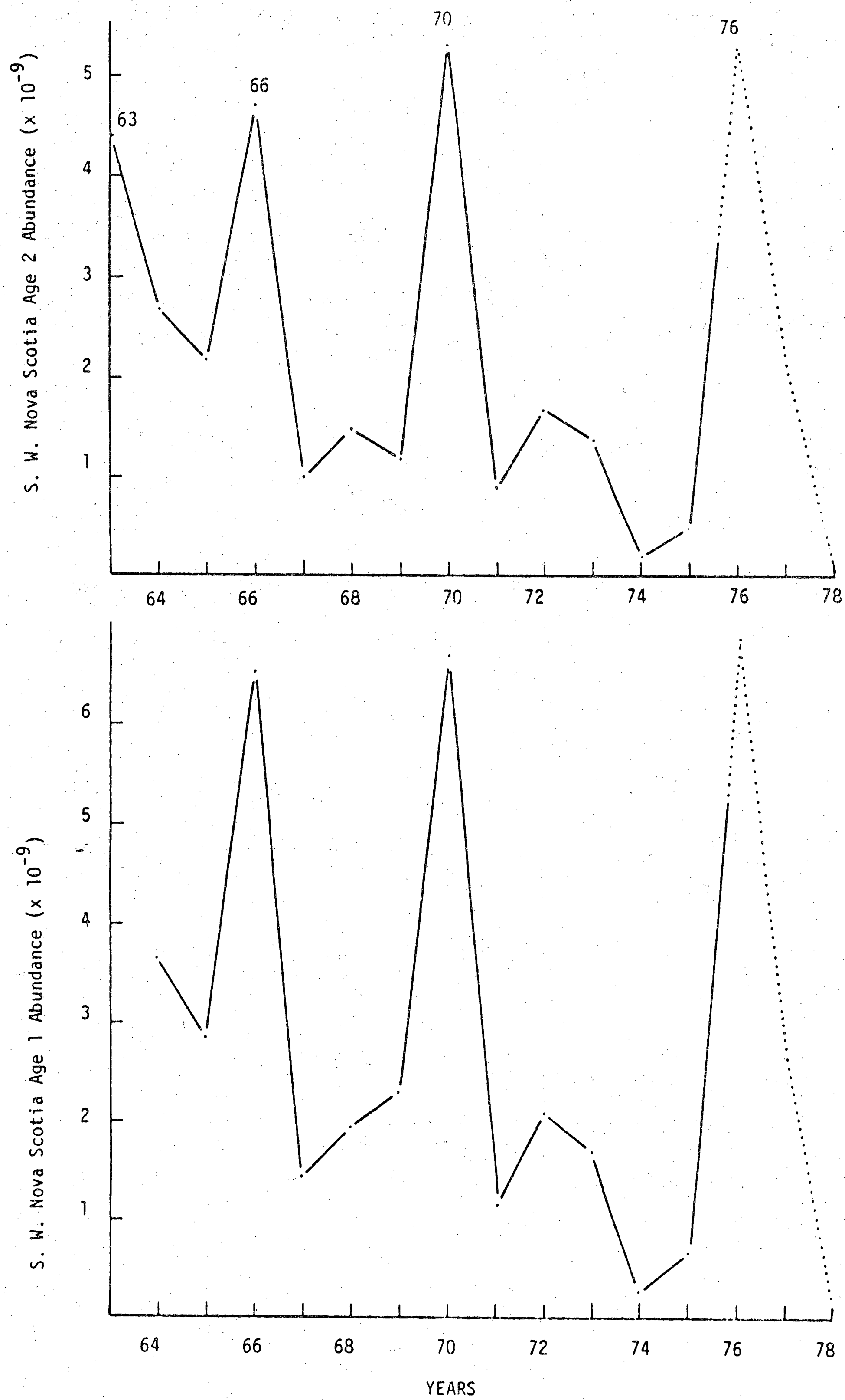


Figure 2. 4WX herring year-class strenth estimates (1963 to 1978).

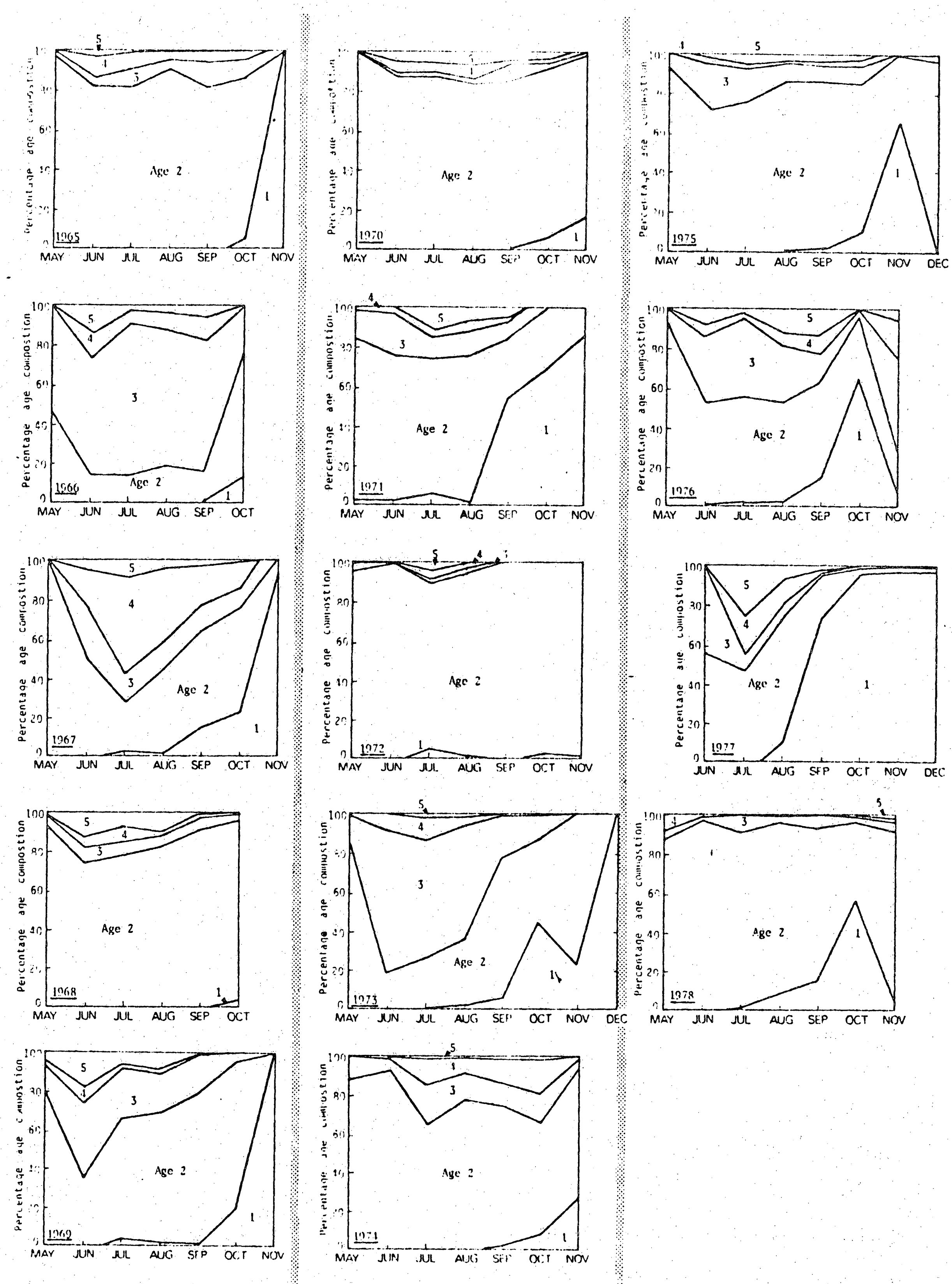


Figure 3. Monthly age composition of the 4Xb weir catches from 1965-78.

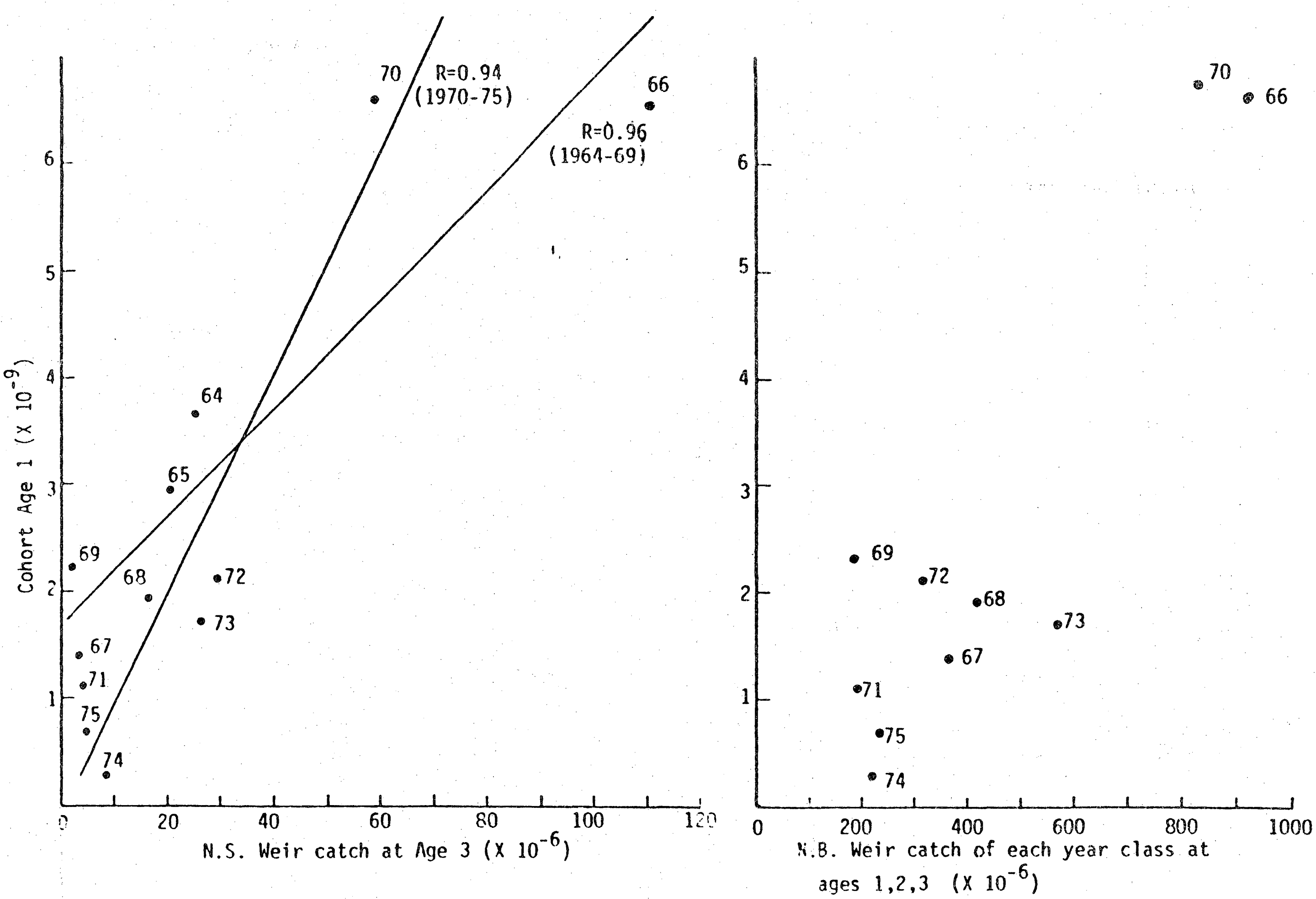


Figure 4. The relationship between two of the juvenile fishery catch rate indices and 4WX herring year-class strengths.

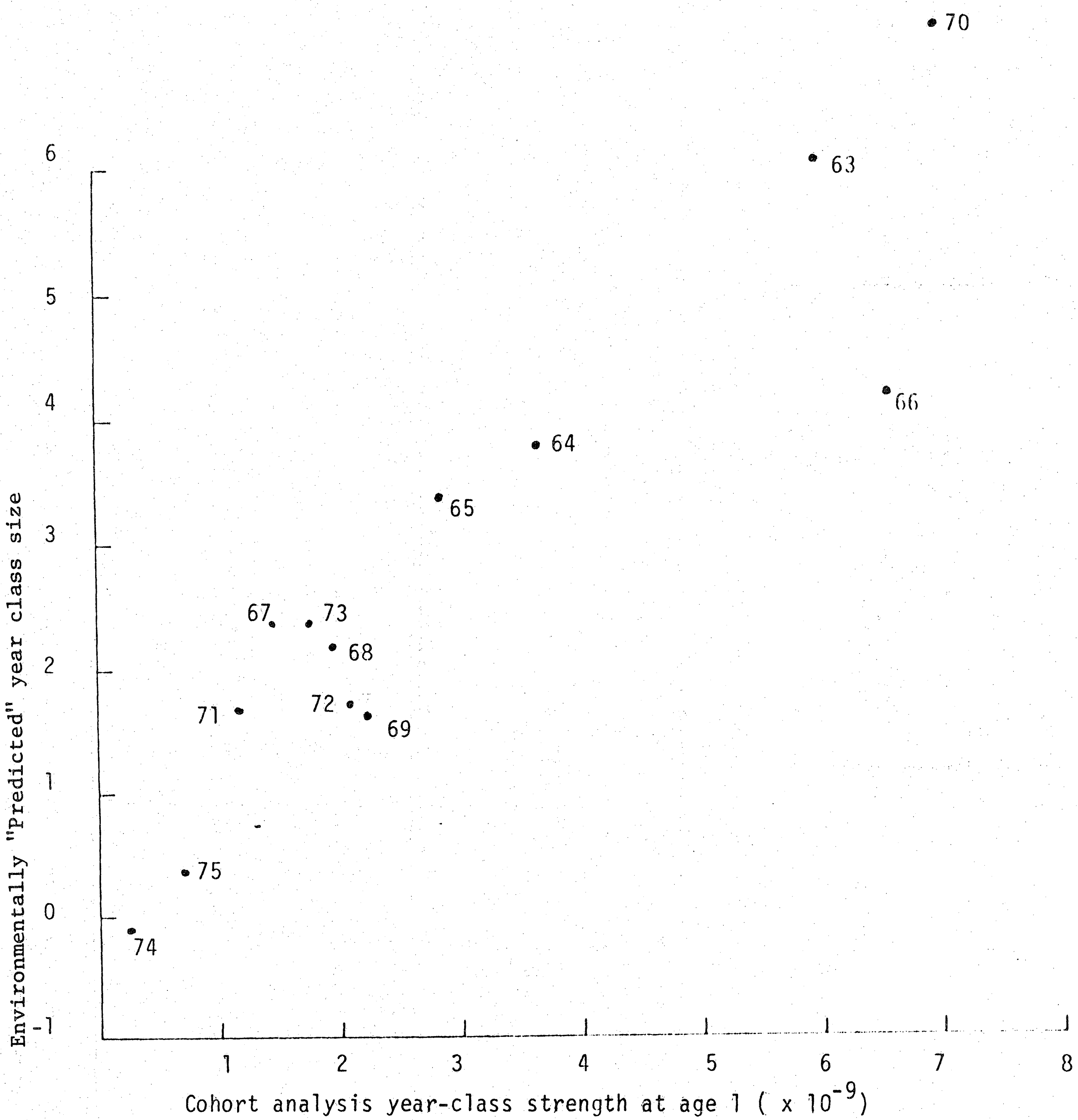


Figure 5, Relationship between environmentally predicted year class strengths at age and cohort analysis estimates.

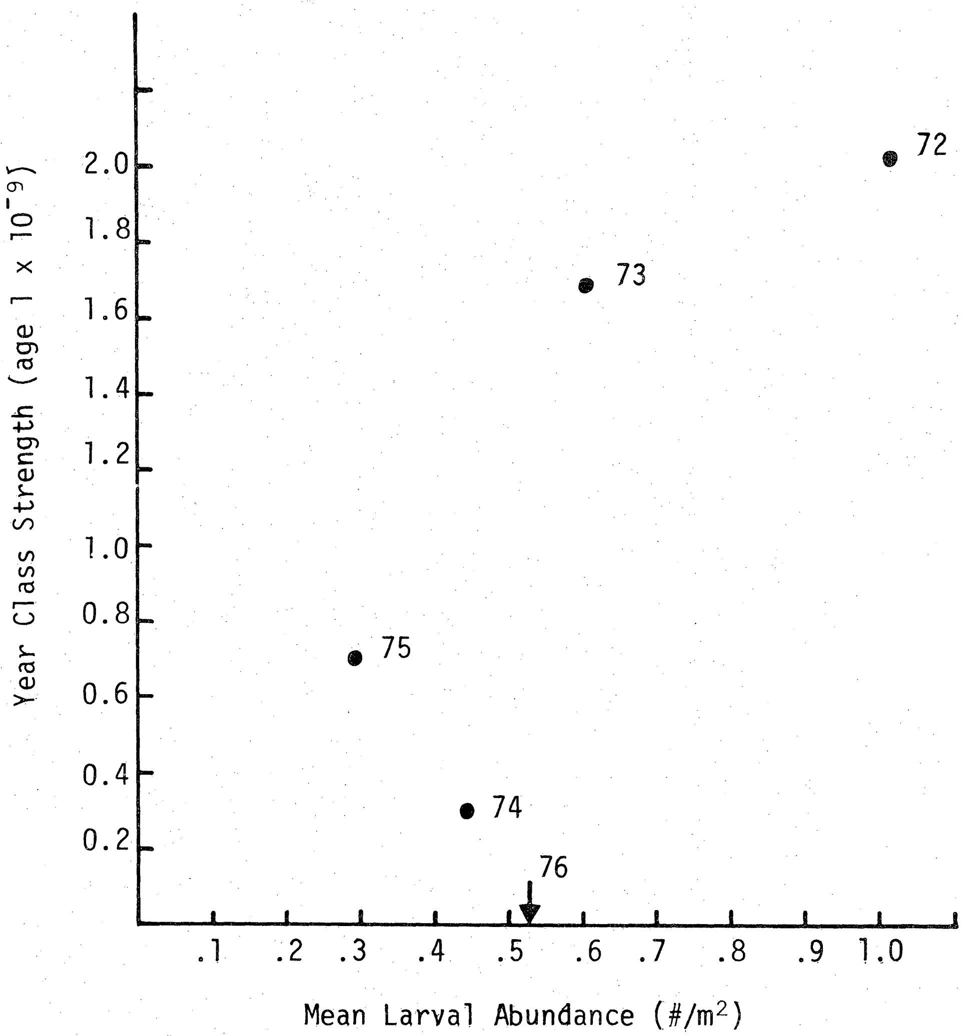


Figure 6. Relationship between the Bay of Fundy spring survey mean larval abundance estimates and 4WX herring year-class strengths.