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Relationship between environmental factors and mackerel recruitment

by

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Abstract

Surface water temperature and offshore wind stress in SA 6 were compared with mackerel year-class strength. Mean temperature for April-June was negatively correlated with recruitment. No consistent relationship over time could be demonstrated between offshore wind stress and recruitment. Wind stress was very high in 1961 and 1963 when poor year-classes were produced. The very high wind stress in 1975 suggests a poor 1975 year-class.

Introduction

The broad spectrum of biotic and abiotic factors present and interacting in the marine environment is undoubtedly the major source of influence on the strength of a year-class of mackerel. Lett et al. (1976) indicated, in a simulation of the Gulf of St. Lawrence herring, that recruitment is independent of spawning stock size over a fairly wide range, and that a stock-recruitment relationship emerges only when the stock is collapsing due to overfishing. For mackerel, as for many species, the absolute number of eggs spawned probably bears little, if any, relationship to the ultimate size of the year-class, unless the spawning stock is at an extremely low level of abundance. Hatching success of the eggs and the survival rate of the larvae during the first several months, both dependent on the environment, will determine the fate of the year-class.

It is probable that few, if any, environmental parameters can independently or singularly influence the size of a year-class, but rather it is the influence and interaction of many factors which determines this. Unfortunately, it is difficult to quantify the interactive effect of these factors. However, it is possible to examine selected and easily-measured parameters in an attempt to find clues concerning the extent of their influence.

In this paper, surface water temperature and offshore wind stress are compared with mackerel recruitment levels to determine if any apparent relationships exist. These factors are important because temperature influences the time of spawning, egg incubation time, rate of larval development, rate of plankton production, and so on, and offshore wind stress relates to the degree of offshore drift of eggs and larvae into unfavorable areas.

Methods

Mackerel recruitment, in terms of numbers of fish at age 1 as calculated by cohort analysis for the SA 3-6 stock (Anderson et al. 1976), was obtained for the 1961-74 year-classes.

Monthly average surface water temperatures (°C) for April, May, and June were determined for 1961-72 from daily measurements taken at the U.S. Coast Guard Five Fathom Bank Lightship located off the mouth of Delaware Bay (Chase 1964, 1965, 1966, 1967, 1969a, 1969b, 1971a, 1971b, 1971c, 1972; Kangas 1973, 1974). These measurements were discontinued after 1972.

Offshore wind stress values for the same general area were calculated for April, May, and June of 1961-76 from northward and eastward stress components (x 10^{-3} dynes per cm^2) prepared by the National Marine Fisheries Service, Pacific Environmental Group, Monterey, California. The two components were added vectorally and then resolved by axial rotation into alongshore and offshore components.

Means of the three monthly temperature and offshore wind stress values were assumed to represent average conditions for those environmental factors during the time of mackerel spawning and egg and larval development.

Results and Discussion

Offshore wind stress indices, mean surface temperatures, and year-class sizes are presented in Table 1. The relationship between April-June mean temperature and year-class size is plotted in Figures 1-2. Mean temperature decreased steadily from 14.0°C in 1962 to a low of 10.5°C in 1967 and then fluctuated sharply although trending upwards in the following years. A significant ($p = 0.01$) negative correlation was found between temperature and year-class size (Figure 2). The very strong 1967 year-class was produced when temperature was at its lowest point in the series, and the poor 1962 year-class occurred when temperature was at the highest point. It is not known whether the temperature range indicated here is sufficient to have an influence on the strengths of the various year-classes. These results, however, suggest a relationship between temperature and recruitment which is directly opposite to the findings of others (Sette 1950; Taylor et al. 1957; Lett et al. 1975; Winters 1976). The conclusions of Lett et al. (1975) and Winters (1976) relate to the Gulf of St. Lawrence, and it is possible that temperature has a greater positive influence on recruitment there than it does in the SA 6 spawning area. Other factors may be more critical in the southern area.

The relationship between offshore wind stress and recruitment is illustrated in Figure 3. Although there appears to be no consistent meaningful relationship over the entire time-series, there are several points of interest. The offshore wind stress indices were very large in 1961 and 1963, and the year-classes produced in those years were very poor. The inverse situation was not consistently evident. The lowest wind stress index (1964) was also accompanied by a poor year-class. In 1967, when a very strong year-class was produced, wind stress was of average size. The 1966, 1968, and 1969 year-classes were all about equal in size and were strong in comparison to all others except the 1967 year-class (which was 2.5 times stronger), and they were all produced under conditions of low offshore wind stress.

The very high offshore wind stress index in 1975 is of particular interest. Based on the other two years (1961 and 1963) which had high offshore wind stress and which produced poor year-classes, conditions in 1975 would also suggest a poor year-class. Anderson et al. (1976) have estimated the 1975 year-class to be the poorest since those in the early 1960's. Sette (1943) attributed the failure of the 1932 mackerel year-class to adverse winds which drifted the larvae away from their usual nursery grounds. A high offshore wind stress index in a given year would presumably indicate the potential for this type of adverse drift.

In conclusion, the results of this paper suggest some potential interaction of temperature and offshore wind stress with mackerel recruitment. It is apparent, though, that other environmental parameters also exercise some influence since the strengths of the 1961-74 year-classes are not consistently explained from the information presented. Of importance relative to the assessment of the mackerel stock is the indication, based on offshore wind stress, that the 1975 year-class may be poor.

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Table 1. Offshore wind stress indices ($x10^{-3}$ dynes/cm^2) and mean surface temperatures (°C) for April-June in the Mid-Atlantic area (SA 5-6) compared with mackerel recruitment (age 1) determined from cohort analysis.

Year	Offshore wind stress				Surface temperature °C				Year-class size-age I (10^6 fish)
	April	May	June	Mean	April	May	June	Mean	
1961	334.577	93.980	102.545	183.70	7.4	11.8	16.3	11.8	776.8
1962	187.496	0.454	1.362	69.77	7.7	15.6	18.7	14.0	364.7
1963	460.580	23.955	71.579	192.03	7.2	12.2	18.2	12.5	366.3
1964	-44.259	21.974	57.126	18.28	7.5	12.3	17.9	12.6	441.3
1965	34.147	61.275	47.291	54.24	5.9	11.5	16.8	11.4	1020.5
1966	-4.977	1.765	68.107	28.30	6.7	10.7	16.5	11.3	2715.5
1967	207.164	32.382	-19.034	80.17	5.3	9.8	16.4	10.5	7007.4
1968	24.358	9.296	66.150	59.99	7.8	12.3	17.4	12.5	2692.2
1969	47.293	45.164	-0.022	37.48	6.1	11.0	15.3	10.8	2789.6
1970	15.652	34.261	29.619	33.18	6.3	12.7	18.0	12.3	1425.8
1971	248.694	52.807	4.472	108.66	7.5	12.7	17.1	12.4	1440.3
1972	76.512	-34.062	55.992	39.48	6.8	11.3	16.3	11.5	918.5
1973	166.464	47.417	34.302	89.39	-	-	-	-	1131.0
1974	326.526	25.300	-4.909	122.31	-	-	-	-	1909.1
1975	480.874	-9.954	2.622	164.51	-	-	-	-	-
1976	251.175	79.998	21.294	124.16	-	-	-	-	-

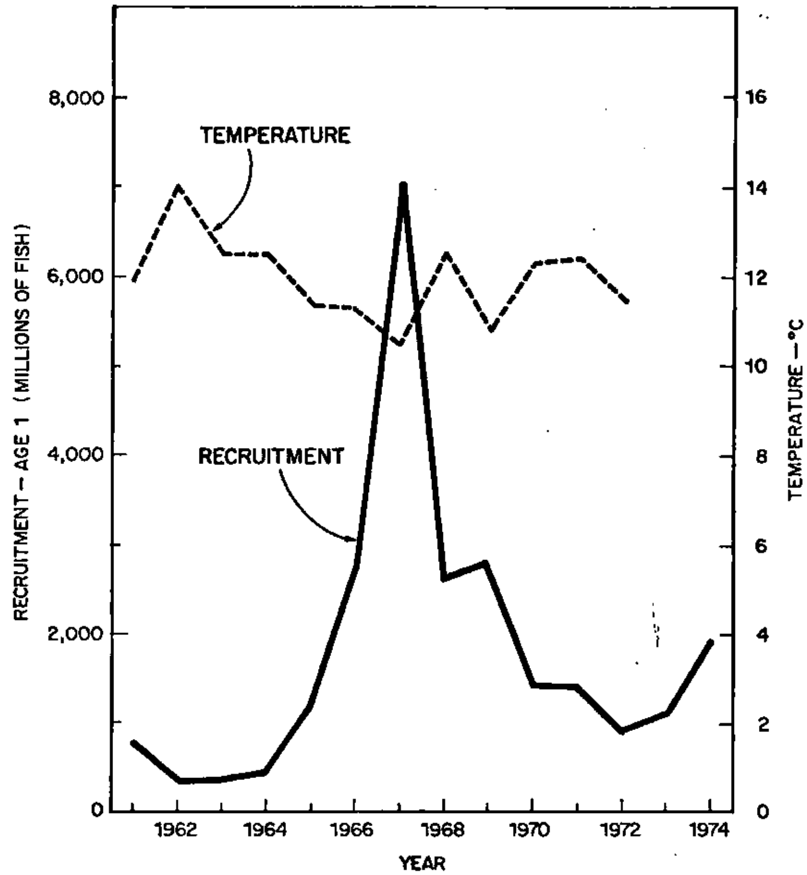

Fig. 1. Mackerel recruitment levels in SA 3-6 and April-June mean surface water temperature off Delaware Bay (SA 6).

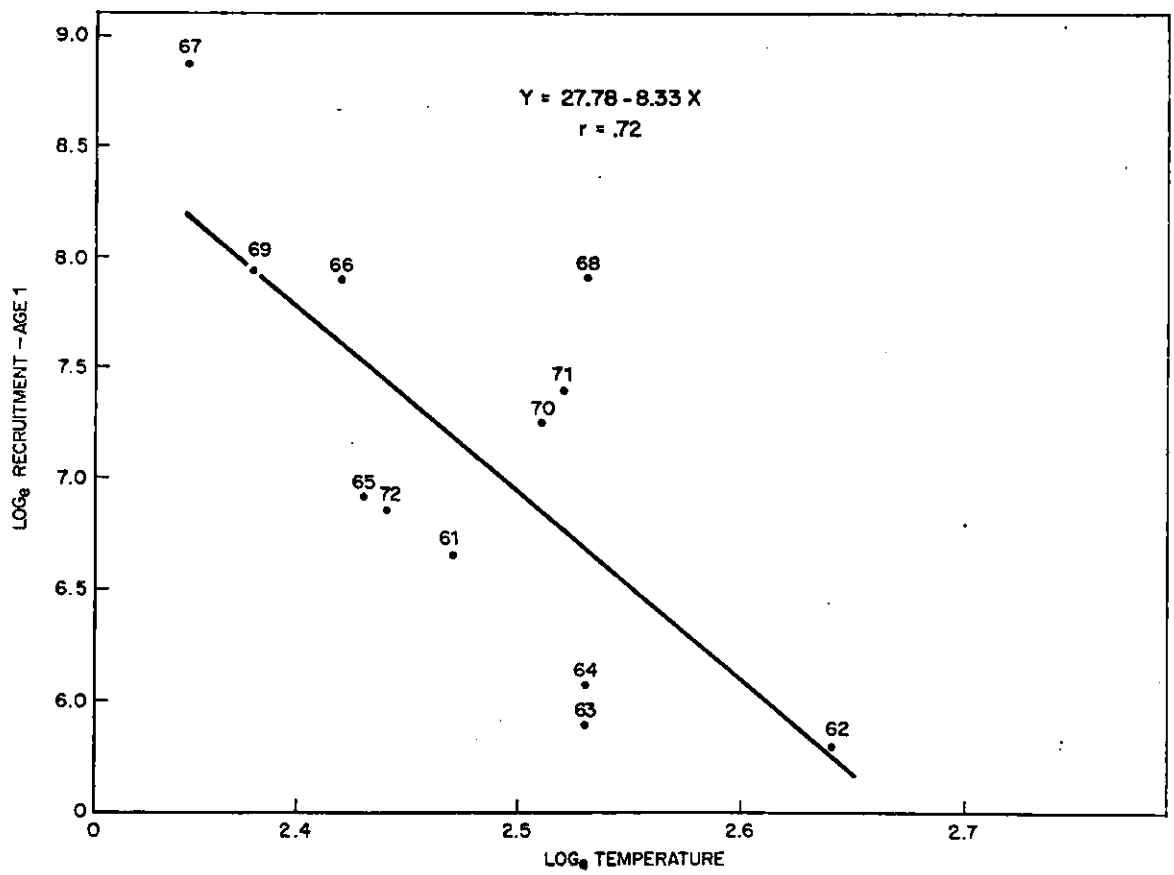

Fig. 2. A log-log regression of mackerel recruitment (SA 3-6) on April-June mean surface water temperature off Delaware Bay (SA 6) for the 1961-72 year-classes.

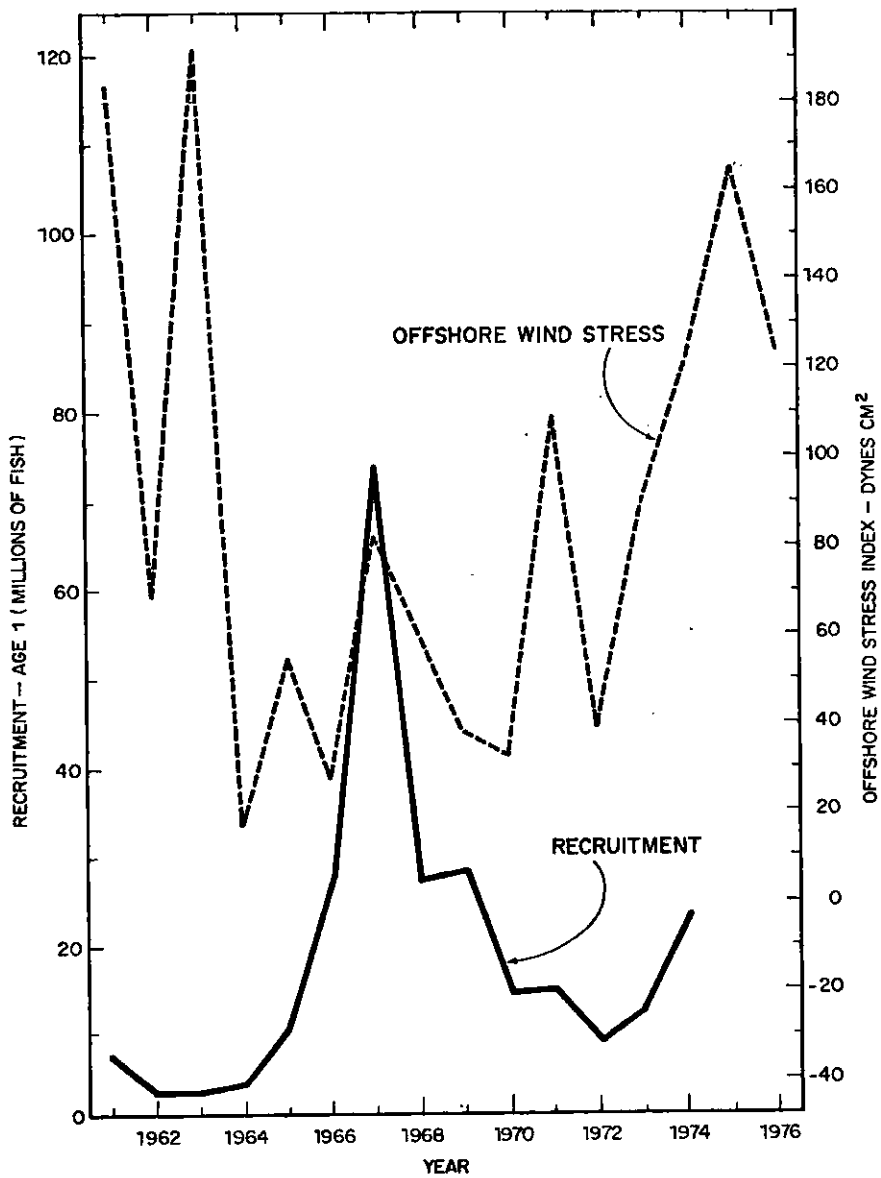

Fig. 3. Mackerel recruitment levels in SA 3-6 and April-June mean offshore wind stress indices for SA 6.