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A CORRELATION BETWEEN ANNUAL CATCHES OF DUNGENESS CRAB, *CANCER MAGISTER*, ALONG THE WEST COAST OF NORTH AMERICA AND MEAN ANNUAL SUNSPOT NUMBER

A recent paper by Driver (1978) described the prediction of shrimp landings off northwest England based on sunspot activity. Stimulated by this work, we examined the relationship between the Dungeness crab, *Cancer magister*, commercial fishery off the west coast of North America and mean annual sunspot number. The Dungeness crab is commercially important and its fluctuating catch has made it the subject of numerous papers (Reed 1969; Peterson 1973; Botsford and Wickham 1975, 1978), some of which noted a distinct rhythm in annual catch. Moreover, Dungeness crab catch statistics are particularly favorable for this study, as it has been estimated that almost every legal crab within the species' range is taken during the commercial season (Pacific Marine Fisheries Commission 1965) and hence there was no need to factor fishing effort into the computations.

Catch statistics were provided by the Pacific Marine Fisheries Commission and comprise commercial landings made in Alaska, British Columbia, Washington, Oregon, and California from 1955 (the earliest year for which complete records were available) to 1980. We utilized the mean annual sunspot values in Waldmeier (1961, 1978) with additional data supplied by Adkins[1] and Eddy.[2] Data were plotted (Figure 1) and correlation coefficients and associated values generated by linear regression (Table 1) for two complete cycles, 1955-64 and 1965-75.

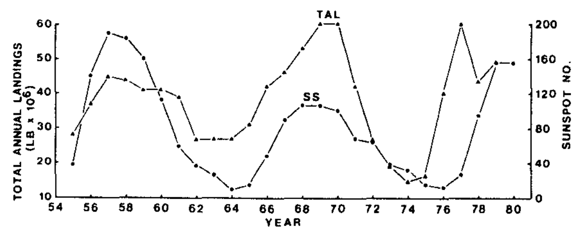

FIGURE 1.—Total annual landings of Dungeness crabs off the west coast of North America (TAL) and mean annual sunspot number (SS) for the period 1955 through 1980.

TABLE 1.—The correlation between commercial Dungeness crab catch and mean annual sunspot number off the west coast of North America.

Period	*r*	df	*f*-ratio	*P*
1955-64	0.90	1, 8	35.3	<0.001
1965-75	.87	1, 9	29.3	<.001

Dungeness crab catches and sunspot numbers both varied in approximately 11-yr cycles and the cycle periods for the two were strongly correlated

[1]J. Adkins, Solar Observer, Mt. Wilson and Las Canpanis Observatory, 813 Santa Barbara Street, Pasadena, Calif., pers. commun. August 1980.

[2]J. Eddy, High Altitude Observatory, National Center for Atmospheric Research, Boulder, CO 80307, pers. commun. March 1981.

(1955-64, $r = 0.90$; 1965-75, $r = 0.87$) as the peak catches of 1957, 1969, and 1970 closely corresponded to sunspot maxima years 1957, 1968, and 1969. However, the amplitude of the two phenomena appeared to be asynchronous. The very high sunspot peak of 1957 saw a considerably lower peak crab catch than did the relatively low sunspot peak of 1969.

Woelke[3] suggested that Dungeness crab landings were influenced by water temperature during the crabs' larval stage about 4 yr before, with temperatures at that time being inversely correlated to landings. We analyzed the relationships between crab catches and the sunspot numbers of 4 and 5 yr previous. Correlation coefficients were generated for two crab catch cycles (cycle 1 = 1955-64; cycle 2 = 1965-74). The highest correlation (cycle 1, $r = 0.82$; cycle 2, $r = 0.95$) was between Dungeness crab catches and the sunspot number of 5 yr before (Figure 2, Table 2). The correlation was strongly negative. That is, high sunspot number in a particular year seemed to be a predictor of relatively low crab catches 5 yr hence.

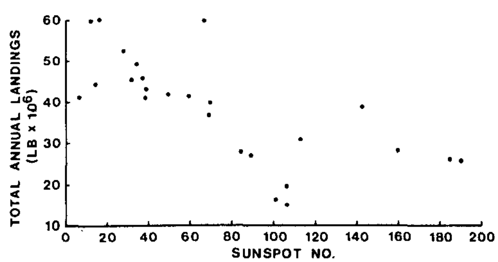

FIGURE 2.—Mean annual sunspot numbers (SS) of the years 1950-69 plotted against total annual landings of Dungeness crabs (TAL) 5 yr later (1955-74).

TABLE 2.—The correlation between commercial Dungeness crab catches and the mean annual sunspot number 5 yr previous (cycle 1 = sunspots of 1950-59, crab landings 1955-64; cycle 2 = sunspots of 1960-69, crab landings 1965-74).

Period	r	df	f-ratio	P
Cycle 1	0.82	1, 8	16.7	<0.01
Cycle 2	.95	1, 9	87.6	<.001
Cycles 1 and 2	.69	1, 23	20.8	<.01

A number of factors may be involved in the cyclical *C. magister* catches. Upwelling, by influencing food density, may have an effect (Peterson 1973). Water temperature and salinity, as well as current pattern may influence larval survival (Lough 1976). Botsford and Wickham (1975) felt that density-dependent biotic factors, such as cannibalism, might play a part.

However, as Eddy (1979) stated, in discussing sunspot studies, "We start into the deep waters of uncertainty not from rocks but from the sand, and with statistics our only lifeline." Sunspots, relatively dark areas about 2000°K cooler than their surroundings, have been noted for more than 1,500 yr (Herman and Goldberg 1978). In the past 200 yr, sunspot activity has been correlated to many planetary processes. Statistical correlations have been made between sunspots and both climatological and biological phenomena (Gnevyshev and Ol' 1977; Pittock 1978). However, increased sunspot activity brings about only slight changes in both magnetic fields and incident radiation levels and, unfortunately, there exists no completely acceptable hypothesis which explains how these slight alterations act on the various processes.

Thus, whether sunspot activity somehow influences any of the above (including crab catches) is unknown. The work of Southward et al. (1975) suggests that an array of events, including intertidal barnacle, *Chthalamus* sp., numbers, hake and cod trawl catches and pilchard egg densities are correlated, in 11-yr cycles, to sunspot number. There is the strong suggestion in this work that sea surface temperature (also strongly correlated to sunspot activity) may be responsible for the cyclical events. Hence, sunspot activity may be linked to biotic events through the agencies of another level of phenomena (in this case temperature).

Whether the crab catch and sunspot cycles remain congruent will have to be seen. Other correlations of this nature have proven spurious with time. If the pattern holds, however, annual sunspot number may be a useful predictor of Dungeness crab catch, delineating periods of catch maxima and minima and perhaps predicting catch amplitude, i.e., how many crabs will be taken.

Acknowledgments

We would like to thank J. Eddy and P. Gilman for enlightening discussions on solar activity, S. Penn and K. Zerba for the illustrations, and S. Warschaw and J. Schulz for typing the manuscript.

[3]Woelke, C. E. 1971. Some relationships between temperature and Pacific Northwest shellfish. Proc. 51st Annu. Conf., Western Assoc. Game Fish Comm., p. 132-135.

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FECUNDITY OF THE AMERICAN LOBSTER, *HOMARUS AMERICANUS*, IN NEWFOUNDLAND WATERS

In lobster (genus *Homarus*) fisheries generally, current minimum legal size limits are below the size at 50% female maturity and fishing mortality rates are very high (Anonymous 1979). Under such conditions, widespread recruitment overfishing appears to be a distinct possibility. Conventional yield per recruit assessment models are not totally adequate when dealing with lobsters and this has led to the development of models which are much more species oriented (Caddy 1977, 1979; Ennis and Akenhead 1978). A feature of these models which resulted from concern with recruitment overfishing is provision for assessing the effect on population fecundity of changes in size limit and fishing mortality. In addition to size-maturity information, such assessments require data on fecundity.

Unfortunately, the general applicability of size-fecundity relationships for the American lobster, *Homarus americanus*, which are available from the literature, is suspect. Saila et al. (1969) concluded that the methodology used by Herrick (1911) resulted in quite substantial overestimates of egg numbers. The size-fecundity relationship Saila et al. (1969) presented was based on samples obtained from three widely separated areas; however, Squires (1970) and Squires et al. (1974) suggested that size-fecundity relationships for American lobsters in different areas could be quite different. Squires' (1970) methodology was similar to that of Herrick but he found that his estimates varied from actual counts by <2%, an error factor comparable with that reported by Saila et al. (1969) and Perkins (1971) using electronic counters. Aiken and Waddy (1980) suggested that standardized egg counts from different areas would clarify the question of geographic variation in American lobster fecundity and concluded that Herrick's estimates should not be dismissed until the results of these or other, more explicit studies are available.

This paper presents new fecundity data for a Newfoundland area as a contribution to the literature on the subject and provides comparisons with published size-fecundity relationships.

Materials and Methods

Ovigerous females were included in samples ob-