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COMPARISON OF PACIFIC SARDINE AND ATLANTIC MENHADEN FISHERIES

By

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INTRODUCTION

The rise and fall of the North American Pacific coast sardine fishery is well known. Once the most important fishery in the western hemisphere in weight of fish landed, it now produces virtually nothing. The meal and oil industry based on the Pacific sardine (*Sardinops caerulea*) resource no longer exists. The sardine fishery (Fig. 1A) began in 1915, rose fairly steadily to its peak in 1936 (with a dip during the depression), maintained an average annual catch of more than 500 000 tons until 1944, then fell off sharply. Annual production has not exceeded 100 000 tons since 1951, and commercial sardine fishing now is prohibited in California waters. A much smaller fishery for the southern sub-population developed off Baja California in 1951.

The decline of the west coast sardine fishery gave impetus to the much older menhaden (*Brevoortia tyrannus*) fishery (Fig. 1B) along the Atlantic coast of the United States. Fishing for Atlantic menhaden began early in the nineteenth century. From the 1880's until the middle 1930's the annual catch varied around about 200 000 tons. In the late 1930's annual landings began to increase and from 1953 to 1962 inclusive remained above 500 000 tons. The peak year was 1956, with a catch of nearly 800 000 tons. After 1962 the catch began to fall off sharply, reaching a low of less than 250 000 tons in 1967.

The remarkable similarity in history of landings of the two species is illustrated in Fig. 1. If the sardine curve is shifted in time about twenty years the coincidence is startling (Fig. 1C). The following questions arise:

1. Is the Atlantic menhaden fishery doomed to extinction?

Contribution given in honour of Gunnar Rollefsen at his 70th birthday.

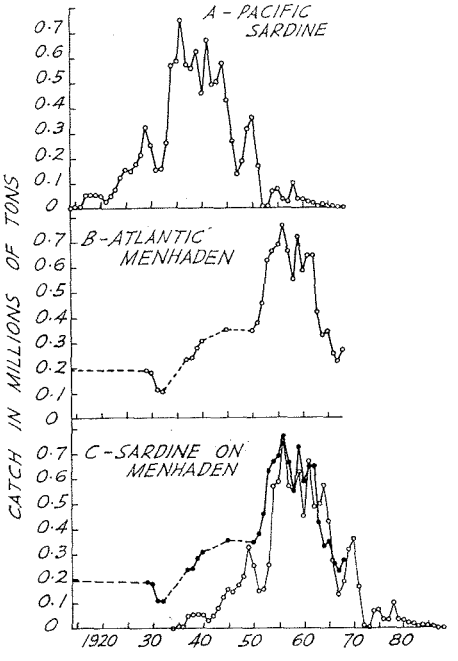

Fig. 1. Historical record of Pacific sardine landings (A), Atlantic menhaden landings (B), and sardine landings shifted twenty years and superimposed on menhaden landings (C). Data from AHLSTROM (1960), HENRY (1968), and Statistical Digests of the Bureau of Commercial Fisheries.

2. Is there anything in the history of the Pacific sardine fishery or in knowledge of the biology of the species that would lead to inferences about the future of the menhaden resource and its fishery?

3. Does the history of the sardine fishery offer any lessons that might help the menhaden industry or other fishing industries anywhere in the world to avoid the fate of the sardine industry?

In this paper these questions are examined only briefly.

COMPARISON OF LIFE HISTORIES

Both species have relatively wide ranges of distribution along coasts that trend generally north and south (Fig. 2). The Pacific sardine once ranged from south-eastern Alaska to the Gulf of California (55° to 23° N. Lat.). The Atlantic menhaden has been taken from Nova Scotia to southern Florida (46° to 23° N. Lat.). It does not pass around the southern tip of Florida into the Gulf of Mexico, but another species, *Brevoortia patronus*, supports the important menhaden fishery in the Gulf.

Within these geographic ranges, samples of the commercial catch of Pacific sardine and Atlantic menhaden usually contain larger and older fish with increasing latitude. Not only do the older fish go farther north, but also apparently the larger fish of each age, for the apparent growth

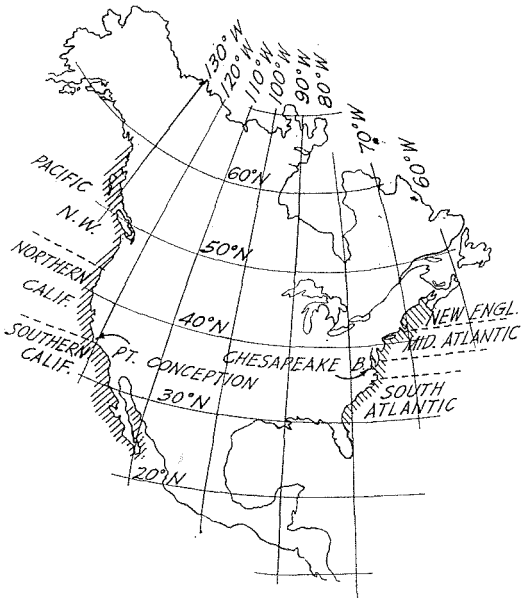

Fig. 2. Geographic distributions of Pacific sardine and Atlantic menhaden along North American coasts.

rate increases from south to north (Fig. 3). Both species are found in northern oceanic waters usually only in summer. Usually, adults are found farther north than young, and young farther north than the pelagic eggs. Adult Pacific sardines and juvenile Atlantic menhaden sometimes spend the winter in northern inlets or tributaries. From these observations it has been inferred that most spawning occurs towards the southern part of the range of each species and that most of the mature fish make an annual northward migration in spring and summer, returning south in late fall and winter, and moving farther northward with increasing size and age. These inferences have been confirmed by tagging. In

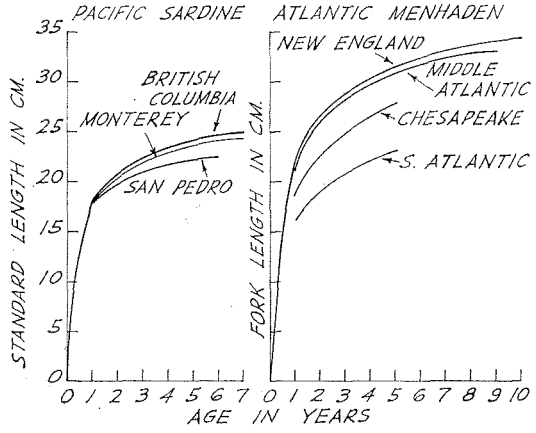

Fig. 3. Apparent growth rates of Pacific sardines and Atlantic menhaden from commercial catches at different latitudes.

common with many clupeioid fishes there is also a tendency for older and larger fish to be farther offshore. Both species are divided into subpopulations, which do not intermingle completely, although their geographic ranges overlap considerably.

Plankton studies have confirmed the inferences about major spawning areas, but Pacific sardine spawning progresses in a wave from south to north, winter to summer, whereas Atlantic menhaden spawning apparently progresses from north to south, summer to winter. The location and intensity of spawning of both species may vary widely from year to year, and survival to the stage of recruitment into the commercial fishery varies widely.

Scientific studies of the Pacific sardine and its fishery have been under way since the early days of the fishery, and the biology and ecology of the species and the response of the stocks to fishing are reasonably well understood. Substantial continuing studies of the Atlantic menhaden and its fishery began little more than a decade ago, and scientific investigations are still not adequate to obtain all the information necessary to understand the population dynamics and ecology of the species and to stabilize the economics of the fishery. For both species funding of scientific investigations was difficult to obtain until substantial declines in the resource and the catch created responsive political climates.

COMPARISON OF THE FISHERIES

Although the Pacific sardine fishery began off California, toward the southern part of the geographic range, and the Atlantic menhaden fishery began to the northward, off New England, the reaction of the two resources to fishing has been similar. As could have been predicted from knowledge of the biology of the species and of the known effects of a developing fishery on fish stocks, fishing reduced the life expectancy. Thus the northern fisheries were affected first (Fig. 4). The peak of the sardine fishery in the Pacific North-west covered the period from 1929 to 1943, and the fishery collapsed before 1950. In northern California the peak was from 1934 to 1944 and the collapse in the early 1950's. In southern California landings were substantial from 1934 to 1950, with a peak in 1950, and fishing continued at a lower level of catch into the early 1960's, after the industry in the north had suspended operations.

The history of menhaden landings has been similar (Fig. 4). In New England the catch reached a peak in 1899, then fell off virtually to nothing in the 1930's and 1940's. There was a resurgence in the 1950's, which lasted until about 1960. The peak of the fishery in the middle Atlantic region covered the period 1953 to 1963, and by 1965 that segment

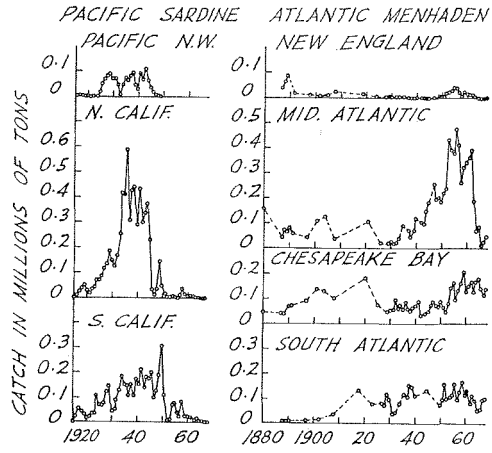

Fig. 4. Historical catch records of Pacific sardine and Atlantic menhaden at different latitudes.

of the industry was virtually dormant. In Chesapeake Bay a high level of catch has been maintained since 1954, with some decline in the last two years. The catch in the Chesapeake has been maintained only at the expense of a substantial increase in fishing effort. In the area south of Chesapeake Bay the catch has fluctuated about the same level since 1936.

The decline and collapse of both fisheries from north to south is demonstrated better by considering the trends in percentage of the total catches taken in the northern parts of the species range. For the Pacific sardine the northern area includes waters north of Point Conception, for the Atlantic menhaden it is the area north of Chesapeake Bay. From the peak of the fishery in the decade beginning about 1934 the percentage of the sardine catch taken to the north fell from about 80 per cent in the late 1930's to zero in the late 1960's (Fig. 5). From the peak of the Atlantic menhaden fishery in the middle 1950's the percentage of the total catch taken north of the Chesapeake fell from over 70 per cent in 1953 to less than 20 per cent after 1965 (Fig. 5). For both fisheries, once the peak was reached the percentage of the catch taken in northern waters was a direct

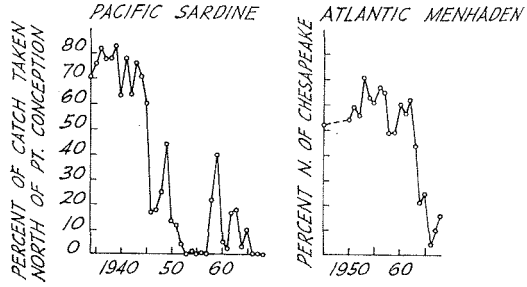

Fig. 5. Trends in percentage of the total catches of Pacific sardine and Atlantic menhaden taken in northern waters as each fishery declined from its peak.

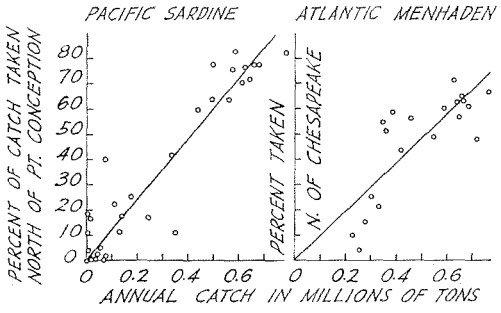

Fig. 6. Relation between total annual catches of Pacific sardine and Atlantic menhaden and percentage of the catch taken in northern waters.

function of abundance as reflected in the total catch (Fig. 6). Such declines do not necessarily connote overfishing, but they do throw the bulk of fishing effort on the younger fish to the south, and increase the risk of overfishing.

ROLES OF OTHER FACTORS DETERMINING ABUNDANCE

The evidence is strong that there has been no reduction in total biomass of pelagic fishes in the California Current System. The drop in sardine abundance has been offset by increases in other species, especially anchovy. McHugh and Ahlstrom (1951) suggested that fuller utilization of species such as anchovy, saury (*Cololabis saira*), and jack mackerel (*Trachurus symmetricus*) should be encouraged. The possibility exists that similar compensatory changes may be taking place in the environment of the Atlantic menhaden but the research program has not been broad enough to determine if this is so. Several species could be involved in such ecological adjustments, including sea herring (*Clupea harengus*), thread herring (*Opisthonema oglinum*), and jacks (*Caranx crysos, Trachurops crumenophthalma*), to name just a few. The catch of sea herring has increased steadily in the last few years, and the fishery (mostly by nations other than the United States) now extends south to Cape Hatteras (about 35° N. Lat.). Whether this southern herring fishery has been made possible by an increase in abundance favored by the menhaden decline is not known. The relationship between menhaden abundance and biomass of other species such as thread herring also is not known. It is important that such ecological interactions be understood.

LESSONS TO BE LEARNED FROM THE SARDINE FISHERY

Many people have contributed to scientific knowledge of the Pacific sardine resource and the effect of fishing on it. Particularly useful references are the work of Ahlstrom (1960, 1966), Clark and Marr (1955),

MARR (1960, 1963), MURPHY (1966) and RADOVICH (1962). Scientific studies have shown beyond reasonable doubt that the sardine stocks were reduced by a combination of intense fishing and poor spawning success, and that the Pacific northern anchovy (*Engraulis mordax*) invaded the environmental niche vacated by the sardine. It has been estimated that the sardine resource has dropped to 5 per cent or less of its former biomass, and that the standing crop of anchovy has increased at least twenty-fold over the same period.

A fishery based on a single species, highly variable in abundance, is not likely to be a stable fishery. If there is a profitable market for the product, capital investment in boats, fishing gear, and processing plants will grow. The exigencies of natural fluctuations in abundance, and the stimulating effect on survival to recruitment caused by reduction of the total stock, make it highly probable that as the fishery develops towards maturity, two or more strong year classes will follow each other in a relatively short span of time. Encouraged by this unusually high productivity the industry will continue to enlarge its capacity to catch and process the fish. Inevitably the time will come when biological productivity of the species drops from environmental causes. Since in a fully developed fishery the standing stock usually is about half the size of the unexploited population, other species may be given a competitive advantage which may inhibit production of strong year classes in the species being fished. Moreover, the time lag of a year or two in building vessels and plants usually may provide maximum catching and processing capability when the resource is already declining. In the absence of effective fishery regulation disaster is probably almost inevitable. Even with an effective regulatory mechanism, backed by adequate scientific knowledge, management is far from easy. There is no single optimum sustainable yield in a widely fluctuating resource. Only in certain salmon fisheries has a widely flexible scale of annual catch quotas been applied successfully.

When the sardine fishery was at its peak, there was no interest in alternative resources. Each species has different habits and reactions to fishing gear, and the industry had no time to waste in learning how to catch other species when sardines were present. As the resource declined many units in the fleet were preoccupied with searching for the absent schools of sardines, buoyed by the persistent optimism of fishmen that next year would be better. This optimism was strengthened by a brief resurgence of the resource in 1949 and 1950, and by a lesser increase in the middle and late 1950's. The concern of industry is illustrated by its action in imposing a voluntary tax on landings, the funds to be used in support of research. The industry was aware of the existence of a substantial anchovy resource, and in 1953 landed more than 40 000 tons.

But they were unable to develop a viable market for canned anchovies, and opposition to use of anchovies for oil and meal was already strong.

As the sardine stocks declined, the political climate for developing alternate resources for the fish meal and oil industry on the Pacific coast was becoming more difficult. The powerful sportfishermen's organizations in the State of California, convinced that disappearance of the sardine was reducing the availability of forage fishes, successfully sponsored restrictive legislation and regulations. This placed increasing restrictions on the commercial sardine fishery and also made it difficult to develop an anchovy fishery. Commercial fishing for sardines in California waters is now prohibited entirely. Attempts to develop a viable commercial anchovy fishery in the last few years led to a proposal by the scientists for an annual quota of 200 000 tons, with provision for carefully controlled scientific monitoring. This quota was selected because it was about the smallest catch that could be expected to produce a measurable effect on the resource, yet offer no threat of overfishing. A much lower quota of 75 000 tons finally was adopted, but this small quota has never been reached, partly because it has been divided into sub-quotas by areas, partly because the uncertainty of being permitted to continue a commercial anchovy fishery may have discouraged commercial fishermen from acquiring modern, efficient catching equipment, but probably mainly because such a small quota offers little promise of developing a profitable industry. If a fishery for anchovy and other suitable pelagic species had been allowed to develop while the sardine resource was still in good condition there might still be a prosperous fish meal and oil industry on the Pacific coast. It would be unfortunate for American fishermen if fishermen of other nations were to demonstrate successfully that these unutilized resources are abundant and can be taken economically in international waters.

As often happens in fishery investigations, scientific studies were not adequately supported until the sardine resource was already well on its way to obscurity. When the expanded investigations of the California Cooperative Oceanic Fisheries Investigations (CalCOFI) began in 1948 the catch was down to about 25 per cent of its former levels. CalCOFI has sponsored an impressive series of scientific studies, which have advanced fishery science considerably, but this knowledge came too late to be of much value to the sardine industry. The ecological implications of this valuable work should not be ignored in funding, investigating, and managing other fisheries.

PRESENT CONDITION AND FUTURE PROSPECTS FOR ATLANTIC MENHADEN

The literature on the menhaden fishery is by no means as extensive as that for the sardine. The principal references used were HENRY (1968) and REINTJES (1969).

Although it has not been demonstrated conclusively that the menhaden resource has been overfished, the striking similarity in trend of landings should give cause for concern (Fig. 1). It should be noted especially that the sardine catch improved substantially for a period of two or three years following the poor catch of 1947. This caused most people in industry, and some scientists, to say that the sardine decline was temporary. Actually, no one knew at that time exactly what was happening. The catch fell almost to nothing in 1952 and 1953, and following two brief and much smaller upsurges in 1955 and 1958, the fishery soon collapsed. If the Atlantic menhaden fishery were to follow the same trend, the point of collapse could come as early as 1972, and certainly no later than the early 1980's (Fig. 1C). This cannot be regarded as a valid prediction, but the possibility should not be dismissed lightly.

The menhaden industry was encouraged in 1968 by an increase in the catch in the middle Atlantic and Chesapeake areas. The middle Atlantic catch was almost double the catch in 1967 and the Chesapeake catch increased by more than 20 per cent. There is some evidence that the 1966 year class was larger than any year class since 1963, and this could account for improved catches in 1968, but the 1966 and the 1963 year classes were much smaller than the dominant year class of 1958 and the other large year classes that supported the peak years of the fishery.

The Atlantic menhaden fishery has not declined to quite the low level that finally led to increased scientific attention to the sardine resource some twenty years ago. Indeed, it cannot be predicted with assurance that the Atlantic menhaden fishery will take the same course as the sardine fishery, although there is no scientific basis for optimism. To some it may appear that neither the industry nor fishery managers have drawn any lessons from the history of the sardine fishery. The industry remains optimistic that the situation will improve, and has hailed the improved catches of 1968 as evidence that the decline may have been temporary, especially in the area north of Chesapeake Bay. The three peaks in sardine catches after 1947 were also accompanied by increased catches north of Point Conception (Fig. 4) as would be expected from the migratory habits of the resource. Meanwhile, sport fishermen on the Atlantic coast are becoming increasingly concerned about the menhaden fishery, and pressures for restrictive legislation are increasing in each session of several State legislatures.

MURPHY (1966) estimated that the maximum sustainable yield of Pacific sardines for the period ending in 1946 was about 470 000 tons a year. From 1937 to 1945 the sardine fishery took an average annual harvest of about 570 000 tons, or about 100 000 tons per year over the estimated surplus production. This intense fishery was removing about 79 per cent of the stock of sardines of commercial size each year. Considering the geographic range of the Atlantic menhaden resource as compared with the Pacific sardine, the similarity in life histories, and the remarkably similar patterns of landings during the peak years of the two fisheries, it would have been prudent to assume that the maximum sustainable yield of Atlantic menhaden would not exceed 470 000 tons annually. The average catch of menhaden from 1953 to 1962 inclusive was about 658 000 tons. Thus, if the assumption about maximum sustainable yield of menhaden is tenable, the stock was being overfished by about 40 per cent.

Concentration of the fishery for menhaden or sardine in the southern part of the species range has other disturbing biological and economic implications. This forces the fishery to take increasing proportions of younger fish, many of which have never spawned. A menhaden fishery conducted exclusively north of Chesapeake Bay would take larger and older fish, increasing the odds that substantial numbers would be able to spawn at least once before capture. Moreover, if menhaden are like other clupeid fishes, the average oil yield should be considerably greater in northern waters, but the yield of meal should not be substantially less. Thus, the economic return per unit weight of fish could be greater. It is unlikely that the industry in the south would be willing to restrict its operations in favor of operators in more northern waters, although this might prove to be the simplest way to manage the fishery. The question has not been examined carefully, but it would merit study.

The menhaden industry, with government assistance, has been giving attention to the need for alternate resources, not only along the Atlantic coast, but also in the Gulf of Mexico, where menhaden catches have been dropping since the early 1960's. Thus, some of the lessons have been heeded, but they may have been heeded too late and with too little sense of urgency by industry and scientists alike. For example, no scientific evidence is available to show whether other species in the same geographic areas are reacting in any way to the changed abundance of menhaden. Essentially, history may show that the menhaden industry today is at the critical stage reached by the sardine industry two decades ago. Here is an opportunity for government and industry to build on the experience of the sardine industry, before it is too late, in a joint effort to broaden the resource base of the Atlantic fish meal and oil industry and to take

advantage of the considerable advances in fishery science that have been made since the end of World War II.

It is not necessary to wait until indisputable scientific evidence is available before taking action to manage a fishery. History has shown that such caution usually leads to disaster. The history of the Pacific sardine fishery, and present knowledge of the ecology of the resource, suggest that the industry might have been prospering today if the knowledge necessary for appropriate action had been available, and such action had been taken. The menhaden industry has taken some tentative voluntary steps in this direction. It is to be hoped that industry will recognize the need to continue seeking a rational fishing policy.

SUMMARY

The Pacific sardine resource, which once supported an important American fishery, declined abruptly in the late 1940's and early 1950's, and the fishery is now defunct. Scientific research during the peak of the sardine fishery and subsequent to the decline has demonstrated fairly clearly that the cause was overfishing, fluctuations in abundance from natural causes, and invasion of the vacated niche by the Pacific northern anchovy. It has been concluded that it may not be possible to harvest a sustainable yield from a highly fluctuating resource like the Pacific sardine, for the reduced population will yield available energy to other ecologically similar species. Thus, the concept of a broad resource base made up of several species may be essential to the economic viability of most fishing industries. Perhaps the best documented example of the effect of selective fishing on the ecology of a large body of water is the history of the fishery resources of Lake Michigan (SMITH 1968).

About twenty years later the Atlantic menhaden fishery went through a remarkably similar cycle. The northern fishery is virtually defunct, but the southern fishery is still in operation. The total annual catch now is a little more than one-third as large as the average catch from 1953 to 1962. Although it has not been demonstrated that the Atlantic menhaden resource is overfished, it might be prudent to borrow from the experience of the sardine industry and develop management plans accordingly. An important consideration would be to determine as soon as possible which species in the environment of the menhaden are utilizing the energy released by the decline of the resource. It is unlikely that fishery management in the ocean will ever be generally successful if action is postponed until absolute proof of overfishing is available.

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My interest in herring-like fishes and their variations in abundance was stimulated very early in my professional life by the work of Dr. GUNNAR ROLLEFSEN. I am honored to dedicate this paper to him.

It was not possible to make a thorough literature review in preparing this article. I believe I have consulted most of the major recent comprehensive papers on pertinent aspects of the two fisheries. If I have missed important papers or have not given appropriate emphasis to the recent literature it was not intentional. I apologize to authors whom I may unwittingly have slighted.

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