# PARTIALLY ANNOTATED BIBLIOGRAPHY OF PURSE SEINES AND THEIR EFFECT ON TARGETED FISHERY STOCKS

by

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## ABSTRACT

Available literature concerning purse seine fisheries was reviewed. Literature was selected for this report if 1) it presented information that provided insight into the history and long-term trends in a fishery and 2) it presented information on purse seines unique to a fishery. Information found in the reviewed literature revealed that purse seines are a highly efficient fishing gear and without adequate regulation are potentially damaging to targeted fish populations.

## INTRODUCTION

Purse seines have been used to harvest finfishes throughout the world. Atlantic menhaden (Brevoortia tyrannus) were harvested from sailing vessels prior to the American Civil War (Atlantic Menhaden Management Board 1981). Herrings and sardines (Family Clupeidae) have been harvested for food and reduction since the 1930's in the Atlantic Ocean, Pacific Ocean and Gulf of Mexico (Croker 1954, Burd 1974, Ness 1977b, Crouter 1985). Purse seine fisheries for tunas (Family Scombridae) began in earnest during the early 1960's (Sakagawa et al. 1977).

During 1983, a purse seine fishery for adult red drum developed in the Gulf of Mexico (Anonymous 1988). Concern was expressed by fishery managers and scientists from the Gulf of Mexico Fisheries Management Council when almost 3.6 million kg of red drum were taken in the third year of the fishery. Age distribution of fish caught in purse seines indicated a significant portion of red drum in the 6-12 year old age class was absent in the purse seine catches (Goodyear 1987).

The present report is a response to concerns about the effect of purse seine fishing on targeted fish populations. The objectives of the present report are to review and summarize literature that provide historical and trend data for various purse seine fisheries throughout the world, and to provide a synopsis of the reviewed literature concerning the effect of purse seines on fish populations.

## MATERIALS AND METHODS

Information for the present report was obtained from scientific literature dealing with purse seine fisheries. Literature was obtained during June-November 1986 through library searches at the Texas Parks and Wildlife Department, Coastal Fisheries Branch, Austin, Texas; the Texas Parks and Wildlife Department, Coastal Fisheries Branch, Rockport, Texas; Texas A&M University, College Station, Texas; University of Texas, Austin, Texas; and at the National Marine Fisheries Service Southwest Fisheries Center, La Jolla, California. Library card and computer files were searched using key words such as purse seines, seines, pelagic, fish, names of fish species known by the author to contribute to purse seine fisheries, and names of countries using purse seines in their fisheries.

Various state and federal fisheries agencies located along the Pacific Ocean, Atlantic Ocean and Gulf of Mexico coasts of the United States were solicited by form letter (Appendix A) for purse seine literature and information in October 1986. Names and addresses of agencies and agency directors (Appendix B) were taken from the 1985 Conservation Directory (Bryant and Gordon 1985).

Literature reviewed was included in the present report if it met the following criteria: 1) the report presented information that provided insight into the history and long-term trends in a fishery and 2) the report presented information on purse seines unique to a fishery.

# RESULTS

The following annotations provide summaries of selected literature that met the objectives of this report. All landings are reported in metric tons (t).

Anonymous. 1985. Annual report of the Inter-American Tropical Tuna Commission. Inter-American Tropical Tuna Commission. La Jolla, California.

This report reviewed the tuna fishery and fluctuations in catches and abundance of yellowfin tuna (Thunnus albacares) and bluefin tuna (Thunnus thynnus).

Increased demand for tuna products prompted increased capitalization of the tuna industry, generally in the form of technological advances (new fishing gear and techniques), and increased carrying capacity of vessels. Three primary gear used to harvest yellowfin tuna were, in order of importance, purse seines, pole and line, and longline.

Prior to 1960, fishing for yellowfin tuna was unregulated. Subsequently, the population was significantly depleted by overfishing. This caused the fishery to divert fishing effort from the eastern to western Pacific Ocean and to other species like the skipjack tuna (Katsuwonus pelamis). Following initiation in 1966 of a conservation program that reduced fishing pressure, yellowfin abundance improved. When conservation measures were suspended in 1979, abundance decreased.

Analysis of catch/t of carrying capacity (CPTCC) revealed an overall decline in CPTCC of all tuna species from 1970-82 with a slight increase in 1983.

Declines similar to those observed for yellowfin tuna were reported for bluefin tuna except total landings and CPTCC continued to decline through 1984.

Burd, A. C. 1973. The Northeast Atlantic herring and the failure of an industry. Pages 167-191. In: F. H. Jones, editor. Sea Fisheries Research. Halstead Press, New York, New York.

The author reviewed the Northeast Atlantic herring (Clupea harengus) fishery and probable causes of its decline.

The herring fishery was divided into three basic stocks: 1) the shelf stocks, including North Sea herring and all catches from the shelf adjacent to the British Isles; 2) oceanic herring include those fish caught in the open ocean and consist mainly of the Atlantic-Scandian stock; and 3) the Baltic stocks.

Total herring landings declined by 1970 to < 50% of record catches reported during 1964-67. Landings from the shelf remained relatively stable during 1932-70; those from the Baltic increased slightly during that same period. However, landings from the oceanic stock declined severely from about 2 million t in 1968 to < 100,000 t in 1970. Increases or perceived stability of other stocks were thought to be due in part to a shift of fishing effort to previously unfished stocks.

Documented environmental changes occurred in the North Atlantic from 1930-70 and coincided with increases in exploitation of the stocks. These environmental changes primarily affected the growth rate of the fish and the age at which they recruited to the spawning stock.

The North Sea stocks were divided into three main spawning groups; the Buchan stock, the Bank stock (Dogger Bank) and the Downs stock. Larval densities indicated the spawning stock in the Downs and Bank areas had declined to < 10% of the stock present immediately after World War II. In fact, no larvae were found from the Dogger Bank area and the Southern Bight herring fishery (Downs stock) finally collapsed in 1970. One theory advanced for the demise of the Southern Bight fishery suggested changing environmental conditions had altered behavior of the herring. A second theory held the decline was due to overfishing the adult stock and the effects of increased growth increased the recruitment of 3-year old fish to the fishery. A third theory blamed the decline on Danish industrial fishing for juvenile herring in the eastern North Sea.

While scientists argued the causes of the decline of the fisheries, Norwegian purse seiners expanded their efforts and landings of herring. Subsequently, CPUE declined from about 2,100 t/boat in 1965 to just over 1,000 t/boat in 1967. Scientists continued to argue whether the decline was due to natural causes or to overfishing; however, the stocks still declined and several fisheries failed.

With the decline of the Southern Bight fishery, effort shifted to the Dunmore herring stock where a correlation between observed fishing mortality rates of adults and total fishing effort was demonstrated. It was concluded observed changes in stock abundance was caused by fishing. Increased effort increases fishing mortality. It was also concluded changes in yield and catch/effort were induced by fishing.

In the northern seas between Norway, Spitzbergen and Iceland, the Icelandic herring fishery had deteriorated by 1966. Landings had declined from 403,000 t in 1962 to 82,000 t in 1967. Also, declines in average size and age of the catch from 32 cm and 5.8-6.6 year old fish in 1961-63 to 26.5 cm and 3.0 years old in

1965 indicated the fishery had shifted to harvesting juveniles, a situation similar to the fishery in the North Sea. It was concluded the decline in the stock was due to increased exploitation of young herring, high total mortality and reduction in recruitment. A reduction in total fishing mortality to 0.4 and imposition of a total ban during the spawning season was recommended.

The Norwegian spring-spawning stock was noted for its large fluctuations in year-class strengths. However, estimates of fishing mortality in 1963-67 had increased by three-fold relative to 1952-57. Coupled with this increase was an indication that recruitment was extremely low during 1963-67. At this same time, fishing effort increased on juvenile stocks. The decline in stocks was associated with the accelerated exploitation rate and with environmental conditions affecting recruitment.

In summary, it was demonstrated in the Northeast Atlantic herring fishery, declines in stock abundance and recruitment were directly related to overfishing and were exacerbated by changes in environmental conditions.

Croker, R. S. 1954. Tragic story of California's vanishing sardine fishery. Pan American Fisherman. May 1954:10-11, 19.

The author reviewed in narrative form the history of the rise and fall of the Pacific sardine (Sardinops caeruleus) fishery. The fishery began as a food fishery during World War I. Following development of reduction plants, the fishery expanded rapidly until 1936. At that time, there were 300 boats each able to take 91-181 t/day. As age of fish caught and CPUE gradually decreased, high fishing effort maintained the levels of landings. Concurrently with decreased CPUE, sardine spawning success plummeted. Fisheries failed first in Canada then declined progressively further south. A temporary increase in landings occurred with increased effort and harvest of fish from the spawning areas off San Francisco. Quotas recommended by fishery researchers went unheeded. The upsurge in landings lasted only 2 years and the fishery almost entirely collapsed by 1953.

Crouter, R. A. 1985. Quotas by fishing gear for the herring fishery of the Bay of Fundy. Pages 409-414. In: FAO Fisheries Report Number 289 Supplement 3.

The author summarized the herring (Clupea harengus) fishery in the Bay of Fundy. A collapse of the Canadian west coast fishery provided boats for an expanding fishery on the east coast. The foreign fishing fleet increased in the Georges Bank area. The stocks on the Georges Bank collapsed and those in the Bay of Fundy were significantly depressed.

The Georges Bank spawning stock once partially contributed to the recruitment to the Bay of Fundy population. But overfishing on the Georges Bank stocks temporarily eliminated this stock's contribution to the Bay of Fundy stock. Without controls, catches declined from 230,000 t in 1968 to 60,000 in 1976.

Dornheim, H. 1978. Status of the herring stocks fished by the Federal Republic of Germany fleet. Marine Fisheries Review. 40(4):21-24.

The author reviewed the status of herring (Clupea harengus) stocks in the North Sea, Celtic Sea, Hebrides, Norwegian Sea and Georges Bank.

North Sea: In the middle 1960's, high fishing effort led to high yields and, consequently, to serious reductions in stock abundance as shown by small numbers of larvae, high mortality rates, and low CPUE. Landings declined steadily from about 1.5 million t in 1965 to about 8,000 t in 1976. Due to the magnitude of the decline, the Herring Assessment Working Group recommended an immediate total ban on all types of directed herring fisheries in the North Sea to avoid the threatening danger of a total and irreversible breakdown.

Celtic Sea: Catches declined from 50,000 t in 1969 to 7,000 t in 1976. The low catch in 1976 was not due to reduced effort. The fishing mortality rate of this stock remained at about the same level as recorded in 1972-73. The 1976 low stock levels were a result of high fishing mortality since 1972-73 and low recruitment observed for the first time in 1970. There were indications that 2-year-old fish were heavily fished during 1972-79 but prior to that time there was only moderate fishing pressure on that age class. The author recommended a total fishing ban in the Celtic Sea.

Hebrides: Landings declined from about 203,000 in 1971 to about 107,000 t in 1976. This decline in landings was due, in part, to restrictions placed on the fishery by the Scottish government at the recommendation of the research scientists. Estimates of the size of the adult stock dropped from 601,000 t in 1971 to < 300,000 t by 1975. Scientists further estimated potential recruitment to future adult stocks and proposed total allowable catch quotas in successive years that would theoretically increase stock abundance, given normal spawning and larval recruitment.

Norwegian Sea: Landings declined from about 1.8 million t in 1966 to 1,000 t in 1976. Spawning stock was at such a low level that no larvae were found in the spawning grounds in 1970 and 1971. The sharp decline after 1966 was due to a very high fishing effort especially by Norwegian purse seiners and to a failure of recruitment.

Georges Bank: This fishery was heavily fished by foreign fleets from 1967-1972. As quotas were imposed, catches declined accordingly. However, by 1976 quotas were never reached. Also in 1976, larval recruitment was at lowest levels ever recorded. By 1977, no exploitable concentrations of fish were found in the fishing area and the international fishery failed completely.

The author reported it was expected the stocks would decline further and would no longer reach the levels of the late 1960's and early 1970's.

Guillory, V., and G. Hutton. 1982. A survey of bycatch in the Louisiana Gulf menhaden fishery. Proceedings of the Annual Conference of Southeastern Association of Fish and Wildlife Agencies. 36:213-223.

Incidental catch in the Louisiana gulf menhaden (Brevoortia patronus) purse seine fishery was examined during 1980-81. Random samples of off-loaded fish were examined for by-catch composition. Species contributing most to by-catch included Atlantic croaker (Micropogonias undulatus), silver seatrout (Cynoscion nothus), threadfin shad (Dorosoma petenense), Atlantic bumper (Chloroscombrus chrysurus), sea catfish (Arius feils) and spot (Leiostomus xanthurus). Percent bycatch ranged from 0% to 24.82% (2.35% mean) by weight and 0% to 14.77% (2.68% mean) by number.

Generally most fish were not considered game fish; however, gafftopsail catfish (Bagre marinus), Florida pompano (Trachniotus carolinus), spotted seatrout (Cynoscion nebulosus), southern kingfish (Menticirrhus americanus), sheepshead (Archosargus probatocephalus), king mackerel (Scomberomorus cavalla), and Spanish mackerel (Scomberomorus maculatus) were caught incidental to gulf menhaden. The authors, however, generally believed that the significance of the bycatch was minimal.

June, F. C. 1972. Variations in size and length composition of Atlantic menhaden groupings. Fishery Bulletin. 70(3):699-713.

The author estimated size and length composition of schools of Atlantic menhaden (Brevoortia tyrannus) based on single-set purse seine catches from 1955-62. The data reveal Atlantic menhaden school by length, and average size of summer schools decreases with declining density.

Moreover, findings suggested there is an optimum school size for fish of a given length that is most favorable for survival. If this is true, the author hypothesized there must be a level below which a population must not be fished in order to avoid disrupting schooling to the point of irreparable damage to population resilience. Even though this hypothesis was not provable with the data presented, the author inferred schooling marine fishes sought by surface sightings were more vulnerable to unregulated fishing than nonschooling species not subject to direct observation.

Since fish tend to school by size, and an inverse relationship between fish size and school size was determined, exploitation of younger (smaller) fish may have a greater impact on populations, especially regarding recruitment to the spawning stock.

Klima, E. F. 1977. An overview of the fishery resources of the west central Atlantic region. Pages 231-252. In: H. B. Stewart, Jr., editor. Cooperative investigation of the Caribbean and adjacent regions--II. FAO Fisheries Report Number 200.

The author reviewed various fisheries within the west central Atlantic region.

Gulf of Mexico fishery for gulf menhaden (*Brevoortia patronus*): landings declined from 728,000 t in 1971 to around 500,000 t in 1976. Landings of gulf menhaden were 6% less in 1976 than in 1974 despite an 11% increase in fishing effort. Maximum Sustainable Yield (MSY) was calculated to be 500,000 t. The author predicted that an increase in effort of 6% would result in an associated increase in landings to 603,000 t. Consequently the author theorized that if MSY actually had been reached, catches would decline after 1976.

Atlantic fishery for Atlantic menhaden (*Brevoortia tyrannus*): while landings during 1971-75 remained relatively constant at 250,000 t, effort increased 36%. The minimum point at which the fished population could sustain itself was estimated to be 220,000 t. There was a continual decline in the percent of fish older than optimum-age (2-3 years old). In 1972, 11% were ≥ 3 years old whereas in 1973-75, 5% or less were ≥ 3 years old. The author stated a continuation of current harvesting practices would be detrimental to the resource. He recommended a reduction of fishing effort, curtailment of fishing for juvenile menhaden and the establishment of a quota.

MacCall, A. D., G. D. Stauffer, and J. P. Troadec. 1976. Southern California recreational and commercial marine fisheries. Marine Fisheries Review. 38(1):1-32.

Authors reviewed several sport and commercial fisheries in southern California. They discuss finfish species targeted by the purse seine fishery. These included northern anchovy (*Engraulis mordax*), jack mackerel (*Trachurus symetricus*), Pacific bonito (*Sarda chiliensis*), Pacific sardine (*Sardinops caeruleus*) and

Pacific mackerel (Scomber japonicus).

Northern anchovy fishing increased following the collapse of the Pacific sardine fishery in 1951. Landings increased from 2,300 t in 1960 to 101,000 t in 1973, however, large year-to-year fluctuations occurred. Mean lengths of fish in catches declined between 1965 and 1973. Authors stated that "because of high natural mortality of anchovy, there is no need to limit the size at first capture in California at the present (1973) level of harvest." Stocks apparently showed very large year-to-year fluctuations. If higher exploitation rates were considered, "careful monitoring of stock abundance and size composition would be essential...to prevent over exploitation during periods of successive low recruitment."

Pacific Bonito landings fluctuated widely with catches of 900-3,600 t taken between 1926 and 1941 and 45-450 t between 1942 and 1957. An apparent rebound or reappearance of stocks contributed to increased fishing effort in 1973, possibly due to a level in excess of equilibrium yield. No further data were available.

Jack mackerel fishing increased following the collapse of the Pacific sardine fishery. Landings declined from 121 million t in 1950 to 19 million t in 1973. However, the authors stated landings had been influenced by the increased availability of more lucrative species. Declines since 1965 were attributed to expansion of fisheries on Pacific bonito and northern anchovy. Authors also stated biomass estimates indicated jack mackerel were about 50% as abundant in 1973 as they were in the mid-1960's. Also noted was a decrease in average age of the catch which indicated a higher mortality rate and/or a smaller stock size as previously believed.

Pacific mackerel landings exhibited a sudden rise caused by demand of canneries in the late 1920's. This demand and an exceptionally strong year class (1932) peaked landings at a record 66,000 t. Subsequently, landings declined to the point of severe stock depletion in 1933. A successful spawn in 1953 boosted the stock and fishery until 1963 when six consecutive recruitment failures destroyed the commercial fishery.

Authors reported the fishery tended to capitalize on strong year classes and overexploit successive weak year classes. Spawning stock declined, larval recruitment declined, mean age and number of age classes declined to a point where populations could not withstand extended periods of recruitment failure.

Authors also stated environmental changes could have caused the observed severe fluctuations in spawning success. In addition, the increase in relative abundance of bonito may have created more trophic competition, as was theorized for the anchovy and sardine.

Pacific sardine biomass estimates declined from 1.3 million t in 1940 to less than 5,000 t in 1971. Authors reported the apparent cyclic nature to the presence or absence of Pacific sardines with respect to the northern anchovy. Core samples of ocean bottom reflect scale shedding rates of both species with sardines periodically almost equaling, but never surpassing those of anchovies.

McInnis, R. 1985. Anchovy management by quota. Pages 421-430. In: FAO Fisheries Report Number 289 Supplement 3.

The author described historic and present management practices, impacts of regulations and landings of northern anchovy (Engraulis mordax).

Total landings, including live bait, declined from 149,000 t in 1975 to 56,000 t in 1981. A severe decline in landings occurred from 1977 to 1978 (108,000-17,000 t) with an increase to 58,000 t in 1979. Effort was not reported.

Harvest quotas were imposed in 1978. From 1978-83, the set quotas were met only once. Consequently, the author believed that the quota system afforded anchovy populations the necessary protection for sustaining anchovy stocks.

Ness, H. O. 1977a. The recent development of the southeastern Alaska herring fishery. Marine Fisheries Review. 39(12):10-14.

The author reviewed the new roe herring (Clupea pallasii) fishery and the economic implications for southeastern Alaska.

Entrance into this fishery was prompted by low catches of salmon during 1974 and 1975 and by Japanese demand for roe herring. The herring roe fishery was concentrated in a few areas in Alaskan waters. Because of imposed quotas and limited entry requirements, the duration of the 1975 Juneau area fishing season lasted 2.5 h and the southeast Alaska fishery lasted 4 h. Fishing success during the 1975 season varied considerably. Some vessels landed great quantities of fish while others landed no fish.

Ness, H. O. 1977b. The recent development of the southeastern Alaska herring fishery. Marine Fisheries Review. 39(12):15-18.

The author reviewed the history of the herring (Clupea pallasii) fishery in southeastern Alaska and recent (1974-77) developments for a renewed fishery for roe herring.

Fishermen found it necessary to diversify fishing efforts into the herring fishery due to reduced catches of salmon during 1974-75. Japanese interest in herring roe also encouraged this diversification. Historically, the herring fishery in Alaska supplied reduction plants. The author attributed the demise of this fishery in 1966 to several regulatory and marketing events that caused the reduction fishery for herring to be uneconomical. The author indicated there was room for expansion in the herring roe fishery.

Parks, W. W. 1985. Numbers of dolphin chased, captured and injured incidental to fishing by the U.S. purse seine fishery for tropical tuna in the eastern Pacific Ocean. Administrative Report LJ-85-15. National Marine Fisheries Service, Southwest Fisheries Center. La Jolla, California.

The author reviewed the effect of purse seining for tuna on dolphin in the eastern Pacific Ocean.

The United States purse seine fishery for tropical tunas in the eastern Pacific Ocean uses schools of dolphins (Stenella spp.) to locate schools of tuna with which they are associated. In the process of catching tuna, dolphins are chased, captured and occasionally injured.

Estimated numbers of dolphin chased steadily declined from 9.5 million in 1977 to 1.7 million in 1983. Estimated numbers captured have similarly declined from 4.7 million to 1.2 million during the same period. Estimated numbers injured using two different definition of injury also revealed declines during this period. When estimates of injury and numbers killed were totaled, assuming all injured dolphins die, then estimates of numbers of dolphins killed annually increased from 3.6-15.7% depending on the definition of injury. Definition 1: dolphins were observed to be injured but of uncertain status (dead or alive). Definition 2: dolphins were observed of uncertain condition (uninjured or injured) and, of uncertain status (dead or alive).

Sakagawa, G. T. 1975. The purse-seine fishery for bluefin tuna in the northwestern Atlantic Ocean. Marine Fisheries Review. 37(3):1-8.

The author reviewed the history of the purse seine fishery for bluefin tuna (Thunnus thynnus) in the northwestern Atlantic Ocean and discussed events that contributed to fluctuation of catch.

The fishery began in 1958 producing 5,770 t at its peak in 1963. The catch by a fleet with a carrying capacity of 4,900 t declined from 4,290 t in 1970 to about 1,780 t in 1973. Average length of bluefin tuna in the purse seine catch decreased from about 140 cm in 1960 to about 89 cm in 1973, due in part to a southward expansion of the fishery into areas where small bluefin tuna were more available. There had been a prevailing downward trend in catch rate from 1963 to 1973 with the 1973 rate at a low level.

Fishery efficiency increased with increased carrying capacity of vessels, aerial spotting of the schools, by extended fishing seasons, and by fishing in more southerly areas.

Sakagawa, G. T., A. L. Coan, and T. C. Murphy. 1977. A review of the yellowfin-skipjack tuna fishery of the Atlantic Ocean and American participation, 1956-75. Marine Fisheries Review. 39(12):1-10.

The authors reviewed the development of the yellowfin (Thunnus albacares) and skipjack (Katsuwonus pelamis) tuna fisheries in the Atlantic Ocean.

The fishery was divided into longline and surface components. Purse seines and baitboats comprised the surface component. The purse seine fishery began in 1956, yet until 1966, most Atlantic yellowfin tuna were landed by longlines. Since that time, purse seines dominated the yellowfin catch.

During the 1960's, intense fishing pressure was placed on yellowfin tuna. Consequently, catch rates dropped dramatically and fishermen shifted effort to skipjack tuna. As the skipjack tuna catch declined, effort was redirected at yellowfin tuna.

Analysis of the status of tuna stocks indicated to the authors that at that time (1977), yellowfin tuna stocks were healthy and catch was increasing due to fishery expansion and good recruitment. Production and yield-per-recruit models indicated increased catches would occur only at the expense of decreased CPUE.

Analysis of the skipjack tuna catch data revealed a highly variable stock. The major controlling factor of this variability was believed to be prevalent oceanographic conditions. In addition, catch variability was affected by fishing gear, time and area fished, and whether or not skipjack were the target species.

The authors indicated minimum size regulations placed on yellowfin tuna had been beneficial in maintaining recruitment to the fishery. However, because of high natural mortality (biological and emigration) of fish older than 2 years, and reliance of the fishery on 1-2 year old fish, size limits and catch regulations were not necessary at that time.

Shapiro, S. Editor. 1971. Our changing fisheries. United States Government Printing Office, Washington, District of Columbia.

Introduction of purse seines to the tuna fleet greatly increased the ability of fishermen to locate and land fish. Fishermen no longer had to rely on feeding schools of tuna for their landings. Data subsequently revealed yellowfin tuna (Thunnus albacares) populations were being overexploited. Recommendations were made by the Inter-American Tropical Tuna Commission in 1966 that regulations should be enacted and quotas placed on the harvest of yellowfin tuna.

The collapse of the Pacific sardine (Sardinops caeruleus) fishery was also reviewed. It rapidly changed during World War I from a food fish fishery to an intensive reduction fishery. Sardine abundance declined steadily from 1936 until 1951 when the San Francisco Bay fishery stopped. By 1960 most canneries in Monterey were out of business and in 1967 a 2-year moratorium was placed on all sardine fishing. The consensus of fisheries scientists was the decline was due to overfishing exacerbated by poor spawning success caused by adverse environmental conditions. The decline in abundance of sardines was accompanied by an apparent increase in anchovy abundance.

Thomson, C., and R. Klingbeil. 1984. California's northern anchovy fishery in 1983-84. Administrative Report LJ-84-23. National Marine Fisheries Service, Southwest Fisheries Center. La Jolla, California.

The authors summarized regulations and landings of northern anchovy (Engraulis mordax) for the reduction and non-reduction fisheries in California. Established optimum yield for 1983-84 reduction fishing was 104,800 t based on a spawning biomass of 1.405 million t. Anchovy reduction landings were a record low 1,680 t in 1983-84, of which only 79 t were landed in the southern permit area. Many vessels targeted mackerel because they had difficulty finding commercial concentrations of anchovy, even with aerial spotters. The problem of low availability also plagued the bait fishery.

There was a rapid decline in anchovy reduction fishery landings from 1974 to 1983, and, because of greater accessibility, an equally striking increase occurred in landings of mackerel. Anchovy landings declined from 128,000 t in 1975-76 to 1,680 t in 1983-84. The total number of reduction fishery vessels also declined from 40 in 1973-74 to 5 in 1983-84. Mackerel landings, however, increased from 11,000 t in 1974 to 48,000 t in 1977 and subsequently fluctuated between 40,000 and 49,000 t through 1983. Between 1974 and 1984, the total number vessels remaining in the fishery fluctuated from a low of 41 in 1979 to a high of 48 in 1974 and 1975. A total of 46 vessels operated during 1984.

Estimated spawning biomass of the northern anchovy increased from < 50,000 t in 1954 to over 2.5 million t during 1975 and declined through 1984 to about 300,000 t.

Zuleta, A., and J. R. Serra. 1983. The management of Chilean pelagic fisheries with emphasis on the Spanish sardine (Sardinops sagax musica). Pages 457-470. In: FAO Fisheries Report Number 289 Supplement 3.

The authors reviewed the Chilean purse seine fishery for anchovy (Engraulis ringens), horse mackerel (Scomber japonicus peruanus), jurel (Trachurus murphyi), and Spanish sardine (Sardinops sagax musica).

Following the collapse of the anchovy fishery in 1977, fishermen shifted effort to other species such as horse mackerel, jurel and Spanish sardine. The combination of these three species increased total landings to levels never achieved by the anchovy fishery alone.

During the reporting period (1961-1981), the total number of vessels decreased from 251 in 1965 to 100 in 1974 then increased to 128 in 1981. Despite the significant decline in numbers of vessels, the ability of the fleet to locate and catch target fishes greatly improved through technical advances such as acoustic equipment, better nets and design, power blocks, aerial surveys used for location of schools, and night fishing. Also, vessel size, as measured by holding capacity, increased almost 250% from 187 $m^3$ in 1961 to 646 $m^3$ in 1981.

The authors' analysis of the Spanish sardine fishery revealed classic patterns of overexploitation. The exploitation rate was 43% compared with 30% for other world pelagic fisheries. Modal sizes of landed fish decreased significantly between 1978 and 1980. The authors indicated these factors coupled with increased efficiency of the fleet put the fishery at high risk. The authors recommended several measures to reduce pressure on the sardine stocks, and reviewed the subsequent regulations placed on the fishery.

## DISCUSSION

Information presented in the reviewed literature revealed that purse seines, if not adequately regulated, are very efficient and potentially damaging to targeted fish populations. The Pacific sardine fishery along the west coast of the United States remains a classic example of a fishery collapse caused by over-exploitation of a species coupled with several successive poor spawns.

Other world fisheries exhibited symptoms of decline similar to the Pacific sardine. Declines were generally preceded by a tremendous expansion in the industry as a result of increased demand for the product. In the case of small pelagics like herrings, sardines and anchovies, development of fish reduction plants to meet the increased demand for oil and fish meal greatly expanded the clupeid fishery. Reduction plants required millions of metric tons of product just to stay in business.

Next, there was an improvement in harvesting efficiency and vessel holding capacity. The development of the power block revolutionized the purse seine fishery. This allowed larger vessels with greater holding capacities to be built. Aerial spotters enabled the larger vessels to locate and capture schools of fish more quickly, increasing the number of successful trips made during a season. While record landings of these fish were being made, CPUE began to decline; more trips were made to maintain catch levels.

At the same time, an overall juvenescence of fished populations began to take place. Spawning age adults had been virtually eliminated from the fishery and vessels concentrated on schools of successively younger fish. These schools were usually found near the spawning grounds. Coincidentally, unfavorable environmental conditions for spawning and/or larval survival, exacerbated the decline in catches in successive years.

Consequently, reduction plants closed and vessels were sold to other fisheries. Fishermen that could not make a living from a declining fishery moved to harvest another, more profitable species. Temporary reductions of fishing pressure allowed populations to rebound slightly. When an increase in population levels was discovered, fishing pressure was reapplied and landings declined again.

Not all fisheries collapsed as did the Pacific sardine fishery, the Georges Bank and the North Sea herring fisheries. Tuna fisheries, like that for yellowfin tuna, displayed harvest trends similar to those of the smaller clupeids. However, the tuna fisheries have been able to maintain reduced harvest levels because strict quotas and regulations controlling the fisheries were implemented once serious declines were observed.

Although landings from the gulf menhaden fishery and the northern anchovy fishery appear to be doing well, they exhibit some of the same symptoms characteristic of other declining fisheries. To some extent, there have been recent declines in both catch per effort and age of fish caught.

In summary, purse seines are very efficient fishing gear and have the potential of decimating populations of finfish as long as their use remains unchecked. The ability of a fish population to withstand continuous pressure from a purse seine fishery depends upon its level of recruitment to the spawning population and its continued spawning success. Uncontrolled harvest of these populations without knowledge of the resilience of the fish to harvest pressures could lead to fishery disasters as classic and devastating as that of the Pacific sardine.

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Appendix A. Copy of form letter sent to each solicited fishery agency.

TEXAS
PARKS AND WILDLIFE DEPARTMENT
4200 Smith School Road Austin, Texas 78744



CHARLES D. TRAVIS
Executive Director

3 October 1986

John P. Doyle
Marine Advisory Program
Sea Grant Program
University of Alaska
605 W. 4th Ave. G7
Anchorage, Alaska 99501

Dear Colleague:

The Texas Parks and Wildlife Department, Coastal Fisheries Branch is currently investigating the use of purse seines in fisheries around the world. We are primarily interested in information detailing trends in landings, effort and catch per effort for current and historical fisheries. We are also interested in information concerning possible impacts of the fishery on target populations as well as incidental species.

We would greatly appreciate any reports your agency has generated and reprints of other pertinent literature you may have. However, if this is not possible, a list of references relating to our above needs would be helpful.

Additionally, we would be interested in discussing the possibility of examining any unpublished purse seine data your agency may have collected and are in your files or data base. If these data are available, please refer us to the appropriate individual with whom we could make contact in the future.

Thank you in advance for your consideration of this request. I look forward to hearing from you.

Sincerely,

Paul C. Hammerschmidt
Fisheries Specialist
Texas Parks and Wildlife Department
P. O. Box 688
Port O'Connor, TX 77982
(512) 983-4425

PH:nz

Appendix B. Listing, by state, of agencies and individuals contacted by letter requesting purse seine fishery information. Listing taken from Bryant and Gordon 1985.

## ALABAMA

| AGENCY | INDIVIDUAL CONTACTED |
|---|---|
| Department of Conservation and Natural Resources<br>P.O. Box 189<br>Dauphin Island, Alabama 36528<br>(205) 861-2882/261-3346 | Hugh A. Swingle, Director, Division of Marine Resources |
| Sea Grant Program<br>Auburn University<br>101 Duncan Hall<br>Auburn University, Alabama 36849<br>(205)826-5323 | R. Warren McCord, Ph.D., Marine Advisory Programs State Leader |

## ALASKA

| AGENCY | INDIVIDUAL CONTACTED |
|---|---|
| Alaska Cooperative Fishery Research Unit<br>138 Arctic Health Research Building<br>University of Alaska<br>Fairbanks, Alaska 99701<br>(907) 474-7661 | Dr. James B. Reynolds, Leader |
| Department of Fish and Game<br>P.O. Box 3-2000<br>Juneau, Alaska 99802<br>(907) 465-4210 | Kenneth Parker, Director, Commercial Fish Division |
| Sea Grant Program<br>Marine Advisory Program<br>University of Alaska<br>605 West 4th Avenue, G7<br>Anchorage, Alaska 99501<br>(907) 274-9691 | John P. Doyle, Leader |

## CALIFORNIA

| AGENCY | INDIVIDUAL CONTACTED |
|---|---|
| Department of Fish and Game<br>1416 Ninth Street<br>Sacramento, California 95814<br>(916) 445-8386 | Al Petrovich, Chief, Marine Resources |

| | |
|---|---|
| Sea Grant College Program<br>University of California<br>San Diego<br>La Jolla, California 92093<br>(619) 452-4440 | Dr. James J. Sullivan,<br>Program Manager |
| Sea Grant College Program<br>Institute for Marine & Coastal<br>Studies, University of Southern<br>California, University Park<br>Los Angeles, California 90007<br>(213) 741-6068 | Stuart A. Ross,<br>Director, USC Marine<br>Advisory Program |

## CONNECTICUT

| AGENCY | INDIVIDUAL CONTACTED |
|---|---|
| Department of Environmental Protection<br>Office Building<br>165 Capitol Avenue<br>Hartford, Connecticut 06115<br>(203)566-2287 | Robert Jones, Director,<br>Fisheries State Bureau |
| Sea Grant Program<br>University of Connecticut<br>Marine Advisory Service<br>Building 24, SE Branch,<br>Room 108, Avery Point<br>Groton, Connecticut 06340<br>(203) 445-8664 | George S. Geer, Program<br>Leader, Marine Advisory<br>Program |
| State Extension Services<br>Box U-87<br>University of Connecticut<br>Storrs, Connecticut 06268<br>(203) 486-2839 | W. R. Whitworth, Ph.D.,<br>Fisheries Expert,<br>Professor of Fisheries |

## DELAWARE

| AGENCY | INDIVIDUAL CONTACTED |
|---|---|
| Department of Natural Resources<br>and Environmental Control<br>89 Kings Highway<br>P.O. Box 1401<br>Dover, Delaware 19903<br>(302) 736-3441 | Charles A. Lesser,<br>Manager, Fisheries |

| | |
|---|---|
| Sea Grant Program<br>College of Marine Studies<br>University of Delaware<br>Lewes, Delaware 19958<br>(302)738-8062 | Andrew T. Manus,<br>Director, Marine Advisory<br>Service |

**FLORIDA**

| AGENCY | INDIVIDUAL CONTACTED |
|---|---|
| Department of Natural Resources<br>Marjory Stoneman Douglas Building<br>Division of Marine Resources<br>Tallahassee, Florida 32303<br>(904) 488-6058 | Edwin A. Joyce, Jr.,<br>Director |
| Marine Laboratory<br>Florida State University<br>Route 1, Box 219A<br>Sopchoppy, Florida 32358<br>(904) 644-4740 | William F. Herrnkind,<br>Director |
| Sea Grant College<br>Building 803<br>University of Florida<br>Gainesville, Florida 32611<br>(904) 392-5870 | Dr. James C. Cato,<br>Director |

**GEORGIA**

| AGENCY | INDIVIDUAL CONTACTED |
|---|---|
| Department of Natural Resources<br>270 Washington Street, Southwest<br>Atlanta, Georgia 30334<br>(404) 656-3530 | Duan Harris, Division<br>Director, Coastal<br>Resources<br>Gibson Johnston,<br>Information |
| Sea Grant Program<br>University of Georgia<br>Ecology Building<br>Athens, Georgia 30602<br>(404) 542-7671 | Dr. Edward Chin<br>Director, Sea Grant<br>Program |

| AGENCY | INDIVIDUAL CONTACTED |
| --- | --- |
| State Extension Services<br>University of Georgia<br>Athens, Georgia 30602<br>(404) 542-3824/3446 | Dr. George W. Lewis,<br>Fisheries Specialist |

**LOUISIANA**

| AGENCY | INDIVIDUAL CONTACTED |
| --- | --- |
| Department of Wildlife and Fisheries<br>P.O. Box 15570<br>Baton Rouge, Louisiana 70895<br>(504) 342-5866 | Bennie Fontenot, Chief,<br>Division of Fisheries |
| Sea Grant Program<br>Advisory Program<br>Sea Grant Program Center for<br>Wetland Resources<br>Louisiana State University<br>Baton Rouge, Louisiana 70803<br>(504) 388-6710 | Ronald E. Becker, Marine<br>Asssociate Director |

**MAINE**

| AGENCY | INDIVIDUAL CONTACTED |
| --- | --- |
| Department of Marine Resources<br>Fisheries Research Station<br>West Boothbay Harbor, Maine 04575<br>(207) 633-5572 | Richard W. Langton,<br>Director of Bureau<br>of Marine Sciences |
| Sea Grant Program<br>UME Sea Grant Marine Advanced Program<br>Coburn Hall, University of Maine<br>Orono, Maine 04469<br>(207) 581-1443 | David J. Dow, Director |

**MASSACHUSETTS**

| AGENCY | INDIVIDUAL CONTACTED |
| --- | --- |
| Executive Office of Environmental Affairs<br>Department of Fisheries, Wildlife<br>and Recreational Vehicles<br>100 Cambridge Street<br>Boston, Massachusetts 02202<br>(617)727-1614 Extension 3194 | Phillip G. Coates,<br>Director, Division<br>of Marine Fisheries |

| Agency | Individual Contacted |
|---|---|
| Sea Grant Program<br>Marine Advisory Program<br>Massachusetts Institute of Technology<br>Room E38-324<br>77 Massachusetts Avenue<br>Cambridge, Massachusetts 02139<br>(617)253-7042 | Norman Doelling,<br>Associate Director |

**MISSISSIPPI**

| AGENCY | INDIVIDUAL CONTACTED |
|---|---|
| Department of Wildlife Conservation<br>Southport Mall<br>P.O. Box 451<br>Jackson, Mississippi 39205<br>(601)961-5300 Extension 5341 | Jack Herring,<br>Chief of Fisheries |
| Gulf Coast Research Laboratory<br>Fisheries Research and Management<br>Ocean Springs, Mississippi 39564<br>(601) 875-2244 | Thomas D. McIlwain,<br>Assistant Director |
| Sea Grant Program<br>Mississippi Sea Grant Advisory<br>Services Program<br>4646 West Beach Boulevard<br>Suite 1-E<br>Biloxi, Mississippi 39531<br>(601)388-4710 | C. David Veal, Ph.D.,<br>Leader |
| State Extension Services<br>Delta Branch Experiment Station<br>Stoneville, Mississippi 38776<br>(601)686-9311, Extension 302 | Dr. John R. MacMillian,<br>Area Extension Fisheries<br>Specialist |

**NEW HAMPSHIRE**

| AGENCY | INDIVIDUAL CONTACTED |
|---|---|
| Fish and Game Department<br>34 Bridge Street<br>Concord, New Hampshire 03301<br>(603)271-3421 | Charles F. Thoits,<br>Chief, Inland and<br>Marine Fisheries<br>Division |

| | |
|---|---|
| Sea Grant Program<br>Sea Grant Marine Advisory Program<br>NEC Administration Building<br>University of New Hampshire<br>Durham, New Hampshire 03824<br>(603)862-1255 | Brian Doyle, Director |

**NEW JERSEY**

| AGENCY | INDIVIDUAL CONTACTED |
|---|---|
| Department of Environmental Protection<br>Division of Fish, Game, and Wildlife<br>CN 400<br>Trenton, New Jersey 08625<br>(609)441-3289 | Paul Hamer, Chief<br>Bureau of Marine<br>Fisheries |
| Department of Environmental Protection<br>Division of Coastal Resources<br>CN 401<br>Trenton, New Jersey 08625<br>(609)292-2795 | John R. Weingart,<br>Director (Acting) |
| Sea Grant Program<br>New Jersey Marine Science Consortium<br>Fort Hancock, New Jersey 07732<br>(201)872-1300 | Dr. Robert Abel,<br>Director |

**NEW YORK**

| AGENCY | INDIVIDUAL CONTACTED |
|---|---|
| Department of Environmental Conservation<br>of Fish and Wildlife<br>50 Wolf Road<br>Albany, New York 12233<br>(518)474-8390 Extension 5420 | Bruce Shupp, Chief,<br>Bureau of Division<br>Fisheries |
| Sea Grant Program<br>Cornell University Laboratory<br>39 Sound Avenue<br>Riverhead, New York 11901<br>(516)727-3910 | Bruce DeYoung,<br>Marine District<br>Extension Leader |

## NORTH CAROLINA

| AGENCY | INDIVIDUAL CONTACTED |
|---|---|
| Department of Natural Resources and Community Development<br>Office of Coastal Management<br>P.O. Box 27687<br>Raleigh, North Carolina 27611<br>(919) 733-4984 Extension 2293 | Dave Owens, Director |
| Department of Natural Resources and Community Development<br>Division of Marine Fisheries<br>P.O. Box 769<br>Morehead City, North Carolina 28557<br>(919) 726-7021 | Bob Mahood, Director |
| Sea Grant Program<br>Marine Advisory Program<br>Box 8605<br>North Carolina State University<br>Raleigh, North Carolina 27650-8605<br>(919)737-2454 | James D. Murray |
| State Extension Services<br>3109 Gardner Hall<br>North Carolina State University<br>Raleigh, North Carolina 27695<br>(919)737-2811 Extension 2741 | D. J. DeMont, Jr., Extension Fisheries Specialist |

## OREGON

| AGENCY | INDIVIDUAL CONTACTED |
|---|---|
| Department of Fish and Wildlife<br>P.O. Box 3503<br>Portland, Oregon 97208<br>(503) 229-5551 Extension 5440 | Harry H. Wagner, Assistant Director, Fisheries |
| Sea Grant Program<br>Extension/Sea Grant Program<br>Oregon State University<br>Corvallis, Oregon 97331<br>(503)754-4531 | Howard F. Horton, Program Leader Fisheries & Wildlife |

| | |
|---|---|
| State Extension Services<br>Nash Hall 104C<br>Oregon State University<br>Corvallis, Oregon 97331<br>(503) 754-2713 Extension 4531 | Richard A. Tubb, Head,<br>Fisheries and Wildlife |

## SOUTH CAROLINA

| AGENCY | INDIVIDUAL CONTACTED |
|---|---|
| Sea Grant Consortium<br>Marine Advisory Program<br>221 Fort Johnson Road<br>Charleston, South Carolina 29412<br>(803)795-8462 | Thomas Sweeny, Project<br>Leader |
| Wildlife and Marine Resources Department<br>Rembert C. Dennis Building<br>P.O. Box 167<br>Columbia, South Carolina 29202<br>(803)795-6350 | Dr. Paul A. Sandifer,<br>Director |

## VIRGINIA

| AGENCY | INDIVIDUAL CONTACTED |
|---|---|
| Institute of Marine Science<br>College of William and Mary<br>Gloucester Point, Virginia 23062<br>(804)642-2111/642-6131 Extension 110 | Frank O. Perkins,<br>Dean-Director |
| Marine Resources Commission<br>P.O. Box 756<br>2401 West Avenue<br>Newport News, Virginia 23607<br>(804)247-2200 | Jack G. Travelstead,<br>Assistant Commissioner,<br>Fisheries Management |
| Sea Grant Program<br>Marine Advisory Program<br>Virginia Institute of Marine Science<br>Gloucester Point, Virginia 23062<br>(804)642-2111 | Dr. William DuPaul |
| State Extension Services<br>Virginia Polytechnic Institute &<br>State University<br>Blacksburg, Virginia 24061<br>(804)961-5059 | Louis A. Helfrich, Ph.D.,<br>Extension Fisheries<br>Specialist |

## WASHINGTON

| AGENCY | INDIVIDUAL CONTACTED |
| --- | --- |
| Department of Fisheries<br>115 General Administration Building<br>Olympia, Washington 98504<br>(206)753-6623 | William R. Wilkerson,<br>Director |
| Sea Grant Program<br>Advisory Program<br>University of Washington<br>3716 Brooklyn Avenue Northeast<br>Seattle, Washington 98105<br>(206)543-6600 | Robert E. Harris, Marine<br>Assistant Director |

PWD-RP-3400-321-7/90