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A prospectus on the basis for fishery management on the northwest Atlantic continental shelf off the coast of the United States of America

by

Bradford E. Brown
National Marine Fisheries Service
Northeast Fisheries Center
Woods Hole, Massachusetts 02543

Introduction

In recent years fishery management developed rapidly within the International Commission for the Northwest Atlantic Fisheries for the area off the northeast coast of the United States. Beginning with only mesh regulations, a comprehensive system of species catch limitations, with national allocations of quotas, a total overall catch limitation including all species, seasonal and area closures, and gear restrictions have evolved. Recently the Law of the Sea negotiations appeared to be approaching agreement on some form of 200-mile economic zone. In March 1977 domestic legislation of the United States, declaring a 200-mile fishery zone, takes effect. Such overall domestic authority to manage fisheries has not previously existed in the USA. At this time, management authority is shifting to place more responsibility in the hands of coastal states. This responsibility includes joint maximization of meeting coastal state needs and total fish production. It will therefore become critical to define the surplus productivity, that which can be harvested, in relation to more severely defined goals which include greater emphasis on availability. It means that we need to know more about the ecological basis of fisheries in order to provide a more credible basis for allocation of the yield. Therefore it is an auspicious time to examine the underlying bases for fishery management and discuss the problems inherent in developing such a framework.

Description of the ecosystem

The first item of concern in developing a program of fishery management is the underlying productivity of the resource to be harvested. All management must rest on this base. Determination of this productivity can best be examined through the consideration of the ecosystem within which it exists. An ecosystem is defined by Odum (1959) as any area of nature that contains living organisms and nonliving substances interacting to produce an exchange of material between them. The material of the ecosystem can be classified as belonging to abiotic, i.e. nonliving substances; autotrophic organisms, primary producers which are able to use abiotic materials to store solar energy in the form of organic matter; and decomposers, which break down organic matter to its inorganic components. Of particular interest within the ecosystem of the continental shelf off the northeast coast of the United States are the consumer organisms which transfer organic material from one form to another. The rate of transfer of this material which produces the end product to be harvested by man is affected by the amount, type, and conditions of those abiotic materials and biotic materials. The major abiotic material in this system, of course, is water. As summer approaches, an anti-cyclonic clockwise eddy develops over Georges Bank, while a cyclonic counter-clockwise eddy develops in the Gulf of Maine. These transport movements may well be the major factor determining year-class strength of certain species of interest of harvest to man. River runoff and storms at times also influence the water movements. There are seasonal temperature and salinity cycles which vary from year to year and are affected by the wind-driven currents and turbulence.

The primary producers, mostly phytoplankton, store solar energy by converting oxygen, phosphorus, nitrogen, and carbon into protoplasm. During the winter plankton abundances are low, for while nutrients are available production is suppressed by low levels of solar radiation. As spring approaches and the level of solar radiation increases, an intense diatom bloom occurs. As the bloom progresses, concentration of inorganic nutrients decreases. Regeneration of nutrients by bacteria primarily in the bottom sediments is limited by the still low water temperatures; zooplankton populations remain low because of the slow development of early life stages. As temperature increases during late spring and summer, zooplankton becomes abundant because of the more rapid development of the early life stages and the spawning of fish and benthos. Some but not all zooplankton feed on phytoplankton, as some feed on other zooplankton, while others, particularly *Sagitta* and Ctenophores, are predators of fish larvae. Ichthyoplankton serve as competitors and as forage within the zooplankton, while zooplankton are one of the main sources of food for many species of fish. During summer, zooplankton abundance reaches a maximum while phytoplankton declines. During autumn, as water temperatures decrease, the water column becomes unstable and the nutrient level of the euphotic zone is renewed. This stimulates another phytoplankton bloom which is cut short by low levels of solar radiation. Anomalous years from the generalized annual cycles described above, resulting from such things as storms and temperature differences, may be common. The possibility of disruption by the environmental factors of the timing between spawning of fish and the abundance of interacting planktonic prey or predator species is undoubtedly important in determining year-class strength. For some species, currents may be an adversary which tends to transport larvae from the spawning grounds to a hostile environment, while other species depend on suitable currents to transport eggs and larvae to a more favorable environment.

The nekton, swimming organisms as opposed to plankton which are drifters, are predominantly fish. The feeding habits of nekton vary by species size, season, and food availability. Small fish and the young of some larger species often feed on plankton. There are also very large species, whales, basking sharks, and sunfish, for example, which are plankton feeders. Other fish, squid, and benthic invertebrates are also common food of the nektonic species. While adults of many commercially important species of fish of the northwest Atlantic continental shelf may be classified as either fish or invertebrate feeders, such a classification is not likely to be valid for all life stages. Some nektonic species, notably silver hake and *Loligo* squid, feed on their own young. This ability of nektons to select and maintain a desired location allows groups of individuals of a particular species to obtain a desired spawning location with some consistency year after year. Such groups are called stocks and though they may mix with other stocks some of the time they are generally isolated during the breeding season. The stock structure of several species of the region requires considerably more investigation to be understood.

Benthic organisms are those living on the bottom or within the bottom sediments. They are not capable of moving freely by swimming. Among the most important of the factors determining distributions of benthic species are the composition of the sediment and the stability of the physical environment. Benthic communities play an important role in the flow of energy and material through the ecosystem. The primary source of food of the benthos is sinking organic matter. There are also benthic predators and scavengers, such as shrimp, crabs, and lobsters. While the benthos is dependent on sinking organic matter for food, many benthic species such as lobsters, sea scallops, and surf clams interact with the plankton and nekton in the water column in their larval stages. Therefore the abundance of these species depends on the interaction of their larvae with planktonic predators and prey and on the transport of larvae by currents to suitable benthic environments.

Unlike most terrestrial ecosystems where the standing crop of primary producers far exceeds that of all consumers, the standing crop of primary producers in the coastal water ecosystems is often far lower than the standing crop of the zooplankton, nekton, and benthos. Thus standing crop information may shed little light on the productivity of the system. As with all ecosystems, the production rate of a trophic level is lower than that of the preceding trophic level. Ultimately the sustainable yield of any fish stock is limited by its productivity, therefore the potential yield to man from the ecosystem is increased by exploiting lower trophic levels. The marine ecosystem does not separate itself out well by species into different trophic levels, as indeed many species would appear to occupy several trophic levels at different life stages.

A conceptual model of a fishery system

The fishery system of the northwest Atlantic continental shelf of the USA includes fishermen, fishing gear, processing facilities, and consumers, as well as the ecosystem described in the preceding section of this paper. Because of the overwhelming complexity of the system it is impractical to analyze in detail each interaction, therefore it is advisable to represent the system by a conceptual model in which components of the system with similar characteristics are grouped together and only activities of the system that significantly affect the responses of variables are considered. The entities of interest to the fishery system are the fish sought by fishermen, the food supply, and predators of the fish during all stages of their life cycle, the fishing gear--commercial and recreational--used to capture the fish, and the equipment used to process the fish. Each of these entities have attributes which affect the system's response to fishing. Attributes of the fish are the species, size, stage of life cycle, location, spawning area, food preferences, and their desirability by the fishery sector. Important attributes of food organisms are size, energy, content, and availability. For fish predators, attributes of interest are food preference and feeding rate. For fishing gear the attributes are relative efficiency at catching fish for each combination of species, size, or life cycle stage. Cost of operating the gear, the cost of transporting the gear to the grounds, and the unit or group of units using the gear, the rate at which combinations of species and size can be processed, the cost of processing, and markets are attributes of the processing facility. All of the varying marketing factors, consumer factors, and sociological factors such as those affecting employment policies, and traditional attitudes and habits of the fishermen and consumers are considered as exogenous factors at this stage of modeling. Since many entities of the system have some of the same attributes, one needs to consider the entities collectively, and this collectivity is referred to as a compartment. The number of entities in a compartment would be called the "level" of a compartment. Fish can be considered to be a compartment S of fish of species i, stock j, size group k, at time t. Food and predator organisms excluding those in S_{ijk} are assigned to compartments in such a manner that organisms in each of the compartments have a similar appeal as prey for, or similar feeding habits on, each S_{ijk}. Fishing gear can be grouped into compartments of similar operating and transportation course fishing power of each S_{ijk}. Each compartment of processing would contain equipment suitable for processing the same group of fish in about the same group of operating cost and capacity. The production of each compartment will be determined by exogenous factors, that is, factors affecting the activity of the system but not affected by any entity of the system, such as the amount of solar radiation, wind stress, or temperature. The net production of food is the difference between the exogenously determined production and the loss of food by predation and fishing activity. The net production of each fish compartment will depend on growth in fishing and natural mortality. As individuals of S_{ijk} grow and mature beyond limits of their compartment, they transfer to $S_{ijk}+1$. Furthermore, spawning results in transfer of the biomass from mature compartments of each species combination to the appropriate S_{ijk}. The net production of fishing gear or processing equipment is the result of capital investment and depreciation. These are the results of exogenous factors such as availability of the product from other sources, prevailing interest rates, etc., interacting with the supply available on the fishing grounds. The result of fishing depends on the temporal and spacial pattern of fishing and on the gear used. Since the distribution of S_{ijk} is dynamic in time and space, Q_{ijkmt} can be used to represent the proportion of S_{ijk} in area m at time t. The gradual influx of fish from other areas to area m might be envisioned as a diffusion process, therefore:

$$C_{ijt} = \sum_{\substack{\text{over} \\ \text{all} \\ l,\, m}} \sum E_{lmt} \cdot R_{ijklm} \cdot S_{ijklm} \cdot Q_{ijkmt}$$

where C_{ijkt} is the rate that species i, stock j, and size k are caught at time t; E_{lmt} is the rate at which gear l is fished in area m at time t; R_{ijklm} is the catch per unit time fishing per unit density of fish of species i, stock j, size group k, gear l in area m. S_{ijkm} and Q_{ijkmt} are defined as previously. This model can then be optimized for specific goals although this requires considerably more mathematical development. In any case, the model can be used to compare the likely outcome of several alternative exploitation schemes.

Discussion of this conceptual framework is useful as it focuses attention on the complexity of the system and our limited understanding of it. It is, however, pointless to extend the effort much beyond preliminary stages without more sound biological insight to determine the basic productivity of the system upon which various social and economic factors play. Most fishery biologists are well aware of the deficiencies in our understanding of the biology of early life stages of fish and the factors that determine year-class and strength. Initially, more restricted models of the system should be useful for some practical purposes in evaluating effects of fishery management strategies. However, the restricted models must be interpreted with the realization that they represent only a small portion of the total fishery system.

Problems of stock definition

Although the biological definition of a stock is as has been defined previously, it is usually used slightly differently, for purposes of fisheries management, as a "group" of fish (most often of one species but in certain unique instances of more than one species) within a specified area, which is the object of a fishery or fisheries--that "group" having similar biological characteristics, such as growth and mortality rates, and a similar response to the effects of fishing. Thus, for management uses, stocks are dynamic units. The precision for which one defines a biological component of stocks depends upon the precision with which one wishes to make management allocations and the extent to which the maximum productivity of each component of the system is desired to be harvested. Therefore such units will always be changing as management needs change, and should thus be viewed. A couple of illustrations of these should suffice.

Cod

Cod in ICNAF SA 5 and 6 are currently grouped into two stocks for management: Div. 5Y and Div. 5Z. However, within this area there are probably a number of separate populations. Wise (1962) identified four major groups: Georges Bank east of 68°, Gulf of Maine, Southern New England including the Great South Channel, and New Jersey coastal area. There is undoubtedly some movement between these areas, especially the latter two. There is also apparently some exchange between Georges Bank and Browns Bank (Div. 4X). Cod are considered within ICNAF Div. 4X to be two separate groups for management: inshore and offshore stocks. Cod are found both inshore and offshore throughout most of their range, with the inshore range extending virtually to the shore. The Gulf of Maine, although considered by Wise (1962) to be a single stock, may also have localized spawning stocks which may be critical to certain commercial and sport fishery interests.

Herring

Herring in SA 5 and 6 are currently assessed and managed as two stocks: the Gulf of Maine (Div. 5Y) and Georges Bank-Mid Atlantic (Div. 5Z and SA 6). Two additional stocks are managed in Div. 4WX. Recent Canadian herring tagging studies (Stobo, 1976) have demonstrated the relationships between herring from all four presently defined stocks although the degree of intermixture is unknown. There are three major spawning areas in the Gulf of Maine-Georges Bank region: Georges Bank-Nantucket Shoals (these two areas are, however, not contiguous), Jeffreys Ledge, and Lurcher Shoals. Other smaller spawning stocks also exist. There is considerable seasonal movement of both juvenile and adult herring throughout this general area which undoubtedly results in fish which are spawned in one stock area possibly being fished at certain times in another stock area. Their origin of recruiting fish, particularly with respect to Div. 5Y-Div. 4WX stocks is of critical concern with respect to the adult stock assessment.

Mackerel

Mackerel are found from Labrador to North Carolina, and two major spawning groups have been located: a southern group spawning in April and May south of Cape Cod in SA 5 and 6, and a northern component spawning in the Gulf of St. Lawrence (SA 4) in June and July. Both groups probably overwinter primarily between Georges Bank and Cape Hatteras. Since 1975 all mackerel within ICNAF has been assessed as a unit stock and separated later into areal TAC's.

Other flounders

A more complex "unit stock" is the management unit for other flounders. This group includes winter flounder, summer flounder, witch flounder, American plaice, windowpane flounder, Atlantic halibut, and fourspot flounder. Within some of these species there are undoubtedly certain discrete stocks which would be specific management consideration if the needs of localized fisheries harvesting these stocks were to become a priority for consideration.

It is therefore obvious from this brief review that while there are underlying biological components that basically define a genetic stock unit, the actual use of such stocks in management has to be an iterative process determined between the economic and sociological management goals and the productivity of the fishery system. Only as the productivity of the system becomes better understood can the allocation problems resulting from socioeconomic goals be solved without risking either deprivation of the system or extreme underutilization of the productivity.

Fisheries units for management

Fisheries, as we discussed earlier with the conceptual model, are a group of harvesting units with similar characteristics, harvesting similar products for the same general processing and consumer process. Thus, fisheries are basically an economic unit. Ultimately, the decision as to which economic grouping of units to call a fishery is one which has to be made within a specific time frame and for specific goals. Thus there are dynamic definitions constantly changing depending on the management decisions. There are a number of traditional fisheries in the USA - redfish, the Maine sardine, the Gulf of Maine offshore herring, the Gulf of Maine mixed groundfish fishery, the Gulf of Maine food whiting fishery, an offshore Georges Bank, Nantucket Shoals, groundfish fishery (cod, haddock, and pollock). The mixed fishery at Cape Cod ports, the flounder fishery of New Bedford, the Point Judith-Long Island mixed fishery, a mixed trawl fishery in the Middle Atlantic, a mixed trawl fishery at Hampton, Virginia, river herring fisheries, scallop fishery, a shrimp fishery in the Gulf of Maine, offshore lobster fishery, all with varying, interacting components. In addition, in the same area, are major recreational fisheries. These sport fishermen take cod, pollock, mackerel, silver hake, haddock, flounders, fluke, scup, among other species. Canada also has specific fisheries in the area, a Gulf of Maine adult herring fishery, a groundfish fishery on Georges Bank, and a scallop fishery on Georges Bank. A possible classification of the distant-water fleets fisheries could be as follows (from the viewpoint of a coastal state which provides a greater lumping within the distant-water fleet fisheries than the countries themselves might do): The USSR purse seine herring fishery, the pelagic trawl fisheries for hakes, and other fish - e.g. argentines and dogfish (Cuba, USSR), the pelagic trawl fisheries for herring, mackerel, and squid (Bulgaria, Cuba, Federal Republic of Germany, German Democratic Republic, Poland, Romania, and the USSR), the squid-butterfish fishery (Italy, Japan and Spain), other non-ICNAF countries such as Ireland and Greece also occasionally have vessels in ICNAF Subarea 5 and Statistical Area 6.

To illustrate the complexity of the problem of defining fisheries, a few examples should suffice. Until recently, the New Bedford flounder fishery has been considered a major fishery unit, in fact, it has often been considered to be "the New Bedford yellowtail flounder fishery". This fishery consists of boats operating out of the home port of New Bedford, Massachusetts. Presently, the species of flounder sought are yellowtail, winter flounder, summer flounder, witch flounder, American plaice, and windowpane flounder, with yellowtail accounting for 65% of the catch in 1975, with winter flounder second at 21%, windowpane 8%, and the others each less than 4% of the flounder landed. New Bedford landings of yellowtail made up 64% of the total yellowtail landed in New England, and their total flounder catch was 28% of the flounder landed in the area. Although New Bedford-based boats land primarily in New Bedford, at various times, due to pricing strictures, vessels land at adjacent ports. Although the yellowtail flounder are differentiated apparently into three groups, the Cape Cod stock, Georges Bank stock, and those in the Southern New England-Middle Atlantic area, and the Cape Cod and combined with the Southern New England stock for management purposes, the fishing boats operate on all of them as one unit with the exception that the smaller boats are not capable of going to Georges Bank in the rougher weather season as the largest boats do. The summer flounder enters this fishery with an eastwardly migration occurring in the summer months. Although the majority of the flounder landed are taken in the New Bedford flounder fishery, significant yellowtail on both Nantucket Shoals and particularly the areas in the Middle Atlantic are captured by vessels fishing in mixed fisheries from the ports to the south of New Bedford. On Georges Bank vessels in the mixed groundfish fishery operating out of ports such as Boston, Gloucester, harvest flounders as a by-catch in the cod-haddock-pollock fisheries. The sport fishermen make major harvests of summer flounder in the Middle Atlantic and Southern New England area, and of winter flounder throughout the region. In turn, the New Bedford flounder vessels have significant catches of cod, haddock, pollock, silver hake, and red hake and occasionally bring inother mixed groundfish such as goosefish. The utilization of species now discarded, such as dogfish, would further complicate the mixed nature of the landings from this fleet. Although no distant-water fleets currently engage in directed yellowtail flounder fishing, yellowtail flounder does occur as by-catches wherever bottom trawling gear is fished on the Georges Bank-Southern New England yellowtail grounds. Fluke entered the squid fisheries in the Middle Atlantic area during the winter months, again as a by-catch. All of these interacting factors must be taken into account in consideration of management directives and improving the conditions of the New Bedford flounder fishery.

A second fishery of definite increasing interest to management is the recreational fisheries in the Gulf of Maine. Although annual statistics for this fishery do not exist, surveys have been taken during 1960, 1965, and 1970. Allocation problems with commercial fishermen come primarily from those private or party boats which are fishing in the open ocean on stocks of fish being fished commercially concurrently. The extent to which sport fish harvest concentrates on the same stocks as commercial fishermen or are limited to localized inshore is not known due both to the lack of adequate catch/effort statistics and understanding of stock structures. A prime example of these are the party boats which fish Stellwagen Bay in May, June, and September, alongside commercial vessels which harvest this area during the May to December period. The principal species involved in both sport and commercial fisheries are mackerel, winter flounder, cod, pollock, haddock. In 1970, mackerel produced more landings than any other species taken in the recreational fishery in this area, an estimated 6,000 tons in the New York-New England area (the exact amount in the Gulf of Maine is not known), more than twice the recorded commercial USA landings in that area. Approximately 13,500 metric tons of cod were taken by sport fishermen in 1970 in the New York-New England area. The winter flounder is the third most popular sports fish species in terms of the number taken in the New York-New England

In 1970 an estimated 2.9 million winter flounder were taken, mostly by privately-owned boats fishing with hook and line on the bottoms, resulting in about 1,350 metric tons of flounder in 1970 compared to the 1,080 metric tons landed by the commercial fishermen in the Gulf of Maine in that year. Pollock, like cod, are taken year-round. According to the 1970 survey about 2.2 million pollock, totalling 2,250 metric tons were taken by sports fishermen, almost twice the commercial catch at that time. Sports fishermen in 1970 harvested an estimated total weight of 1,150 metric tons of haddock, almost equal to that taken by the commercial fishermen in the Gulf of Maine. Other species which are regularly caught in the sport fishery are scup, searobins, and tautog, which enter only minor amounts into the commercial fishery, but could increase in importance as more discard is utilized.

The squid-butterfish fishery provides another example of the complex interactions involved in defining fisheries. This fishery is primarily directed at Loligo squid but also takes Illex squid in significant quantities. In addition, there is a major component directed toward butterfish. This fishery is conducted from late fall to early spring, when butterfish and squid are in the slope waters. By-catch in 1974 of other species amounted to 15%, consisting of such species as silver hake, red hake, flounder, mackerel, crabs, and lobsters. Other species such as scup and black sea bass have been observed in some catches. All of the by-catch fishery species are objects of directed fish catches by other nations' fisheries. The butterfish supply is an inshore mixed fishery in the summertime at a period of time when that year's production has already been harvested in part prior to becoming available to the inshore gear. Likewise, Loligo and Illex enter the inshore mixed fishery. Furthermore, there are significant quantities of squid taken for bait in the sport fisheries and not entered into the statistics. Sport fishermen have expressed a desire to have a significant quantity of squid remain unharvested to provide an optimum food supply to obtain maximum growth of desired sport fish species such as striped bass. The squid fishery in itself, has to be shared between vessels from Japan, Italy and Spain, which have directed fisheries during the same period but fish slightly differently as they do not harvest the same amount of butterfish. These differences, as well as other national differences with the distant-water fleet categories listed earlier, complicate the task of management to achieve credible allocations of the yield. The Illex squid enters into pelagic fisheries as a by-catch of the fleets directed at herring and mackerel in seasons later in the year than the Japanese directed fisheries.

It can be seen from this discussion that defining a fishery is not an easy task. Whenone has decided upon specific management goals then the fisheries can be defined and the interaction with other fisheries taken into account in the actualization process. This is the problem facing the establishment of management regimes.

Management planning

The first step in development of a management plan for the offshore fisheries of the continental shelf of the northeast United States is the establishment of appropriate management goals. These goals are determined by economic, social and political factors. Having decided upon these goals, the problem arises as to whether the ecosystem is capable of meeting these goals. Where management and harvesting interests have been directed to a very small portion of the total foodfish ecosystem, then the biological information on productivity necessary to decide to what extent the resource is capable of supplying these goals is relatively simple. Where the entire resource is under utilization, at different times by many different fisheries, many of which harvest several components of the resource, the ability to meet the optimum desired goals of each segment of the fishery is unlikely. Several terms have been used in consideration of the goals of management. Full utilization of the fisheries has been defined as requiring that all fish within the size range customarily considered usable be harvested. Here again, in a single-stock fishery with relatively little else being harvested in the same environment, such a policy would be feasible and appropriate biological estimates of the amount of production could be made. Even in this case there remains to be considered the difficulty in the ability to have appropriate assessment knowledge of the stock. Therefore, it would be desirable to build a method into the system to avoid catastrophes. Given the present state of stock and recruitment knowledge, the maintenance of a spawning stock size larger (two-thirds rather than one-half maximum size-Doubleday, 1976) than that which would give the maximum sustainable yield is desirable. This also provides a buffer against collapse of the stock based on environmental fluctuations causing year-class failures combined with excessive fishing mortality driving the stock size too low for maximum productivity, thus setting into effect a downward spiral in productivity resulting from the stock and recruitment relationship.

Maximum economic yield is another goal that has been stated as desirable for fisheries management. This has often been considered as maximizing income to the primary harvesters, but with further refinements could take on a broader connotation. Usually this has been approached by determining the catch per unit effort which gives the maximum net economic gain over the cost of the effort. Again, this is conceptually simple if, in fact, the species and stocks have no interaction with other species which themselves are also not fluctuating radically under the demands of other fishing pressures. It is difficult in the Northwest Atlantic to select such a single-species fishery to maximize the economic yield when one is trying to maximize a much larger total yield from the system in terms of net economic return to a fleet which harvest several species and where, in turn, several fisheries harvest the same stocks. A very complex matrix of cause and effect must be considered along the lines of the conceptual models discussed earlier.

The term 'optimum sustainable yield' has become popular recently. This has the virtue of being obscure. Everyone is in favor of optimizing the yield. The only question is, whose optimum in the face of a multitude of conflicting interests? Optimizing the catch per unit effort in a sport fishery may well require a much larger stock size tham optimizing the maximum economic yield from the commercial fleet harvesting the same stock. Similarly, determining or optimizing criteria for fisheries, harvesting several stocks and sharing these with others, would appear almost an impossibility. Considering that even if a very fine mix of decisions of desirable optimums can be established for all fisheries operating in this area, the ability of fishery biologists to estimate the productivity factors within the stocks is a near impossibility at the current state of the knowledge of the ecosystem. Furthermore, even if the productivity were well defined, it is not the result of productivity alone that determines the harvest, but that productivity combined with its availability to those harvesting it. Therefore, while the first object is to estimate potential total yield from the entire system and the second is to estimate the potential yield from various components of that situation at differing values of other components adjusted for size consideration. The third is to determine the availability factors which would affect the ability to harvest the allocation.

At current levels of knowledge, where we lack understanding of interactions between stocks and of the consequences on individual stocks of regulations made on the whole, and the lack of ability to predict the abiotic effects on recruitment processes, mortality rates, etc., it is important to take a conservative approach that attempts at this stage to maintain spawning stock size at a level above that which best current estimates would give maximum sustainable yield. This also provides a buffer against poor estimates of the size stock needed and our lack of understanding of the effect of perturbations in stock size on the entire system.

The first level of approach to the problem of the exact amount harvest involving both productivity and availability is to minimize the catch of species in other than the directed fisheries. This can be done through an approach of regulating gear, area, and seasons. In addition to regulations governing the yields of the entire system, each of these regulations, however, may increase the cost of harvest, and, therefore, the trade-offs economically must be investigated. Where two or more fisheries harvest, even on a directed basis, the same stock, the total productivity of the stocks may not be capable of being harvested due to the areal/seasonal effect of the harvest of one component of the fishes on the availability of the stock to the harvest by the other component.

In summary, it can be seen that management faces the problem of understanding the total productivity of the ecosystem and of its components in appropriate combinations of harvesting desires. Determining the optimization desired for the units and fisheries harvesting these resources should be based on an understanding of the socio-economic factors involved. Studies in these areas should enable more rational decisions to be made, with knowledge of the socio-economical consequences of such decisions for all components. The prime necessity is to determine the extent to which the underlying productivity of the ecosystem is capable of meeting these optimization goals. Only if these goals in total are well within the overall biological constraints of the system including adequate safety factors for the lack of the ability to obtain precise information on cause and effect factors in biological productivity and to maintain the greatest flexibility of the system to adjust to other options for optimality can these plans hope to achieve anything resembling a desired goal. These difficult choices must be made as the pressure to harvest more and more of the resource in all of its components continues to increase along side of desires of each segment of the fisheries to have maximum availability of the resource.

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Appendix to

A prospectus on the basis for fishery management on the Northwest Atlantic Continental Shelf off the coast of the United States of America

by

Bradford E. Brown
National Marine Fisheries Service
Northeast Fisheries Center
Woods Hole, Massachusetts 02543

Description of the ecosystem

by

Michael P. Sissenwine
National Marine Fisheries Service
Northeast Fisheries Center
Woods Hole, Massachusetts 02543 USA

Any area of nature that contains living organisms and non-living substances interacting to produce an exchange of material between the non-living and living parts of the system is called an ecosystem (Odum, 1959). The material of the ecosystem can be classified as belonging to the following fundamental groups which are necessary for the system to continue indefinitely: abiotic (non-living) substances; autotrophic organisms (primary producers) which are able to use abiotic material to store solar energy in the form of organic matter; and decomposers which break down organic matter, using its stored energy, to its inorganic constituents. Most ecosystems also have consumers which transfer organic material to another form using some of its stored energy for maintenance. The rate of transfer of material and energy between parts of the ecosystems is effected by the amount, type or condition of biotic and abiotic material in the system (biotic and abiotic factors, respectively).

Abiotic material

Most of the material on the Northwest Atlantic continental shelf of the United States is water. Water circulation of the area results from tidal forces, wind stress, pressure gradients and the Coriolis force. River flow is an important factor in many nearshore areas.

Tidal currents are distinguished from non-tidal circulation by their periodic nature (average period about 12 hours and 25 minutes). Pure tidal currents are uniform vertically except near the bottom where they are retarded by friction. In deep continental shelf waters, tidal currents are generally less than 5 cm/sec (Bumpus et al., 1973), but in constricted inshore areas and on some shallow banks the velocity of tidal currents may exceed this value by more than an order of magnitude.

Along the Northwest Atlantic continental shelf of the USA, the non-tidal transport is generally to the southwest. There may be a shoreward transport component during the warm months of the year and an offshore transport component during the colder months. The surface currents may be modified by varying wind stress (Bumpus, et al., 1973).

During the warmer part of the year large portions of the continental shelf are dominated by eddies instead of the more general southwesterly transport system. As summer approaches an anti-cyclonic (clockwise) eddy develops over Georges Bank, while a cyclonic (counterclockwise) eddy develops in the Gulf of Maine (Bumpus, 1975).

The temperature and salinity distributions of temperate continental shelf waters are usually cyclic with a one-year period. There is little difference in salinity lengthwise along the Northwest Atlantic continental shelf of the USA regardless of season and depth. The annual cycle of salinity results from the annual cycle of fresh water runoff and the indrafting of salty slope water along the bottom. Salinity is at its maximum at the end of winter. Spring stream runoff reduces salinity to its minimum by early summer, from which time salinity gradually increases due to indrafting from offshore. The salinity of the region increases with the distance from shore and increases with water depth during periods of high stream runoff. During winter, the salinity of the shelf is nearly uniform vertically (Bumpus,et al., 1973).

The temperature distribution of the shelf is chiefly affected by solar radiation. The water temperature reached its minimum during late winter at which time it is usually lowest in northern inshore areas and is nearly uniform vertically. On the other hand, the summer temperature distribution of the region is marked by a steep thermocline. The depth of the thermocline increase toward the southern end of the region as does the temperature of the water overlying the thermocline. Because of tidal and wind driven currents and turbulence in shallow areas such as Nantucket Shoals and Georges Bank, water temperature may remain nearly uniform vertically and usually several degrees Centigrade colder than surrounding areas during summer (Bumpus,et al., 1973 and Bumpus, 1975).

The primary producers of the continental shelf (mostly phytoplankton) store solar energy by converting oxygen, phosphorase, nitrogen and carbon into protoplasm which is eventually returned to an inorganic form by decomposers. Therefore, production of the region is linked to the abundance of these and some other chemical constituents of the marine environment (silica, trace metals, and some vitamins). While other chemical constituents may limit primary production in some local areas, nitrogen is generally the chemical limiting factor of production over the NW Atlantic continental shelf of the USA. The annual cycle of nutrients will be discussed simultaneously with the plankton community.

Annual cycle of the plankton community

A generalized representation of the annual cycles of a plankton community of the temperate zone is given in Figure 1. During the winter phytoplankton and zooplankton abundances are low in temperate continental shelf waters. Nutrients are available, but production is suppressed by low levels of solar radiation and temperature. There is disagreement as to the effect of water temperature on phytoplankton production. Steeman-Nielson (1960) stated that temperature has little influence on production in the sea but Eppley (1972) and Goldman and Carpenter (1974) reviewed numerous reports of phytoplankton production in laboratory experiments and concluded that the maximum production rate is determined by temperature.

As spring approaches and the level of solar radiation increases, an intense diatom bloom occurs. As the bloom progresses concentrations of inorganic nutrients decrease. Regeneration of nutrients by bacteria (particularly in the bottom sediments) is limited by the still low water temperatures. Holozooplankton populations remain low because the development of early life stages is slow at low temperatures.

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As water temperature increases during late spring and summer, zooplankton become abundant because of the more rapid development of early life stages, because of spawning of fish and benthos and because of the abundant food (phytoplankton) supply. But not all the zooplankton feed on phytoplankton. Fish larvae commonly feed on copepods (Sherman and Honey, 1971; Sherman and Perkins, 1971; Marak, 1960; Marak, 1974; all cited by Cohen, 1975). Some zooplankton, particularly Sagitta and Ctenophores are predators of fish larvae (Lillelund and Lasker, 1971; Therlacker and Lasker, 1974; Bigelow, 1926; Herman,et al., 1968; all cited by Cohen, 1975).

During summer, zooplankton abundances reach their maximum while phytoplankton abundances decline to nearly as low a level as during the winter minimum. The decline in phytoplankton abundance may be a result of predation and/or low nutrient levels. Dinoflagellates and other forms thought to be better suited to warm nutrient poor waters than are diatoms become more abundant during summer. Bacteria are active in the sediment regenerating nutrients, but because of the vertical temperature and salinity gradients, the water column is stable and nutrients are not returned to the euphotic zone. Some organic nitrogen and phosphorus excreted by zooplankton is available to phytoplankton for immediate use (Martin, 1968; McCarthy, 1972; Carpenter, et al., 1972). Because of mixing on Georges Bank, nutrients regenerated by the sedimentary bacteria are also immediately available to phytoplankton in this area, thus diatoms dominate throughout the year (Cohen, 1975).

During autumn, as the water temperature decreases, the water column becomes unstable and nutrients are renewed to the euphotic zone. This stimulates another phytoplankton bloom which is cut short by low levels of solar radiation. Phytoplankton and zooplankton levels then decline to their winter minimum while nutrient levels increase to their winter maximum.

The preceding discussion of the annual cycle of the plankton community ignores the importance of nannoplankton (small green flagellates) as primary producers. Little is known about nannoplankton because, due to their small size, they are seldom studied, but they may contribute significantly to the total primary production of the region (Cohen, 1975).

Anomalous years from the generalized annual cycles described above are probably common. The stability of the water column which effects nutrient availability may be disrupted by severe storms. Anomalies in temperature may disturb the timing between the annual cycles of interacting species. The possibility that the disruption by environmental factors, of the timing between the spawning of fish and the abundance of interacting planktonic prey or predator species is a factor important in determining year-class strength has not yet been explored (Cushing, 1973). The success of year-classes may also depend on the proper circulation to allow a large number of planktonic eggs and larvae to be maintained on or transported to a favorable nursery ground. For some species, currents are an adversary which tend to transport larvae from the spawning ground into a hostile environment (winter flounder, haddock, for example); while other species depend on suitable currents to transport eggs and larvae to a more favorable environment (menhaden, North Sea plaice, for example).

Nekton

The nekton (swimming organisms as opposed to plankton which are drifters) is predominantly fish, although there are nektonic mammals (whales and porpoise) and molluscs (squid). Nektonic species may be classified according to their association with the sea bed. Demersal species (flounder, haddock, cod) are those usually found near or on the bottom while pelagic species (herring, mackerel) are distributed throughout the water column over the continental shelf. It is difficult to classify some species into either category (silver hake, squid). Most of the traditional species sought by USA fishermen in the NW Atlantic are demersal.

The feeding habits of nekton vary by species, the size of the individual and probably with season and food availability. Small fish, including the young of some large species, often feed on plankton. There are also some very large species (whales, basking sharks and sunfish, for example) which are plankton feeders. Other fish, squid and small benthic invertebrates, are also common food of nektonic species. Maurer's (1975) work indicates that many commercially important species of the NW Atlantic continental shelf of the USA can be classified as either fish or invertebrate feeders (Figure 2), but such a classification is not likely to be valid for younger individuals of the species. Some nektonic species, notably silver hake and Loligo squid, for example, (Maurer, 1975; Vovk, 1972) feed on the young of their own species. Ricker (1954) suggested cannibalism as a possible form of compensatory mortality that would tend to stabilize the size of year-classes.

Nektonic organisms are distinguished from other biotic components of the ecosystem by their ability to distribute themselves over the continental shelf in a desired manner independent of the circulation of the region (although some species may use currents for transportation or orientation). This ability to migrate between locations or to maintain a desired location allows groups of individuals of a particular species to obtain a desired breeding location with some consistency year after year. Such groups are called stocks and though they may mix with other stocks some of the time, they are generally isolated from other members of their species during the breeding season (usually once each year). The stock structure of several species of the region is known (yellowtail flounder, cod, haddock) but it is unknown or a topic of debate for others (herring, silver hake, Loligo squid). Because of the stock structure of some species, declines in stock abundance in some areas, may not be compensated for by an influx of individuals from surrounding areas.

Benthos

Benthic organisms are those living on the bottom or within the bottom sediments. They are distinguished from demersal members of the nekton, who may rest on the bottom, by the latter's ability to move from one location to another by freely swimming in the water column.

Numerous factors determine the distribution and abundance of benthic species. Among the most important of these factors are the composition of the sediment and the stability of the physical environment (reflecting water depth). Thorson (1957) identified groups of species which are found in specific environments common to vast regions of the continental shelf. All benthic communities, to a greater or lesser degree, play an important role in the flow of energy and material through the ecosystem.

Except in shallow water where autotrophic macroalgae are common, the primary source of food of the benthos is sinking organic matter (phytoplankton, detritus). Many benthic organisms filter suspended matter from the water (suspension feeders). Most large bivalve molluscs (scallops, surf clams), some amphipods and anemones are suspension feeders. Other organisms find their food in the sediments (deposit feeders). Among the deposit feeders are polychaetes and some amphipods. There are also benthic predators and scavengers including shrimp, crabs, lobsters and gastropods. Ultimately, most of the energy and nutrients stored in organic material is released by the bacteria of the sediments. There are also marine bacteria in the water column, but these are of lesser importance in the recycling process (Russell-Hunter, 1970).

While the benthos is dependent on sinking organic matter for food, many benthic species interact with the plankton and nekton in the water column. These species have planktonic larvae (lobsters, sea scallops, surf clams) and therefore the abundance of their benthic stages depends on the interaction of larvae with planktonic predators and prey and on the transport of larvae by currents to a suitable benthic environment.

Discussion

Unlike most terrestrial ecosystems, where the standing crop of primary producers far exceeds that of all consumers, the standing crop of primary producers in coastal waters is often far lower than the standing crop of the zooplankton, nekton and benthos (see Riley, 1956 and Harvey, 1950 for example). As with all ecosystems, the production rate of each trophic level (the rate at which energy is stored) of the marine system is lower than the production rate of the preceding trophic level.

Ultimately, the sustainable yield of any fish stock is limited by its productivity. Therefore the potential yield to man from the ecosystem is increased by exploiting lower trophic levels, but the increased cost (in money and energy) of harvesting may exceed the realized gains. Furthermore, in the marine environment most species feed at several trophic levels during their life and it is often difficult to determine the trophic level of many adults.

A brief description of some aspects of a coastal ecosystem has been given above. This discussion was intended to indicate the degree of complexity of the system and the interdependence of system components. Determining the ultimate impact of man's exploitation of the ecosystem may require consideration of the system as a whole, although decisions on how to exploit components of the system must be made now with only a limited understanding of the entire systems.

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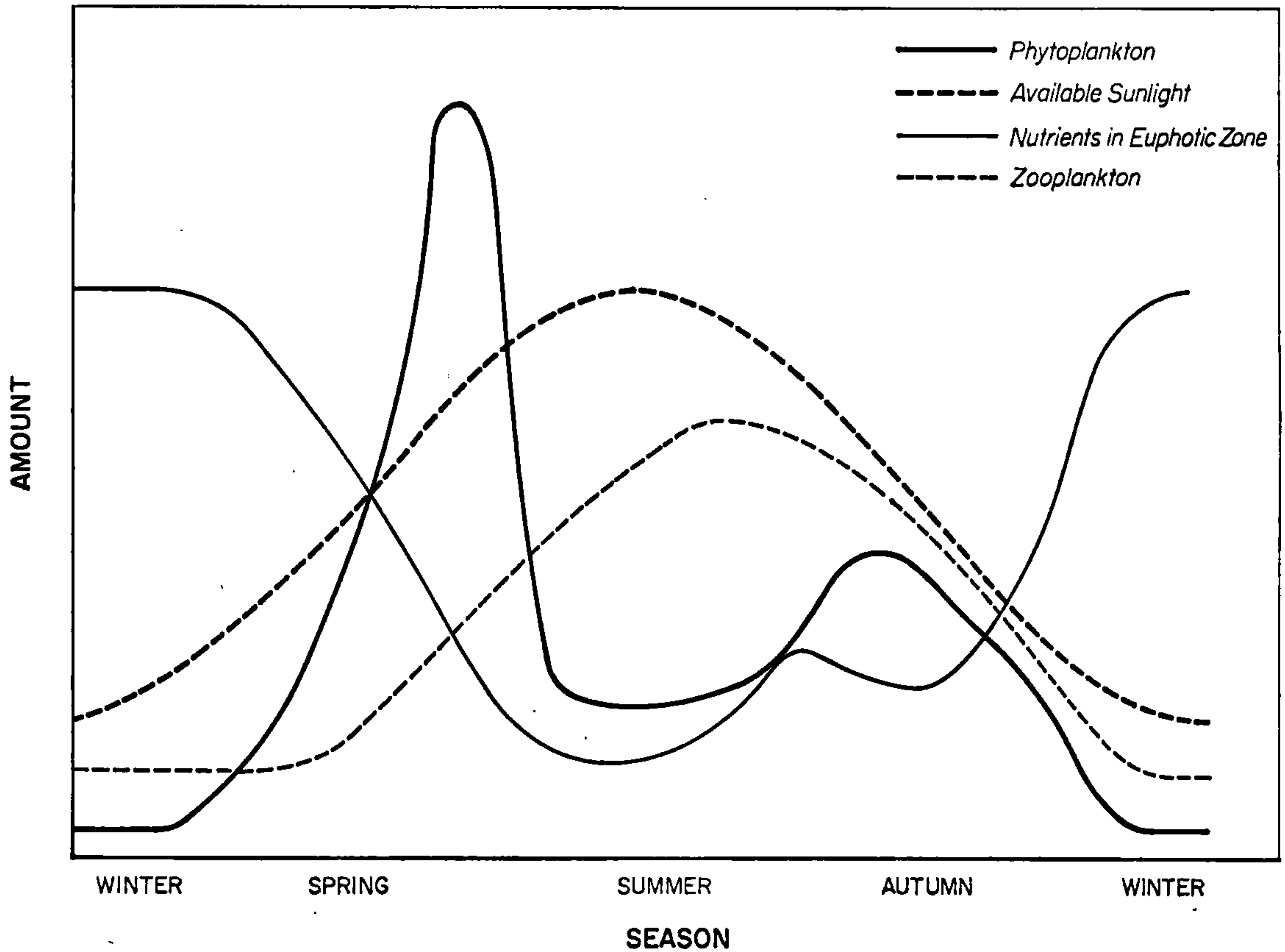

Figure 1. Generalized representation of annual cycle of the plankton community.

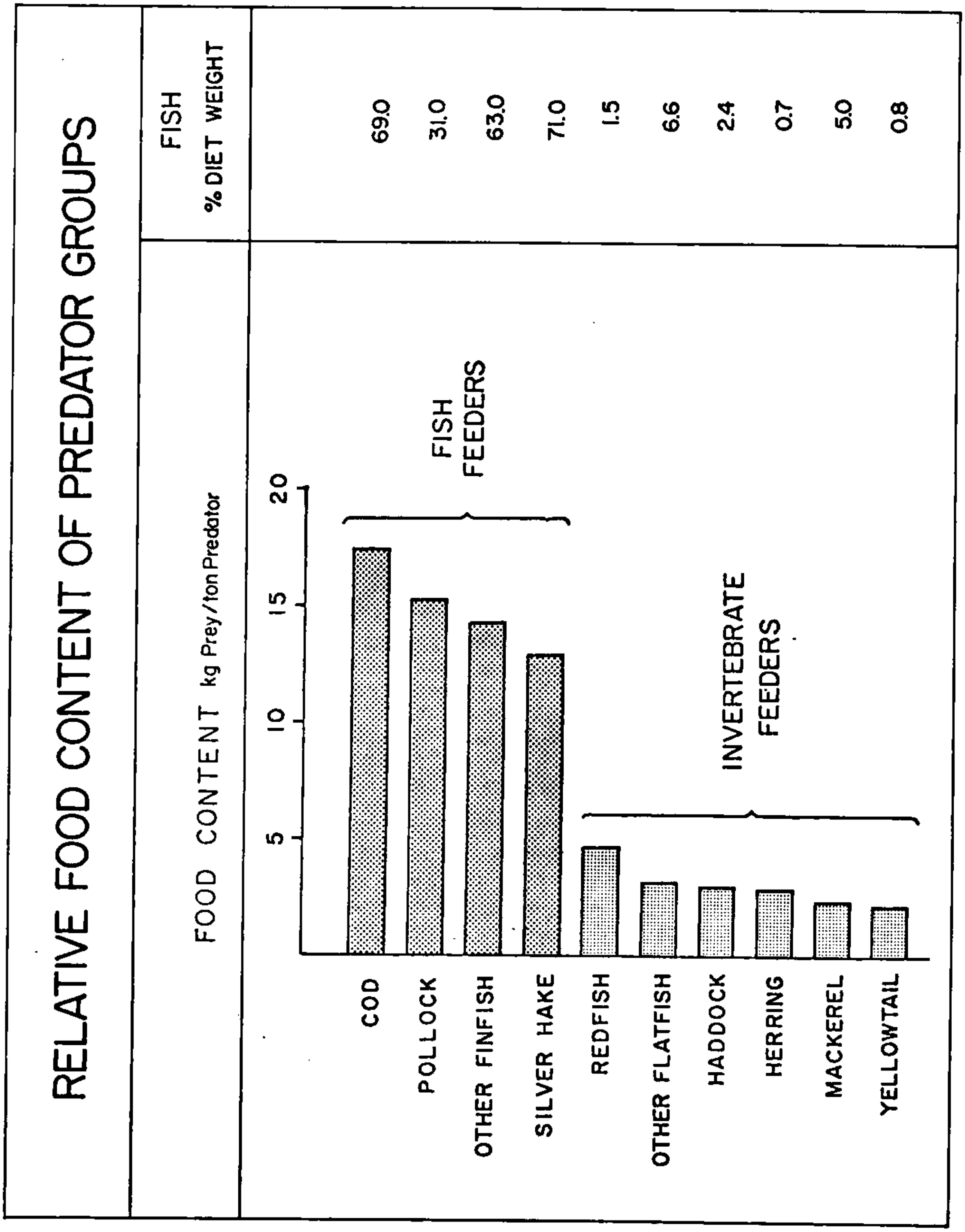

Figure 2. Relative food content of predator groups (from Maurer, 1975).

Conceptual model of a fishery system

by

Michael P. Sissenwine
National Marine Fisheries Service
Northeast Fisheries Center
Woods Hole, Massachusetts 02543 USA

The fishery system of the Northwest Atlantic continental shelf of the USA includes fishermen, fishing gear, processing facilities and employees and consumers as well as the ecosystem described in the preceding section of this document. Because of the overwhelming complexity of the system, it is impractical to analyze the effect of fishing on the system as a whole. Therefore it is advisable to represent the system by a conceptual model in which entities of the system with similar characteristics are grouped together and only activities of the system that significantly effect the response of variables to be controlled are considered. Such a conceptual model is outlined below. Although the model is far simpler than the real fishing system, it is still so complex that it is unlikely that adequate data will be available in the near future to permit its application to any specific fishery. The model might serve as a basis for further simplification.

For this discussion, a fishery will be defined by its areal expanse. The fishery of the NW Atlantic continental shelf of the USA will include all fishing activity of the specific area. The area considered should be vast enough to include the targets of fishing (fish, some macrobenthos and squid; all referred to generically as fish) for any time interval during which they suffer fishing mortality.

The entities of interest of the fishery system are the fish of any species sought by fishermen, the food supply and predators of the fish during all stages of their life cycle, the fishing gear (commercial and recreational) used to capture fish, the equipment used to process the fish, fishermen and other persons directly employed by the industry. Consumers are not included as entities in the model of the system, but they are an exogenous factor (factors effecting activities of a system, but not itself effected by the system). The exogenous factors reflecting consumers effect the price paid for processed fish.

Each of these entities has attributes which effect the system's response to fishing. Among the attributes of the fish are their species, their size or the stage of their life cycle, their location, the location at which they will spawn, their food preferences and their price to the processor. The important attributes of food organisms are their size, energy content and availability. For the fish predators, attributes of interest are the predator's food preference and feeding rate. Attributes of the fishing gear are its relative efficiency at catching fish for each combination of species and size or life cycle stage, the cost of operating the gear on the fishing ground, the cost of transporting the gear to the fishing ground and the nation using the gear. The rate at which fish of each combination of species and size can be processed, the cost of processing and the sales price of the processed fish are attributes of the processing facilities. Attributes of the fishermen and other persons employed by the industry are their income, where they live, the jobs they are capable of doing within the industry and their quality of life. The latter attribute is subjective and may be difficult to represent in a model, but may merit consideration in decision processes.

Since many entities of the system have some of the same attributes (for example, fish of the same species and size), it is appropriate to consider these entities collectively. A group of entities of the system with some of the same attributes is referred to collectively as a compartment. The number of entities of a compartment is called the level of the compartment.

For this conceptual model of a fishery system, fish are assigned to compartments by species, stock (location of breeding ground) and size. S_{ijk} is the compartment comprised of fish of species i, stock j and size group k. S_{ijkt} is the biomass of organisms in S_{ijk} at time t. The food and predator organisms (excluding those in S_{ijk}) are assigned to compartments in such a manner that organisms of each of these compartments have a similar appeal as prey to each S_{ijk} or have similar feeding habits on each S_{ijk}. For example, the typical food of demersal invertebrate feeders would be grouped together (polychaetes, amphipods, euphausiids). Fishing gear is grouped into compartments of similar operating and transportation cost and fishing power for each S_{ijk}. It may also be grouped by nation. Each compartment of processing equipment would contain equipment suitable for processing the same group of fish at about the same operating cost and capacity. Fishermen and employees of the industry are grouped into compartments according to where they live and the job they perform.

Activities of the fishery system considered in the conceptual model are fishing, the selling of fish and the production of the food of fish, the production of predators of fish, of fishing gear and of processing equipment and the associated employment of people of each job category-location compartment. The production of each food compartment will be determined by exogenous factors such as the amount of solar radiation, wind stress or temperature. In practice, food production might be described by a periodic function, unchanged from year to year. The net production of food is the difference between the exogenously determined production and the loss of food by predation and fishing activity. While planktonic food is probably not disturbed by fishing, some benthic invertebrates are likely to be lost as a result of the operation of a scallop dredge, for example.

The net production of fish predators will depend (at least in theory) on availability of prey (both fish and the food of fish) and the mortality caused by fishing. The net production of each fish compartment (S_{ijk}) will depend on growth and fishing and natural mortality. Natural mortality results from predation (because of the activity of the predator compartments and other fish compartments), possibly starvation and from other causes. Growth is a function of the amount of food available.

As individuals of S_{ijk} grow or mature beyond the limits of that compartment they are transferred to S_{ijk+1}. Furthermore, spawning occurs in a periodic pattern resulting in some transfer of biomass from mature compartments of each species-stock combination to the appropriate S_{ij1}.

The rate of fishing depends on the price paid for unprocessed fish, the cost of fishing (including operating cost and transportation cost), fisheries regulations, exogenous factors (such as the weather) and the availability of fish, fishing gear and fishermen. The rate of processing of fish depends on the price paid for processed fish by consumers, the availability of unprocessed fish, labor and processing equipment and profit realized from processing. Employment as fishermen or in processing facilities is a function of the level of fishing and processing activities.

The net production of fishing gear and processing equipment is a result of capital investment and depreciation. The rate of capital investment will be a function of exogenous factors (such as the overall state of the USA or world economy, the availability of the product from other sources, the prevailing interest rates), the price of fish, the profit of the industry and fishing regulations (which are an additional exogenous factor). The price of fish might be a function of the supply available from the fishery being considered or determined by exogenous factors (such as the supply available worldwide).

The result of fishing depends on the temporal and spatial pattern of fishing and gear used. The areal expanse of the fishery is divided into subareas. These subareas could be ICNAF areas, depth strata or geographic features. The catch per unit time fishing per unit density of fish for species i, stock j, size group k, gear l and area m, is represented by R_{ijklm}. The fishing power of gear l is probably less dependent on j than on i, k and m. Since the distribution of S_{ijk} is dynamic in time and space, Q_{ijkmt} is used to represent the proportion of S_{ijk} in area m at time t. Q_{ijkmt} is probably periodic with respect to t in the absence of fishery. For a population free from fishing mortality (both directed and by-catch), Q_{ijkmt} would vary with time in a manner adequate to represent the seasonal nature of the stocks distribution. With fishing however, Q_{ijkmt} for a specific area, m, might be substantially reduced. The gradual influx of fish from other areas to area m might be envisioned as a diffusion process. Therefore

$$C_{ijkt} = \sum_{\substack{\text{over all} \\ l,\, m}}\sum E_{lmt} \cdot R_{ijklm} \cdot S_{ijkt} \cdot Q_{ijkmt} \qquad (1)$$

where C_{ijkt} is the rate at which stock j of species i and size k is caught at time t. The amount of fish landed would be determined by multiplying C_{ijk} by 0 or 1 depending on whether or not the catch is discarded at sea or brought to shore.

In the preceding discussion, a conceptual model has been outlined. The model provides a framework within which the effect of fishing on the system can be investigated. Ultimately, the purpose of such a model is to determine the best (with respect to a specific goal) way to exploit the system within certain predetermined constraints. Typical goals of exploitation are to maximize food production by all nations or a specific group of nations, maximize total profit, maximize profit to fishermen or processors, maximize employment in all ports or specific ports, or maximize some subjective measure (such as quality of life). The strategy used to exploit the system will depend on the period over which the specific goal is to be pursued. For example, the desired rate of fishing to maximize the profit of fishermen is considerably higher if this goal is only to be pursued for one year than if it is to be pursued indefinitely. Similarly, the catch from a stock during a single year may far exceed the maximum sustainable yield of the stock.

The predetermined constraints that limit the manner in which the system is exploited may be imposed by man. For example, the minimum size which will be allowed for each stock may be specified. The exploitation strategy may also be constrained physically by such factors as the availability of gear or fishermen. The process of determining how to exploit the system in order to accomplish a specific goal within certain constraints is called optimization. The optimization process should specify such things as the rate to fish (number of days per year) with each gear type in each area for intervals of time throughout the year. The rate of capital investment may also be specified. Depending on the complexity of the representation of a specific fishery system, the optimization procedure may require some mathematical development. In any case, a model could be used to compare the likely outcome of several alternative exploitation schemes.

Discussion of a conceptual framework to represent a fishery is useful because it focuses attention on the complexity of the system and our limited understanding of it, but it seems pointless to extend the effort beyond such preliminary stages without more sound biological insight. Most fisheries biologists are well aware of the fact that we are deficient in our understanding of the biology of early life stages of fish and the factors that determine year-class strength.

Perhaps a more restricted model of some tractable parts of the system might be useful. The annual total allowable catch (TAC) of several stocks are set by ICNAF based on a projected stock size at the beginning of the year and a target stock size for the end of the year. The target stock size may be based on an estimate of the stock size corresponding to MSY, based on some minimum stock size below which recruitment failure is feared or it may be the long term mean stock size of the population. The fact that some of the catch is likely to result from by-catch as well as directed fishing is considered in setting the TAC. Using part of the conceptual model described above, it may be possible to specify an optimum (to accomplish some predetermined goal within constraints) fishing strategy resulting in the desired stock size (or possibly age-class structure) of each stock at the end of a year given initial stock sizes. Catch would be calculated in the same manner as in Equation (1). S_{ijkt} would be dependent on natural mortality (constant), growth (from growth functions), recruitment and losses to fishing. Recruitment might be based on a prerecruit index or assumed equal to the recruitment of the average of several preceding years. E_{lmt}, R_{ijklm} and Q_{ijkmt} are defined as before. The constraints imposed on the optimization procedure might include an upper bound on the amount of by-catch of young fish permitted (either in absolute numbers or as a percent of large fish).

Even this restricted model of the system requires considerably more information than is now available, but at least it should be possible to describe experiments and surveys which are necessary to apply this approach. R_{ijklm} may be estimated by comparing the catch per effort of gear l in area m with independent estimates of stock size (for ijk) based on virtual population analysis or tagging studies for example. Q_{ijkmt} is based on a comparison of the relative abundance of S_{ijk} between areas using the same gear. In some cases enough information about a single species may already be available to optimize fish in time and/or space. Based on experience with certain fisheries, there may be general agreement as to certain steps that can be taken to advance a particular goal without rigorous analysis.

The purpose of this discussion of a conceptual model of a fishery system was to stress that such steps should only serve as a useful prelude to more advanced optimization schemes which await further study.

Description of major stocks in ICNAF SA 5 and 6

by
Emory D. Anderson
National Marine Fisheries Service
Northeast Fisheries Center
Woods Hole, Massachusetts USA 02543

A fish stock can be defined, for the purpose of assessment and management, as a group of fish (most often of one species, but in certain unique instances of more than one species) within a specified area which is the object of a fishery or fisheries, have similar biological characteristics such as growth and mortality rates, and have a similar response to the effects of fishing. Unit stocks may be defined on the basis of various types of information, such as distributional limits; distinct spawning areas or times; exploitation by the same fishery and similarities in catch and effort data; similarities in age composition, year-class strength, mortality rates, etc.; tagging results; and similarities in morphological and physiological characteristics.

The following stocks are defined for the purpose of assessment and management within ICNAF and are delineated by ICNAF areas. In some cases, they represent units defined on the basis of information mentioned above; however, in other cases where precise information is lacking, they are defined by ICNAF areas to conform with the reporting of catch and sampling statistics.

Cod (*Gadus morhua*)

Cod in ICNAF SA 5 + 6 are currently grouped into two stocks: (1) Div. 5Y and (2) Div. 5Z. However, within this area there are probably a number of separate populations. Wise (1962), on the basis of tagging results and other evidence (commercial catches, parasite studies, and meristic studies), identified four major groups: (1) Georges Bank (east of 68°), (2) Gulf of Maine, (3) southern New England including the Great South Channel, and (4) New Jersey coastal area. There is apparently some movement between these areas, especially the latter two. There is also apparently some exchange between Georges Bank and Browns Bank (Div. 4X). Cod are found both inshore and offshore, their inshore range extending virtually to the shore.

There are no available estimates of the size of the Div. 5Y stock. Commercial catches averaged 7,100 tons during 1966-1975, but recreational catches, although relatively unknown, are possibly as large or larger than the commercial catch. The MSY is presently assumed to be 8,000 tons (Anderson, 1976a) based on average catches. The recommended 1977 TAC is 3,200 tons which corresponds to $F_{0.1}$. Recovery time to the MSY level was assumed to be approximately five years (Anderson, 1975a). Stock biomass, as measured by survey catch/tow, has fluctuated since 1963 and has declined steadily since 1968.

The Div. 5Z cod stock has remained relatively stable since 1963. MSY has been estimated to be 35,000 tons (Brown and Heyerdahl, 1972) which, at F_{max} corresponds to a stock biomass of about 150,000 tons. The recommended TAC for 1977 is 15,000 tons based on fishing mortality at $F_{0.1}$.

Haddock (*Melanogrammus aeglefinus*)

All of the haddock in SA 5 are managed as a unit stock. They are generally distributed throughout all of the Georges Bank-Gulf of Maine area with the Nantucket Shoals area being the southern limit to their range. Based on analyses of vertebral numbers, Clark and Vladykov (1960) concluded that all haddock in SA 5 belong to the same stock. Grosslein (1962),however, on the basis of tagging results, identified three distinct stocks: (1) Browns Bank and the inshore part of the Gulf of Maine south to the Great South Channel; (2) Georges Bank(east of 69° W);and (3) Nantucket Shoals to Cape Cod. Several Canadian tagging studies (reviewed by Halliday , 1974) also demonstrate a relationship between haddock in the Gulf of Maine (Div. 5Y) and Bay of Fundy-Browns Bank area (Div. 4X).

Haddock generally are found in depths of 45-135 meters (Bigelow and Schroeder, 1953) and consequently are not common to the coastal waters.

MSY for the SA 5 stock was estimated by Hennemuth (1969) to be 50,000 tons. This level of harvest was dependent on an average biomass level of 140,000 tons. Massive overexploitation in the mid-1960's coupled with poor recruitment since that time reduced the stock to very low levels. Some recovery has occurred since 1972, but the current biomass is still less than half of the pre-1960 level (Clark, 1976). A zero TAC is advised for 1977. However, unless recruitment improves substantially over recent levels, anticipated by-catch of haddock in other fisheries will prevent recovery of the stock to optimum levels.

Redfish (*Sebastes marinus*)

Redfish are found primarily north and east of Georges Bank throughout the Gulf of Maine and along the Scotian Shelf,but are also found in deep water along the southern slopes of Georges Bank. Little is known concerning distinct stocks of redfish, but the species appears to be very localized in distribution. For management in ICNAF, stocks have been defined as: (1) SA 5 and (2) Div. 4VWX. There may be some relationship between fish assigned to these two stocks. There are perhaps localized movements of redfish into shoal coastal waters on a seasonal basis contingent upon suitable water temperatures.

There are no available estimates of stock size, however,biomass has apparently declined steadily since 1968. The MSY for the SA 5 stock was estimated by Mayo (1975) at about 17,000 tons. Assuming M = 0.1 and F_{max} = 0.18 (Mayo and Miller, 1976), the MSY of 17,000 tons would correspond to a stock biomass of about 110,000 tons. A 1977 TAC of 9,000 tons was advised to reduce fishing mortality to a level below F_{MSY}. Since redfish is a long-lived, slow-growing species, recovery time to the MSY level will require a number of years.

Silver hake (*Merluccius bilinearis*)

Three silver hake stocks are currently defined for management by ICNAF: (1) Div. 5Y (Gulf of Maine), (2) Subdiv. 5Ze (Georges Bank), and (3) Subdiv. 5Zw-SA 6 (Southern New England-Middle Atlantic). Attempts have been made to identify discrete stocks in SA 5-6. Conover et al. (1961) reported two separate stocks on the basis of meristic differences, one in the Gulf of Maine and one south of Cape Cod. Tagging studies (Fritz; 1959, 1962, 1963) and analysis of otolith growth patterns (Nichy, 1969) similarly indicated two such separate stocks. Konstantinov and Noskov (1969) distinguished, on the basis of physiological differences, one stock on Georges Bank and another stock between Cape Cod and Cape Hatteras, with some apparent mixing of the two in the Nantucket Shoals area. Distribution patterns (Anderson, 1974) as well as other evidence, suggest that silver hake from the Gulf of Maine and from the northern part of Georges Bank comprise a single stock. Similar evidence also suggests that another unit stock extends from southeastern Georges Bank to Cape Hatteras.

Silver hake are widely distributed within SA 5+6, but are probably separate from the SA 4 stock(s). There is considerable inshore-offshore movement seasonally by this species, and in the summer it can be found within a few miles of shore.

The average sustained yield for the Div. 5Y stock, based on the exploitation of an average year-class at a fishing mortality rate of $F_{0.1}$ and with average patterns of fishing and mortality at age, is about 17,000 tons (Anderson, 1976a). This level of yield is based on a stock biomass of about 135,000 tons. This stock declined steadily from about 200,000 tons in the late 1950's to only about 20,000 tons in 1971, and has since increased to around 40,000 tons. The TAC advised for 1977 is 5,000 tons assuming fishing mortality at $F_{0.1}$. The time needed for recovery of the stock to optimal levels will be dependent on future recruitment and catch levels; a minimum of five years will probably be required.

The Subdiv. 5Ze stock has an estimated average sustainable yield of about 55,000 tons (Anderson, 1976a), which is dependent on a stock biomass of about 420,000 tons. Stock biomass increased from about 100,000 tons in the mid-1960's to about 800,000 tons in 1963 and then declined to 170,000 tons in 1970. Biomass has since improved to over 500,000 tons in 1975-1976. The recommended TAC for 1977 is 70,000 tons. The stock appears to be currently above the optimal level as the result of strong recruitment.

Average sustainable yield for the Subdiv. 5Zw-SA 6 stock is estimated to be 35,000 tons (Anderson, 1976 which corresponds to a stock biomass of 245,000 tons. This stock increased in size from about 60,000 tons in the mid-to-late-1950's to 440,000 tons in 1965. This was followed by a decline to about 75,000 tons in 1970. As the result of improved recruitment, stock biomass in 1975-1976 was about 320,000-340,000 tons, above the level associated with average sustainable yield. The advised TAC for 1977 is 55,000 tons.

Red hake (*Urophycis chuss*)

There are two red hake stocks currently under management in SA 5+6: (1) Subdiv. 5Ze (Georges Bank) and (2) Subdiv. 5Zw + SA 6 (southern New England-Middle Atlantic). These groups essentially conform with stock groupings indicated by Rikhter (1970). Red hake are also found in the Gulf of Maine but commercial catches have not been of sufficient magnitude to justify assessment and management.

MSY for the Subdiv. 5Ze stock is estimated to be about 20,000 tons (Anderson, 1976a). This level of catch, assuming fishing mortality at F_{max}, would require a stock biomass of about 47,000 tons. Assuming $F_{0.1}$, this level of stock biomass could support catches of about 12,000 tons. The TAC recommended for 1977 is 16,000 tons, the mean of two estimates of 12,000 and 20,000 tons. Rikhter (1976) estimated the 1976-1977 stock size to be about 60,000 tons. Biomass has fluctuated considerably since the early 1960's, reaching a low in about 1967 and undergoing a general upward trend since that time.

MSY for the Subdiv. 5Zw + SA 6 stock is approximately 40,000 tons (Rikhter, 1972; Anderson and Au, 1972) which corresponds to a stock size of about 95,000 tons assuming fishing mortality at F_{max}. At this stock biomass, fishing mortality at $F_{0.1}$ would generate a catch of about 23,000 tons. A 1977 TAC of 28,000 tons was recommended. Stock abundance has apparently improved in the last several years, although it has fluctuated since the 1960's.

Pollock (*Pollachius virens*)

Pollock in SA 5 and Div. 4VWX are presently considered to belong to the same stock and are managed accordingly in ICNAF. Tagging studies (Steele, 1963; Kohler, 1968) suggest the existence of separate groups of pollock in the Bay of Fundy, western Nova Scotia, and southern Gulf of Maine areas. Apparently the single major spawning area for pollock is in the western Gulf of Maine from Massachusetts Bay to the Isles of Shoals (Bigelow and Schroeder, 1953; Steele, 1963), although some spawning probably occurs to the east on the Scotian Shelf. Clark et al.(1976) provide a review of the available information relating to stock structure.

Pollock migrate between SA 4 and SA 5 seasonally as adults to spawn. Young-of-year pollock are found inshore during the summer and yearling or "harbor" pollock are found in large numbers inshore the following summer.

An assumed MSY for pollock is 55,000 tons which is based only on commercial catches and trawl survey indices of abundance (Anderson, 1976a). The recommended TAC for 1977 is 20,000 tons. Stock abundance declined from 1963 to a low in 1967-1968, then increased again, but has declined steadily since 1973 (Clark et al., 1976). Stock biomass was estimated to be about 120,000 tons in 1975 and is expected to decline further to 100,000 tons in 1977 (Clark et al., 1976). Since the level of biomass associated with equilibrium yield is not known, a recovery time to such a level cannot be precisely ascertained.

Yellowtail flounder (*Limanda ferruginea*)

The yellowtail flounder in SA 5+6 are grouped into two stocks for management: (1) SA 5 (east of 69° W) and (2) SA 5 (west of 69° W) and SA 6. Royce et al. (1959) and Lux (1963) indicated two stocks in SA 5, one on Georges Bank and the other off southern New England. A third, small stock is found along the east side of Cape Cod. Yellowtail flounder are also present in the northern part of the Gulf of Maine but are not sufficient to support a fishery. An additional group of yellowtail is found in SA 6 and extends as far south as Chesapeake Bay (Grosslein and Bowman, 1973). Since no distinct geographical or abundance density boundaries are known to exist between the southern New England and SA 6 yellowtail, it is unlikely that they represent discrete stocks (Parrack, 1974). These two groups and the Cape Cod stock are currently managed as a unit stock.

Brown and Hennemuth (1971) estimated the MSY for the Georges Bank stock (SA 5 east of 69^{o}) to be 9,000-18,000 tons. However, a value of 16,000 tons has generally been accepted and was set as the TAC for 1971-1976. Stock size has declined steadily since 1963 but appeared to stabilize initially under quota regulation. However, biomass has declined since 1974 and is expected to continue to decline as a result of poor recruitment. The TAC recommended for 1977 is 7,000 tons. Unless fishing mortality is reduced and recruitment improves, this stock will continue to decline.

The MSY for the southern New England portion of the SA 5 (west of 69^{o}) and SA 6 stock was estimated to be 16,000 tons (Brown and Hennemuth, 1971). Including the estimated MSY for the Cape Cod and SA 6 groups which was based only on average catches in recent years, the overall MSY for the SA 5 (west of 69^{o}) and SA 6 stock would be about 23,000 tons (Anderson, 1976a). This stock has declined dramatically since the mid-1960's and will continue to decline because of very poor recruitment (Parrack, 1974). In view of the depressed state of this stock, a zero TAC was recommended for 1977.

Flounders except yellowtail

This group includes winter flounder (*Pseudopleuronectes americanus*), summer flounder (*Paralichthys dentatus*), witch flounder (*Glyptocephalus cynoglossus*), American plaice (*Hippoglossoides platessoides*), windowpane flounder (*Scophthalmus aquosus*), Atlantic halibut (*Hippoglossus hippoglossus*), and fourspot flounder (*Paralichthys oblongus*). These species have collectively been regulated as a single stock in SA 5+6 by ICNAF. There are undoubtedly discrete stocks of each species distributed throughout the area. There is also possible overlap of some of these stocks into SA 4. Some, if not all, of these species range from offshore areas into estuarine areas.

There are no estimates available of stock biomass since removals occur in both commercial and recreational fisheries and catches from the latter are primarily unreported. Chang and Pacheco (1976) suggest an MSY for summer flounder of about 20,000 tons. The overall MSY for all of the flounders (except yellowtail) has been assumed to be 25,000 tons (Anderson, 1976a) on the basis of a total commercial catch since 1965 of 20,000-25,000 tons per year. Stock biomass for all flounders, as measured by survey catches, has declined drastically in the last decade (Clark and Brown, 1975). A TAC of 20,000 tons was recommended for 1977.

Herring (*Clupea harengus*)

Herring in SA 5+6 are currently assessed and managed as two stocks: (1) Gulf of Maine (Div. 5Y) and (2) Georges Bank-Middle Atlantic (Div. 5Z and SA 6). Two additional stocks are managed in Div. 4VWX. Recent Canadian tagging studies (Stobo, 1976a)have demonstrated interrelationships between herring from all four presently defined stocks, although the degree of intermixture is unknown. There are three major spawning areas in the Gulf of Maine-Georges Bank area (Anthony, 1972): (1) Georges Bank-Nantucket Shoals (Div. 5Z),(2) Jeffreys Ledge (Div. 5Y), and (3) Lurcher Shoals (Div. 4X). Other smaller spawning areas also exist. There is considerable seasonal migration of both juvenile and adult herring throughout this general area which undoubtedly results in fish being spawned in one stock area but being fished at certain times in other stock areas (Anthony, personal communication). The origin of recruiting fish, particularly with respect to the Div. 5Y-Div. 4VWX stocks, is of critical concern with respect to adult stock assessment. The juvenile herring fisheries are conducted within US and Canadian territorial waters and are not included in the assessment and management of the adult fisheries.

The MSY and optimum stock biomass for the Div. 5Y adult stock (age 4+) have been estimated as 50,000-60,000 tons and 100,000-120,000 tons, respectively (ICNAF, 1973). Equilibrium yield at the $F_{0.1}$ level is probably 20,000-40,000 tons, depending whether a low or high mean level of recruitment is assumed (Anthony, personal communication). Stock biomass declined from about 147,000 tons in 1967 to about 30,000 tons in 1973 (ICNAF, 1975), and was estimated at about 60,000 tons in 1976 (ICNAF, 1976). In order to maintain biomass at the minimum size constraint of 60,000 tons set by ICNAF, a zero TAC is recommended for 1977.

The adult stock in Div. 5Z and SA 6 has an MSY of about 250,000 tons and an optimum stock biomass of 500,000 tons (ICNAF, 1973). The equilibrium yield at $F_{0.1}$ is 120,000-180,000 tons (Anthony, personal communication). Stock biomass (age 4+) peaked at about 1.4 million tons in 1967, declined rapidly to 118,000 tons in 1973 (ICNAF, 1975), and was estimated to be 204,000 tons in 1976 (ICNAF, 1976). The TAC recommended for 1977 is 50,000 tons which will allow the stock to rebuild to 225,000-245,000 tons at the beginning of 1978 (ICNAF, 1976). However, a zero TAC for 1977 would permit a 20% increase in stock size in 1977 (Anthony, personal communication).

All herring stocks are presently in a depressed state due to excessive fishing and poor recruitment. Recovery to optimum levels will be contingent upon the production of some strong year-classes coupled with stringent controls on fishing mortality. In addition, the future management of the SA 4-6 herring stocks may require that they be treated as a unit stock to overcome the problems brought about by seasonal migrations and the uncertainties associated with the source(s) of recruitment.

Mackerel (*Scomber scombrus*)

Mackerel are found from Labrador (Parson, 1970) to North Carolina and consist of two major spawning groups which belong to one overall population (Sette, 1950). The southern group spawns in April-May south of Cape Cod in SA 5+6 while the northern component spawns in the Gulf of St. Lawrence (SA 4) in June-July. Both groups overwinter primarily between Georges Bank and Cape Hatteras.

Recent tagging experiments (Beckett et al., 1974; Parsons and Moores, 1974; Moores et al., 1975; Stobo, 1976b) have confirmed that some mackerel present in SA 3+4 during summer and autumn overwinter in SA 5+6 as far south as Delaware Bay. Both groups, therefore, support the intensive international fishery conducted during December-April in SA 5+6 (Anderson, 1975b). Moores et al. (1975) suggest that the northern component has been the dominant of the two in recent years and has supported the bulk of the winter-spring catch in SA 5+6. Their hypothesis is supported by observed similarities in growth rate, length-at-age, and age composition data from samples taken in SA 3+4 in the summer and in SA 5+6 in the winter, as well as other evidence. Since 1975, all mackerel in SA 3-6 have been assessed as a unit stock.

Within SA 5+6, the southern group ranges into coastal waters to spawn after overwintering offshore. While inshore (generally inside territorial waters) they are the object of an intensive recreational fishery.

Estimates of the MSY for mackerel include 310,000 tons (Anderson, 1973), 263,000 tons (Walter, 1975), and 313,000 tons (Walter, 1976). These values probably overestimate the long-term sustainable yield because of the effect of two strong year-classes on the catch and effort data used in the estimation procedures. The stock biomass associated with the estimate of 313,000 tons is about 1.25 million tons (Walter, 1976).

Mackerel biomass has apparently fluctuated widely historically. Measures of abundance are available, however, only from 1963 to the present (Anderson, 1976b). Biomass increased to a peak in 1969 and has declined steadily since. Biomass (age 1+) calculated from virtual population analysis peaked at 2.5 million tons in 1969 and declined to only 374,000 tons in 1976 (ICNAF, 1976). If the full TAC is taken in 1976, the 1977 biomass will be reduced further to only 137,000 tons. A zero TAC has been advised for 1977. Estimates are not available of the time required to rebuild this stock or even to what level it should be rebuilt, but it is obvious that the stock has been severely reduced by overfishing and that for the near-future, all surplus production should be utilized to rebuild the stock.

Other finfish

This category includes the remaining finfish species (except menhaden, billfishes, tunas, and large sharks) for which individual assessments are either not available or are available only in preliminary form. These species, which number between 40 and 50, have been regulated by a single TAC in SA 5+6. Obviously, the distribution of all these species within SA 5+6 is complex and is not totally defined. Many of these range into SA 4, and also in and out of present territorial waters in SA 5+6.

Quite obviously, an estimate of MSY for this component of the resource is very difficult to obtain. A TAC of 150,000 tons has been set each year since 1974 and is again advised for 1977. This level, based on recent commercial catches, could be considered as a rough first approximation of MSY. For 1977, advisory TAC's within the total of 150,000 tons are recommended for argentine (*Argentina silus*) (25,000 tons), dogfish (*Squalus acanthias* and *Mustelus canis*) (40,000 tons), butterfish (*Peprilus triacanthus*) (18,000 tons), and river herring (*Alosa pseudoharengus* and *A. aestivalis*) (10,000 tons).

According to research vessel survey catches, the relative abundance of this group of species has declined by 40% since 1963. Individual species, of course, have experienced changes in biomass of varying degrees. Ultimate recovery of the reduced species to higher levels in the future will be dependent on reductions in fishing mortality from by-catch in directed fisheries for more desired species.

Shortfin squid (*Illex illecebrosus*)

This species is found between Greenland and Florida, is most abundant in the Newfoundland region, and moderately abundant between Newfoundland and New Jersey (Mercer, 1965). There is a northward migrating component which is found in SA 2-4 during the warm months which moves to the southward to overwinter, possibly as far south as SA 5+6 (Mercer, 1975). It is found in SA 5+6 throughout the year, more predominantly in the warm months (Tibbetts, 1975), suggesting that part of the overall stock(s) is residual to SA 5+6. *Illex* migrates inshore to 10-15 meters of water in the spring and summer but moves offshore in late autumn to overwinter (Tibbetts, 1975). Very little is known concerning stock structure or relationships among possible stocks throughout the range. Consequently, the approach chosen by ICNAF in 1975 was to assess *Illex* as a single stock complex in SA 2-6.

Illex is fast growing and has a life span of only 12-16 months (Squires, 1967). Biomass has apparently increased in SA 5+6 in recent years based on trawl survey catches (Tibbetts, 1976). Recent estimates of minimum stock size were 100,000 tons in 1972 (Efanov and Puzhakov, 1975) and 90,000 tons in 1973 (Lipinski, unpublished data). Analyses of yield-per-recruit and stock-recruitment relationships suggest that yield could be about 40% of the biomass (Sissenwine and Tibbetts, 1976). However, reliable estimates of stock size are currently not available, and since the individuals present now will not be alive in 1977, and since a precise parent-progeny relationship has not been defined, there is no way of knowing exactly the 1977 stock size on which to advise a 1977 TAC. A TAC for 1977 of 55,000 tons was recommended for SA 2-6 (25,000 tons for SA 2-4 and 30,000 tons for SA 5+6). This maintains the TAC at the level of past years to regulate the orderly development of the fishery.

There are no estimates of sustainable yield for *Illex*. However, assuming a stock biomass of approximately 100,000 tons and an exploitation rate of 40-50%, an MSY of 40,000-50,000 tons could be expected.

Longfin squid (*Loligo pealei*)

This species is distributed primarily from Cape Hatteras to Corsair Canyon on Georges Bank (Tibbetts, 1975). It migrates inshore within territorial waters in spring and summer and overwinters at the edge of the continental shelf. *Loligo* are considered to be a single stock in SA 5+6. There does not appear to be any significant occurrence of this species in SA 4 waters.

Various estimates of stock biomass have been made for recent years. Ikeda and Sato (1976) indicated a stock of 92,000 tons in October 1972 and of 89,000 tons in October 1973. Tibbetts (1976) indicated an average minimum biomass of 84,000 tons for 1973-1975, and an increase in abundance since 1971. Based on yield-per-recruit and a moderate stock-recruitment relationship which indicated that maximum sustainable yield could be achieved with an exploitation rate of 40%, a 1977 TAC of 44,000 tons was advised. It is assumed, therefore, that the stock is presently at or near the optimum level.

Total biomass

Prior to 1960, the continental shelf waters in SA 5+6 were exploited almost exclusively by a coastal fleet of US vessels of under 300 gross registered tons. Catch as reported to ICNAF averaged less than 500,000 tons annually, a level substantially lower than MSY estimates of 900,000-950,000 tons obtained for the total finfish resource (Au, 1973; Brown *et al.*, 1973, in press). Historical data indicate that certain stocks were being exploited at or near their respective MSY points, but others were only being lightly exploited, if at all. Consequently, it appears that total biomass fluctuated around a substantially higher level than at present.

Distant water fleets entered the area in 1961, and since that year these fleets have been continually modernized and expanded. As a result, fishing effort and catch have increased greatly in recent years. Brown *et al.* (in press) estimated that during the 1961-1972 period standardized effort increased sixfold, while catch more than tripled. As a result, all major stocks in SA 5+6 are now fully exploited, and some,notably SA 5 haddock, Div. 5Z + SA 6 herring, and SA 5 (west of 69^{o}) + SA 6 yellowtail, have been demonstrably overfished (Hennemuth, 1969; Brown and Hennemuth, 1971; Schumacher and Anthony, 1972). In addition, catch as reported to ICNAF from 1971 to 1974 appears to have substantially exceeded the MSY point.

The above expansion in fishing effort has stimulated considerable interest in its effects on biomass levels and productivity. Recent analyses of research vessel survey data for 1963-1975 indicate that biomass has been reduced by approximately 50% during this period (Clark and Brown, 1975). Survey data further indicate sequential changes within the community in response to shifts in directed effort. Distant water fleets concentrated primarily on groundfish (e.g., haddock and hake) in the mid-1960's, shifting to herring and mackerel as groundfish abundance declined (Schumacher and Anthony, 1972; Anderson, 1973). The resulting sequential declines in groundfish and pelagic stocks are reflected in research vessel survey data (Clark and Brown, 1975). There is also evidence to suggest increases in certain stocks in response to exploitation. For example, squid abundance has increased dramatically in recent years, possibly in response to declines in finfish abundance, while strong year-classes of mackerel appeared in 1966 and 1967, possibly in response to declining abundance of herring. It should be noted, however, that such changes have not compensated for the declines in other stocks, and analyses to date do not indicate that any degree of stabilization has occurred (Clark and Brown, 1975).

Evidence for pronounced biomass declines, together with recent catch data, implies that a significant degree of overfishing has occurred and that the resource has been reduced below the level corresponding to maximum sustainable yield. Recent analyses suggest that biomass levels approximated 7 million tons prior to 1964, from which (allowing for the US coastal fishery) it may be inferred that the actual virgin biomass approximated 8-9 million tons (Clark and Brown, 1975). Under the assumptions of the Schaeffer yield model, maximum sustainable yield will be achieved at 50% of the maximum biomass (Schaefer, 1954); i.e., 4-4.5 million tons. However, total biomass was estimated at about 2 million tons at the beginning of 1975 (Clark and Brown, 1975)implying that a lengthy period of reduced exploitation will be required to rebuild the stock to the MSY level. The second-tier TAC for 1976 is 650,000 tons and was designed to initiate recovery to this point, although present information suggests that a minimum of seven years will be required (ICNAF, 1975). As the result of continued stock declines in 1975, the second-tier TAC for 1977 will probably be set in the area of 500,000 tons for SA 5+6.

Stock-recruitment

Fisheries scientists have long attempted to interpret the relationship between the size of the parent or spawning stock and the subsequent progeny or recruitment produced from that stock. Ricker (1954) and Beverton and Holt (1957) have developed basic mathematical stock-recruitment models to describe the theoretical effect of stock density on recruitment. Numerous others have set forth additional predictive models in attempts to describe and understand this relationship (see Parrish, 1973). In spite of the great progress made in this area, there remain significant gaps in the state of knowledge. Unfortunately, understanding of stock-recruitment relationships is vitally important to the successful management of exploited fish stocks.

Little work has been done on stock-recruitment for stocks in SA 5 + 6, except for haddock. Herrington (1941) found a dome-shaped recruitment curve from data for 1914-1940 which indicated that the best recruitment came from intermediate levels of spawning stock. Grosslein and Hennemuth (1973), however, using better data from 1931-1969, detected no clear stock-recruitment relation. Their data did suggest that the probability of good recruitment is reduced at extremely low spawning stock levels.

Lett et al. (1975a) derived a stock-recruitment relationship for mackerel in SA 3 - 6 which suggested a strong density dependence between spawning stock biomass and egg production which was modulated by environmental effects as measured by temperature. The relation ship between egg production and larval abundance was shown to be strongly density dependent through competition for food and predation. These relationships demonstrated that maximum recruitment is produced by a spawning stock biomass of 650,000 tons with symetrically declining recruitment from smaller and larger biomasses. Results of the most recent mackerel assessment (ICNAF, 1976) indicate that the 1974 spawning stock biomass was approximately at this optimal level (636,000 tons), but that the year-class produced from this parent stock was small (1.6 billion fish at age 1 compared to 7.0 billion in the 1967 year-class). Although the temperature factor is not considered here, it would appear that the parent-progeny relationship advocated by Lett et al. (1975a) is contradicted by this recent data.

Although there are no published accounts of stock-recruitment studies on herring in SA 5 + 6, numerous such studies on herring stocks in the Northeast Atlantic (e.g. Hempel, 1963; Cushing and Harris, 1973) have indicated relationships for a few stocks but generally either a considerable variation in the shape of curves between stocks or no apparent relationship at all. The lack of pronounced stock-recruitment relationships for herring stocks, as well as for virtually all other fish stocks, based on available fishery and survey statistics, is felt to be due to the strong influence of and interactions among a variety of biological and physical environmental factors. Both density-independent and density-dependent or compensatory mechanisms serve as limiting factors in the production of recruitment. Lett et al. (1976), in a simulation of the Gulf of St. Lawrence herring, indicated that recruitment is independent of stock size over a fairly wide range, and that a stock-recruitment relationship emerges only when the stock is collapsing as a result of overfishing. In order to derive stock recruitment models which will have a reliable predictive capability for management, it will be necessary to understand and measure the mechanisms and factors which determine the ultimate strength of a year-class of fish.

It is generally conceded that the strength of a year-class is established sometime during the first year of life. Unless the adult stock is reduced to an extremely low level of abundance, the absolute number of eggs spawned probably has little, if any, relationship to the ultimate size of the cohort. Instead, the survival of the eggs and larvae and hence the size of the year-class is virtually contingent upon the environment. The principal environmental factors which are critical to egg and larval survival include food, predation, disease and parasites, water temperature, wind and currents. There is obviously a complex interaction among these factors as they affect egg and larval survival. Templeman (1972) discussed many of these factors in relation to North Atlantic cod and haddock stocks.

Water temperature has probably been the most commonly monitored of all environmental factors, and consequently considerable temperature data exist. Numerous investigators have attempted, and often succeeded, to correlate temperature with year-class success. Temperature limits have been defined approximately for many species, at least for the adult stage. Time of spawning and length of incubation are generally governed by temperature. Timing of plankton blooms upon which larvae must feed is also determined largely by temperature. Templeman (1972) concluded that moderately low temperatures are favorable to the production and existence of large populations of cod and haddock, with lower temperatures to the north and higher temperatures to the south limiting year-class success. Anthony (1972) obtained a significant regression relating the percent change from spawning stock to recruitment and the temperature at the time of spawning. Cooler water temperatures appear to be favorable for the production of strong year-classes of yellowtail flounder. Lux (1964) and Sissenwine (1974) showed inverse relationships between temperature and abundance (year-class strength). Taylor et al. (1957) showed that fluctuations in mackerel catches during 1820-1890, which they assumed reflected variations in abundance, were correlated with temperature but that such a relationship was not evident in later years. MacKay (1967) related a strong 1959 year-class of mackerel to above-average water temperature in July-September in the Gulf of St. Lawrence and a poor 1962 year-class to below normal temperature. Lett et al. (1975a, 1975b, 1975c, 1976) in simulations of cod, herring, and mackerel stocks and fisheries in the Gulf of St. Lawrence have shown temperature to be the key environmental factor influencing year-class success.

Egg and larval drift induced by wind and currents is quite critical to year-class formation. Sette (1943) attributed the failure of the 1932 year-class of mackerel to extremely high mortality during the transitional stage from larvae to post-larvae caused to a large part by the prevalence of northeasterly winds which drifted the planktonic larvae farther than usual from their nursery grounds. Colton and Temple (1961) concluded that under average conditions most fish eggs and larvae are carried away from Georges Bank by the easterly-flowing slope-water current, and only under exceptional hydrographic conditions are appreciable numbers of eggs and larvae retained on the Bank or in nearby coastal areas. They felt that egg production for all species is always sufficent to produce a strong year-class, but that only a small percentage survive because of mortality at the egg and larval stages induced by drift and other factors.

In order for fish larvae to survive and grow, they must have an available supply of plankton on which to feed at the time of yolk absorption. Most larvae drift involuntarily for 4-5 months before complete metamorphosis occurs and they are able, as juveniles, to control their own distribution (Colton and Temple, 1961). Year-class size, therefore, is influenced by the availability of suitable prey during the pelagic stage. Ridgway (1975) reviewed the effects of food availability on herring survival and growth and indicated that prey density in late winter is one of the major factors controlling the size of a herring year-class. Sette (1943) suggested that the poor 1932 mackerel year-class was due, in part, to a general scarcity of plankton in the nursery grounds. Competition with other species for the available food supply is very critical in determining year-class strength, particularly if the food supply is not sufficient for all species. Data presented by Maurer (1975) suggest that herring and mackerel are possible competitors for food.

Predation on eggs and larvae is another important factor in that they are an important food component of many species. For example, moon snails, haddock, and cod are known predators of herring eggs while chaetognaths (*Sagitta)*, mackerel, silver hake, and adult herring prey on herring larvae (Ridgway, 1975). Lett et al. (1975a, 1976) suggest, as mentioned earlier, a strong density dependence between mackerel egg production and larval abundance through both competition for food and predation (cannibalism), and major influence on herring abundance through predation by adult mackerel on herring larvae.

Species interactions

It is fairly obvious that a given fish species cannot exist in the ecosystem without influencing or being influenced by other species. Scientists agree that intricate interrelationships occur in marine ecosystems, but they have only begun to examine and understand these complexities. Basic analyses of food habits indicate gross relationships among species. Food habits have generally been described for most species (e.g., Bigelow and Schroeder, 1953). Maurer (1975) has recently described some feeding relationships among various of the major commercially-exploited species in SA 5+6 (Table 1). Fish (including fish eggs) constitute a major part of the diet of cod and silver hake and at least a portion of the food of all species. Squid, which is rapidly becoming an important commercial species, is a significant component of the diet of some demersal species. Herring and mackerel were also shown to eat the same pelagic invertebrates, thus implying possible competition. Aspects of competition and predation between herring and mackerel were discussed earlier. It is interesting to note that mackerel biomass increased in the late 1960's in SA 5+6 simultaneously with a decline in herring biomass. Papers presented and discussions at the ICES "Symposium on the Changes in the North Sea Fish Stocks and their Causes" held at Aarhus, Denmark in 1975, suggest the possibility that recent increases in demersal species in the North Sea may be related to the decline in herring and mackerel.

In view of the extensive interspecific relationships which exist, it has become apparent that a single-species approach to fishery management is no longer adequate. Consequently, attention has been directed towards multi-species modeling and assessment. A first attempt to take some account of interspecific relationships was the second-tier TAC in SA 5+6 which began in 1974 and which was set at a level less than the sum of the individual species TACs.

Attempts have been made to apply mixed fisheries theory to stocks having possible biological interactions (Pope, 1976a, 1976b; Pope and Harris, 1975). The use of such models leads to the conclusion that the total yield from an interactive system would be less than the sum for the individual species.

The current knowledge of food habits, distribution patterns, etc. of fish species in SA 5+6 may suggest obvious species interactions. Recent fluctuations and trends in abundance of various species may also offer clues. Given initial information such as this, one could hypothesize a possible species interaction matrix. In order to define specific mechanisms of interaction, the use of complex multispecies models requiring basic biological and population dynamics parameters must be utilized (e.g., Parrish and Saila, 1970; Saila and Parrish, 1972; Andersen et al., 1973; Parrish, 1975). The future management of the marine resource in SA 5+6 (as well as elsewhere) which will insure optimum yield to the fisheries must be predicated on a comprehensive knowledge of the dynamics of all components of the resource and of the effects of each one upon the others.

Table 1. Predator-prey relationships expressed as grams prey per metric ton predator (from Maurer, 1975).

PREY	PREDATORS										
	COD	HADDOCK	REDFISH	YELLOWTAIL	OTHER FLATFISH	HERRING	MACKEREL	POLLOCK	S.HAKE	OTHER FINFISH	TOTAL
COD	-	-	-	-	-	-	-	-	-	-	-
HADDOCK	66	-	-	-	-	-	-	38	-	78	182
REDFISH	414	-	-	-	-	-	-	10	-	160	584
YELLOWTAIL	305	-	-	-	-	-	-	-	7	94	406
OTHER FLATFISH	280	-	-	-	-	-	-	-	-	259	539
HERRING	2592	-	-	-	-	-	-	22	1317	18	3949
MACKEREL	484	-	-	-	-	-	-	-	2406	1375	4265
POLLOCK	-	-	-	-	-	-	-	5	-	-	5
SILVER HAKE	115	-	-	-	153	-	50	222	322	337	1199
OTHER FINFISH[1]	7631	73	73	18	59	22	69	4486	5520	6714	24556
SQUID	-	-	-	-	124	-	17	-	266	1207	1614
OTHER INVER-TEBRATES	5399	2897	4578	2095	2869	2799	2238	10490	3415	3994	40774
TOTAL	17486	2970	4651	2113	3196	2821	2374	15273	12953	14236	78073

[1]This prey category includes other finfish, unidentifiable fish of all species, and fish eggs.

D 3

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The USA redfish fishery

by

R. Mayo
National Marine Fisheries Service
Northeast Fisheries Center
Woods Hole, Massachusetts 02543 USA

Redfish fishery

The USA fishery for redfish is currently being conducted in ICNAF Subarea 5 and Divisions 4VWX. Intensive fishing commenced in the mid-1930's with vessels initially fishing the closer areas in the Gulf of Maine and gradually proceeding to further grounds off Nova Scotia. Throughout the whole period, the fishery has undergone a series of expansions and contractions with vessels fishing at certain times as far as the Gulf of St. Lawrence and the Grand Banks off Newfoundland. The USA fishery is currently in a period of contraction.

Although redfish are thought to be distributed in small localized pockets throughout their geographical range, a number of traditional fishing grounds exist. Those within the Gulf of Maine include the northern part of the Great South Channel, areas off Cape Cod Highlands, Cashes Ledge, Fipennies Ledge, Platt's Bank, Jeffreys Bank, and off the coast of Maine along the 180 m depth contour.

The principal ports involved in the fishery are Portland and Rockland, Maine and Boston and Gloucester, Mass. Most of the vessels fishing on the Scotian Shelf are based in Portland and Rockland only. Vessels fishing in the Gulf of Maine range in size from 23-33 gross tons to 441-500 tons. In general, the smaller vessels, primarily out of Gloucester, fish the inshore areas while the larger vessels fish offshore grounds on extended trips of up to 10-12 days. The vessels fishing in Subarea 5 can and sometimes do alternate between the redfish and groundfish fisheries.

The dominant gear in this fishery is the bottom otter trawl and, due to the tendency of redfish to migrate off the bottom at night, most of the effort directed towards redfish is expended during daylight hours. Recently some attempts have been made to employ midwater trawls. The mesh size on the otter trawls varies between 64 and 130 mm.

Although redfish are caught throughout the year, a pronounced seasonality in the magnitude of the catches is evident. Catches are usually highest from February to July with the maximum occurring in April and May in the Gulf of Maine and in May and June on the Scotian Shelf. In the Gulf of Maine over 80% of the catch of redfish is taken on trips in which this species comprises over 80% of the catch. On the Scotian Shelf, over 95% of the redfish are landed on trips in which redfish comprise over 90% of the catch. Species occurring in the by-catch include such desired groundfish as pollock, cod, haddock, shrimp and silver hake as well as other miscellaneous species. The latter two are usually discarded.

Participation in the Subarea 5 redfish fishery by nations other than the USA began in 1958 with four metric tons caught by Canadian vessels. Since then, USSR and Canada have been the major non-USA participants in this fishery. In 1975, approximately 1600 tons out of a total catch of 10,674 tons were taken by these other countries, almost exclusively in Division 5Z.

Within Division 4VWX, the major participants in addition to the USA have been Canada, USSR, Japan, and Poland. In 1975, out of a total redfish catch of 27,940 tons, Canada accounted for 17,248, and was followed by USA with 5,465, USSR with 4,817, and Poland with 230 tons.

In the initial phase of the fishery, the USA catch from the Gulf of Maine alone rose from 519 tons in 1934 to 59,783 tons in 1941, and subsequently declined, reaching 30,077 tons in 1951, 11,375 tons in 1960, and 9,075 tons in 1975.

In the fishery in Division 4VWX, large catches did not occur until 1936 when 7,195 tons were landed by USA fishermen. The period of initial exploitation was complete by 1951 with a maximum catch of 77,142 tons occurring in 1949. This was followed by a longer period extending from 1952 to 1970 which was characterized by lower catches with fluctuations between 10,000 and 40,000 tons per year. Catches by distant water fleets caused a sharp rise in the total redfish catch from this area to 62,381 and 50,300 tons in 1971 and 1972, respectively. This total has subsequently declined to 32,819 tons in 1974 and 27,940 tons in 1975 under catch limitations.

US Juvenile Herring Fishery

by

Gordon Waring
National Marine Fisheries Service
Northeast Fisheries Center
Woods Hole, Massachusetts USA 02543

The juvenile herring fishery has been in existence at least since early in the 17th century when the first New England settlers observed Indians fishing for herring with brush weirs. The canning of "sardines" began in 1875 and was the leading fishery through the first half of the 20th century.

The fishery occurs almost entirely in the state of Maine and the catch of juvenile herring has fluctuated since 1880. From 1886-1916 the catch averaged 60,000 metric tons, then declined to 25,000 tons during the period 1917 to 1940. From the late forties through the fifties the catch levels resembled those of 1896-1916.

Historically the catch was primarily two year old fish with some contribution of one and three year olds. In recent years of low population abundance, older fish have entered the sardine processing system. Since 1963 the catch has been unusually and consistently small at about 30,000 tons or less. The 1975 catch amounted to 15,182 tons. The fishery usually begins in June and continues through November.

Since 1947 catches have been recorded by section along the Maine coast. These are western, central, and eastern sections. The ports that have or had sardine plants by section along the Maine coast are as follows: western - Bath, Yarmouth, and Boothbay Harbor*; central - Rockland, Belfast, Stonington, Prospect, Bass Harbor, Southwest Harbor, and Portland*; eastern - Milbridge, Machios Port, S. Goldsburgh, N. Perry*, Eastport*, Robinson*, Jonesport*, Cutler*, and Lubec*.

Since the 1950's catches began to decline in the eastern section and remained at about 5,000 tons during the 1960's and decreased to less than 1,000 tons in 1970 and 1971; by 1975 the catches increased to 4,528 tons. The catches in the western section steadily increased from 5,878 tons in 1951 to 31,029 tons in 1958 and provided a good fishery until 1964 when catches totaled 12,110 tons. The catches since 1964 have averaged 5,554 tons and have been the poorest since 1951. The 1975 catch totaled 1,169 tons. Catches in the central section averaged 24,657 tons during the period 1947-1966. After 1966 the catch of herring in the central section leveled off at approximately 10,000 tons due to catches of adult herring near the spawning grounds of Monhegan Island. The 1975 catches totaled 9,457 tons.

Of the various methods used in catching herring during the history of the fishery, only three are of importance today: weirs, stop seines, and purse seines. The weirs were historically the main gear employed by the fishermen, particularly in the eastern section where strong tides and long shallow bogs made stop seines

*no longer have sardine plants

impractical.

In 1949, 219 weirs were in operation in Maine. By 1975 the number of weirs was reduced to 28, 26 of which were in the eastern section and 2 of which were in the central section.

The number of weirs used for catching herring along the Maine coast exceeded the number of stop seines until the late 1950's. The catch by stop seine, however, surpassed that of weirs in the early forties when the catch in the western section became more important than the catch of herring in the eastern section. The change in type of gear was partially due to the decline in abundance of herring in the eastern section and the change to fishing in the western section where weirs cannot be easily used.

After 1965 when the catch of herring was poor, the number of stop seines declined rapidly throughout the coast of Maine. In the western section the decline was from 91 to 9 from 1962 to 1970, increasing to 26 in 1972 and down to 9 in 1975. In the central section the decline was from 80 to 19 from 1962 to 1970, increasing to 38 in 1972, and declining to 23 in 1975. In the eastern section the decline was from 36 to 8 from 1962 to 1970, increasing to 18 in 1976.

Purse seiners were in operation as early as 1890 near Boothbay Harbor, although a strong purse seine fishery never developed. During the middle fifties when the Maine catch of herring was large, an average of only three purse seiners fished for herring along the Maine coast. In the late sixties because of the decline in herring abundance there was an increased use of the purse seine to catch juvenile herring for the canning of sardines. The number of purse seiners increased to 24 in 1967 and declined to 6 in 1975 in the western section. In the central section the number increased to 22 in 1967 and declined to 15 in 1975. In the eastern section the number in 1975 was 1, declining from 8 in 1969.

In 1975 the catch in metric tons by gear along the Maine coast was 5,884 (purse seine), 6,867 (stop seine), and 2,417 (weirs), which accounted for 39%, 45%, and 16% of the catches, respectively.

USA Div 5Y adult herring fishery

by

Gordon T. Waring
National Marine Fisheries Service
Northeast Fisheries Center
Woods Hole, Massachusetts 02543 USA

The ICNAF Div 5Y fishery for adult herring in the Jeffreys Ledge and Cape Cod Bay areas became established in 1967 with a catch of 7,807 metric tons. The catch rapidly increased to a high of 42,900 tons in 1972 and then declined to 16,000, 18,000, and 20,000 tons in 1973-75.

The USA catches were initially taken by fishermen from the ports of Gloucester, Sandwich, and Provincetown, Massachusetts using purse seines, otter trawls, pound nets, and floating traps. In 1971 fishermen from various Maine ports, using purse seines, entered the fishery on a seasonal basis (prior to the start of the Maine juvenile fishery in June). The introduction of pair trawling by Pt. Judith, Rhode Island, fishermen in 1973, has resulted in an increase in USA catches. There were approximately 30 USA vessels in the fishery in 1975 averaging 63 feet in length and 25 years of age. The 1975 USA catch by gear type was 11,000 (purse seine), 5,000 (pair trawler), 300 (otter trawl), and 71 (fixed gear) metric tons.

While herring have been caught in all months, the fishery has traditionally increased in June, with the major portion of the catches being taken in August-October when the fish move to the fall spawning grounds on Jeffreys Ledge.

The largest single species by-catch is mackerel, with smaller quantities of alewives, bluebacks, and menhaden also being taken.

Nations other than the USA which have or are still fishing in this fishery include Bulgaria, Canada, France, Federal Republic of Germany (FRG), German Democratic Republic (GDR), Japan, Poland, Romania, and the USSR. The Canadian, GDR, and FRG fleets have traditionally taken the largest portion of the catch, other than the USA. In 1975 and 1976 no national allocations were given to countries other than the USA and Canada.

USA food silver hake fishery

by

Anne M. Tibbetts
National Marine Fisheries Service
Northeast Fisheries Center
Woods Hole, Massachusetts 02543 USA

The USA silver hake fishery, which began in the early 1840's had until the 1930's been concentrated primarily in inshore waters from Maine to Maryland. In the 1930's, with interest in the silver hake fishery increasing, operations extended offshore and the otter trawl became the primary gear. Essentially all present USA catch is taken by side trawlers, with small (less than 50 gross tons) vessels taking the greatest share.

Currently cathces from the Gulf of Maine and Georges Bank areas are landed in Gloucester and other ports as Portland, Maine and Provincetown, Massachusetts. Catches from Southern New England waters are landed primarily in Point Judith, Rhode Island, while Middle-Atlantic catches are brought, for the most part, into New York and New Jersey ports.

The present USA fishery is seasonal, with peak periods varying throughout SA 5-6. In Division 5Y, most catches are taken by small vessels making one-day trips in May-December. Since 1964, Jeffreys Ledge and Casco Bay (USA Statistical Area 513) have been the most productive grounds. Prior to that time, the greatest landings were taken from Stellwagen Bank and Cape Cod Bay grounds. Landings from SA 522 have been greater than those of SA 521 in seven of the last 20 years. The Subdivision 5Ze fishery off the edge of Cape Cod by day boats and on Cultivator Shoals by vessels making overnight trips is conducted primarily from June to September by medium-sized vessels (50-150 gross tons). Some vessels in these areas use nets with cod end mesh of 46-51 mm, while others use mesh as large as 130 mm particularly in the Gulf of Maine. Peak catches in Subdivision 5Zw occur in May-July, though silver hake are taken from this area throughout the year. Landings from USA Statistical Area 539, around Block Island, Rhode Island, are usually greater than from other areas of Southern New England. The USA fishery in SA 6 (primarily Division 6A) is conducted principally from November through May. Cod end mesh used in 5Zw varies from 40 mm to 64 mm and greater. The 5Zw-SA 6 catches are by vessels which are part of the Southern New England-Middle Atlantic mixed fishery.

The main by-catch problem in the silver hake fishery is not the inadvertent harvest of other species, but rather, capture of small unmarketable silver hake which are generally discarded at sea. These are taken throughout the year, but the major catches occur during the summer and autumn, primarily in Division 5Y and Subdivision 5Ze. Assorted mixed groundfish species and shrimp are also taken; marketable sizes are sorted out and landed.

Silver hake is commonly taken in the recreational fishery from Maine to North Carolina. They are caught by hook and line from shore or from inshore boats. Annual sport fishery catches are unknown, but angler surveys, conducted at five-year intervals since 1960, estimated the 1960, 1965, and 1970 silver hake catches to be 1,801, 2,717, and 950 MT, respectively.

The USSR is the only other nation which participates in a directed silver hake fishery, at the present time, though apparently incidental catches have been taken by other countries. The USSR fishery began in SA 5 in 1962 and in SA 6 in 1963, concentrating first on Georges Bank and then on the Southern New England-Middle Atlantic offshore areas. The fishery is somewhat seasonal, with March-April and June-August catches averaging about 65% of their yearly totals. Stock intermixture questions particularly between the fish on Cultivator Shoals and those in the Gulf of Maine hamper allocation decisions.

Catches from Division 5Y, almost exclusively by USA vessels, averaged 28,500 MT from 1955 to 1966, dropped to 14,650 MT in 1967, increased to 24,700 MT in 1968, but have declined steadily since, to about 5,000 MT in 1974 (with 580 MT caught by the USSR). USA landings in Subdivision 5Ze averaged 18,200 MT from 1955-1963. USA catches dropped to 5,500 MT in 1964 and have fluctuated between 14,000 and 880 MT since then, with a 1975 catch of about 4,600 MT. Foreign catches, mainly USSR, peaked at 238,870 MT in 1965, dropped sharply, and fluctuated between 18,400 MT and 77,500 MT since then, with about 52,000 MT caught in 1975. Total landings from Subdivision 5Zw and Statistical Area 6 averaged 12,400 MT from 1955 to 1962, increased to 136,050 MT in 1966. Since 1968, they have fluctuated between 18,300 and 65,100 MT until 1974. The 1975 total catch was 54,000 MT. USA landings in this area averaged 13,700 MT from 1955-1959, dropped to 8,151 MT in 1960, then increased to 25,000 MT in 1964. Declines in USA 5Zw-6 silver hake landings after 1965 are due, in part, to a decline in demand, in the industrial fishery concurrent with the greatest use of this species as food. USA catches in 1975 totaled about 8,260 MT in this area.

Gulf of Maine mixed fishery

by

Paul Wood
National Marine Fisheries Service
Northeast Fisheries Center
Woods Hole, Massachusetts 02543 USA

The predominant species comprising the Gulf of Maine mixed fishery are cod, haddock, pollock, the flounders (yellowtail, winter, witch, and American plaice), cusk, white hake, menhaden for industrial products, bluefin tuna, scallops, and lobsters. The preceding list excludes the following species, each of which constitutes, for the most part, a directed fishery: shrimp, redfish, silver hake or whiting, sea herring, and alewives or river herring. It should be noted that there are significant by-catches of some of those species comprising the mixed fishery in the directed shrimp fishery. Additionally, many of the shrimpers, from Maine ports, change gear in the spring and fish for mixed groundfish until late fall when they resume shrimping.

The grounds fished are Western Maine, Central Maine, the Inner Grounds, Stellwagen Bank, Jeffreys Ledge, the Middle Bank, off Seal Island, and Cashes Ledge. The larger ports where the catches are landed are Boston and Gloucester, in Massachusetts, and Portland and Rockland, in Maine; while there are numerous small ports in Maine from which the landings are taken overland, by truck, to processing plants in both Maine and Massachusetts.

The vessels involved in this fishery range in size from undertonnage to those of approximately 300 gross tons with the greater majority from 5-50 tons which make day trips. The gear fished may vary with the seasons, but include lobster pots, purse seines, gill nets, scallop dredges, line trawls, and otter trawls.

There is a small directed fishery in the winter for pollock on Jeffreys Ledge, which is their spawning ground. The by-catch of this fishery is mixed groundfish - mainly cod, white hake, cusk, angler, and some flounders.

The lobster fishery of the Gulf of Maine is an inshore fishery conducted from about April to September with many of the vessels changing gear in the winter to join the inshore shrimp fishery. Many of the shrimpers change gear in the spring and work the mixed groundfish and/or fish for menhaden in the summer. There is also a mixed industrial fishery conducted from late spring to early winter. The inshore sea scallop fishery is pursued from November to about May and, depending on abundance, may be joined by many vessels utilizing any type of gear that will successfully catch scallops.

USA offshore groundfish

by

M. M. McBride
National Marine Fisheries Service
Northeast Fisheries Center
Woods Hole, Massachusetts 02543 USA

The successful fishing efforts of the first New England settlers supplied the first American articles of export and laid the foundation for worldwide sea navigation and commerce. The earliest fishery was for cod which was sought exclusively for food until about 1818. After 1818, other species entered the market and by 1830, mackerel, herring, white hake, menhaden, shad, and halibut were taken extensively. Later haddock, whiting, flounders, and ocean perch became important in the offshore fisheries and were harvested on a grand scale. In recent years the demand and the commercial value of pollock has increased steadily. In Subdivision 5Ze, cod, haddock, and pollock constitute the major species of the USA groundfish fishery. These fish are mostly landed by both side and stern bottom otter trawlers in the ICNAF tonnage classes three or four (3 = 50 - 149.9 tons, 4 = 150 - 499.9 tons).

The USA cod fishery has changed greatly within the past 300 years of its existence. Originally an inshore fishery with hand lines and small boats,it moved offshore to banks as distant as the Grand Bank off Newfoundland and then retracted back to the Georges Bank area.

Since the early 1960's the annual USA cod landings have been about 15 million pounds. The magnitude of the fishery has greatly fluctuated since its onset, however, it has gradually been reduced as other fish species have become more essential to the industry.

When haddock abundance has been low, fishermen have landed more cod to supply the market demand for fish. Of the leading New England groundfish species, cod alone has been landed in ever increasing quantities during the past two decades.

Most cod caught by USA vessels are landed at New England ports, where there is a year-round fishery although the effort shifts locations along with seasonal changes in stock. Traditionally most were caught by large otter trawlers that fish out of Boston. Presently the most productive grounds are Georges Bank, Browns Bank and Nantucket Shoals but now New Bedford and Gloucester have become important.

During the first period of development of the New England haddock fishery, from the early 1900's to the early 1930's, landings peaked to about 115,000 tons in 1929, but then declined abruptly to about 26,000 tons in 1934.

The fishery then experienced a rather stable period after the early 1930's to the early 1960's, during which time catches and effort did not fluctuate markedly.

In 1953, a 4½ inch mesh regulation was introduced through ICNAF. Its true effectiveness will, perhaps, never be known, however it did serve to reduce the amount of discards which in effect dropped from 10-15% pre-regulation to 1%-5% post-regulation.

Georges Bank provides the bulk of USA haddock landings and is viewed as a prime example of how overfishing can negatively influence physical and economic yields. During the years from 1935 to 1960 the average stock size of haddock was approximately 140,000 MT, and was able to sustain landings of 50,000 MT annually, thus constituting a vital element of the New England fishing industry. The recruitment of an outstanding 1963 year-class induced a largely increased fishing effort by foreign fleets in 1965 and 1966, the result being a period of intense overfishing. Further overfishing throughout the 1960's went unregulated, and this, coupled with poor recruitment, prompted dramatic declines in stock abundance and in landings. This pattern of stock impoverishment led to establishment of a TAC of 12,000 MT for Subarea 5 in 1970-71. In 1972 the TAC was further reduced to 6,000 MT, and in 1974 the TAC reached the ultimate low of 0, allowing incidental catches only. Such a policy of catch limitation continued through 1976 with the TAC set at 6,000 MT, which was considered a realistic lower level where incidental catches were allowed.

Since 1970, the USA and Canada together accounted for 87% of the ICNAF landings during 1970-74; USA landings approximating 70% of the total figure. Spain has taken small amounts as by-catch in cod fisheries.

Historically, pollock has not been a prime species although closely related to the much sought after cod and haddock. The USA catch of pollock generally has been landed by boats fishing for these other species. Hence, there has been little opportunity to measure the fishing effort directed specifically toward pollock. Amounts landed have apparently been in answer to demand for the species rather than availability. Landings have fluctuated markedly since 1960, seemingly in response to changes in abundance of cod and haddock, and in response to shifts in directed effort.

The USA pollock fishery is conducted primarily in Subarea 5. In all the years since 1970, between 70% and 97% of USA pollock landings have come from this area, the remainder coming from SA 4. By 1967, USA landings in SA 5 had dropped to 34% of the former 1960 level. However, landings have increased since 1967, paralleling in 1975 the 1960 high of 8,186 MT.

The USA pollock fishery in SA 5Z has been roughly equivalent to that of Canada (total catch from 1964-1974 is approx. 24,000 MT for Canada and 26,000 MT for USA). Pollock landings at New England ports are highest in the fall and early winter during the spawning season which, on Georges Bank, last from December to February.

Although cod, pollock and haddock are the big three in USA offshore groundfish fishery other species are frequently landed. These include yellowtail flounder, winter flounder, American plaice, witch, summer flounder, sand dab, white hake, wolffish, cusk, halibut, silver hake and redfish.

Cape Cod ports mixed fishery

by

Paul W. Wood
National Marine Fisheries Service
Northeast Fisheries Center
Woods Hole, Massachusetts 02543 USA

This fishery is composed mainly of the day boats operating out of the ports south of Plymouth, Massachusetts, and east of New Bedford, Massachusetts. The ports from which vessels make significant catches in this fishery are Sandwich, Provincetown, and Chatham. The majority of the fishing is conducted in inshore waters, although there are offshore draggers, tuna seiners, offshore pot lobster vessels, swordfishing vessels, etc., operating out of these ports as well.

The vessels are, in the main, undertonnage vessels or vessels less than about 20 tons. A variety of fishing gear is utilized in this fishery including sink gill nets, handlines, longlines, otter trawls, traps or pound nets, scallop dredges, and purse seines. Many of the vessels vary the gear utilized during the year depending on the seasonal availability of the species sought.

The main species sought are cod, haddock, pollock, yellowtail and other flounders, whiting, herring, mackerel, scup, squid, bluefin tuna, striped bass, and scallops. Seasonal availability for some of the species are as follows: whiting - June to December; pollock - October to January; squid - summer; fluke - summer and fall; herring - December to March; and mackerel - fall.

New Bedford flounder fishery

by

W. L. Cain
National Marine Fisheries Service
Northeast Fisheries Center
Woods Hole, Massachusetts 02543 USA

The present day New Bedford flounder fishery is comprised of yellowtail, winter, summer, witch, American plaice, and windowpane flounder. The major species is yellowtail flounder which accounted for 65% of the flounder landed in 1975. Winter flounder was the second major species at 21% of the flounder landed. Windowpane, first landed in 1975, comprised 8%, and the other species were each less than 4% of the flounder landed. The New Bedford landings of yellowtail in 1975, although down from previous years, made up 64% of the total USA landings from SA 5 and 6, and 83% of the New England landings. Total other flounder were 28% of the USA landings and 58% of the New England landings from SA 5 and 6.

All the boats in the New Bedford flounder fishery are side or stern trawlers and, between 1964 and 1975, 60%-70% of those landing yellowtail were in the 50-150 tonnage class. All use the standard bottom otter trawl.

The other species caught on yellowtail and other flounder trips are cod, haddock, pollock, silver hake, and red hake. In 1974 the most abundant of the by-catch species on yellowtail trips were winter flounder, summer flounder, and cod. Witch flounder and haddock were next in abundance, followed by American plaice and pollock. Mixed groundfish, silver hake, red hake, and redfish were the least abundant although the discarded amounts would be highest in these categories.

The only flounders of recreational as well as commercial importance are the winter and summer flounder. In 1970, 11,197 MT of winter flounder were caught in the North Atlantic area (New England-New York). Statistics for the same year show 5,267 MT of summer flounder were caught.

The USSR and Canada are the primary foreign countries in the flounder fishery. In 1969 the USSR showed a yellowtail catch of 19,448 MT, a 600% increase over the previous year. The catch of other flounder showed a 500% increase over the previous year. In recent years (1973-1974), however, the USSR catch is down to 530 MT for other flounder. Nations reporting flounder catches at various times since 1965 have been Bulgaria, Canada, Cuba, France, FRB, GDR, Japan, Poland, Romania, Spain, USSR, and the United Kingdom. Currently there are by-catches.

Flounder had long been landed at New Bedford, but it did not become a chief flounder producing port until the late 1930's. With the decline of the winter flounder, yellowtail, once considered trash fish because of their thin fillets, became the major flounder landed--70% of the total fish in 1942. Other flounder were winter flounder, summer flounder, American plaice, and witch flounder. New Bedford had established itself as the chief flounder port and by 1949 landed 66% of the total annual yellowtail landings.

The increased fishing for yellowtail saw an immediate decline in the population and catch dropped from 31,107 MT in 1942 to a low of 5,789 MT in 1954. Since then the catch has climbed to 37,581 MT in 1964 but dropped again to 14,479 MT in 1970. Currently (1975) the catch is 8,723 MT.

With the decline of the yellowtail, the windowpane flounder has been landed for the first time in 1975. Previously discarded because it was even thinner than the yellowtail, the fishermen are looking to it as a substitute.

Southern New England and Long Island mixed fishery

by

R. Mayo
National Marine Fisheries Service
Northeast Fisheries Center
Woods Hole, Massachusetts 02543 USA

Mixed fisheries along the Southern New England and Long Island coasts are centered in the ports of Newport and Pt. Judith, Rhode Island and Greenport and Amagansett, Long Island. Most of the catch is taken from inshore fishing grounds and local inlets by day trip vessels, although some extended trips, principally from Newport and Pt. Judith, occur. The major grounds include Long Island Sound, Block Island Sound, Rhode Island Sound, Nomans, and areas off the southern coast of Long Island.

At the port of Pt. Judith, the largest of these ports, over half of the catch since 1969 has consisted of menhaden and mixed species landed for reduction purposes. This industrial fishery first began in 1949 at a number of New England ports, but in recent years only Pt. Judith vessels have consistently participated. However, since 1969, landings of this mixed category at Pt. Judith have declined from 25,000 tons to 5,400 tons in 1975. Concurrent with the steady decline in magnitude of the landings, this component has also undergone a shift in species composition from predominantly ocean pout, red hake, and sculpins in 1969 to silver hake, red hake, and ocean pout in 1975. The latter composition more closely agrees with that observed in the late 1950's. In addition to the mixed industrial species category at Pt. Judith, the major components of the fishery are flounders, scup, butterfish, and squid. Newport vessels have traditionally landed large quantities of yellowtail flounder, principally from the Southern New England grounds; however, in recent years this stock has undergone a sharp decline and summer flounder has become an increasingly important component of the landings at Newport and Pt. Judith. Some recent changes involving these two ports include Newport's current dominance of the offshore lobster fishery and the institution of a pair trawl fishery for sea herring and a longline fishery for swordfish at Pt. Judith.

At the Long Island ports of Amagansett, Greenport and Montauk primarily, the principal species include menhaden, summer flounder, silver hake, scup, butterfish, bluefish, striped bass, squeteague and squid in addition to large quantities of shellfish such as quahogs, surf clams, oysters, and lobster.

Most of the vessels involved in this Southern New England-Long Island fishery are small day trip boats of less than 50 gross tons using otter trawls. At Newport and Pt. Judith, some large purse seiners and steel hull stern trawlers are actively engaged in the fishery. In addition to otter trawls, fishermen on Long Island use fyke nets and haul seines to capture winter flounder and striped bass. Shellfish are harvested with tongs, dredges, and pots.

The availability of many of the species caught in this fishery varies seasonally. Those which are most abundant in the area from late spring to early autumn include summer flounder, menhaden, squid and lobster. Appearing slightly later in the year from early summer to late autumn are scup, bluefish, and striped bass. The occurrence of silver hake is most pronounced during the period from autumn to spring. Butterfish are caught consistently throughout the year, although some increase in landings is evident during summer months, probably due to increased effort rather than availability of the species.

As this is a mixed fishery with a number of species being sought throughout the year, the concept of a by-catch is not applicable. However, considerable conflict may exist between the commercial fishery and the recreational fishery in the area for two reasons. First, most of the fishing grounds are located close to shore and secondly, some of the species involved, such as bluefish, striped bass, and summer flounder are highly sought by sport fishermen.

Some of the species landed such as silver hake, butterfish, sea herring, and squid are taken from the same stocks which are fished in offshore waters by distant water fleets of GDR, Japan, Poland, and USSR.

This fishery is currently prospering as evidence by the recent fleet upgrading and gear innovations at Pt. Judith. However, continued dependence of Long Island ports on species which are also heavily fished in recreational fisheries is not favorable to future expansion. Increased yields in this fishery may be obtained under extended jurisdiction by seeking less traditional species such as butterfish, scup, and squid.

Middle Atlantic mixed fishery

by

Frank P. Almeida
National Marine Fisheries Service
Northeast Fisheries Center
Woods Hole, Massachusetts 02543 USA

The Middle Atlantic fishery is included in ICNAF Statistical Areas 6A and 6B. The fishery includes ports from three states, New York, New Jersey, and Delaware, with catches from New Jersey ports consistently making up the greatest percentage of the total annual landings. The major ports are: Port Monmouth, Atlantic City, Wildewood, and Cape May in New Jersey and Lewes, on Delaware Bay.

There are a large number of vessels operating in the Middle Atlantic, but the majority of them are boats less than five net tons in size (average of 89% since 1959). This large number of smaller vessels makes up the inshore or day boat fleet, working in the rivers and along the immediate coast. The larger vessels, those with a net tonnage greater than five tons, constitute the Middle Atlantic's offshore fleet.

There is a large variety of gears employed in the mixed fishery due to the variety of species available. The most effective offshore gear is the otter trawl, but purse seines, gill nets, scallop dredges, longlines, and pots are also used. In the inshore areas, otter trawls, weirs, pound nets, handlines, stake nets, haul seines, and pots are used.

From November to May, the primary fish caught by the offshore fleet are scup and fluke, with red and silver hake, sea bass, squid, butterfish, and some mackerel taken incidentally. May is usually the last month in which the offshore fleet has good catches of edible finfish until October. Lobsters are also caught in the fall and winter months but they are not as important a constituent of the total landings in those months.

Beginning in June and continuing through October, most of the vessels in the fleet concentrate on catching lobsters. Butterfish and sea scallops are also landed during this period.

The primary species caught by the inshore or day boat fishery are silver and red hake from November to June. Significant landings of yellowtail and cod are also caught during this period. By the end of May, the fluke, which have been offshore all winter, begin to migrate inshore to spawn in the bays and near the beaches along the shores of New Jersey, and become available to the inshore fishery. These fish remain close to the shore throughout the summer until they migrate offshore again in the fall. Accompanying the catches of fluke in the summer months there are also catches of weakfish, croacker, and bluefish.

Eleven species of fish out of a total of approximately 15 total species of which the commercial fisheries caught over 450 MT in 1974 are caught by both the commercial and recreational fisheries in the Middle Atlantic. These include bluefish, striped bass, mackerel, silver hake, red hake, scup, fluke, blackback flounder, weakfish, bluefin tuna, and cod. Of these 11, the most important to both fisheries are bluefish, striped bass, and fluke when they migrate inshore to spawn. There is also competition between the USA offshore commercial fishing fleet and the foreign distant water fleet. Japan catches cod, silver hake, yellowtail, scup, butterfish, and squid in ICNAF SA 6. Poland catches cod, scup, squid, and some silver hake. Bulgaria catches small amounts each of cod, silver hake, yellowtail, red hake, scup, butterfish,and squid. The GDR catches cod, scup, butterfish, and squid. Spain catches cod and squid. Romania lands silver hake, yellowtail, red hake, scup, butterfish, and squid. The USSR lands cod, silver hake, yellowtail, red hake, scup, butterfish, and squid. Of these countries and species, Japan catches more butterfish and squid than the USA, and the USSR catches more silver hake, mackerel, squid, and red hake than the USA.

River herring

by

R. Mayo
National Marine Fisheries Service
Northeast Fisheries Center
Woods Hole, Massachusetts 02543 USA

The USA river herring fishery has been of historic importance since the early colonial period. This fishery,located in estuaries and coastal rivers from Maine to Georgia, is based on two species of anadromous clupeids, the alewife and blueback herring. In general, alewives tend to predominate in the northern areas from New Jersey to Maine (the geographic range of the species extends north to Nova Scotia streams), while blueback herring are more numerous in the fishery from Chesapeake Bay to Georgia. The major areas of commercial activity are the Chesapeake Bay region and the New England coast. Within Chesapeake Bay a major pound net fishery exists in the James, York, Rappahannock and Potomac Rivers.

Virginia processing plants which pickle and can river herring are located in Mundy Pt., Reedville, Palmer, and Mt. Holly.

In the New England area, river herring are captured off the coast of Gloucester as a by-catch in the sea herring purse seine fishery and in a pound net fishery in coastal Maine streams.

Highly seasonal, this fishery only operates during the fishes' upstream spawning migration from March to May in the Chesapeake area and from April to June in New England.

In the Chesapeake Bay region, the major by-catch species in the pound nets are menhaden, sea herring and American shad. In addition, small amounts of white perch, summer flounder and striped bass are also caught.

Since the late 1960's there has been the offshore commercial fishery conducted by distant water fleets from Georges Bank to the area off Chesapeake Bay that harvested river herring primarily as a by-catch. This fishery, also conducted in the spring, commenced in 1966 when the USSR caught 6,500 tons, mostly from ICNAF Subarea 5. Since then, GDR began harvesting river herring in 1968, Bulgaria in 1969, and Poland in 1971. Catches increased until 1969 when a maximum of 61,419 tons were caught; the USSR accounted for 58% of the total while the USA fishery took 41%. In 1974 the total catch of river herring was only 16,320 tons. Of this total, the USA fishery accounted for 11,075 tons, GDR took 2,659 tons, Poland 1,088 tons, Bulgaria 773 tons, and USSR took 473 tons. From 1967 to 1974, approximately 70% of the offshore river herring catch caught off the USA east coast by other countries has been taken from ICNAF Subarea 5. Of particular concern in this offshore fishery is the high proportion of immature fish in the catch and the possible unequal fishing mortality on different home stream stocks.

Hampton, Virginia, trawl fishery

by

M. M. McBride
National Marine Fisheries Service
Northeast Fisheries Center
Woods Hole, Massachusetts USA 02543

The Hampton, Virginia, trawl fishery is the major port for off-shore fishing fisheries along the Virginia-Maryland coastline. The fishery is quite seasonal and the major species composition can vary greatly throughout the year. The main species of the fishery are summer flounder, fluke, scup, and sea bass. Other important species to the fishery are butterfish, squid, sea trout, lobster, whiting, mackerel, and croaker. Numerous other species are landed in lesser quantities. The largest trawl fishery operate in the winter months and some vessels move to northern ports in the summer.

For the state of Virginia, landings of the past five years (1971-1975) have been predominated by summer flounder, with a total of approximately 13,000,000 pounds taken. Scup is next in abundance with approximately 6,700,000 pounds landed, and sea bass stands thirdly with landings totaling approximately 5,000,000 pounds. The statewide trend for scup landings reflects a steady decline from 1971 to 1974. In 1975 there was a substantial increase in catch, but it remains considerably less than the 1971 level. Summer flounder landings, on the other hand, have been steadily improving since 1971. Landings of sea bass have dropped abruptly in 1974 after three preceding years of increase. However, 1975 landings again showed an increase, even surpassing that of 1973.

Fishing effort at Hampton correlates closely to those seasonal fluctuations in stock abundance which characterize the fishery. Summer flounder landings tend to drop during the spring and/or summer months. The particular months and the magnitude of decrease vary from year to year. Scup landings can show dramatic decreased during the summer and autumn months. In July of 1974, 9 trips were made out of Hampton in comparison to 37 that were made in April. These landings consisted almost entirely of summer flounder. In July of 1975, only 22 trips were made relative to the 49 that occurred during the previous month. Landings of sea bass generally show decline during the autumn months, and are highest around March.

Trips out usually do not extend over 6 days. Fishing is generally carried out with small or medium sized bottom otter trawlers (small=0-50 tons, medium=51-150 tons).

USA sea scallop fishery

by

Paul W. Wood
National Marine Fisheries Service
Northeast Fisheries Center
Woods Hole, Massachusetts USA 02543

The Atlantic sea scallop, *Placopecten magellanicus* (Gmelin), occurs from the Gulf of St. Lawrence to the Virginia Capes. Density levels sufficient to support a fishery are normally found at depths between 40-100 meters. The Hudson Canyon area has shown an appreciable contribution to the total catch, but the most consistent source of the sea scallop has been the Georges Bank area.

For the last 30 years (1946-1975), New Bedford has been the leading scallop port, with Provincetown and "other Maine ports" providing the remainder of the landings in the New England area. New England landings have constituted approximately 80% of the USA landings since 1946.

The majority of the New Bedford scallop vessels are between 50 and 200 gross tons, average 12-15 years of age, and are full-time scallopers. The gear utilized by these vessels is the scallop dredge. The by-catch of the scallop dredge is very minor (i.e. less than 100 metric tons per year), with three species comprising about 80% of the by-catch and divided fairly equally (yellowtail flounder, winter flounder, and--since ca. 1970--sea urchins).

USA landings of sea scallops from Georges Bank averaged 63,000 metric tons live weight (= meat weight x 8.33) per year during the period 1950-1964, with an historical peak of 89,000 MT occurring in 1961. In the last eleven years (1965-1975) the average annual landing has been about 9,500 MT.

Canada entered the sea scallop fishery on Georges Bank, to an appreciable degree, in 1951. From 1957 to 1962 her catch rose from .758 MT to 47,000 MT. Since 1962 Canadian catch has averaged approximately 42,000 MT. Both 1974 (50,900 MT) and 1975 (62,100 MT) exceeded that of any previous year.

Statistical Area 6 has been exclusively a USA fishery with the exception of a few years when Canada fished in the area. Only in the years 1965, 1966, and 1968 was Canada's catch significant; but the large catches in 1965-1966, combined with the USA catch, appear to be responsible for the rapid decline in stock to a level which has remained fairly constant since 1970.

Offshore lobsters

by

Thurston Burns
National Marine Fisheries Service
Northeast Fisheries Center
Woods Hole, Massachusetts 02543 USA

The US fishery for offshore (>12 miles) lobsters is presently being conducted from Georges Bank to Virginia. Until recently offshore lobster landings were of minor commercial importance, but with the advent (about 1969) of the offshore pot fishery, the catches increased significantly, peaked at about 8.4 million pounds in 1970 and have since declined to an estimated 5.9 million pounds in 1975. Because of incomplete reporting, numbers of landings sites, and odd times of landing, offshore lobster statistics are considered as estimates and actual catches may be considerably greater than those reported.

Canyon areas (Corsair, Lydonia, Oceanographer, Hydrographer, Veatch, Atlantic, Black, Hudson, Baltimore, Wilmington, Washington, and Norfolk)are fished intensively, but fishing is also conducted in inter-canyon areas, and seasonally closer to shore, as lobsters migrate into shallow water during the spring and summer. Most pot fishing occurs in the 35-150 fathom range although during the winter months the fishermen may fish deeper.

Currently, the offshore fishery is centered in Rhode Island and Massachusetts with approximately 74% of the 1974 and 81% of the 1975 catch being landed in these two states. In Rhode Island, Point Judith and Newport are the principal ports, while Sandwich, Harwichport, Westport, and Boston are the major ports of landing for Massachusetts. South of New England, lobsters are landed primarily in Hampton and Norfolk, Virginia; Cape May, Atlantic Highlands, Belford, and Point Pleasant, New Jersey; Montauk, Greenport, and Hampton Bays, New York.

Otter trawling, the principal method of harvesting prior to 1972, is now only a seasonal operation (winter months) with the exception of a few vessels. The lobster pot vessels (approximately 117 in 1975) are small, ranging from 45-60 feet and fish 400-800 pots each, although some fish in excess of 1,000 pots from May to early December.

Offshore lobsters are harvested only by US and Canadian fishermenas the northern lobster has been declared a continental shelf fishery resource.

USA developing and developable fisheries

by

Wanda L. Cain
National Marine Fisheries Service
Northeast Fisheries Center
Woods Hole, Massachusetts USA 02543

With the decline in abundance of the more traditional food fishes the USA has had to look toward other species to supplement catches and income. Some of the species included ti this effort are: goosefish, squid, spiny dogfish, ocean pout, and red crabs.

Goosefish food landings have increased from 67 MT in 1971 to 641 MT (tails only) in 1975. It is probably not economically feasible to develop a directed fishery for this species, but it is possible to increase the landings by not discarding.

Of the two species of squid available in New England waters the longfin or winter squid (*Loligo pealei*) is mostly fished by the USA. It is available inshore from April to September and is trawled by boats from such ports as Point Judith, New Bedford, and Newport. Distant water fleets catch *Loligo* offshore during the winter months. The demand for *Loligo* has mostly been for the export market with only a small amount going toward domestic ethnic sales.

The shortfin or summer squid (*Illex illecebrosus*) is fished by the USA only in small quantities from April to September. *Illex* is used mostly for bait. Except for the *Illex* trap fisheries from Provincetown and Chatham, the squid is trawled. Foreign boats trawl for *Illex* during the same months but on the edge of the continental shelf, whereas the USA fishes on the shelf.

In 1975 1,593 tons of *Loligo* and 107 tons of *Illex* were landed. Presumably, the majority of this was *Loligo*. However, the 1976 preliminary catches indicate a significant increase.

The spiny dogfish is known to fishermen only as a nuisance fish. It is found in the industrial and food fishery of the United States in small quantities. The spiny dogfish is caught readily by longliners and trawlers but is usually thrown overboard. The rough skin of the dogfish has proved to be the largest problem in dressing the fish for industrial and food use, and although a small quantity is marketed in this country under the name of "grayfish", it does not share the popularity here as in Europe. The possibilities are good for utilization of the spiny dogfish in the industrial as well as the food fishery if the mechanical problems of dressing the fish can be overcome.

In 1975 only 2.2 MT of ocean pout were landed as food fish, a drop from 23.6 MT in 1972, 330 MT in 1965, and 1,450 MT in 1964. Most of the catch of ocean pout is in the industrial fishery. As recently as 1974 50% of the catch by weight in the industrial fishery was ocean pout. This has dropped to 5% in 1975 as ocean pout has given way to silver and red hake.

In past years ocean pout has been filleted and sold as food fish but a problem with a non-dangerous microsporidian parasite has made the fish aesthetically unpleasing to consumers. Ocean pout is, however, available for use as fish sticks, other fish items, or fillets if the parasite problem can be overcome.

The red crab fishery landed 308 MT in 1975. This is reduced from the 1973 landings of 549 MT. The fishery operated mainly out of southern New England ports. The gear used in the red crab fishery are either lobster pots or modified crab pots. In fact, most red crabs are caught incidental to the lobster fishery. However the development of a small directed red crab fishery to supplement declining more traditional species is likely.

USA-Gulf of Maine recreational 'party boat' fishery

by

Anne M. Tibbetts
National Marine Fisheries Service
Northeast Fisheries Center
Woods Hole, Massachusetts USA 02543

Salt water angling in the Gulf of Maine has reached proportions comparable to commercial catches for some species, with most fish species in inshore and estuarine waters as well as open ocean now being harvested by both commercial and recreational fishermen. Annual statistics for this sport fishery do not exist; however, angler surveys have been conducted at five-year intervals since 1960.

Sport fishing takes place over the entire Gulf of Maine, from Passamaquoddy Bay, Maine, to Cape Cod, Massachusetts; in tidal reaches of rivers and bays and in the open ocean; from beaches, jetties, and piers, and from a variety of vessel types. The main concern of this report involves those private or party boats which are fishing in 'open' ocean, on stocks of fish which are also fished commercially. A prime example of this is party boats which fish Stellwag Bank in May, June, and September while commercial vessels are fishing this area in May-December.

The principal species involved in both sport and commercial fisheries are mackerel, winter flounder, cod, pollock, haddock, and tunas; also taken in large amounts, with lesser consequence to commercial fishermen, are bluefish and striped bass. Mackerel, highly migratory, schooling fish, are taken generally near the surface by jigging or trolling with live bait or lures. They are caught from Casco Bay, south, from mid-May to November, with best catches from July-October, in most depths. According to the 1970 salt water angler survey, mackerel produced more landings than any other species taken in the recreational fishery in this area. The 1970 estimate was 12.7 million fish in New York-New England areas, producing a calculated weight of about 6,000 MT. The USA commercial mackerel landings in the Gulf of Maine, Division 5Y , in 1970 totaled 2,601 MT, only 30% of the total USA landings, and has dropped to about 400 MT in 1975.

Cod, the most popular groundfish caught by recreational fishermen in the Gulf of Maine, is found over this entire area. Approximately 3.1 million cod were taken in the New York-New England area by sport fishermen in 1970, producing an estimated total weight of about 13,500 MT (the proportion taken in the Gulf of Maine itself is not known but could be as much as 50% of the total) when USA Division 5Y commercial catches totaled only 7,500 MT.

Winter flounder, the third most popular fish species (in number) taken by the recreational fishery in the Gulf of Maine, is found throughout this area. It is found to depths of over 300 feet, on gravel, sand-shell, sand, clay, or muddy-sand bottoms. Sport fishermen take them throughout the year, but primarily from April-May and September-October to the south of Casco Bay, Maine, and June-September east of that area. In 1970, 2.9 million winter flounder were taken in the New York-New England area, mostly by privately owned boats fishing with hook and line on the bottoms. This means that about 1,350 MT of winter flounder were taken by sport fishermen in 1970 compared with 1,080 MT landed by USA commercial fishermen in Division 5Y in that year.

Pollock, like cod, are taken year-round. Sport fishermen catch most pollock from May to June and from September to October. According to the 1970 survey, about 2.2 million pollock, totaling about 2,250 MT were taken by sport fishermen, almost twice the 1,360 MT caught by commercial fishermen at that time. USA commercial catches in 1975 increased to 5,100 MT, and though TAC's have not been set for this area alone, there is potential for conflict in allocations if the recreational catch increased proportionally in 1975.

Haddock are also taken year-round. In 1970 sport fishermen caught about 0.5 million haddock with a total weight of 1,150 MT, while USA commercial fishermen had reported landings of 1,430 MT in Division 5Y.

Other species which are caught in the Gulf of Maine sport fishery in smaller amounts are: scup (270 MT), sea robin (400 MT), tautog (540 MT), puffers (54 MT), kingfishes (635 MT), and cunner (320 MT caught in 1970).

Middle Atlantic-Southern New England party boat fishery

by

Frank P. Almeida
National Marine Fisheries Service
Northeast Fisheries Center
Woods Hole, Massachusetts USA 02543

The Southern New England-Middle Atlantic recreational fishery includes the area from Block Island to Delaware Bay, Delaware. This area is included in ICNAF SA 6A + 6B and is dominated by a body of water known as the New York Bight. The area covered by the Bight is from Montauk Point, Long Island, south to the edge of the continental shelf, and from Cape May, New Jersey, east, also to the edge of the shelf.

The major species involved in the Middle Atlantic-Southern New England recreational fishery, those with greater than 1,000 MT caught in 1970 are: bluefish, mackerel, striped bass, blackback, fluke, weakfish, spot, white perch, yellow perch, catfish, black sea bass, puffers, searobins, shad, and kingfish. Cod, silver hake, and red hake, three species that are commercially important, are also caught in this fishery. During the warmer months, from May through October, the main species caught are striped bass, bluefish, fluke, and mackerel, with catches of weakfish, tuna, sharks, scup, sea bass, tautog, and cod also reported. In the winter months, from November to March, the remaining species are bluefish, silver hake, red hake, cod, blackback flounder, tautog, and black sea bass, with some tilefish and striped bass also caught.

In 1965 there were 1,399 sport fishermen in the Middle Atlantic, with 878 fishing from either private or rented boats. By 1970, there were 1,741 fishermen with 1,310 in either private or rented boats. In 1965 there were 57.4 million fish caught by private or rented boats, but by 1970 this number climbed to 136.8 million, a 238% increase in the number of fish caught with a 149% increase in manpower. The number of fish caught in 1970 equalled approximately 11,200 MT as compared with 49,200 MT in the Middle Atlantic commercial fishery.

There were 13,300 MT of mackerel caught by the sport fishery in this area in 1970, while only 760 MT were caught by USA commercial fishermen; the USSR caught 49,583 MT, Poland 23,045 MT, Japan 990 MT, and the FRG 45 MT. Sport fishermen landed 650 MT of silver hake in Div. 6A and B in 1970 with 2,000 MT landed by USA, 1,953 MT by USSR trawlers, and 191 caught by Japan. Four hundred ten MT of red hake were caught by sport fishermen in 1970, while 400 MT were caught by the USA commercial fishery. Sport fishermen landed 3,500 MT of fluke in 1970 while USA commercial fishermen landed 1,300 MT in SA 6A and B, and the USSR landed 11 MT. Nine hundred sixty MT of scup were landed by the sport fishery in 1970, while 2,000 MT were landed by USA commercial fishermen. No landings were reported by any foreign countries.

Canadian 5Y adult herring fishery

by

G. W. Waring
National Marine Fisheries Service
Northeast Fisheries Center
Woods Hole, Massachusetts 02543 USA

Canadian catches of herring in the Division 5Y adult fishery, in the area of Jeffreys Ledge, were first reported in 1967 and totaled 5,226 metric tons. Catches increased to 21,497 MT in 1968 and steadily declined to 4,045 MT in 1975.

Catch statistics for the period 1967-1975 as reported to ICNAF indicate that the Canadian fishermen use purse seines of the following tonnage groups: 26-50, 51-150, and 150-500; and have fished during the months of April to October. In 1975 the Canadians took herring in this fishery during the months of July-September. This period of time coincides with the migration of adult herring into the spawning grounds of Jeffreys Ledge.

In 1971 Canadian fishermen worked under a contract to a US herring processor in Gloucester, Massachusetts, and landed 15,000 MT.

The current low levels of stock abundance, and the decreasing TAC, combined with the increased ability of US herring fishermen using pair trawling to catch herring has served to reduce the allocation of Division 5Y herring to the Canadian fishermen.

Canadian groundfish fishery on Georges Bank

by

M. McBride

The Canadian groundfish fishery on Georges Bank centers primarily around three closely related species: cod, haddock, and pollock which are generally the most abundant and commercially desirable species landed. There are relatively insignificant catches of red hake, white hake, the various flounders, and other less popular groundfish species. Since 1965 cod and haddock have been the mainstays of the fishery with pollock being, for the most part, an incidental catch (or by-catch) to that of the other two species. Most landings are made by stern or side bottom otter trawlers in the ICNAF tonnage classes 4 or 5 (4=150-499.9 tons, 5-500-999.9 tons).

In the 1950's the annual catch of cod for the ICNAF countries declined to an average of 11,000 MT, which amounted to 50% of the average for the previous two decades. Canada entered the cod fishery in the early 1960's along with Spain, and the USSR. The catch rose to its pre-1950 level and, with a few years of continued large catches by the participating countries, rose to 53,000 tons in 1966, a level not reached since 1938. The catches then declined sharply. In 1966 Canada also reached its peak of 16,000 tons, but accordingly dropped to 8,000 MT in 1967. There was a slight rise in 1968 to 9,000 MT followed by more decline until a leveling off period was reached: from 1970 to 1973, catches remained around 3,000 MT. At present catches appear stable at a lower level than in 1973 with little evidence toward immediate improvement.

Canada's cod fishery ranks second to that of the USA in average catch size by weight, Canada totaling approximately 71,000 MT during the last 12 years (beginning 1964) in comparison to approximately 160,000 MT landed by American vessels.

The events of the Canadian haddock fishery on Georges Bank closely parallel those of its cod fishery. Canada entered into the fishery in the early 1960's along with several distant-water fleets. This resulted in a dramatic increase in landings with peaks of 150,000 MT in 1965 and 121,000 MT in 1966. Canada's fishery likewise reached its peak in 1966, landing 18,000 tons of haddock. Continued intense fishing effort, coupled with poor recruitment, led to a steady decline in stock size after 1966, reaching a low in 1972 of approximately 600 MT. There was an increase to 1,500 MT in 1973, but in 1974 landings dropped to even less than those of 1972. A slight improvement was again shown in 1975.

Up until the present time, the Georges Bank pollock fishery has been dominated by Canada and the USA, although other nations, notably the GDR and the USSR have on occasion made significant catches. The USA pollock catch has been chiefly incidental in nature, whereas Canada appears to have directed more effort towards this species, particularly since 1950.

Most Canadian pollock catch has been taken in Divisions 4VWX and landed at New Brunswick and Nova Scotian ports. Canadian fishermen account for about 90% of total pollock landed in SA4. These landings reflect a gradual increase up until the mid-1940's and a brief period of relative stability between 1945 and 1952, followed by a continued increase until 1962. There has been an overall drop in pollock landings from the Northwest Atlantic since 1964.

On Georges Bank the Canadian pollock fishery, as with the fisheries of cod and haddock, began in the early to mid 1960's. Its peak catch occurred in 1967 and was followed by a serious decline in 1968. Landings have since been relatively stable, and reflect a gradual increase. Declines and subsequent upswings which have occurred in the overall fishery since the early 1960's, are thought to relate to changes in abundance, although changing availability of primary species (cod and haddock) and subsequent transfer of fishing effort may also have been involved.

Canada SA 5 & 6 sea scallop fishery

by

Paul Wood
National Marine Fisheries Service
Northeast Fisheries Center
Woods Hole, Massachusetts 02543 USA

Canada began her sea scallop fishery on Georges Bank in 1951 but did not make appreciable catches until 1956. From 1956 to 1962 her catch rose from 317 MT live weight (= meat weight x 8.33) to 47,000 MT. Since 1962 the catch has averaged approximately 42,000 MT. The catch in both 1974 (50,900 MT) and 1975 (62,100 MT) exceeded that of any previous year.

Upon first entering onto Georges Bank the scallop fishery was restricted to the northeastern part of the bank, but by 1963, as a result of increased fishery pressure and dwindling stocks, Canada was fishing on the southeastern part as well.

In 1965 Canadian scallopes moved into Statistical Area 6 and in the years 1965 and 1966 caught 21,700 MT and 23,200 MT, respectively. Since 1966 the only year in which Canada made an appreciable catch was 1968 (3,500 MT).

As of 1974 the majority of the Canadian scallopers were vessels of between 150 and 250 MT with Lunenberg, Nova Scotia, being the major part. The other two prominent parts were Yarmouth, N.S., and Riverport, N.S. Canada has implemented a license limitation program which has frozen fleet size and fishing effort at current levels. By-catch in the Canadian scallop fishery is negligable as in the US scallop fishery.

Developable Canadian fisheries

by

Ralph K. Mayo
National Marine Fisheries Service
Northeast Fisheries Center
Woods Hole, Massachusetts USA 02543

Future development of a limited number of Canadian fisheries in SA 5 and 6 is likely. Stocks which may potentially be exploited include herring on Georges Bank and mackerel and squid in ICNAF SA 5 and 6.

Canada has been harvesting herring from Div. 5Ze since 1967 in varying quantities ranging from 7 tons in 1970 to 13,674 tons in 1968. However, since 1972, Canadian allocation of the 5Z + 6 herring TAC has shrunk from 5800 tons to 1000 tons in 1976. A number of Nova Scotian and New Brunswick ports such as St. Andrews, Yarmouth, Lunenburg, and Halifax are within a day's steam of Georges Bank, making a fishery in this area quite accessible, and as the herring recover, the Canadian fishery may be expected to expand.

The mackerel and squid fisheries can be conducted over a much larger geographical area varying from the Gulf of Maine to the Mid-Atlantic Bight. Canadian participation in the SA 5 and 6 mackerel fishery has been negligible and that country's national allocation of the 5 + 6 TAC has declined from 22,500 tons in 1973 to 4,400 tons in 1976. Based on Canadian Subarea 3 + 4 catches which averaged over 14,000 tons per year since 1965, a considerable expansion of that mackerel fishery is likely prior to entry into SA 5 and 6. Similarly, the Canadian squid fishery has been limited only to harvesting *Illex* in Subarea 3 + 4. Catches since 1965 have averaged approximately 2,300 tons per year. Canada has not had national allocations of either *Loligo* or *Illex* in SA 5 + 6, but its allocation of the *Illex* TAC in Subarea 3 + 4 was set at 10,000 tons in 1975 and 1976, considerably above its current catch.

USSR purse seine

by

G. W. Waring
National Marine Fisheries Service
Northeast Fisheries Center
Woods Hole, Massachusetts 02543 USA

The USSR purse seine fishery for herring began in 1968 in Georges Bank with catches of 5,371 metric tons. The reported catches peaked at 29,113 MT in 1973, and have averaged 18,150 MT during the period 1968-74.

The fishing season is between May and October. In late May and in June, herring fishing is conducted on the southern slopes of Georges Bank at depths of 50-100 m. During July to August, the fishery operates on the eastern, northern, and southern slopes, and in September to mid-October in the spawning areas on the northern slopes. The herring disperse after spawning and the fishery ends for the season.

During the period 1968-74 some catches have been reported for USSR purse seiners from Division 5& and Statistical Area 6.

The vessels employed in the fishery are converted side trawlers of the following classes: SRT (150-500 tcl.), SRTR (501-900 tcl.), SRTM (501-900 tcl.), RT-motor (501-900 tcl.). The SRT vessels average 125-144 feet in length, have no freezing or chilling equipment, so the hold capacity is 100-200 tons. The SRTM vessels are 178 feet in length, can freeze about 6 tons of fish per day. The SRTR vessels are 167 feet long, can carry 150-200 tons of fish products in chilled holds.

The largest single species by-catch is mackerel, and lesser quantities of unknown mixed pelagics are also taken.

USSR - Pelagic Trawl Fisheries

by

Frank Almeida
National Marine Fisheries Service
Northeast Fisheries Center
Woods Hole, Massachusetts USA 02543

The history of the USSR pelagic trawl fishery must begin with its bottom fishery. For many years, the Soviets relied on their bottom trawls to catch all the species they desired in ICNAF Areas 5 and 6. It is only in the past 8-10 years that they began relying more heavily upon purse seines to catch herring, and midwater trawls to seek the pelagic species such as mackerel, red hake, and silver hake, and more recently, squid, argentine, and dogfish. The trend from using the perennial bottom trawl to the midwater trawl was begun for basically two reasons: (1) the midwater trawl is a more efficient gear for catching pelagic species, and (2) ICNAF regulations are prohibitive towards demersal gear in some areas. The USSR pelagic trawl fishery is a substantial part of the largest foreign distant-water fleet found in the USA coastal waters annually.

The Soviets have been fishing extensively for herring for many years with much success. Total catches, with all gears included, from the years 1961-1968, averaged 109,000 MT, with the largest catch in 1962 of 151,000 MT. The catch then began to decline in 1969 and has continued to do so, and in 1974 the catch was the lowest ever at 41,639 MT. Most herring are caught by the Soviet fleet in the summer months between May and September, although they are caught in virtually all months of the year from SA 5Ze to SA 6.

The USSR began reporting mackerel catches in 1963 and reported an almost logarithmic increase until 1973, when their catch totaled 145,796. Although the total catch continued to increase until 1972, the trawl catch leveled off in 1970 and averaged 120,000 MT until 1972, and has declined since. The reason for the continued rise in total catch but decrease in trawl catch was again due to an increased purse seine fishery.

Mackerel have been caught in all months of the year although the directed fishery runs from January to March in the deep waters off Georges Bank and Southern New England and from January to May in the Middle Atlantic. The fishery for mackerel in the Georges Bank-Southern New England area usually switches over to the hakes, red and silver, toward the end of March to April. The primary by-catch in the mackerel fishery is red and silver hake, which are not discarded and are used to supplement their own fisheries.

The silver hake catch is annually the largest of all the fisheries in the Soviet fleet. Reported catches began in 1962 with a catch of 42,000 MT and increased steadily until 1965 when 231,000 MT were landed. The catch then began to decrease and has averaged 76,000 MT since 1967. This species is also landed in all months of the year but its principal fisheries are from March to August on Georges Bank and Southern New England waters. Mackerel is the most significant by-catch species in this fishery, which again is utilized in its own right but often increases the amount of total catch above the regulated ICNAF quotas for that species.

The red hake fishery is another important USSR pelagic fishery, and began reporting catches in 1963 with a catch that year of 3,500 MT. After a two-year period of low catches, 1963 and 1964 (average catch 3,500 MT), the catch increased to its highest level in 1966 with 109,000 MT landed. The catches then decreased and have averaged 40,000 MT since 1967 with very poor years in 1968 and 1970 with catches of 13,000 and 7,000 MT, respectively.

This species is also caught in all months, but the principal months this fish is caught are also from March to August, and also with a significant by-catch of mackerel as in the silver hake fishery.

The total squid fishery is a relatively new one with the first landings reported in 1970. In 1970 the landings were small, only 656 MT, but they increased to 9,000 MT in 1973. The fishery has included both the long-finned squid, Loligo, and the short-finned squid, Illex, but annually the landings of Loligo have probably been slightly greater than those of Illex.

Squid are fished primarily in January and February in the Georges Bank-Southern New England area of SA 5Ze and w. The primary by-catch species of this fishery are silver and red hake and mackerel. From May until August, squid are fished in the Middle Atlantic (SA 6).

In recent years, two other species have been fished by the Soviet fishery, argentines and dogfish. The first reported catches of argentines were in 1968, when 2,000 MT were caught. For the first four years at the fishery, the landings were low, averaging 1,600 MT frc 1968-1971. In 1972 the reported catch was 32,600 MT, with 31,000 MT coming from SA 5Ze. In 1973, the catch was back down to 2,400 MT but in 1974 was high again at 19,700 MT. Small amounts of this species have been caught in every month of the year, but the principal period of the year is the winter months, from November to January.

Dogfish catches have been reported since 1973 when 9,600 MT were caught; in 1974 13,534 MT were caught, mostly in SA 5Ze.

Miscellaneous by-catch of numerous groundfish species have been reported by the USSR. Increasing use of pelagic rather than bottom trawls should reduce this by-catch. Allocation problems with coastal state fisheries exist because of the large nature of the fishery. These problems involve both total production and availability, complicated by the lack of an adequate understanding of stock structures.

Polish pelagic trawl fisheries

by

Pamela Lanham
National Marine Fisheries Service
Northeast Fisheries Center
Woods Hole, Massachusetts USA 02543

Polish fisheries commenced in 1961 with a catch of 4,000 metric tons consisting mainly of redfish and cod. The nominal catch steadily increased with only an insignificant decline in 1969 and rose again to reach a peak of 270,000 metric tons in 1971. There has since been a steady decrease. Initially Polish fisheries were conducted with bottom trawls but increasingly pelagic trawling has become dominant. ICNAF regulations require this for much of SA 5 and 6. Polish fisheries aim for a catch of three main species: mackerel, herring, and squid.

Mackerel catches in ICNAF SA 5 and 6 began in Polish fisheries in 1962 with the catch amounting to 111 tons. Having a two year lapse of mackerel catches, the fishery began again with only 1 ton for the year 1965. It was not until 1968 that the Polish fishery had any sizable catch, mackerel being 10,608 tons. From 1968 to 1971 mackerel catches rose steadily, almost doubling each year and coming to a peak in 1972 at 141,999 tons. In that year the Polish catch of mackerel surpassed that of any other country. Poland is one of three countries which dominated the international mackerel fishery in SA 5 and 6 from 1967-1974.

Statistical Area 6 constituted the greatest amount of mackerel caught by Poland from years 1968-1974. Prior to year 1968 mackerel was being fished for mainly in Subarea 5. All Polish catches of mackerel in 1973 and 1974 were fished from Div. 5Z and SA 6, the greatest amount being in 6A.

The heaviest catches of mackerel by Poland in SA 5 were generally taken during the months of March through May and during the months of January, February, and December in SA 6.

Poland also has a sizable catch of herring. Herring catches by Polish fisheries in 5Z and SA 6 began in 1962 and no catches were reported again until 1964. It wasn't until 1967 that the fishery had a fairly abundant catch at 37,677 tons. The fishery then increased from 37,677 tons in 1967 to 75,080 tons in 1968 and dropped back down in 1969 to 45,021 tons. The catch in 1971 was the highest reached by Polish fisheries at 88,325 tons and has been dropping considerably up to the present.

The greatest portion of herring was taken from Div. 5Z in 1973 and 1974. There was a decrease from 1973 to 1974 in herring catches from SA 5 and 6 as a result of the drop in the fishing quota. Herring catches from SA 6 increased about 30-50% between 1972 and 1974.

The most abundant herring catches from Subarea 5 were during the months April through June and October through November, and during the months of January, February, and December in SA 6.

Squid catches started in 1971 with 11,000 metric tons. Squids were caught in Div. 5Z, 6A and 6B during the year 1971 where the fishery had its most abundant catch. Since then the catch decreased as low as 7,000 metric tons in 1974. The high peak in 1972 was at 19,000 metric tons. The Polish fishing season for squid in 1972-1974 was mainly conducted during the months of April and May.

Besides mackerel, herring, and squids, other species were not the objective but they constituted only a by-catch when fishing the former species. The by-catch for Polish fisheries in 1973 was about 8% of the total catch. Some species which Poland lists as by-catch are butterfish, alewife, silver hake, cod, sharks and rays, scup, and searobins.

The tonnage classes for Polish vessels between 1968-1974 were 500-999, 1000-1999, and 2000 GT.

German Democratic Republic Trawl Fisheries

by

P. Lanham
National Marine Fisheries Service
Northeast Fisheries Center
Woods Hole, Massachusetts 02543 USA

In 1960 GDR had its first record of catches from the Northwest Atlantic area, amounting to 12,000 metric tons. The fishery had no data reported from 1961-1963. In 1964 the nominal catch totaled 96,000 metric tons and held steady for the next two years. The fishery hit its peak in 1969 with 187,000 MT in that year. In the following years the catch diminished to a low of 89,000 MT, then increased in the next three years by 10,000 to 50,000 MT. In 1974 the catch dropped to 131,000 MT. Originally a bottom trawl fishery it has increasingly switched to pelagic trawls.

The main species sought in ICNAF SA 5-6 by the GDR are herring and mackerel.

Mackerel catches began in 1967 amounting to 211 tons. The catch fluctuated up and down finally peaking in 1972 at 80,537 tons. Since then the catch declined steadily to 76,758 tons in 1973 and dropped further in 1975 to 48,343 tons. From years 1967-1974, 64% of the mackerel catch was from SA 6 and the rest from SA 5. Mackerel was fished January through May and November through December by GDR fisheries.

GDR along with Poland and USSR dominated the international mackerel fishery from 1967-1974.

Herring catches began in 1966 with 1,000 tons and increased steadily until 1969 when the highest peak was reached at 88,000 MT. Catches from 1970 to the present have fluctuated between 18,000 and 53,000, hitting the low of 18,447 tons in 1971.

The most abundant herring catches were taken from Div 5Z. From 1973 to 1975 93% of herring catches by GDR fishery was from Div 5Z, 2% from SA 6, and 5% from 5Y.

GDR fish for herring during the spring months and fall months with the most abundant catches during the months of April and November. The vessel tonnage classes in 1974 were 1000-1999 and >2000 GT.

Federal Republic of Germany pelagic fisheries

by

P. Lanham
National Marine Fisheries Service
Northeast Fisheries Center
Woods Hole, Massachusetts 02543 USA

The first record of FRG fishing in the ICNAF convention areas was in 1954 when 2,000 metric tons of fish were caught. The nominal catch bounced up and down reaching its highest peak in 1968 at 281,000 MT; 67% of the total catch for that year was cod and 29% was herring.

The main species sought by FRG fishery in SA 5 and 6 are herring, mackerel, and squid.

Abundant herring catches in ICNAF SA 5-6 began in 1967 with the catch amounting to 28,171 MT. The catch steadily increased, hitting its peak of 82,498 MT in 1970. In 1971 the catch declined to 54,744 MT and wavered between 22,000 and 27,000 MT for the remaining years.

The main fishing grounds for more abundant catches of herring have been in Division 5Z. In 1973, 31,188 MT of herring were caught in 5Ze, 315 MT in 5Zw, and 876 MT in 5Y. None were caught in SA 6. In 1974, 26,153 MT were caught from all areas of 5. None were caught, again, from SA 6.

Federal Republic of Germany's herring fishery is mainly conducted during the months of August through November.

FRG has had a fairly small catch of squid and mackerel and occasionally pollock.

Squid catches by FRG fisheries were first recorded in 1972, amounting to 1,000 metric tons. The highest catch of squid caught was 2,000 MT in 1973. The greatest amount of squid for the past three years has been taken from SA 6 fishery for squid is carried out mainly during the months of January and November.

Japanese squid and butterfish fishery in ICNAF SA 5 + 6

by

Anne M. Tibbetts and Gordon T. Waring
National Marine Fisheries Service
Northeast Fisheries Center
Woods Hole, Massachusetts USA 02543

Japan reported first catches from their squid-butterfish fishery in 1967. This fishery, directed at squids (*Loligo pealei* and *Illex illecebrosus*) and/or butterfish, began with landings of only 146 MT of butterfish and 2 and 5 MT of *Illex* and *Loligo*, respectively. The major portion of the catches of all three species from 1967 to 1975 have been from SA 6. Total catches by species have ranged from 146 MT in 1967 to 12,172 MT in 1973 for butterfish; from 5 MT in 1967 to 17,102 MT in 1972 for *Loligo*; and from 2 MT in 1967 to 3,327 MT in 1974 for *Illex*. The nine-year averages (1967-1975) for this combined fishery are: butterfish - 4,909 MT; *Loligo* - 9,719 MT; and *Illex* - 1,282 MT.

The Japanese squid-butterfish fishery currently reports that effort is conducted entirely with bottom fishing stern otter trawlers of medium (500-2,000 gross tons) and large (over 2,000 gross tons) size. In 1974 about 82% of the Japanese squid catches were taken by large vessels (fluctuating from 84% in 1972 to 61% in 1973).

Large otter trawls also took the majority of the 1974 Japanese butterfish catch. Net mesh in this fishery ranges from 20 to 100 mm, with 30 mm most common on vessels using bottom gear and 20 mm most prevalent on vessels fishing the bottom with pelagic gear.

This fishery is conducted from late fall to early spring when squid and butterfish have migrated to the slope waters (October-early May), and is probably directed mainly at Loligo, with Illex and butterfish taken in significant amounts as by-catch. There is also, probably, a small butterfish fishery conducted at times when squid are less prevalent in the area.

By-catch in this combined fishery amounts to only about 15% (in 1974) and consists of commercially important species such as: silver hake, red hake, flounder, mackerel, crabs, and lobster. The other shellfish, taken mostly in November, are thrown overboard; while different vessels either process and freeze, or discard the hakes, flounder, and mackerel.

Spanish and Italian squid fisheries in the Northwest Atlantic (ICNAF SA 5 + 6)

by

Anne M. Tibbetts
National Marine Fisheries Service
Northeast Fisheries Center
Woods Hole, Massachusetts USA 02543

Spain and Italy have conducted a directed squid fishery in ICNAF Subarea 5 and Statistical Area 6 since 1970 and 1972, respectively. These fisheries have included both commercially important species of squid from this area, i.e. *Loligo pealei* and *Illex illecebrosus*, though both countries consider *Loligo* to be the more valuable species. Total squid landings for Spain have been: 4,510, 4,187, 11,859, 14,932, 16,138, and 9,878 MT for the years 1970 to 1975, respectively. Italian squid landings for 1972-1975 were: 3,200, 3,165, 4,260, and 4,231 MT, respectively. Average estimated yearly catches by species are: 7,125 MT *Loligo* and 3,128 MT *Illex* for Spain, and for Italy an average of 3,147 MT *Loligo* vs. 567 MT *Illex* per year.

Fishing by both countries is done primarily with stern otter trawlers, along the edge of the continental shelf. Spanish vessels range in size from 150 to over 2,000 gross tons, with the majority of these between 150 and 500 gross tons. Italian vessels fishing for squid are generally between 1,000 and 2,000 gross tons. Net mesh size used in this fishery ranges from 25 to 125 mm, with both countries' vessels generally fishing with 40 or 60 mm mesh.

Spain fishes for Loligo from September to April, generally from Veatch canyon, south of Nantucket to Cape Hatteras, along the 125-150 meter contour; and for Illex in approximately the same areas from May to September. During the summer Illex fishery, the total number of Spanish vessels fishing for squid drops, with larger (greater than 500 gross tons) vessels changing to fish for other species. The Italian fleet, fishing for squid, remains in the same general area as do the Spanish (from Nantucket to Cape Hatteras, in 125-150 meter depths). They are primarily interested in Loligo and fish for this species from September through June, catching Illex in lesser amounts at the same time.

By-catch of other species from these fisheries is high (up to 65% in March and April is reported by Spain). The Spanish report by-catch percentages from their 1973-1974 squid fisheries as follows: mackerel from January through April, peaking at 19% of the catch in March; silver hake from November through February, with a maximum of about 5% in December; red hake, caught between September and March, with greatest percentage of the total (6%) in September; and butterfish, producing the highest single percent of by-catch, essentially from January through December, with a peak of about 38% in September. Totals of all other species such as goosefish and shellfish (most of which are thrown overboard) range from 2 to 40% of the monthly catches from the Spanish squid fishery.

Though Italy reports no by-catch directly, they do report about 5% of the catch in their squid fishery as other species. Actual catches probably consist of the same spcies as the Spanish report, in about the same proportions, and are also generally thrown overboard.

Other country fisheries

by

Ralph K. Mayo
National Marine Fisheries Service
Northeast Fisheries Center
Woods Hole, Massachusetts USA 02543

A number of other countries have conducted fisheries in ICNAF SA 5 and 6 to varying degrees. Two countries in particular have had major fisheries in these areas in recent years.

Bulgaria has maintained herring and mackerel fisheries since 1969 in ICNAF Divs 5Ze, 5Zw, and Subarea 6. The herring catch in these areas rose from 812 tons in 1969 to 4,551 tons in 1971 and has subsequently declined to 416 tons in 1975. Mackerel catches increased from an initial 1969 level of 2,083 tons to 31,743 tons in 1973, dropping to 18,764 tons in 1975. The Bulgarian fleet consists of stern trawlers greater than 2000 gross tons using mid-water gear. In Div. 5Ze the herring and mackerel fisheries are conducted from April through December, while in the 5Zw and 6 areas, catches occur from November through June.

Silver hake and red hake constitute a considerable by-catch in these fisheries, especially in the spring and summer months.

The Romanian herring and mackerel fisheries have been in existence since 1965 in Divs 5Ze and 5Zw and in SA 6. The herring catch has remained relatively stable from the beginning of this fishery, fluctuating between a high of 2,677 tons in 1966 and a low of 297 tons in 1973. In 1974 the Romanian herring catch was 2,018 tons. In contrast, mackerel yields have steadily increased from 11 tons in 1965 to 6,966 tons in 1974. The Romanian fleet also consists of stern trawlers greater than 2000 tons using mid-water trawls. In 1974, Romania reported having four such vessels operating in the northwest Atlantic. The seasonality of these fisheries is similar to the Bulgarian herring and mackerel fisheries with most of the 5Ze catches occurring from April through November and catches from the 5Zw and 6 areas occurring from November through June.

By-catch in the Romanian fishery has reported only small catches of silver hake, cod, haddock, and mixed fisheries.

The only other directed fishery of any importance in Subareas 5 and 6 is the Spanish cod fishery in Div. 5Ze. Cod catches increased from 18 tons in 1964 to 14,730 tons in 1967. The Spanish cod catch, however, has since been steadily declining as only 4,070 tons were reported caught in 1975. Vessels in this fishery are between 150 and 1000 gross tons and fish as pair trawlers using bottom otter trawls. In 1974 Spain reported 77 such vessels fishing in either SA 5 or 6. Most of the cod catch occurs in the winter and spring months. The predominant by-catch species are haddock, pollock, and miscellaneous groundfish.

Cuba has just entered the fisheries in SA 5 and 6 and is expected to develop hake fisheries.

Resources needed for management of the fishery resources off the Northeastern Coast of the U.S.A.

by

V. C. Anthony and S. H. Clark
National Marine Fisheries Service
Northeast Fisheries Center
Woods Hole, Massachusetts 02543 USA

A. Data needed for describing fisheries and effects of fishing.

1) Catch and effort data by area and time. Information should include catch by species and area, indicating principal species sought and by-catch, and, for all species, quantities discarded. In addition, existing data banks should be improved through addition of historical data. Data should be collected as follows:

a) A logbook system on commercial vessels.

b) Dockside interviewing activities with commercial fishermen and dealers.

c) It is imperative that reasonably complete recreational catch data be obtained; at present, little data exists for certain species although assessments are vitally needed. To accomplish this goal, the following appear necessary:

(1) Knowledge of the number of recreational fishermen;

(2) Telephone, portal, and direct interviewing of recreational fishermen, with statistical evaluations of the reliability of the estimates obtained, and

(3) Logbooks for party boat captains.

2) Fishing intensity data (numbers of fishing units, standardized per unit area and time by species and country).

1) Description of vessels.

2) Gear employed (type and size of nets; mesh size, and configurations of other types of gear), and

3) Information relative to use of equipment which increases efficiency, such as hydroacoustical gear.

3) Biological data

A variety of data must be collected both in catch sampling programs and in research vessel surveys. Specific requirements are itemized as follows:

a) Length-frequencies, and materials for age determinations (e.g., scales and otoliths) must be collected from all sectors of the fishery exploiting each stock. Sampling may be necessary in certain situations; furthermore, sea sampling may be required to obtain information relative to discard. Supplementary sampling may also be necessary for obtaining information for length-weight relationships, maturation and fecundity, food habits, etc.

b) Research vessel surveys. Continued (and intensified) survey activity is necessary to provide information on the population structure. Present bottom trawl survey activity should be expanded to include three surveys (fall, summer and spring); in addition, inshore surveys and surveys should be expanded. Directed surveys for benthic invertebrate fisheries are needed also. Plankton and larval fish cruises should also be continued and intensified. Obviously, such a level of cruise activity will require a considerable degree of international cooperation if the program is to prove effective. The following data will be collected:

   (1) Relative abundance indices for fish and invertebrate species (numbers and total weight);
   (2) Length frequencies and samples for age determinations.
   (3) Maturation and fecundity data;
   (4) Plankton samples;
   (5) Oceanographic measurements, and
   (6) Other data (food habits, samples, etc.).

4) A well-rounded management program for Coastal State Allocations. This zone will require a variety of economic data and beginning with the price information collected from the dealers along with the data in 1, b:

5) Social and cultural information such as employment consideration.

6) Surveillance activities. Surveillance of fishing activity (including boardings) must be intensified to ensure compliance with regulations including data reporting and sampling in the Conservation Zone. This work should be directed towards the following:

B. A.D.P. requirements

A regional ADP center should be created to process and store the basic data from the above programs. This center would be responsible for creating tape and disc files from which data could be readily retrieved by users and would, in addition, serve as the primary computing facility for stock assessment work and related studies.

C. Support studies.

A variety of research programs will be necessary for effective fisheries management. These are itemized in the following sections:

1) Assessment studies (single and multi-species). Present assessment work shall be continued and upgraded. Outstanding problems are as follows:

a) Estimation of recruitment.

b) Estimation of mortality rates.

c) Yield studies.

d) Stock recruitment studies.

e) Other studies. A variety of related studies will also be required if assessment efforts are to be complete. These should encompass the following areas:

(1) Effort studies. Such work would involve continued updating of information relative to fishing power and changes in efficiency resulting from learning.

(2) Catchability studies work should be intensified to evaluate catchability in reference to survey and commercial gear and to measure changes in catchability, if any, resulting from changes in abundance or from environmental changes.

2) Ecosystem dynamics; description and sensitivity analyses. The need for considering the fisheries resource within the Fisheries Conservation Zone as an interacting interdependent system, rather than as an assemblage of independent stocks, has been clearly established in recent years. Considerable additional study will be required to provide the necessary information to describe this system quantitatively; the most pressing research needs would appear to be as follows:

a) Food chain dynamics.

b) Productivity studies.

c) Fisheries oceanography.

d) Larval studies.

3) Engineering studies. Studies on commercial gear configuration to improve gear efficiency should be continued, together with studies to evaluate the performance of various survey gears under differing conditions (the latter would employ improved methods of measuring speed and depth). Out of such work would come improved estimates of catchability and expansion factors for improved biomass estimates (computed from swept area methods and application of catchability coefficients to survey catches).

4) Statistical sampling studies to improve existing programs.

5) Tagging. Intensive programs involving state, federal, and foreign interests should be initiated to provide information on stock boundaries, migrations, and local movements. Growth and mortality estimates can be made from such studies also. Such programs are deemed essential for effective management within the 200-mile Conservation Zone as allocations to fishery units become more critical.

6) Enforcement effectiveness evaluation studies.

7) Economics studies. Studies will be needed to evaluate relationships between cost and gross revenue (breakeven analyses, etc.), relations between maximum biological and maximum economic yield, etc. In addition, the impact of marketing and shipping problems and import levels on domestic production should be studied.

8) Biological parameters. Continued study of biological parameters relating to stock identification, assessment, and management will be necessary.

9) Environmental studies. Oceanographic data should be used to document short-term and long-term trends in environmental parameters and to determine the influence of various environmental changes on fish distribution.

D. Forum for evaluating assessments.

1) Assessment group. As now exists within ICNAF, an assessments group from all nations engaged in fishing in the Conservation Zone should participate in assessments and other scientific studies as a body such as STACRES.

2) Publications and reports. Assessment results should be published as in the current ICNAF and ICES practice.

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by

V. C. Anthony and S. H. Clark
National Marine Fisheries Service
Northeast Fisheries Center
Woods Hole, Massachusetts 02543 USA

ANNEX I

Procedures for Scientific Samples

I. INTRODUCTION

The requirement for sound biological information on fisheries stocks as a basis for stock assessment, management, and allocation are well understood. This annex defines a minimum sampling and data acquisition procedures which will assure adequate data and will standardize the methods by which samples are obtained from the catch and the types observations required. Samples are designed to enable assessment scientists to estimate the number caught for each species, by length, age, and sex category.

II. LENGTH - AGE COMPOSITION SAMPLES

A. Samples should be taken separately for each gear type (e.g. otter trawl, purse seine) and fishing strategy (e.g. mid-water pelagic trawling) combination every month for which fishing is pursued in any 30 min. square area throughout the agreement region. One sample should be taken for every 1000 tons or fraction thereof within the above categories.

B. Data to be recorded in each sample:

Vessel classification

Method of fishing, i.e., pelagic

Specific type of trawl, including reference to its construction or actual scale drawing

Mesh sizes

Tonnage in the trawl haul of the species sampled

Total weight of all fish sampled

Time of day of haul

Date

Latitude and longitude of haul

C. Sampling procedures

(1) Species for which the catch is sorted

(a) From a single net haul take 4 random aliquots of approximately 50 fish each. (For species with less than 200 fish in a single trawl haul accumulate samples over trawl hauls until approximately 200 fish are taken)

(b) Measure each fish to nearest cm, except for herring where the measurement will be the total length to the nearest cm below.

(c) Take a subsample of one fish from each cm interval and remove scales and otoliths as appropriate, and record the sex of mature individuals

(2) Species for which catch is not sorted

(a) From a single trawl take two random aliquots of approximately 30 kilos each

(b) Sort to individual species (for "river herring" this means sorting to alewife Alosa pseudohorenges and blueback A. asetivalis)

(c) Take biological information as in (1), (b) and (c).

III. LENGTH-WEIGHT SAMPLES

Individuals of one sample of each principal species of fish (e.g. expected yearly catch in area of agreement 500 or more tons), per ICNAF Division per month should be weighed in grams and measured in millimeters for each major species. Each sample to contain 10 fish per centimeter interval, length range of fish and may be accumulated if necessary from small samples taken over several catches and days. Sex shall be recorded for mature individuals.